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Framework for margins-based planning: Forest biorefinery case study

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ABSTRACT

The biorefinery concept offers a promising solution to transform the struggling forestry industry. Not only will the implementation of new products and processes help to diversify revenues, it will also offer an opportunity to change the manufacturing culture by better managing the flexibility of assets to react to volatile market conditions. In this paper, an integrated supply-chain planning framework is presented. It is based on optimizing a superstructure to help decision makers identify different supply-chain policies to adapt to different market conditions. It integrates revenue management concepts, activity-based cost accounting principles, manufacturing flexibility and supply-chain flexibility in a tactical model to maximize profit in a price-volatile environment. A case study of a newsprint mill implementing a parallel biomass fractionation line producing several biochemicals is used to illustrate this approach. Results and benefits are presented for the traditional pulp and paper business and for the transformed biorefinery in different market scenarios.

1. Introduction

The forest products industry of North America has been facing a difficult economic situation recently. To exit this stalemate situation, some major companies have shown increasing interest in the biorefinery concept, which consists in a more complete utilization of renewable forest biomass to manufacture value-added products such as biochemicals, biomaterials and biofuels, in addition to the traditional production of the industry.

From a forest products industry perspective, investments in biorefinery strategies will represent more than typical capital-spending projects. As stated by Chambost, McNutt, and Stuart (2008), the biorefinery represents at first a diversification of the product and process portfolio, but it will also change the enterprise, its vision, mission and reason for existence. Such transformation decisions should be planned wisely. For instance, environment and social aspects should be somehow included. As well, new marketing, product distribution, production and procurement strategies should be investigated.

According to Thorp (2005), the biggest challenge for the forest products industry will be to move away from the commodity business mentality. Traditionally, this industry is manufacturing-centric: it views process efficiency as the key for low-cost manufacturing and profitability. However, using this strategy, other supply-chain costs are often ignored, resulting in lesser profit, especially in difficult and changing market conditions (Dansereau, El-Halwagi, & Stuart, 2009; Feng, D'Amours, & Beauregard, 2008).

In a transformed biorefinery business, producing high volumes of undistinguished products with low margins will not be sustainable. Indeed, bioproducts will likely face market volatility as they will replace or substitute mainly traditional fossil-based commodities. Their price should ultimately be linked to crude oil and natural gas prices, as fossil products will still dominate the marketplace.

At the same time, biomass prices will increase as the demand for new bioproducts such as biofuels grows (Söderholm & Lundmark, 2009). Moreover, biomass quantities are typically limited per location and over the year, resulting in biorefineries that will be potentially smaller than their petrochemical counterparts.

As an example, Browne, Singbeil, Gilsenan, and Paleologou (2011) compared the biggest Canadian pulp mill with a medium-small sized refinery. The now-closed Shell refinery of Montreal was treating about 130 000 barrels per day (~18 200 ton/day), while the biggest Canadian pulp mill treats about 5000 tons/day of biomass. From this comparison, it is obvious that forest biorefineries will hardly reach the same level of economies of scale as petrochemical sites do, and be able to compete on price based on production efficiency. Biorefineries will therefore have to deal with

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significant margin pressure on both the sales and procurement sides.

To be profitable in the long run, forest biorefineries (FBR) should produce more than one type of products, and especially value-added ones rather than producing solely commodity products (Lynd, Wyman, Laser, Johnson, & Landucci, 2005). In order to better compete in this new market environment but also in the current one, companies should also seek to maximize their margins over the overall supply chain, even if it implies higher manufacturing costs due to increased grade/product changes.

In recent times, considerable efforts have been put on efficient supply-chain management in the chemical process industry. Maravelias and Sung (2008) present an overview of the integration of production planning and scheduling in the process industry. Sousa, Shah, and Papageorgiou (2008) developed a multi-level planning framework where they first design the global supply-chain network of an agrochemical supplier and then optimize production and distribution. Kim, Yun, Park, Park, and Fan (2008) developed an integrated model of supply network and production planning for multi-site refineries. Kannegiesser and Gunther (2011) developed a mathematical model for the global value-chain planning of a chemical commodity manufacturer. Guillen-Gosalbez and Grossmann (2009) address the design and planning of sustainable chemical supply chains in the presence of uncertainty. Feng et al. (2008) developed an integrated tactical planning framework for an oriented strand board company.

