# Service Quality Evaluation of Railway Freight Transportation Network Based on Bayes Theory

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**Abstract.** With the continuous improvement of the railway freight network, the effective evaluation can ensure that the railway remains competitive in the competition of freight market. Based on the analysis of the influencing factors of railway freight transportation network service quality, this paper constructs the event tree model according to the logical relationship among the factors, and then maps it into Bayesian network model. By calibrating the probability value of the basic events, the Bayesian network probability calculation method is used to obtain the top event probability value, which can determine the grade of the railway freight network service quality. Finally, a case study of Chengdu-Chongqing region is made was carried out to verify the effectiveness of the method.

**Keywords:** Railway transportation · Freight transport network · Service quality · Bayesian network · Evaluation

## 1 Introduction

Railway freight transportation plays an important role in national economic activities. With the development of social economy, the demand for quality of railway freight service has also been improved, and the transportation of cargo has become more and more timely and personalized. With the continuous reform of railway freight transportation in China, the construction of railway freight transportation network is becoming more and more perfect. The railway freight network mainly consists of two parts: the cargo transportation infrastructure network and the related operation service. The evaluation of the quality of the freight network service is beneficial to provide the basic basis for the reform and development of the freight transport, and further enhance the service level of the railway freight service network.


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Scholars at home and abroad have done a great deal of research on the service quality evaluation of transport network. However, existing research mainly focused on the field of road transport, and has done little direct research on the railway transport network. Moreover; it studies mainly the supply and demand of transport service network and the equality index. Chen [1] introduced capacity reliability as a new network performance index which includes connectivity reliability and travel time reliability, and a comprehensive methodology combining reliability and uncertainty analysis was used to analysis the performance of networks. Choiu [2] used the concept of reserve capacity of signal-controlled junctions and a projected gradient approach was presented. Chen and Kasikitwiwat [3] provide a quantitative assessment of capacity flexibility for the transportation network and two approaches based on the concept of reserve capacity and demand pattern were proposed. Zhou [4] used grey relationship analysis method and principal components analysis method to evaluation the networks. Ji [5] puts forward a railway network capacity adaptability study framework including supply and demand total amount adaptability, distribute structure adaptability, service quality adaptability and capacity flexibility, and AHP-grey fuzzy evaluation method was used.

Bayesian network is based on the Bayesian formula of the graphical probability method, which has shown a wide range of applicability in the transport of dangerous cargo on the railway, emergency rescue decision-making and other engineering computing. The influencing factors of the quality of railway freight network service is analyzed, the event tree model of network service quality is established, and the event tree model into Bayesian network model is mapped in this paper. Through the Bayesian network probability calculation method, we can obtain the network quality of service probability to determine the network quality of service level.

## 2 Analysis on the Influencing Factors of Network Service Quality

The service object of the railway freight transportation network is the owner of cargo, and the satisfaction of the owner's demand directly determines the service quality of the network. Therefore, the impact of quality factors of the network service in this paper is mainly considered from the perspective of the needs of the owner, including security, flexibility and reliability, rapidity, adaptability and economy. The established evaluation index system of service network is shown in Table 1.

**Table 1.** Evaluation index system of service network in railway freight transport

| Target layer | Index layer | Category | Evaluation index |
|---|---|---|---|
| Evaluation index system of service network in rail way freight transport (Q) | Security (A) | Accident (F) | Accident rate of ten thousand freight ($F_1$) |
| | | | Turnover accident rate of millions of cargo ($F_1$) |
| | | Accident emergency rescue capability | Accident emergency rescue capability (L) |
| | Flexibility and reliability (B) | Flexibility | Service flexibility (M) |
| | | Reliability (G) | Fulfillment rate of delivery period ($G_1$) |
| | | | Average delivery period ($G_1$) |
| | Fastness (C) | Rapidity (H) | Carrier handling time ($H_1$) |
| | | | Average delivery speed of goods ($H_1$) |
| | | Convenience (I) | Distribution density of freight station ($I_1$) |
| | | | Connectivity of road network ($I_1$) |
| | Adaptability (D) | Transport network adaptability | Adaptation coefficient of transport network (N) |
| | | Transport capacity adaptability | Adaptability of transport capacity (O) |
| | Economy (E) | Social and economic (J) benefits | Economic growth rate ($J_1$) |
| | | | Freight transport revenue ($J_2$) |
| | | Transportation cost benefits (K) | Freight transport rate ($K_1$) |
| | | | Transport facility cost ($K_2$) |

# 3 Service Quality Evaluation of Railway Freight Transportation Network Based on Bayes Theory

## 3.1 Theory Foundation of Bayesian Networks

Bayesian networks, also known as Bayesian belief networks (BBN), belong to the family of probabilistic graphical models in a set of variables. Generally, the Bayesian network consists of the directed acyclic graph (DAG) and the conditional probability table (CPT).

