

Supplier selection in supply chain management with disruption risk and credit period concepts

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Abstract: Supplier selection is one of the most critical activities of purchasing management in supply chain and managers increasingly face sourcing decisions of how to selected suppliers. This paper illustrates the development of a sourcing decision that provides support for the buyer firm in supply chain. The models developed here, involved selecting between single and dual sourcing. Outside and local suppliers are considered in our model. To encourage the buyer for purchasing from the local supplier, he gives the credit period to the buyer that is determined according to the partner's opportunity costs. In this paper first the researchers model and explain this problem. Then the model is solved and critical decision values are identified. These are the base values used for sourcing selection. Finally, numerical examples are solved to show the model and illustrate numerical sensitivity analysis.

Keywords: Supply chain management; Decision making; Disruption; Credit period

1. Introduction

The supply chain of a product describes the sequence of activities to be carried out in order to create the desired output from one or several inputs factors.

Nowadays, competitive business environment has forced companies to satisfy customers who demand increasing product variety, lower cost, better quality, and faster response (Vondrembse *et al.*, 2006). Therefore, offering higher product quality is the main requirement to gain global market share. In addition, companies operate at the lowest possible cost in a competitive market to generate substantial profit (Lau *et al.*, 2002). With uncertainty in customer expectation, quantum leaps in technology and high-speed Internet links, business transcends local and national boundaries. In this environment, organizations face sophisticated customers who demand increasing product variety, lower cost, better quality, and faster response. To compete successfully, organizations are embracing supply chain management (SCM) because it focuses on actions along the entire value chain (Bechtel and Jayaram, 1997).

The supply chain perspective is predicated on the fact that competition is shifting from firm versus firm to supply chain versus supply chain, and SCM is the approach to designing, organizing, and executing these activities.

As competition shifts from a company orientation to a supply chain orientation, SCM is touted as a strategy of choice for successful competitors (Rich and Hines, 1997; Quinn, 1997). Therefore, rapid industrialization and growth of many countries around the world has spurred the development of supply chains that reach around the world. In today's ever-changing markets, many businesses move human resources, materials and information from a place to some other places throughout the world. Businesses around the world are attempting to position themselves to operate in a highly competitive marketplace (Lin *et al.*, 2009).

Suppliers are the critical links to any supply chain and consequently sourcing decision is one of the important decisions to be taken at the planning stage either a short or long term planning (Awasthi and Chauhan, 2009).

Supplier selection is one of the most critical activities of purchasing management in supply chain, because of the key role of supplier's performance in cost, quality, delivery, service and achieving the objectives of a supply chain (Guo *et al.*, 2009). Typical manufacturer spends 60% of its total sales on purchased items such as raw materials, parts, subassemblies and components. In automotive industries, these costs may be more than 50% of the total revenues. That can go up to 80% of the total product costs for high technology firms (Kokangul and Susuz, 2009).

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Supplier selection is the process by which suppliers are reviewed, evaluated, and chosen to become part of a company's supply chain. Companies need to work with different suppliers to continue their activities (Ustun and Demirtas, 2008). Many experts believe that the supplier selection is the most important activity of a purchasing department. Therefore, the supplier link in the supply chain appears to have significant cost-cutting opportunities. Determining selection criteria and selection techniques are the most important sides of supplier selection.

There are plenty of advantages and disadvantages attached with single or multiple suppliers. Although single sourcing foster better collaboration and partnership but relying on the single supplier reduces the supply chain robustness (Awasthi et al., 2009). Capacity disruptions cause the loss of all or a significant fraction of the production at a supplier or group of facilities in the same geographic area for a fixed period of time due to a single cause like a fire, earthquake, hurricane, act of terrorism, etc. For example, the Kobe earthquake in 1995 disrupted some supply chains that relied on liquid crystal displays. Hurricane Katrina in 2005 disrupted the supply chains of companies that were dependent on the New Orleans port (Xu and Nozick, 2009). Therefore, there are occasions when the preferred supplier may not be able to accommodate extra demand for a limited time and the buyer has to source from other suppliers or make a short term partnership with external suppliers (suppliers who were not a part of the current supply chain). Furthermore, relying on more than one source of supply for forming a short term partnership is sometimes inevitable because of suppliers' limitations on capacity (suppliers may invest on capacity for long term partnerships) and yield uncertainty particularly in forestry and agricultural based industries.

