FORAC

FOREST TO CUSTOMER

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

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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

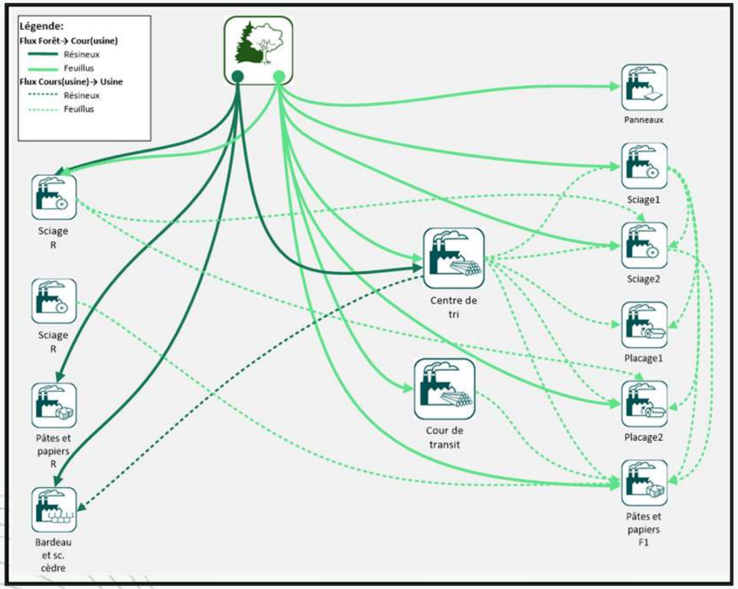
Integrated P&P mill

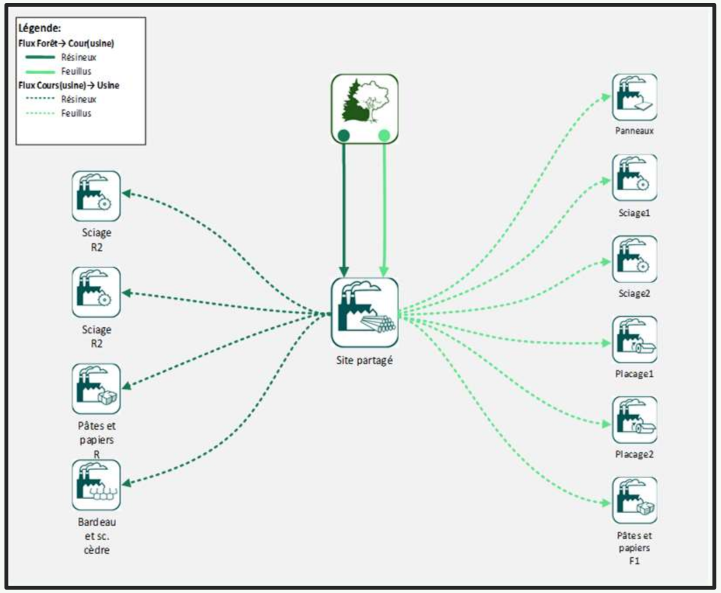
642 000 tonnes/yr paper

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…**



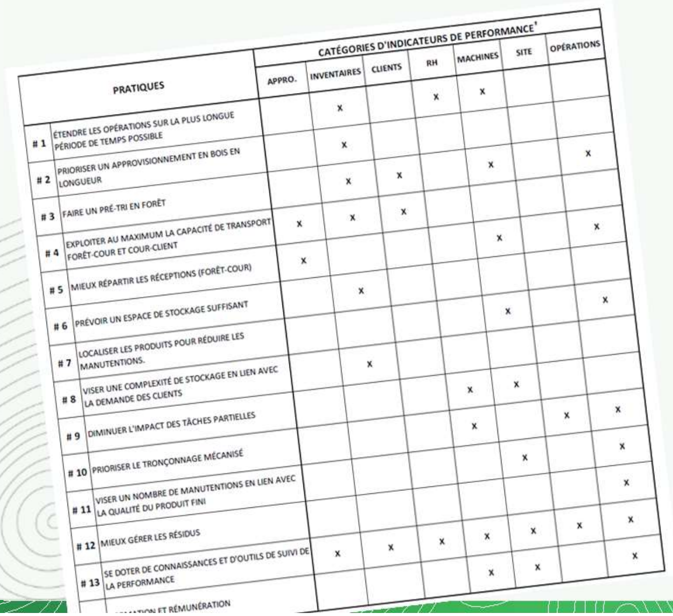


Can something be done NOW for one company ?

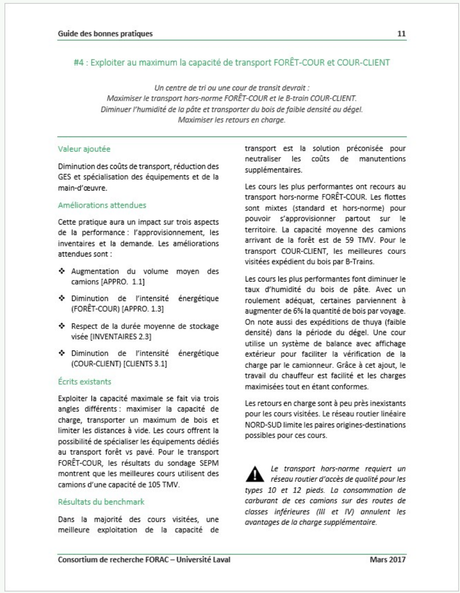
In a previous woodyard study

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



PRATIQUES		CATÉGORIES D'INDICATEURS DE PERFORMANCE[1]						
		APPRO.	INVENTAIRES	CLIENTS	RH	MACHINES	SITE	OPÉRATIONS
# 1	ÉTENDRE LES OPÉRATIONS SUR LA PLUS LONGUE PÉRIODE DE TEMPS POSSIBLE		x		x	x		
# 2	PRIORISER UN APPROVISIONNEMENT EN BOIS EN LONGUEUR		x					
# 3	FAIRE UN PRÉ-TRI EN FORÊT		x	x		x		x
# 4	EXPLOITER AU MAXIMUM LA CAPACITÉ DE TRANSPORT FORÊT-COUR ET COUR-CLIENT	x	x	x				
# 5	MIEUX RÉPARTIR LES RÉCEPTIONS (FORÊT-COUR)	x				x		x
# 6	PRÉVOIR UN ESPACE DE STOCKAGE SUFFISANT		x					
# 7	LOCALISER LES PRODUITS POUR RÉDUIRE LES MANUTENTIONS.					x		x
# 8	VISER UNE COMPLEXITÉ DE STOCKAGE EN LIEN AVEC LA DEMANDE DES CLIENTS		x					
# 9	DIMINUER L'IMPACT DES TÂCHES PARTIELLES				x	x		
# 10	PRIORISER LE TRONÇONNAGE MÉCANISÉ				x		x	x
# 11	VISER UN NOMBRE DE MANUTENTIONS EN LIEN AVEC LA QUALITÉ DU PRODUIT FINI					x		x
# 12	MIEUX GÉRER LES RÉSIDUS							x
# 13	SE DOTER DE CONNAISSANCES ET D'OUTILS DE SUIVI DE LA PERFORMANCE	x	x	x	x	x	x	x
	MATION ET RÉMUNÉRATION				x	x		x



