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An integrated framework for outsourcing risk management

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Abstract

Purpose – The purpose of this paper is to present a generic framework to assess and simulate outsourcing risks in the supply chain.

Design/methodology/approach – This combination approach involves a qualitative risk analysis methodology termed as the supply chain risk-failure mode and effect analysis (SCR-FMEA) which integrates risk identification, analysis and mitigation actions together to evaluate supply chain outsourcing risk. The qualitative risk assessment will allow risk manager to provide a visual presentation of imminent risks using the risk map. Monte Carlo simulation (MCS) on the imminent risks of delivery outsourcing using the Milk-Run system is adopted.

Findings – With basic statistical concepts, key performance variables and the risk of delivery outsourcing are analyzed. It is found that a newly implemented delivery outsourcing arrangement on the Milk-Run system reduces the average customer lead-time and total cost. However, a certain extent of risk or uncertainty can still be detected due to the presence of variation.

Research limitations/implications – This paper reveals that company can manage the risk by adopting a systematic method for identifying the potential risks before outsourcing and MCS can be applied for examining the quantifiable risks such as lead time and cost.

Practical implications – The paper provides a generic guideline for practitioners to assess logistics outsourcing, especially for logistics management consultants and professionals for evaluating the risk and impact of outsourcing. It is believed that the proposed risk assessment framework can help to analyze the operational cost uncertainty and ensure the stability of the supply chain. However, the limitation of this research is that the full spectrum of outsourcing risk, especially the non-quantifiable risk may not be analyzed by MCS.

Originality/value – This paper proposed an integrated framework which combines qualitative and quantitative method together for managing outsourcing risk. This research provides a standardized metric to quantify risk in the supply chain so as to determine the effectiveness of outsourcing.

Keywords Risk management, Outsourcing, Monte Carlo simulation, Risk map, Failure mode and effect analysis

Paper type Research paper

1. Introduction

In the globally connected supply chain, any single point of failures will lead to disruptions in the supply network. Different types of risk can occur in supply chain. Hence, it is the responsibility of any supply chain entities involved in the network to adopt effective risk assessment methods to manage and mitigate all possible risks. Outsourcing is a popular option for the enterprises as it keeps cost down and leans the supply chain. High responsiveness together with cooperation efforts with other suppliers can help to formulate a good risk assessment strategy.

Outsourcing, which is a US$6 trillion global industry (Corbett, 2004), attracts the attention of both industry and academic. Outsourcing is regarded as transferring

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previous activities conducted in-house to a third-party (Lonsdale and Cox, 2000). For the last decade, outsourcing spending in all business activities has increased by 10 percent regardless of good or bad economic situation (Corbett, 2005). Although outsourcing can bring the benefit of cost reduction, less investment on physical asset and flexible human resource allocation, enterprises should align the outsourcing activities with long term corporate strategy rather than short term benefits.

Apart from recognizing the advantage of outsourcing, firms should also realize the risk of making wrong outsourcing decisions. A firm can outsource different functions and signifies different degree of commitment and integration between the company and the outsourcing service providers. As the degree of commitment in outsourcing differs, complexities of interaction will arise leading to different risk concerns. Any outsourcing decision should be made with the full consideration of the potential risks that go along with operations.

The objectives of this research are to:

(1) Explore both established and emerging risk in supply chain.

(2) Propose a risk analysis methodology guided by strong risk management practices that integrates risk identification, analysis and mitigation actions and evaluates supply chain outsourcing risks.

(3) Design a mathematical model for analyzing risk of outsourcing activities in the supply chain network.

(4) Evaluate the risks of a specific outsourcing function in a supply chain network using qualitative and quantitative approaches.

This rest of the paper is organized as follows. An introduction of outsourcing industry is presented in Section 1. Section 2 reviews the literatures related to outsourcing and risk management so as to identify the research gap. Section 3 proposes a risk assessment methodology to analyze risks both qualitatively and quantitatively. Section 4 shows how the case company with the milk-run system uses the proposed methodology in Section 3 to analyze the delivery risk. Finally, a detail discussion about the results, managerial implications and limitations are presented in Section 5.

2. Literature review

Outsourcing is to perform a function or process such as manufacturing operation and other value-adding activities with reliance on external sources, a third-party or supplier, so as to attain business level benefits (Lei and Hitt, 1995). Strategic outsourcing includes "make-or-buy" (Hendrick and Moore, 1985; Zenz, 1987; Dobler and Burt, 1996) decision which produces the company's product internally or subcontract to other service providers. Some researchers focus on international sourcing of components, subsystems and completed products (Bettis *et al.*, 1992; Feenstra and Hanson, 1996). Willcocks (2011) observed over 1,600 outsourcing arrangements from 1989 to 2010 and he found out that outsourcing is still on the learning curve. The shift of power-based orientation to governance structure to build up trust (Tian *et al.*, 2007) and tight collaboration can enhance outsourcing management. Similarly, cooperative strategic logistics outsourcing is also advocated by researchers instead of tactical outsourcing which focuses on cost only (Wang *et al.*, 2010; Núñez-Carballosa and Guitart-Tarrés, 2011).

In fact, outsourcing has become very widespread in the last decade and it changes from peripheral business functions in the past, to more vital business functions being outsourced today (Tafti, 2005; Yang *et al.*, 2008). The assembly line of the firm which is indispensible to the production process that creates value to the enterprise is gradually outsourced. Firms start with the outsourcing of their peripheral activities and they gradually move on to outsource activities which is of closer core to the heart of the enterprise (Salma *et al.*, 2007). In any supply chain network with the sharing of leading edge technology, members are exposed to the risk of their competitive advantages being lost to competitors. Lonsdale and Cox (2000) also reinstate that logically firm should draw its boundary around skills and capabilities that are responsible for its competitive pre-eminence.

