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An optimization approach for multiperiod production planning in a sawmill

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ABSTRACT

Forest industry plays an important role in the national economic and social context, due to the production volume with significant impact in the region where it is located (northeast of Argentina). Sawmill production planning is a key factor for the development of this industry with serious challenges taking into account the involved interrelated tasks. Assuming a multiperiod perspective, several elements can be considered and more interesting results can be attained. The appropriate procurement of logs is an important part of the problem costs and logging can be improved if the sawmill consumption can be foreseen in advance through an integrated approach. In this work, a mixed integer linear programming (MILP) model for the optimal multiperiod planning in sawmills is proposed. An efficient solution is obtained considering a set of cutting patters (CP) for each type of log that optimize raw material yield. As a result of this optimization, appropriate procurement, distribution policy and stock management of logs can be achieved, as well as suitable production plan along the considered periods in order to fulfil the demand, with significant impact on the sawmill performance and profitability.

1. Introduction

The Argentinean forest industry is mainly located in the north-eastern region of the country (85% of the production, approximately 850,000 ha). More than one thousand forest factories (sawmills, plywood mills, pulp mills, and Medium Density Fibreboard factories) are concentrated in this region, where small and medium-sized enterprises represent 98% of these facilities (Broz et al. 2016). For these reasons, forest industry has a very important role in the economic and social development of this region. However, inefficient production and high transport cost have a negative impact on the competitiveness of this sector.

In the particular case of sawmills, efficient production can be achieved through optimal production planning considering raw materials (logs availability), final products (boards) and demands (customers), taking into account the characteristics of primary products (logs diameter and length), and industrial parameters, among others.

Sawmills convert logs of different diameters and lengths into boards using cutting patterns (CP). A CP is an arrangement of rectangles (thickness and width of the boards) within a circle. Each CP can be applied to logs of different lengths, if available. In addition, different CPs can be applied to logs of the same diameter, producing different amounts of diverse boards, as well as residues. Therefore, the production performance strongly depends on CP selection considering that different yields can be attained and certain product demands must be fulfilled. But also, planning operations at a sawmill involves complex tasks, since several decisions as raw material supply, suitable logs cutting, inventories management and demands satisfaction among others, are simultaneous assessed. Obviously, an efficient cutting operation depends on logs availability, so a proper procurement is a key success factor. Moreover, these decisions lead to various tradeoffs that complicate the problem resolution. Mathematical modeling appropriately allows addressing this problem. Therefore, a mixed integer linear (MILP) programming model for the optimal production planning in a sawmill is presented in this work. The proposed approach addresses all the previous mentioned elements in a multiperiod framework, in such way that all the decisions are simultaneously assessed.

There are many published works dealing with production planning of sawmills. Maturana et al. (2010) present a mathematical formulation for determining the volume and type of logs to be processed assuming that each log is cut according to its optimal CP, i.e. CP selection is not a decision. They consider the production over six weeks, with an ideal scenario of log supply which is then adjusted. Results are compared with a heuristic schedule used by a Chilean company. A similar approach is proposed by Alvarez and Vera (2014) but considering an annual planning period and solving the uncertainties through robust

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Nomenclature

Subscripts

a	Providers
c	Discrete size for trucks
d	Diameters of logs
i	Cross section of boards
l	Length of logs and boards
p	Cutting pattern
t	Time period

Parameters

BM	Big constant
Dis_{dla}	Logs of diameter d and length l available from supplier a (units)
DM_{il}	Maximum demand of product with cross section i and length l (units)
cap_c	Available daily load capacity c (ton)
Cap_{LO}	Minimum percentage of allowed load
$CapS_{il}$	Stock capacity for board with cross section i and length l (units)
$Cprd_{dlp}$	Production cost for CP p applied to logs of diameter d and length l ($/unit)
Crm_{dla}	Unit raw material cost paid for log of diameter d and length l bought to supplier a ($/unit)
$Crmp_{dl}$	Cost for stored old logs of diameter d and length l ($/unit)
$Cset_p$	Unit setup cost for CP p ($)
PM_{ilt}	Minimum production of boards of cross section i and length l required in period t (units)
PV_{il}	Selling price of board of cross section i and length l ($/unit)
t_{dlp}	Operating time for processing a log of diameter d and length l using CP p (h)
ts_p	Setup time for using CP p (h)
$Tmax_t$	Maximum daily operation time for sawmill (h)
φ_{dl}	Weight of a log of diameter d and length l (ton/units)
ρ_{dpi}	Conversion factor: number of boards of cross section i produced when CP p is applied to logs of diameter d