A number of papers focus closely on supply chain disruptions and discuss the measures that companies should use to design better supply chains, or study different ways that could help buying firms to mitigate the consequences of a supply disruption. Analytical studies address supplier selection and quantity allocation decisions. Horowitz (1986) developed an economic analysis of dual sourcing, a single input with different costs and shows that uncertainty in supply price and risk-aversion of the buyer motivate a firm to place positive orders from the high cost seller. Gerchak and Parlar (1990) have examined second-sourcing in an EOQ context to reduce the effective yield randomness of a buying

firm's purchase quantity. D. Berger et al. (2004), model the decision-making process using a decision tree approach and regard the operating cost of working with multiple suppliers in decision trees, from which the expected cost function is obtained and the optimal number of suppliers is determined. Burke et al. (2007), indicate that single sourcing is a dominant strategy only when supplier capacities are large relative to the product demand and when the firm does not obtain diversification benefits.

On the other hand, recently, the concept of credit period is considered as a strategy in SCM (Davis and Gaither, 1985; Arcelus and Srinivasan, 1993; Shinn et al., 1996; Salameh et al., 2003; Chen and Kang, 2007; Luo, 2007). The credit period is a negotiated time between the two parties in a supply chain according to which payments are implemented with a certain delay. In some real-life situations, the buyer has the option of either paying for the goods immediately upon receipt of the order or at a time period by the end of which payment must be received. Credit period is a coordination mechanism that encourages the buyer to supplier selection.

Yu et al. (2009), study the sourcing decision alternatives in the context that the demand is price-sensitive and the market scale increases when a supply disruption occurs. The disruption risk is captured by a probability, the non-stationary demand is modelled with an exponential function of the wholesale price multiplied by the maximum market scale, and the decision is analyzed based on expected profit functions.

In this paper, the researchers extend Yu et al. model (Yu et al., 2009). They assume the new model for demand functions of the price dependent. Moreover, they consider that a local supplier offers a credit period to encourage the buyer. This mechanism encourages the buyer to supplier selection.

The researchers observe this model that their decision making, is really dependent on these two critical value of p (The probability of disruptions faced by the main supplier (outside supplier) during a supply cycle), L_p and U_p . In the other worlds, if $p > L_p$, single sourcing from the outside supplier will be selected; if the disruption probability is between (L_p, U_p) , then selecting dual sources maximizes the profit; and if $p > U_p$, buying from the local supplier is the best purchasing choice. Also, there is the lower bond of the length of T (credit period) (T_{min}) that is using the local supplier as the only source outperforms using both suppliers.

The rest of the paper is organized as follows: In Section 2 the researchers define the model with determined assumptions. Then they develop the expected profit function in disruption state, when the manufacturer selects one supplier (single sourcing), and expected profit function in disruption state, when the manufacturer can select both outside supplier and local suppliers (dual sourcing). In Section 3, the researchers argue about constraints that play important role to choose the supplier and analyze the sourcing methods. A set of numerical analysis of the EPFs and sensitivity analysis of the associated results are given in Section 4. Finally, in Section 5, concludes the paper and provides some further research topics.

2. Model formulation

2.1. Model assumptions and notations

Suppose that there are two suppliers and one manufacturer (buyer) when the manufacturer faced a sourcing problem to decide how to prepare its demand. One of supplier is located outside the manufacturer's geographical scope, and offers a competitive price. Moreover, this supplier is prone to breakdowns or the supplied material can experience a substantial loss during transit due to the long lead time and distance. Another supplier is a local supplier that is more reliable but more expensive. Furthermore, consider the case that the local supplier induces the buyer to increase his order quantity through credit period. Therefore, the manufacturer has three sourcing alternatives to select: an alternative is single sourcing and select the outside supplier as main supplier, the other is single sourcing and selecting the local supplier as the main supplier and the third one is dual sourcing where local supplier is the secondary supplier who is given a portion of the demand, x , to produce during each supply cycle. Also in this case (dual sourcing), consider that the local supplier induces the buyer to increase his order quantity through credit period. Let T be the length of the credit period. This subject, could encourage the buyer to order more from local supplier.

There are some questions: How should the manufacturer choose the sourcing method?, when it is possible that outside supplier faces breakdown?