Guide des bonnes pratiques 11

#4 : Exploiter au maximum la capacité de transport FORÊT-COUR et COUR-CLIENT

Un centre de tri ou une cour de transit devrait :
Maximiser le transport hors-norme FORÊT-COUR et le B-train COUR-CLIENT.
Diminuer l'humidité de la pâte et transporter du bois de faible densité au dégel.
Maximiser les retours en charge.

Valeur ajoutée

Diminution des coûts de transport, réduction des GES et spécialisation des équipements et de la main-d'œuvre.

Améliorations attendues

Cette pratique aura un impact sur trois aspects de la performance : l'approvisionnement, les inventaires et la demande. Les améliorations attendues sont :

- ❖ Augmentation du volume moyen des camions [APPRO. 1.1]
- ❖ Diminution de l'intensité énergétique (FORÊT-COUR) [APPRO. 1.3]
- ❖ Respect de la durée moyenne de stockage visée [INVENTAIRES 2.3]
- ❖ Diminution de l'intensité énergétique (COUR-CLIENT) [CLIENTS 3.1]

Écrits existants

Exploiter la capacité maximale se fait via trois angles différents : maximiser la capacité de charge, transporter un maximum de bois et limiter les distances à vide. Les cours offrent la possibilité de spécialiser les équipements dédiés au transport forêt vs pavé. Pour le transport FORÊT-COUR, les résultats du sondage SEPM montrent que les meilleures cours utilisent des camions d'une capacité de 105 TMV.

Résultats du benchmark

Dans la majorité des cours visitées, une meilleure exploitation de la capacité de transport est la solution préconisée pour neutraliser les coûts de manutentions supplémentaires.

Les cours les plus performantes ont recours au transport hors-norme FORÊT-COUR. Les flottes sont mixtes (standard et hors-norme) pour pouvoir s'approvisionner partout sur le territoire. La capacité moyenne des camions arrivant de la forêt est de 59 TMV. Pour le transport COUR-CLIENT, les meilleures cours visitées expédient du bois par B-Trains.

Les cours les plus performantes font diminuer le taux d'humidité du bois de pâte. Avec un roulement adéquat, certaines parviennent à augmenter de 6% la quantité de bois par voyage. On note aussi des expéditions de thuya (faible densité) dans la période du dégel. Une cour utilise un système de balance avec affichage extérieur pour faciliter la vérification de la charge par le camionneur. Grâce à cet ajout, le travail du chauffeur est facilité et les charges maximisées tout en étant conformes.

Les retours en charge sont à peu près inexistants pour les cours visitées. Le réseau routier linéaire NORD-SUD limite les paires origines-destinations possibles pour ces cours.

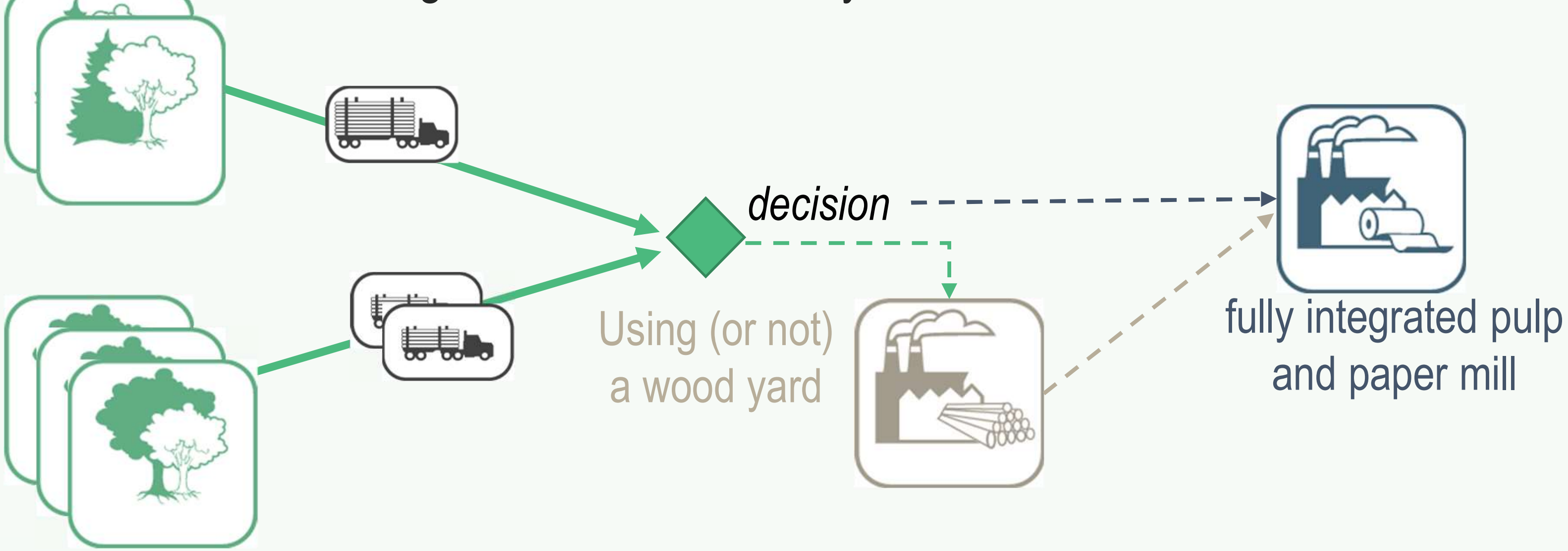
Le transport hors-norme requiert un réseau routier d'accès de qualité pour les types 10 et 12 pieds. La consommation de carburant de ces camions sur des routes de classes inférieures (III et IV) annulent les avantages de la charge supplémentaire.

Consortium de recherche FORAC – Université Laval Mars 2017

Source : Brotherton, Gravel, LeBel, & Trzcianowska (2017)

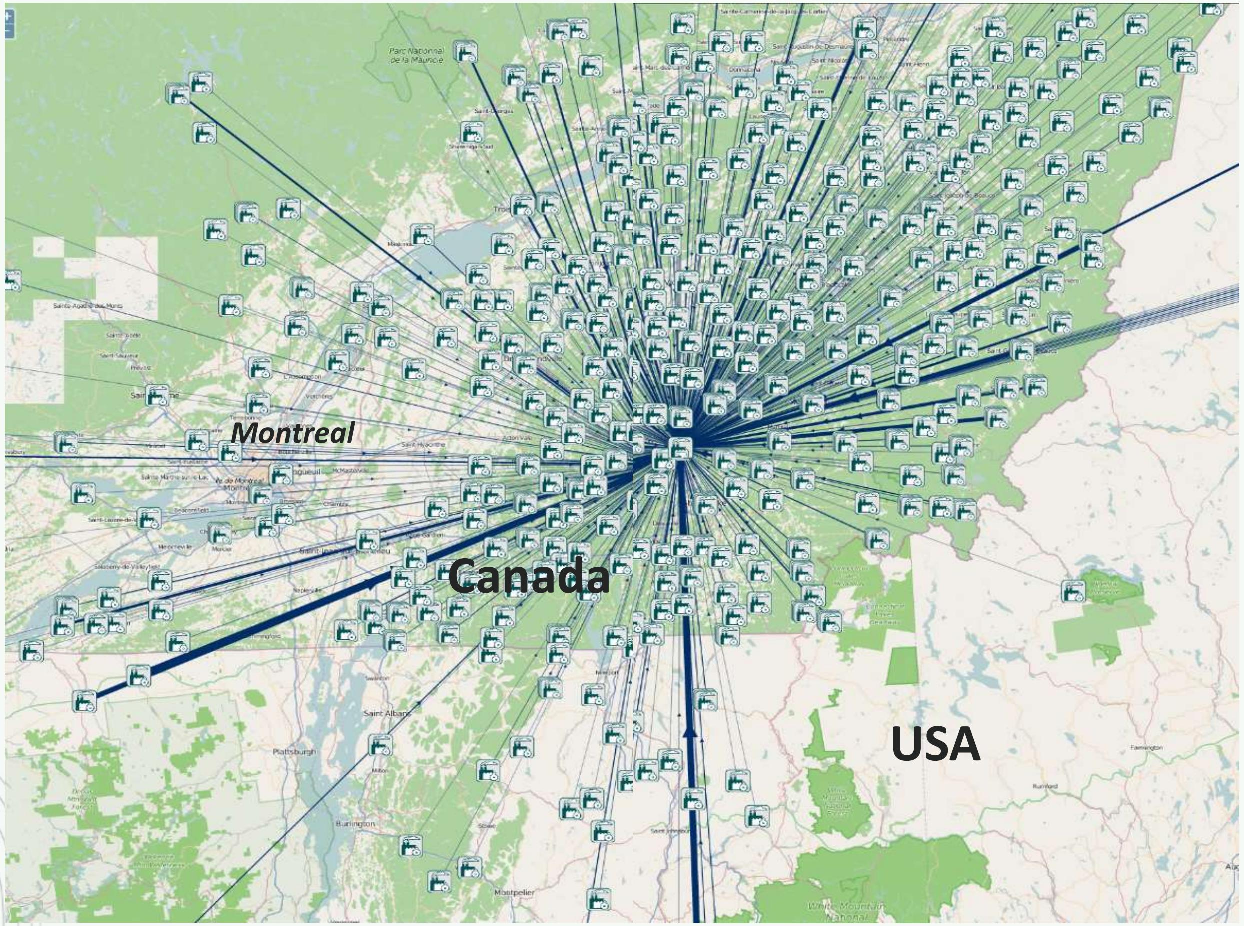
Fiber procurement challenge

>1.8 Million Tonnes per year
over 200 trucks per day
Trucking distances extend beyond 300 km

