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# Simulation-optimisation based framework for Sales and Operations Planning taking into account new products opportunities in a co-production context

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ABSTRACT

The North American lumber industry produces mostly commodity products (i.e. products with standard dimensions and properties). However, some customers also want products showing very specific characteristics. Because sawing involves co-production (many different types of lumbers are obtained from a single tree), sawmills do not know how the introduction of a new "speciality" product will affect quantities for the other products they also produce. We propose a simulation-optimisation based framework to tackle the kinds of problems such as these, where classical formulations cannot be used. A log breakdown simulator is used in combination with a tactical planning model in order to realise Sales and Operations Planning. The plan gives the information to the decision maker about which orders for speciality products should be accepted, what to produce and when, as well as the equipment settings to use and the raw material to buy/consume at each period. Through an industry-inspired case study, we show how the framework can lead to substantial benefits.



## 1. Introduction

The North American softwood lumber industry produces mainly commodity products having standard dimensions and characteristics (e.g. 2 in. × 3 in. × 8 ft, grade 3). This means that products of any company are interchangeable with those of their competitors. The market of each company is considered limitless, as every product made in each sawmill can be sold on this huge market. However, prices change all year round.

Softwood lumber sawmills show another particularity. From a given unit of raw material (log), it produces several different finished products (divergent process) at the same time (co-production). Companies try to maximise profits by using hardware with embedded software which optimises production value in real time without taking either orders into account or human intervention. The equipment analyses each log and then cuts it adequately in order to obtain the *mix of products* that will generate the highest possible value, knowing they can all be sold on the spot market.

In a particular situation where a sawmill receives a demand for a non-standard product (dimensions and/or characteristics), settings of the machinery have to be modified in order to 'allow' the equipment to produce this customer's specific request. However, it is unclear for the company what quantity of that product will be obtained, given the fact that the decisions of how to cut each log are made in real time by the hardware, based on the expected value of each product, with no consideration for demand. It is then difficult to predict how it will affect the rest of the production and subsequently the overall profit. Additionally, if there are several potential demands for different speciality products, the choice of the contract(s) to accept (i.e. demand to fulfil) becomes a complex combinatorial problem. Moreover, as the commodity products' prices change all year round, the company strategy should differ for each period. Likewise, when the raw material supplied (e.g. dimensions of consumed logs) changes, it is difficult to evaluate its consequences on the mix of products obtained and on the profits.

This paper proposes a decision-making framework based on simulation-optimisation to tackle these problems. It uses a sawing simulator to evaluate how the alternative modifications to the equipment settings and new supplied raw material impact the mix of products obtained. Simulation results feed a multi-period combinatorial Sales and Operations Planning (S&OP) model. This

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model enables determining which orders should be accepted, what to produce and when, as well as the equipment settings to use and the raw material to buy/consume at each period. The main contribution is the methodology combining these two techniques (simulation and optimisation) to select/change plant configurations over time in order to accommodate new products demand without compromising profit, a challenge which is very important and difficult from an industrial point of view.

## 2. Preliminary concepts

### 2.1. The lumber industry

In North America, the lumber supply chain is characterised by some specificities. Logs (corresponding to felled trees that have been limbed and cut to length) are transferred from the forest to a lumber mill log yard.

Logs are processed by the sawmill according to a 'push' production system in order to produce the range of products with the highest possible market value using a fully automated process [1]. Each log generates many products at the same time (it is a divergent process with co-production). At the physical level, when a log is processed by the sawing unit, an optimiser[1] decides which cutting pattern will be used in order to maximise the profitability. The goal of the optimiser is to maximise the value of the log and minimise the material losses. Since North American lumber products are normalised (they are classified by dimensions, length and grades according to the NLGA[2] standard grading rules) there is a limited number of different products that can be produced. Each log is automatically sawn following the recommendations of the optimiser. The decision concerning the cutting pattern is done individually for each log. The decision is not influenced by actual customer orders. For this reason, and because it is impossible to produce a single particular product without getting some other products at the same time (co-production), it is difficult to plan production according to customer orders [2].

However, logs in the yard are usually stored according to their 'class'. Each class corresponds to logs which have similar characteristics. Based on past production data, sawmills are able to estimate the quantities of each product that a log class can produce [3], as shown in Fig. 1. By deciding which quantities of each log class will be sawn at each period, we then have some control over the production quantities of the different finished products we should obtain.

