Introduction

Wood supply chain (WSC) planning has been discussed in several papers. For a recent survey, the reader is referred to D’Amours et al. (2008). The wood supply chain includes various decisions and operations. They range from strategic to operational levels of planning, depending on the planning horizon. The differences in time for each level are not clearly defined and may differ from a problem context to another. Even though wood supply chain planning has helped to ameliorate the performance of forest companies, integrating the needs of different planning problems in the supply chains is still challenging. For example, in customer-oriented and short-term wood procurement planning, it is more important to improve the fit between mills’ demand and the output of bucking operations, than to minimize the operational costs. This would not be possible if tree bucking and wood-supply planning are not synchronized, since some of the supply plans may be infeasible due to the heterogeneity of the forest (see Chauhan et al. (2009)). Arce et al. (2002) proposed a mixed integer linear programming MIP problem that describes a harvest planning problem including forest bucking and transport decisions. Their objective was to maximize the total net revenue at the forest level. In their model, bucking patterns are generated using simple heuristic rules. Even, they limited the number of different products bucked per stand; they did not consider their impact on the harvesting cost.

Chauhan et al. (2009a) presented a short term (e.g., one week) multi-commodity procurement planning problem. They proposed an extension of the procurement model presented in Chauhan et al. (2009) in order to take bucking decisions into account. They used a bulk-process-based bucking, which is a simplification of the real bucking process. They were the first to take into account the impact of the number of different harvested assortments on the harvesting cost.

Epstein et al. (1999) proposed a multi-period procurement planning problem including cut block scheduling, bucking and transportation activities. The developed method relies on a decomposition technique where bucking patterns are generated in the sub problem and included in the master problem during the optimization process. As noted by many authors, this decomposition approach is theoretically correct and computationally efficient (Laroze
A.J. (1993), Sessions et al. (1989)). However, it is difficult to implement because of operational constraints such as the generation of a large number of cutting instructions and the difficulty of subdividing the stand into different stem classes.

Karlsson et al. (2003) proposed a MIP model to solve a wood procurement problem integrating transportation and road maintenance annual planning. In this short-term harvest planning problems, bucking patterns are not considered because cutting instructions are provided by the harvesters’ on-board computers.

In the same line, Bredström et al. (2010) presented a MIP problem closely related to the problem described Karlsson et al. (2003). The model integrates the assignment of machines and harvest teams (crews) to harvest areas and the scheduling of the harvest areas during the year for each machine. They propose a two-phase solution approach where, first the assignment problem is solved then they consider the scheduling.

In our first project, we propose an annual wood-procurement plan that respects the harvesting practices used in Eastern Canada. The decisions in the model incorporate bucking and transportation activities. Bucking optimization is based on the customer demand and generates adequate bucking patterns using a priority-list approach. The model includes a harvesting cost function that considers the nonlinearity of the harvester productivity function. This is an important issue of the decision-making process in forest management (Arce et al. (2002)). We present a comparison between different bucking scenarios in order to support decision makers develop a more efficient forest procurement system.

In the second project, we present a multiperiod multicommodity wood procurement planning problem with multiple sources of supply (cut blocks) and multiple destinations (sawmills). It generates an annual wood-procurement plan that respects the harvesting practices used in Eastern Canada. The procurement planning integrates bucking, transportation and inventory decisions. The model aims to extend the procurement problem presented in our first project in order to take multi-periodicity into account. In fact, we use the same priority list approach developed in Dems et al. (2013) to generate bucking patterns that are practical and easy to implement. We also use the same formulation of the harvesting cost, which takes into account the non-linearity of the harvester productivity function.

**Executive Summary**

**PROJECT (1): EFFECTS OF DIFFERENT CUT-TO-LENGTH HARVESTING STRUCTURES ON THE ECONOMIC VALUE OF A WOOD PROCUREMENT PLANNING PROBLEM.**

We develop a mixed integer linear model for a practical multi-facility wood-procurement planning problem using a cut-to-length (CTL) bucking system. This forest management problem is difficult to solve since it integrates the forest bucking problem and the multi-facility supply planning problem. A priority-list approach was used to generate adequate bucking patterns in the Eastern Canadian context.

The model provides decision support with respect to how to harvest the different cut-blocks according to the bucking priority list used, and in what quantities harvested logs
should be transported to sawmills. It aims to minimize the nonlinear harvesting cost, the transportation cost, and the inventory cost and to maximize the product value (i.e., profit maximization). The harvesting cost considers the nonlinearity of the harvester productivity function, which is an important aspect of the decision-making process in forest management.

The model was used to compare the current bucking scenario to two new possibilities. These scenarios allow us to investigate the gains and losses that arise from the use of different bucking aggregations. Specifically, we consider the impact on the number of different log types per block and thus on the associated harvesting cost. Moreover, we aim to better understand the cost/benefit trade-offs of a more complex decision structure in a Canadian wood-procurement context.

The model provides a good solution for a realistically sized problem, within a reasonable time limit. The two new scenarios generated a larger profit (between 5% and 11% higher) than the base scenario (forest aggregation). A loss of value occurs in various stages along the forest-to-mill value chain: the harvesting cost, the inventory management, and the order-fulfillment level.

Scenarios 2 and 3 induce a decrease in the number of different products per block, which generates a potential decrease in the harvesting cost (≥3%). The results of the scenario tests showed that forest bucking aggregation (the current practice) significantly reduces the company’s profit. A simple bucking disaggregation that does not increase the operational cost can improve the outcome. To conclude, we believe that strategic changes to the harvesting structure without shift in the technology in use, in the form of the disaggregation presented in scenarios 2 and 3, would be profitable for forest companies. However, we recognize that the priority-list bucking approach is effective for the relatively simple, but realistic, market restrictions considered in this project.

Future research could extend the model to consider a multi-period wood-procurement plan for a cut-to-length (CTL) bucking system using sort yards which we will present in the next project.

PROJECT 2: SOLVING AN INTEGRATED MULTI-PERIOD WOOD PROCUREMENT PROBLEM

The problem we consider is a practical multiple period wood procurement planning problem from the perspective of Eastern Canadian context. Within this context, forest cut blocks are large, heterogeneous and have different densities, and diameter class of trees. The total planning horizon considered is one year, divided into 12 time periods (months).

This forest management problem is difficult to solve since it integrates two inter-related problems: the forest bucking problem using a cut-to-length (CTL) bucking system and the multi-facility supply planning problem. In fact, the choice of areas to harvest in each period and how to harvest it, affects the amount of different assortments provided to mills. The main decisions deal with which areas to harvest during each period so that orders from various wood-processing facilities, located in distant places are satisfied. Moreover, the model provides decision support with respect to how to harvest the different cut blocks according to the bucking priority list used, and in what quantities harvested logs from each
block should be transported to sawmill. Also, the model was used to compare the current planning procedure to a new planning one. The new strategy presents a centralized inventory management policy.

In this project, we extend the procurement model presented in DEMS et al. (2013) in order to consider a more detailed multiple period planning. We develop a mixed integer linear model describing the problem (MIP) that we solve using Cplex. We are still working on the computational results from an Eastern Canadian forest company.

**Fit within Network Research Theme(s)**

Our research work fits more within the fourth VCO Research team: Value Optimizing, Scheduling and Control. The two projects were done in collaboration with *FPInnovations*. Mr. Jean Favreau and Mr. Sebastien Lacroix from FPInnovations proposed the first optimization problem and provided costs and operational data. For the second project, we work in collaboration with Mr. Jean Favreau.
References:


