1 INTRODUCTION

1.1 Uncertainty in Supply Chain and Its Effects on Individual Firms

Increasing product proliferation, shrinking product life cycles, demand for customized product, and business opportunities in a wider global market have induced enormous amount of uncertainties in the supply chains of the firms in the recent years. Competitive advantage of a firm is often related to the strategic fit achieved by a firm in terms of appropriately combining their internal core competencies with those of their supply chain partners (e.g. suppliers and customers). During last few decades, due to explosive improvement in accessibility of different countries, the supply chain nowadays can span over the entire globe. This phenomenon has provided the firm with numerous advantages as well as greater risks and uncertainties. The success of a firm heavily depends upon the firm’s ability to garner the advantages, mitigating the risks and coping with uncertainty in adequate manner.

A supply chain can face uncertainty from both demand side as well as supply side. Uncertainty in demand arises due to the fluctuations in the demand, whereas uncertainty in supply occurs due to inefficient production processes and unreliable supply sources (Lee and Billington, 1992; Van der Vorst and Beulens, 2002). Supplier lead time, delivery performance and the quality of raw material are few of the major sources of supply side uncertainty. Supply uncertainties have a direct impact on inventory stocking and supplier selection policies that a firm adopts (Anupindi and Akella, 1993). For example, when the supply of a product with high stockout cost is uncertain then the firm will usually prefer a high amount of inventory holding (risk hedging strategy) (Lee, 2002). Similarly, firms procure materials from multiple sources in order to mitigate the uncertainty arising from a single unreliable source (Anupindi and Akella, 1993).
The effect of globalization is comparatively more apparent in some of the aspects of the business processes, one of them being the procurement process. Higher access means a larger possible supplier pool along with a bigger market for the firm, along with greater risk and uncertainty for them. A firm’s procurement policy is typically operationalized as three key interrelated decisions (Burke et al. 2007): “(a) the criteria for qualifying approved suppliers; (b) the supplier(s) selection from the approved base for order placement; (c) the order quantities to place with each selected supplier.” The first decision is about identifying the number of supplier(s) to be taken into consideration. The basis of building this supplier pool is whether the supplier(s) is being able to fulfill all corporate requirements for the concerned product as decided by the firm. In case of single sourcing or “sole sourcing” models, this condition becomes an obligation, since there is only one supplier available (Ramsay and Wilson, 1990). However, in case of multiple sourcing, the firm can split the order to two (dual sourcing) or more suppliers at the same time (Seshadri et al., 1991). This complex choice can have a huge impact on the procurement policy in an uncertain environment, because the presence of other suppliers will reduce the uncertainty for the firm in case one of the suppliers defaults.

1.2 Single Sourcing vs. Multiple Sourcing Dilemma

Relying on multiple suppliers to avoid stockouts and improve the service levels have traditionally been the strategies of many supply chains. In extant supply chain literature, several researchers have argued that, in presence of multiple supply sources, overall inventory holding and distribution costs gets reduced in most of the cases (Ganeshan, 1999; Minner, 2003). In the multiple supplier contexts the issues facing the purchasing managers are selection of a reliable set of suppliers and allocation of order quantities to each of the selected supplier (Burke et al., 2007). Though firms select suppliers based on various assessment criteria such as cost or price
(net price, discounts or payment terms), capacity, supplier service (reliability, lead time variability, delivery time and flexibility), and quality; cost becomes the primary selection criteria for most of the firms (Burke et al. 2009; Minner, 2003). However, selection of a set of suppliers solely on the basis of price/cost may not ensure adequate order fill rate. Inadequate order fill rate from suppliers may arise due to various reasons including supplier's inadequate capacity for a specific order, long transit time or inaccurate order scheduling by the suppliers. Irrespective of the reasons, there is always a chance that a particular supplier will not be able to deliver the ordered quantities and that in turn creates detrimental effects on the service level commitments of the buying firm. It is therefore pertinent to analyze the multiple supplier sourcing strategies in the context of supplier's service level uncertainties.

