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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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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Heuristic solution approaches

Two different approaches:

- **Time decomposition**

- **LP relaxation**
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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
## Contribution margin and share of the optimal solution in %

<table>
<thead>
<tr>
<th>Method</th>
<th>CAD</th>
<th>%</th>
<th>runtime</th>
</tr>
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<tbody>
<tr>
<td>MIP model</td>
<td>1,584,390</td>
<td>100</td>
<td>~154 min</td>
</tr>
<tr>
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<td>43</td>
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### Revenue, profit and cost of the heuristics in %

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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

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
Conclusion and outlook

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Thank you for your attention!