More research is increasingly focused on risk and benefit analysis of outsourcing (Frost, 2000; Gonzalez *et al.*, 2010). Perçin (2008) makes use of fuzzy hierarchical TOPSIS methodology as a quantitative method for evaluating business process outsourcing. McIvor (2009) combined transaction cost theory and resource-based view as risk event and survey provides quantitative data analysis on subjective risk perception of outsourcer and in-house chain. Trappey *et al.* (2010) propose a two-stage clustering approach combined with Ward's minimum-variance method and K-means algorithm is used to prioritize services offered by logistics service providers. The concept of outsourcing can be explained further using an economics perspective. The Transaction Cost Analysis (Sanders *et al.*, 2007) provides a set of principles to analyze outsourcing transactions and determine cost structure. As companies decide whether to outsource or produce goods and services in-house, market prices are not the sole factor. Deming (1986) suggested long term integrated strong relations with single vendor but Porter (1980) recommended having multiple vendors to increase the bargaining power of outsourcer. Ngwenyama and Bryson (1999) make use of transaction cost theory approach to analyze the profit of outsourcer and cost of vendors so as to decide among single or multiple vendors outsourcing strategy. Mapping supply chains on risk and customer sensitivity allows corporation to formulate the suitable supply chain strategy (Faisal *et al.*, 2006).

Adopting multiple vendors can reduce the risk of shirking of single vendor. Risk can be interpreted as outcome variation and loss potential which can be also divided into loss magnitude and loss probability. The loss potential of risk provides an indication to the level of risk of a particular situation. Based on extant literatures (Zsidisin *et al.*, 2004; Keizera *et al.*, 2002), there is a variety of risk scores, failure events and conditions influencing failure. Supply risks are associated with failures in delivery, cost, quality, flexibility and general confidence category (Kull and Talluri, 2008), which are traditionally the purchasing department's competitive priorities. To mitigate risk, information sharing, agility in supply chain structure, option contract are the major enabler to reduce the risks. Tang and Musa (2011) have conducted a comprehensive review about supply chain risk (SCR) management. Risk mitigation in general can be modeled with qualitative and quantitative approach. With regard to qualitative aspect, alternative sourcing in and out of home country (Fitzgerald, 2005) have been explored by Crone (2006) and Stalk (2006) concerned the outsourcing risk and realize the necessary of avoid outsourcing/off shoring in certain situation. Solesvik and Westhead (2010) suggested establishing outsourcing links with overseas partners so as to reduce cost and risk exposure. Risk ontology is also able to surface the information system exploitation risk (Peng and Nunes, 2009). For quantitative approach, researchers have proposed decision tree-based optimization (Berger *et al.*, 2004) foreign suppliers supply risk ranking model (Levary, 2007), incentive conflict and coordinating model (Agrell *et al.*, 2004) and supplier selection under uncertainty with spreadsheet (Wu, 2009).

Based on the literature review, there is a lack of standardized method to quantify risk in the supply chain to determine the effectiveness of outsourcing. Hence, SCRs reported in literatures are predominantly reliant on the manager's estimates which are subjective rather than objective analysis. Without standardized method, it is difficult to measure the effectiveness of risk management implemented on outsourcing projects in the supply chain. As a result, although there are very useful risk mitigation methods being proposed on literatures, the feasibility and effectiveness of its usefulness in the industries are still difficult to be determined. Hence, more applications or simulations from the industries would be helpful to compare different cases and risk management methods. In this study, simulation will be used to realize how outsourcing risk affects the supply chain performance.

3. Methodology

The proposed framework shown in Figure 1 consists of two main parts which are qualitative risk assessment (in Section 3.1) and quantitative risk assessment (in Section 3.2). For the qualitative risk assessment, the SCR-failure mode and effect analysis (FMEA) is used and a risk map is constructed. The risk map shows the associated risk score and risk priority number of each individual risk. This helps to identify the critical risks for outsourcing. According to the company's performance indicators such as cost and time, mathematical models are developed to represent the stochastic factors in logistics outsourcing. For quantitative risk assessment, Monte Carlo simulation (MCS) is adopted to study the variation of cost and time for the scenarios of "before outsourcing" and "after outsourcing".

