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RISK OF THE MARITIME SUPPLY CHAIN SYSTEM BASED ON INTERPRETATIVE STRUCTURAL MODEL

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ABSTRACT

Marine transportation is the most important transport mode of in the international trade, but the maritime supply chain is facing with many risks. At present, most of the researches on the risk of the maritime supply chain focus on the risk identification and risk management, and barely carry on the quantitative analysis of the logical structure of each influencing factor. This paper uses the interpretative structure model to analysis the maritime supply chain risk system. On the basis of comprehensive literature analysis and expert opinion, this paper puts forward 16 factors of maritime supply chain risk system. Using the interpretative structure model to construct maritime supply chain risk system, and then optimize the model. The model analyzes the structure of the maritime supply chain risk system and its forming process, and provides a scientific basis for the controlling the maritime supply chain risk, and puts forward some corresponding suggestions for the prevention and control the maritime supply chain risk.

Keywords: Interpretative Structural Mode; Maritime Supply Chain Risk; System Structure

INTRODUCTION

With the economic globalization, the organization is to survive in a network, rather than as an independent individual to participate in international market competition [1]. Marine transportation is considered to be the world's most important means of transport, and which can promote international trade. About 80% of the world's trade and more than 70% of the value is through the sea transport. The maritime supply chain needs many organizations to participate in the network which is facing many risk from natural and human factors [2]. Because the complexity of network structure, the uncertainty of the external environment, the top management pursuit to lean and other factors, the maritime supply chain becomes more and more vulnerable to various risks of the invasion. Once a certain risk occurs, it will cause irreversible damage to the maritime supply chain and suffer huge losses, and even lead to the complete disruption of the entire maritime supply chain. The effective maritime supply chain risk management can make the supply chain more flexible, so that the enterprise in the supply chain can avoid or reduce the loss caused by the risk. Therefore, it is very important for each member of the maritime supply chain to analyze the influencing factors of maritime supply chain risk and clarify the internal relationship among the factors.

Many scholars have studied the maritime supply chain risk: Yang attempts to evaluate the impact of risk factors from the container security initiative on the maritime

supply chain in Taiwan, and find out the leading categories of container security initiative risk factors are operational risk, physical risk and financial risk [3]. Lam et al. reveal that geographical location and changes in the constitution of players can have reverberations on the maritime supply chain dynamics that traverse the port [4]. Banomyong discuss the impact of the US container security initiative on maritime supply chains [5]. Barnes et al. suggests that the complexity of interaction between ports, maritime operations and supply chains create vulnerabilities that require analysis that extends beyond the structured requirements of these initiatives and creates significant management challenges [6]. Through the analysis, it is found that most of the research on the risk of the maritime supply chain focuses on the risk identification and risk management. Different scholars put forward different evaluation index system from different aspects. It has not established a perfect risk evaluation index system of maritime supply chain, and has not carry on the quantitative analysis of the logical structure of each influencing factor. Therefore, this paper attempts to use the interpretative structural model to make up for this gap.

The interpretative structural model (ISM) as a system analysis tool, which is characterized by the complex system is decomposed into several sub elements of the system, and find out the relationship between all the factors (including causality, size relationship, upstream and downstream relationships), form figure and structure matrix [7]. By means of the corresponding matrix calculus and transformation, the structure of the fuzzy and complicated system is clarified. At the same time, a hierarchical structure model is constructed to facilitate the analysis of the system.

The risk of maritime supply chain is a complex system formed by many factors. Based on the literature review, this paper establishes a risk assessment index system of the maritime supply chain, and introduces the structural model analysis method to study the risk model of the maritime supply chain, in order to clarify the maritime supply chain risk factors and to identify the key factors. The model analyzes the structure of the maritime supply chain risk system and its forming process, and provides a scientific basis for the controlling the maritime supply chain risk, and puts forward the corresponding countermeasures.

ANALYSIS ON THE INFLUENCING FACTORS OF MARITIME SUPPLY CHAIN RISK

THE CONCEPT OF MARITIME SUPPLY CHAIN RISK

An increasing amount of risk in supply chains is a current logistics trend [8], and according to Singhal et al., disruptions are a critical issue for many companies [9]. More recently, scholars have emphasized the importance of further studying supply chain risks and their management [10, 11]. Supply chain risk management is defined as "the identification of potential sources of risk and implementation of appropriate strategies through a coordinated approach among supply chain members to reduce supply chain vulnerability" [12]. Similarly, maritime supply chain risk management can be defined as the "process of making and carrying out decisions that will minimize the adverse effects of accidental losses, and is based on risk assessment methods involving operation and communication between all members involved in maritime supply chain activities" [3].

