Abstract

This article reviews the impact of demand and supply uncertainty on the supply chain and presents scenarios for managing the supply chain under each. It becomes clear that while we have a reasonably good understanding and years of experience in managing the supply chain where demand uncertainty is a factor, we do not have that same level of understanding or competence when coping with supply uncertainty. Gaining an appreciation of the similarities, differences and alternative strategies that may be applied is crucial if we are to effectively manage our supply chains in a world threatened by disruptions, demand volatility, and other forms of randomness.
Introduction

Every supply chain is subject to disruptions. Although supply chain disruptions have existed as long as supply chains have, they have only recently begun to receive significant attention from practitioners and researchers. One reason for this increase in interest is the recent spate of high-profile disruptions, including September 11, the west-coast port lockout of 2002, and hurricanes Katrina and Rita in 2005. Another reason is the focus in recent decades on the philosophy of “lean” supply chain management, which calls for slimmed-down systems with little redundancy or slack. Although lean supply chains are efficient when the environment behaves as predicted, they are extremely fragile, and disruptions can leave them virtually paralyzed.

Supply chains are multi-location entities, and disruptions are almost never purely local—rather, they cascade through the system, with upstream disruptions causing downstream stock-outs. For example, in 1998, strikes at two General Motors parts plants led to shutdowns of over 100 other parts plants, which caused closures of 26 assembly plants, finally resulting in vacant dealer lots for months. Another, scarier, example relates to port security. National-security analysts estimate that if a terrorist attack closed New York Harbor in winter, New England and upstate New York would run out of heating fuel within ten days. Even temporarily hampering the port’s operations would have immeasurable cascading effects.

Despite this, very little research has considered disruptions in multi-location settings. Instead, the current research focuses on single-location systems and examines the purely local effects of supply disruptions. This white paper begins to fill this gap by examining disruptions in a multi-location context, and asking how strategies for coping with disruptions should differ from those for coping with demand uncertainty.

Supply vs. Demand Uncertainty

Supply uncertainty (SU) and demand uncertainty (DU) share several similarities. In both cases, the problem boils down to not having enough supply to meet the demand. Firms may use similar strategies to protect against SU and DU—for example, they may hold extra inventory, utilize multiple suppliers, or try to improve their forecasts of uncertain events.

It is also important to understand the differences between SU and DU in multi-tier supply chains. The following examples demonstrate that the optimal answer under SU is different than under DU.

Centralization vs. Decentralization

Consider a system with one warehouse that serves N retailers (Figure 1). Under DU, if the holding costs are equal at the two tiers and transportation times are negligible, then it is optimal to hold inventory at the warehouse (a centralized system) rather than at the individual retailers (a decentralized system) due to a phenomenon known as the risk-pooling effect.
Now consider the system under SU. If inventory sites are subject to disruptions, it may be preferable to hold inventory at the retailers rather than at the warehouse. Under the decentralized strategy, a disruption affects only a fraction of the retailers, while a disruption affects the whole supply chain under the centralized strategy. This is known as the risk-diversification effect.

**Inventory Placement**

In a system such as the one in Figure 2, a common question is which stages should hold inventory. Under DU, the tendency is to push inventory as far upstream as possible ("upstream" is to the left in Figure 2), since the cost of holding inventory tends to increase as one moves downstream in a supply chain. Under SU, however, the tendency is reversed: It is preferable to hold inventory downstream, since such inventory can be used to protect against disruptions anywhere in the supply chain.

**Hub-and-Spoke vs. Point-to-Point Networks**

Figure 3 depicts two possible networks for a firm with a single factory wishing to distribute product to multiple retailers. The network in Figure 3(a) is a hub-and-spoke network, with an intermediate warehouse that holds inventory and distributes it to the retailers, while that in Figure 3(b) is a point-to-point network in which the warehouse is bypassed and the retailers hold the inventory. Many firms operate hub-and-spoke networks because of the economies of scale and other savings from consolidating inventory locations. Even absent economies of scale, the hub-and-spoke network is optimal under DU because there are fewer inventory stocking locations, and hence a smaller total inventory requirement. On the other hand, under SU, the point-to-point network is preferred due to the risk-diversification effect: More stocking locations means reduced severity of disruptions.

**Supplier Redundancy**

Consider a single firm with a single supplier. The question here is, what would be the value of adding additional, backup, suppliers? Let’s suppose that each supplier has sufficient capacity to meet a reasonable level of demand. Then, under DU, the value of the backup suppliers is small—they fill in only when the demand exceeds the capacity, which happens infrequently. On the other hand, the backup suppliers play a vital role under SU, since they can provide capacity both to meet demand during a disruption to the primary supplier and to ramp back up after a disruption.
Figure 3. (a) Hub-and-spoke network and (b) point-to-point network. The sites that hold inventory are shaded.

The Cost of Reliability

A firm that is used to planning primarily for DU may recognize the importance of planning for SU but may be reluctant to do so if it requires a large up-front investment in inventory or infrastructure. Fortunately, a small amount of extra inventory goes a long way in protecting against disruptions. Figure 4 depicts the tradeoff between the vulnerability of a system to disruptions (on the y-axis, measured by the percentage of demands that cannot be met immediately) and the cost under DU (on the x-axis), i.e., the cost the firm is used to considering. Each point represents a possible solution, with the left-most solution representing the optimal solution if there are no disruptions. This solution is cheap but very vulnerable to disruptions. On the other hand, the second solution from the left has 21% fewer stock-outs but is only 2% more expensive. In general, the left-hand portion of the curve is steep, suggesting that large improvements in reliability are possible with only small increases in DU cost.

Conclusions

There are two types of uncertainty that require different optimal strategies in terms of centralization, inventory placement, and supply chain structure. In fact, the optimal strategy for dealing with supply uncertainty is, in many cases, the exact opposite from that for demand uncertainty. However, we are not suggesting that firms are currently doing everything wrong. Rather, we are arguing that although demand uncertainty brings about certain tendencies in supply chain management (tendencies toward centralization, etc.), supply uncertainty suggests opposite tendencies that should be accounted for more than they currently are. In practice, both demand and supply uncertainty are present, and the optimal strategy should consider the interaction between the two. Fortunately, we have also shown that it can be relatively inexpensive to shift this balance enough to account for supply uncertainty adequately.

This article is adapted from "Supply and Demand Uncertainty in Multi-Echelon Supply Chains" by Lawrence V. Snyder and Z.J. Max Shen. A working version of this paper is available for download at www.lehigh.edu/~lvs2/research.html.