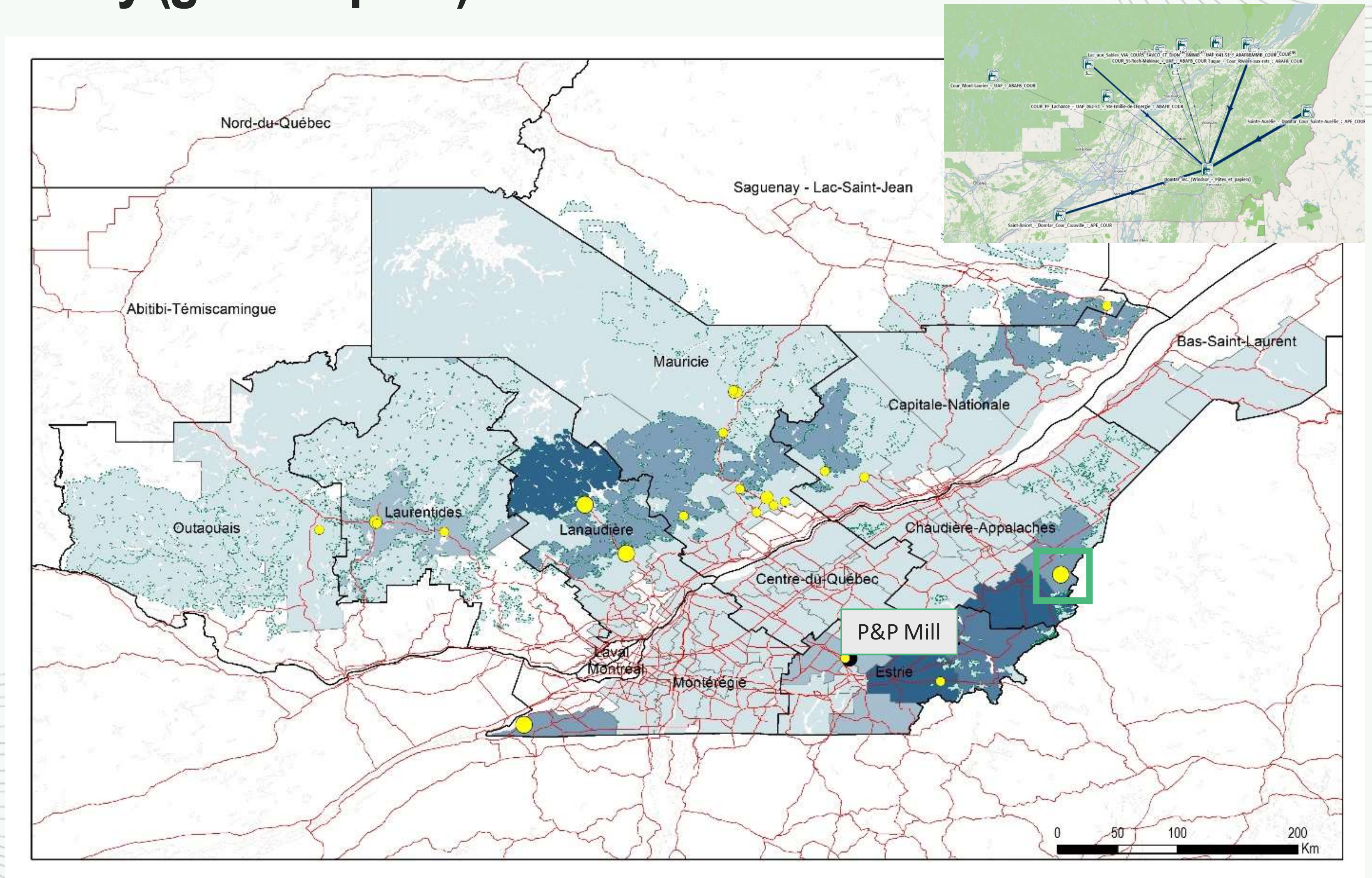


- Transport cost accounts for up to 30% of fibre procurement

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

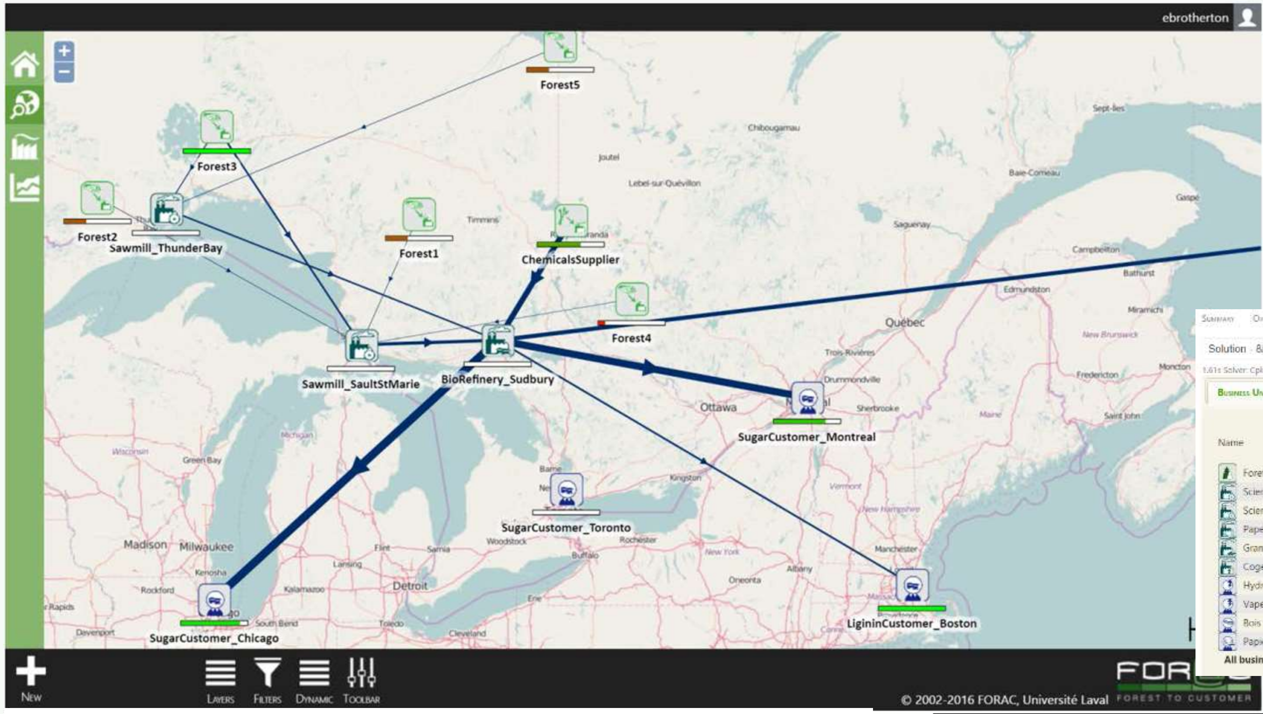
Source: ministère des Transports, de la Mobilité durable et de l'Électrification des transports au www.transports.gouv.qc.ca

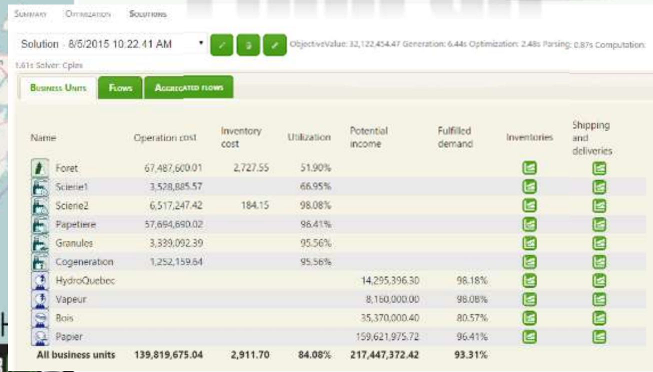
Comparison of existing models (1/2)

Reference	Objective function	Advantages	Gaps
Almeida Sfeir T., Pecora J. E., Ruiz A., LeBel L. (2016)	Cost minimization (transport, handling and operations of yards).	Includes : - weight restrictions during thaw season using Québec thawing zones - wood drying - truckloads	- Costs <u>penalties</u> 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)
Gautam S., LeBel, L., Carle, M.-A. (2017)	Cost minimization (transport, handling and operations of yards).	Includes : - moisture curves for wood drying in yard - additional cost of maintaining operations in the forest	- Aggregate transport cost (hourly rate) that does not provide information on the fuel consumed. - No concept of "truckload" which is critical to evaluate the fuel consumed. - No concept of thaw period

Comparison of existing models (2/2)

Reference	Objective function	Advantages	Gaps
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)





