INTRODUCTION
Biorefining is now recognized as a promising solution to transform the pulp and paper (P&P) industry and to generate value-added pathways. The implementation of new products and processes will help companies to diversify revenues, but involves several strategic changes in the business model. Companies will face the dilemma of exiting or not the traditional P&P operations, while selecting their biorefinery product and process portfolio. They will also have to enter new markets and manage production to minimize the risk of market volatility.

The objective of this project was to propose and illustrate an integrated supply-chain planning framework based on optimization for the management and the evaluation of forest biorefinery strategies. This framework, called margin-based, integrates principles from revenue management, activity-based cost accounting, and manufacturing flexibility in a tactical planning model that maximizes the profit of a company.

METHOD
The framework was developed in close collaboration with a Canadian P&P company in order to represent as closely as possible, the different activities of the company. Through interactions with the industrial partner, mathematical and cost models that enable the representation of different process configurations leading to manufacturing flexibility were developed. This tool model was then used as a platform for evaluating various operating strategies of a company, at both production and supply-chain levels.

A case study of a newsprint mill implementing a parallel biomass fractionation line which produces several bioproducts was used to illustrate the approach (Figure 1).

RESULTS AND DISCUSSION
At the strategic level, the planning tool was used to evaluate the profitability of a company during the transformation to the biorefinery by taking into consideration the gradual divestment in P&P activities, while implementing a new biorefinery process.

Both strategic and tactical level analyses were conducted to show the relevance of the framework as a decision-making tool for management problems related to the forest biorefinery.
by providing insights that help develop a phased implementation strategy for the transformation to the biorefinery. As an example of the different model outputs, Figure 2 shows the manufacturing costs and their source of different mill configurations.

![Figure 2: Manufacturing costs of different mill configurations](image)

At the tactical level, the tool was used to study the management of a product portfolio to mitigate the risk of market volatility. One analysis focused on the exploitation of thermomechanical (TMP) and deinked pulping flexibility in order to minimize the cost of raw material procurement in different market conditions. Another analysis examined the impact of feedstock and production flexibility of a fractionation process on sales and profitability.

Results of both case studies show that the procurement and production needed to manufacture the product mix that provides the optimum margins vary significantly. P&P and biorefinery processes can have complex interrelations that make dynamics and trade-offs between manufacturing options difficult to identify and understand.

For the P&P case study shown in Figure 3, adapting the pulp mix according to market conditions resulted in a profitability increase by up to 35% in certain instances, compared to using the standard recipe.

![Figure 3: Optimal TMP mix in paper machines to maximize profitability in changing market conditions](image)

Results of the biorefinery case study show that, in a context where sales can be varied to a certain level, it may be beneficial to pay more for certain types of biomass if they offer a product portfolio mix with higher revenues.

**CONCLUSION**

The future environment in which biorefineries will evolve will be highly competitive. Successful biorefineries will be those that manage optimally their assets and their supply chain to ensure the most profitable products are manufactured. The development and application of integrated planning tools could greatly help the transforming North American forestry industry to compete globally.

**FURTHER READING**
