Study on Supply Chain Disruption Risk Management Strategies and Model

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Abstract—**In this paper, the reasons that make a supply chain vulnerable to disruption risks are analyzed; the necessity and significance of developing supply chain disruption risk management strategies that have direct impacts on the effectiveness of supply chain disruption risk management is discussed, combined with the practice of China. Considering the characteristics of disruption risks, the supply chain disruption risk management strategies with the properties of efficiency and resilience are developed and analyzed, and related with actual practice, which include supply management strategies, supply management strategies, product management strategies and information management strategies. And then, in order to offer decision-making support for adopting reasonable strategies, a mathematical model is developed.**

Key Words—Supply chain disruption risks, Efficiency, resilience, Strategies, Model

I. INTRODUCTION

Over the last 10 years, earthquakes, economic crises, SARS, strikes, terrorist attacks have disrupted the supply chain operation repeatedly. The supply chain disruptions have significant impact on the whole supply chain short-term performance. For example, in China, transportation industry lost 38 billions RMB, wholesale and retail trade industries lost 12 billion RMB and manufacturing industry lost 27 billion RMB between April and June in 2003 because of SARS. In addition, the supply chain disruptions have long-term negative effects on the whole supply chain financial performance as well. For instance, some companies have suffered from the supply chain disruptions experienced 33%-40% lower stock returns relative to their industry benchmarks (Hendricks and Singhal, 2005). There are many factors reflecting the uncertainties of operational process of a supply chain, and then make the supply chain is vulnerable to various disruptions mainly include the tendency of globalization and complexity of the supply chain, all kinds of "slim approaches" (such as JIT, lean production, zero inventory). Modern supply chain management technology and thinking emphasis on efficiency rather than effect, e.g., the reduction of suppliers, the concentration of manufacturing and distribution, the increase of outsourcing business, and the increase of complexity and instability of the external environment. These will result in it is impossible to avoid the occurrence of disruptions, developing the theory of the supply chain disruption risk management has already become an urgent issue in today's business environment. Although, more and more Chinese state-owned and private firms have started to enter the international market, participate in international competition and develop the transnational operations. For example, Haier sets up factories in the world widely, Lenovo acquires of IBM's personal computer business. It is the requirement of Chinese economy and the firms' own develop to implement the "going out" strategy, and also it complies with the trend of economic globalization. Resources advantages, technological advantages, brand advantages, product advantages and channel advantages are gained by the firms through its transnational mergers, acquisitions, listing in overseas and so on. However, there are more disruption risks for the supply chain of multinational enterprises, and almost each disruption in the world will affect the operation of the supply chain. In addition, compared with the international multinational enterprises, the most Chinese enterprises are small and medium-sized enterprises that are very vulnerable to disruption risks. Chinese enterprises mainly rely on cost advantage to share market which lead to the supply chain operation of a cost-oriented, and don't attach importance to risk factors, particularly the disruption risks with small probability to occur. Therefore, it is necessary discuss how to make the supply chain support its operation during a disruption and rapid recovery to normal operation after a disruption, and it is significant for the supply chain reengineering and operation of Chinese enterprises, especially the multinational enterprises entering one after another. In fact, the supply chain disruption risk management strategy is of a crucial element that has a direct impact on the effectiveness of the supply chain.

Thus, in this paper, we firstly develop and analyze supply chain disruption risk management strategies with the properties of efficiency and resilience from point of supply management, demand management, product management and information management. Also, we relate various supply chain disruption risk management strategies examined in the literature with actual practice. And then, in order to offer decision-making support for adopting reasonable strategies, a mathematical model is developed.

II. STRATEGIES FOR MITIGATING DISRUPTION RISKS

The objective of a supply chain is the whole competitive competence improvement, whole value maximization, whole

