SUPPLY CHAIN RISK MANAGEMENT IN THE INTERNATIONAL LOGISTICS ENVIRONMENT

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Abstract: This paper discusses the matter of how to manage supply chain risks in the international logistics environment. It is divided into four parts: first, classification of supply chain risks in the international logistics environment is given, including external risks and internal risks; second, a new method of risk assessment based on fuzzy entropy is put forward, which is validated by a following case study; then some measures about how to manage the supply chain risk in the international environment are summarized; in the end, main conclusions are summed up and several directions of future research are provided.

Key Words: *Supply Chain, International Logistics, Risk Assessment, Fuzzy Entropy*

1.INTRODUCTION

Supply chain management has become an important means for companies today to keep or gain competitive advantages through cooperation with their partners, but supply chain is vulnerable to many risks, especially in today's international logistics environment, such as natural disasters, terrorism, supply disruption, demand variation, etc. Interdependency between supply chain's partners increases such kind of risk, for risk of one company can be passed to its partners through supply chain. And emergence of various new logistics management practices like " Just-In-Time", "Lean production", "outsourcing" and "single supplier" all increase supply chain's exposure extent. All these uncertainties both in the supply chain and out the supply chain have negative impacts on the performance of supply chain, for billions of losses have been generated by such kind of supply chain risk and disruption. For example, Ericsson lost 400 million Euros after their suppliers' semiconductor plant caught on fire in 2000, and Apple lost many customer orders during a supply shortage of DRAM chips after an earthquake hit Taiwan in 1999(Christopher S. Tang, 2006).

Research interest of Supply chain risk management(SCRM) is growing rapidly recently. SCRM deals with identifying all sorts of risks that can lead to interruptions in the supply chain(Giunipero & Eltantawy, 2003), and SCRM is "the management of supply chain risks through coordination or collaboration among the supply chain partners so as to ensure profitability and continuity"(Christopher S. Tang, 2006).

Though research of SCRM has become very hot, this topic is still fairly new, and few articles is committed to quantify the supply chain risk, only a few of them give a qualitative framework for supply chain risk assessment, needless to say risk identification and assessment of supply chain in the international logistics environment. This paper aims to put forward a framework of risk identification and a feasible risk assessment model of supply

chain in the international logistics circumstance. Firstly, the classification of risk and a framework of risk identification are given. In the following part, a fuzzy entropy risk assessment model is established to measure supply chain risk in the international logistics environment, which is combined with a case study to illustrate the model's validity. This approach can quantify supply chain risk based on risk indicators analyzed in the former section. In the end, some suggestions about how to manage and mitigate the supply chain risk in the international logistics circumstance are put forward.

2.RISK IDENTIFICATION AND CLASSIFICATION

Identifying and recognizing relevant supply chain risks is the first step in the SCRM-process. Risk identification is also a fundamental phase in the risk management practice. By identifying the risks, a decision-maker or a group of decision-makers become conscious about events or phenomena that cause uncertainty. The main focus of risk identification is to recognize future uncertainties to be able to manage these scenarios proactively (Hallikas,2004).

In the process of risk identification, risk factors and risk sources of supply chain are revealed, then we can classify risks into various kinds, such classification can help us know more about potential uncertainties which will result in losses in the supply chain. In this study, we divide the supply chain risks into two distinct classes: external risks and internal risks. The former refers to those risk exposed to external environment, the latter is related to uncertainties existing in the supply chain. And each category is subdivided into several sorts.

2.1 External risks

2.1.1 International logistics

Before the classification of external risks, some research about "international logistics" should be done, for the supply chain in the international logistics environment is longer and hence more vulnerable than domestic supply chain owning to complexity of international trade and security of ocean shipping.

"International" means that it will deal with transactions in more than one nation. "Logistics" means the organized movement of goods, services, and, sometimes, people(Donald F. Wood, 1995). So "international logistics" refers to the flow of goods, services, or people between different countries. Figure 1 illustrates the process of international logistics process, and table 1 gives the differences between the domestic logistics and international logistics.

