When taking your time is the best approach for improving logistic performance

FEC 2018
Rotorua, New Zealand

Luc LeBel, Director, FORAC
Edith Brotherton, PE, MBA
Marie-Lou Gravel, FE, MBA
Context and objectives

- In its attempts to **reduce procurement cost ($)** and **decrease GHG emissions**, a large pulp and paper mill is deploying a data acquisition system to monitor environmental conditions and truck movements.

- In this project, our team builds on this data to determine …
  1. **how to use satellite woodyards** as processing nodes in the forest to mill delivery system
  2. **the best utilization of its transport fleet given strict or adaptive seasonal weight restrictions.**
Industrial partner for this project

Integrated P&P mill
642 000 tonnes/yr paper
447 000 tonnes/yr pulp
In a previous woodyard study

- We compared the existing network with a new SC design (sorting and transit yard) that would serve multiple business entities having different wood fiber requirements,

- Results showed significant gains in GHG and $ reduction (+/- 10%). But...

Can something be done NOW for one company?
Best practice #4: Make the most out of available transport capacity

- Emphases that by using a good turnover in the woodyard, wood humidity could be reduced by 3-9%
- Using a mixed fleet of trucks (regular, off-road, b-train) can also improve loading without exceeding legal loads capacities
Fiber procurement challenge

- Transport cost accounts for up to 30% of fibre procurement

>1.8 Million Tonnes per year
over 200 trucks per day
Trucking distances extend beyond 300 km
Inbound roundwood loads
Potential woodyards (in yellow) and the one selected for case study (green square)
Weight restrictions

- In effect from March to June for each zone, depending on data from weather-road station (determined by the government)

Zone 3
- April 16 to June 15

Zone 2
- April 2 to June 1

Zone 1
- March 5 to May 4

Source: ministère des Transports, de la Mobilité durable et de l'Électrification des transports au www.transports.gouv.qc.ca
## Comparison of existing models (1/2)

<table>
<thead>
<tr>
<th>Reference</th>
<th>Objective function</th>
<th>Advantages</th>
<th>Gaps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almeida Sfeir T., Pecora J. E., Ruiz A., LeBel L. (2016)</td>
<td>Cost minimization (transport, handling and operations of yards).</td>
<td>Includes:</td>
<td>- Costs penalties for wood drying and thawing restrictions in the variables makes it hard to compute the number of trucks (required for the fuel and GHG estimates)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- weight restrictions during thaw season using Québec thawing zones</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- wood drying</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- truckloads</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- moisture curves for wood drying in yard</td>
<td>- No concept of &quot;truckload&quot; which is critical to evaluate the fuel consumed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- additional cost of maintaining operations in the forest</td>
<td>- No concept of thaw period</td>
</tr>
</tbody>
</table>

When taking your time is the best approach - FEC 2018
New Zealand
## Comparison of existing models (2/2)

<table>
<thead>
<tr>
<th>Reference</th>
<th>Objective function</th>
<th>Advantages</th>
<th>Gaps</th>
</tr>
</thead>
</table>
| Morneau-Pereira M., Arabi M., Ouhimmou M., Gaudreault J., Nourelfath M. (2014). | Maximization of overall value ($) | - Scalable for large-scale projects (industrial data)  
- Tested, validated and used previously | - Maximization of the value, not minimization of GHG |
| LogiLab | Maximization of overall value ($) | - Developed internally (technical support available)  
- User-friendly platform no programming required to enter a new case.  
- Concept of truckload partially integrated (platform in evolution) | - Was not designed initially to consider the humidity and drying (but processes at customizable) |
max \sum_{t \in T} \left( \sum_{p \in P} \sum_{u \in W_{Tu}} D_{up} \left( e^{-t} \right) \right) = \sum_{u \in E} \left( \sum_{p \in P} \sum_{e \in W_{Te}} c_{ep} F_{ep} \right)

Sujet à :

\sum_{t \in T} \left( \sum_{w \in W_{Tu}} \sum_{k \in K} \gamma_{pw} Y_{kwu} \right) + \sum_{e \in E} \left( \sum_{k \in K} \lambda_{keu} Y_{kwu} \right) - \sum_{w \in \mathbb{Z}} \alpha_{pw} Y_{kwu} - \sum_{e \in E} F_{ep} - D_{ep} = 0 \quad \forall t \in T, u \in U, p \in P