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robustness, “symbiosis” vision and taking response to society together. Therefore, the supply chain emphasizes on the collaborative relationship between supply chain and enterprises. However, with supply chain hierarchies increasing, emergency inevitably (e.g., the great scope snow disaster in spring 2008, China), non-collaboration among the member enterprises in a supply chain, those may result in disruption of the supply chain. Therewith, the supply chain disruption risk management strategies are used to mitigate disruption risks, and effective strategies should improve the resiliency of a supply chain, allowing a supply chain to support its operation during a disruption and recover quickly after a disruption. On the other hand, the disruption is a small probability event, and since high uncertainty and few historical data referenced, good estimates of the probability of any particular disruption occurrence and accurate measure of potential impact of each disruption are difficult to obtain. These make enterprises tend to underestimate disruption risks and invest little time or resources in mitigating supply chain disruption risks, which is concluded by Zsidisin *et al*. (2001), and Closs & McGarrell (2004) who conducted various case studies. Strictly, supply chain disruption risk management strategies can make a supply chain not only possess the ability of sustaining its operation during a disruption and rapid recovery after a disruption, but also improve the efficiency of a supply chain by managing operational risks regardless of the occurrence of disruptions. These two specific characteristics that are critical for a supply chain to operation continuity and ensure profitability are as follows (Tang 2006): (1) Resiliency. The strategy will enable a supply chain to support its operation during a disruption and recover quickly after a disruption. (2) Efficiency. The strategy can enable a supply chain to manage operational risks efficiently regardless of the occurrence of disruption.

Next, we will discuss four aspect strategies based on supply management, demand management, product management and information management in a supply chain as follows.

2.1 Supply management strategies

·*Multi-supplier strategy*

Although single-supplier strategy is in favor of cost advantage and control quality, multi-supplier strategy is proved from the perspective of theory and practice to be the most common approach for reducing operational risks and disruption risks, which shifts the orders among the selected suppliers to ensure operational continuity and business efficiency of a supply chain (Sheffi, 2001; Kleindorfer *et al.*, 2005). Especially, having multiple suppliers in different countries can make a supply chain more resilient during a disruption. For example, when Indonesia Rupiah devalued by more than 50% in 1997, many Indonesian suppliers were unable to pay fee of the imported components or materials, hence, were unable to deliver the finished items to US customers in time. However, with network of 4000 suppliers throughout Asia, Li and Fung, the largest trading company in Hong Kong, shifted some planned order form Indonesia to suppliers in other countries, hence ensures the whole supply chain stability. However, the multi-supplier strategy is not implemented by every successful enterprise. For example, Toyota with JIT strategy was affected by conflagration of its single supplier in 1997, which cost committed by the Toyota about estimated $195 million and 70,000 units of production. However, Toyota still implements such strategy. In fact, the close supplier relationship is important for the choice of single-supplier strategy, or the supply chain will be disrupted easily. However, we must note that the cost committed by developing strategic relationship with a single supplier is very large. Therefore, to reduce disruption risks, most enterprises can enjoy multi-supplier strategy.

·*Real options strategy*

Although multi-supplier strategy could significantly improve the supply chain resilience, the ability is still limited. Because when a disruption affects certain supplier, especially the core supplier in a supply chain, though other suppliers may supply products to the downstream enterprise, total supply magnitude will be decreased, which will lower the speed for the supply chain to recover from failure. Therefore, real options strategy is put forward to complement multi-supplier strategy. Real options strategy is used to obtain the redundancy from its suppliers with the relative investment. After an enterprise pays some options cost to its supplier, it can get redundancy based on the supplier reserving redundant capability or sufficient inventory. When the inbound supply process of an enterprise is disrupted by a case, its supplier with options can provide redundant supply so that the supply chain resilience will be improved. Similarly, real options strategy can be used to mitigating operational risks of a supply chain.

2.2 Demand management strategies

In fact, many enterprises have attempted to use different demand management strategies to manipulate uncertain demands dynamically, so that the modified demand will be better matched with the limited supply. Here, we primarily analyze two demand strategies involving the responsive pricing strategy and the demand postponement strategy, which can make a supply chain more efficient and resilient by mitigating uncertain demand risk and disruption risks.

·*Responsive pricing strategy*

The responsive pricing strategy can enable some customers or firms in supply chain to shift demand across products by using price as a response mechanism (Chod and Rudi, 2005). Hence, when an enterprise sells multiple products and faces uncertain demand risk, it can offer its customers the right products at the right price by adjusting products’ prices to ensure profitability, i.e., a responsive pricing strategy will improve supply chain efficiency by mitigating uncertain demand risk. In addition, a responsive pricing strategy could improve a supply chain resiliency as well. This strategy has the capability to shift demand across products, so when the supply process of some products fails because of disruption, it can be deployed quickly to entice its customers to shift their demand from the product to another to reduce the losses. For example, when facing a supply disruption of computer parts from Taiwan after an earthquake, Dell immediately offered special price incentives to entice their online customers to buy

computers that utilized components from other countries. The capability of shift customer choice swiftly enabled Dell to increase its earnings in 1999 by 41%.

