MITIGATE SUPPLY RISK IN SUPPLY CHAIN

Xiaoyu Yang and Shaochuan Fu
Schoole of Economics and Management, Beijing Jaotong University, Beijing, China

Keywords: Disruption Risk Management, Supply Chain, Supply Risk, Multi-supplier.

Abstract: As one of the most important part of supply chain, the supply disruption has more influence than other disruptions. Once the supply disruption occurs, that may lead to serious consequences; even break the whole supply chain. This paper analyses the composition of supply risk, addresses an effective method to mitigate supply risk, i.e., dual-supplier or multi-supplier supply model. In order to choose suppliers for the whole supply chain, a mathematical model is developed and verified by a numerical example.

1 INTRODUCTION

With the developing of business model, such as procurement of corporate globalization, outsourcing non-core business, single-source supply and lean supply, the supply chain gets longer in the space, while shorter in time. These changes increase the possibility of disruption. And the growing perturbations of external elements like natural disasters, terrorism, war, epidemics, computer viruses, economics fluctuations, makes the supply chain more fragile, and the probability of disruption higher.

Procurement is the leading force of "upstream control" overall supply chain. Supply disruptions may bring great loss to the enterprise and the whole supply chain. Take the year 2000 lightning incident in Albuquerque, New Mexico as an example (R. Eglin, 2003).The incident catastrophically destroyed a Phillips Electronics semiconductor plant, which was Ericsson's single supplier. As a result, when the plant had to shut down after the fire, Ericsson had no other sources of microchips and ultimately lost $400 million in sales. Due to such negative influence of supply disruptions, large numbers of researchers have started to investigate how to mitigate disruption risks in a supply chain

Most supply chain disruptions can be broadly classified into three categories, supply-related, demand-related, and miscellaneous risks (Oke and Gopalakrishnana, 2009). Supply disruptions can be defined as unforeseen events that interfere with "the normal flow of goods and (/or) materials within a supply chain" (Craighead et al., 2007). Supply disruption occurs when suppliers could not fill the orders placed with them. Supply risks could affect or disrupt the supply of products or services that the supply chain offers to its customers potentially. Supply disruptions has various causes, including natural disasters, equipment breakdowns, labor strikes, political instability, traffic interruptions, terrorism and so forth(S. Chopra, M. Sodhi,2004). Supply disruptions may cause immediate or delayed negative effects on procurement firm performance over the short and (/or) long-term, depending on the severity of the disruption and the recovery capabilities of procurement firm (Sheffi and Rice, 2005). While revenue loss from supply disruptions may stem from the inability to meet demand and inventory mark-downs, "expediting, premium freight, obsolete inventory, additional transactions, overtime, storage and moving, selling, and penalties paid to customer" make operating costs higher (Hendricks and Singhal, 2003).

Recently supply disruption management received increasing attention from both industry and academia. There are a number of literatures about supply disruption management. Jian Li, Shouyang Wang investigated the sourcing strategy of a retailer and the pricing strategies of two suppliers in a supply chain under an environment of supply disruption(Jian Li, Shouyang Wang,2010). Tomlin went beyond the existing literature by explicitly modelling the trade-off sand limitations inherent in mitigation and contingency strategies (Tomlin, 2005). Then he considered a model that a firm may order from a cheap but unreliable supplier and (/or) an expensive but reliable supplier. He examined the

Yang X. and Fu S..
MITIGATE SUPPLY RISK IN SUPPLY CHAIN.
DOI: 10.5220/0003608105440549
In *Proceedings of the 13th International Conference on Enterprise Information Systems* (IAST-2011), pages 544-549
ISBN: 978-989-8425-55-3