THE INFLUENCING FACTORS OF MARITIME SUPPLY CHAIN RISK

The research on the risk of maritime supply chain is relatively few. Chang et al. (2014) considered that the risk of maritime safety loss may be caused by the container shipping operations [13]. Vilko and Hallikas (2012) think that port workers strike, information system failure, water hidden iceberg, fire is the most important risk of shipping [14]. Gurning and Cahoon (2011) consider the most important maritime risk is port disorder, equipment failure, cleaning problems, container shortage and tariff issues [15]. Richard Oloruntoba studies the complex relationship between ports, shipping and supply chain, and points out a lot of risk from the unreasonable organizational structure and should improve the risk management ability of the maritime supply chain and focus on training managers' crisis management ability. UNCTAD (2006) argues that many researchers pay too much attention to the environmental and organizational risks, while ignoring the risks associated with the network [16]. The risk will be divided into three categories: 1 – external risk (environmental risk), from the uncertainty of external environment factors, such as earthquake and terrorism; 2– supply chain risk (network related), the risk from outside the organization but limited to the internal supply chain. 3– internal risk comes from internal risk. This classification is supported by other scholars ([17, 18]) Jyri Vilkoa et al(2012) identified 103 factors of maritime supply chain risks based on interviews with senior managers and divided into external and internal risks, then point out that the exogenous risks had a greater impact in terms of time and costs, whereas the endogenous were responsible for more of the quality damage. Exogenous risks accounted for approximately 53% of the time delays, and endogenous risks made up about 49%. Additional costs accompanied 38% of the exogenous risks and 33% of the endogenous.

The paper carries out a special study to analysis the risk factors of maritime supply chain to, we investigate the issue of the 39 managers engaged in maritime operations management. On this basis, we set up a panel of experts and analysis the maritime supply chain risk preliminarily through the literature review and questionnaire survey, then use of Delphy method and reach an agreement finally. The expert group divides the maritime supply chain risk into external risk, cooperation risk, logistics service risk and information risk.

External Risk

The external risk of the maritime supply chain includes the natural environment risk (F_1), macroeconomic risk (F_2), social instability factors (F_3), policy risk (F_4), uncertainty in market demands (F_5).

The natural environment risk (F_1):mainly refers to the natural disasters (earthquake, tsunami, etc.) and bad weather (typhoon, storm, flood and other factors, etc.). Due to the delivery of maritime supply chain must be achieved through shipping, shipping is affected by natural conditions. Macroeconomic risk (F_2) affects the operation of the maritime supply chain indirectly by influencing the economic operation. It mainly includes interest rate change, exchange rate fluctuation, economic crisis, inflation, stock market risk and so on, the impact of the economic crisis on maritime supply chain is the most obvious. Social environment risk (F_3) refers to the risk of abnormal changes in the internal and external social environment faced by the maritime supply chain, which mainly including social order risk and war risk. Social order risks such as strikes, pirates, terrorist attacks, demonstrations and so on, which once happen the maritime supply chain will suffer huge losses. Policy risk (F_4) mainly includes legal risks and government intervention risks. In order to make the market economy orderly, the state has promulgated and implemented a series of laws and regulations, such as: tax laws and regulations, financial regulations, financial regulations and other laws and regulations, so that the country's legal system is becoming more and more perfect. However, all kinds of laws have a process of gradual improvement, the adjustment of laws and regulations, revision and so on, which is full of uncertain and cause risk. For some special industries and products, the state to macro-control, there will be restrictions. As the cross national and cross regional supply chain, the maritime supply chain also could meet the restriction from government. Uncertainty in market demands (F_5): As the maritime supply chain belongs to the pull supply chain, demand driven services and fluctuation of demand will have a direct impact on the operation of the supply chain. Specifically including downstream customer demand reduction or interruption risk (For example, because of the high price of the products or materials, the demand of downstream customers will be reduced), the expansion of the highway and railway, the development of the aviation industry, which all have an important influence on the demand of the maritime supply chain.

Cooperation Risk

Because the maritime supply chain is facing a lot of uncertainties, the uncertainties will bring some risks to relationship of the partners in supply chain. The cooperation risks include: interest distribution risk (F_6), cooperation mechanism (F_7), information asymmetry (F_8).

Interest distribution risk (F_6): The maritime supply chain operation has the advantage of win-win, which is the material premise that different partners or different interest groups can ally with each other. But if the partners, especially the core partners cannot do justice to the distribute benefits, it will lead to a decline in partnership working enthusiasm, and even mutual constraints of the situation.

Cooperation mechanism (F_7): The research of supply chain coordination mechanism can make the node enterprises in maritime supply chain realize the effective integration of internal and external supply chain, which also provides a new opportunity to improve the operational performance and competitive ability in the whole supply chain. Once the cooperation mechanism is unreasonable, it will affect the performance of the whole maritime supply chain.

Information asymmetry (F_8): In the field of production and distribution in the maritime supply chain, the rapid and accurate transmission of information plays an important role in the whole process. In the case of information asymmetric, it is difficult to achieve the real optimization of logistics distribution and the whole supply chain, which will affect the performance in the whole supply chain

Logistics Service Risk

The goal of logistics operation is to deliver the goods at the specified time to the designated location, but also need to ensure the overall balance of the entire supply chain and supply chain operation efficiency. Logistics service risk mainly including personnel operational risk (F_9), facility and equipment maintenance (F_{10}), the loss or damage of goods (F_{11}), delayed in delivery (F_{12}).

Personnel operational risk (F_9): Personnel operational risk mainly refers to the unskilled staff, Work is not enthusiasm, personnel mobility and so on.

Facility and equipment maintenance (F_{10}): Facility and equipment maintenance mainly refers to the maintenance of the infrastructure and equipment, or if there is a failure, there will be a huge loss.

The loss or damage of goods (F_{11}): On the ship the cargo loss, the common species are damaged, wet, dirty, rotten, and the number of average weight shortage. Is one of the most common port supply chain risk.

Delayed in delivery (F_{12}): If there is time delay in logistics operation, it will reduce the effect of the whole logistics service, and even lead to the failure of the whole logistics project.

Information Risk

The information transmission between nodes in the supply chain is carried out through information system, the normal operation of the information system can ensure the orderly and efficient operation in the maritime supply chain. The information system risk mainly includes the IT system failure (F_{13}), the speed of information transmission (F_{14}), the information authenticity (F_{15}), the information sharing (F_{16}) and so on.

IT system failure (F_{13}) mainly refers to the stability of the IT system, once the system is attacked by hackers or the virus,

the entire maritime supply chain information system will be in a state of paralysis, resulting in huge losses. The speed of information transfer (F_{14}), information authenticity (F_{15}), and information sharing (F_{16}) are both directly or indirectly affecting the decision makers, which are crucial to the whole supply chain

THE CONSTRUCTION OF MARITIME SUPPLY CHAIN RISK MODEL

3.1 ESTABLISHMENT OF ADJACENCY MATRIX

The key issue of this paper is the maritime supply chain risk system, first of all, adjacency matrix is established. The adjacency matrix describes the direct relationship between the factors of supply chain risk system. In accordance with the requirements of the interpretative structural model, the adjacency matrix of system for n factors $S(F_1, F_2 \cdots F_n)$ is defined as following.

$$A=[a_{ij}]=\begin{cases} 1, & \text{if A has a direct impact on B} \\ 0, & \text{else} \end{cases}$$

In order to ensure the adjacency matrix is reliable, on the basis of consulting the opinions of 5 experts, this paper constructs the adjacency matrix A as shown in Table 1.

Tab. 1. The adjacency matrix of risk factors of maritime supply chain

	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}
F_1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1
F_2	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1
F_3	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1
F_4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
F_5	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1
F_6	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
F_7	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	1
F_8	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	1
F_9	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1
F_{10}	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
F_{11}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
F_{12}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
F_{13}	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	1
F_{14}	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	1
F_{15}	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	1
F_{16}	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1
F_{17}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

ESTABLISHMENT OF REACHABILITY MATRIX

Based on the adjacency matrix A of risk factors of maritime supply chain, we can obtain matrix (A+E), The power operation of the matrix (A+E), based on Boolean algebra is established, until $(A+E)^i \Rightarrow (A+E)^{i+1}$. The reachability matrix M can be obtained by calculation. It indicates whether there is a link from one factor of the supply chain risk to another factor, that is, whether or not. Based on the reachability matrix, the reachable set of the factors affecting the maritime supply chain risk is calculated: $P(S_i)$, linear set: $Q(S_i)$ and common set: $P(S_i) \cap Q(S_i)$, As shown in Table 3. When $P(S_i) \cap Q(S_i)=P(S_i)$, get the highest rank factor, which will draw from the table, With the same method to get the next level of elements, so has been done, you can level by level to divide the elements according to the grade, and as a basis for the rearrangement of the reachable matrix, as shown in table 2.

