

Shipping Route Optimization and Risk Management based on Big Data Analysis

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Abstract

In the global economic map, the shipping industry plays an important role. At the same time, it has to face many challenges, especially the thorny issue of risk management. In view of these challenges, this study deeply explores the application value of big data analysis in shipping route optimization and risk management. The research aims to improve the optimization of shipping routes and the accuracy of risk management with the help of big data analysis technology. In order to provide scientific and efficient support for the decision-making of shipping enterprises. On the basis of discussing the traditional means of shipping route optimization and risk management and pointing out their shortcomings, this paper expounds the shipping route optimization strategy and risk management system based on big data in detail. It covers key steps such as data collection, processing, feature extraction, and risk identification, evaluation, early warning and response. The results fully demonstrate the broad prospects of big data analysis in the field of shipping. Future suggestions include strengthening data governance, improving algorithm model, promoting interdisciplinary cooperation, and paying attention to data security and privacy protection.

Keywords

Big Data Analysis; Optimization of Shipping Routes; Risk Management; Prediction Model; Data Governance.

1. Introduction

As the lifeline of the global economy, the shipping industry undertakes the core task of international trade cargo transportation. Its strategic position is obvious [1]. This industry not only connects economies all over the world in series, but also accelerates the circulation of goods, capital and technology, and is the key to the stability and efficiency of global supply chain [2]. However, with the sustained growth of the global economy and the increasing complexity of the international trade environment, the shipping industry has also encountered a series of challenges [3]. The rising cost, such as the fluctuation of fuel price and the increase of labor cost, makes the operating cost of shipping enterprises continue to rise. Improper route selection may lead to prolonged sailing time and increased cargo loss [4]. The escalation of risks, including unpredictable threats such as piracy and natural disasters, poses a serious challenge to shipping safety.

In the face of these challenges, big data analysis technology has brought innovative solutions to the shipping industry with its uniqueness [5]. Through the collection, processing and analysis of massive shipping data, this technology can dig out the rules behind route selection and provide more accurate and efficient route optimization strategies for shipping enterprises [6]. In terms of risk management, big data analysis can also quantitatively evaluate all kinds of risks, helping shipping companies to formulate countermeasures in advance to reduce the losses caused by risks [7].

Based on the above, the purpose of this paper is to explore how to optimize shipping routes and reduce risks through big data analysis technology. This paper deeply studies the application methods of big data analysis in the shipping field, and explores its potential in route planning, cost control and risk early warning. In order to provide scientific and feasible decision support for shipping enterprises. The significance of this study should not be underestimated. Theoretically, it will enrich and expand the theoretical framework of shipping route optimization and risk management, and provide new research perspectives and methods for academic circles. From the practical value, the research results will be directly applied to the actual operation of shipping enterprises to help them improve operational efficiency, reduce costs, enhance risk resistance and promote the sustainable development of the shipping industry.

2. Theoretical Basis of Shipping Route Optimization and Risk Management

In the traditional methods of shipping route optimization, the shortest path algorithm and cost-benefit analysis are two common technologies. The shortest path algorithm is to find the shortest distance or shortest time between two points. This method is more effective in a simple shipping network [8]. However, in the face of the complicated shipping network, especially when it involves multiple transshipment points, different modes of transportation and fluctuating transportation costs, the practicability of the shortest path method is limited. In contrast, cost-benefit analysis is a more comprehensive strategy. Cost-benefit analysis is a more comprehensive method. It not only pays attention to the length of the path, but also considers many factors such as transportation cost, time cost and possible risk cost [9]. However, this method generally needs a lot of data support and complicated calculation process. In practical application, it is difficult to accurately estimate all cost factors. Therefore, this method also has some limitations.

Risk management is an indispensable part of the shipping industry. It mainly includes three steps: risk identification, risk assessment and risk response, as shown in Figure 1.

