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Intertemporal stochastic sawmill planning: Modeling and managerial insights

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A B S T R A C T

Optimization models have long been used in the Forest Industry. Here, as well as in other areas, models are used in different time horizons to support planning and scheduling. Guaranteeing the consistency of the production policies in those different time periods is highly relevant for efficiency and demand fulfilment. This paper presents a set of Sawmill Planning Models that cover tactical planning, as well as operational planning. Aggregated planning decisions are modeled in order to determine the log supply for the sawmill. At the operational level, detailed weekly production plans are defined using the actual log supply, which might not be consistent with what was originally planned, due to several variabilities. We address the issue of coordinating short-term decisions with mid-term planning using a two-stage stochastic optimization formulation. Various models with certain variations are proposed in order to simulate all of the complexities that are present in the Sawmill Planning Problem. To test the models, we simulated a special Rolling Horizon method using different demand scenarios. Finally, we present results and managerial insights regarding the effects of uncertainty.

1. Introduction

Intertemporal decision problems are common in many areas of management. A typical intertemporal problem is planning production using monthly data, while the actual production takes place on a daily or weekly basis. In this sense, problems such as these present different levels of aggregation in the different time spans that are adopted. The aggregation of data and other elements is used for two main reasons. The first is because no precise or detailed information is available, especially when referring to the future. The second reason is in order to simplify the problem. One of the main challenges when working with intertemporal problems is achieving a certain level of consistency between decisions that are made using different levels of aggregation and in different time horizons. While an optimization model might predict excellent performance using aggregated monthly data, if demand and production has to be decided on a daily or weekly basis then the detailed production plan might be a complete failure. Furthermore, various sources of uncertainty add to the lack of information, making it difficult to make truly consistent decisions.

This study focuses on questions regarding intertemporal consistency in the context of a real problem taken from the forest industry. The problem consists of planning operations at a sawmill. In this case, the supply of raw materials and manual labor is planned on a monthly basis, whereas production is planned from week to week, depending on the actual availability of the raw materials. This immediately raises questions regarding consistency; especially as monthly planning uses aggregated information and therefore the actual supply of raw materials might differ from the original plan.

Forestry companies have been active users of Operations Research methodologies. In fact, Optimization and Simulation have been widely used in the forestry industry over the last 50 years (see, for example, D'Amours, Rönnqvist, & Weintraub (2009) and Rönnqvist (2003)). In this sense, several issues have already been addressed. These issues include how to make best use of the land and improve planting decisions, as well as how to build roads in order to optimize the transportation of logs from the forests to the sawmill/pulp plants and other facilities. Optimization and Simulation has also been used to look at production planning in sawmills, pulp plants and processed wood facilities, in order to satisfy demands for products in different time periods. Many of such applications are described in D'Amours et al. (2009), Rönnqvist (2003), Epstein, Morales, Serón, and Weintraub (2010).

According to Rönnqvist (2003), decisions in forestry optimization can be divided into three categories. The first of these are strategic decisions, which have a long-term effect (several

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decades), such as planting and facility location. The second category is tactical decisions, involving periods of approximately 6 months to 5 years, such as harvesting planning. The final category consists of operational decisions, which cover a time span ranging from a few days to several weeks and determine the details of the operations. Given this, several issues arise regarding intertemporal planning, and coordinating these decisions represents a significant problem.

The previous characteristics are not exclusive of forest problems, of course. Operations Research models have been used for production planning in many industrial areas (see, for example, Díaz-Madroñero, Mula, & Piedro (2014), for a review) and have been very successful tools. There are differences, however, in the time scope of the decisions, the fact that forestry operations are subject to several seasonal constraints and, specially, the uncertainty that comes from the fact that raw material is of natural origin and evolving over time, making it difficult to classify in advance its final characteristics.

The problem of sawmill production planning is particularly challenging because of various different complexities. With this type of problem, a sawmill company has to decide on the amount and type of logs that it has to buy in order to satisfy a given demand for lumber (the final product). Lumber is produced when logs are cut following certain patterns in order to obtain boards. The yield is the amount and type of lumber that is produced when a cubic meter of a given type of log is cut using a certain cutting pattern. One common difficulty is the level of uncertainty involved in predicting demand. However, there is also variability among production yields because of the inherent irregularities that come, as we mentioned, from the biological nature of the raw material. Furthermore, sawmills are inserted in a network of complex logistic operations, which can lead to additional variability. Traditional manufacturing operations, on the other hand, present more significant variabilities in demand or prices, for instance.