The notations used to develop the proposed model are:

- D: The realized demand for a given unit wholesale price.
- x : The portion of the demand allocated to the secondary supplier (local supplier) each cycle, $0 < x < 1$.
- p : The probability of disruptions faced by the main supplier (outside supplier) during a supply cycle.
- L_p : The first critical probability that break seven the profit with the outside supplier as the single source and the profit with dual sourcing.
- U_p : The second critical probability that break seven the profit with the local supplier as the single source and the profit with dual sourcing.
- S : The buyer's unit sales price for the final product, in \$/unit.
- K : The maximum market scale.
- C : The unit whole sale price of a supplier.
- γ : The parameter that shows sensitivity of demand to retail price.
- C_m^s : The outside supplier's unit wholesale price in single sourcing.
- C_m^d : The outside supplier's unit wholesale price in dual sourcing, $C_m^s > C_m^d$ (this relation exist because the buyer in single sourcing purchases the whole demand from the outside supplier, in spite of the dual sourcing that the buyer purchases the $(1-x)$ portion of whole demand from the outside supplier).
- C_{bn} : The secondary supplier's unit wholesale price in normal state, $C_{bn} > C_m^d$.
- C_{bd} : The secondary supplier's (local supplier's) unit wholesale price in disrupted state, $C_{bd} > C_{bn}$.
- C_u : The buyer's unit loss of the unsatisfied demand.
- T : The length of the credit period.
- i : The buyer's cost of capital or opportunity cost in annual percentage (decimal).
- Π_n^{so} : The buyer's expected profit with the outside supplier as the single source in a normal state.
- Π_n^{sl} : The buyer's expected profit with the local supplier as the single source in a normal state.
- π_n^d : The buyer's profit with dual sourcing in a normal state.

- π_n^{so} : The buyer's profit with the outside supplier as the single source in a disrupted state.
- π_n^{sl} : The buyer's profit with the local supplier as the single source in a disrupted state.
- π_d^d : The buyer's profit with dual sourcing in a disrupted state.
- Π^d : The buyer's expected profit with dual sourcing.
- Π_m^{so} : The manufacture's expected profit with the outside supplier as the single source.
- Π_m^{sl} : The manufacture's expected profit with the local supplier as the single source.
- EPF: Expected profit function.

2.2. Demand function determination

In this model the researchers assume the demand functions of the price dependent is expressed:

$$D = KC^{-\gamma} \tag{1}$$

where C is the price charged to customers, k is a scaling parameter, and γ is the price elasticity, which is always positive (Yue et al., 2006).

The manufacturer has two main alternatives to choose sourcing method as its strategy: single and dual sourcing. Let's consider that the supply disruption risk consideration is needed to regard and present. The state variables, symbols and decision scenarios are shown in Table 1.

In adaption with Haisheng et al., let's define two discrete groups of parameters: the first group is (m,d) that denote the main supplier and the secondary supplier, respectively. Other group is (n,d) that denote a normal state and a disrupt state, respectively. Moreover, a group of (s,d) is used to indicate the single and dual sourcing, respectively.

2.3. Expected profit function

2.3.1. Expected profit function in normal state

Consider a normal state, demand function when the manufacturer selects the outside supplier as main supplier (single sourcing), is:

$$D = KC_m^s^{-\gamma} \tag{2}$$

Thus, the profit function of this situation is calculated as:

$$\pi_n^{so} = (S - C_m^s)KC_m^s^{-\gamma} \tag{3}$$

Whereas, if the manufacturer selects the local supplier as main supplier (single sourcing), the demand function would be as:

$$D = KC_{bn}^{-\gamma} \tag{4}$$

In this case the local supplier offers a credit period (T). Thus the manufacture's total interest saving on the money payable during the credit period is $C_{bn}KC_{bn}^{-\gamma}Ti$. Thus, the profit function of this situation is calculated as:

$$\Pi_n^{sl} = (S - C_{bn})KC_{bn}^{-\gamma} + C_{bn}KC_{bn}^{-\gamma}Ti \tag{5}$$

Profit function when the manufacturer selects two suppliers (dual sourcing) in a normal state is:

$$\begin{aligned} \pi_n^d &= (1-x)(S - C_m^d)K(0.5(C_m^d + C_{bn}))^{-\gamma} \\ &+ x(S - C_{bn})K(0.5((C_m^d + C_{bn}))^{-\gamma} \\ &+ C_{bn}xK(0.5((C_m^d + C_{bn}))^{-\gamma}Ti \end{aligned} \tag{6}$$

Table 1: The scenarios, state variables and market demands.

