Managing the Supply-Demand Mismatch with Complementary Product Flows

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A mismatch between supply and demand occurs when demand exceeds available supply, which results in lost sales or backlogged orders, or when demand falls below available stock in the system, which leads to excess inventory in the supply chain. Backlogged orders and excess inventory both increase costs in the supply chain, and the impact of those two prongs of the supply-demand mismatch can be quite significant. In 2001, Cisco, a major networking equipment supplier, had to write off $2.1 billion in excess supply chain inventory. A number of strategies has been implemented in industry to deal with the problem (and cost) of excess inventory. Most of those strategies, such as the popular lean supply chain practice implemented by Cisco in the wake of the 2001 fiasco, leave a company short on flexibility to respond to unexpected increases in customer demand. Thus, from mid-2009 to late 2010, lean supply chain practices made it "impossible for Cisco to ship orders, as sales ramped faster than expected" (Pimentel 2010). By running a lean supply chain, Cisco was unable to respond to rapidly growing sales, thus finding itself on the other prong of the supply-demand mismatch, namely, lost sales and backlogged demand. More generally, what can be observed in industry is that companies and supply chains tend to employ either a strategy to deal with excess inventory, or a strategy to deal with excess demand, but not both.

A similar situation characterizes the literature on supply chain management. Many strategies to help coordinate the supply chain have been extensively explored (e.g., Cachon 2003). Most of those strategies help protect the supply chain from only one of the two prongs of the supply-demand mismatch. Further, managing the supply-demand mismatch has been extensively researched in the context of the newsvendor setting, with two stages in the system and one or two periods in the time horizon. The study of such strategies in multi-stage, multi-period supply models under stochastic demand is sparse.

In this paper, we study a combination of two strategies in the supply chain, in the form of product flow options: one to manage the cost of excess demand, and another to protect against the cost of excess inventory. To deal with excess demand, we jointly manage: regular orders in the supply chain, and the option to expedite downstream shipments and production decisions at any stage in the system. To manage the cost of excess inventory, we allow for returning excess stock upstream at each stage.

To the best of our knowledge, our research is the first to consider a combination of strategies (expedited order and regular orders to downstream locations, and returning stock upstream locations) to deal with the supply-demand mismatch. Lawson and Porteus (2000) were the first to address expediting of items in a multi-stage supply chain, by extending the classical multi-echelon model of Clark and Scarf (1960) to include expediting. Stock returns have been researched in the context of the single-period newsvendor model in the form of buy-back contracts (e.g., Cachon 2003, Krishnan et al. 2005, Chou 2008). However, stock-returns in the context of multi-period, multi-stage supply chains do not seem to have been studied before (e.g, Özer 2011).

Formally, we formulate a periodic review multiechelon inventory model to jointly optimize regular ordering, expedited ordering, and upstream stock return decisions, under stochastic, Markov-modulated demand. We assume backlogging of unfulfilled demand, at a unit backlogging cost, and carry-over of left-over inventory at each stage, at end of each period, at a unit inventory holding cost. There are unit costs for regular ordering, expedited ordering and stock returns at each stage in the system. Our objective is to minimize total expected costs over a finite time horizon. Multiechelon inventory problems are notoriously difficult to analyze, due to curse of dimensionality that is inherent in the multidimensional nature of the problem. Our problem bears extra complexity due to three different order decisions at each stage, each of which depends on the entire state of the system.

Nevertheless, we are able to prove some new results in convex analysis that make it possible to: (i) establish the structure of the optimal policy for this model; and, (ii) show that this form of the optimal policy achieves the Clark-Scarf decomposition of the multi-dimensional problem into a nested sequence of single-dimensional subproblems. These theoretical results make it possible for us to conduct a series of numerical studies concerning cost savings in a variety of supply chains with both expediting and returns of stock. Thus, our third contribution is quantify the value of the options to expedite stock downstream and return stock upstream, when used both individually and together in the supply chain. Finally, we are able to demonstrate that stock expediting and stock returns are complementary, acting synergistically in the supply chain to generate savings in excess of the sum of those obtained by using each of them individually.

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