firm's optimal strategy is to manage supply disruption. He also investigated the influence of the firm's attitude towards risk on mitigation and contingency strategies for managing supply disruption risk (Tomlin, 2006). Suppliers' responses, such as their pricing strategies, are also crucial factors that impact the supply chain. The wholesale price setting problem has been extensively studied in the literature. Recent literatures gave the optimal pricing strategies of the suppliers under different scenarios (Lariviere and Porteus 2001; Wang and Gerchak 2003; Tomlin 2003; Bernstein and DeCroix 2004; and Cachon and Lariviere 2001). Game analysis of supply chains is another direction of the study about supply risk management. Papers using cooperative game theory to study supply chain management are much less prevalent, but are becoming more popular (Cachon and Netessine, 2004). Scott C. Ellis, Raymond M. Henry, Jeff Shockley, operationalized and explored the relationship between three representations of supply disruption risk: magnitude of supply disruption, probability of supply disruption, and overall supply disruption risk. They also showed that both the probability and the magnitude of supply disruption are important to buyers' overall perceptions of supply disruption risk (Scott C. Ellis, Raymond M. Henry, Jeff Shockley, 2009). Xueipng Li, Yuerong Chen, developed a simulation model for such an inventory system and investigated the impacts of supply disruptions and customer differentiation on this inventory system. (Xueipng Li, Yuerong Chen, 2009).Due to the complexity of supply risk management, in this paper we talk about a method to mitigate the risk, i.e., dual-supplier or multi-supplier. Furthermore we apply a mathematical model to choose the right suppliers. We believe the model developed within this paper may serve as the basis for future research about supply risk management.

The remainder of this paper is organized as follows. Section 2 introduces the composition of supply risk and one method to mitigate the supply risk, i.e., supply mode of dual-supplier or multi-supplier. Section 3 presents a mathematical model for buyers to choose the right suppliers, and numerical results are presented to illustrate the theoretical results. Conclusions are given in Section 4.

2 SUPPLY RISK

Supply risk is the probability of supply accident. It stems from the upstream enterprises of the supply chain member companies, including potential or actual disruption of raw materials, spare parts, and information flows in supply chain. Supply risk can be led to by individual suppliers, or by the elements of whole market. Problems of individual supplier may be caused by natural disaster, failure respond to fluctuations of demand, quality problems in the production process, failure to keep up with the requirements of technological development and so on. Problems of whole supply market may relate to patent issues or market capacity constraints.

2.1 The Composition of Supply Risk

Supply risk consists of supply disruption risk and supply delay risk.

Supply disruption risk mainly comes from exogenous variables in the supply chain system.

- Natural disaster: earthquake, hurricane, flood, snowstorm, epidemic, lighting;
- Operational incidents: supplier's bankruptcy, equipment trouble, information infrastructure close to collapse;
- Political instability: labor disputes, war, terrorism;
- Single-source supply risk: dependence on single source supply and optional alternative suppliers' capacity and responsiveness.

The larger the network is and the longer the route is in the supply chain information system, the greater the threat of supply disruption is. In addition, due to the high use of resources or the lack of flexibility, the delayed flow of materials and supply delay risk often occurs when a supplier can not respond to changes in demand.

Supply delay risk caused by the inherent uncertainty of supply of the system, mainly comes from production risk, inventory risk, product service level risk, technology risk, production quality problems and systemic risk.

- Production risk: capacity utilization, capacity cost, capacity flexibility, production and technology lags behind competitors;
- Inventory risk: lot quantity, mixed changes in species, stock retirement rates, holding cost and uncertainty of supply;
- Product service level risk: products can not meet the needs of the number of shipments, transportation or distribution, lead time and so on;
- Quality risk: poor quality of supply resources;
- Technology risk: changes of manufacturing technique and product design lead to

production and technology lags behind competitors;
- Systemic risk: risk of system network expansion and data security of information (hacker, virus, non-involvement).

Since production can only increase or decrease over time, one strategic choice could be build excess capacity. However, excess production capacity will damage the financial performance, generate production capacity risk. Inventory risk comes from the customers' the fluctuation in demand of the suppliers' lot quantity and product variety, out of stock and excess inventory obsolescence for example. Product service risk comes from that products can not meet the needs of the number of shipments, transportation or distribution and the lead time. Risk about quality includes the maintenance of assets, the damage occurred in transit, and the lack of quality principle and technical training. Technology risk includes the risk of improvement of current technology and giving up development efforts.