Each data sample is represented by an n-dimensional eigenvector $X = \{x_1, x_2, \ldots, x_n\}$, which describes n measures of n attribute samples $A_1, A_2, \ldots, A_n$ respectively. Assuming

that there are m classes $C_1, C_2, \ldots, C_m$, and an unknown data sample X is given, the Bayesian network can estimate the posterior probability of each class, and the basic reasoning formula is shown in formula (3).

$$P(C_i|X) = \frac{P(X|C_i) \cdot P(C_i)}{P(X)} \tag{1}$$

Since $P(X)$ is constant for all classes, it only need that $P(X|C_i) \cdot P(C_i)$ is the maximum. Among them, $P(C_i) = s_i/s$. $s_i$ is the number of training samples in class $C_i$, and $s$ is the total number of training samples. In order to simplify the calculation, the simple assumption of which the class conditions are independent can be made, that is, the attribute values are independent of each other, namely:

$$P(X|C_i) = \prod_{k=1}^{n} P(x_k|C_i) \tag{2}$$

Where, Probability $P(x_k|C_i)$ can be estimated from the training samples.

### 3.2 The Event Tree Model of Freight Network Service Quality

An event tree is a representation of the logical relationship between a certain event that may occur in the system and the various causes of events by using arborescence. Therefore, according to the analysis of the influencing factors in the first section, this paper constructs the event tree model of the railway freight network service quality evaluation, as shown in Fig. 1.

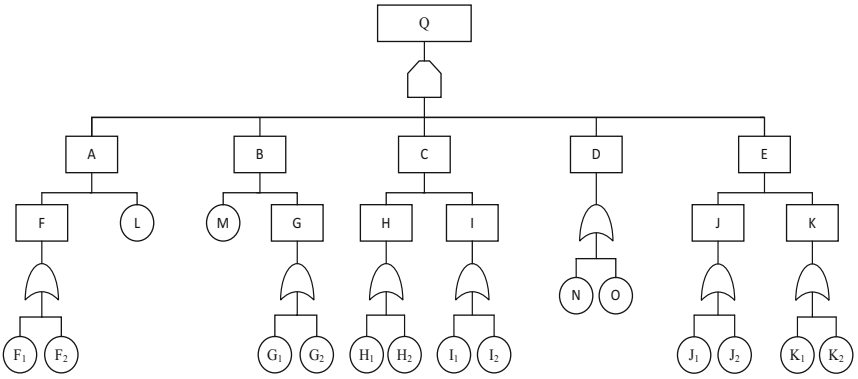


**Fig. 1.** Event tree model of freight network service quality evaluation

### 3.3 Probability Calculation Based on Bayesian Network

When the fault tree model is mapped to the Bayesian network model, the node corresponds to the event; the logic gate corresponds to the connection strength in Bayesian network, as shown in Fig. 2.

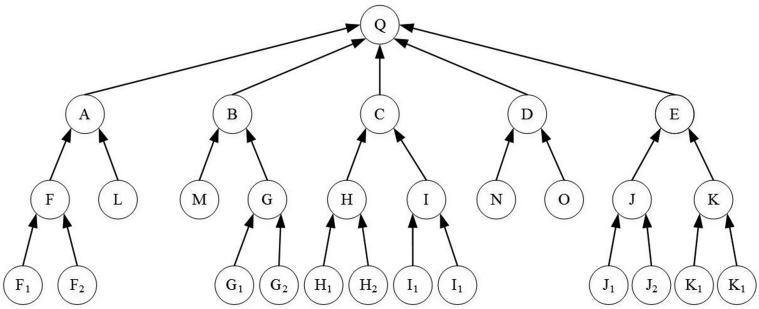


**Fig. 2.** Bayesian network of railway freight network service quality

Starting from the basic event node step by step, the probability value of the top event is calculated, and then the quality grade of the network system can be determined according to the probability value. If the event node contains a logical structure, the probability distribution formula is calculated as shown in Eq. (3):

$$P(S=1|X_1,X_2,\ldots,X_n)=\begin{cases} P(X_1=1)\times P(X_2=1)\times\ldots\times P(X_n=1), \ logic \ \ AND \ \ gate \\ 1-P(X_1=0)\times P(X_2=0)\times\ldots\times P(X_n=0), \ logic \ \ OR \ \ gate \end{cases} \tag{3}$$

Where, $X_i = 1$ indicates that the quality of network services is affected, and $X_i = 0$ is not affected.