Summary Optimization Solutions

Solution 8/5/2015 10:22:41 AM ObjectiveValue: 32,122,454.47 Generation: 6.44s Optimization: 2.48s Parsing: 0.87s Computation: 1.61s Solver: Cplex

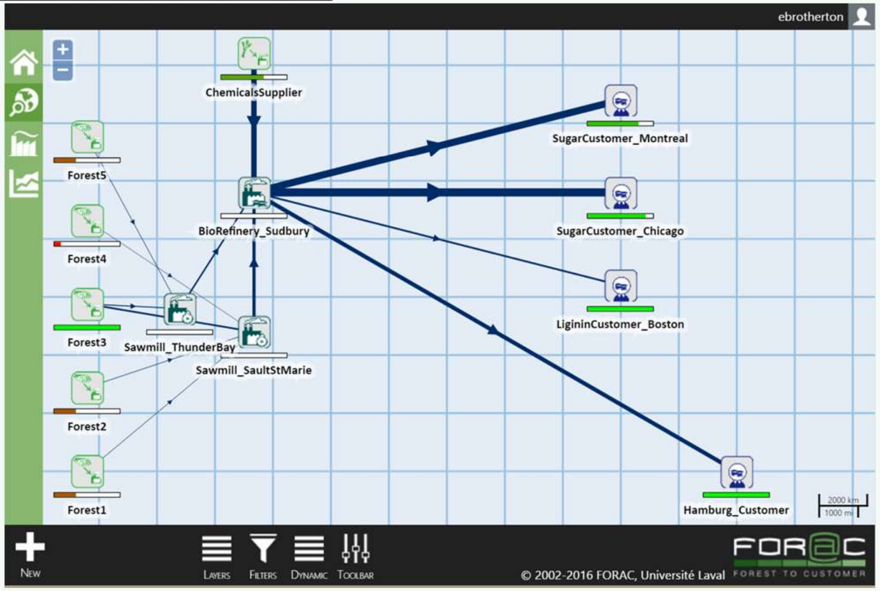
Business Units | Flows | Aggregated flows

Name	Operation cost	Inventory cost	Utilization	Potential income	Fulfilled demand	Inventories	Shipping and deliveries
Foret	67,487,600.01	2,727.55	51.90%				
Scierie1	3,528,885.57		66.95%				
Scierie2	6,517,247.42	184.15	98.08%				
Papetiere	57,694,690.02		96.41%				
Granules	3,339,092.39		95.56%				
Cogeneration	1,252,159.64		95.56%				
HydroQuebec				14,295,396.30	98.18%		
Vapeur				8,160,000.00	98.08%		
Bois				35,370,000.40	80.57%		
Papier				159,621,975.72	96.41%		
All business units	**139,819,675.04**	**2,911.70**	**84.08%**	**217,447,372.42**	**93.31%**		

$$\max \sum_{t\in T}\left(\sum_{u\in U}\left(\sum_{p\in P|d_{tup}>0}\rho_{tup}D_{tup}-\sum_{w\in W_{tu}}c_w Y_{tuw}\right)-\sum_{e\in E}\left(\sum_{p\in P}c^f_{etp}F_{etp}\right)\right)$$

Sujet à :

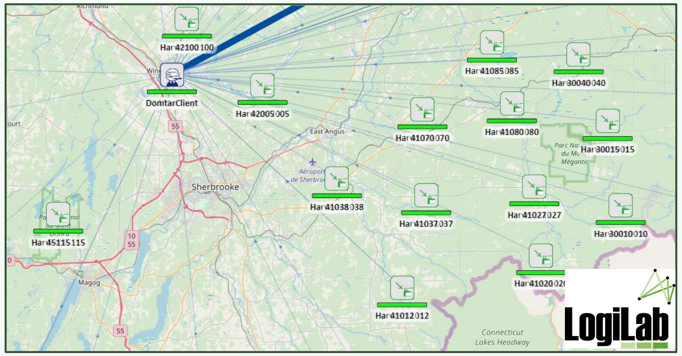
$$\begin{aligned}
&\sum_{t_1\in T}\left(\sum_{w\in W_{t_1u}|t_1+s_w=t}\gamma_{pw}Y_{t_1uw}\right)+\\
&\sum_{e\in\delta^+_u}\left(\sum_{t_2\in T|t_2+l_{et_2p}=t}F_{et_2p}\right)-\\
&\sum_{w\in W_{tu}}\alpha_{pw}Y_{tuw}-\sum_{e\in\delta^-_u}F_{etp}-D_{tup} &&= 0 && \forall t\in T,u\in U,p\in P && (1)\\
&D_{tup} &&\le d_{tup} && \forall t\in T,u\in U,p\in P && (2)\\
&\sum_{w\in W_{tu}}\lambda_{kuw}Y_{tuw} &&\le q_{ktu} && t\in T,u\in U,k\in K && (3)\\
&f^l_{et}\le\sum_{p\in P}F_{etp} &&\le f^u_{et} && t\in T,e\in E && (4)\\
&f^l_{etp}\le F_{etp} &&\le f^u_{etp} && e\in E,t\in T,p\in P && (5)\\
&Y,D &&\ge 0 && && (6)
\end{aligned}$$



LogiLab network optimization model

Considering :