·*Demand postponement strategy*

Demand postponement strategy is intended to entice some enterprises or customers to accept their shipments or service in delayed period. For example, based on the demand postponement strategy, a manufacture may offer price discounts to some retailers to accept delayed shipments; in the service industries such as airlines and hotels, enterprises usually set higher prices during peak seasons in order to shift demand to off-peak seasons; essentially, this strategy is similar to the overbooking situation in which an airline may offer incentive to entice a fraction of customers who are willing to take a later flight. In a word, using by the demand postponement strategy, the enterprise in a supply chain offers different prices at different times, which will enable the supply chain to increase the profit generated form a limited supply capacity by capturing customers in different period who are willing to pay different prices. Thus, the demand postponement strategy can improve supply chain efficiency by making the demand better matched with the limited supply. What's more, a demand postponement strategy could improve a supply chain resiliency as well. When a particular enterprise in a supply chain is influenced by a disruption, the satisfaction rate of its downstream enterprise and end-customers will decline rapidly. Such strategy has the ability to shift some of the demands to the delayed period will result in the supply chain operation continuity or win extra time to restore against the disruption.

2.3 Product management strategies

With customer demands are more and more diverse and personalized, an enterprise must increase product variety and serve heterogeneous market segments to meet customer demand and increase market share. However, product varieties usually increase manufacturing cost since increase of manufacturing complexity. Moreover, product variety can increase inventory cost committed in increase of demand uncertainty. In this condition, some cost-effective product variety strategies can mitigate uncertain demand risk are developed, for example, interchangeable strategy and postponement strategy (Lee, 1996; Rajaram and Chang,. 2001; Su *et al*., 2005). These product management strategies can also improve the resiliency of a supply chain by improving manufacturing flexibility. The detailed analysis is as follows.

·*Interchangeability strategy*

Essentially, flexibility means feasible choice in every situation. To a supply chain, when the supply chain fails because of disruption, the losses can be reduced by using plant and production system or component with good interchangeability that creates an opportunity for supply chain to recovery from failure. Here, interchangeability of plant, production system and component are discussed. ① Interchangeability of plants. Intel has plants in Ireland, Israel, China, and America. Its plants distribution is so wide, so Intel is easily influenced by the types of disruptions, such as Oregon earthquake, Philippines typhoon, Israel war, China SARS. Intel improves the supply chain resilience with flexibility strategy of "copying exactly" , i.e., the enterprise transfers production capacity easily among these plants. For example, many plants were closed or stopped production since SARS in 2003. But Intel declared that even if the production of plant in Shanghai was stopped, its total outbound supply can't be affected, i.e., the interchangeability of production capacity ensures the stabilization of supply, and then mitigates the supply chain disruption risks. ② Interchangeability of production processes. In the era of mass production, not only production lines have flexibility, also interchangeability of plants. For instance, General Motors Corporation uses a plant to product different kinds of cars, namely, it uses the same cutter and fixture to produce parts of different types of cars. ③ Interchangeability of parts. The more general parts the products have, the greater interchangeable the parts are. If a company uses more general parts in different products, it is easy to forecast and control parts supply and demand, which is articulated (Chong *et al*., 2004). When the inbound supply process of certain parts is disrupted, it is easy to find back-up supplier of general parts. Moreover, standard parts can be disassembled easily in different product inventory which can cushion supply failure and improve resilience of a supply chain.

·*Postponement strategy*

The production process could be divided into two processes, namely, general production process and customization production process. Based on postponement strategy, customization point should be moved as backward as possible, which will provide convenience for adjusting production quickly. When demand fluctuating (increasing or decreasing suddenly and significantly) since disruption, postponement strategy can be effect to improve the supply chain resilience. That's because it is easier to adjust general production than customized production. The resilience improved by postponement strategy not only reflects on quick response to customer demand but also to supply. For example, after Philip's semiconductor plant was damaged in conflagration in 2000, Nokia was in a serious supply disruption of radio frequency chips. Since Nokia's cell phones are designed based on the modular fashion, Nokia was able to postpone the insertion of these radio frequency chips. Consequently, Nokia can meet customer demand stably and win a higher market position. In addition, the advantages of postponement strategy reflect raw material can be produced in different plants from the perspective of supply. The effect is as well as that of multi-supplier strategy, which improves the supply chain resilience.