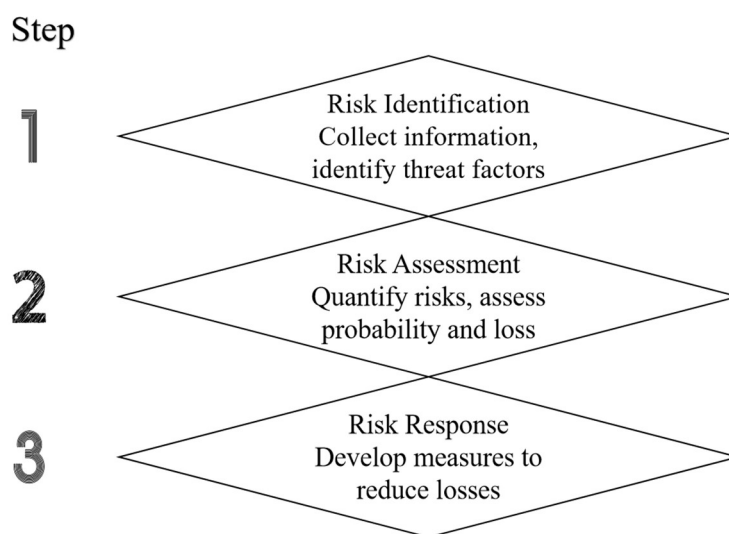


Figure 1. Risk management steps of shipping industry

Risk identification is the first step of risk management. This step identifies the risk factors that may pose a threat to shipping activities by collecting and analyzing all kinds of information [10]. Risk assessment is to quantify and evaluate the identified risks, and determine the probability

of their possible occurrence and the degree of possible losses. Risk response is to formulate strategies to mitigate the impact of risks based on the evaluation results. Traditional risk management methods are generally based on experience and subjective judgment, and lack sufficient scientificity and accuracy.

The emergence of big data analysis technology provides a new method for shipping route optimization and risk management [11]. Data mining technology can extract key information from a large number of shipping data to support route planning and risk management. Machine learning technology can establish a prediction model by learning historical data to predict future shipping routes and risks. These models can comprehensively consider various variables (meteorological conditions, sea conditions, cargo types, ship status, etc.) and improve the reliability of forecasting. The application of big data technology in the shipping industry has shown its remarkable results. For example, through big data analysis, shipping companies can more accurately predict the arrival time of ships, optimize route planning, and reduce navigation time and cost. Big data analysis can also help identify potential risks (piracy, natural disasters, etc.), plan coping strategies in advance and reduce the damage caused by risks.

3. Shipping Route Optimization Strategy based on Big Data Analysis

In the process of applying big data analysis technology to improve the efficiency of shipping routes, the first task is to carry out comprehensive data collection. This involves historical navigation data, meteorological and sea state information, port operation data and cargo-related information. There are many data sources and different formats. Therefore, it is necessary to ensure the accuracy and consistency of data through integration and cleaning. Next is the data processing stage. We need to use data preprocessing technology (missing value filling, abnormal value detection and processing, and data standardization, etc.) to lay a solid foundation for the subsequent analysis. Feature extraction is a key link in data analysis. By mining the hidden features in the data, we can understand the operation law of shipping routes more deeply. Implicit features include ship speed, route congestion, port loading and unloading efficiency, etc.

The optimization model of shipping route based on big data is the core of realizing route intelligence. The route selection model provides the best route advice for ships by comprehensively considering various factors such as sailing distance, time, cost and risk. The cost prediction model can accurately predict the transportation cost under different routes and assist enterprises to make more economic decisions. The advantage of these models is that they can process a large amount of data in real time and respond to market changes quickly. They provide accurate and comprehensive optimization schemes while considering various constraints. The effect of big data analysis in shipping route optimization is obvious. Through route optimization, ships can reduce unnecessary sailing time and improve transportation efficiency. The application of cost forecasting model helps enterprises to control costs more accurately and enhance profitability. Big data analysis can also help enterprises find potential transportation bottlenecks and risk points, and take countermeasures in advance to ensure the smooth progress of shipping activities.

Big data analysis also encounters challenges and limitations in shipping route optimization, as shown in Table 1. Data quality and security are key issues. Inaccurate or incomplete data may lead to deviation of optimization results, and data leakage may bring losses to enterprises. The complexity of the model and the demand for computing resources are also factors that cannot be ignored. In order to meet these challenges, it is necessary to strengthen data governance and ensure the accuracy and security of data. These are shown in Table 1.

