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Profit Maximizing Network Modeling With Inventory and Capacity Considerations

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INTRODUCTION

Developing integrated strategic, tactical and operational manufacturing and distribution plans for the global supply chain of a large, international firm represents a formidable planning, as well as organizational undertaking. Moreover, to develop and execute plans that are not only *integrated*, but which *maximize profits* on a global basis presents a challenge of far greater magnitude. The use of advanced optimization modeling based analytics can generate keen insights for management decisions regarding sourcing, production, distribution, inventory and demand management on supply chain networks. This includes scenario planning analyses of complex strategic trade-offs such as the optimal balance between inventory levels and reserve manufacturing capacity on a network. The use of these techniques can bring clarity to the complex decisions that make integrated manufacturing and distribution planning both difficult and important (Shapiro 2010).

For purposes of this chapter, we will define "optimization modeling based analytics" as the utilization of mathematical optimization models to provide decision support for supply chain network decisions and management (i.e., models employing linear, mixed integer and nonlinear programming and related heuristic algorithms). Thus, optimization based modeling techniques represent an important component of the overall set of analytic decision support tools that can help facilitate efficient and effective supply chain network planning and management.

In summary, the objectives of this chapter include the following:

1. To review the role of optimization modeling based analytics in supporting a firm's supply chain planning and management activities,
2. To discuss how mathematical optimization models with profit maximizing objective functions fit into a hierarchical framework for a firm's supply chain network planning and scheduling processes,
3. To illustrate how optimization models can support key strategic network design decisions such as the appropriate balance between inventory and manufacturing capacity investment,
4. To review why optimization modeling based analytics will continue to play an increasingly important role in supply chain network decision support and management.

BACKGROUND

Supply chain management mathematical optimization models are the optimal tools for analyzing complex supply chain management problems (Shapiro 2010). In this chapter, we will focus on "deterministic" mathematical optimization models where a model solution is driven by an exogenously given (i.e., pre-determined) forecast. We note that in industry practice, the vast majority of optimization models employed are deterministic.

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Practitioners typically address the potential limitations of using a single, fixed forecast by running their optimization planning models under multiple forecast scenarios, where often probabilities are assigned to each scenario. This approach alleviates the potential limitations of developing a planning solution based upon just one, deterministic forecast (Shapiro, 2010). Examples of potential uses of advanced optimization based analytics are as follows: in planning, the analysis of data to predict market trends of products and production capacity requirements; in sourcing, the use of an agent-based procurement system; and in delivering products, the applications of business analytics in logistics management to bring the products to the markets more efficiently (Trkman et al. 2010).

The methodologies and technology to support integrated profit maximization planning are well established, and the required resources are not exorbitant. In fact, the use of mathematical optimization to support logistics and supply chain management practice can be found in such industries as the oil and chemical industry as early as the 1960s (Miller, 2002) Yet despite early pioneering work in certain industries, this remains an area of terrific opportunity for many firms because surprisingly few employ these techniques in their current strategic and tactical planning processes.

There are several reasons for the underutilization of optimization techniques in supply chain planning. Briefly, factors that have contributed to this relatively slow uptake include:

1. Until the last 15 to 20 years, employing these techniques required that a firm have employees with advanced operations research skills (- note this is no longer a requirement because of commercial software advances)
2. Many senior managers remain relatively unfamiliar and/or uncomfortable with the true benefits of this mathematical technique
3. Many senior managers believe they can make effective network planning decisions without investing resources in optimization tools (- this is related to factor 2 above).

MAIN FOCUS OF THE ARTICLE

A well-constructed and maintained decision support system (DSS) supported by advanced optimization analytics represents a critical tool to facilitate coordinated supply planning and execution. A supply chain planning DSS typically has numerous components (see Liberatore and Nydick, 1998 and 2003, and Liberatore and Miller, 2012) and will vary significantly by firm. For global manufacturing and distribution planning, the inclusion of mathematical optimization models within a DSS structure can represent the difference between a DSS that provides information and a DSS that truly facilitates integrated planning and execution.

Specifically, advanced analytics for global manufacturing and distribution that utilize optimization models which consider all of a firm's manufacturing facilities, distribution locations, transportation routes and modes, and customer demands can facilitate the development, implementation, and maintenance of globally coordinated plans and schedules. A cost minimization methodology represents the most common optimization modeling approach for integrated manufacturing and distribution planning. Particularly in single country domestic applications or in environments where tax rates in local regions do not represent major decision factors, a cost minimization methodology can help formulate an effective integrated plan. However, in planning scenarios where there exist differing local country tax structures, tax rates and intra-company transfer pricing options, cost minimization methodologies generally cannot identify profit-maximizing global production and distribution plans. Instead, profit maximization models that explicitly evaluate decisions such as where to incur tax liabilities and how to set intra-company prices are required to develop the optimal, integrated global manufacturing and distribution plan. An example may help to clarify this point.

Consider a firm that has a global three echelon supply chain consisting of: