Research on the Risk Assessment on the Mass Freight Transportation Network Methods and Application Study

Yingting Long[1, a], Xifu Wang[2,b]

[1]School of Traffic and Transportation, Beijing Jiaotong University, Beijing, 100044, China

[2]School of Traffic and Transportation, Beijing Jiaotong University, Beijing, 100044, China

[a]email:1551835427@qq.com, [b]email:wxfkyg@vip.sina.com

Keywords: Mass Freight Transportation, Risk Assessment, Sea-railway Combined Transportation, Hierarchy Grey Model.

Abstract. In today's society, mass freight logistics demand is growing stronger, market competition is becoming increasingly fierce, and transport uncertainty is increasing. Risk assessment is one of the most important parts; it is conducive to the realization of low cost, high quality transport services. In this paper, mass freight transport networks (mainly on the sea-railway combined transport network) is an study object of risk assessment, analyze risk factors, design indexes system of assessment, and use the multi hierarchical grey assessment model to risk assessment. Taking Shanxi coal transport network as an example put forward the improvement method.

Introduction

The price fluctuation of mass freight is big, they have a large quantity of supply and demand, value added is usually low, and transport mileage is often longer. For example, coal is more representative of mass freight, transport volume accounts for about 40% of national railway and waterway freight volume a year. Sea-railway combined transportation can be conducive to the realization of economic advantage. Today, mass freight logistics demand and competition are strengthened; its uncertainty makes the transport network risks. Above all, this paper will do the risk assessment by using coal sea-railway combined transportation as a representative, design risk indexes and establish assessment model to provide reference for risk reduction of mass freight sea-railway combined transportation network.

Mass Freight Sea-railway Combined Transportation Network Risk Factors and Assessment Index System

Risk factors
Risk analysis of internal factors

Mass freight sea-railway combined transportation network internal risk factors include network structure and internal mechanism and the system. From the topological structure, it has the structural characteristics of complex networks[1]. For example, the relationship between the internal factors and the risk of coal sea-railway combined transportation network show that the higher the node density, the higher the link density, the greater the network connection, the higher network availability, the smaller the network risk. As for internal mechanism and the system, network comprised of several interdependent and interaction internal module,such as railway, ports, freight forwarding, shipping etc.

Risk analysis of external factors

The external factors include the risk caused by the imbalance relationship between supply and demand, the risk caused by external environment including natural risk, policy and law risk, economic risk, industry risk.

Assessment index system

Combining with the analysis on the main factors of sea-railway combined transportation network above, in accordance with the establishment principles, including objective, scientific, systematic, applicability, level and effectiveness. I designed a mass freight sea-railway combined transportation network hierarchical framework of risk assessment index system consisting of the target layer, criterion layer and index layer, as shown in figure.1.
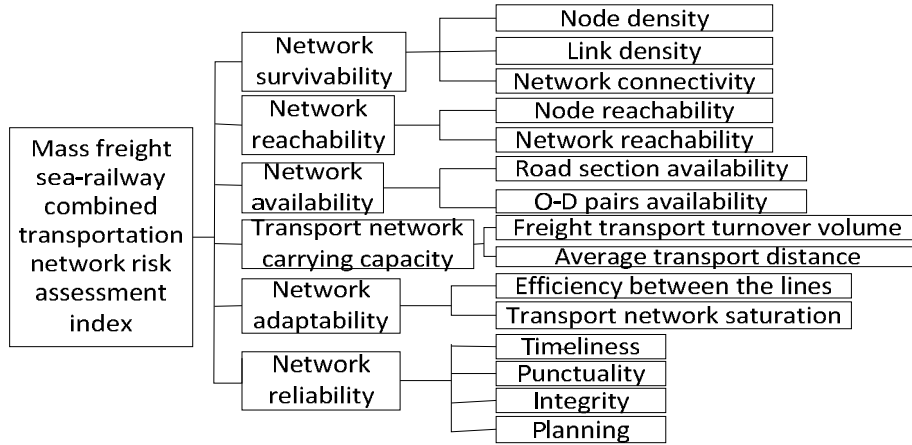

Fig.1 Risk assessment index system

Network survivability

Node Density. Transport network node density equal to the number of nodes network coverage area divided by the area of the region. The higher node density, the stronger the network survivability.

Link Density. In mass freight sea-railway combined transportation network system, put the railway transportation lines or air route connecting nodes as a link. Link density refers to kilometers per square kilometer area in the region number of transport routes, measurement unit is km/km². The higher link density, he stronger the network survivability.