Tab. 2. The relationship of influence factors of maritime supply chain risk system

number	factors	$P(S_i)$	$Q(S_i)$	$P(S_i) \cap Q(S_i)$
1	natural environment risk (F_1)	$F_1,F_{10},F_{11},F_{12},F_{17}$	F_1	F_1
2	macroeconomic risk (F_2)	$F_2,F_4,F_5,F_6,F_7,F_8,F_{13},F_{15},F_{16},F_{17}$	F_2	F_2
3	social instability factors (F_3)	$F_3,F_6,F_7,F_8,F_{13},F_{15},F_{16},F_{15},\ F_{16},F_{17}$	F_3	F_3
4	policy risk (F_4)	$F_4,F_{13},$	F_4	F_4
5	uncertainty in market demands (F_5)	$F_5,F_6,F_7,F_8,F_{12},F_{13},F_{16},F_{17}$	F_2,F_5	F_5
6	interest distribution risk (F_6)	$F_6,F_7,F_8,F_{12},F_{13},F_{16},F_{17}$	$F_2,F_3,F_4,F_5,F_6,F_7,F_8,F_{13},F_{14},F_{15},F_{16}$	$F_6,F_7,F_8,F_{13},F_{16}$
7	cooperation mechanism (F_7)	$F_6,F_7,F_8,F_{12},F_{13},F_{16},F_{17}$	$F_2,F_3,F_4,F_5,F_6,F_7,F_8,F_{13},F_{14},F_{15},F_{16}$	$F_6,F_7,F_8,F_{13},F_{16}$
8	information asymmetry (F_8)	$F_6,F_7,F_8,F_{12},F_{13},F_{16},F_{17}$	$F_2,F_3,F_4,F_5,F_6,F_7,F_8,F_{13},F_{14},F_{15},F_{16}$	$F_6,F_7,F_8,F_{13},F_{16}$
9	personnel operational risk (F_9)	F_9,F_{12},F_{13},F_{17}	F_9	F_9
10	facility and equipment maintenance (F_{10})	F_{10},F_{12},F_{17}	F_{10},F_{10}	F_{10}
11	the loss or damage of goods (F_{11})	F_{11},F_{17}	F_{11},F_9,F_{10},F_{13}	F_{11}
12	delayed in delivery (F_{12})	F_{12},F_{17}	$F_{11},F_{12},F_9,F_7\sim F_{16},F_{12}\ F_{13},F_{14},F_{15},F_{16}$	F_{12}
13	IT system failure (F_{13})	$F_6,F_7,F_8,F_{11},F_{12},F_{13},F_{14},F_{15},F_{16},F_{17}$	F_{13}	F_{13}
14	the speed of information transmission (F_{14})	$F_6,F_7,F_8,F_{12},F_{13},F_{16},F_{17}$	F_{13},F_{13},F_{14}	F_{14}
15	the information authenticity (F_{15})	$F_6,F_7,F_8,F_{12},F_{13},F_{16},F_{17}$	$F_2,F_3,F_4,F_5,F_6,F_7,F_8,F_{13},F_{14},F_{15},F_{16}$	$F_6,F_7,F_8,F_{13},F_{16}$
16	the information sharing (F_{16})	$F_6,F_7,F_8,F_{12},F_{13},F_{16},F_{17}$	$F_2,F_3,F_4,F_5,F_6,F_7,F_8,F_{13},F_{14},F_{15},F_{16}$	$F_6,F_7,F_8,F_{13},F_{16}$
17	maritime supply chain risk(F_{17})	F_{17}	$F_1\sim F_{17}$	F_{17}

Further, according to the level of the maritime supply chain risk system, the hierarchy of the supply chain risk system is drawn, which is shown in Figure 1.