Binary variables

x_{pt}	Indicates whether the primary CP p is used in period t
w_{aclt}	Indicates whether the provider a sends c tons of logs of length l at day t

Continues variables

CPr	Production cost ($)
CR	Raw material cost ($)
CSt	Setup cost ($)
In	Income for sales ($)
Ib_{dlt}	Logs of diameter d and length l stored in period t (units)
If_{il}	Final stock of board of cross section i and length l at the end of planning horizon (units)
Ip_{ilt}	Boards of cross section i and length l stored in period t (units)
It_{dlt}	Old logs of diameter d and length l stored in period t (units)
Pi_{ilt}	Number of boards of cross section i and length l produced in period t (units)
Qa_{dlt}	Logs of diameter d and length l used in period t (units)
Qb_{dlat}	Logs of diameter d and length l delivered from supplier a in period t (units)
Qp_{dlpt}	Logs of diameter d and length l processed in period t (units)
Qt_{dlt}	Old logs of diameter d and length l processed in period t (units)
VF_{il}	Sold boards of cross section i and length l (units)

optimization. In Zanjani et al. (2010), sawmill planning is applied to 30 days horizon time, and the authors also propose robust optimization for solving the problem with random raw material characteristics and yields. They also evaluate the customer service level through back-orders, inventory size and costs. In Lobos and Vera (2016), a decomposition algorithm involving two levels is developed: a tactical planning horizon with monthly information and an operational level with detailed weekly production under supply uncertainty are stated. Pradenas et al. (2013) propose an integer programming (IP) model for determining the number of logs to be cut over a period of several days, according to a set of known CPs, in order to fulfil certain demand. They address two different approaches: one based on a metaheuristic algorithm to determine the number of logs and a constructive heuristic to generate the CPs for each log, while the second one solves the exact IP considering CPs generated by heuristic methods.

Dumetz et al. (2015) propose a discrete event simulation model to evaluate and compare different sawing planning strategies, size of the planning horizon, re-planning frequency, and order acceptation criteria. They state that the presented framework represents a tool for choosing a right production planning and ordering management strategies. Wery et al. (2018) integrate a sawing simulator and linear programming optimization for determining which orders should be accepted, what and when to produce, equipment settings and raw material purchase/consumption at each period. These last references give insights for guiding the decision making process in sawing industry with the aim of improving raw material procurement, stock management of logs and boards, and sales policies. These are also very critical issues for production planning.

Although the production yield strongly depends on the CP selection and use, there are few practical tools that support the CPs generation and, to the best of our knowledge, there is no optimization model that involves all the possible CPs for the sawmill production planning. On the other hand, several final products can be obtained from different CPs, and therefore several tradeoffs must be assessed. In this way when production planning is performed, different decisions must be integrated, as raw material purchase, production, inventory, and demand satisfaction. Moreover, sawmills are embedded in a chain that involves complex logistic operations which must be coordinated.

In particular, when a multiperiod approach is adopted, a better procurement can be achieved. Logging can conform to specific production requirements. The northeast region of Argentina is characterized by very favourable conditions for the development of the forest production. However, the climatic conditions affect the quality of the cut logs by the appearance of spots due to fungi. Therefore, these logs must be processed in a relatively short time after logging. Thus, if a specific logs requirement is available, forest harvest can be planned in order to satisfy this demand: logs can be cut in the required sizes and quantities. Hence, it is necessary to address this problem from a comprehensive point of view for attaining a good supply procurement policy along the time horizon, in order to reach the desired production for fulfilling the required demand. Therefore, a multiperiod approach with a time horizon of several days represents a useful tool for the forest industry as a whole.

Taking into account the cited and revised literature, few works have addressed this problem. Undoubtedly, the specific conditions of the northeast region of Argentine encourage this article. However, the