The objective of this paper is to propose a margins-based framework that can be used by existing chemical and forest products companies, as well as future retrofitted biorefineries, for maximizing their profitability over the supply chain by a better management of their multi-product portfolio. The framework consists of an integrated tactical planning model based on optimization that aims to maximize profit considering sales and manufacturing flexibilities. A case study of an existing forestry looking for the implementation of a selected promising biorefinery process and product portfolio is presented to illustrate the framework.

The paper is structured as follows. First, five key concepts related to margins-based planning are introduced. The model and case study are then briefly described, the full mathematical formulation being in appendix. Finally, results for different runs of the model, representing different operating policies for both pulp and paper and biorefinery operations, are discussed to show the benefits of this framework and the importance of each concept of the framework.

2. Margins-based planning framework

The key aspects of the margins-based framework are depicted in Fig. 1 and will be further discussed in the following sections.

2.1. Profit maximization

In a margins-based planning framework, the planner should seek to maximize the overall profit of the company rather than just minimizing costs. This aspect is highlighted by Shapiro (2007), who argues minimizing manufacturing costs at the tactical and strategic level is a timid objective: usually, companies have a certain flexibility over the medium and longer term in regards to the level of each product to sell. In this time horizon, a planner has power to play on both terms of the equation *Profit = Revenues − Costs.*

In a typical commodity market, where sales are stable or growing, maximizing throughput and minimizing costs will indeed lead to higher profitability. Orders are fulfilled mostly as requested, and since the product is sold in a standardized configuration, price is the main buying criterion. Therefore, companies compete by being the most efficient in production and distribution channels, and by being one of the biggest suppliers to control the market place.

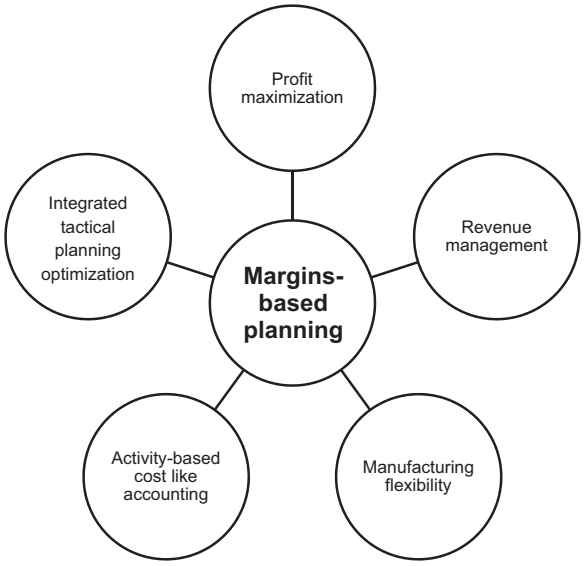

Fig. 1. Margins-based planning framework.

In a declining market such as in the P&P industry, there is a paradigm shift. The demand for P&P products, especially publication paper, is declining. Moving more products to the market place may adversely affect the selling price, and therefore have a significant impact on profitability. Huge efforts must be put to rationalize production and inventory in order to adapt production capacity to the market while still minimizing costs. Controlling sales and keeping the most profitable customers should be sought, but one must be careful as in competitive environments, rejecting sales may result in a loss of a customer to the competitor.

In diverging production processes such as the biorefinery, several products are produced from the same few raw materials. The product portfolio may also contain different types of products, ranging from biofuels, to fine chemicals and specialty biomaterials. Each of these products requires a different operating policy, with a different trade-off between efficiency and responsiveness. Therefore, minimizing production costs only may hinder the opportunity of selling more of the most profitable products. Planning at medium and longer term should rather look at identifying the best equilibrium in terms of sales of each product of the portfolio depending on the market situation. In certain instances, it can be more profitable to sell more of one item of the portfolio, even if it implies more costs.

2.2. Revenue management

Revenue management aims to increase revenues of a company by actively managing demand (Talluri & van Ryzin, 2004). According to these authors, this can be done either by exploiting the differences between customers and their willingness to pay, or by using dynamic pricing strategies to influence actively demand.

In industrial practice, two main types of demand can be distinguished: contract demand, which must be fulfilled, and spot demand, which is transaction specific and may not be repeated. Companies can therefore make active sales decisions on the acceptance or rejection of spot sales requests (Kannegiesser, Gunther, Beek, Grunow, & Habla, 2009). Moreover, each product has a different market structure. For example, a specialty product can be sold to one customer at a certain price and at a different price to another customer because of a different end-use. In a margins-based framework, it is important to identify these different customer segments