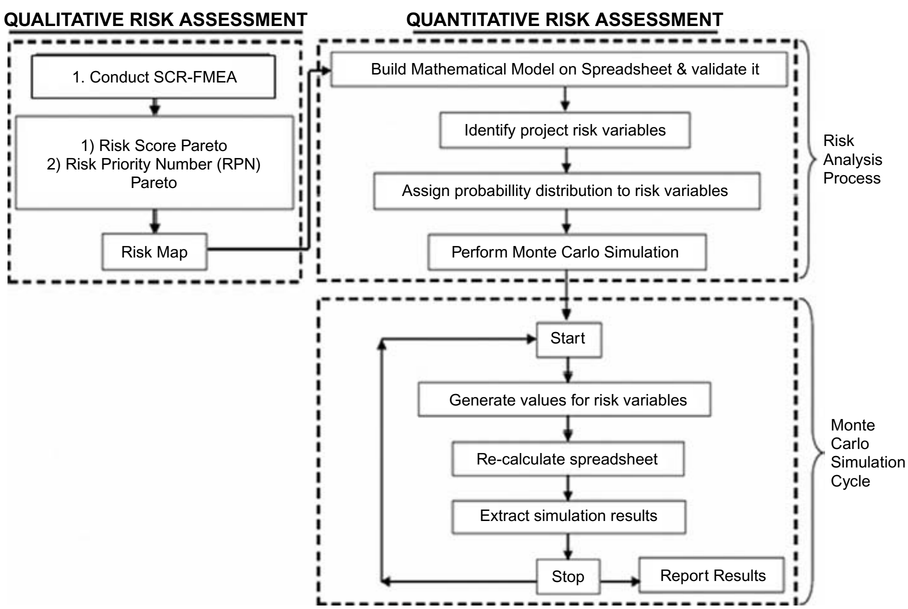

Figure 1.
Proposed framework of risk measurement

3.1 Design of qualitative risk assessment

Successful risk management cannot plan in single stage. Instead, management needs to formulate the risk management plan into several stages. A number of factors are taken into consideration for risk analysis with SCR-FMEA. SCR-FMEA (Carbone and Tippett, 2009) are developed to explore and diagnose the problem at progressive stages.

In stage one, risk events needs to be identified; explored and examined in supply chain outsourcing. Hence, the domains of risk ID and risk events in SCR-FMEA are defined. Stage two emphasizes that an important part of risk analysis is to quantify the risks hence accounts for the domains of risk components such as risk probability factor, impact factor and detection factor in SCR-FMEA. In stage three, it is essential to state all risks consequence for a common understanding of the impact that each risk entails. An understanding of the consequences is crucial for strategy formulation to minimize the negative impacts of risk under recommended risk mitigation domain. In stage four, the method to understand the cost and benefit of any outsourcing decision is important and this could possibly be done through statistical techniques. Stage five is to design the action plan. Finally in stage six, the process is iterative as taking actions on risk will lead to various consequences; while a measure that might ameliorate one risk could exacerbate another. The SCR-FMEA is a qualitative method to document and mitigate SCRs.

3.1.1 Supply chain risk-failure mode and effect analysis. A successful supply chain depends on a great extent identification of risk. Occurrence of risk can lead to undesirable consequence and disruption for the supply network. The FMEA is one of the important planning tools to analyze the cause and consequence of failure. This proposed framework applies the FMEA format (i.e. failure modes for occurrence, severity and detection) to quantify, analyze and aid risk contingency planning for outsourcing risks in the supply chain. It can be coined as SCR-FMEA since this method is modified based on the known FMEA technique. Before SCR-FMEA is implemented, the potential risk is identified and listed within each project phase. During risk identification, risk events are recognized and the contingency plan is formulated. The impact can be in the form of bad reputation, customer dissatisfaction, reduce in revenue or increase in expense. One risk event can lead to adverse consequence and bring up multiple impacts. The risk score is based on probability of risk, detection and impact shown in Figure 2.

FMEA and SCR-FMEA are different in defining the attribute of detection. FMEA's highest detection value means the firm has no ability to detect risk while a low detection value means the firm can find out the risk. In SCR-FMEA, detection definition is "the ability of detection technique or method (s) to detect the risk event with enough time

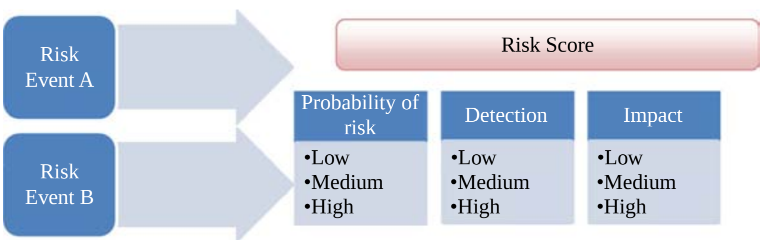

Figure 2. Relation of risk event and its risk score

to plan for a contingency and act upon the risk" and detection factor is defined based on Carbone and Tippett (2004). Table I illustrates a modification from the standard FMEA and the SCR-FMEA.

3.1.2 Risk evaluation. Risk evaluation includes the step of assessing the risk probability, impact, and detection domain of each risk event. The guidelines on assigning risk probabilities, impact factors and detection factors can be found in Table II.

The scores may require additional data from experts or a review of past FMEA. The quality of the risk analysis done by SCR-FMEA will be greatly increased if inputs on assigning scores are taken from experienced supply chain professionals. The scoring procedure is replicated for the impact and detection factors. The risk probability multiplied by the risk impact value is expanded by multiplying a detection value for each risk. Once the factors for each of the three factors are entered, both the risk score and the RPN values are calculated based on the formulas:

Table I.
Headings of a sample standard FMEA vs designed SCR-FMEA

Sample FMEA headings						
Failure ID	Failure mode	Occurrence	Severity		Detection	RPN = Occurrence × Severity × Detection
Sample SCR-FMEA						
Risk-ID	Risk event	Risk probability	Impact	Risk score = Risk probability × Impact	Detection	RPN = Occurrence × Severity × Detection

Table II.
Risk probability factors, impact factors and detection factors

Number	Risk probability factors	Detection factors	Impact factors
9-10	80-100 percent chance to occurrence. Circumstances frequently encountered daily; weekly; monthly	There is no detection method available that will provide an alert with enough time to plan for a contingency	Very major loss of service; bad reputation; cost increases >20 percent
7-8	60-80 percent chance of occurrence Regular occurrence few times a year	Detection method is unproven or unreliable; or effectiveness of detection method is unknown to detect in time	Complete loss of important service for short period; adverse publicity of major nature; customer dissatisfaction, cost increase 10-20 percent
5-6	40-60 percent chance of occurrence. Likely to happen at some point within 1-2 years	Detection method has medium effectiveness	Service disruption = 4-5 days; statutory prosecution of non-serious nature; severe loss of revenue; cost increase 5-10 percent
3-4	20-40 percent chance of occurrence, only likely to happen three or more years	Detection method has moderately high effectiveness	Brief disruption of important service area; adverse local publicity; lower productivity; cost increase 10-20 percent
1-2	<20 percent chance of occurrence Has never or rarely happened before	Detection method is highly effective and it is almost certain that the risk will be detected with adequate time	Service disruption = 1 day; contained within department; cost increase insignificant

$$\text{Risk score} = \text{Risk probability} \times \text{Impact}$$

$$\text{RPN} = \text{Risk probability} \times \text{Impact} \times \text{Detection}$$