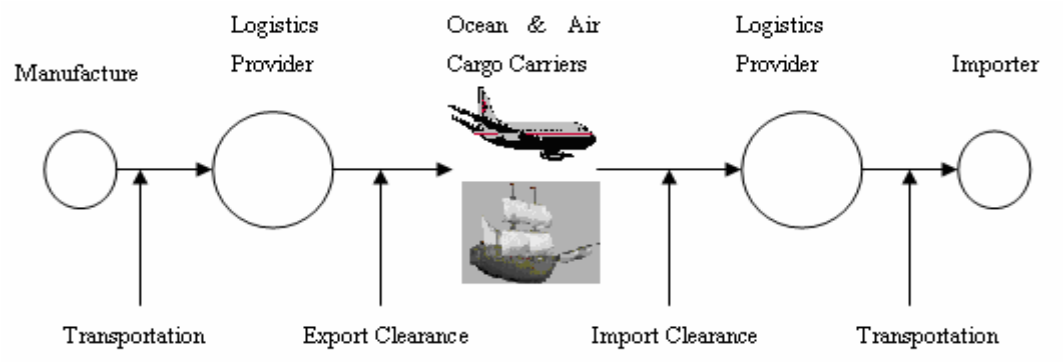

Figure 1 International logistics process

Table 1 Differences between domestic logistics and international logistics

	Domestic logistics	International logistics
Cost	about 10.5%of American GNP	about 16% of the total world's GNP，
Transport mode	most are transported by road and rail	international ocean shipping, air-express, or multimodal transport
Inventory	stock level is low, for shorter lead time and safer transport	stock level is high, for longer lead time and more uncertainties in transit
Agent	used less, except for railroad	mainly depends on freight forwarder, centralized shipper and customs broker
Finance risk	lower	higher, for fluctuation of exchange rate
Cargo risk	lower	very high, for longer transport distance, more links and complicated operation
Governanc e	mainly on dangerous cargoes, load capacity, security rules and freight charge	many institutions are involved, including custom, ministry of commerce, agriculture, and transport
Documenta tion	a few, such as purchase list, transit documentation and invoices	a great deal, more than 100 per transit, which is estimated by American commerce ministry
Communic ation	phone, mailing, and EDI	more EDI for lower efficiency of phone and mailing, but is limited as EDI is not standardized
Culture differences	background of culture is similar, only need to make litter change on products	big culture differences, marketing and design of goods must suit to local demand.

From the above figure and table, we can see that compared with internal logistics, international logistics is more complex, costly, and has to cope with different jurisprudence systems or culture of the local. So it has higher risk. In a survey, 497 Indiana firms that exported were asked to list the chief problems of exporting. The major problem with the percent of firms selecting them were as follows: export documentation, 23%; transportation costs, 20%; high import duties, 17%; unable to find foreign representative with appropriate know-how to market products, 16%; delay in transfer of funds, 13%; currency fluctuations, 12%; language barriers, 10%; and difficult to service product, 10%(Donald F. Wood, 1995). Because of all these uncertainties faced by the supply chain in the international logistics circumstances, their risks are higher than normal supply chain.

2.1.2 Classification of external risks

Base on the above analysis on the international logistics, we can divide external risk of supply chain in the international logistics environment to six groups: "political risks", "economy risks", "culture risks", "technical risks", "natural risks" and "demand risks". Such kind of classification has taken characteristics of international logistics into account, so it can be seen as the basis for risk assessment of supply chain risk in the logistics environment.

Each category has its risk factors, risk sources, and risk consequences. All these are listed in table 2.