2.2 Methods to Mitigate Supply Risk

There are several methods to mitigate supply risk, such as design a robust supply network, improve the flexibility of suppliers, ant alter the procurement path, flexible logistics (transportation of multi-mode or multi-carrier or multi-route). One proven method is supply mode of dual-supplier or multi-supplier.

A single source of supply means the buyer define, discuss and purchase services with single service supplier. This is a very popular approach, because it is simple and quick, and can reduce the purchase cost. And companies can get the best price when companies and suppliers achieve a close working relationship. But a single source of supply will lead to supply security problems in many ways. For example, if suppliers met special evens like fires and other accidents, that will lead to supply disruption; if suppliers shorted of production capacity or can not product timely, that will lead to supply disruption. Enterprises adopt a single source of supply, some because of low cost, and some because of the lack of qualified alternative suppliers.

When people noticed the importance of prevent the influence of short supply, walkout and other emergency, dual-supplier or multi-supplier procurement becomes an acceptable choice. There are some advantages of multi-supplier procurement. First is a reserve of resources available to ensure the companies can maintain their competitiveness. The second is the company will no longer restricted by a single supplier. The third is that the quantity of supply can be greater guaranteed. When suppliers competed with each other, buyer can get more advantages, such as lower costs, promotion of service and quality.

Dual-supplier or multi-supplier procurement means there are two or more than two suppliers. The first supplier is the main supplier with high efficiency and low transaction cost to satisfy the demand. The second (and others except the first one) supplier is used to satisfy the demand variation to adapt the restrictions of low or high capacity, with higher price. Flexible procurement strategy enables enterprises to cope with a temporary supply chain disruption. But the development of suppliers is often difficult, managers should recognize the long-term strategic significance of development of suppliers, then choose the right suppliers.

3 CHOOSE THE RIGHT SUPPLIERS

3.1 Model

Here we consider the situation where multiple suppliers supply for one enterprise. As the buyer, we use decision theory to choose the main supplier and the second or other suppliers.

Encode the suppliers and the risk indicators. Let S_i denote the optional supplier i, E_i denote the risk indicator i, and P_i denote the weight of E_i. Define summation of P_i is 1. If choose supplier i, each risk indicator's evaluation score is a_{ij}.

Define six risk indicators:
- Probability of supply risk: the smaller the probability of risk, the better;
- Harmful levels of supply risk: the smaller the harmful level of risk, the better. Indicators evaluated by five levels: very serious, severe, general, not too serious, and not serious ;
- Financial support: the more financial support, the better. For example received financial support based on national or industry policy and investment guidance;
- Allowable time to deal with risks: it denotes the time how long be allowed to respond to reduce the damage of risk. The longer, the better;
- Number of affected units: the less the affected units after the risk occurred, the better;

- Risk management mechanism: the more perfect a risk management mechanism, the better. Indicators evaluated by five levels: very well, perfect, general, not sound, very sound.

Quantitative indicators directly obtained from data, qualitative indicators rely on experts' judgments. Generally, subjective judgements can be reasonably distinguished to five grades. So we use five-judge in this paper. The value corresponding to each level is shown in table 1.

Table 1: Corresponding value of five-judge.

Grade	Value
Very high	10
High	8
General	6
Low	4
Very low	2

In order to unify the indicator, transform the indicators which "the more, the better" into "the less, the better" indicators. So define the three "the more, the better" indicators evaluation score is the opposite number of their value. Setting different P_i can highlight the indicators which the buyer is more concerned about. The more important the indicator to the buyer, the higher the weight of E_i i.e., P_i is.