Alternatives	Normal state with probability $(1 - \varphi)$		Disrupted state with probability (φ)	
	Prices	Market demand	Prices/loss	Market demand
Single sourcing (the foreign supplier)	C_m^s	$KC_m^s^{-\gamma}$	C_u	$KC_m^s^{-\gamma}$
Single sourcing (the local supplier)	C_{bn}	$KC_{bn}^{-\gamma}$	C_{bn}	$KC_{bn}^{-\gamma}$
Dual sourcing	$\begin{cases} C_m^d \\ C_{bn} \end{cases}$	$K(0.5(C_m^d + C_{bn}))^{-\gamma}$	$\begin{cases} C_u \\ C_{bd} \end{cases}$	$K(0.5(C_m^d + C_{bn}))^{-\gamma}$

Notice that the local supplier offers a credit period (T). For this state, it is clear that by allocating portion x to local supplier; the manufacture's total interest saving on the money payable during the credit period is

$$C_{bn}xK(0.5(C_m^d + C_{bn}))^{-\gamma}Ti$$

that less than $C_{bn}KC_{bn}^{-\gamma}Ti$ when the manufacturer selects the local supplier as main supplier (single sourcing).

2.3.2. Expected profit function in disruption state

During a disruption state, in single sourcing alternatives, when the outside supplier as the main and single supplier faces breakdown, the supply disruption occurs. Therefore, the profit function is calculated as:

$$\pi_d^{so} = -KC_m^s C_u \tag{7}$$

Notice when the local supplier is selected as the main and single supplier break down does not change the local profit function, because the breakdown occurs just for the outside supplier.

In the dual sourcing alternative, the local supplier gets a portion, x , of the average demand each cycle, the wholesale price charges by the secondary supplier changes when occurs the disruption: for the first x portion of the demand, the price remains unchanged, which is C_{bn} and for the rest $(1-x)$ portion, the price increases to C_{bd} . Therefore, the buyer's profit in the disrupted state with dual sourcing, π_p^d , becomes:

$$\begin{aligned} \pi_p^d &= (1-x)(S - C_{bd})K(0.5(C_m^d + C_{bn}))^{-\gamma} \\ &+ x(S - C_{bn})K(0.5(C_m^d + C_{bn}))^{-\gamma} \\ &+ C_{bn}xK(0.5(C_m^d + C_{bn}))^{-\gamma}Ti \end{aligned} \tag{8}$$

Also, in this case the local supplier offers a credit period (T). In this case it is noticeable that the credit period is considered just for a portion, x , of the average demand each cycle. Thus, the manufacture's total interest saving on the money payable during the credit period is $C_{bn}xK(0.5(C_m^d + C_{bn}))^{-\gamma}Ti$.

The expected profit function of the manufacturer with single sourcing (i.e., only the

outside supplier is used) in the presence of supply chain disruptions is

$$\Pi_m^{sd} = (1-p)\pi_n^{so} + p\pi_d^{so} \tag{9}$$

where, p is disruption probability.

And the associated expected profit function in the case of dual sourcing for the manufacturer is:

$$\Pi^d = (1-p)\pi_n^d + p\pi_d^d \tag{10}$$

Also, if manufacturer selects the local supplier as the main supplier (single sourcing), the expected profit function is:

$$\Pi_m^{sl} = (S - C_{bn})KC_{bn}^{-\gamma} + C_{bn}KC_{bn}^{-\gamma}Ti$$

3. The analysis of sourcing methods

To analyze the sourcing methods, the following propositions are helpful:

Proposition 1: When the probability of disruptions (p) satisfies the relationship, $L_p < p < U_p$, then the dual sourcing method outperforms single sourcing. Where:

$$L_p = \left(1 + \frac{\pi_d^d - \pi_d^{so}}{\pi_n^{so} - \pi_n^d}\right)^{-1} \tag{11}$$

and

$$U_p = \left(\frac{\pi_n^d - \Pi_m^{so}}{\pi_n^d - \pi_d^d}\right)^{-1} \tag{12}$$

Proof: To choose the dual sourcing as optimal alternative, it is clear that these constraints are satisfied:

$$\begin{cases} \Pi_m^{so} < \Pi^d; \text{constraint 1} \\ \Pi_m^{sl} < \Pi^d; \text{constraint 2} \end{cases} \tag{13}$$

Equation (13) indicates that the dual sourcing method is selected if the buyer's expected profit with dual sourcing increases.