Table 2 Classification of external risks

Category	Risk factors	Risk sources	Risk consequences
Political risks	law	imperfect laws and rules	chaos of import-export and claim process, increased transaction costs
		trade barrier of customs duties and entrance investigation	profits space is compressed and more difficult to export
		strict environment protection policies	restrict transport modes and strict rules of product performance
	social order	frequent regime change	materials and assets are confiscated
		confusion of local public security	thefts , highjack, bilks
		war	breakdown of international trade
		terrorism	more complicated import-export procedures, and longer lead-time
Economy risks	world economy	depression of the whole world	decreased scale of international trade
	exchange rate	fluctuation and adjustment of currency rate	increased risks of global manufacturing
Culture risks	culture background	big culture differences between countries	different acceptance and preference on products
Technical risks	R&D of products	accelerated R&D technologies in the industry	emergence of upgraded products, and shorter lifetime, more severe competitiveness
Natural risks	natural disaster	earthquakes, hurricanes, tsunamis	damage or loss of goods, supply breakdown
	climate	random variation of wind, wave, tide, etc.	increased risk of ocean shipping, longer sailing date
Demand risks	Substitutive products	increased substitutes	decreased demand on products, and smaller market share
	rivals	increased competitors	

2.2 Internal risks

A new grouping method is put forward, which classify the internal risks of supply to three types based on three kinds of flow in the supply chain: materials flow, capital flow and information flow. That is to say, we divide internal risks to “logistics risks”, “capital risks”, and “information risks”. Materials, capital and information is the connection media and bridge on the supply chain which link all partners together, from supplier’s supplier to customer’s customer. All uncertainties and variation will be conveyed by them from supply chain’s one end to the other, so this kind of classification can reveal risk factors, sources and consequences more clearly. Detailed factors, sources and consequences of inter risks are listed in table 3.

Table 3 Classification of internal risks

Category	Risk factors	Risk sources	Risk consequences
Logistics risks	technology	behindhand conveyance, inventory infrastructure	damage ,loss, delayed transit and arrival of goods
	operation	machine failures	supply disruption
		manmade errors	incorrect information of cargoes
	process	contingencies	premium of goods' damage and loss, claim for delayed delivery
		business fraud	
Capital risks	capital demand	increased price of raw materials, labor force	increased cost, decreased profit space
	capital recycling	unmarketable products	overstock and unable to recycle capital
		customers unable to pay for goods in time	difficulty in carry with next manufacturing
		failure in R&D	ineffective or defective goods which result in claims and loss of market share
	money market	lower share price	less company value
Information risks	information pooling	suspicion and hostile attitude	impossible information share between partners, which results in exaggeration of all kinds of variations and fluctuations
		incompatible data interface and nonuniform information	
	information transfer	bull-whip effect	distortion of information on inventory, and increased cost
		late information transfer	delayed response to change, weakened supply chain agility
	opportunism	adverse selection	information asymmetry between partners, and uncertainties caused by partners' cheat
		deliberate defect or fraud	