Network Connectivity. Transport network connectivity refers to the degree to connect all the nodes in the network, the network cable is the maximum possible number of the ratio of the number of connections. The larger the network connectivity, the stronger the network survivability.

Network reachability

Node Reachability. It is represented by a node from the beginning to the average distance Di to every other node. The smaller the ratio, the better the network reachability, the lower the risk. Calculated as follows:

$$D_i = \frac{\sum_{\substack{j=1 \\ j \neq i}}^{N} d_{ij}}{M}, (j = 1, 2, ..., N) \tag{1}$$

d_{ij} is the shortest average traveling distance from node i to node j, N is the number of nodes within the region, M is the difference between the number of nodes and non-reachable nodes in the region.

Network Reachability. It reflects the degree of traffic convenience between nodes. The smaller the network reachability,the more convenient the transportation, the smaller the risk. Calculated as follows:

$$D = \frac{\sum_{i=1}^{N} D_i}{O} \tag{2}$$

D_i is the average distance from node i to each other node, O is the number of the starting point in the region.

Network availability

Network availability is the probability that at some time within the network capabilities required to perform the function of transport, namely the probability that sea-railway combined transportation network can normally use.

Road Section Availability.A section's availability is calculated as follows:

$$r_e = \frac{\mu_e - \chi_e}{\mu_e} \tag{3}$$

μ_ε is the section planned transport capacity,χ_e is the actual flow. The higher r_e, the higher availability, the stronger stability. Ifχ_e is not less than μ_ε, then this sector has become a restricted zone or interruption, r_e =0, it is no longer available in the study.

O-D Pairs Availability. In mass freight sea-railway combined transportation network,all valid up paths between any OD pair can be seen as a parallel system. In an OD pair, as long as there is a path to be able to communicate on the OD will be connected.

Transport network carrying capacity

Transport network transport system carrying capacity refers to satisfy the service and quality requirements of users and resources, environment, transportation systems to meet the traffic demand maximum capacity, reflecting the actual sea-railway combined transportation network carrying the load status.

Freight Transport Turnover Volume. It refers to sea-railway combined transportation network complete cargo transport tonne-kilometers a period of time,equal to the product of cargo shipping tonnage and transportation mileage. The smaller the freight transport turnover volume, the better transport carrying capacity, the smaller the risk.

Average Transport Distance. It reflects the average travel distance transport objects on the transport network.The smaller the average transport distance, the better the state of the road network convergence space.

Network adaptability

Network adaptability refers to sea-railway combined transportation network for the rational allocation of limited resources, with minimal consumption of resources to maximize the ability to meet the transport needs.

Efficiency Between The Lines E. It is defined as the average efficiency of the path of sending station to arrival station in the network .The closer to 1, indicating that the traffic situation and the best closer on the line, the higher the efficiency.

Transport Network Saturation. It is a reflection of the degree of saturation of an integrated transport network congestion, equal to the actual amount of traffic and design through the transport network on the ratio V / C. Learn Highway Research Institute of China's Ministry of Transportation scientific research, the assessment results can be drawn from standard tables integrated transport network.

Network reliability

Mass freight sea-railway combined transportation network reliability factors include: timeliness (timely delivery), punctuality (time issue), integrity (safety rate undamaged goods or people), planning (whether in accordance with the inherent operational plan), risk (flights canceled and so the probability of occurrence).

Mass Freight Sea-railway Combined Transportation Network Risk Assessment and Models

Because mass freight sea-railway combined transportation network risk assessment type, quantity, complex relationships,and its index informations have randomness, fuzziness, incompleteness, incompatibility and other uncertainties features. After the comparative analysis, in this paper, it will use the Analytic Hierarchy Process[2] combined with hierarchy grey model method to establish assessment model. According to the index system above, hierarchy grey model assessment method steps follows:

(1)Based on the assessment index system,establish the assessment factors. The assessment factors into the target layer A, criteria layer B, index layer C.

(2) Determine the assessment set.Each set of assessment factors may be expressed as $E=\{E_1,E_2,E_3,E_4\}=\{$Low risk,Medium risk,High risk,Higher risk$\}$.

(3) Determine the weights of level of each index C_{ij}. Clear assessment objective,use AHP, establish judgment matrix by pairwising comparison of the importance of scoring. Solve it by matrix eigenvalues method.

