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A time staged linear programming model for production loading problems with import quota limit in a global supply chain

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ABSTRACT

Globalization has ushered in a new era when more and more companies are expanding their manufacturing operations on a global scale. This poses some special challenges and raises certain issues. This paper examines production loading problems that involve import quota limits in the global supply chain network. Import quota, which is imposed by importing countries (mostly in North America and Europe), requires that certain types of products imported into these countries are against valid quotas held by the exporters. Globally loading of production, therefore, requires new methods and techniques, which are different from those used in domestic loading of production. This paper presents a time staged linear programming model for production loading problems with import limits to minimize the total cost, consisting of raw materials cost, machine cost, labour cost, overtime cost, inventory cost, outsourcing cost and quota related costs. To enhance the practical implications of the proposed model, different managerial production loading plans are evaluated according to expected changes in future production policies and situations. A series of computational results demonstrate the effectiveness of the proposed model.

1. Introduction

Today's business has inevitably set in a global environment in which materials and products can be bought, manufactured and sold anywhere in the world. Managing supply chains in such an environment has become an important factor for gaining competitive advantages for business organizations. A vast majority of manufacturers have some form of global presence through exports, strategic alliances, joint ventures, or as part of a committed strategy to sell in foreign markets or locate production abroad (Dornier, Ernst, Fender, & Kouvelis, 1998). Although global supply chains have many of the same fundamental functions and concepts as domestic supply chains, the differences are quite substantial and require different managerial approaches and techniques.

This study is motivated by the production loading problems faced by multinational manufacturing companies that participate in global supply chain activities. In the global supply chain, the multinational companies have their headquarters at one place, somewhere in the world. Product sales, R&D and customer service are typically centred in different markets, mainly North America and Europe. However, companies would like to establish production facilities in low-cost countries. Investment destinations have been diverse with production networks now extending to practically all over the world. China (mainland) is so far one of the favourite places for companies because of its low production and labour costs. This kind of global supply chain network plays an important role in today's business.

In the global supply chain systems, one of the most important decisions is loading production among plants, which are typically located in different regions and/or countries. While loading production, companies not only consider cost and capacity in terms of raw materials, machine, workforce, inventory and market demand, but also the import quota limits allowed to the country of manufacture. Import quotas are assigned by importing countries. Quotas control the quantity or volume of certain merchandise that can be imported into North American and European countries. The importing countries allocate a certain quantity of quota to each exporting country. Any products that belong to quota restriction categories have to have the corresponding quotas for the exporting countries. Many developing countries, including China, face restraints on textile and clothing exports to their trading partners that maintain import quotas, including the US, Canada, and European Union. For example, clothing and textile products are divided into 147 categories by the US and 143 categories by the European Union. Dickson (2005) states that not all the exporting countries face the same quota limitations for products. For example, China faces the US's quota limitation in 81 of 147 categories, while for India the figure is 30. At the same time, China faces quota limitation in 61 of 143 categories assigned by the EU, while for India it is 17. Therefore, global manufacturing companies have to consider quota limitations when they distribute manufacturing tasks among

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different plants, which are typically located in different cities and countries. If the quota for a certain category or product is used up in a country or quota price for that product/category is very high, companies may need to find alternatives in other countries that own quotas with reasonable price for the same product. Quota prices fluctuate because of many factors, like changing market demand and government policies.

In this study, we will look at a multinational garment manufacturing company, whose headquarters is in Hong Kong, and product sales, R&D, customer service and consumer markets are spread across North America and Europe. The Hong Kong headquarters collects customer information through its American and European branch offices. Then the headquarters commissions the plants, which are located in Mainland China, Sri Lanka, the Philippines, etc., to undertake the processing work. The finished products are then shipped to Hong Kong for onward shipping to overseas markets. Thus loading production among different plants is a critical managerial task for the company. The aim of this paper is to present a decision-making framework for modelling the production loading problems involving import quota limitation in the global supply chain. The rest of the paper is organized as follows. Section 2 is literature review part. Section 3 describes production loading process in the global supply chain. Section 4 presents a time staged linear programming model for the production loading problems with import quota limits. In Section 5, a set of data from the company is used to test the effectiveness of the proposed model. Different production loading strategies are provided to match different production requirements so that decision-makers can handle complicated changes under the global supply chain management environment. The final section gives the conclusions of the paper and the recommendations for future research.