Choose the right suppliers:

First normalize the evaluation score a_{ij}, let a_{ij}' be the normalized score of E_i, $a_{ij}' \in [-1,1]$, then compute each supplier's expectancy evaluation:

$$\sum_j p_j a'_{ij}, \quad i = 1,2,\dots,n \tag{1}$$

Then choose the minimum one from these expectancy evaluations, the corresponded supplier is the best supplier for buyer.

$$\min_i \sum_j p_j a'_{ij} \to S_k^* \tag{2}$$

3.2 Numerical Example

In a manufacturing supply chain, one automobile producer, namely A, is the core firm. In order to mitigate supply risk, the firm A considers choosing 2 suppliers as its main supplier and second supplier from six alternative suppliers.

S_1-S_6 represents each of the six suppliers, and E_1-E_6 represent six indicators, i.e., probability of supply risk, harmful levels of supply risk, financial support, allowable time to deal with risks, number of affected units, and risk management mechanism. The data of all the six suppliers' indicators is shown in table 2.

Table 2: Data of suppliers' indicators.

S_i \ E_j	E_1	E_2	E_3	E_4	E_5	E_6
S_1	0.25	8	2.1	25	23	8
S_2	0.1	8	1.8	20	9	4
S_3	0.12	6	2.6	14	15	4
S_4	0.18	10	2.8	17	12	8
S_5	0.24	6	1.9	19	25	6
S_6	0.16	8	1.5	12	7	4

The firm A firstly requests his main supplier should have low probability of supply risk, and it is better if the number of affected units could be fewer. Then it cares about the harmful levels of supply risk, allowable time to deal with risks, and the risk management mechanism, and financial support is the last one to be considered. For his second supplier, firm A firstly requests the financial support should be enough, second the harmful levels of supply risk better be lower. The probability of supply risk, the number of affected units, and the risk management mechanism are on the third place. The harmful levels of supply risk are considered last.

Based on the firm A's requirements of supply, evaluate P_i. For the main supplier: let P_i be 0.25, 0.15, 0.10, 0.15, 0.20, and 0.15. For the second supplier: let P_i be 0.15, 0.10, 0.25, 0.20, 0.15, and 0.15.

The decision matrix is showed in table 3 and table 4.

Choose the minimum one from the last row of the two decision matrixes, the corresponded supplier is the most suitable supplier for buyer.

Table 3: Decision matrix of the main supplier.

E_i / P_i / S_i	*E*1	*E*2	*E*3	*E*4	*E*5	*E*6	Σ
	0.25	*0.15*	*0.10*	*0.15*	*0.25*	*0.15*	
S_1	0.24	0.17	-0.17	-0.23	0.25	-0.24	0.06
S_2	0.10	0.17	-0.14	-0.19	0.10	-0.12	0.01
S_3	0.11	0.13	-0.20	-0.13	0.16	-0.12	0.03
S_4	0.17	0.22	-0.22	-0.16	0.13	-0.24	0.03
S_5	0.23	0.13	-0.15	-0.18	0.27	-0.18	0.08
S_6	0.15	0.17	-0.12	-0.11	0.08	-0.12	0.04

Table 4: Decision matrix of the second supplier.

E_i / P_i / S_i	E_1	E_2	E_3	E_4	E_5	E_6	Σ
	0.15	*0.10*	*0.25*	*0.20*	*0.15*	*0.15*	
S1	0.24	0.17	-0.17	-0.23	0.25	-0.24	-0.03
S2	0.10	0.17	-0.14	-0.19	0.10	-0.12	-0.04
S3	0.11	0.13	-0.20	-0.13	0.16	-0.12	-0.04
S4	0.17	0.22	-0.22	-0.16	0.13	-0.24	-0.05
S5	0.23	0.13	-0.15	-0.18	0.27	-0.18	-0.01
S6	0.15	0.17	-0.12	-0.11	0.08	-0.12	-0.02

In this example, firm A should choose the fourth supplier S_2 as its main supplier, and the fifth supplier S_4 as its second supplier.

If a firm considered more factors when it chooses suppliers, such as distance, methods and price of transportation, exchange rate fluctuations, changes in demand and raw materials cost, etc, these factors can be transformed to special risk indicators, and use this model to choose the suitable suppliers.

