European Journal of Operational Research 241 (2015) 435–448

Contents lists available at ScienceDirect

European Journal of Operational Research

journal homepage: www.elsevier.com/locate/ejor

Decision Support

Formation of a strategic manufacturing and distribution network with transfer prices

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ARTICLE INFO

Article history:
Received 12 June 2013
Accepted 21 August 2014
Available online 23 September 2014

Keywords:
Supply chain network design
Transfer pricing
Decision support systems
Logistics
Production

ABSTRACT

We propose a profit maximization model for the decision support system of a firm that wishes to establish or rationalize a multinational manufacturing and distribution network to produce and deliver finished goods from sources to consumers. The model simultaneously evaluates all traditional location factors in a manufacturing and distribution network design problem and sets intra-firm transfer prices that take account of tax and exchange rate differentials between countries. Utilizing the generalized Benders decomposition approach, we exploit the partition between the product flow and the cash allocation (i.e., the pricing and revenue assignment) decisions in the supply chain to find near optimal model solutions. Our proposed profit maximizing strategic planning model produces intuitive results. We offer computational experiments to illustrate the potential valuable guidance the model can provide to a firm's supply chain design strategic planning process.

1. Introduction

The process of establishing a new manufacturing and distribution network or significantly modifying an existing supply chain represents a major challenge for both new or established firms alike. The global dimensions of 21st century business where sourcing, manufacturing and marketing options often exist worldwide compound the complexity of this problem. Consider a firm that wishes to establish a new manufacturing and distribution network (supply chain) to source, make and deliver a product or set of products to an international marketplace. To weigh its options, the firm must first evaluate a set of potential supply chain alternatives from a very high level, strategic vantage point. Then in the supply chain network design process, the firm will consider all traditional supply chain operations factors such as sourcing, manufacturing and distribution costs and capacities, and all freight, duty and tax costs. Additionally, the firm will incorporate the potential impact of exchange rates and intra-company internal prices between different countries and entities on this network. In this paper, we study this decision making process by evaluating all pertinent operational costs and capacities, as well as the impact of exchange rates and tax rates on profits in establishing a global manufacturing and distribution network.

To facilitate a quantitative perspective on this complex decision, we propose a mathematical optimization model that provides decision support and guidance on constructing a supply chain network from a wide assortment of sourcing, manufacturing, and country alternatives. Briefly, our modeling approach allows a firm to develop a set of major production and distribution activities (echelons) that will collectively comprise a complete supply chain from original sourcing locations to final market demand points. The firm can identify and propose as many alternative production and distribution activities as desired. Once the firm identifies all potential activities, the mathematical model generates the optimal supply chain to satisfy the market demand forecast and maximize the firm's profits (i.e., the model creates a comprehensive sourcing, manufacturing and delivery network). Plans generated by the model include a description of how the selected production and distribution activities collectively link together to form this supply chain, as well as the projected output levels of, and flows between all links on the network.

The model also considers the fixed cost of providing support services, for example, any access roads and loading or unloading capabilities that a firm may have to develop. Additionally, the model projects the optimal internal prices between the firm's affiliates in individual countries as they ship the intermediate products and finished goods across the supply chain to the ultimate market destination. Commonly referred to as a transfer price, the internal price is an instrument that the firm utilizes to manage its internal markets, coordinate decisions of autonomous subordinate divisions (often called affiliates), and track division performance. The internal

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http://dx.doi.org/10.1016/j.ejor.2014.08.042
0377-2217/