2.4 information management strategies

A supply chain is a network constituted by series of joint enterprises. So decision-making in a supply chain is a kind of group decision-making. The accuracy and consistency of decision-making can be determined by timely and perfect information exchange. The information is important for decision-making of every plans, such as materials

procurement, production scheduling, marketing strategies etc. The information flow is one of the important driven factors that ensure the normal operation of a supply chain. However, with the development of globalization of supply chain, the structure of a supply chain is more and more complex, which results in the information often be distorted and delayed, and then results in more uncertainties in the supply chain and lower responsive to the market. Thus, some information management strategies can improve supply chain effect are developed. Here, we analyze how information sharing strategy improves the supply chain efficiency and resilience, and how to establish a resilient information system depend on information technology.

·*Information sharing strategy*

In a supply chain, it is necessary for the member enterprises to share information, including inventory level, sales data, order state, demand forecast, production plan, distribution plan and so on. Information sharing strategy can improve the supply chain visibility. As supply chain visibility improves, every enterprise will more quickly obtain the useful information from other member enterprises, which makes each enterprise in the supply chain could generate more accurate forecast plan, reduces the uncertainty caused by information distortion and delay, and then enables the supply chain quickly responsive market. Especially, once an enterprise is influenced by a disruption, other enterprises will find relative information as quick as possible. In fact, why many supply chains suffered heavy losses in disruption is that they couldn't obtain useful timely information and then lose the good opportunity to mitigate the disruption risks. On the other hand, information sharing strategy will foster a close coordination and strong collaboration among member enterprises that can make them more capable to mitigate operational risks and disruption risks. Hence, information sharing strategy can improve the supply chain efficiency and resilience.

·*Resilience information system strategy*

There are many failure cases of information system affect the whole supply chain. For example, in 2003, 'SQL Slammer' virus quickly infected 90% computers that have vulnerability in the world, which made the information systems paralysis of American 911 Emergency Call Center, American Express Service Center and Continent Airline Company. Slammer resulted in more than one billion dollars losses in world. In addition, the impact of failure of information system reflects not only on an enterprise itself, but also on the information exchange among the member enterprises in a supply chain. To higher depending information technology industry, it is very important to establish a resilient information system, such as backup the data of information system in a certain period, then once the failure of information system it can be recovered at short time. For instance, there were 657 employees of financial brokerage firm in Cantor Fitzgerald lost their lives in "9.11". At that time, many people thought Cantor Fitzgerald would be closed down because its operation mainly depended on the relation between customers and employees. However, the backup data helped the firm to recover quickly. More importantly, to establish the resilient information system, it is not only to backup data but also backup information system. And, the opportunity of procuring hardware when disruptions occur is important, i.e., the firm needs to sign the contracts with some companies such as Dell, HP. For example, after World Trade Center collapsed, the operation institution in New York of Deutsch Bank failed too and the relation with American market was disrupted. However, at the same time, the backup information system in Ireland was continued the operation, e.g., the People's Bank of China is planning to establish a national bank disaster backup center in Chongqing or Chengdu city, based on this center, it will ensure that all banks could operate normally even if disruptions occurs.

III. SUPPLY CHAIN DISRUPTION RISK MANAGEMENT STRATEGIES MODEL

3.1 Model

For a supply chain, in order to adopt reasonable supply chain disruption risk management strategies, it should be based on the actual situation of the supply chain involving in the type of supply chain risks and their influences. Although the strategy is intended to enhance the profit of supply chain by mitigating supply chain risks, it may improve the employ of resource, and then increase the operating cost of the supply chain. For example, to increase the number of suppliers, implement real options strategy or establish a resilient information system, the firm in supply chain needs to invest extra cost. In this condition, when considering whether to adopt a specific supply chain disruption risk management strategy, and how much cost should be invested, decision maker should synthetically analyze the increased profit and the increased cost to maximize the effectiveness of the strategy.

Here, we mainly discuss a specific supply chain disruption risk management strategy, namely S. Let B_1 and B_2 denote the relative supply chain operational risks and disruption risks respectively. In order to quantify the impact of the risks on the supply chain, two basic indexes are introduced: ① the probability that the supply chain is influenced by risks; ② the losses that the supply chain suffers because of risks. Obviously, the two indexes are related with the cost invested in the strategy S. Let $p_1(K)$ and $p_2(K)$ respectively denote the probabilities that the supply chain is influenced by operational risks B_1 and disruption risks B_2, and $L_1(K)$ and $L_2(K)$ respectively denote the average losses that the supply chain suffers because of operational risks B_1 and disruption risks B_2, where K is the cost invested in the strategy S, and $K=0$ describes strategy S is not adopted. Hence, we would the calculate the value of decision variable K to maximize the expected profit of the supply chain under the circumstance that the supply chain isn't influenced by disruption risks B_2 and minimize the losses that the supply chain suffers because of

disruption risks B_2 , which is aimed to maximize the effectiveness of strategy S for the supply chain.

