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A modified failure mode and effects analysis method for supplier selection problems in the supply chain risk environment: A case study ☆

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ABSTRACT

In the emerging supply chain environment, supply chain risk management plays a more important role than ever. Companies must focus not only on the efficiency of supply chain, but also on its risks. If an unanticipated event occurs, all of the supply chain members will be impacted, and the result will cause significant loss. Therefore, this research proposes a modified failure mode and effects analysis (MFMEA) method to select new suppliers from the supply chain risk's perspective and applies the analytic hierarchy process (AHP) method to determine the weight of each criterion and sub-criterion for supplier selection. An IC assembly company is then studied to validate this model. The result shows that the case company can categorize its suppliers more effectively and at the same time select a low-risk supply chain partner. Moreover, the case company can provide unsatisfactory suppliers with valuable feedback that will help them improve and become its partners in the future.

1. Introduction

Supply chain risk management (SCRM) has become an essential issue for supply chain management (Neiger, Rotaru, & Churilov, 2009; Schoenherr, Rao Tummala, & Harrison, 2008; Tang, 2006; Thun & Hoenig, 2011; Wu & Olson, 2008). Hallikas, Karvonen, Pulkkinen, Virolainen, and Tuominen (2004) have described supply chain not as a simple vertical chain, but as a multi-layer supply network. The supply chain network has to confront four types of risks: demand, due date, cost management, and risk associated with production capability and operation flexibility. Tang (2006) described that the supply chain risk as comprised of operational and disruption risks. Operational risk was associated with the uncertainty of a process such as customer demand, the amount of supply, and cost fluctuations. Disruption risk encompassed natural and human disasters, such as earthquakes, floods, hurricanes, terrorist attacks, financial crises, or labor strikes. For example, the flood of Thailand in 2011 caused serious damage to warehouses of hard drives suppliers. These suppliers were unable to fulfill PC customers' orders on time during the flood. Since these suppliers provided large quantities of hard drives for PC manufacturers, this created a shortage of hard drives throughout the entire PC supply chain. This was a typical supply chain risk caused by a natural disaster.

However, since disruption risk is difficult to predict and prevent, this research focuses on decreasing the operational risk. In order to reduce the uncertainty of the supply, the SCRM should construct a good supplier selection and assessment system (Srinivasan, Mukherjee, & Gaur, 2011; Tang, 2006). Collaborating with suppliers at a low operational risk could reduce the chances of losses for all members of the supply chain.

Based on the literature review, previous researchers have viewed supplier selections as a multi-criteria decision problem (Che & Wang, 2008; Ho, Xu, & Dey, 2010). The multi-attribute decision making technique is often used to solve this problem (Ho et al., 2010; Ng, 2008). However, this research considers this type (operational risk) of problem as a SCRM problem; few researchers have focused on this field (Sawik, 2011; Wu, Blackhurst, & Chidambaram, 2006). Pillay and Wang (2003) found that the result of the FMEA could assist managers in making the right decisions in the face of supply chain risk. In practice, the FMEA has been used in product design and manufacturing improvement. Therefore, introducing the FMEA into the supplier evaluation and selection is feasible. Further, this study considers the SCRM in suppliers' evaluation and selection. In order to develop a supplier selection procedure, this study proposes a modified FMEA (MFMEA) method, which integrated the FMEA and AHP methods, to construct a supplier evaluation system and to discuss potential failure factors and their effects on the system in a risky supply chain environment. Moreover, this research will assist companies in improving their ways of selecting and evaluating suppliers. Finally, preventive strategies to the potential failure factors are identified, and the results are discussed and summarized.

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The rest of this article is organized as follows. Section 2 summarizes the literature review of supplier selection. Section 3 describes the case company. Section 4 proposes a MFMEA method. Section 5 discusses the results of this study and summarizes the managerial implications based on this case study. The conclusions and future research are presented in Section 6.

2. Literature review

Selecting the right suppliers is an important step in supplier management (Shu & Wu, 2009; Tseng, Chiang, & Lan, 2009; Wu et al., 2006). The selection of the right suppliers can reduce operational costs and delivery time (Che & Wang, 2008). Similarly, choosing the wrong suppliers may increase the number of defective products, unstable deliveries, or refabricated costs, all of which can increase company's total cost and tarnish its reputation. Therefore, how to select the right suppliers has become an essential topic for companies wishing to minimize their supply chain risks.

Previous studies have identified some criteria for evaluating suppliers. Based on the relationships between suppliers and manufacturers, Dickson (1966) summarized 23 criteria, which fell into four categories: quality, deliverability, performance, and warranty policy. Tracey and Tan (2001) chose quality, delivery reliability, product characteristics, and unit price as criteria when manufacturers assessed their suppliers' ability to increase customers' satisfaction and improve companies' performance. Similarly, Katsikeas, Paparoidamis, and Katsikea (2004) considered suppliers' reliability, competitive price, service, and technical skills. In their review of research studies from 2000 to 2008, Ho et al. (2010) cited quality as the critical criterion, followed by deliverability, price, manufacturing capability, service, management, and technology.