2.3 Configuration of supply chain risk

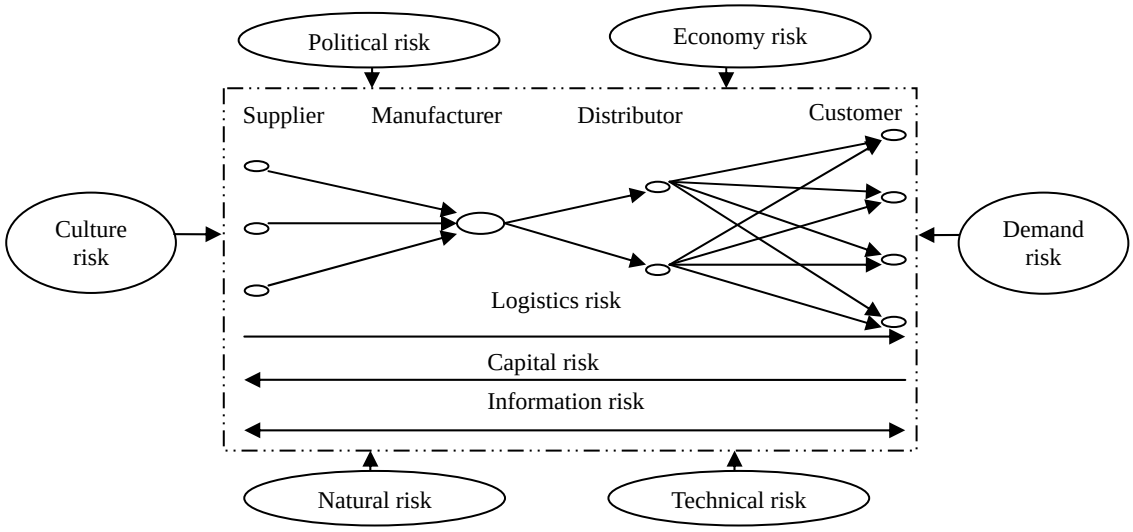

Figure 2 Configuration of supply chain risk

Figure 2 illustrates the configuration of the whole supply chain risk, which is composed of external risks, internal risks, and detailed items analyzed in the above section. The more complex of the supply chain network, the higher risks existing on the chain, because in a networked environment, risk identification must take into account the dependencies on other organizations. So risk management work for the whole supply chain is more difficult and totally different from that for only one company.

3. RISK ASSESSMENT

Risk assessment is a key process in the process of risk management, it is based on the outcome of risk identification, and aims to estimate the consequences of risks. The assessment of supply chain risk is important, because it helps to focus on essential risks and could be seen as references for strategy choices.

Articles involving in quantitative risk assessment of supply chain is very few, Hallikas et al.(2002) put forward a semi-quantitative method to assess risks in the network environment, in which the risks have been divided into two components: probability and severity. The former is subdivided into four grades: “very unlikely”, “improbable”, “probable”, and “very probable”; the latter is also subdivided into four ranks: “insignificant”, “minor”, “serious”, and “catastrophic”. This method is easy, but how to grade probability and severity of risks is subjective. DING Weidong et al. (2003) develop an assessment formula of supply chain reliability: $P_s = R_1 \bullet R_2 \cdots \bullet R_n$, $R_i = \sum_{j=1}^{m} p_j a_{ij}$, $i = 1, 2, \cdots n;\ j = 1, 2, \cdots m,$ in which P_s is the reliability of total supply chain, R_i is the reliability of company i in the supply chain, p_j is weight of risk factor j, and a_{ij} is estimation for risk factor j of company i. Such calculation method is clear-cut, but it doesn’t take risks’ probability into account. Here we propound a new assessment model, its detailed method, procedures and a case study are as follows.

3.1 Fuzzy entropy

“Entropy” is a measure of the uncertainty , Shannon first defines entropy in terms of a discrete random variable *x*, with possible states (or outcomes) $x_1, x_2 \ldots x_n$ as:

$$H(X) = \sum_{i=1}^{n} p(x_i) \log_2 \left(\frac{1}{p(x_i)}\right) = -\sum_{i=1}^{n} p(x_i) \log_2 p(x_i) \quad (1)$$

where $p(x_i) = \Pr(X = x_i)$ is the probability of the i^{th} outcome of X.

A.Kaufman(1973) and Delaca(1974) put forward the definition of “fuzzy entropy”: Suppose A is a fuzzy set, and $A = (u_A(x_1), u_A(x_2), \wedge, u_A(x_n))$, let $\pi_A(x_i) = \dfrac{u_A(x_1)}{\sum_{i=1}^{n} u_A(x_i)}$,

then $H(\pi_A(x_1), \pi_A(x_2), \wedge, \pi_A(x_n)) = -\dfrac{1}{\ln n} \sum_{i=1}^{n} \pi_A(x_i) \ln(\pi_A(x_i))$ i=1,2, $\cdots$n (2)

is “fuzzy entropy”, which is an evaluation method for fuzzy extent of fuzzy set.

3.2 Assessment process

1. List risk factors of supply chain, classify them, and establish index system of risk assessment;

2. Suppose there are n supply chains to be assessed, and risk system is made up of n indices, then based on objects' actual circumstances, we can obtain following matrix:

$$R' = (r'_{ik})_{m\times n} = \begin{pmatrix} r'_{11} & r'_{12} & \cdots & r'_{1n} \\ r'_{21} & r'_{22} & \cdots & r'_{2n} \\ \vdots & \vdots & & \vdots \\ r'_{m1} & r'_{m2} & \cdots & r'_{mn} \end{pmatrix} \tag{3}$$

Where, r'_{ik} denotes the state of index i for supply chain k

Then we standardize matrix R', we can get $R = (r_{ik})_{m\times n}$, in which

$$r_{ik} = [r'_{ik} - \min_k(r'_{ik})]/[\max_k(r'_{ik}) - \min_k(r'_{ik})] \tag{4}$$

