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Analysis of Risk Factors for Disruptions in International Maritime Shipping Supply Chains

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Abstract: The international maritime shipping supply chain is an indispensable component of the globalized economy, yet it also faces numerous and complex risks due to its cross-border operational nature. This study aims to systematically identify and deeply analyze the disruption risks of the international maritime shipping supply chain, revealing the unique vulnerability factors of this supply chain and discussing its preventive measures. Through quantitative statistical analysis of international shipping routes, it discloses the disruption events of major maritime transportation routes in the past five years and the direct economic losses they have caused, and comprehensively assesses various risk factors such as natural disasters, geopolitical conflicts, pirate attacks, and changes in shipping policies. In addition, combined with case analysis, it identifies different risk response strategies adopted by companies in the industry, such as decentralized logistics nodes, emergency material reserves, and supply chain insurance. The achievements of this study not only have profound practical significance for related enterprises in early warning and responding to the risks of the international maritime shipping supply chain, but also provide theoretical and methodological innovations for academic research on supply chain management.

Keywords: International maritime shipping, Supply chain disruption, Risk analysis, Data analysis, Risk management.

1. Main Causes of Disruption Risks in International Maritime Shipping Supply Chains

1.1. Natural or Environmental Events

The disruption risk factors of the international maritime shipping supply chain are multi-faceted, among which natural or environmental events have a particularly significant impact on the supply chain. For example, the occurrence of natural disasters such as typhoons, earthquakes, and tsunamis often lead to the closure of ports, interruption of transportation routes, and even the suspension of the entire supply chain system [1]. Under these extreme climate conditions, maritime ships may face the risk of accidents, resulting in the risk of cargo loss or delayed delivery to the end consumers. Specific data shows that in the past few years, the daily economic loss due to super typhoons causing cargo delays can be as high as several million dollars. Due to the long distance of the maritime shipping supply chain and its susceptibility to the natural environment, any weather change may pose a threat to the stability of the shipping route. In addition, the rise in sea level and the increase in extreme weather events caused by global climate change have also increased the vulnerability of port infrastructure and logistics nodes, thereby increasing the uncertainty and potential risks of the maritime shipping supply chain. To cope with these risks, transportation companies have to increase insurance coverage and design more rigorous emergency response plans to ensure the rapid recovery of the supply chain in the event of natural disasters.

1.2. Transportation Failures

Among the multiple links of the international maritime shipping supply chain, transportation failures are one of the important risks that lead to disruptions. Such failures often stem from problems such as mechanical system failures of cargo ships, severe weather at sea, navigation errors, and overloading of containers. Mechanical failures of ships, especially problems with the main engine and auxiliary engines, can cause ships to lose power and be unable to continue sailing or require emergency repairs. Failures at sea occur frequently. According to statistics, the average number of events where ships need to leave the shipping route for rescue or repair due to main engine failures exceeds 200 per year. In addition, failures of automation systems may also trigger potential risks. For example, the failure of the navigation system may lead to deviation from the shipping route or even grounding accidents [2]. The problem of container overloading cannot be ignored either. The resulting center of gravity shift will increase the risk of capsizing in bad weather conditions. Therefore, in response to these risk factors, shipping companies also need to conduct regular ship maintenance to ensure operational efficiency, formulate strict loading standards to avoid loading errors, and invest in advanced navigation and automation equipment to enhance the safety and stability of ships at sea. In addition, ensuring rapid repair and restoration of the supply chain when transportation failures occur is the key to managing risks. Establishing emergency plans and rapid response mechanisms is also an indispensable part of preventing supply chain disruptions.

1.3. Workers' Strikes

Workers' strikes are one of the risks that lead to disruptions in the international maritime shipping supply chain, and their impact cannot be underestimated. In the maritime shipping field, workers mainly include crew members, port loading and unloading workers, and logistics distributors. Among them, strikes by crew members will directly affect the normal operation of ships, and products and materials stranded at the port cannot be transported to the destination on time; strikes by loading and unloading workers will affect the operational efficiency of the port, thereby delaying the time for ships to berth and depart, and prolonging the cargo turnover cycle;

strikes by logistics distributors may make it difficult to complete the last-mile distribution, making it impossible for goods to be delivered to end users in a timely manner. The reasons for strikes are complex and diverse, including wage and treatment issues, as well as disputes over labor conditions and working hours. Once it occurs, the direct result is usually the interruption of supply chain services, causing poor circulation of goods, and the indirect impact may lead to the obstruction of the production plans of upstream and downstream enterprises in the industrial chain, deteriorating the market supply and demand relationship, and causing fluctuations in commodity prices. Against the background of global economic integration, the disruption of the international maritime shipping supply chain will affect the production and sales of multinational companies and affect the global market pattern. Past cases have shown that strike activities on important shipping routes usually cause economic losses ranging from millions to billions of yuan, indicating that its potential destructive power is very huge. To reduce supply chain risks, shipping companies and port operators need to formulate detailed response plans and reduce potential losses through strategies such as advance negotiations, increasing alternative labor forces, and multi-channel logistics planning before the risk of workers' strikes occurs. In addition, in the long term, measures such as improving employees' working conditions and adjusting the salary and welfare structure can also help resolve the root causes of workers' strikes, thereby fundamentally reducing the disruption risks brought by workers' strikes to the maritime shipping supply chain.