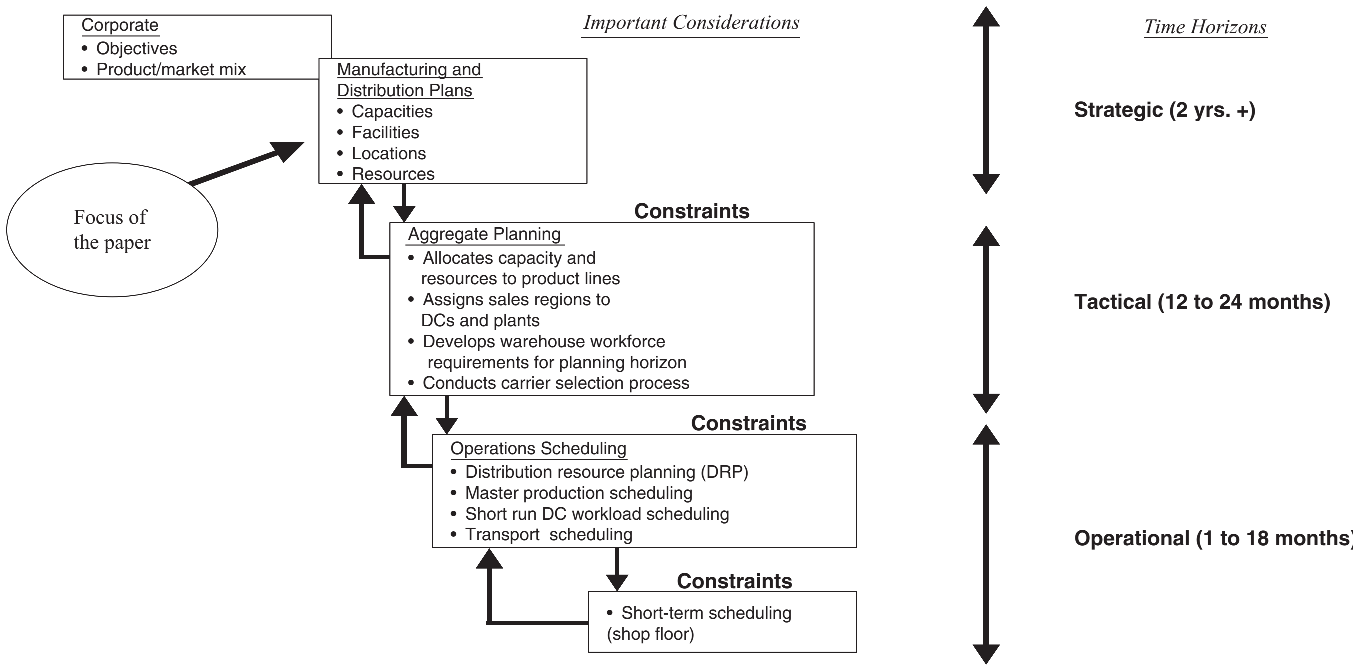

Fig. 1. The hierarchical manufacturing and distribution planning framework.

transfer price is typically determined by using the actual cost of producing the product as a base, and then adding a markup or profit margin to this base to derive the intra-company selling price from one affiliate to another. The actual cost plus a markup is a natural choice to employ as the intra-company price because a market price often does not exist at intermediate stages of production and distribution. Through transfer prices, the firm not only can allocate global profits to its affiliates in producing countries, but also control where affiliates buy their intermediate products. The model's profit maximization methodology also incorporates the impact of exchange rates and local tax rates on the global profit of the firm as calculated at its home office (i.e., country of registry). Thus, our model integrates traditional supply chain network location design decisions with multi-national, corporate intra-company (i.e., inter-affiliate) pricing decisions.

In this study, we formulate the above problem as a mixed integer nonlinear programming (MINP) model. We develop a heuristic procedure to solve the problem. The procedure uses a Benders decomposition-based solution method. Our choice of Benders decomposition is motivated by an observation that there are two distinct but related decisions in our problem, namely the product flow and cash allocation decisions in the global supply chain. Specifically, the product flow pertains to the production and shipment of intermediate products between producing countries and the delivery of finished products to satisfy market demands. The cash allocation decision allocates the revenues to plants (i.e., affiliates) to meet all their costs and also provide them their operating profits. Such a problem structure naturally leads to a primal decomposition scheme which was originally developed by Benders (1962) to solve a linear program and extended by Geoffrion (1972) to solve a non linear program. Here we use Geoffrion's generalized Benders decomposition.

To evaluate the efficacy of our solution algorithm, we conducted a computational study of our model utilizing simulated and actual data based on the authors' experience working with several firms. This study evaluates the performance of our solution procedure and investigates through sensitivity analysis the impact of factors such as currency depreciation, a reduction in the global production capacity, and high demand variability on the supply chain network design and transfer pricing solutions of the model.

Our study of numerous decision scenarios showed the supply chain formed by the profit maximization model was fairly robust under mild changes in the decision environment, and that the optimal transfer prices adjusted to those changes appropriately. Also, we compared the profit maximization solution that our model develops with the cost minimization solution.[1] We found that large currency depreciations, capacity reductions or variability in demand can significantly impact the optimal design of the supply chain networks that are formed (when a profit maximization rather than cost minimization methodology is employed).

We now consider how the model proposed in this paper fits into the firm's overall planning process. As noted, we construct this model to provide decision support to the initial planning efforts of a firm wishing to establish a new supply chain. Alternatively this model could also support analyses of the impact of planned major revisions to an existing supply chain. The mathematical formulation of the Manufacturing and Distribution Network (MDN) model presented in this study reflects the intended "preliminary planning", high level strategic role of this model. For example, we do not explicitly model individual production lines at potential plants or sources. Instead in this model, manufacturing capabilities are modeled as production activities that have a total output capacity, as well as fixed and variable costs associated with this capacity. These production activities can be pieced together to form a complete supply chain. Fig. 1 illustrates this model's strategic role and how it fits into the overall manufacturing and distribution planning framework. Note that at this stage of the planning process, firms typically consider many locations and geographies before determining both the eventual sites for their new facilities and the transportation links which will connect sources, plants and DCs. Our model facilitates the flexibility required at this stage of the decision-making process.

Once a firm determines the exact construction of its supply chain (using the MDN model), the firm would need to utilize more detailed planning models to support additional strategic and tactical planning activities. For example, the Global Profit Maximization (GPM) model

[1] Traditionally a supply chain network design problem is formulated as a cost minimization problem.