(4)Score qualitative indicators. According to the assessment results of the evaluators, and seek assessment of the assessment sample matrix G

$$G = \begin{pmatrix} g_{111} & \cdots & g_{11m} \\ \vdots & \ddots & \vdots \\ g_{ij1} & \cdots & g_{ijm} \end{pmatrix} = \begin{matrix} C_{11} \\ \vdots \\ C_{ij} \end{matrix} \tag{4}$$

The greater the risk, the greater the experts'value score. Rank the scores can set a standard based on the actual situation. Shown in the following table 1:

Table 1 The correspondence between the assessment indexs and the scores

Score	5.0-4.0	4.0-3.0	3.0-2.0	2.0-0.0
Assessment index	Higher risk	High risk	Medium risk	Low risk

(5) Determine index classification assessment table. According to the actual situation of mass freight sea-railway combined transportation network assessment indexs, Establish specific qualitative and quantitative indicators grading standards.

(6)Determine assessment of gray and calculate the number of gray assessment. Choose certain whitenization weight function to describe the gray type, depending on the specific circumstances[4] . The k-th expert's score to index C_{ij} is recorded as d_{ijk}.The greater the risk, the greater the value of expert scoring.For C_{ij}, gray assessment number belonging to the n-th assessment gray is recorded as X_{ijn}.That is:

$$X_{ijn} = \sum_{k=1}^{p} f_n （d_{ijk}） \tag{5}$$

The total gray assessment number for C_{ij} is recorded as X_{ij}. That is:

$$X_{ij} = \sum_{n=1}^{p} （X_{ijn}） \tag{6}$$

(7) Calculate the gray assessment weight vector and weight matrix.Evaluators give gray assessment number to assessment index C_{ij}'s n-th assessment of gray.The number is recorded as r_{ijn}.

Then there is the equation:

$$r_{ijn} = \frac{x_{ijn}}{x_{ij}}$$

(7)

Then get B_i's,which belongs to C_{ij}, gray assessment weight matrixR_i for each grey assessment:

$$R_i = \begin{pmatrix} r_{i1} \\ r_{i2} \\ \vdots \\ r_{ij} \end{pmatrix} = \begin{pmatrix} r_{i11} & \cdots r_{i1n} \\ r_{i21} & \cdots r_{i2n} \\ \vdots & \vdots & \vdots \\ r_{ijn} & \cdots r_{ijn} \end{pmatrix}$$

(8)

(8)Do comprehensive assessment for B_i,and calculate comprehensive assessment value.The result of comprehensive assessment is recorded asβ_i.Then there is:

$$\beta_i = A \times R = A \times \begin{pmatrix} A_1 \cdot R_1 \\ \vdots \\ A_m \cdot R_m \end{pmatrix} = (b_1, b_2, \ldots, b_n)$$

(9)

It follows that gray assessment weight matrixR of each criteria layer index to each assessment grey type. Assign the various kinds of grades in accordance with the gray level,and get vectorZ=(d_1,d_2,⋯, d_n).Comprehensive assessment valueZ=B・C^T .

Application Examples

In this section,it takes Shanxi Coal sea-railway combined transportation network as an example, according to statistics,a length of about 2603km, a width of about 2384km, with a network covering

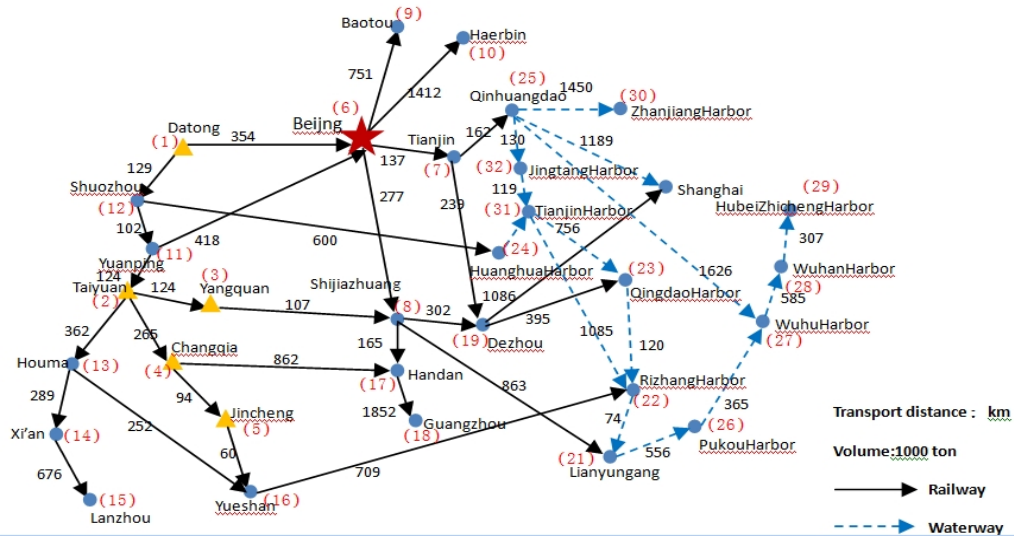an area of $6,241,435 km^2$. The network is abstracted into a network diagram as shown in figure.2.