1.4. Geopolitical Instability

Under political turmoil and geopolitical instability factors, the disruption risk of the international maritime shipping supply chain significantly increases. These risks not only stem from policy changes in a single country but may also involve intensified tensions among multiple countries, and even military conflicts or sanctions [3]. Therefore, it is crucial to conduct in-depth analysis of the risk factors and the cost of risk occurrence of the international maritime shipping supply chain in a politically turbulent environment. Taking international shipping lanes such as the South China Sea and the Strait of Hormuz as examples, the unstable political environment and frequent geopolitical events in the region directly lead to freight disruptions or detours, resulting in increased transportation costs and potential risks of cargo loss and delayed delivery. According to relevant statistical analysis, transportation delays and disruptions caused by political factors in the Strait of Hormuz have caused an average economic loss of approximately $250 million each time in the past three years. In addition to direct economic losses, political turmoil also triggers a chain reaction in multiple links of the supply chain, increasing the uncertainty and operational costs of the supply chain. The unstable political environment also greatly affects trade trust in the supply chain. Demand and supply sides may re-evaluate and select partners due to the deterioration of international relations, which poses a strategic threat to the long-term stability of the supply chain. Measured by the increase in escort fees for civilian ships and insurance premiums, insurance premiums can increase significantly by 70% before and after the conflict, and both shipping companies and cargo owners need to bear higher additional costs. Therefore, in the management of the international maritime shipping supply chain, it is particularly important to establish a comprehensive political risk assessment system, monitor the probability of occurrence and possible degree of influence of political risk events, and construct a crisis event response mechanism. In terms of responding to political risk management, companies can avoid potential risks and reduce losses caused by supply chain disruptions through measures such as multilateral diplomatic channels, strategic resource reserves, and dynamic adjustment of shipping route planning.

2. Response Mechanisms for Disruption Risks of International Maritime Shipping Supply Chains

2.1. Establishing a Supply Chain Disruption Risk Warning System

To ensure the continuous and stable operation of the international maritime shipping supply chain in the face of a changing environment and potential threats, it is particularly crucial to establish an efficient supply chain disruption risk warning system. The core of this warning system lies in real-time monitoring and rapid response to risk factors through massive data analysis to reduce or avoid losses. Firstly, through deep learning algorithms, historical data is used to learn and identify patterns of risk situations, thereby achieving accurate prediction of potential disruptions. Specifically, for different types of risk sources, such as natural disasters, geopolitical changes, and pirate attacks, different data models are constructed to generate corresponding risk warning signals. For example, using remote sensing technology, real-time monitoring of meteorological conditions along the route can be carried out. Once there is a disaster risk such as typhoons and storms, the emergency plan is immediately activated, the shipping route is adjusted, or the departure time is postponed to ensure the safety of goods and the smooth progress of the voyage [4]. In terms of route selection, simulation scenarios are created in combination with political and economic dynamics. Through the analysis of the impact effects of historical events, the robustness of each route is evaluated, and additional strategic considerations are required for shipping lanes in high-risk areas [5]. In addition, with the help of big data technology, in-depth research can be conducted on the connections between various nodes of the supply chain, especially on key nodes for focused monitoring to ensure information symmetry and further enhance the response speed and processing capacity of the entire warning system. Mathematical models and computer simulations are important tools for constructing this warning system. By establishing a risk assessment index system and collecting and analyzing thousands of complex data structures from various sources, scientific and reasonable risk assessment results can be given in the shortest time and the corresponding warning mechanism is triggered [6]. From a practical perspective, after the oil well leakage accident in the Gulf of Mexico, British Petroleum began to implement such a risk warning system. By installing sensors on oil transport ships, collecting environmental data and analyzing possible risks, an effective prevention strategy was formed, greatly reducing the possibility of such events affecting supply chain disruptions. In the process of strategic implementation and operation, the combination of dynamic planning and game theory will provide mathematical decision support for supply chain risk management.

