Kriging analysis of an integrated demand management process in softwood industry

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Abstract: Objective: This paper aims to develop a basic understanding of a demand management process integrating sales and operations planning (S&OP) and order promising in a Make-To-Stock environment and to compare different demand management policies. Contribution: Typical researches about demand management processes analyze few system specifications or vary few potential factors one at time. Yet, we can get additional insights by employing design of experiments (DOE). Methodology: For making promises, we compare a First-Come First-Served approach to an approach using nested booking limits and giving advantage to profitable customers and attractive periods. Considering various sequences of order arrival, we generate Kriging metamodels that best describe the nonlinear relationships between the simulation responses and system factors for Canadian softwood lumber firms. We employ a Latin hypercube design to take into account different environmental scenarios. Results: Our analysis reveals the potential to improve the performance of the demand management process if we know high-priority customers needs before fulfilling less-priority orders and if we use nested booking limits concept.

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1. INTRODUCTION

1.1 Motivation and background

This research is motivated by the need of Canadian softwood lumber firms operating in a supply-constrained environment and facing heterogeneous and seasonal market, to improve their demand management process and to anticipate how this process will perform in different situations. The dominant thinking currently in the Canadian lumber industry is to maximize the production volume with the available resource, which is constrained by raw material availability and complexity of divergent production processes. Although sawmills are operating at full capacity most of the time, they are not taking advantage from seasonal fluctuations of prices and from the willingness of some customers to pay more for better services. For this end, an integrated demand management process (IDMP) has been proposed by Ben Ali et al. (2014). They integrate sales and operations planning (S&OP) and order promising models, particularly those based on revenue management (RM) concepts. Our paper aims i) to develop a basic understanding of this process facing various sequences of order arrival and taking various market disturbances into account and ii) to compare different management policies.

To efficiently make sales decisions, the impact of relevant factors affecting the IDMP performance must be well understood. Based on multiple meetings with softwood lumber managers, we identify that sales managers have two principal preoccupations: to maximize margin profits and to sell scarce products to the right customer at the right time. The simulation of the IDMP proposed by Ben Ali et al. (2014) offers the possibility to experiment several demand management approaches and to measure the impact of different factors on the IDMP performance. However, it is inefficient to vary factors one at a time (Kleijnen et al. (2005), Montgomery (2009), Law and Kelton (2000)) since it fails to consider any possible interactions between factors and nonlinear relationships. Therefore, using design of experiments (DOE) becomes substantial in order to lead sales managers in softwood industry to good practices in different situations.

1.2 Related literature

S&OP and revenue management in manufacturing:

S&OP is a tactical process which supports cross-functional integration (Oliva and Watson, 2011) and links company strategy and operational planning. Although there is diverse researches available concerning S&OP implementation (Pedroso et al., 2016), systematic revues of Thom et al. (2012) and Tuomikan gas and Kaipia (2014) show that there is still a need for “more in-depth case studies with multiple perspectives to provide a deeper understanding and guidelines for companies to manage the S&OP implementation challenges”. In this context, this paper aims to provide a better understanding of the link between the S&OP and the order promising function, particularly when the organization strategy focuses on customer heterogeneity.

While S&OP makes mid-term decisions, order promising is a real-time problem which has impacts not only on company profitability and customer service level in the short, medium and long term, but also has significant influence on scheduling and execution of manufacturing and logistics activities.
The right customer at the right time. The simulation of the IDMP we identify that sales managers have two principal preoccupations affecting the IDMP performance must be well understood. To efficiently make sales decisions, the impact of relevant factors is significant. From seasonal fluctuations of prices and the willingness of customers to purchase, production processes are constrained by raw material availability and complexity of divergent product flows (generating many products at the same time). Yet, we can get additional insights by employing design of experiments (DOE).

**DOE for simulation systems in supply chain settings and Kriging metamodeling:**

Kleijnen et al. (2005) summarize the main goals of DOE as: 1) developing a basic understanding of a particular simulation model or system by analyzing factor effects, 2) finding robust decisions and 3) comparing the merits of various decisions or policies. Factorial designs (full or fractional) are the most popular DOE used in supply chain settings, but the disadvantage of these designs is that they use a limited number of scenarios. Therefore, using design of experiments (Kleijnen et al., 2005) offers the possibility to experiment several demand management approaches and to measure their performance.

**Contribution and paper structure**

Overall, the contributions of our paper are: (1) we propose a procedure to experiment different demand management approaches and to analyze the behavior of an IDMP facing various sequences of order arrival and taking various market disturbances into account, (2) we employ a design of experiments and we use LHD and Kriging metamodeling to scan relevant market factors on the IDMP performance. The proposed approach is relatively new in theory and in particular for demand management purpose in a supply-constrained environment, such as Canadian softwood firms, to choose the best approach/practice in different market situations.

The remainder of this paper is organized as follows. In Section 2, we describe the industrial context. Section 3 exposes the chosen factors and the response measures. We present the procedure adapted to analyze the behavior of an IDMP facing various sequences of order arrival and taking various market disturbances into account, and to experiment different demand management approaches. Section 4 rationalizes how experiments have been performed and analyzes results, while Section 5 concludes this research and provides industrial recommendations.

### 2. INDUSTRIAL CONTEXT

**Market characteristics:** Confronting various trade and economic pressures, Canadian softwood lumber companies try hardly to remain profitability and to maintain positive profit margins (Dufour, 2007). In this context, the studied firm is an illustrative case inspired by softwood lumber manufacturers located in Eastern Canada. In this region, lumber manufacturers offer their products to Canadian market, Northeastern American market and others. A large portfolio of products is offered to heterogeneous customers, having different attitudes and priorities. Home improvement warehouse companies and housing component manufacturers, for example, are willing to pay more for better services. Other customers, such as dealers and distributors, are more sensitive to price.

**Demand characteristics:** Demand for softwood lumber products greatly exceeds supply. In addition, prices are expected to move higher going into some periods of the year as demand increases. Most of these seasonal fluctuations in softwood lumber prices can be explained by demand seasonality related to construction activities.

**Sawmills/production characteristics:** The studied network is composed from 3 sawmills with the same capacity and dispersed over Quebec province. Sawmills can be considered as an MTS environment as its activities are driven by forecasts. Unlike traditional manufacturing (i.e. assembly) which have a convergent product structure, sawmills have complex transformation processes with heterogeneous raw materials (great diversity in terms of wood quality, diameters, length, etc.), divergent product flows (generating many products at the same time) and radically different planning problems to be solved by each mill.

Although most of the time sawmills operate at full capacity, products are not always available in stock at the right time to take advantage of price fluctuation for many reasons. First, there is almost no flexibility in raw material availability, depending on regulations of forestry activities and on the seasonal nature of harvesting operations, which limits the variation in the lumber sawing process. Second, production operations are complex since divergent processes force different products to be made dependently.

**Actual situation:** Whatever the market conditions, the dominant thinking of the Canadian lumber manufacturers is to produce the maximum volume with the available resource. Production is oriented towards large batches resulting in large inventories, low flexibility and low agility. Ben Ali et al. (2014) have shown the potential profit that can be obtained by taking into account demand/price seasonality and by rejecting orders, not only if
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