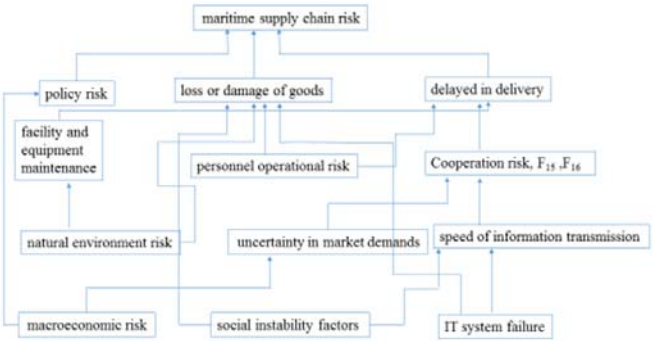

Fig. 1. Hierarchical structure of risk system of maritime supply chain

MODEL ANALYSIS

The maritime supply chain risk is directly affected by policy factors, the loss or damage of goods, delayed in delivery, which is in the second layer. Obviously, there is conducive to all countries to establish international trade agreements, such as the establishment of the FTA tariff reduction, the reduction of trade barriers, as well as assure the quality and quantity of goods, timely and accurate delivery, these measures can achieve the direct reduction of maritime supply chain risk. As can be seen from the figure, the damage caused by natural disasters caused by the destruction of facilities and equipment, and thus the destruction of the goods in the supply chain and lead to delays in delivery, so the natural disasters has a direct effect on the maritime supply chain risk. The macroeconomic factors will directly effect on the formulation of relevant policies, but also through the uncertainty of market demands, the risk of cooperation, which leads to delayed in delivery. The factors of social instability will directly cause the loss and destruction of goods in the maritime supply chain, which is also possible to cause the delay in delivery through

the information transmission. Now shipping information is transmitted through the Internet, therefore, if the IT system failure, which will cause the maritime supply chain is in a state of collapse, cannot run normally, also causing loss / damage of goods and delay in delivery.

Through the ISM method to analyze the structural relationship model of the risk factors of the maritime supply chain, we can clearly describe the complex relationship among the factors into a multi-level hierarchical structure model. Based on this model, we can distinguish the relationship between risk factors. The factors that affect the risk of maritime supply chain are classified: the surface layer factors, the middle layer factors and the underlying factors. Which is conducive to understanding the formation and development mechanism of maritime supply chain risk. Fundamentally speaking, the risk of maritime supply chain is mainly from natural disasters, macroeconomic risk, social instability factors and fault information system. It can be seen, to ensure sustained and effective operation of maritime supply chain, which cannot do without cooperation, the efforts of all sectors of society.

In this paper, the author puts forward the following suggestions for the prevention and control of maritime supply chain risk:

(1) We should establish the accurate natural disaster forecasting system, do a good job in the prediction of natural disasters. And we need to set up a perfect maritime rescue system, once the natural disasters happen, we can rescue rapidly, and so that the loss will be reduced to a minimum

(2) We should stabilize the world economic environment, stabilize interest rates / exchange rates, lower tariffs and cut trade barriers.

(3) We should maintain social peace, to establish a good social order, at the same time do a good job security measures.

(4) Strengthen the development of IT technology, it needs to establish a stable information system to achieve the organization and integration of information between the enterprise and the maritime enterprise supply chain node enterprises

CONCLUSION

The risk of maritime supply chain is a complex system composed of a number of key factors, which play a different role in the process of maritime supply chain risk formation. This paper constructs the maritime supply chain risk model using ISM method, the model shows that the factors directly affect the supply chain risk is policy factors, the loss or damage of goods, delayed in delivery. The root causes of risk are natural disasters, macroeconomic factors, social instability and IT system failures.

Empirical research is an important method of management research, but it is still in the stage of theoretical model. Based on literature review, expert consultation and exploratory factor analysis, this paper presents a theoretical model for empirical research. The maritime supply chain risk system based on ISM method is more reliable, which can effectively avoid the failure of empirical research.

In short, with the economic globalization, the maritime supply chain plays an increasingly important role in international trade. In recent years, the uncertainties of international economic and political are increasing, and correctly grasp the logical structure of the risk factors faced by the port supply chain, which is valuable for the decision-makers in the prevention and control of the supply chain risk. The conclusion of this paper can provide theoretical support for the construction of maritime supply chain risk system, which has practical value, and has important reference value for further research.

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