3. Calculate indices' fuzzy entropy. Let H_i denotes the fuzzy entropy of index i, and

$$H_i = -\frac{1}{\ln n}\sum_{k=1}^{n}\pi_{ik}\ln\pi_{ik} \qquad i = 1,2,\cdots m \tag{5}$$

Where $\pi_{ik} = r_{ik}/\sum_{k=1}^{n} r_{ik}$, and assume that if π_{ik}=0, $\pi_{ik}\ln\pi_{ik}$=0

4. Calculate indices' fuzzy entropy weight. Let ω_i denotes fuzzy entropy weight of index i, and

$$\omega_i = (1-H_i)/(m-\sum_{i=1}^{m}H_i) \qquad i = 1,2,\cdots m \tag{6}$$

Where $0 \le \omega_i \le 1$, 且 $\sum_{i=1}^{m}\omega_i = 1$

5. Calculate indices' weights given by experts, which is denoted by α''_i. Suppose there are n experts, whose weights for index i are $\alpha''_{i1}, \alpha''_{i2}, \cdots \alpha''_{in}$, then $\alpha''_i = (\alpha''_{i1} + \alpha''_{i2} + \cdots \alpha''_{in})/n$ (7)

6. Calculate indices' integrated weight. Suppose α''_i is weight of index i given by experts, then integrated weight of index i is: $\partial'_i = \partial''_i\omega_i / \sum_{i=1}^{m}\partial''_i\omega_i \qquad i = 1,2\cdots m$ (8)

7. Select indices. If ω_i and ∂'_i are both very tiny, that is to say, index i isn't important in experts' eyes, and every supply chain's value on index i is similar, so index i could be eliminated, and let ∂'_i=0. Then adjust integrated weight of other indices, and obtain new integrated weight ∂_i.

8. Calculate final evaluation value of supply chain. The risk of supply chain k is: $R_k = (\partial_1, \partial_2, \cdots \partial_m)\bullet(r_{L1}, r_{L2}, \cdots r_{Lm})^T \qquad k = 1,2,\cdots n$ (9)

3.3 Case study

We collect five supply chains' data to evaluate their risks extent, their core companies are the top 5 food manufacturing companies in Dalian.

The original evaluation indices system is made up of risk factors discussed in section 1, including external and internal risks. First, we standardized collected data and get matrix "R", corresponding r_{ik} are listed in table 4.

Table 4 Standardized state matrix

Indices	Chain 1	Chain 2	Chain 3	Chain 4	Chain 5
Technology- R_1	0.1	0	0.3	0.7	1
Operation-R_2	0	0.5	1	0.6	0.8
Process-R_3	0.4	1	0.9	0.5	0
Capital demand-R_4	0.2	0.7	1	0	0.3
Capital recycling-R_5	0.9	0.8	0	1	0.4
Money market-R_6	1	0.9	0.6	0.7	0
Information pooling -R_7	0.8	1	0.7	0	0.5
Information transfer-R_8	0	0.2	0.8	0.4	1
Oppotunism-R_9	1	0	0.3	0.3	0.7
Law-R_{10}	0.8	0.6	0	1	0.3
Social order-R_{11}	0.5	1	0	0.7	0.6
World economy-R_{12}	0	0.1	0.2	1	0.8
Exchange rate-R_{13}	0.8	0.9	0.7	0	1
R&D-R_{14}	0.3	0	1	0.2	0.9
Culture background-R_{15}	1	0.3	0.6	0	0.4
Natural disaster-R_{16}	0.6	1	0.7	0.9	0
Climate-R_{17}	0	0.4	1	0.4	0.4
Substitutive products-R_{18}	0.3	0	0.8	1	0.5
Rivals-R_{19}	0	0.7	0.6	0.9	1

