Maintenance Reliability index system and its analysis method of Public Transit

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Abstract. The service reliability of the public transit is highly related with the occupancy rate of the urban public transit. Most existing research focus on waiting time, travel time, headway distribution, in-vehicle time, etc. but neglect the maintenance performance. For the current urban public bus, it is difficult and complex to improve reliability through improving planning and operation. The paper builds the index system on the maintenance reliability, and provides a analysis method for the service reliability of the public transit. The analysis method is a two-layer analysis method for the influence factors with index system, which includes the number of bus and station, the shut-down frequency, the stop frequency, the troubleshooting time etc. An example shows that the analytical approach is feasible, and it will be helpful for the improvement of the service reliability.

1. Introduction
Rapid development of public transport is considered as the one of the most common methods of ease congestion for urban traffic. The project of the transit metropolis has been incorporated into the “12th and 13th” five-year of Urban Comprehensive Transportation Planning in China. To realize the transit priority was part of goal to the project of the transit metropolis. The transit priority focuses on the key issues with existing approaches: complexity, especially for reflects the relationship between the service capacity of public transit system and passenger demand. For example, evaluation and comparison of transit satisfaction and public transit occupancy rate of traffic mode is very difficult. The service reliability of the public transit is an important index to measure the transit priority, and is closely related to the transit satisfaction and Public transit participation rate. The research shows that the service reliability index is the most important index in the evaluation of transit satisfaction, like this [1].

The service reliability of the public transit was described as the ability of transit system to complete its prescribed functions within prescribed time. The concept of service reliability of the public transit was proposed by Sterman in the 70’s of last century. Sterman [2] carries out the research according to the qualitative analysis for improving the service level of public transit. Currently, the practical research shows the service reliability of public transit has improved service level of the public transit.

There are many influence factors with the reliability of transit service, including the travel time, the departure interval, the travel time, the punctuality, the full - load rate, the service level, etc.

For the current urban transport, improving the service reliability is very difficult and complex. Reliability study will be helpful to improve traffic conditions, to reduce time of the passenger carrying and to enhance the ability of carrying passengers. The researchers think that the planning of bus transit and service is important factor, which can effectively improve the operational time. Based on the purpose of the public transit satisfaction, the reliability index plays an extremely important role,
including the reliability of operational time and maintenance time. Therefore, the reliability of transit will be very important for the passengers under the situation of road dynamic traffic.

In the process of reliability analysis, like [3], the reliability analysis method based on the rough Petri nets of the multi-state system is a representative method idea. The paper establishes a reliability analysis method based on the maintenance reliability of public transit, which can improve the capacity, the operational ability and the service level of transit.

2. Service Reliability of Public Transit
For the service reliability research of public transit, most of the existing research focuses on the factors such as travel time, waiting time and so on. In [4~6], many essays have provided the analysis method of service quality of the public transit.

The reliability indexes generally include safety, convenience, economy, speed, accuracy, comfort and so on. It is often difficult to improve the level of the service reliability based on the fixed bus planning and the operation improvement of the transit. The maintenance reliability involves the evaluation of operation and service level of the public transit. The influence factors of maintenance on the service reliability is often ignored by the traditional methods.

The operation characteristics of the bus including start quickly, idle speed instability, brakes frequently and overloading. Compared with other operating vehicles, the bus has more faults, more orders, larger batches fault, more changes in use and configuration requirements, and higher requirements for vehicle maintenance proximity. It was obvious that, the fault of the public transit will greatly affect the feelings of the bus passengers.

The maintenance reliability is important for the operation of service level of the public transport. It will reduce the passenger travel time by schedule intelligent, especially emergency bus. Quick response for the vehicle failure and the traffic accident will make rapid progress for the service level of the bus. Therefore, the maintenance reliability is one of the most important index of the transit.

3. Maintenance Index System and Analysis Methods
The paper provides the analysis method of service reliability index, the indexes include the line length, the number of buses, number of fault during operation, the troubleshooting time and number of stops.

3.1. Reliability Analysis of Public Transit Service
The service reliability of public transit is a kind of contingency ability of routine public transit in daily and occupy operation problems. It can reflect the executive ability of the line of the public transit operation. The service reliability of conventional public transport involves the safety, punctuality, comfort and stability of public transport service.

The service reliability indexes of the public transit involve travel time, waiting time, travel support, maintenance and other aspects. Service index analysis method of the transit usually carries on the normalization or standardization to each index. A considerable part of these indexes are nonlinear, and the impact of the changes on the evaluation object is nonlinear which makes the evaluation value of the same evaluation index change with the sample data compared with it.

3.2. The Index System of Maintenance Reliability
Maintenance index system is introduced to evaluate the reliability of the public transit. The whole reliability and evaluation maintenance index system of public transit is shown in Figure 1.
3.3. Index Analysis Methods

There are two kinds of analysis methods of index system: subjective decision method and data statistical analysis method. Subjective judgment method is based on expert experience knowledge to determine the evaluated object. Considering the complexity of the public transit index system and the evaluation index, combining the AHP and the fuzzy comprehensive evaluation method, a principal component quantitative analysis method is provided.

Based on the analysis of the complex system structure and the evaluation index of the quality of public transport service, this paper proposes a two-layer decision analysis approach for the maintenance index of public transport.