By simple computation from Constraint 1, the researchers have:

$$p > \left(1 + \frac{\pi_d^d - \pi_d^{so}}{\pi_n^{so} - \pi_n^d}\right)^{-1} = L_p \tag{14}$$

In fact, (14) implies that the probability of disruptions (p) has a lower bound, L_p , which can be expressed as:

$$L_p = \left(1 + \frac{\pi_n^d - \pi_n^{so}}{\pi_n^{so} - \pi_n^d}\right)^{-1}$$

Similarity, from Constraint 2, the researchers have:

$$p < \frac{\pi_n^d - \prod_m^{sl}}{\pi_n^d - \pi_n^d} = U_p \quad (15)$$

In fact, (15) implies that the probability of disruptions (p) has an upper bound, U_p , which can be expressed as:

$$U_p = \frac{\pi_n^d - \prod_m^{sl}}{\pi_n^d - \pi_n^d}$$

Therefore, dual sourcing is selected when $L_p < p < U_p$.

Proposition 2: When the probability of disruptions (p) satisfies the relationship, $p \geq U_p$, that is, using the local supplier as the only source outperforms using both suppliers.

Proof: If $p \geq U_p$, then $\prod_m^{sl} > \prod_m^d$, i.e. constraint 1 is not satisfied. So the result is obtained.

Proposition 3: In choosing the most profitable sourcing method, there are two critical values of the disruption probabilities, (L_p, U_p), given by (11) and (12), respectively, guiding the decisions in the following method:

If $p \leq L_p$, then choose the foreign supplier as the single source.

If $L_p < p < U_p$, then choose dual sourcing.

If $p \geq U_p$, then choose the local supplier as the single source.

Proof: with regard to obtained results in Propositions 1 and 2, the results are obtained.

Proposition 4: for any given p , there is the lower bound of $T(T_{min})$ that is using the local supplier as the only source outperforms using both suppliers:

$$T_{min} = \frac{(1-p)\pi_n^d + p\pi_n^d - (S - C_{bn})KC_{bn}^{-\gamma}}{C_{bn}KC_{bn}^{-\gamma}i} \quad (16)$$

Proof: to choose the single sourcing as optimal alternative, it is clear that this constraint is satisfied:

$$\prod^d < \prod_m^{sl} \quad (17)$$

By substituting Equations (8) and (10) in constraint (17), the researchers have:

$$(1-p)\pi_n^d + p\pi_n^d < (S - C_{bn})KC_{bn}^{-\gamma} + C_{bn}KC_{bn}^{-\gamma}Ti$$

This means:

$$T_{min} = \frac{(1-p)\pi_n^d + p\pi_n^d - (S - C_{bn})KC_{bn}^{-\gamma}}{C_{bn}KC_{bn}^{-\gamma}i} < T$$

Thus the result is obtained. This range of T ($T > T_{min}$) is very important for local supplier, because he can adjust the length of credit period and earn the whole manufacture purchased quantity. Thus, the credit period has a critical role in supply chain.

4. A numerical example

Some numerical experiments have been carried out to illustrate the application of the proposed model. The main scope of the subsequent numerical studies is to represent the presented model and its sensitivity to the some model parameters. The base values of numerical example for this decision problem are given in Table 2. The result of using decision procedure is shown in Figure 1. Figure 1 demonstrates the effectiveness across all scenarios as a function of the disruption probability (p).

We may observe from this figure that our decision making is really dependent on two critical value L_p and U_p . In the other words, if $p < L_p = 0.08$, single sourcing from the main supplier will be selected; if the disruption probability is between (0.08, 0.26), then selecting dual sources maximizes the profit; and if $p < U_p = 0.26$ buying from the local supplier is the best purchasing choice. This result is confirmed by Proposition 3 which states that the necessary condition for our selection.

To further study the effects of varying parameters on the supply chain profits in the proposed models with dual sourcing, let's resort to numerical approaches. The researchers focus in this section on the effects of the (M, p) and (T, p) on the associated expected profit function in the case of dual sourcing (Relation 10).