D_{ep} \leq d_{ep} \quad \forall t \in T, u \in U, p \in P

\sum_{w \in W_{Tu}} \sum_{k \in K} \gamma_{pw} Y_{kwu} \leq \eta_{ku} \quad \forall t \in T, u \in U, k \in K

f_{et} \leq \sum_{p \in P} F_{ep} \leq f_{et} \quad \forall t \in T, e \in E

f_{et} \leq F_{ep} \leq f_{et} \quad \forall e \in E, t \in T, p \in P

Y, D \geq 0
LogiLab network optimization model

Considering:

• Available wood from different areas (45 areas)
• A heterogeneous transport fleet (3 types of trucks)
• One yard for wood transit/conditioning
• Thawing period zones
• A variation in wood moisture level that depends on (1) the timing of the delivery and (2) the time spent in a yard

It must be determined:

• When to deliver each wood supply area
• If the loads must transit (or not) by a woodyard
• How many periods logs stay in the woodyard
• What truck configuration to use (to and from the woodyard)
Multiperiod mathematical model to solve

A set of suppliers (forest)

- Which source and quantity
- Which period of delivery (H%)

A customer (pulp and paper mill)

- Direct delivery from forest
- Deliver to a woodyard
- Deliver from woodyard

Process at the woodyard: drying

- Time periods at woodyard
Wood moisture content (source deliveries)

- Historical data from the paper mill provided moisture level of delivered wood over the year (considering usual harvesting).

Moisture level profile through the year
Modelling the drying process (woodyard)

- Empirical study in a woodyard over 26 weeks to develop a specific wood seasoning model of weight reduction using weather station data.

![Graph showing moisture variation over time with a label indicating 36 samples per pile in the yard.](image)
Scenarios

Scenarios differ in regard to flexibility. One or more parameters are allowed to change:

A. Range of delivery periods allowed per area (supply zone)
B. Quantity delivered per period and per area
C. Destination (for each area)
D. Quantity delivered per period from the yard

This way it becomes possible to observe the gains obtained for each level of flexibility.
Results
(Scenarios with fixed destinations only)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>TruckLoads</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Forest to Mill</td>
<td>Forest to Yard</td>
</tr>
<tr>
<td>S1 : Base Case</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>S2 : Optimal Drying</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed Deliveries/Source</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>S3 : Optimal Drying</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal deliveries</td>
<td></td>
<td><strong>-3.3</strong>%</td>
</tr>
<tr>
<td>Fixed Destinations</td>
<td>Fixed Period Range</td>
<td></td>
</tr>
<tr>
<td>S6 : Optimal Drying</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal deliveries</td>
<td></td>
<td><strong>-3.5</strong>%</td>
</tr>
<tr>
<td>Fixed destinations</td>
<td>Fixed Period Range</td>
<td></td>
</tr>
</tbody>
</table>

Gains obtained from wood « taking time » in the yard (optimal duration of drying)

Higher gains when optimizing the flows from the forest in an integrated planning model (initial wood moisture)

*For comparison purpose, we give a reference value to the S1 scenario with historical flow to 0.
Results
(Scenarios with fixed destinations only)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Thawing periods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Truckloads</td>
</tr>
<tr>
<td>S1 : Base Case</td>
<td>*</td>
</tr>
<tr>
<td>S6 : Optimal Drying Optimal deliveries Fixed destinations</td>
<td>C1 : -100%</td>
</tr>
<tr>
<td></td>
<td>C5 : +150%</td>
</tr>
</tbody>
</table>

*For comparison purpose, we give a reference value to the S1 scenario with historical flow to 0.

- Truck type not used during thawing period
- Better fleet utilization during thawing period (more trips with shorter distances)
Conclusion

When taking your time is the best approach to improve logistic performance

• Actual results indicate a 5% reduction in the number of truck movements.

• This is conservative. Managing wood humidity should not be limited to wooyard operations. Gains could increase by relaxing constraints concerning wood to mill and wood to yard deliveries.

• Better data acquisition system for weather, wood condition, road bearing capacity, traffic,… will allow to obtain the above benefits and some more.

• Industry 4.0
When taking your time is the best approach - FEC 2018
New Zealand
Follow-up project

- Dedicated wood-flow corridor
References


• LogiLab platform [https://www.forac.ulaval.ca/transfert/plateformes/logilab/](https://www.forac.ulaval.ca/transfert/plateformes/logilab/)