Table 5 Weights of indices

Indices	H_k	ω_k	$\alpha_k^{''}$	$\alpha_k^{'}$	∂_k
Technology- R_1	0.708	0.077	0.073	0.100	0.13
Operation-R_2	0.838	0.043	0.041	0.031	0.031
Process-R_3	0.817	0.048	0.048	0.041	0.041
Capital demand-R_4	0.752	0.065	0.068	0.079	0.085
Capital recycling-R_5	0.829	0.045	0.051	0.041	0.041
Money market-R_6	0.847	0.040	0.037	0.026	0
Information pooling -R_7	0.841	0.042	0.053	0.039	0.039
Information transfer-R_8	0.767	0.061	0.062	0.068	0.084
Oppotunism-R_9	0.778	0.058	0.042	0.044	0.044
Law-R_{10}	0.810	0.050	0.053	0.047	0.047
Social order-R_{11}	0.838	0.042	0.037	0.028	0
World economy-R_{12}	0.676	0.085	0.096	0.146	0.146
Exchange rate-R_{13}	0.854	0.038	0.023	0.016	0
R&D-R_{14}	0.744	0.067	0.071	0.085	0.125
Culture background-R_{15}	0.795	0.054	0.048	0.046	0.046
Natural disaster-R_{16}	0.847	0.040	0.032	0.023	0
Climate-R_{17}	0.799	0.053	0.064	0.060	0.06
Substitutive products-R_{18}	0.804	0.052	0.045	0.041	0.041
Rivals-R_{19}	0.847	0.040	0.056	0.040	0.04

Then we calculate the "entropy"- H_k, "entropy weight"- ω_k, "expert weight"- $\alpha_k^{''}$, "integrated weight"- $\alpha_k^{'}$ and "adjusted weight"- ∂_k of every index, in which "expert weight" is averaged

by 30 experts' evaluations. The outcome is given in table 5.

In the process of calculation, we can find out "entropy weight" and "expert weight" of R_6, R_{11}, R_{13}, and R_{16} are all very tiny, so let $\partial_6 = \partial_{11} = \partial_{13} = \partial_{16} = 0$. Weights of other indices are adjusted by experts' advices. If we dig reasons why weights of those four indices are tiny, we can find that because these five food manufacturing companies are all from Dalian, and their export countries are similar, products exporting transport routes and modes are approximate too, so their risks of exchange rate, natural disaster, and social order don't differ greatly. And owning to they all have come into the market recently, so their risks of finance market have no much difference.

At last, we obtain risk values of these five supply chains by multiplying the "adjusted weight" ∂_k (see table 5) with standardized state matrix R(see table 4). The risk values are showed in table 6.

Table 6 Supply chains' risk value

	Chain 1	Chain 2	Chain 3	Chain 4	Chain 5
Risk value	0.292	0.313	0.598	0.537	0.677

From table 6, we can see that risk value of supply chain 5 is biggest, supply chain 1's is smallest, and most of them exceed 50%.

4. MEASURES OF RISK MANAGEMENT

To mitigate supply chain disruptions associated with various types of risks, many researchers have developed different strategies for managing supply chain risk: Deloitte(2004) offer advice on the possibilities of reducing, transferring, exploiting or eliminating risks. Perter Finch(2004) enumerats many types of information risk, and provide corresponding best practices in his secondary case studies, such as manage potential risks proactively, make through and ongoing project risk management process, actively assess the risks and threats, etc. Mark Hillman(2006) put forwards two main strategies for managing supply chain risk, which is assessing the risk and responding to the risks.

Of course, measures must contrapose relevant risks, each supply chain should has its own risk management and mitigation measures. In this article, we propose take the following measures to manage and mitigate supply chain risks as a general rule.

4.1 Strengthen performance evaluation for suppliers

Supplier is headstream of supply chain and provide raw materials or semi-manufactured goods to downstream companies, if such supply has any problem, all other companies will be influenced. So it's important to strengthen performance evaluation for suppliers and select several long-term reliable suppliers. Special attentions must be given to the fact that core company can't depend on one supplier totally. Single outsource will increase supply chain risks even though sometimes it could have some cost saving. At the same time, such performance evaluation for suppliers must be carried out termly, for suppliers' situation will change from time to time, if find some question, must ask them correct. Decision of having other alternative supplier should be made when it really can't achieve the requirements.