**Table 2.** Result remarks

| Remarks | Excellent | Good | General | Poor | Bad |
|---|---|---|---|---|---|
| Intervals | [0.9, 1.0] | [0.8, 0.9) | [0.7, 0.8) | [0.6, 0.7) | [0.0, 0.6) |

The probability values of the network service quality are calculated, and the remarks of the probability values are shown in Table 2. Therefore, when the freight market changes, it's easy to find out the key influencing factors, and adjust the service marketing strategy and transportation organization measures timely to maintain the competitiveness of railway freight transportation.

## 4 Case Study

Taking the railway freight network in Chengdu and Chongqing as an example, this paper evaluates its service quality. Chengdu-Chongqing region takes Chengdu-Chongqing economic circle as the basis, with a total area of about 200,000 $km^2$, population 87.24 million, mainly covering 16 cities in Sichuan and 29 districts and counties in Chongqing.

According to the socio-economic and railway freight development status of Chengdu-Chongqing area, the statistical indicators are collected and the evaluation values are transformed into the [0, 1] range, as shown in the table.

In Table 3, the evaluation value of each evaluation index is the prior probability of the basic event, and the middle event probability can be obtained by formula (5): $P(G = 1|G_1, G_2) = 1 - P(G_1 = 0)P(G_1 = 0) = 1 - 0.4531 * 0.1997 = 0.9095$, the same can be obtained $P(F = 1|F_1, F_2) = 0.9640$, $P(H = 1|H_1, H_2) = 0.8799$, $P(I = 1|I_1, I_2) = 0.7046$, $P(J = 1|J_1, J_2) = 0.9149$, $P(K = 1|K_1, K_2) = 0.8439$, $P(D = 1|N, O) = 0.9868$.

**Table 3.** The statistics value about related evaluation index

| Evaluation index | Index value | Evaluation value |
|---|---|---|
| Accident rate of ten thousand freight $F_1$ | 0.08 | 0.8147 |
| Turnover accident rate of millions of cargo $F_2$ | 0.045 | 0.8058 |
| Accident emergency rescue capability L | A | 0.9134 |
| Service flexibility M | B | 0.6324 |
| Fulfilled rate of delivery period$G_1$ | 0.60 | 0.5469 |
| Average delivery period $G_2$ | 4.5 | 0.8003 |
| Carrier handling time $H_1$ | 0.67 | 0.7922 |
| Average delivery speed of goods $H_2$ | 26.83 | 0.4218 |
| Distribution density of freight station $I_1$ | 0.03 | 0.1419 |
| Connectivity of road network $I_2$ | 0.67 | 0.6557 |
| Adaptation coefficient of transport network N | 8.92 | 0.8491 |
| Adaptability of transport capacity O | 0.83 | 0.9130 |
| Economic growth rate $J_1$ | 0.07 | 0.6487 |
| Freight transport revenue $J_2$ | 45.21 | 0.7577 |
| Freight transport rate $K_1$ | 4.50 | 0.7431 |
| Transportation facility cost $K_2$ | 126.7 | 0.3922 |

Note: the data came from "The statistical communique on national economic and social development of Sichuan Province in 2016", "The statistical communique on national economic and social development in Chongqing in 2016" and "Regional planning of Cheng Yu Economic Zone (2011–2020)".

Then we use the BNT toolkit in Matlab to compute the posterior probability of each node in the Bayesian network: $P(A = 1|F, L) = 0.9734$, $P(B = 1|M, G) = 0.9875$, $P(C = 1|H, I) = 0.9649$, $P(E = 1|J, K) = 0.9972$. So we can get $P(Q = 1|A, B, C, D, E) = 0.9128$. According to the quality remarks table, the service quality of the network is the highest.

## 5 Conclusions

The development of community economy makes the railway pay more attention on the integrity in the competition of the freight market. The evaluation of the service quality of the railway freight network can improve the competitiveness of the railway in the freight transportation market. Based on the analysis of the factors affecting the service quality of railway freight transportation network, this paper uses event tree model and

logical relationship to combine and analyze the relationship between the factors. Through the collection of related information, calibration the prior probability of basic events, based on the fault tree model is mapped to a Bayesian network model, Bayesian conditional probability formula is used to obtain the posterior probability of network quality of service, which is a basis of quality evaluation. The Bayesian network model constructed in this paper provides a theoretical basis for the analysis and evaluation of railway freight transportation service network.

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