Model and solution method for an integrated value chain problem for sawmills

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Overview

1. Problem description
2. Optimization approach
3. Heuristical solution approach
4. Literature
5. Numerical experiments
6. Conclusion and outlook

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Problem description

Goal

Optimization of the Canadian value chain from forest to customers passing four production units

- harvesting unit
- sawing unit
- drying unit
- finishing unit

with a mixed integer program including detailed dry kiln scheduling.

Problem description cont'd

Context

- Solving on a tactical level
- Satisfying demand for specific products
- Problem of co-production in sawing and planing, e.g. chips, sawdust and shavings
- Characteristics of MIP model which makes it difficult to solve; symmetric with respect to drying units, high flexibility in flows, weak LP formulation
- LP model for solving material flow from forest to customers and between sawmills
- IP model for detailed dry kiln schedule solved as a sub-problem with an IP model and is fed to the MIP model as good starting solution
- Decomposition to solve large scale MIP problem

Motivation

Value Chain from forest to customers

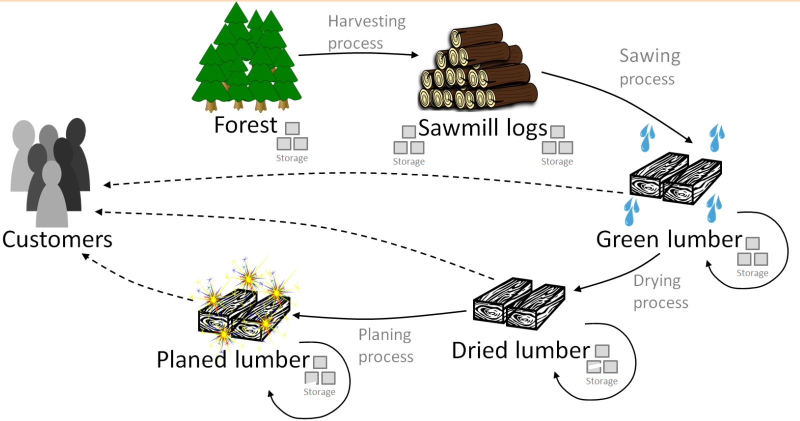

Figure : Integrated value chain problem for sawmills

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Mixed integer program

MIP model

- Maximizing revenue of delivered products, profit of green, dried and planed lumber minus sum of costs (harvesting, sawing, drying, planing, transportation and inventory costs)
- Capacity constraints
- Inventory constraints
- Demand satisfaction constraint for green, dried and planed lumber
- Binary constraint for dry kiln scheduling

Model properties

Characteristics

- Divergent and complex problem
- Symmetric with respect to drying units
- High flexibility in flows
- Weak LP formulation
- No solution in reasonable amount of time

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Split heuristic

Heuristic based on time composition

1. Divide the planning horizon into n **equal intervals** with length k
2. Solve problem P_j and get the solution and keep **binary variables**
3. Set these binary variables equal to 1 and add them as **new constraints** in the problem P_{i+1}
4. Solve the problem P_{i+1} and get the solution and keep binary variables
5. Increment i, $i = i + 1$
6. If $i > n$ then stop
7. Go to step 3.

Split heuristic cont'd

Divided planning horizons

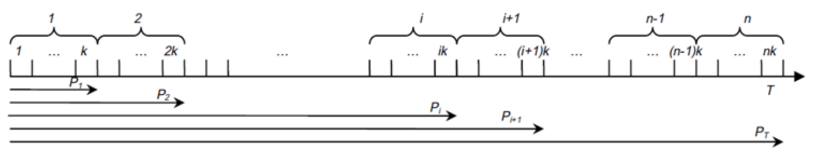

Figure : Time decomposition over the planning horizon to solve overall model

LP relaxation heuristic

MIP based heuristic

1. Solve **linear relaxation** of problem.
   Get optimal supply plan and fix all continuous variables
2. Solve **MIP-based heuristic** to fix kiln drying batch decisions
3. Resolve original model while **fixing integer kiln drying decision variables**

LP relaxation heuristic cont'd

Solution phases

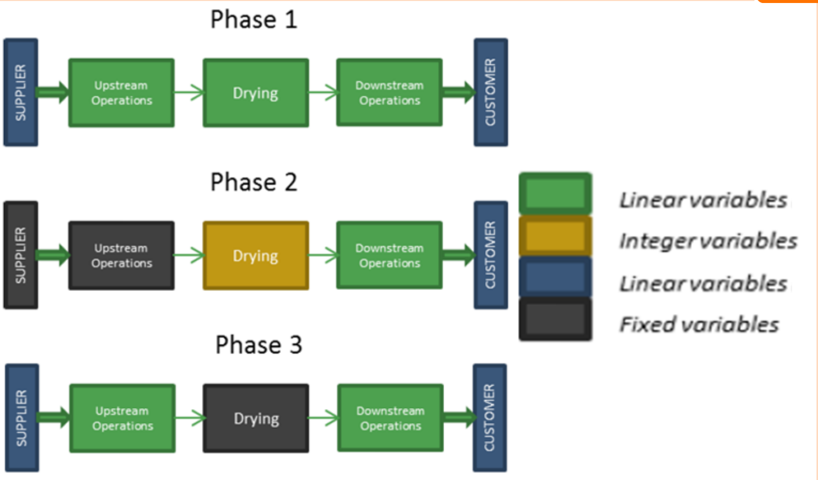

Figure : The three phases method

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Literature

Heuristic solution approaches

Two different approaches:

- Time decomposition
  - Ouhimmou, M., D'Amours, S., Beauregard, R., Ait-Kadi, D., and Chauhan, S. S. (2008). Furniture supply chain tactical planning optimization using a time decomposition approach. *European Journal of Operational Research*, 189(3):952–970
- LP relaxation
  - Chauvin, D. (2014). La comptabilité par activités appliquée aux scieries pour la planification de production et la valorisation des produits. Master's thesis, Université Laval

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Data

Case study

- 5 forest
- 4 saws
- 6 dry kiln
- 63 periods
- 9 log types
- 23 green lumber
- 21 dried lumber
- 85 planed lumber
- 4 customers
- 4 harvesting processes
- 39 sawing processes
- 6 drying processes
- 3 planing processes

Data

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Complexity of problem

```
Presolve eliminates 0 constraints and 11088 variables.
Adjusted problem:
573111 variables:
        9072 binary variables
        564039 linear variables
142665 constraints, all linear; 2882445 nonzeros
        39675 equality constraints
        102990 inequality constraints
1 linear objective; 483147 nonzeros.

CPLEX 12.6.1.0: mipdisplay 2
```

Solution

Contribution margin and share of the optimal solution in %

	CAD	%	runtime
MIP model	1,584,390	100	$\sim$ 154 min
Split heuristic	681,885	43	$\sim$ 5 min
LP relaxation heuristic	1,382,620	87	$\sim$ 9 min

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Revenue, profit and cost of the heuristics in %

	revenue	profit	cost
Split heuristic	43	33	33
LP relaxation heuristic	87	82	84

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Conclusion and outlook

Conclusion

- Value chain from forest to customer satisfying all orders
- Bucking decision at forest in model
- Introduction of dry kiln planning on the tactical level
- Reduction of computational time by about 95 % with heuristic approach
- 87 % of optimal solution with heuristic

Conclusion and outlook

Conclusion

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Outlook

- Including bin packing problem into drying constraint
  - Stacking restrictions
  - Placement restrictions
  - Heterogeneous batch loads
- Comparing Canadian case to an Austrian case
- Expanding the value chain to additional subsequent processing users

Thank you for your attention!

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