### 2.2. Tactical planning and optimisation models

In standard manufacturing situation, it is considered that there are three different planning levels [5]. Blackstone [6] names them *strategic level* (long-term decision making, e.g. building a new plant), *tactical level* (mid-term decisions, e.g. Sales and Operations Planning), and *operational level* (short-term production planning and scheduling).

Sales and Operations Planning (S&OP) joins together sales, marketing, procurement, development, finance and production around plans [7]. S&OP process can be supported by a mathematical model using linear programming. In the Canadian lumber industry, the main objectives are to determine, in an integrated way: (1) the quantities of raw material to use and which ones to buy, (2) the optimal mix of products to make, (3) the transformation process to use, (4) the whole set of contracts/market

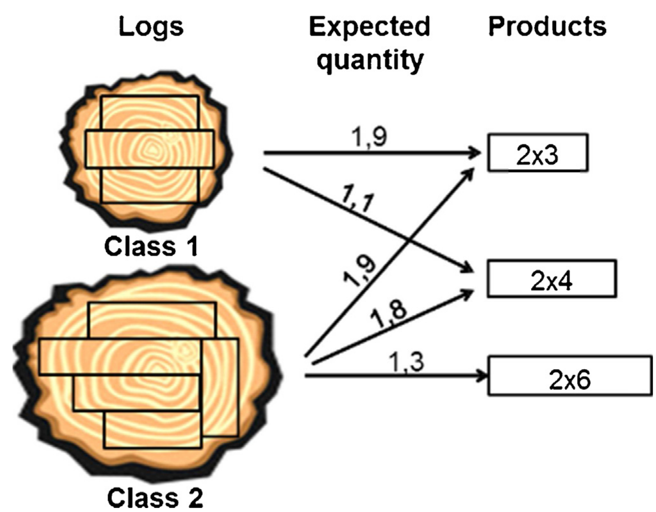


**Fig. 1.** Example of a production matrix, adapted from Gaudreault, Forget, Frayret, Rousseau, Lemieux and D'Amours [4].

opportunities that the sawmill should take. S&OP planning horizon is generally one year (twelve one-month periods or 52 one-week periods). Planning takes into account production lead time, transfer lead times between sawmills and distribution centres, production capacities with the objective of maximising profits. It allows sawmills to foresee the production of its different units, to size resource capacities (humans/machines) if needed and inventories. S&OP replanning is generally carried on once a month and gives the guiding lines and objectives of the operational planning level.

In order to establish a tactical plan, the particularities/physical constraints of the plant must be taken into account. For example, as decisions about how to cut the logs are made in real time by the hardware after scanning the log, it would be illusory to suppose that this decision can be made in advance by the tactical planning model. However, the tactical planning model can be used to decide how the plant will be *configured*[3] at each period, and the quantities of each log class that will feed the sawing unit at each period. In order to do this, we have to 'feed' the tactical planning model with data that allows predicting what the production will be for a given *plant configuration* (settings) and raw material. We can extract this data from the ERP system of the company.

Among authors who have worked on the specific problem of softwood lumber production planning, Maness and Adams [8] have proposed a mixed programming model that simultaneously determines the optimal bucking and sawing policies based on demand and final product price (integration of stem bucking and log sawing). This model was later modified to handle several periods [9].

Taking a more global view of the supply chain, Singer and Donoso [10] presented a model for optimising planning decisions in the sawmill industry. The objective was to demonstrate how collaboration can benefit the partners, by transferring timbers and using the competitive advantages of each. Bajgiran, Kazemi Zanjani and Nourelfath [11], Kong and Rönnqvist [12] use a Mixed Integer Programming model to plan the whole supply chain from harvesting to the delivery. Marier, Bolduc, Ben Ali and Gaudreault [13] developed a mathematical model that allows making the Sales

[1] Software integrated to the hardware
[2] NLGA stands for National Lumber Grades Authority and is the organisation responsible for lumber grading rules and standards in Canada

[3] Each machine from the mill can be configured/set up according to different parameters (e.g.: positioning of the blades, maximum degrees of rotation while processing a log, etc.). Setup can only occur at the beginning of the production shift. The set of the machines setup defines what we call the "plant configuration" that will be used for this production shift.