Firstly, calculate the effectiveness of strategy S for mitigating operational risks B_1 under the circumstance that the supply chain isn't influenced by disruption risks B_2 . In this paper, the objective is to maximize the expected profit of the supply chain, then:

$$\max \quad G(p_1(K),K) = R - p_1(K)L_1(K) - K \qquad (3\text{-}1)$$

where R is the average profit when the supply chain is not influenced by operational risks B_1 or disruption risks B_2 .

Now, let us analyze the following conditions.

① The strategy S is not adopted, that is, $K = 0$.

If the supply chain is not influenced by operational risks B_1 , the profit of the supply chain can be expressed as follow:

$$G(p_1(K),K)_{11} = R \qquad (3\text{-}2)$$

If the supply chain suffers losses because of operational risks B_1 , the profit of the supply chain can be expressed, which is as follows:

$$G(p_1(K),K)_{12} = R - L_1(0) \qquad (3\text{-}3)$$

② The strategy S is adopted, that is, $K \neq 0$.

If the supply chain is not influenced by operational risks B_1 , the profit of the supply chain can be expressed as follows:

$$G(p_1(K),K)_{21} = R - K \qquad (3\text{-}4)$$

If the supply chain suffers losses because of operational risks B_1 , the profit of the supply chain can be expressed, which is as follows:

$$G(p_1(K),K)_{22} = R - L_1(K) - K \qquad (3\text{-}5)$$

According to the expression of (3-2) and (3-4), when the supply chain is not influenced by operational risks B_1 , the decreased profit of the supply chain since the strategy S is adopted can be deduced:

$$\Delta G(p_1(K),K)_1 = G(p_1(K),K)_{11} - G(p_1(K),K)_{21} = K \qquad (3\text{-}6)$$

In addition, according to the expression of (3-3) and (3-5), when the supply chain suffers losses because of operational risks B_1 , the retrieved losses since the strategy S is adopted can be deduced:

$$\begin{aligned}\Delta G(p_1(K),K)_2 &= G(p_1(K),K)_{22} - G(p_1(K),K)_{12} \\ &= L_1(0) - L_1(K) - K\end{aligned} \qquad (3\text{-}7)$$

In order to make sure that the strategy S is effective to mitigate operational risks B_1 , the following inequality should be satisfied:

$$p_1(K)\Delta G(p_1(K),K)_2 \geq (1 - p_1(K))\Delta G(p_1(K),K)_1$$

Namely, $$K \leq p_1(K)(L_1(0) - L_1(K)) \qquad (3\text{-}8)$$

Secondly, calculate the effectiveness of strategy S for mitigating disruption risks B_2 . Here, the objective is to minimize the losses that the supply chain suffers because of disruption risks B_2 , then:

$$\min \quad D(p_2(K),K) = p_2(K)L_2(K) \qquad (3\text{-}9)$$

i.e., $$\max \quad -D(p_2(K),K) = -p_2(K)L_2(K) \qquad (3\text{-}10)$$

Generally, the degrees of attaching importance to operation risks B_1 and disruption risks B_2 are different. So we introduce two weight factors, namely α_1 and α_2 , to transform the two objective functions (3-1) and (3-10) into single objective function, where α_1 and α_2 show the degrees of attaching importance to operation risks B_1 and disruption risks B_2 , respectively , the detailed data are given by the decision maker during calculation, then:

$$\max \quad \alpha_1(R - p_1(K)L_1(K) - K) + \alpha_2(-p_2(K)L_2(K))$$

where $\alpha_1, \alpha_2 \in [0,1]$, $\alpha_1 + \alpha_2 = 1$

Thus, the optimization model based on the strategy S can be expressed as follows:

$$\max \quad \alpha_1(R - p_1(K)L_1(K) - K) + \alpha_2(-p_2(K)L_2(K))$$

$$s.t. \quad \begin{cases} K \leq p_1(K)(L_1(0) - L_1(K)) \\ \alpha_1 + \alpha_2 = 1 \\ \alpha_1, \alpha_2 \geq 0 \\ K \geq 0 \end{cases}$$

For this single objective optimization model, the optimal solution K^* could be obtained easily. If $K^* = 0$, it denotes that the strategy S would not be adopted; if $K^* \neq 0$, it denotes that cost K^* would be invested to implement the strategy S .

3.2 Numerical example

In a manufacturing supply chain, the automobile producers, namely M , is the core firm. In order to mitigate supply chain operational risks that would make the stock shortage and supply chain disruption risks that would disrupt the supply process, the firm M considers adopting real options strategy for the procurement of a kind of key components. In the current situation when real options strategy isn't adopted, the probabilities that the supply chain is influenced by relative operational risks and disruption risk are 50% and 5% respectively, and under the circumstance that the supply chain is influenced by relative operational risks and disruption risks, the average losses that the supply chain suffers are 200,000RMB/month and 1,000,000RMB/month respectively. In addition, $R = 20{,}000{,}000\mathrm{R}MB/\mathrm{month}$. According to the

statistics, if the options cost is added by 1000RMB, the probabilities that the supply chain is influenced by relative operational risks and disruption risk decrease by 2% and 0.3% respectively, and under the circumstance that the supply chain is influenced by relative operational risks and disruption risks, the average losses that the supply chain suffers decrease by 3% and 5% respectively. Then

$$p_1(K) = \max\{50\% - \frac{K}{0.1} \times 2\%, 0\} = \max\{0.5 - 0.2K, 0\}$$

$$L_1(K) = \max\{20(1 - \frac{K}{0.1} \times 3\%), 0\} = \max\{20 - 6K, 0\}$$

$$p_2(K) = \max\{5\% - \frac{K}{0.1} \times 0.3\%, 0\} = \max\{0.05 - 0.03K, 0\}$$

$$L_2(K) = \max\{100(1 - \frac{K}{0.1} \times 5\%)\} = \max\{100 - 50K, 0\}$$

Now, according to the optimization model above, we can get the results that are shown in Figure 1. We can conclude that for $\forall \alpha_1 \in [0,1], K^* \neq 0$, that is, whatever the value of α_1 is, adopting real options strategy is optimal for the supply chain.

Fig.1 The optimal solution K^* and corresponding target value with different values of α_1

α_1	0	$(0, \frac{7}{11}]$	$(\frac{7}{11}, 1]$
K^* (RMB/month)	$\frac{5}{3} \times 10^4$	$\frac{5.5 + 0.5\alpha_1}{5.4 - 3\alpha_1} \times 10^4$	$\frac{5}{3} \times 10^4$
$G(p_1(K^*), K^*)$ (RMB/month)	1.997×10^7	$\frac{5966.9\alpha_1^2 - 21521.8\alpha_1 + 19390.1}{3(1.8 - \alpha_1)^2} \times 10^4$	1.997×10^7
$D(p_2(K^*), K^*)$ (RMB/month)	$-\frac{5}{3} \times 10^4$	$\frac{17.88\alpha_1^2 - 26\alpha_1 + 9.28}{3(1.8 - \alpha_1)^2} \times 10^4$	0
$\alpha_1 G(p_1(K^*), K^*) - (1 - \alpha_1) D(p_2(K^*), K^*)$ (RMB/month)	$\frac{5}{3} \times 10^4$	$\frac{5984.78\alpha_1^3 - 21565.63\alpha_1^2}{3(1.8 - \alpha_1)^2} \times 10^4 + \frac{19425.33\alpha_1 - 9.28}{3(1.8 - \alpha_1)^2} \times 10^4$	$1.997 \times 10^7 \alpha_1$

IV. CONCLUSIONS

Currently, supply chains are vulnerable to disruption risks. Facing the fact that it is impossible to avoid the occurrence of disruption risks, a supply chain should have the capabilities of sustaining operation during a disruption and rapid recovery to normal operation after being influenced by a disruption. In this paper, firstly, the reasons that make a supply chain vulnerable to disruption risks are analyzed; the necessity and significance of developing supply chain disruption risk management strategies that have direct impacts on the effectiveness of supply chain disruption risk management is discussed, combined with the practice of China. Secondly, considering the characteristics of disruption risks, the supply chain disruption risk management strategies with the properties of efficiency and resilience are developed and analyzed, and related with actual practice, which include supply management strategies, supply management strategies, product management strategies and information management strategies. Finally, in order to offer decision-making support for adopting reasonable strategies, a mathematical model is developed.

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