Although sometimes firms prefer ordering to multiple suppliers to deal with the supplier uncertainty, there are situations when firms prefer placing their order to single supplier rather than multiple suppliers. For example, Toyota Production System (TPS) philosophy and Just-in-Time (JIT) philosophy urges the manufacturer to have a strong and long term relationship with their suppliers, which is feasible only if the number of suppliers is low (Sheth and Sharma, 1997). There are instances when a firm chooses sole supplier to supply their raw materials. For example, in 2004, Beazer Homes USA decided that for all their new constructions, all the hardware as well as other entry devices would be solely supplied by Kwikset with the notion that single sourcing process would reduce the product variation, training required, and cost of quality which would in turn reduce the overall supply chain cost (“Kwikset Named as Exclusive Door Hardware Supplier to Beazer Homes USA, Inc.” Lexis-Nexis. July 2004).

Similarly in 2004, Toshiba Electronics named Asyst Technologies Inc. as their sole supplier for Fab production for their new 300mm Fab facility in Oita, Japan in order to streamline the
training process and reduce downtime and inefficiencies occurring due to the presence of different technologies (“Toshiba Installs Asyst Automation Tools in 300mm Fab.” Electronic News (North America). June 2004).

However, single supplier sourcing is not always desirable as the failure of the supplier would have significant and detrimental impact on the performance of the firm. Also, presence of single supplier sourcing would give the supplier a huge bargaining power over the said firm. There are instances where firms have suffered due to single supplier sourcing. For example, in 1998, Ford's Fiesta and Puma manufacturing facilities in Cologne and Dagenham, Germany was temporarily shut down for three days due to supply failure. Finally it was discovered that the source of supply problem was a computer glitch at Ford's supplier who supplied Ford with door and trunk latches. But this problem had caused Ford to lose approximately £70 million in terms of labor costs as well as production of around 7000 vehicles was hampered (“Supply Failure Won’t Change Ford Policy.” Professional Engineering. June 1998). Similarly, when a fire broke out at the Philips manufacturing plant in Albuquerque, USA in March 2000, their customers, Nokia and Ericsson, faced a huge disruption. However, since Nokia proactively reduced the pressure on Philips as their supplier by using multiple suppliers, the problems faced by them were much less compared to Ericsson. As a result of this predicament, Ericsson lost $1.8B and almost 4% market share to Nokia. (A. Mukherjee, “The Fire That Changed an Industry: A Case Study on Thriving in a Networked World”, FT Press, October 2008). Thus whether to go for single supplier or multiple suppliers always remains a very difficult question to the manager of a firm.

1.3 Motivation of the Study

Therefore, in the context of a manufacturing or a retailing firm, scheduling of their supply is of immense importance. This scheduling is a part of their aggregate planning process where they
chalk out their strategies for the firm's foreseeable future (1-3 years). This is very important for the firm because an accurate and intelligent planning will give the firm a competitive advantage over their competitors. Also, immaculate management of their inventory will lead to minimization of the inventory holding cost and the stock-out cost for the firm, hence maximizing their profit.

Thus, scheduling and optimization of supply chains is very important for manufacturing and retailing firms in the context of competition. Demand uncertainties and supply uncertainties in the presence of multiple supplier sourcing option increase the complexity of the situation. Past researchers developed models considering either demand uncertainty or supply uncertainty or both but in the context of a newsvendor scenario (Anupindi and Akella, 1993; Agrawal and Nahmias, 1997; Dada et al., 2007; Burke et al., 2009). Also, most of the studies assumed single or dual supplier to be available for the firm.

Apart from having multiple suppliers to counter uncertainty in supply chain, Kouvelis and Li (2008) introduced the idea of flexible back-up supplier to aid the firm in case of emergency. They cited the example of semiconductor industry where this practice is prevalent. Allowance of a back-up supplier along with the option of multiple suppliers will further enrich the model.

Therefore, there is an urgent need to develop mathematical models considering simultaneously demand and supply uncertainties, multiple suppliers and a back-up supplier; and derive an optimal solution for a generalizable scenario where multiple periods are considered. It will be interesting to develop a single period model and extend it to multi-period context. This involves development of sophisticated mathematical models and finding corresponding solutions which is a challenge to any aspiring researcher.
Chapter 2 of this thesis contains the review of the relevant literature to bring the problem in perspective. In Chapter 3, the gaps in the extant literature are identified. It also gives the motivation for taking up this particular area for research. Chapter 4 contains the problem statement and the formulation of the mathematical models. In Chapter 5, the analytical solutions are obtained. Also, a dynamic programming method of finding the solution is demonstrated in case when analytical solution is either difficult or time consuming to obtain. Chapter 6 gives numerical analysis for the sensitivity of the analytical solutions. Chapter 7 concludes the thesis by suggesting the avenues for future research.