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Quality Risk Research in the Supply Chain Environment

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Abstract
Quality issue on supply chain is essential. It affects not only the cost of quality, but also customer's satisfaction. Supply chain's upstream should be good quality, the level of quality risk management can be introduced, and it can consider the current cost of quality, combine with supply chain risk transfer and improve overall efficiency. The paper will quantify the quality of risk, and use mathematical models to simulate risk transfer to help suppliers to determine the best lever of quality risk management.

Key words: Quality risk; Quality costs; Product recalls; Supply chain risk management

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INTRODUCTION
In recent years, global enterprises are facing the risk of product recall. For example, Johnson & Johnson broke again massive drug recall in January 2011, involving 47 million drugs. According to incomplete statistics, this is the 8th massive recall of Johnson & Johnson from 2010. In fact, the problem drugs come from McNeil Pharmaceutical factory, which located in Pennsylvania. 2010 Toyota due to "pedal" incident recalls 8.5 million vehicles all the global, the incident shocked the global automotive industry. Similarly, the Yili Group announced that part of the mercury content of milk products is abnormal, emergency recall, involving the production of milk power with excellent 2, 3, 4 segment form November 2011 to May 2012. Recalls ring inconvenience to consumers, and the corporate brand image among consumers affected at the same time. Third quarter of 2010, Johnson & Johnson's total sales in the United States from 2009's $ 1.7 billion greatly reduced by 25% to $ 1.3 billion, there are about $ 600 million losses of Johnson & Johnson in 2011. What's more, Toyota's losses could total amount of more than 2 billion U.S. dollars, which can buy the entire Volvo.

It can be seen, the upstream businesses, as manufacturers, suppliers, are essential for corporate earnings. There's data indicating that the cost of components purchased from suppliers has reached 50%-80% of total income, especially for high-tech products (Xu, 2002). Visibly, suppliers' quality risk management is an important competitiveness of the dynamics supply chain. When inferior product enters supply chain, it can cause considerable damage. In the inferior product recall process, recall costs of product in the downstream is higher than in the upstream, that is, the cost of recalls risk increases in the downstream. If not well controlled upstream into the supply chain, the number of substandard products, it will cause great damage the interests of the downstream enterprises and the whole supply chain. If upstream enterprises could not well control the number of substandard products that enter the supply chain, it will cause great damage to the interests of the downstream enterprises, even the whole supply chain. Therefore, suppliers' quality of risk management capability is very important (Wang & Liu, 2006). Moreover, suppliers determine their own level of quality management and consider the potential risk of loss of the other members

of the supply chain, which helps suppliers to improve the supply chain's credibility and get more orders.

The quality risk management of the supply chain is an important aspect of the supply chain risk management. Most of the risk factors in supply chain (such as accidents, natural disasters, terrorist attacks), performance for product quality fluctuate greatly, make customer's satisfaction decreased, the market revenue also decreased. Generally speaking, the quality of risk is a negative quality event consequence and the possibility of happen. And the quality of the supply chain risk is not only to study quality event in the consequences of local, but also to study the consequences of each node transfer prediction in the supply chain. Because of the expansion of the transfer effect may be the consequences of expanding and deepening, and thus have more attention to supply chain management. To ensure that product quality is stable and controllable risk, has become the important foundation of modern supply chain system, supply chain quality management and quality risk in supply chain has gradually become the focus of attention of business circles and academia and research.

Cost of quality was first to study by the cost of quality management experts A.V. Feigenbaum and J.M. Juran, who from the United States Fort, and in the 50s of last century, they made the traditional quality cost model. In general, the cost of quality includes quality loss cost and quality control cost. The former is the loss which caused by the absence of satisfactory quality, the latter is the investment which ensure satisfactory quality. So in order to ensure the product quality rate eligible, it is necessary to find the optimal decision point of the two costs for suppliers. In addition, suppliers need to consider the risk costs of future recall, because products' eligibility is determined by the product manufacturer and the customers, so the risk costs of future recall is uncertainty (Qu, 2007).