Mathematical models for decision making in a sawmill plant are not new. For example, a model is presented in Maturana, Pizani, and Vera (2010) to decide which patterns (cuts) will be applied over a six-week period. In this study, the log supply is fixed and there is no uncertainty in the data (yields, demands). In Kazemi Zanjani, Ait-Kadi, and Nourelfath (2010) the situation is different; the yields are considered uncertain and the problem is modeled as a two-stage problem.

This problem has also been studied over longer periods of time, such as Alvarez and Vera (2014) and Kazemi Zanjani, Nourelfath, and Aït-Kadi (2010), where operations were modeled over a period of several months and years. In Alvarez and Vera (2014) the amount of logs to be purchased is not fixed and there is no uncertainty in the log supply (i.e. the amount and type of logs that were ordered matched those that were received). In Kazemi Zanjani, Nourelfath, et al. (2010) uncertainty was simulated for both the yield and the demand, while log supply was considered as fixed for each period. The first problem was solved using robust optimization, while the latter was a multistage stochastic model that was solved using a scenario approach.

In this study, uncertainty will not be considered for yield or demand. Instead, it will address short-term uncertainty in the supply of raw materials. Supply uncertainty and variability occur because the purchase of logs involves cutting down certain areas of a forest and the harvest schedule might not be in sync with the demand. Additionally, logistic considerations in the forest operations might lead to changes in the harvest and transportation schedule and the demand for raw material might not be met exactly. Therefore, only an estimate can be given for the amount and type of logs that will be obtained (to the best of our knowledge, this type of uncertainty has yet to be addressed by the literature). This particular situation was observed by one of the authors in a large forest company in Chile and prompted the questions that are explored in this paper.

To help coordinate decisions, we have modeled the hierarchical planning process using a two-stage stochastic approach. This approach uses tactical decisions to calculate the log requirements. Using recourse, these requirements are calculated by taking into account the potential impact they will have on operational decisions, which in turn consider uncertainty in the actual supply. The two-stage model is then simulated in a Rolling Horizon (RH) setting. Two stage models are a viable option for these problems as they have been used in other areas. Alfieri, Tolio, and Urgo (2012), for instance, present a two stage decision model for production and project planning and the approach has been widely used for a long time in the operational planning of power systems, see Pereira and Pinto (1991). Novel applications have been developed also in the management of health system, see Denton, Viapiano, and Vogl (2007).

The paper is organized as follows: The second section presents an introduction to intertemporal planning problems and looks at how they can be modeled using Stochastic Optimization. The third section explains the sawmill planning problem that is central to this study and details the models that are used to solve it. Section 4 explains the RH method, as well as detailing its implementation and how the demand and log supply scenarios were defined. Section 5 presents the computational results for the sawmill planning models and provides managerial insights. Finally, we present our conclusions and recommendations for future work in Section 6.

2. Intertemporal planning and multistage decisions

Intertemporal methods focus on using suitable techniques to allow long-term aggregate planning to “communicate” with short-term disaggregated planning. The popular “Rolling Horizon” (RH) method is one way to achieve this and is widely used in practice. This method supposes that aggregated information is available for long-term planning and that when the short term arrives, real or more up-to-date information can be used for detailed (disaggregated) planning. The results of this detailed planning, as well as any new information, allow the assumptions for the aggregated planning to be updated, with the plan now covering a horizon that has advanced one period in time. An example of a study involving the RH method can be found in Sethi and Sorger (1991).

One of the most obvious ways of modeling these relations is to acknowledge the hierarchy of decisions in different time horizons. Hierarchical planning (see Haas, Bitran, & Hax (1981) and Bitran, Haas, & Hax (1982)) is an approach that was created for solving problems that are too large or complex to be solved by a computer, or that are logically solved by a company in stages. In this approach, an aggregated problem is first solved before the solution to this problem is then disaggregated and used to solve a more detailed problem, which in turn represents the real problem. Zipkin (1980) addressed the issue of obtaining solutions from an aggregated problem and developed bounds to show when a solution to an aggregated problem can provide feasible solutions to a disaggregated problem. Recent studies using this approach include Aghezzaf, Sitompul, and Van den Broecke (2011) and De Araujo, Arenales, and Clark (2007).

Another way to study intertemporal problems involving uncertainty is to use Robust Optimization. This approach is typically used for problems where it is only known that the uncertain