Table 1. Challenges, Limitations, and Countermeasures of Big Data Analysis in Shipping Route Optimization

Challenge/Limitation	Specific Description	Countermeasure
Data Quality	Inaccurate or incomplete data may lead to biased optimization results, affecting the accuracy of decision-making	Strengthen data governance, establish data cleaning and verification mechanisms to ensure data accuracy and completeness
Data Security	Data breaches may cause economic losses and reputational damage to enterprises	Enhance data security protection, implement data encryption and access control, and conduct regular security audits and vulnerability scans
Model Complexity	Complex models may increase the difficulty of understanding and implementation, reducing optimization efficiency	Optimize model design, simplify model structure, and improve model interpretability and usability
Computational Resource Demand	Big data analysis requires significant computational resources, potentially increasing operational and time costs	Enhance computational capabilities, adopt distributed computing and cloud computing technologies, optimize algorithms and code, and improve computational efficiency

4. Shipping Risk Management Strategy based on Big Data Analysis

The shipping industry is a highly complex industry affected by many factors, and it is currently facing many risks. Market risk mainly comes from the uncertainty of international trade environment. Economic fluctuations and policy changes may lead to large fluctuations in shipping demand. Operational risk runs through all aspects of shipping activities: from the maintenance and management of ships to the loading and unloading of goods, any small negligence may trigger a chain reaction, leading to operational interruption or loss. Natural risk is an unavoidable challenge for the shipping industry. Natural disasters such as typhoons and tsunamis pose a serious threat to the safety of ships and cargo. The causes of these risks are complex, including the unpredictability of the external environment and the lack of internal management. In order to effectively deal with these risks, this section constructs a shipping risk management framework based on big data (as shown in Table 2).

Table 2. Big Data-Based Risk Management Framework for Shipping Industry

Stage	Description	Key Technologies/Methods
Risk Identification	Utilize big data technologies to identify various risks faced by the shipping industry, including market, operational, and natural risks	Data mining, text analysis, social media monitoring
Risk Assessment	Quantitatively assess the identified risks to determine their likelihood and impact	Probability statistics, risk matrix, simulation
Risk Warning	Establish a risk warning system to monitor risk changes in real-time and issue early warning signals	Real-time monitoring, warning algorithms, visualization
Risk Response	Develop and implement corresponding risk response measures based on risk assessment and warning results	Emergency plans, decision support, resource allocation

As shown in Table 2, the shipping risk management framework includes four key links: risk identification, risk assessment, risk early warning and risk response. Risk identification is to identify risk factors that may pose a threat to shipping activities by collecting and analyzing

various data. Risk assessment quantifies these risks and evaluates their possibility and potential losses. On the basis of risk assessment, risk early warning sends out early warning signals in time to remind relevant personnel to take preventive measures. Risk response is to formulate corresponding response plans according to the results of risk early warning to reduce the losses caused by risks.

Big data analysis technology plays an important role in improving the accuracy and efficiency of risk management. By establishing a forecasting model, we can dig and analyze the historical data deeply and find out the law and trend of risk occurrence. These models can consider various risk factors and evaluate the risk probability and influence degree more accurately. Big data analysis can monitor shipping activities in real time, quickly discover potential risks, and provide support for early warning and response. The application of big data analysis in shipping risk management has achieved remarkable results. Through accurate risk identification and assessment, relevant personnel can take preventive measures in advance to effectively reduce the incidence of accidents. Big data analysis can also help them estimate the degree of loss more accurately and provide a scientific basis for risk response. These applications improve the quality and efficiency of shipping risk management and provide a solid guarantee for the sustainable development of the industry.

5. Conclusion

The application of big data technology in shipping risk management has shown its obvious advantages. The powerful data processing ability of this technology makes it possible to extract valuable information from a large number of shipping data. This provides a more comprehensive perspective for risk identification. With the construction of forecasting model, big data technology can accurately assess the probability and impact of risks, and improve the accuracy and timeliness of risk assessment. Big data analysis can also monitor the dynamic changes of shipping activities in real time, discover and warn potential risks in time, and win valuable time for risk response. Despite this, big data technology also has limitations in shipping risk management. For example, the quality and integrity of data directly affect the accuracy of analysis results. The complexity of the model and the high demand for computing resources may also limit its wide application.

Aiming at the advantages and disadvantages of big data technology in shipping risk management, this paper puts forward the following research directions and suggestions. ① It is necessary to strengthen data governance, improve data quality and availability, and ensure the correctness of analysis results. ② The algorithm and model need to be continuously optimized to reduce the complexity of calculation and improve the analysis efficiency, so as to better meet the needs of practical applications. ③ Strengthen interdisciplinary cooperation, and combine the professional knowledge in the shipping field to deeply explore the new application and new model of big data analysis in shipping risk management. ④ Pay attention to data security and privacy protection. Ensure that sensitive information is not leaked in the analysis process, and protect the legitimate rights and interests of relevant stakeholders. By implementing the above four research directions and suggestions, it is expected to further improve the application level of big data technology in shipping risk management and provide more support for the sustainable development of the shipping industry.

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