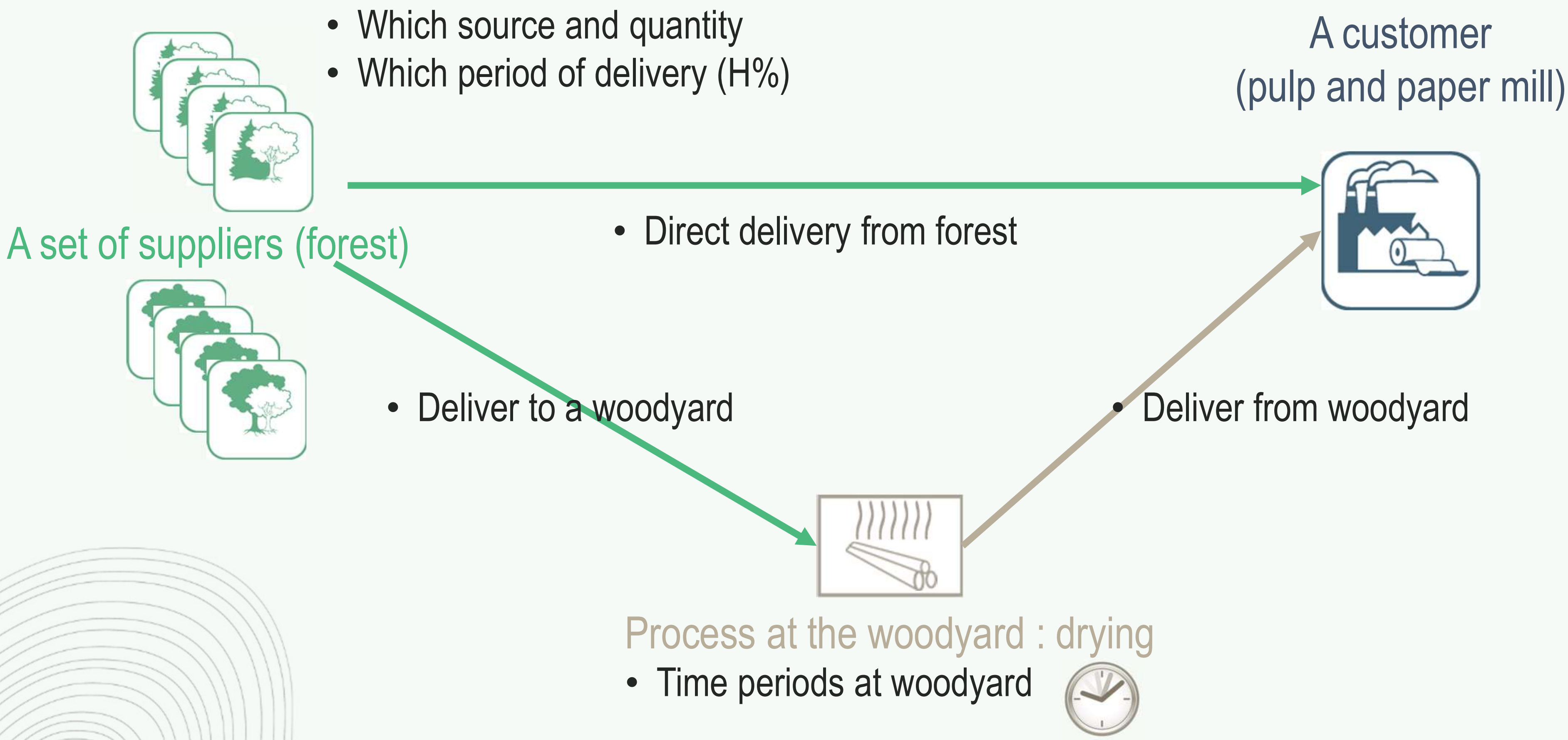
- Available wood from different areas (45 areas)
- A heterogeneous transport fleet (3 types of trucks)
- One yard for wood transit/conditioning
- Thawing period zones
- A variation in wood moisture level that depends on (1) the timing of the delivery and (2) the time spent in a yard



It must be determined:

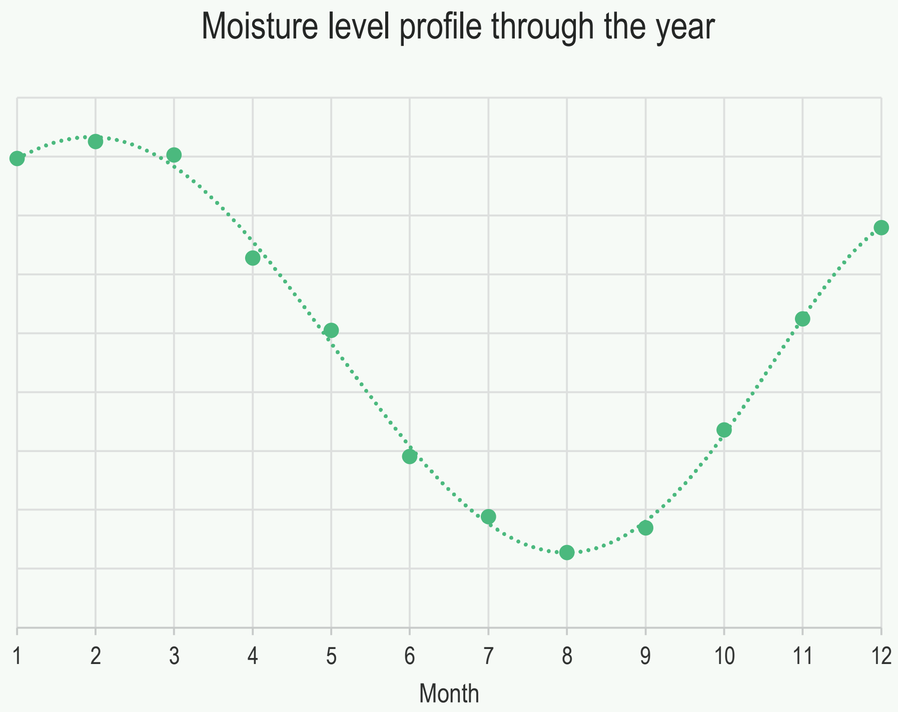
- When to deliver each wood supply area
- If the loads must transit (or not) by a woodyard
- How many periods logs stay in the woodyard
- What truck configuration to use (to and from the woodyard)

Multiperiod mathematical model to solve



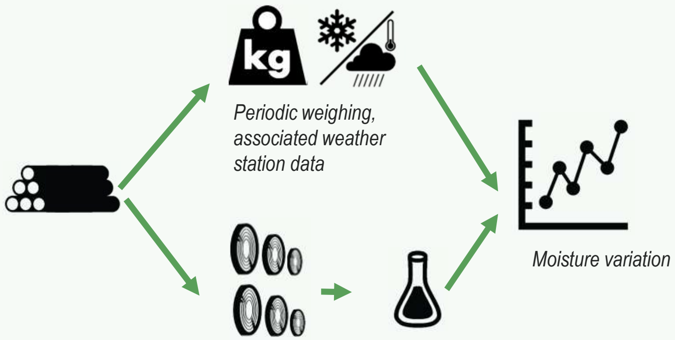
Wood moisture content (source deliveries)

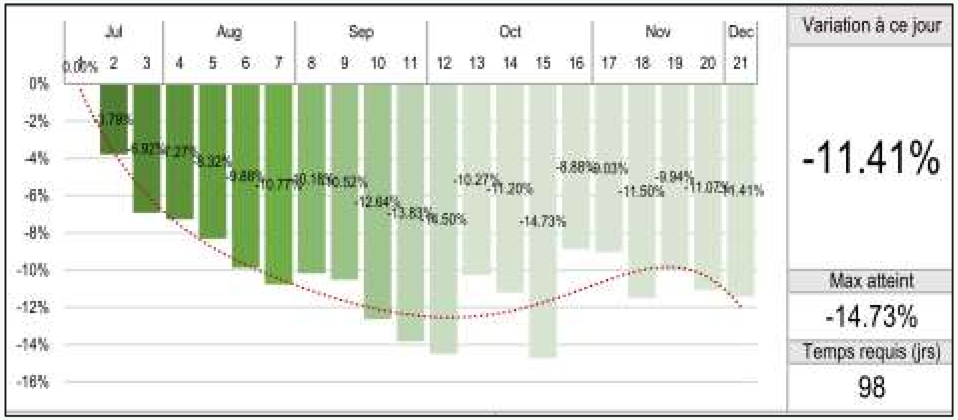
- Historical data from the paper mill provided moisture level of delivered wood over the year (considering usual harvesting).