3.1.3 Critical outsourcing risks identification using risk map. A Pareto chart is generated based on their risk scores tabulated in descending order. This chart provides guidance for prioritizing risk response planning. The RPN Pareto bar chart is plotted which contains RPN values in descending order. As supply chain of each firm is unique, the risk and the corresponding risk score and RPN values may vary. A risk map diagram shown in Figure 3 which constitutes of a scatter plot of RPNs against risk scores is generated. Firms should put more resources for those risks with high RPN and high score which are located at the right top corner of risk map. Tummala and Schoenherr (2011) has generally classified the SCR as demand risk, delay risk, disruption risk, inventory risk, manufacturing process breakdown risk, physical plan risk, system risk, sovereign risks, transportation risks. For instance, a firm is exposed to the following kinds of risks: inaccurate inventory data and limited visibility about the status of components because of lacking warehouse information and delivery tracking system, and employees without sufficient logistics management experience. After calculating the risk score and RPN for all the possible risks identified, it is found out that the following three risks has the highest RPN and risk scores for the case company: transportation risk (A), inventory risk (N) and demand risk (M). Company would tend to outsource the logistics activities such as transportation to third-party logistics company. Then the decision of whether delivery should be outsourced or not needs to be quantitatively assessed using our proposed quantitative risk assessment methodology. After identifying the critical risks, outsourcing plans needs to be generated accordingly.

3.2 Quantitative risk assessment for outsourcing decision making

The risk map in Figure 3 is generated for identifying critical risks. This helps to understand and be warned of these risks with high RPN and RN. The quantitative risk assessment will help to decide whether the logistics function should be outsourced or not.

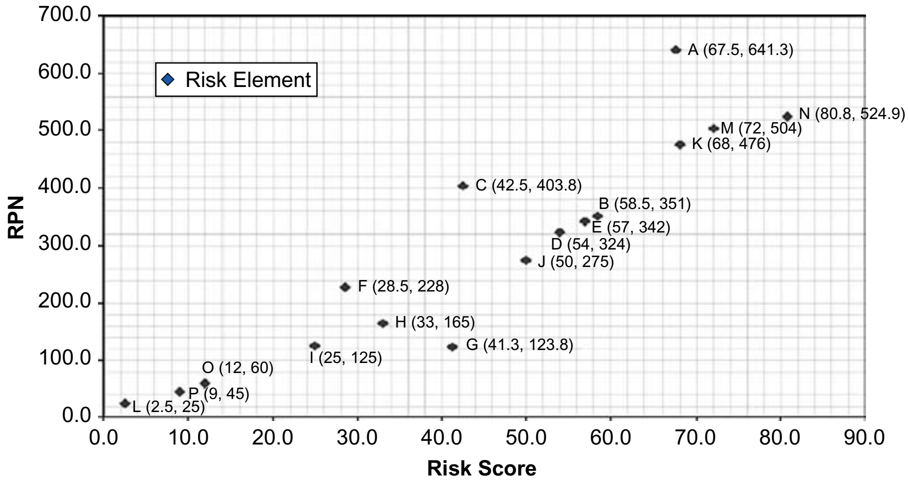

Figure 3.
Risk map of RPN against risk score

Related risk measurements are identified in Subsection 3.2.1. Mathematical models are developed based on these risk measurements. In Subsection 3.2.2, the procedures of how to perform MCS using risk solver are described in detail. The output from the simulation study can be used to help companies to analyze the logistics performance before and after outsourcing.

3.2.1 Risk measurement in terms of cost and lead time. One of the essential responsibilities of management team is to meet the company's strategic mission. In order to achieve the goal, it is common to have performance indicators to help monitor the progress and evaluate its performance. The most commonly used performance indicators in logistics are total estimated customer lead time and total estimated supply chain cost. The mathematical models for quantitative risk assessment should also adhere to these performance indicators.

Each performance indicator can be further divided into small components. The lead time components $L_1, L_2, \ldots, L_n$ are functions of total customer lead time:

$$\text{Total Estimated Customer Lead Time} = f(L_1, L_2, \ldots, L_n);$$

The estimated supply chain cost components $C_1, C_2, \ldots, C_n$ are functions of total estimated cost:

$$\text{Total Estimated Customer Supply Chain Cost} = f(C_1, C_2, \ldots, C_n);$$

After risk management strategy is adopted, the corresponding lead time and cost are as follows:

$$\text{Total Estimated Customer Lead Time} = f(L_1, L_2, \ldots, L_n)_{\text{After}}$$

$$\text{Total Estimated Supply Chain Cost} = f(C_1, C_2, \ldots, C_n)_{\text{After}}$$

Total Estimated Supply Chain Cost Savings equals to:

$$\frac{f(C_1, C_2, \ldots, C_n)_{\text{After}} - f(C_1, C_2, \ldots, C_n)_{\text{Before}}}{f(C_1, C_2, \ldots, C_n)_{\text{Before}}}$$

3.2.2 MCS via risk solver. MCS (using random sampling) is a well-established method for evaluation of risk. It is basically a sampling experiment whose purpose is to estimate the distribution of an outcome variable that depends on simulation of several probabilistic inputs variables to compute their results (Evans and David, 1998). Assumptions about the uncertainty of key inputs are made and this uncertainty is characterized by specifying probability distributions for these model inputs. Different values of each factor are inputted into the spreadsheet model and with different combination of inputs; a distribution of possible values is set up to provide an indication of the likelihood of what practitioners might expect.