The specific steps are as follows:

First layer, low level index extract setp:
(1) Data matrix:

\[
X = \begin{bmatrix}
    x_{11} & x_{12} & \cdots & x_{1r} \\
    x_{21} & x_{22} & \cdots & x_{2r} \\
    \vdots & \vdots & \ddots & \vdots \\
    x_{n1} & x_{n2} & \cdots & x_{nr}
\end{bmatrix}
\]

(2) Normalization:

\[
x_{ij} = \frac{x_{ij} - x_j}{x_j}, \quad x_j = \frac{1}{n} \sum_{i=1}^{n} x_{ij}
\]

\(x_{ij}\) indicates the index value. Such as, \(x_{ij}\) indicates the travel time, then, \(i, j\) respectively indicate the bus and the bus stop.

(3) Decide the key parameter according to the character of the index.

Second layer, high level index extract setp:
(4) According to the relationship between reliability and travel time, waiting time, travel support, maintenance of the index system, the value \(\lambda_r\) is defined.

(5) Feature vector is formed, and the number of influence factor is shown.

| No. | characterize | Influence factors |
|-----|--------------|-------------------|
| 1   | \(\mu_1 = \left(\mu_1(1), \ldots, \mu_1(r)\right) / \max \mu_1\) | \(a_1\) |
| 2   | \(\mu_2 = \left(\mu_2(1), \ldots, \mu_2(r)\right) / \max \mu_2\) | \(a_2\) |
| \ldots | \ldots | \ldots |

Table 1. Characterize and the influence factors
3.4. The Example

In order to improve the level of public transport service and increase the occupancy rate of public transport in a city of Jiangsu Province, the paper takes a line of conventional public transport as an example.

The total length of the line is 13.3 km, and there are 19 stations in the downstream direction, including the first and the last stations. There are 25 buses on the whole line. Fifteen buses have been purchased for more than five years, and one maintenance station along the line, 500 meters from the first station, is the fixed-point station of the line. There are 40 drivers and 2 dispatchers. They are divided into two classes and 20 people in one class. The total mileage of a day is 4520 km. The total working time of a day is 235 hours. The failure causes parking is 1 times, and the time length of the troubleshooting is 13 minutes.

The operation data of the bus line is divided into four sections: bus stop 1 (first stop), bus stop 8, bus stop 13 and bus stop 19 (last stop).

Table 2. The scheduling time

| No. | Stop 1  | Stop 8  | Stop 13 | Stop 19 |
|-----|--------|--------|--------|--------|
| 1   | 16:33  | 16:48  | 17:01  | 17:17  |
| 2   | 16:49  | 17:09  | 17:18  | 17:40  |
| 3   | 17:52  | 18:07  | 18:20  | 18:41  |
| 4   | 18:18  | 18:42  | 18:50  | 19:05  |

Table 3. The time length (min)

| No. | time 1 | time 2 | time 3 |
|-----|--------|--------|--------|
| 1   | 15     | 13     | 16     |
| 2   | 20     | 9      | 22     |
| 3   | 15     | 13     | 21     |
| 4   | 24     | 8      | 15     |

Building the matrix:

\[
X = \begin{bmatrix}
15 & 13 & 16 \\
20 & 9 & 22 \\
15 & 13 & 21 \\
24 & 8 & 15
\end{bmatrix}
\]

Normalization:

\[
X' = \begin{bmatrix}
0.0227 & -0.1136 & 0.0909 \\
0.1765 & -0.4706 & 0.2941 \\
-0.0816 & -0.2041 & 0.2857 \\
0.5319 & -0.4894 & -0.0426
\end{bmatrix}
\]

According to the operation situations of the lines, we define the key parameter for the bus line: the operation time is 0.15, waiting time is 0.35, operation is 0.20, and maintenance is 0.30.

\[
\lambda = \begin{bmatrix}
0.15 & 0.35 & 0.20 & 0.30
\end{bmatrix}
\]

The operation conditions of the lines are classified to form feature vector.

\[
u_r = (u_r(1), \ldots, u_r(r)) / \max u_r
\]

(6) Return the results sorted according to the feature vector.
\[ \mathbf{u} = \begin{bmatrix}
13.3 & 25 & 19 \\
0.1765 & -0.4706 & 0.2941 \\
25 & 15 & 1 \\
4520 & 235 & 13
\end{bmatrix} = \begin{bmatrix}
0.5320 & 1 & 0.76 \\
0.1765 & 0.4706 & 0.2941 \\
1 & 0.6 & 0.04 \\
1 & 0.052 & 0.0029
\end{bmatrix} \]

\( u_1 \) is the bus line value, \( u_2 \) is the travel time, \( u_3 \) is the overload value on the whole line, \( u_4 \) is the line fault value.

According to Table I. The influence factors, is

\[ a = \begin{bmatrix}
0.3438 & 0.3294 & 0.3280 & 0.2109
\end{bmatrix} \]

So, the biggest factor is the operation time.

This indicates that the travel time of the line needs to be optimized, which is also consistent with the actual over-long operational bus-line with 19 bus stops. It needs to operation in segments according to the actual situation, so as to shorten the travel time and improve the maintenance reliability of the bus line.

In fact, the maintenance index system is complicated, the example is only a validation of the relationship with the operation time and maintenance index.

4. Concluding Remarks

In this paper, an analysis method of the maintenance reliability is proposed, which can synthesize the influence factors including the running time of public transit, maintenance and so on. The most important factor to be solved is obtained and verified by an example. With the development of city, maintenance reliability will play an increasingly important role in the operation and management of public transit.

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6. References

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