In order to increase a company's competitive advantage in supply chain management, enterprises have to maintain long-term relationships with their most reliable suppliers. When companies select the right suppliers, cost is not the only criterion to be considered; companies also need to consider quality, deliverability, and service (Ho et al., 2010). Moreover, as mentioned in the previous literature reviews, researchers have focused on suppliers' quality, cost, deliverability, and service. Therefore, the criteria adopted by this research to select preferred suppliers include these four factors.

According to supplier selection criteria, the supplier risk depends on the type and degree of risks. A failure caused by the supplier is viewed as a risk for the manufacturer. The manufacturer should then evaluate and score the impact of each failure; the sum of the scores is the supplier risk. Therefore, the preferred supplier selection procedure is equal to the supplier lowest risk assessment procedure. Although many researchers have studied the supplier evaluation and selection problems (Ho et al., 2010), few have explored supplier selection problems based on supplier risk or supply chain risk. For example, Wu et al. (2006) used the analytic hierarchy process (AHP) to assess supply risk. They considered six factors of risks: internal controllable, internal partial controllable, internal uncontrollable, external controllable, external partial controllable, and external uncontrollable. Through the supply evaluation, a company could understand its supply risks based on each factor and decide which supplier was the most preferred. Schoenherr et al. (2008) studied how a US manufacturing company assessed its supply chain risk and made its offshore sourcing decisions. The case company adopted the AHP method to evaluate the weights of its main objectives (such as product, partner, and environment) and sub-objectives (such as quality, cost, service, and management capabilities). Based on the weights of the 16 factors, the case company could evaluate several offshore alternatives: finished goods from China; finished goods from Mexico; parts from China, Maquiladora, no investment; parts from China, Maquiladora, with investment; and parts from China, with assembly in the US. The results showed that sourcing finished goods from China would be the best offshore strategy for the case company. Further, Thun and Hoenig (2011) surveyed 67 German automotive manufacturers to investigate the supply chain vulnerability and the key drivers of supply chain risks. They applied the probability-impact-matrix to analyze the internal and external supply chain risks. They then offered suggestions for mitigating these supply chain risks.

Beside these supplier risk assessments, the failure mode and effects analysis (FMEA) is a popular method of measuring preventive risks (Ko, 2013; Liu, Liu, & Liu, 2013). The FMEA has been extensively applied in product design and manufacturing process planning (Almannai, Greenough, & Kay, 2008; Chen & Ko, 2009; Ekmekcioglu & Kutlu, 2012). The traditional FMEA evaluated risks by calculating the risk priority number (RPN). The RPN was computed by multiplying three factors (O, S, and D), where O and S represented the occurrence and severity of a failure, and D was defined as the detection that meant the ability to detect the failure before it reached the customer (Chin, Wang, Poon, & Yang, 2009). Each factor was evaluated on a 10-point scale. After calculating the RPNs of each failure, managers could sort the RPNs from largest to smallest. Failures with higher RPNs could be viewed as more important and as meriting greater attention. Therefore, the FMEA could help managers assess the risks of failures and provide the managers with guidelines for improvement. After the system was improved, a reevaluated version of the FMEA could be implemented. New RPNs of failures would be generated. The cycle would continue until the system reached a level of low or acceptable risk ranges. Except for the FMEA applications in the airplane industry, the use of the FMEA has been introduced to other many industries, with the notable exception of airlines (Almannai et al., 2008; Pillay & Wang, 2003).

3. The case company

The case company is a well-known comprehensive semiconductor manufacturing service provider which offers engineering tests, package design, integrated circuit (IC) assembly (or packaging), wafer probing, final test, and design manufacturing services. With these manufacturing capabilities, the case company can provide its customers with complete semiconductor turnkey solutions. The main business services of the case company are IC and system services. For the IC services, the case company offers substrate design and manufacturing, engineering test, wafer probing, final test, package and module design, wafer bumping, and chip packaging (or assembly). For the system services, the case company offers turnkey solutions of module-to-systems products.

In order to provide fast services for global customers, the case company's subsidiaries are based near their overseas customers in South Korea, Japan, Singapore, Malaysia, China, the Americas, and Europe. Since the semiconductor industry is a high-tech industry, the case company invests heavily resources in research and development (R&D). The case company also invests in equipment and state-of-art facilities in order to satisfy its customers' demands.

The case company's main raw materials are lead frames, IC substrates, epoxy, molding compounds, gold wires, and solder balls. Raw material costs account for approximately 50% of the total manufacturing cost of the case company. Except for the molding compounds, the price of the other raw materials is closely related to the price of the industrial and precious metals. However, in 2009, prices of the industrial and precious metals increased by 99.43% and 59.5%, respectively. This indicated that manufacturers