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Multiple sourcing under supplier failure risk and quantity discount: A genetic algorithm approach

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ABSTRACT

This paper investigates an order allocation problem of a manufacturer/buyer among multiple suppliers under the risks of supply disruption. A mixed integer non-linear programming (MINLP) model is developed for order allocation considering different capacity, failure probability and quantity discounts for each supplier. We have shown that the formulated problem is NP-hard in nature and genetic algorithm (GA) approach is used to solve it. The model is illustrated through a numerical study and the result portrays that the cost of supplier has more influence on order quantity allocation rather than supplier's failure probability.

1. Introduction

In today's global business market, sourcing decision is one of the major challenges faced by the buying firms and it has received wide attention from both academicians as well as practitioners. Sourcing decision includes selection of right number of suppliers and order quantity allocation among the selected suppliers (Chopra and Meindl, 2005). The problem of sourcing becomes more crucial when there is a possibility of occurrence of disruptions in the supply which may be natural or created by man. Generally, supply disruptions are caused by the occurrence of high profile catastrophic events such as 9/11, Hurricane and Katrina, in 2004, and tsunami in India in 2004. These events can seriously affect the profitability and performance of the entire supply chain. The largest automaker company of the world, Toyota had to suspend the production at its 12 assembly plants in March 2012 because of the devastating earthquake and tsunami in Japan and estimated a production loss of 140,000 cars (Kim and Reynolds, 2011). For more examples on supply disruption, one can see the study of Kleindorfer and Saad (2005), Ellis et al. (2010), and Wakolbinger and Cruz (2011).

In the literature, many authors (for example, Wu et al., 2007; Yang and Yang, 2010; Ellis et al., 2010) have proposed different strategies to mitigate the effects of supply disruptions. Hou et al. (2010) have defined supply disruption as the sudden non-availability of supplies due to the occurrence of an unexpected event making one or more supply sources totally unavailable. Tomlin (2006) has suggested supply diversification is an efficient strategy to cope with the risk of supply disruptions and avoid the dependence on single supplier. Under multiple sourcing, the major issue before the buyer is the optimal allocation of demand among the selected set of suppliers when the suppliers are exposed to the risk of supply disruptions. There is a paucity of literature on optimal allocation of order among the suppliers under supply disruptions risk.

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Notation

D	total demand of the buyer in a given period
C_P	base price of the item offered by each suppliers (mu) where, mu – monetary units
d_{ij}	discount in percentage given by ith supplier in jth price break
b	per supplier management cost (mu/supplier)
n	number of potential suppliers
s	number of price breaks
L	loss per not obtained unit due to the supplier failure (mu)
Q_{bi}	actual capacity of individual supplier
Q_i	order quantity allocated to the ith supplier
p^*	probability of occurrence of super-event that would fail all suppliers
p_i	probability of occurrence of unique-event that fails the ith supplier
K_i	compensations of supplier(s) that don't fail, where $K_i = (Q_{bi} - Q_i)$
$A^{(i)}$	set of suppliers who fail
$Q_{\min}$	minimum quantity ordered to each selected supplier
Q_{lot}	lot size of any supplier
h	integer multiple which is used to get equal to Q_{lot} from $Q_{\min}$ (i.e. $Q_{\min} = hQ_{lot}$)
k_i	integer multiple required to reach from Q_i to Q_{lot}, for example, $Q_i = k_iQ_{lot}$
H	integer multiple required to reach from Q_{lot} to D, i.e. $D = HQ_{lot}$
S	set of suppliers
$p(S)$	power set of S

In this paper, we have developed a mixed integer non-liner programming (MINLP) model to determine the optimal order allocation among multiple suppliers when the suppliers are exposed to the risk of failure due to man-made or natural disruptions. We have shown here that the formulated problem is NP-*hard* in nature, and genetic algorithm (GA) is used to solve it. The reason of using GA is that it has been proven to excel in solving combinatorial optimization problems in comparison to traditional optimization techniques (Goldberg, 1998; Steiner and Hruschka, 2002).

The remainder of the paper is organized as follows: Section 2 provides a brief review of literature related to order allocation problem. Description of the problem and development of the model are presented in Section 3. The problem complexity is discussed in Section 4. Section 5 presents the GA approach to find the solution. Numerical experiments are conducted in Section 6 and sensitivity analysis of different parameters is performed in Section 7. Finally, conclusions and future scope of the work are presented in Section 8.

2. Literature review

A large number of studies are available in the literature on supplier selection and order allocation problems. Here, a brief review of literature related to order allocation problem is discussed only. The research pertaining to order allocation can broadly be classified into the following two categories:

(i) Order allocation without the consideration of supply disruptions risk.
(ii) Order allocation under supply disruptions risk.

2.1. Order allocation without the consideration of supply disruptions risk

Considerable amount of literature is available in this stream, and to the best of our knowledge, Sculli and Wu (1981) are the frontrunners to study the order allocation problem. They have shown that in comparison to single sourcing, the mean and variance of the lead time and demand distribution are reduced under dual sourcing. Further, they have shown that probability of stock out is less in dual sourcing as compared to single sourcing. Many authors have extended the work of Sculli and Wu (1981) in different directions in the last two decades (for example, Sculli and Shum, 1990; Pan, 1989; Ramasesh et al., 1991; Chaudhry et al., 1991; Lau and Zhao, 1993; Chiang and Benton, 1994; Sedarage et al., 1999; Basnet and Leung, 2005; Kawtummachai and Hop, 2005). Instead of discussing these studies in details, we refer the readers to Minner (2003) and Thomas and Tyworth (2006) who have provided an extensive review on order splitting. In recent years, many authors (for example, Burke et al., 2008a, 2008b; Wang et al., 2008; Qi, 2007; Che and Wang, 2008; Yu and Tsai, 2008; Tsai and Wang, 2010; Cheng and Ye, 2011) also have studied the similar problem. However, all the aforementioned studies have ignored the risks of supply disruption.