2.2. Reasonably Adopting Redundancy Strategies

In the risk management of the international maritime shipping supply chain, the use of redundancy strategies is to resist supply disruptions caused by unexpected events and ensure the stable operation and continuity of the supply chain. During the shipping process, various unpredictable factors, including severe weather, ship failures, channel blockages, or political turmoil, can cause delays or even stagnation in the transportation of goods. Therefore, the reasonable allocation of redundant resources, such as excess inventory, alternate shipping routes, additional ships and port handling capacity, becomes a necessary and effective strategy. The design of redundant resources needs to comprehensively consider product characteristics, market demand fluctuations, transportation costs, and specific risk types that may cause disruptions to the supply chain. For example, in response to seasonal peaks and uncertainties in market demand, enterprises can establish safety stocks or rent additional cargo holds in a timely manner to meet the sudden increase in transportation demand in the short term [7]. In addition, to prevent a single shipping route from being blocked due to specific events, enterprises often establish multiple alternative shipping routes to diversify transportation risks. Correctly assessing the feasibility and cost-effectiveness of each alternative route enables the logistics operation to be quickly restored through other routes when a certain route is disrupted. A reasonable redundancy strategy should reserve sufficient flexibility to deal with unexpected situations while ensuring supply chain efficiency, achieving the optimal balance between cost and risk control. When implementing a redundancy strategy, each node of the supply chain needs to be coordinated to form an effective risk-sharing mechanism and rapid response mechanism, thereby achieving risk dispersion and timely risk mitigation. The comprehensive use of big data analysis and real-time monitoring technology can track the status of goods and the transportation environment in real time, providing data support for the dynamic adjustment of redundant resources and achieving precise risk management and resource optimization allocation.

2.3. Designing Resilient Supply Chain Network Structures

In the process of constructing the international maritime shipping supply chain, building a highly resilient network structure is crucial to ensuring supply continuity and resisting external shocks. A resilient supply chain aims to cope with identified risks, such as natural disasters or policy changes, and maintain a balance of operational efficiency and effectiveness through flexible design. Constructing a resilient supply chain network structure first requires the assessment of existing logistics nodes to ensure that each node has the ability to resist market fluctuations, transportation disruptions, or changes in suppliers [8]. In addition, the selection of core nodes should be based on their strategic position and functional diversity in the supply chain, and be able to quickly reorganize resources in the face of specific risks to maintain the vitality of the supply chain. For example, shipping companies may enhance communication and collaboration among suppliers by deploying advanced real-time tracking systems and information sharing technologies, thereby quickly responding when fluctuations occur at supply nodes. To enhance the overall resilience of the network and avoid huge losses caused by the bankruptcy or market exit of key suppliers, the maritime shipping supply chain should also achieve supplier diversification, that is, having multiple suppliers in different regions to form a stable alternative supply network, which can effectively share risks when a single supplier faces disruptions. The construction of the supply chain network also requires rigorous risk assessment, including understanding trade policies, market demand changes and regional political risks in each region to construct a supply network that can self-repair in the event of a crisis. A resilient supply chain network should not only focus on the assessment and prediction of process vulnerability but also regard the health status of the supply network as a long-term investment project, forming a dynamic updated risk management mechanism through continuous data analysis and risk assessment. In conclusion, designing a resilient supply chain network can provide a complete solution for risk management of the international maritime shipping supply chain and ensure the stable operation and efficiency of international trade.

3. Future Research Directions

Facing the risk factors of disruptions in the international maritime shipping supply chain, future research directions should focus on the following key areas: in-depth exploration and quantification of systemic risks in each link of the supply chain, how to integrate and optimize supply chain operation strategies under different conditions, and further development of a robust supply chain risk assessment and control framework. Firstly, with the increase in the complexity and uncertainty of the global trade environment, it is necessary to establish more complex maritime shipping supply chain models and conduct strict analysis of the sensitivity of model inputs to ensure that the models can effectively simulate real-world supply chain operations and the impact of risk events. Secondly, in actual maritime shipping supply chain management, creating an efficient information sharing platform is crucial. An ideal platform should be able to predict and respond to potential risk factors in a timely manner through real-time data analysis and flow. For example, a platform with advanced data analysis capabilities can collect and process various environment, market and policy-related information to support the formulation of rapid decision-making. In addition, considering the diversity of risks, research on countermeasures for the international maritime shipping supply chain should involve in-depth communication network analysis to identify and strengthen the compressive capacity of key nodes. At the same time, how to design a rapid recovery mechanism after disruptions has become an urgent problem to be solved for inevitable supply chain disruption events. Research on such challenges can provide guidance and application strategies for the rapid response and reconstruction of the supply chain. To sum up, future research should be committed to identifying and assessing risks from a systematic perspective, developing more flexible and resilient supply chain structures, and adopting innovative strategies and technologies to improve the adaptability and resilience of the entire system.

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