Figure 1 shows the process flow of risk analysis using MCS. A mathematical model which determines level or specific type of risk by involving parameters is built and it contributes to the different type of risk. As risks are inherently present in the outsourcing project, the identification of critical risks is crucial due to the high level of impact that entails to finances of the company. Hence, a modeling environment which is well supported by MCS is necessary and it will concentrate on the pre-stages of the outsourcing project.

To perform an MCS, the formula mentioned above is set in spreadsheet as shown in Figure 4. The next step is to identify inputs for the proposed model which is uncertain and use PSI Distribution function or random variables (uncertain variables) to represent the uncertain inputs. Then the output values are generated by risk solver based on the mathematical model. The above steps are repeated for a sufficient number of times to create a distribution of results. Statistics summary is generated and output data is collected in frequency distribution for further analysis.

4. A case study of outsourcing risk using Milk-Run system

4.1 Background of case company

A manufacturing company with alias name as Company X specializes in manufacturing refrigeration compressor. Company X has involved the customers, OEM, the third-party logistics company and local suppliers in her supply chain. All 27 suppliers will be divided into different clusters based on their location proximity targeted at having shortest possible routes. A single route in Milk-Run could start from the parent company travelling to several suppliers of close location proximity to each other and plan via optimization of the shortest possible route. Milk-Run delivery means the same delivery vehicle make multiple pickups at various supplier locations on a regularly scheduled basis (Chen and Sarker, 2010). The Milk-Run system originates from the dairy industry in which the milkmen travel with specified route to the customers' houses to deliver milk bottles and finally take back the empty bottles.

Elements of reverse logistics are incorporated into the Milk-Run, as the third-party truck starts its route from the parent company by loading return pallets. At the same time as the truck return the pallets, new supplies ordered by the parent company would be loaded on the trucks. Depending on scheduled routes, the third-party would go to consolidate supplies at various supplier locations to deliver back to the parent company.

After conducting the SCR-FMEA risk assessment analysis, the management team explores the possibility of outsourcing the logistics operation. The function to deliver supplies from supplier to parent plant for manufacturing can be outsourced to a third-party logistics service providers. Logistics service providers can consolidate

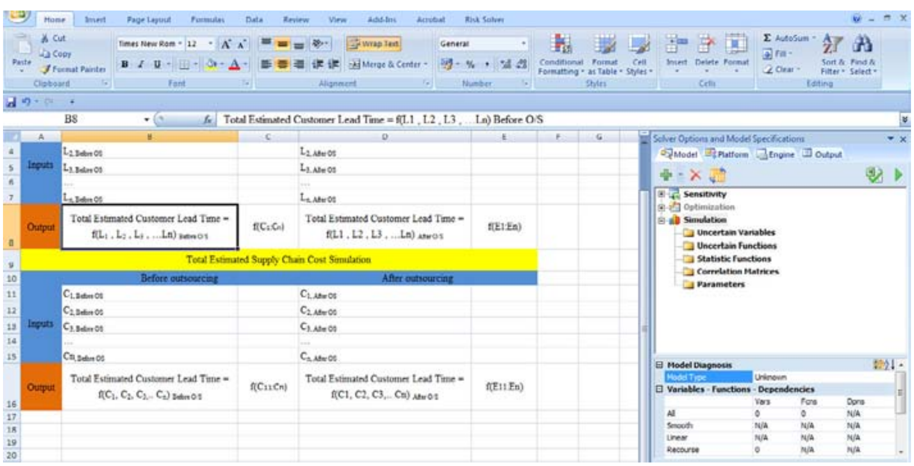

Figure 4.
Risk assessment model on spreadsheet

the shipment with the shortest route. With their expertise in route planning and the capability to deliver products in a more cost effective way, third-party logistics providers charge a lower cost than handling delivery in-house.

4.2 Applying the risk assessment framework on case company

Risk management needs both quantitative and qualitative approach to identify and assess the potential risks. With respect to qualitative approach, the proposed SCR-FMEA analyzes the impact, occurrence probability and detection rate of potential risks. The case study of delivery outsourcing of Milk-Run delivery is carried out in the context of the supply chain of the parent plant. Applying the procedures of SCR-FMEA, the risks scores and RPN values is used to plot risk scores Pareto chart and RPN Pareto bar chart. For those events with high risk score may not have high RPN as detection is one of the factors which affect RPN.

For the Milk-Run delivery system, the two measures including the total average customer lead time and total costs in supply chain are used. Two simplified mathematical representations are used to quantify delivery risk associated with outsourcing transportation.

Total customer lead time is a function of time components shown in the following expression:

$$\text{Total Estimated Customer Lead Time} = f(\mathrm{L_{OP}}, \mathrm{L_{OA}}, \mathrm{L_{POS}}, \mathrm{L_{QCP}}, \mathrm{L_{DC}})$$

L_{OP} Average order processing (OP) time.

L_{OA} Average order acknowledgement (OA) time.

L_{POS} Average time for production of supplies (POS).

L_{QCP} Average quality check and packaging (QCP) time

L_{DC} Average local delivery consolidation (DC) time.