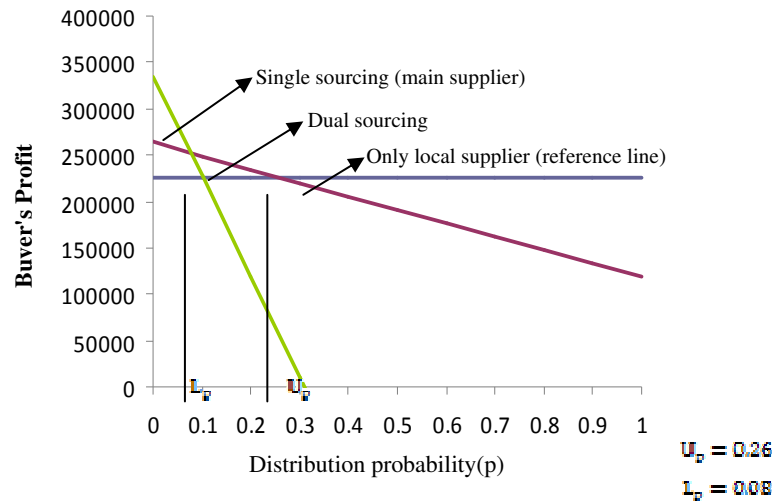


Figure 1: The expected profits under various sourcing alternatives.

Table 2: Parameter base values.

Parameters	α	C_m^s	C_m^d	C_{bn}	C_{bd}	C_u
Values	0.3	330	340	360	400	200
Parameters	S	K	γ	i	T	
Values	420	6×10^6	-1.6	0.15	0.15	