This article consists of four parts. The first part describes the current status of the suppliers' quality risk management. The second part researches the issues from two aspects respectively, which are the supply chain risk management and quality risk. The third part researches the relationship between quality cost and the level of quality risk management by building a model. Finally, the problem studied in this paper is summarized.

1. BACKGROUND

1.1 Supply Chain Risk Management

Supply chain system is a complex system, supply chain risk is hard to define, different scholars from different angles to define it. Foreign scholars of supply chain risk begin of the study from studying the risk of supply. Mitchell (1995) believes that it is brought on by the enterprise staff's different levels of education and nationalities in the supply chain members, and the supplied market's different characteristics, such as the stability of the market structure, changes in market interest rates, etc. Zsidisin et al. (2003) define the supply risk as "a result of not timely supply of goods and lower quality of service". Philip (1993) accordance with the general method of risk, divided supply chain risk into controllable and uncontrollable risk. Such as acts of terrorism, serious labor stoppages, natural disasters and other risks are the controllable risk. Such as supplier's qualification, products and services of the originator are the uncontrollable risk. However, he did not give a precise definition of risk in the supply chain, and there is no detailed analysis of the basis for difference.

Domestic research on supply chain risk began in the last 20th century and early 21st century. Ding et al. (2003) consider supply chain risk can be divided from both the natural and social environment, the social environment which in turn subdivided into seven risk categories: exclusive supplier of risk, the risk of transmission of information, the risk of logistics and distribution, financial position, the risk of market volatility risk, the risk of partners, the risk of profit distribution. Ma (2005) divided supply chain risk into two types of risk, which are endogenous and exogenous risk, he believes the risks arising from endogenous moral hazard, information distortion and individual rationality, and exogenous risk comes mainly from the political, economic, legal and technical. Zhou et al. (2006) classified the factors which lead to supply chain risk. There are quality risk, demand risk, environmental risk, operational risk, institutional risk, supply risk, IT risk. And they pointed out that in all the risk factors, the quality of the risk is the most common and the most important.

Summing up the above view, the basic meaning is as follows. 1) There are various uncertainties factors in the supply chain, which lead to the supply chain risk. 2) Because among enterprises on the supply chain network are interdependent, any business problems are likely to spread and affect other businesses, affecting the normal operation of the entire supply chain, even lead to supply chain cracking and failure.

1.2 Quality Risk Management

Quality risk management is a systematic process. It is the process of risk identification, measurement, control, and process evaluation, and thus achieving a balance of cost and quality in the whole life cycle of the product. Li (2012) believes quality risk management process will be divided into four parts: risk identification, risk measurement, risk control, risk assessment. Hua et al. (2003) consider in the supply chain, the quality of the intermediate products has a critical impact on the final product (or service). Quality defects of the intermediate products will have a significant impact on suppliers, manufacturers and the entire supply chain operations and gain. So in the supply chain,

considering the quality risk issues of the intermediate products is crucial. Chen (2007) pointed out that building a complete and effective supply chain quality assurance system, to ensure that the supply chain has sustained and stable quality assurance capabilities, can quickly respond to the needs of users and the market, and provide high quality products and services, is the main content of the supply chain quality management, and it also is the best practices to resist the supply chain quality risks.

Due to make the whole supply chain to achieve optimal cost and service, it is necessary to quantify the associated cost of quality, and build the model. There are many researches in this area, such as Feigenbaum proposed PAF model in 1956, and Gongboz curve also was once used to solve the interval with the best quality cost control. Another widely used model is the quality loss function, which was proposed by famous Japanese Quality Management experts Taguchi.

In this paper, combining the model, and consider the risk factors, we reveal the cost of quality variation through reconstruction the model. We believe that the quality loss cost in the quality cost includes the cost of internal failure costs and external faults loss damage costs, quality control costs in the quality cost including the cost of prevention and appraisal costs.