Hence, the input expression into the output domain of the simulation can be expressed as a summation of all lead time at different points in the supply chain given by:

$$\text{Total Estimated Customer Lead Time} = f(\mathrm{L_{OP}} + \mathrm{L_{OA}} + \mathrm{L_{POS}} + \mathrm{L_{QCP}} + \mathrm{L_{DC}})_{\text{After O/S}}$$

Similarly, total cost in supply chain is a function of cost components, shown in the following expression:

$$\text{Total Estimated Supply Chain Cost} = f(\mathrm{C_{OP}}, \mathrm{C_{OA}}, \mathrm{C_{POS}}, \mathrm{C_{QCP}}, \mathrm{C_{DC}})$$

C_{OP} Cost/year after electronic order processing (OP).

C_{OA} Cost/year after order acknowledgement (OA).

C_{POS} Cost/year after production of supplies (POS).

C_{QCP} Cost/year after quality check and packaging (QCP).

C_{DC} Cost/year after local delivery consolidation (DC).

Therefore, the input expression into the output domain of total estimated supply chain cost of the simulation can be expressed as a summation of all estimated cost at different points in the supply chain given by:

$$\text{Total Estimated Supply Chain Cost} = f(C_{OP} + C_{OA} + C_{POS} + C_{QCP} + C_{DC})_{After\ O/S}$$

Therefore, the input expression into the output domain of total cost savings can be expressed as a summation of the difference of cost before and after outsourcing with respect to before outsourcing risk shown as following.

Total Estimated Supply Chain Cost Savings equals to:

$$\frac{f(C_{OP} + C_{OA} + C_{POS} + C_{QCP} + C_{DC})\text{After}_{O/S} - f(C_{OP} + C_{OA} + C_{POS} + C_{QCP} + C_{DC})\text{Before}_{O/S}}{f(C_{OP} + C_{OA} + C_{POS} + C_{QCP} + C_{DC})\text{Before}_{O/S}}$$

4.3 Data collection

A set of parameters related to delivery lead time and cost breakdown information are obtained from the parent plant and 27 suppliers in Singapore. The breakdown of costs/lead time into elemental component is useful in finding out the estimations of most likely cost/lead time in the cost/lead time simulation model. The lead time of delivery is assumed as normal distribution. Tables III and IV show the collected data of lead time and cost, respectively, from the case company.

Name	Distribution	Mean	SD	25th percentile	50th percentile	75th percentile
$L_{OP,AfterOS}$	PsiLogNormal	2	2	0.8066	1.4142	2.4796
$L_{OP,BeforeOS}$	PsiLogNormal	2	2	0.8066	1.4142	2.4796
$L_{OA,AfterOS}$	PsiLogNormal	1	1	0.4033	0.7071	1.2398
$L_{OA,BeforeOS}$	PsiLogNormal	1	1	0.4033	0.7071	1.2398
$L_{POS,AfterOS}$	PsiNormal	10.5	3	8.4765	10.5000	12.5234
$L_{POS,BeforeOS}$	PsiNormal	10.5	3	8.4765	10.5000	12.5234
$L_{QCP,AfterOS}$	PsiLogNormal	2	2	0.8066	1.4142	2.4796
$L_{QCP,BeforeOS}$	PsiLogNormal	2	2	0.8066	1.4142	2.4796
$L_{DC,AfterOS}$	PsiNormal	1.0363	0	1.0363	1.0363	1.0363
$L_{DC,BeforeOS}$	PsiNormal	3.014	0.703409	2.5396	3.014	3.4884

Table III. Input summary for lead time information

Name	Distribution	Mean	SD	25th percentile	50th percentile	75th percentile
$C_{DC,BeforeOS}$	PsiNormal	159,619.4	100	159,551.95	159,619.40	159,686.85
$C_{DC,AfterOS}$	PsiTriangular	42,120	21,991.144	23,754.72	38,480.00	57,670.36
$C_{OP,BeforeOS}$	PsiNormal	5,020.8	300	4,818.45	5,020.80	5,223.15
$C_{OP,AfterOS}$	PsiNormal	4,080	300	3,877.65	4,080.00	4,282.35
$C_{OA,BeforeOS}$	PsiNormal	10,368	500	10,030.76	10,368.00	10,705.24
$C_{OA,AfterOS}$	PsiNormal	3,110.4	500	2,773.16	3,110.40	3,447.64
$C_{POS,BeforeOS}$	PsiNormal	191,000	2,000	189,651.02	191,000.00	192,348.98
$C_{POS,AfterOS}$	PsiNormal	196,221.2	10,000	189,476.30	196,221.20	202,966.10
$C_{QCP,BeforeOS}$	PsiNormal	7,824.45	500	7,487.21	7,842.45	8,161.69
$C_{QCP,AfterOS}$	PsiNormal	65,200	200	65,065.10	65,200	65,334.89

Table IV. Input summary for cost information

The collected data can be assigned to the individual risk factor of the spreadsheet model (Figure 5). For example, $L_{OP,BeforeOS}$ is highlighted in Figure 5 to explain how the Psi function is used for parameter setting. After all the values are set in the model, MCS can be performed and outputs are obtained.

4.4 Results

After collecting information related to cost/lead time and conducting the simulation, we can know whether outsourcing is reasonable or not based on the simulation results (Figure 6). To provide a detailed analysis, the variation of lead time and cost is examined for before outsourcing and after outsourcing scenarios in Subsections 4.4.1 and 4.4.2, respectively. A total cost saving analysis is conducted in Subsection 4.4.3. At the end of Section 4, a practical implication is provided to encourage the adoption of the proposed risk assessment methodology by other companies.

4.4.1 Total average customer lead time results. Risk solver's MCS allows user to get the distribution result of total cost and customer lead time based on 1,000 trials. The output for total average customer lead time result is shown in Figure 6. Each possible outcome is obtained by 1,000 trials. The result placed side by side helps to contrasts frequencies distributions of before and after outsourcing of lead time and supply chain cost, respectively.