4 CONCLUSIONS

As one of the most important part of supply chain, supply disruption may bring great loss to the enterprise and the whole supply chain, even break down the whole supply chain. This paper analyses the composition of supply risk, and methods to mitigate supply risk, addresses dual-supplier or multi-supplier supply model may be an effective method. In order to choose suppliers for the whole supply chain, a mathematical model is developed and verified by a numerical example.

ACKNOWLEDGEMENTS

Our thanks go to everyone who supported our work, and who provided us lots of material. We also thank the team members from the company who sponsored this work, whose support is greatly appreciated.

REFERENCES

Jian Li, Shouyang Wang, T. C. E. Cheng, 2010, Competition and cooperation in a single-retailer two-supplier supply chain with supply disruption, Int. J. Production Economics 124, 137–150.

Scott C. Ellis, Raymond M. Henry, Jeff Shockley, 2009, Buyer perceptions of supply disruption risk: A behavioural view and empirical assessment, Journal of Operations Management 28, 34-36.

Xueipng Li, Yuerong Chen, 2009, Impacts of supply disruptions and customer differentiation on a partial-backordering inventory system, Simulation Modelling Practice and Theory 18, 547－557.

Zhang Yi-bin，Chen J un-fang, 2007, A Framework of Identifying Supply Chain Risks and Their Flexible Mitigating Polices, Industrial Engineering and Management, 47-52.

Chen Chang-bin, Miu Li-xin, 2009, An Analysis of Supply — chain Classification， vulnerability and Management Method, business economy, 98-101.

Li Leiming, Liu Bingquan, 2010, Research Review of the Management Research of the Supply Chain Disruption Risk, Science and Technology Management Research, 236-239.

Lou Shan-zu0，Wu Yao-hua，Lu Wen，Xiao Ji-wei, 2010, Optimal inventory management under stochastic disruption, Systems Engineering — Theory & Practice,469-475.

R. Eglin, 2003, Can suppliers bring down your firm? Sunday Times (London), appointments sec., p. 6.

Oke, A., Gopalakrishnana, M., 2009, Managing disruptions in supply chains: a case study of a retail supply chain. International Journal of Production Economics 118 (1), 168–174.

Craighead, C. W., Blackhurst, J., Rungtusanatham, M. J., Handfield, R. B., 2007, The severity of supply chain disruptions: design characteristics and mitigation capabilities. Decision Sciences 38 (1), 131－156.

S. Chopra, M. Sodhi, 2004, Managing risk to avoid supply-chain breakdown, MIT Sloan Management Review 46 (1) 53－61.

Sheffi, Y., Rice Jr., J., 2005, A supply chain view of the resilient enterprise. MIT Sloan Management Review 47 (1), 41－48.

Hendricks, K. B., Singhal, V. R., 2003, The effect of supply chain glitches on shareholder wealth. Journal of Operations Management 21 (5), 501－522.

Tomlin, B., 2005, Selecting a disruption-management strategy for short life-cycle products: diversification, contingent sourcing, and demand management Working Paper, Kenan-Flagler Business School, University of North Carolina.

Tomlin, B., 2006, On the value of mitigation and contingency strategies for managing supply-chain disruption risks. Management Science 52, 639–657.

Lariviere, M. A., Porteus, E. L., 2001, Selling to a newsvendor: an analysis of price-only contracts. Manufacturing & Service Operations Management 3, 293–305.

Wang, Y., Gerchak, Y., 2003. Capacity games in assembly systems with uncertain demand. Manufacturing & Service Operations Management 5, 252–267.

Tomlin, B., 2003. Capacity investment in supply chains: sharing the gain rather than sharing the pain. Manufacturing & Service Operations Management 5, 317–333.

Bernstein, F., DeCroix, G. A., 2004, Decentralized pricing and capacity decisions in a multitier system with modular assembly. Management Science 50, 1293–1308.

Cachon, G., Lariviere, M., 2001, Contracting to assure supply: how to share demand forecasts in a supply chain. Management Science 47, 629–646.