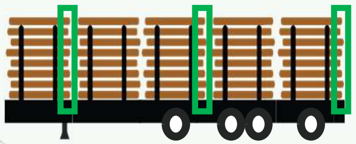


Modelling the drying process (woodyard)

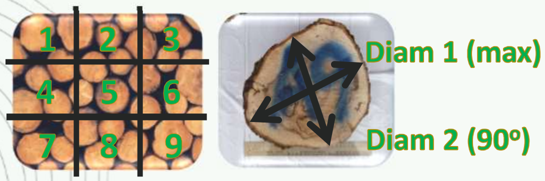
- Empirical study in a woodyard over 26 weeks to develop a specific wood seasoning model of weight reduction using weather station data.







+1 pile in yard = 36 samples



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

#	A	B	C	D
S1 (*Initial state*)	**X**	**X**	**X**	**X**
S2	X	X	X	
S3	X		X	
S4	X	X		
S5	X			
S6			X	
S7				

Flexibility

This way it becomes possible to observe the gains obtained for each level of flexibility

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

Results
(Scenarios with fixed destinations only)

Scenario	TruckLoads			
	Forest to Mill	Forest to Yard	Yard to Mill	TOTAL
S1 : Base Case	*	*	*	*
S2 : Optimal Drying *Fixed Deliveries/Source*	*	*	**-6,6%**	**-1,2%**
S3 : Optimal Drying Optimal deliveries *Fixed Destinations* *Fixed Period Range*	-3,3%	-1,6%	**-9,9%**	**-4,4%**
S6 : Optimal Drying Optimal deliveries *Fixed destinations* ~~*Fixed Period Range*~~	-3,5%	-4,1%	**-11,3%**	**-5,0%**

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)

Scenario	Thawing periods	
	Truckloads	Distance
S1 : Base Case	*	*
S6 : Optimal Drying Optimal deliveries *Fixed destinations*	C1 : -100%	C1 : N/A
	C5 : +150%	C5 : +58%

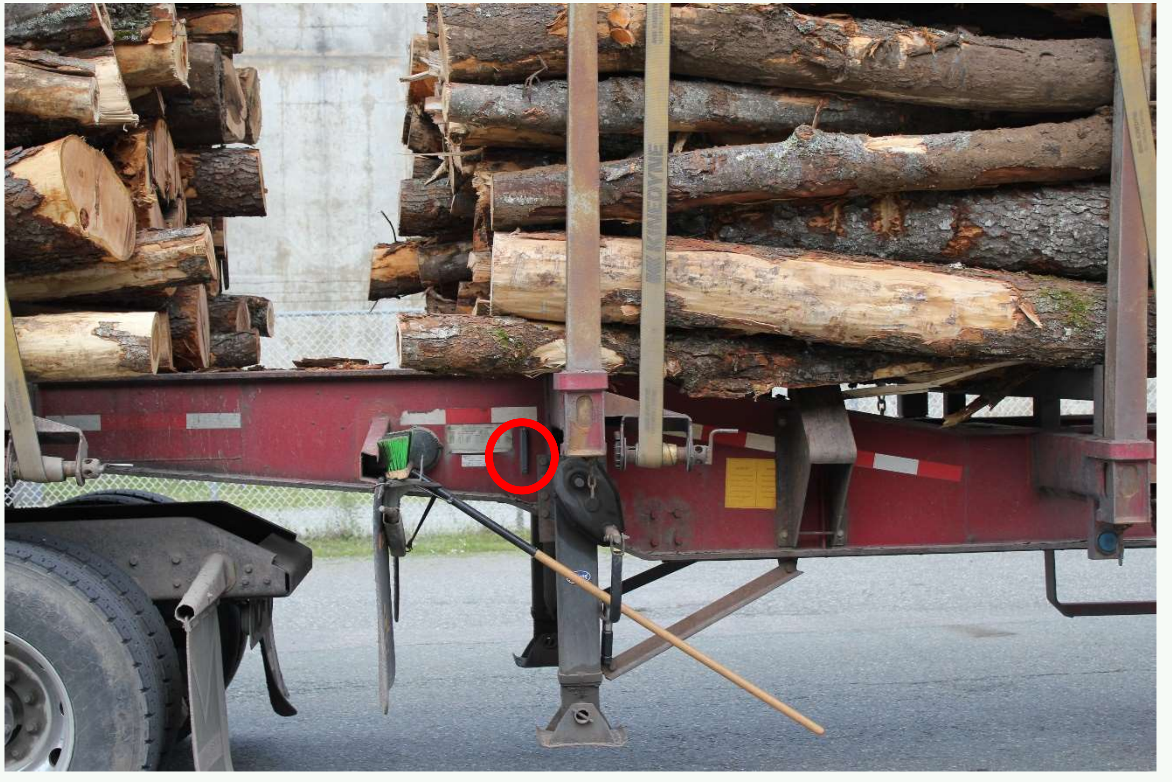
Truck type not used during thawing period

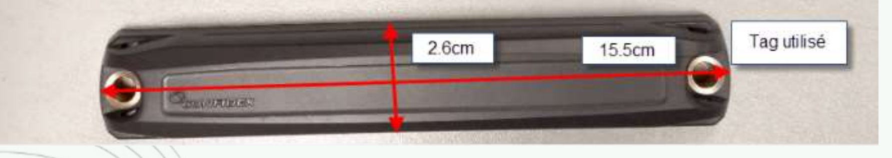
Better fleet utilization during thawing period (more trips with shorter distances)