The outcome can be generated from the probabilistic inputs shown in Table III which provides summary information of the different components of lead time used in the simulation. In Table V, the Total Average Customer Lead Time before outsourcing with the average of 18.60 days is higher than after outsourcing (16.53 days). This implies that a newly implemented delivery outsourcing arrangement on the Milk-Run system reduces the average customer lead time. A shorter lead time achieved after outsourcing can possibly increase customer satisfaction.

The probability of lead time after outsourcing of not exceeding the mean of lead time before outsourcing arrangement is approximately 0.75. However, a certain extent of risk or uncertainty is found due to the presence of variation and the standard

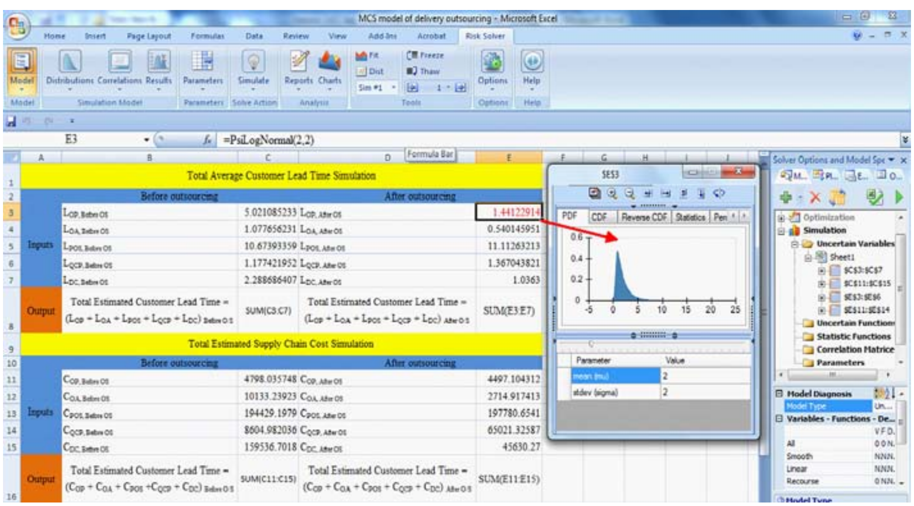

Figure 5.
Simulation of risk assessment for case study

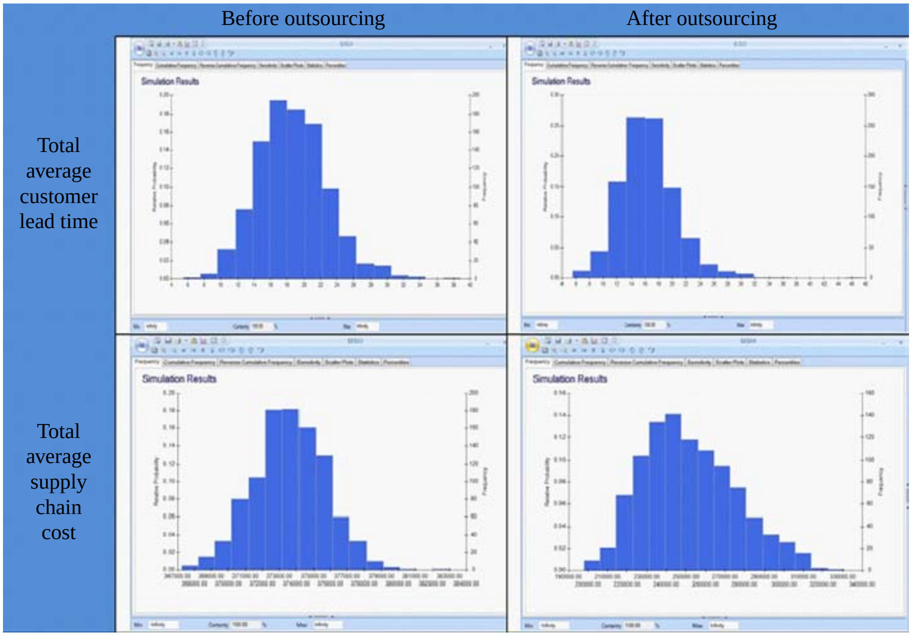

Figure 6.
MCS results for before and after outsourcing

Table V.
Output summary of uncertain lead time

Name	Mean	SD	25th percentile	50th percentile	75th percentile
Total After OS	16.534	4.2343	13.8100	16.0137	18.7825
Total Before OS	18.6017	4.2683	15.6707	18.3415	21.0486

deviation from the mean is by 4.268 days. Based on the results of a considerable variation in the lead time that might occur, it is found that lead time ranges from 4.51 to 35.1 after outsourcing.

The output for MCS provides more information compared with deterministic point estimate calculations. Output distribution function provides a range of results for the risk estimate and the probability of risk exposure after 1,000 trials of simulation. The output variable revealed that the maximum average lead time can go up to 46.03 days. Through the simulation, it allows risk manager to realize the range of the exposed risk as well as the central tendency. The highest end point can alert the risk manager about the extreme situation. Table V shows that the risk exposure level can be represented in terms of 25th, 50th or 75th percentile and the correlated level of protection. The output of MCS allows risk manager to realize the segment of the population to be protected and the confidence level of the protection scheme.

Lead times are bounded by business contracts between partners in the supply chains so the lead time will be closely kept based on contractual agreements. Hence, the rest of other lead time components may not vary except lead time after the delivery function is outsourced. The aim of this study is to determine the variation in overall customer lead time for outsourcing transportation as opposed to before outsourcing.