Fig.2 Shanxi Coal sea-railway combined transportation abstract network diagram

Establish the index system by the above model and calculates every index.Get the assessment weight vector:

$$B = W \cdot B_i = \begin{pmatrix} 0.34 \\ 0.23 \\ 0.19 \\ 0.09 \\ 0.10 \\ 0.05 \end{pmatrix}^T \begin{pmatrix} 0.33, 0.43, 0.43, 0.12, 0.21, 0.10 \\ 0.36, 0.37, 0.37, 0.27, 0.32, 0.25 \\ 0.28, 0.20, 0.21, 0.38, 0.36, 0.36 \\ 0.03, 0.00, 0.00, 0.22, 0.11, 0.30 \end{pmatrix}^T = (0.33, 0.35, 0.27, 0.05)$$

This paper's gray type is divided into four levels: higher risk, high risk, medium risk and low risk. Determine the assignment vector of each assessment grey class $C = (4.5, 3.5, 2.5, 1.5)^T$. Obtain Coal sea-railway combined transportation network risk comprehensive assessment value Z.

$$Z = B \cdot C^T = (0.34, 0.35, 0.23, 0.02) \cdot \begin{pmatrix} 4.5 \\ 3.5 \\ 2.5 \\ 1.5 \end{pmatrix} = 3.46$$

Combined set of comments provided above, this network system is between medium risk and high risk. Each factor's specific assessment value of index layer: 3.36, 3.73, 3.75, 2.76, 3.13, 2.67. Therefore, the degree of influencet on risk assessment value of Shanxi Coal sea-railway combined transportation network in descending order of network availability, network accessibility, network survivability, network adaptability, transport network carrying capacity, network reliability.

Conclusions

In this paper, mass freight transport networks (mainly on the sea-railway combined transport network) is an study object of risk assessment. First thing is comprehensive analysis of sea-railway combined coal transportation network. Secondly, through consulting a large number of literature, analyse transportation network risk and management, identify the steps of risk assessment. Then through qualitative and quantitative point of view again to establish the sea-rail transport network risk assessment index system, and through the grey clustering to optimize index system integration. Finally, do risk assessment to sea-railway combined coal transportation of Shanxi province by using the constructed index system, model and assessment method, then the summary of this network is "risk level is between medium and high". Thus each model can be optimized according to the actual situation of the steps to make it better suited for risk assessment in general mass freight sea-railway combined transportation network.

References

[1] Guo Jinyu, Zhang Zhongbin, Sun Qingyun. Study and Applications of Analytic Hierarchy Process [J]. China Safety Science Journal, 2008, 18 (5): 148-153.

[2] Du Xiaoling, Deng Shaomin. The Application of Analytic Hierarchy Process in Venture Investment Project Evaluation [J]. Journal of Nanchang University, 2005, 27(4): 63-66.

[3] Hu Rong, Huang Nanjing. A Comprehensive Evaluating Model Based on Multi-hierarchy Gray Theory [J]. Journal of Sichuan University, 2005, 42 (5).

[4] Dong Fenyi, Liu Bin. Grey System, Whitenization Discipline and the Whitenization Weight Function [C]. 2010.

[5] Guan Xiaojun. Research on Rlsk Evaluation and Balance to Maintain of TransPort network of Coal Logistics [D]. of Beijing Jiaotong University, 2010. 13-14.

[6] Xu Jing, Wang Xifu. Analysis of Index System of Risk Evaluation of Logistics Transport Network [J]. Logistics Technology, 2010 (216).

[7] Wu Xiandan, The Risk Assessment on the Sea-Rail Transport Network based on the Double-layer Gray Fuzzy Mode. Beijing Jiaotong University [D], 2012, 32-33.