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




2.6cm
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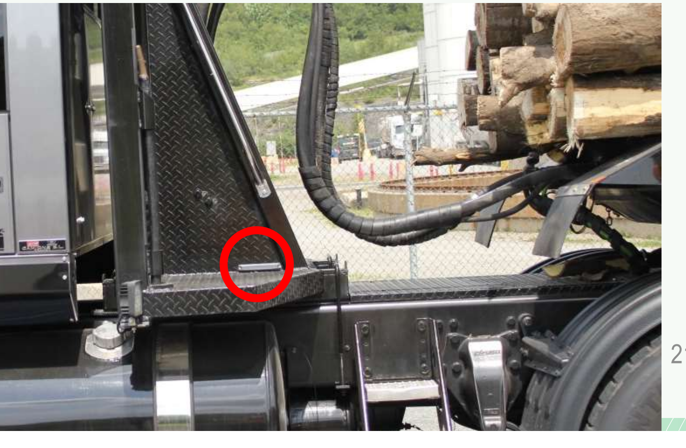
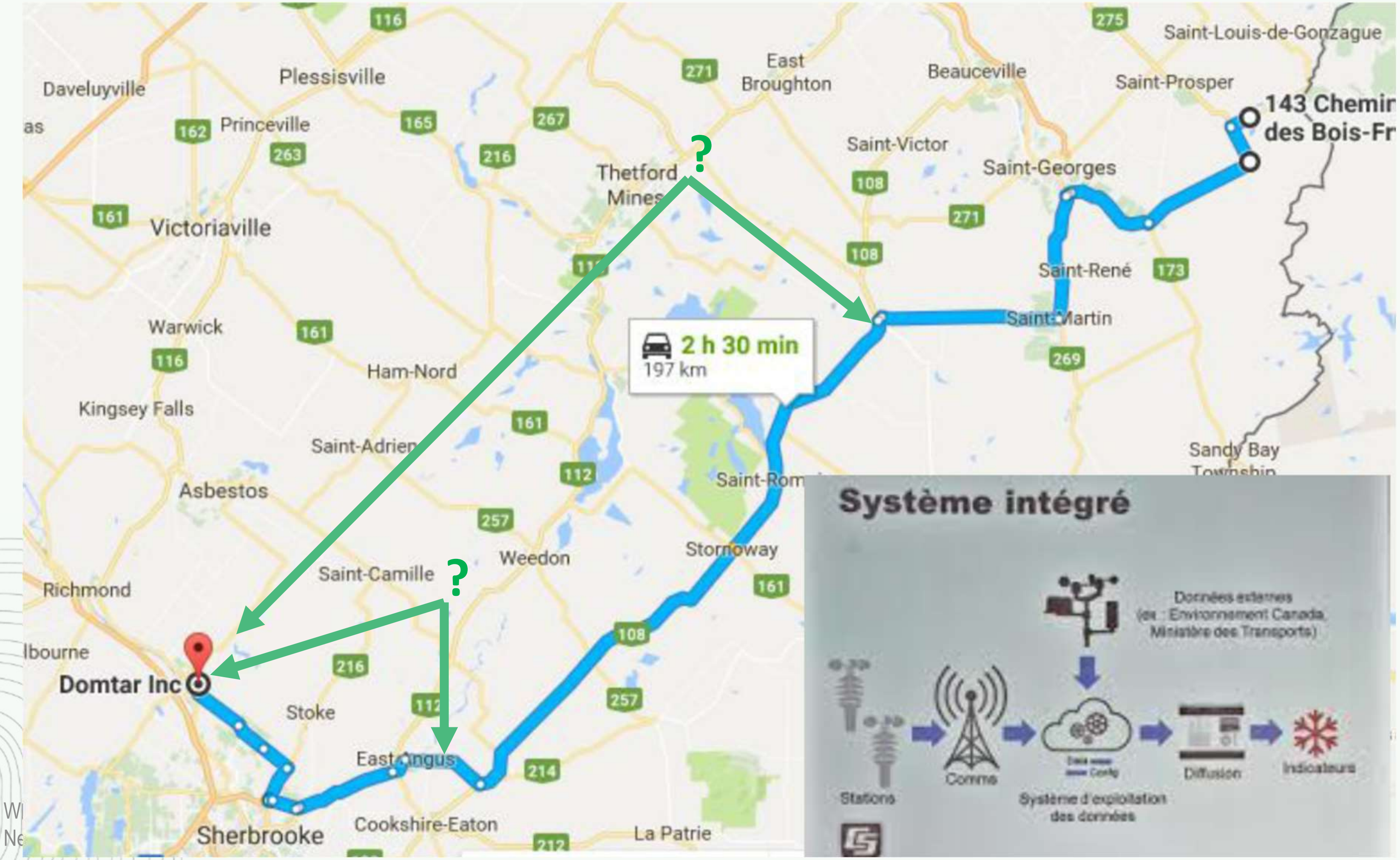


Follow-up project

- Dedicated wood-flow corridor



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- **Morneau-Pereira M., Arabi M., Ouhimmou M., Gaudreault J., Nourelfath M.** (2014). *An optimization and simulation framework for integrated tactical planning of wood harvesting operations, wood allocation and lumber production*. MOSIM14, 10th International Conference on MOdeling, Optimization and SIMlation, 5-7 novembre, Nancy, France
- LogiLab platform https://www.forac.ulaval.ca/transfert/plateformes/logilab/

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

- Fibre procurement for a large (>1.8 million tons per year) fully integrated pulp and paper mill is a constant challenge. Inbound traffic of over 200 trucks per day must be coordinated. Trucking distances extend beyond 300 km. Transport cost accounts for up to 30% of fibre procurement.
- In its attempts to reduce procurement cost and decrease GHG emissions, the consuming mill has already put into place a data acquisition system to monitor environmental conditions. In this project, our team builds on this data to determine (1) the best utilization of satellite woodyards that serve as processing nodes in the forest to mill delivery management system (2) the best utilization of transport fleet that faced seasonal weight restrictions during the year.
- A multiperiod optimization model was developed. This model guides the decision makers when selecting which procurement areas should transit through a satellite woodyard and which ones should be delivered directly to the mill. The yard purpose is to process stems into logs, stockpile, and «season» the wood. A specific wood seasoning model was developed to ensure maximum gains through weight reduction. For our case study, humidity management made possible a net gain in transport efficiency of 14% in certain conditions. If properly managed, wood seasoning and yard utilization could translate into a reduction of 320 truck movements per 100,000 m3 to be procured by the mill. While wood fibre stays in inventory for a longer period of time benefits appears to compensate the possible drawbacks. GHG and financial gains are detailed through sensitivity analyses.