Questions related to risk can be answered by manipulating the end point grabbers or by changing the range and uncertainty values in the model.

4.4.2 Total average supply chain cost results. The result of Total Average Supply Chain Cost shown in Table VI is generated by the probabilistic inputs distributions from the data of Table IV. Table IV provides the summarized information of the different cost components. From the result, the mean of Total Average Supply Chain Cost before outsourcing is S$373,594.33 and it is reduced to S$252,039.20 after outsourcing transportation to third-party logistic provider. The cost after outsourcing is about 77 percent of the original cost before outsourcing. This leads us to conclude that there is substantial cost savings and it is benefited from the outsourcing arrangement.

However, the variation of cost is narrower in total cost before outsourcing, $C_{\text{Total, Before OS}}$ as opposed to total cost after outsourcing, $C_{\text{Total, After OS}}$. Referring to the output for total cost shown in Table VI, $C_{\text{Total, Before OS}}$ has standard deviation of S$2,130.98 which is lower than that of $C_{\text{Total, After OS}}$ S$24,006.70. $C_{\text{Total, After OS}}$ varies between S$195,229.37-S$319,330.04 which is more than the range of $C_{\text{Total, Before OS}}$:

$$\begin{aligned}\text{Range of } C_{\text{Total,Before OS}} &= \text{Max} - \text{Min} = \text{S\$}383,051.36 - \text{S\$}367,224.97\\ &= \text{S\$}15,826.39\end{aligned}$$

$$\begin{aligned}\text{Range of } C_{\text{Total,After OS}} &= \text{Max} - \text{Min} = \text{S\$}319,330.04 - \text{S\$}195,229.37\\ &= \text{S\$}124,100.70\end{aligned}$$

4.4.3 Total cost savings results. Based on the result, the outsourcing project can generate a cost savings of 33 percent on average with a small deviation of 6 percent. The narrow deviation of cost savings is a positive indication to the management that there is a certainty of cost savings with the mean of 33 percent. Also, it is important to note that the minimum cost savings of 12 percent is achieved and the highest cost savings up to 47 percent can be achieved. This resulted in the range of 35 percent difference based on minimum and maximum cost savings.

The case study illustrates how the proposed methodology can be adopted by companies to identify the critical delivery risks, and assess the risk of transportation outsourcing quantitatively. The analysis result shows that outsourcing can help to reduce lead time and total cost. Therefore, it is reasonable for Company X to outsource its delivery. However, the business environment and performance of logistics service providers may change time to time, it is important to monitor the potential risks and have regular risk assessment. If decision makers follows the steps of the proposed methodology and identify their own specific cost/lead time components, the proposed generic risk assessment framework can evaluate the risk qualitatively and quantitatively so as to manage the risk proactively.

Name	Mean	SD	25th percentile	50th percentile	75th percentile
$C_{\text{Total,BeforeOS}}$	373,594.33	2,130.98	372,218.70	373,623.07	375,011.07
$C_{\text{Total,AfterOS}}$	252,039.2	24,006.71	233,281.59	250,183.37	269,479.12
CS_{overall}	0.33	0.06	0.28	0.33	0.38

Table VI.
Output summary of uncertain cost

5. Conclusion

This paper contributes to provide an integrated system including both qualitative and quantitative methods. By adopting this outsourcing decision support framework, firms can improve their supply chain stability and reduce the operational cost at the same time. This integrated system has several implications for practitioners, especially for logistics management consultants, and professionals for strategic management of logistics activities outsourcing:

- The qualitative method is suitable in capturing the impact of risk in the supply chain. The SCR-FMEA method can be regarded as a qualitative risk assessment technique. It can be used to identify the most critical risk. This qualitative method allows practitioners to plan ahead and mitigate vulnerabilities. The qualitative SCR-FMEA risk management technique should be done at the planning stage.
- The quantitative risk assessment is conducted with the support of simulation software. The key performance indicators are used to evaluate the performance of outsourcing certain logistics functions. It is necessary to understand that different firms may have different performance indicators, so the measures of performance should be revised accordantly. For instance, two parameters L_{Total} and C_{Total} are used as the key indicator for delivery outsourcing risks in our case study. Lead time and cost simulations are done for two scenarios (i.e. before and after outsourcing). It will aid the company to make decision on logistics outsourcing. The input variables that involve risks are all described through probability distributions. Although it is difficult to estimate precisely the distribution of parameters in the model, simulation tool provides a rich palette of probability distribution and fitting test to reflect expected performances. The spreadsheet simulation makes it easier to include desired assumptions. Also, simulation provides the ability to measure different outcome variable such as cost saving which determines the profitability of outsourcing.
- The integrated system can identify risks and evaluate performance for both before and after outsourcing scenarios. It will help logistics management consultants to figure out professional solutions to clients, or support decision markers to make the decision relate to logistics activities outsourcing.
- The proposed outsourcing decision support framework is practical and easy-to-use. The simulation report generated by risk solver presents a variety of basic descriptive statistics measures such as mean, standard deviation and future work can be done by using advanced statistical measures such as skewness, kurtosis, etc. These statistics measures may also be used to conduct more deeply analysis if required. In addition, sensitivity analysis can be done to show which logistics process affects the performance indicators the most. This kind of information should be shared with service providers; so that they can further improve the service quality and this is important for the set up of strategic outsourcing partnership.

This system also allows practitioners to have a better understanding of all the possible risks related to logistics. Therefore, it is recommended to adopt different qualitative techniques such as focus group and Delphi to find out more about hidden risk of outsourcing. To conclude, both qualitative and quantitative risk assessment techniques must be balanced so as to support each other.

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