2. Literature review

In recent years, researchers and practitioners have devoted a great deal of attention to global supply chain management. When configuring global supply chains, additional complicating factors arise such as duties, taxes, exchange rates and trade blocks. Effective management of supply chain activities dispersed throughout the global supply chain results in lower production and distribution costs. There is extensive literature on global supply chain management problems. A great deal of research has been carried out for designing supply chain networks on a global scale. Hodder and Jucker (1985) develop a series of models for an international plant location problem. Hodder and Dincer (1986) further develop a model for analysing international plant location and financing decisions with the considerations of uncertain taxes and currencies in different countries. Cohen and Lee (1989) point out how a company should structure its plants around the world to supply a global market with variations, from country to country, in consumers' expectations, recourse conditions, and cost structures. A survey article, presented by Verter and Dincer (1992), presents a review of modelling issues of international plant location, capacity acquisition, and technology selection. Rosenfield (1996) develops a number of deterministic and stochastic models to determine the number of plants and production levels in a global environment for a firm in order to minimize production and distribution costs for geographically dispersed markets. Arntzen, Brown, Harrison, and Trafton (1995) present a global supply chain model at Digital Equipment Corporation to minimize the cost, including fixed and variable production charges, taxes, duties and duty drawback. This model recommends a production, distribution and vendor network and has saved the company over $100 million. Taylor (1997) presents a model to integrate product choices, considering global plant capacities with an assumption of known unit costs and no trade barriers. Ferdows (1997) emphasizes that country attributes would determine whether a country becomes a manufacturing hub with exports to other countries or a market for imported goods, or both. Vidal and Goetschalckx (1997) present an extensive literature review on global supply chain models, and state that there is a lack of research on mixed integer programming models for the strategic design of global supply chain systems. Goetschalckx, Vidal, and Dogan (2002) present the potential savings generated by the integration of the design of strategic global supply chain networks with the determination of tactical production–distribution allocations and transfer prices, which combines strategic planning and tactical planning in global supply chain networks. Charkravarty (2005) develops a model that optimizes plant investment decisions and determines prices of products by countries. The model also analyses labour costs, transportation costs, demand and import tariff on production quantities, etc. Meixell and Gargeya (2005) review decision support models for the design of global supply chains and access the fit between the research literature in this area and the practical issues of global supply chain design. Goh, Lim, and Meng (2007) model the multi-stage global supply chain network problem, and provide a new solution methodology using the Moreau–Yosida regularization. Rudberg and West (2008) present a concept that describes how companies can manage their international operations so as to facilitate the coordination of their manufacturing networks. Gunasekaran, Lai, and Cheng (2008) analyse the performance of agile manufacturing and supply chain management to develop a framework for responsive supply chain in a networked economy.

Supply chain coordination is increasingly viewed as a source of strategic advantage for participating members (Kulp, Ofek, & Whitaker, 2003). Cohen and Mallik (1997) emphasize that competitive advantages can be achieved through global supply chain management only if the management of the chain's geographically-dispersed activities is effectively coordinated. Coordination is, therefore, the key concept in implementing a global supply chain strategy. Kogut (1985a, 1985b) first describe the importance of global coordination and develop global strategies. Dasu and Torre (1993a) and Dasu and Torre (1993b) study a case covering the affiliates of a US multinational firm in three Latin American countries, concentrating on the coordination problem. A single-period deterministic game theoretical model is formulated to determine the price and sale amount for each firm and this is used in two scenarios: one scenario is in the competitive environment, where affiliates compete against each other as well as with other companies; and the other scenario is in the cooperative environment where the affiliates' activities are coordinated. Different factors related with international activities are considered in the model: these include exchange rates, inflation rates and tariff rates. Ahmadi and Yang (1995) study a parallel-import problem in a global supply chain under the assumption that a manufacturer could implement price discrimination in different markets. Thus parallel importers can buy products in low-priced markets and sell them in higher-priced markets. A major issue for global manufacturing companies is the impact of exchange rates. Lessard and Lightstone (1986) propose a qualitative study on the effect of exchange rate fluctuation in a multinational company. An extensive section of the literature (Cohen & Lee, 1989; Dasu & Li, 1997; Hadjinicola & Kumar, 2002; Tombak, 1995) discusses important factors such as tariffs, taxes, currency exchange rates, shipping costs, domestic resources and demand, and trade barriers. Some interesting works include global manufacturing strategy planning problem (Dyment, 1987; Noori, 1994); global outsourcing problems (Flaherty, 1989; McMillan, 1990); and global services operations problems (Lawrence, 1993; McLaughlin, 1993). A wide variety of production loading techniques have been developed since the early 1950s. An important review about models and methodologies for production loading problems can be found in Nam and Logendran (1992), in which 140 journal articles and 14 books are