The following model represents the quality loss cost with a quadratic function, and represents the quality control costs with a negative quadratic function.

$$L(x) = k_1 x^2, x \le |\Delta_1|$$

$$A(x) = k_2 x^{-2}, x \ge |\Delta_2|$$

The model is

$$QC = L(x) + A(x) = k_1 x^2 + k_2 x^{-2}$$

The optimal quality level is

$$x = \left(\frac{k_2}{k_1}\right)^{\frac{1}{4}}$$

k_1 can be determined by the functional boundaries Δ_1 of the product, k_2 can be determined by the guaranteed boundaries Δ_1 of the product.

2. CONSTRUCTION MODEL AND ANALYSIS

The quality risk is the deviation between actual level of quality and standard level of quality. This deviation will cause losses to the supply chain. If supplier wants to recall the defective product from the manufacturer or the customers, this will lead to a series of consequences, such as consuming a lot of logistics costs, damaging to brand reputation and market share decline. The article builds the model from the overall interests of suppliers and downstream manufacturers.

2.1 Quality Risk Loss Model

Quality loss is a practical product quality target value fluctuates generated, and there is a close relationship between the fluctuation range and quality control level. When the quality control effect is good, if the fluctuation range of the actual products quality level is small, quality loss cost is small; when the quality control effect is poor, if the fluctuation range of the actual products quality level is big, quality loss cost is big.

This section, we introduce the level of product quality risk management $R \in [0,1]$. When R is larger, the product quality reliability will be higher, on the contrary, the quality reliability will be lower. The greater the level of supplier's quality risk management R, that is supplier does good quality testing off, the loss of future quality risk will be lower, and the risk of product recalls of downstream partners will reduce.

The quality of the risk of loss model can be written as

$$L(R) = k_1(1-R)^2$$

$R \in [0,1]$ is the level of quality risk management. k_1 is unknown parameter. Assuming a supplier's $R \in [R_1, R_2]$, when $r \in [R_1, R_2]$, the loss of quality risk for the supplier is l, so

$$k_1 = \frac{l}{(1-r)^2}$$

The above model does not consider future recall risk, which has a relationship with the benefits of manufacturers and customers. So it should be considering the quality risk and their transfer from the loss and the possibility perspective.

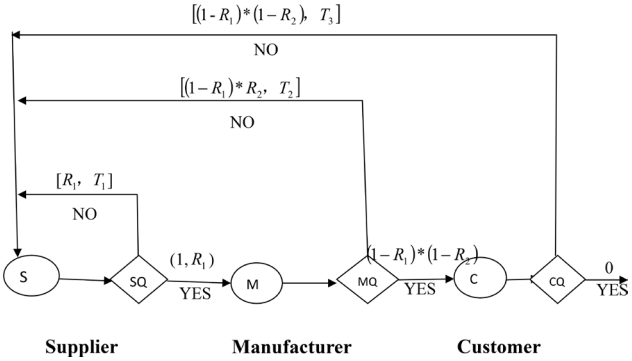

Figure 1
Quality Rrisk Transfer Process

Product enters the supply chain, to go through quality testing of supplier, manufacturer, customers, which indicates the probabilities of inferior products were detected in the three parties respectively are supplier's $p_1=R_1$, manufacturer's $p_2=(1–R_1)*R_2$, customers' $p_3=(1–R_1)*(1–R_2)$. The risk losses of defective product in the

tripartite respectively are T_1, T_2, T_3, ($T_1<T_2<T_3$). Supply chain losses divide into three parts:

Supplier: $p_1T_1=R_1T_1$

Manufacturer: $p_2T_2=(1–R_1)*R_2*T_2$

Customers: $p_3T_3=(1–R_1)*(1–R_2)*T_3$

So the total cost of risk transfer is

$$L= p_1T_1+p_2T_2+p_3T_3=R_1T_1+(1–R_1)\cdot R_2\cdot T_2+(1–R_2)\cdot T_3$$

Consider the cost of risk transfer, there is $l'=l+L$, so

$$k' = \frac{l'}{(1-r)^2}$$

We can get the amendment quality risk loss model, is

$$L(R)=k'(1–R)^2$$

2.2 Quality Risk Control Model

Quality cost refers to all the expense of enterprises to maintain or improve the quality of the products, and all the losses generated due to product quality does not meet the required level. The specific content of the quality cost generally includes the following two parts: All the loss because of product quality does not meet the prescribed standards caused, including internal loss and external loss; all expenses incurred to ensure and improve product quality. There are the costs of prevention and appraisal costs. Generally speaking, along with the changes in product quality, the changes of quality guarantee fee in the same direction, the quality loss is the reverse change. So, theoretically, affirming the existence of the optimal equilibrium point between the two, the quality cost of products becomes lowest. This is the best decision problem of quality cost, quality cost that corresponds to a minimum level of quality cost is called the optimal quality cost. The corresponding level of quality is the best quality level. Thus, led to establish quality cost control model.

Quality loss is generated by deviations arising from quality fluctuations. To reduce losses it is necessary to reduce fluctuations which can be achieved by improving the machining accuracy. Enterprise increasing quality investment corresponding is a necessary requirement of improving the machining precision, that is quality control costs. The higher the accuracy, the smaller the deviation, the higher the quality control costs. In this paper, base on existing research results and research methods, we define the quality risk control cost model as

$$A(R)=k_2(1–R)^{-2}$$

Similarly, $R\in[0,1]$ is the level of quality risk management. $k_2$is unknown parameter. Assuming a supplier's $R\in[R_1, R_2]$, when $r\in[R_1, R_2]$, the loss of quality risk for the supplier is l, so

$$k_2=l\cdot(1–R)^2$$

Therefore, the amended total quality cost of suppliers is

$$QC'(R) = L'(R) + A(R) = k_1^{'}(1-R)^2 + k_2(1-R)^{-2}$$

The relationship between quality cost and the level of quality risk management is:

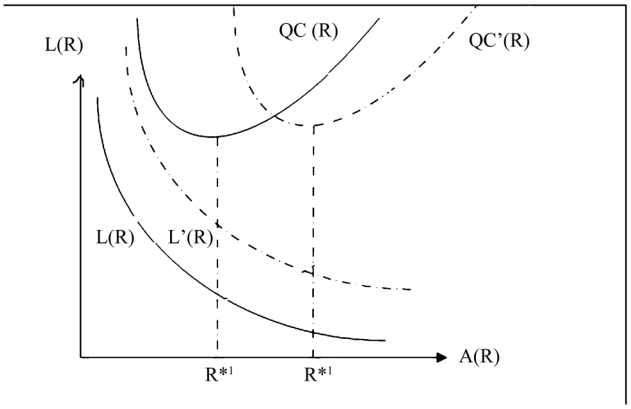

Figure 2
Quality Cost and the Level of Quality Risk Management

CONCLUSION

The quality under the supply chain environment dependencies is studied to put forward the concept of quality of supply chain, and the establishment of the quality risk transfer to the model up and down the supply chain based on quality. Although the concept of quality risk in supply chain has been mentioned in some literature, but has not yet seen can be quantified description transfer model quality risk, the quality risk deeply. The members of the supply chain is established to quantify the quality of the perturbed risk transfer model, to analysis the quality risk in the transfer model between supply chain enterprises. This study will contribute to the enterprise simulation and analysis in the environment of supply chain, because the transfer influence customer demand change risk or technical characteristics change risk in the supply chain, so as to provide basis for decision making of quality risk control of supply chain.

Based on considering the quality loss costs and quality control costs, we build quality risk transfer model, so that by the total quality cost and the level of risk to determine the effect of control, and provides a basis for the members in supply chain when they adjust the parameters of cooperation in the joint quality management process. When carrying out quality risk management work, enterprise can use the above theory to guide the work. By controlling the level of quality risk management and risk factors, enterprise uses the above theory to determine the relationship between quality cost and the level of enterprise quality risk management, to maximize enterprise's profits.

We build model, just based on the quality loss function which by Taguchi proposed. So expanding the quality risk control of the supply chain needs further study.

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