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Optimization of production allocation and transportation of customer orders for a leading forest products company

Mehmet Aydinel[a], Taraneh Sowlati[b,*], Ximena Cerda[a], Eric Cope[a], Mats Gerschman[a]

[a] *Centre for Operations Excellence, Sauder School of Business, University of British Columbia, 209-2053 Main Mall, Vancouver, BC, V6T-1Z2, Canada*

[b] *Department of Wood Science, University of British Columbia, 2931-2424 Main Mall, Vancouver, BC, V6T-1Z4, Canada*

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Abstract

A leading manufacturer of forest products with several production facilities located in geographical proximity to each other has recently acquired a number of new production plants in other regions/countries to increase its production capacity and expand its national and international markets. With the addition of this new capacity, the company wanted to know how to best allocate customer orders to its various mills to minimize the total cost of production and transportation. We developed mixed-integer programming models to jointly optimize production allocation and transportation of customer orders on a weekly basis. The models were run with real order files and the test results indicated the potential for significant cost savings over the company's current practices. The company further customized the models, integrated them into their IT system and implemented them successfully. Besides the actual cost savings for the company, the whole process from the initial step of analyzing the problem, to developing, testing, customizing, integrating and finally implementing the models provided enhanced intelligence to sales staff.

Keywords: Mathematical programming; Mixed-integer programming; Production allocation; Transportation; Forest products

1. Introduction

Advances in information technology with changes in political and economic conditions around the world have promoted globalization. Two thirds of today's businesses operate globally [1]. This means that they sell to foreign markets, produce in foreign countries, purchase from foreign suppliers or partner with foreign businesses. Despite the benefits of increased foreign trade and investment for companies including access to more customers and cheaper resources, globalization increases competition. Companies need to have long-term plans and manage their operations and logistics efficiently to remain competitive in a global marketplace. As a result, coordination between production and transportation scheduling and distribution planning has received increased attention in global companies. To minimize the total cost, manufacturing firms should integrate their production and logistics decisions, especially when considering the rising costs of transportation and distribution of finished products.

* Corresponding author. Tel.: +1 604 822 6109; fax: +1 604 822 9159.
E-mail address: taraneh.sowlati@ubc.ca (T. Sowlati).

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Table 1
Total costs summary for the sample weeks (All costs in CDN$)

Week	Model	Actual	Model	Difference	%
1	Fixed-mode	10,575,310	10,338,204	237,106	2.2
1	Open-mode	10,575,310	10,321,092	254,218	2.4
2	Open-mode	7,381,418	7,243,646	137,772	1.9

Transportation planning has often been considered with the location of facilities and warehouses as part of the facility location problem in the literature. The facility location problem is concerned with a decision on the location of plants or facilities to minimize the total fixed and transportation costs while customers' demands are satisfied. Different techniques including branch and bound, Lagrangian relaxation, Benders decomposition and heuristics were used to solve facility location problems [2–5]. Most of the problems in the literature have dealt with a single commodity and product. Pirkul and Jayaraman [4] developed a mixed-integer programming model for a multi-product plant and warehouse location problem to minimize the total transportation and distribution costs and the fixed costs of opening and operating plants and warehouses. In their formulation, customers' orders, which include multiple units of different products, are shipped from potential warehouses that receive the products from several plants. The increased competition resulting from globalization has forced companies to integrate decisions of different functions such as production and distribution systems. Chandra and Fisher [6] showed that an integrated analysis of production and transportation could reduce the operational costs by 3 to 20 percent. A strategic model was developed by Cohen and Lee [7] to analyze the integration of production and distribution systems in a supply chain network. Four submodules, each representing a section of the supply chain, were optimized subject to the service level defined for that submodule. The output of each submodule was used as the input to other submodules. These submodules include material control, production control, finished goods inventory and distribution system control. Martin et al. [8] developed an optimization model that included decision variables for production, inventory and distribution using a linear programming model. Four production plants producing 200 different products for about 300 customers were considered in the optimization and the authors reported a cost saving of $ 2.0 million per year. Many previous studies focused on integrating decisions of different functions of a company and emphasizing on supply chain models to reduce costs, increase customer service level and flexibility. Different reviews on studies of integrated production and distribution systems were published [9–11] that show the importance of the research area and the abundance of related papers. Sakawa et al. [12] focused on a real production and transportation problem of multiple products to minimize the total cost of production and transportation subject to plant capacities and customers' demands. They formulated mixed binary programming problems and used fuzzy programming to solve the problem in a fuzzy environment. Although they considered the production of multiple products at several existing facilities, one vehicle type (truck) was used to transport the products to customers and customers were in the same region in which facilities existed. The integrated production and transportation of a make-to-order manufacturing company was studied by Zhao and Stecke [13]. They provided an optimal production schedule to minimize the total shipping costs of a single product using mixed-integer programming. Eksioglu et al. [14] studied an integrated production and transportation planning problem in a supply chain of a number of production plants producing a single product to be shipped to a number of retailers. They formulated a network flow problem and did not consider any capacity constraints for production and transportation. Using a spreadsheet optimization model, Cunha and Mutarelli [15] proposed a mixed-integer linear programming model to study the problem of producing and distributing a major weekly newsmagazine in Brazil to minimize the total cost of production and distribution. A cost saving of over 7% was reported by the authors. Integrated production and logistics planning in the forest industry also became attractive in recent years. Troncoso and Garrido [16] developed a mathematical model to select optimal location and size of sawmills, forest production and forest freight distribution simultaneously. The model was used to solve a case study in Chile to find the optimal size and location of a new sawmill, and the level of timber production and flows. This paper refers to previous studies on the forest facility location problem and the forest production problem. Carlsson and Ronnqvist [17] described the decision support tools used for supply chain planning in a large forest company in Sweden. They explained five major projects including a production and distribution planning project for a group of pulp mills.

In this paper, we consider a real production and transportation problem where we deal with a multi-product multi-vehicle problem to minimize the total cost of production and transportation subject to production capacities,