4.2 Establish mechanism of risk sharing

In a network environment, where business relationships are largely based on partnerships between organizations, effective information sharing is the key factor to decrease external and internal uncertainties.(Hallikas et al.,2004).Risks of supply chain can be passed from one company to others, and may will be exaggerated tier by tier. If supply chain visibility is weak, those companies with more information might transfer their risks to their partners deliberately for their own profits. Such actions are partial optimization, and will make damage to the whole supply chain's profitability. In the long term, every supply chain need a mechanism to let the partners share the risks on the chain voluntarily, the mechanism of risk sharing could be set up through lead of the core company, and every company's distribution percentage should be based on every company's position, function, profit, and cost in the chain.

4.3 Reinforce information share

Incomplete information pooling is a major risk source of supply chain, and the typical example is "bull-whip effect": in the process of demand information transfer, fluctuation extent of difference between actual demand and estimated demand become more and more large, which results in exaggeration of stock step by step from end customer to original supplier. This kind of information distortion increases uncertainties of capital demand, inventory, and weaken agility of supply chain. So partners should reinforce their information pooling, and can adopt the technologies of EDI, VMI(Vendor Managed Inventory),and Supply Chain Visibility.

4.4 Foster consciousness of proactive management

Some risks of supply chain can't be forecasted and we can't take measures to mitigate in advance, such as earthquake, hurricane, tsunami, etc. Except that, most risks can be managed before loss really happened, like self-insurance, risk taken, risk transfer, risk decentralization, and risk hedging are common measures to cope with risks. Whatever, the most important thing is managing risks proactively but not waiting to deal with them after actual losses had happened. Idea of risk management should be rooted in daily work, we can collect the actual data of losses happened in the history, then analyze their risk sources, maximum number, minimum number, average value, probability, expected value and variation. After that, we will have a clear knowledge about distribution of losses. The following work is setting a reasonable threshold for losses, if some variations exceed this threshold, we can take measures at once and try to transfer or mitigate relative risks. This mechanism of proactive management could help us to foresee some risks in advance and gives us more time to take corresponding countermeasures.

4.5 Make contingency plans in advance

For those paroxysmal affairs, terrorism and natural disasters, we can only take some remedial measures after they happened. But if we have made various contingency plans ahead of schedule, the procedures of dealing with such kind of things will be orderly, efficient and reasonable, which will help to control spread of risks as soon as possible, and ultimately decrease the loss number and influences caused by risks. It is clear that the impact upon business can be reduced if potential risks are proactively managed, and there is a well-conceived and constructed business continuity plan in place. When making contingency plans, we should find their various deficiencies and amend them continuously through repeating disruption drilling rehearses.

5. CONCLUSIONS

Because uncertainties in the process of international logistics are much more than in the internal logistics, and plus to those inherent risks in the supply chain, the matter of how to manage risks of supply chain in the international environment is indeed a very challenging research area.

Risk identification and classification is the starting point of supply chain risk management, it can help us to know risk factors and risk sources. It is also related to the following procedure-risk assessment directly. Before analyzing risks in the supply chain, we must find out specialties of international logistics, for only by taking characteristics of international logistics into account, can we differentiate SCRM in the international logistics environment from risk management of normal internal supply chain.

Risk assessment is the most important part in the SCRM process, whose evaluation indices are selected from the risk classification analysis directly. Assessment method is critical, a good method can save our time by filtrating indices-getting rid of redundant information.

Each supply chain has its own traits, so each supply chain should has its own risk management skills and measures. But in a common sense, there are still some universal and generic rules which should be abided by.

Except those contents discussed in this paper, there are many other directions deserved our future research, such as the trade-off between risk management and supply chain profitability, which helps us to know how to achieve both profit and risk optimization; inherent dynamic feedback mechanism and potential relations existing among those various kinds of risk sources is also a promising study area, for it will reveal the ultimate origins of supply chain risks and how to keep away them; and research about how decision-makers' different attitudes toward risk(risk-lover, risk- averse or risk-neutral) will influence performance of supply chain is worthy of our efforts too.

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