



Configuration and evaluation of an integrated demand management process using a space-filling design and Kriging metamodeling

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ABSTRACT

Objective: This research 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 with limited capacity.

Contribution: Typical researches about demand management processes analyze few system specifications or vary few potential factors one at a time. Yet, additional insights can be obtained by employing a space-filling design and Kriging metamodeling for analysis.

Methodology: We compare two configurations of the integrated demand management process. While the First-Come First-Served concept is used at the order promising level for the first configuration, the second configuration uses nested booking limits and gives advantage to profitable customers and attractive periods. Considering various order arrival sequences, we generate Kriging metamodels that best describe the nonlinear relationships between four environmental factors (demand intensity, demand forecast error, customer heterogeneity and coefficient of variation) and three performance measures (yearly profit margin, yearly sales and high-priority fill rate) for Canadian softwood lumber firms. Since our simulation experiments are time-consuming, we employ a Latin hypercube design to efficiently take into account different market situations.

Results: Our analysis reveals the potential to improve the performance of the demand management process if we know high-priority customers needs before fulfilling low-priority orders and if we use nested booking limits concept.

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1. Introduction

1.1. Motivation and background

The Canadian softwood lumber industry is struggling to cope with certain challenges. The industry difficulties are mainly due to the increased cost of woody supply and reduced demand during the last decade [1], coupled with the increased low-cost competition from emerging countries in Asia and Latin America [2]. Moreover, sawmills' profitability can be severely affected by fluctuations in the Canada–U.S. exchange rates and the numerous softwood lumber disputes between Canada and the United States [1].

Canadian softwood lumber companies have employed cost-cutting strategies to maintain competitiveness and profit margins [2]. However, they must be able to remain profitable in situations where markets experience disturbances. This requires a deepened understanding of the market side of the supply chain to take advantage of sales opportunities [3], and an improvement of existing processes by using real-time monitoring systems as well as integrated planning systems [4].

This research is motivated by the need for 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 produce maximal volume from the available resource, which is constrained by raw material availability.

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ability and complexity of divergent production processes. Although sawmills operate at full capacity most of the time, they do not take advantage of seasonal fluctuations of prices and of the willingness of some customers to pay more for better products and better services. To this end, an integrated demand management process (IDMP) has been proposed by Ben Ali et al. [5]. They integrated sales and operations planning (S&OP) and order promising models, particularly those based on revenue management (RM) concepts.

The integration between RM and S&OP is not well understood either in theory or in practice, particularly for Canadian softwood lumber firms. It is unclear how an IDMP, that can be configured differently as presented in [5], can perform facing various order arrival sequences and market disturbances. In fact, Canadian softwood lumber managers are confronted with different challenges such as a change of demand intensity, a rise of demand variability, poor accuracy of demand forecasts and increasingly heterogeneous customers. The simulation of the IDMP proposed by Ben Ali et al. [5] offers the possibility to experiment several demand management approaches and to measure the effect of these environmental factors on the IDMP performance.

Searching for effects by varying factors one at a time is an ineffective means to estimate the factor effects [6–8] since it imposes restrictions on the number of factors and the number of values that these factors can take with a limited simulation budget, and so fails to consider nonlinear relationships. Using space-filling designs, and then Kriging metamodeling, is advantageous as an efficient tool with time-consuming simulation experiments to estimate factor effects on the IDMP performance in different situations.

Our paper aims i) to develop a basic understanding of the IDMP proposed by Ben Ali et al. [5] facing various order arrival sequences and taking various market disturbances into account and ii) to compare different demand management policies. For these purposes, we have to identify: which factors are expected to have the most significant impacts on the IDMP? And how can they affect the performance (improvement or deterioration and in which situations)?

1.2. Contributions and paper structure

Most multi-level decision processes and integrated decision-support systems in manufacturing context are too complex to be evaluated analytically and so have to be studied by means of simulation before implementation. This paper addresses the need to evaluate the ability of a multi-level decision process to face the different factors that could affect its performance. One of the main contributions of this paper is the novel procedure to experiment and to analyze the behavior of an integrated demand management process (IDMP) under a variety of scenarios: we employ a space-filling design and Kriging metamodeling to scan the effects of some relevant market factors on the IDMP performance. To the best of our knowledge, our study is among the few papers which use space-filling design and Kriging in a realistic supply chain setting, particularly to analyze factor effects and to compare different demand management approaches/practices. In addition, as motivated by an industrial problem, the paper discusses the potential implications of this analysis for firms operating in supply-constrained environments, such as Canadian softwood firms.

The remainder of this paper is organized as follows. Section 2 presents the related literature. In Section 3, we describe the industrial context. Section 4 exposes the performance measures, the factors considered in the experimentation and the experimental design. While Section 5 explains the different steps for data generation and analysis, Section 6 presents the analysis results and discusses managerial implications. Finally, concluding

remarks and further research opportunities are provided in Section 7.

2. Related literature

2.1. S&OP and Revenue management in manufacturing

S&OP is a tactical process which supports cross-functional integration [9] and links company strategy and operational planning [10,11]. In fact, it is important to create a specific leadership style and a culture in the organization to ensure integrated demand management and supply chain planning. This required the involvement of all functions in each stage through a continuous mechanism. However, the survey of Wagner et al. [12] shows that organizations' current S&OP performance is underdeveloped and many improvements are indispensable to concretize the alignment process. The lack of participants' commitment and information reliability, the absence of cross-functional integration and a siloed culture are the main barriers that jeopardize S&OP success [13].

Although there are diverse researches available concerning S&OP implementation [13], the role of S&OP as a powerful tool for reaching business targets is mostly absent from the current literature [11]. Moreover, systematic reviews of Thom et al. [14] and Tuomikangas and Kaipia [11] 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 [15]. When all demand cannot be fulfilled, introducing RM in order promising activity can be considered as a powerful tool ensuring higher profitability and forging a stronger relationship with customers less sensitive to price [16]: Order promising concerns how to manage capacity allocation, aggregately set by tactical planning, to different customers and introducing RM in order promising activity consists in protecting capacity reserved for each customer segment by defining booking limits [17]. Regarding application of RM concepts in manufacturing context, two research streams can be distinguished. Within the first stream, the focus is on the implantation of RM in Make-To-Stock (MTS) context [18–20]. A second stream has evolved from more advanced work on Assemble-To-Order environment [21–23] and Make-To-Order environment [24,25].

The relevance of integrating order promising with tactical planning tasks was exhibited in a built-to-order context by Volling and Spengler [26], who explicitly model order promising and master production scheduling as distinct and interdependent planning functions. Ben Ali et al. [5] have taken a further step forward by considering complex transformation processes with heterogeneous raw materials and divergent product structure, mid-term market seasonality and customer differentiation.

Unlike existing studies which dealt separately with S&OP and RM in complex manufacturing situations (See Appendix A and Appendix B), Ben Ali et al. [5] proposed an IDMP including S&OP at the tactical level and real-time order promising based on RM concepts at the operational/execution level (see Fig. 1). This IDMP supports sales decisions in a way to maximize profits and to enhance the service level offered to high-priority customers: First, considering demand and prices forecasts, sales commitments made in previous periods and current inventories, S&OP is executed monthly over medium-term horizon to predetermine supply, production,

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