The Decisions on Backup Supply in the Presence of Supply Disruptions

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ABSTRACT
As supply chains are becoming more dependent upon suppliers, the importance of using backup supply is receiving increasing attention. The objective of this paper is to develop a set of models to facilitate manufacturers/buyers' decision as to when to use a backup supply if the main supply source is interrupted. The authors take a number of cost factors such as production, purchasing and inventory holding during the disruption cycle into consideration. The impacts of the duration and the magnitude of the main supplier's breakdown are explicitly studied, and the effect of demand change during disruption is also examined. Numerical illustrations are given to show the applications of the decision-making models developed in the paper.

Keywords: Backup Supply, Decision Making, Production, Purchasing, Supply Chain, Supply Disruption, Supply Management

INTRODUCTION
The best supply chains are not only responsive and cost-effective, but also agile and adaptable to ensure all the supply chain members’ interests stay aligned. The objective of agility is to quickly respond to short-term changes in demand and supply and to smoothly handle external disruptions (Lee, 2004, pp. 102-104). Because of the widespread applications of outsourcing, the manufacturing supply chains are becoming more supplier-dependent. If the main suppliers break down, either partially or totally, then the manufacturer has to quickly find ways to cover the supply gap or shortage; otherwise, the normal operations of the entire supply chain could be affected seriously. In this paper, we consider a supply chain in which the manufacturer buys a critical component from a main supplier that is subject to breakdowns caused by various unexpected events, and an alternative or a back-up supplier is available to offer the product at the same quality but at a higher wholesale price.

At the time when a main supplier is struck by an unexpected event and cannot provide the critical component partially or completely, the manufacturer may rely on inventories to con-
tinue the production if the manufacturer operates under a make-to-stock policy. However, if the amount of inventory cannot cover the demand during the entire disruption period, then the manufacturer has to find alternatives for replenishment, such as using a backup supplier. The decision not only has to be made quickly, but also should take numerous factors into consideration, including the main supplier’s disruption duration, the magnitude of the disruption, the manufacturer’s inventory level, the difference between the two suppliers’ wholesale prices, the financial loss of the unsatisfied demand, and many others. A framework and associated tools for decision comparison and selection are thus needed to guide the manufacturer to make a cost-effective decision.

We examine such a decision based on the manufacturer’s profit when using and not using a backup supplier, respectively. Sensitivity analysis of several critical input parameters on the decision is given after the profit functions are established. Furthermore, the impact of demand change in conjunction with supply disruption on the decision is also analyzed.

The remainder of the paper is organized as follows. First, we summarize the literature related to supply chain risk management. We analyze the entire disruption cycle and magnitude, and provide a list of notations that will be used for model development. The next section focuses on the sensitivity analysis of various parameters through algebraic analysis and numerical examples. The demand change that occurs concurrently with the supply disruption is considered to show how the decision regarding the use or not use of a backup supplier is made. Finally, we provide concluding remarks and directions for future research.

**LITERATURE REVIEW**

Supply risk management has been studied from various angles in the literature (Vanany et al., 2009); for example, ordering policies (e.g., Kim et al., 2005; Ross et al., 2008; Li & Chen, 2010), pricing policies (e.g., Tang & Yin, 2007), capacity allocation (e.g., Hsieh & Wu, 2008), and financial investment (e.g., Babich, 2008). Considering the relevance, we herein review two streams of recent research efforts: one is focused on inventory management in the presence of supply disruption or uncertainty, and the other is related to supply disruption and multiple sourcing.

**Inventory Management in the Presence of Supply Disruption or Uncertainty**

The analysis of the inventory management policy under supply disruption and uncertainty has received a great deal of attention in recent years. A large portion of research in this area is conducted based on two inventory control policies – periodic review and continuous review. In the periodic review situation, Parlar et al. (1995) studies the inventory problem assuming that the probability that an order placed is filled in full, as opposed to not at all, depends on whether supply was available in the previous period. Wang and Gerchak (1996a) investigate a production planning problem with variable production capacity, random yields, and uncertain demand. Snyder and Tomlin (2008) investigate how advanced warnings of disruptions alter the optimal inventory policy, and therefore the optimal disruption-management strategy. A recent study by Schmitt et al. (2010) investigates the inventory system with stochastic demand and supply and combines disruptions and continuous sources of uncertainty.

In the continuous review environment, the effects of variable capacity on optimal lot sizing are analyzed in the work of Wang and Gerchak (1996b). The work of Mohebbi (2003) presents an analytical model for computing the stationary distribution of the on-hand inventory with supply interruptions. To further this model, Mohebbi (2004) presents an exact formulation of the long-run average cost rate function with the consideration of compound Poisson demand, hyper-exponentially distributed lead time, lost sales, and a supply process that maybe randomly interrupted. Qi et al. (2009) formu-
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