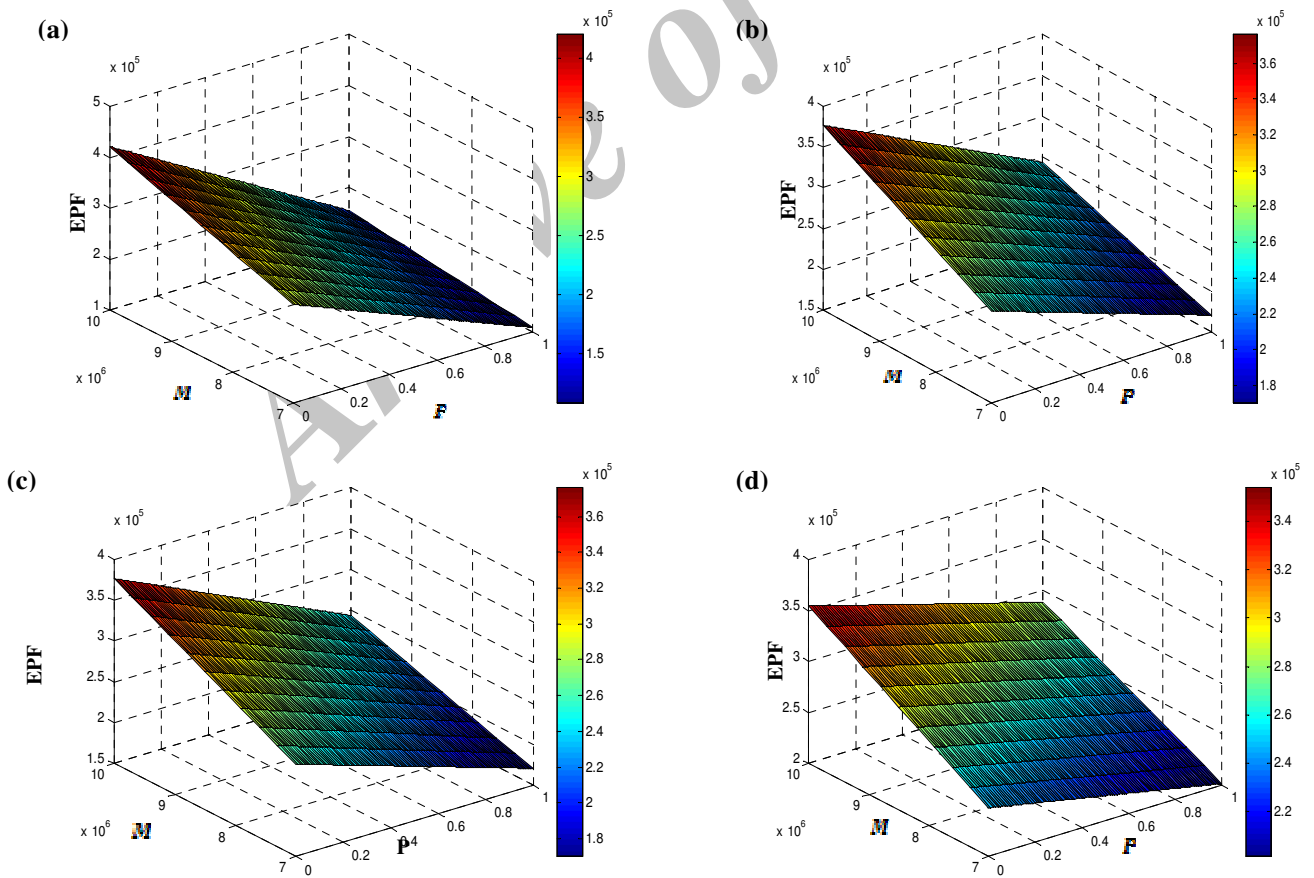
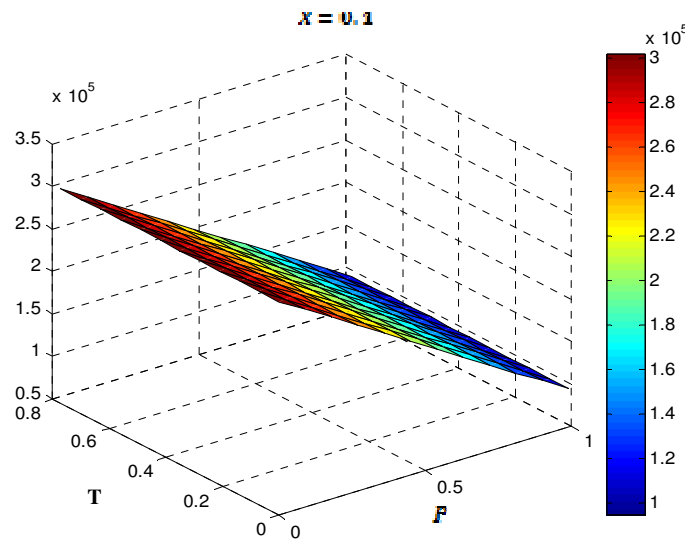
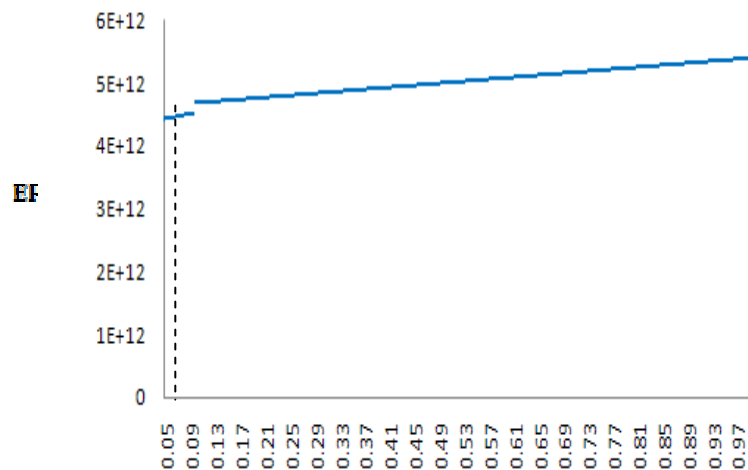


Figure 2: The images of EPF with respect to (p, M) in the four cases.

Figure 3: The images of EPF with respect to (p, T) .Figure 4: The images of EPF with respect to T .

5. Conclusions and future investigations

In this paper, a decision making model with the consideration of benefits, disruption risk is constructed for supplier selections. There are two suppliers for selection. One supplier is local and another is outside. The outside supplier offers the lower price, but disruption risk may occur. The maximum buying portion of local supplier is limited to x . Also the local supplier induces the buyer to increase his order quantity through credit period. The length of this credit period is T . First the model is constructed. Our objective is to maximize the buyer's expected profit function. The range of the probability of disruptions (p) over which dual sourcing can take place has been derived here. Our analysis shows that upon these values, the sourcing selection is obtained.

By applying the model, decision makers can determine the method of the supplier selection. The model can also be modified as required by a firm in any other industry to help it select the best supplier(s).

It is interesting to investigate a situation where there are more than two suppliers. In this case, the buyer needs to consider the suggested price and the probability of disruptions faced by each supplier during a supply cycle to determine the best decision. This may provide interesting results of how the number of suppliers may influence the decisions of the buyer. This model can be extended to state that demand has a fuzzy function.

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