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Using visibility to improve the coordination of a log yard network

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***Résumé* – Une gestion efficace de la chaîne de valeur forestière nécessite la prise en compte de plusieurs facteurs qui opèrent dans un contexte dynamique. Cependant, les cours à bois ont jusqu'à présent été peu exploités en tant que plateforme logistique pour mieux coordonner la chaîne de valeur forestière. Ce projet vise à analyser comment la coordination d'un réseau de cours à bois et la disponibilité de leurs indicateurs de performance peuvent contribuer à réduire les distances de transport et à mieux gérer les stocks dans les cours. Pour ce faire, une étude de cas a été réalisée impliquant trois cours à bois et trois scieries traitant des billots de 8 à 16 pieds. Un modèle de simulation a été développé pour représenter un tel réseau, pour reproduire son état de fonctionnement actuel et pour tester diverses stratégies de coordination des activités d'approvisionnement et de transport. Les résultats ont montré que certaines stratégies pouvaient réduire la distance parcourue sans affecter la chaîne de valeur. De plus, grâce au modèle de simulation développé et au tableau de bord établi, le suivi en temps réel des indicateurs de performance des cours à bois devient possible.**

***Abstract* – Efficient management of the forest supply chain requires the consideration of several factors that operate in a dynamic context. However, log yards have so far been little exploited as a logistical platform to better coordinate the forest value chain. This project aims at analyzing how the coordination of a group of log yards and the availability of performance indicators for each of them can contribute to reduce transportation distances and better manage the inventory at the yards. To do this, a case study was conducted involving three log yards and three sawmills processing logs ranging from 8 to 16 feet in length. A simulation model was developed to represent such a network, to reproduce its current state of operation, and to test various strategies for coordinating supply and transportation activities. Results showed that some strategies could reduce the distance travelled without affecting the value chain. In addition, thanks to the simulation model developed and to the dashboard established, real-time monitoring of log yard performance indicators becomes possible. Thus, this model could be used by managers as a tool to better coordinate the resource supply over a tactical planning horizon.**

***Mots clés* – cour, bois, simulation, coordination, tableau de bord**
***Keywords* – log, yard, simulation, coordination, dashboard**

1 INTRODUCTION

Wood has long been used as a building material and for pulp and paper production [Wang et al., 2018]. This is the case in Canada where forests are part of the country's history and play a major role in its economy and social environment [Mockler & Fairbairn, 2009]. To add value to this resource, the forest products industry is organized into a complex industrial system, known as the forest value chain, extending from the forest to the markets [D'Amours et al., 2017]. After harvesting, the wood is transported to the processing mill yards. This activity directly impacts the cost and supply of raw materials to the industry [Obi & Visser, 2017]. Since forest supply faces great uncertainty and variation in terms of available species, volume, and quality, in addition to being directly affected by weather, log yards are called upon to manage and store varying levels of raw material [Trzcianowska et al., 2019]. These log yards provide several benefits, including better utilization of logs, added value through merchandising and sorting of the resource, and a means for controlling the uncertainty of the raw material [Kons et al., 2020; Schadendorf & Eddy, 1995]. However, seasonal restrictions on transportation can result in high levels of log yards inventory [Myers & Richards, 2003]. In addition, optimizing log yard logistics is complicated by the variety of input products, available handling technologies, vehicle types, seasonal variations, the complexity of the product flow, and the need to ensure a continuous supply from the yards to the mills. Therefore, companies in the forest value chain are invited to implement means to improve the visibility of their product and information flows. In this way, they can improve the competitiveness of the chain by effectively coordinating their production activities and producing and delivering the right products, on time, at a reasonable cost [Forget, 2009]. For the lumber context (i.e., sawmills), demand management is further complicated by the instability of supply as well as uncertainty and fluctuations in demand and prices, typically associated with the seasonality of demand related to construction activities [Ali et al., 2019].

This research aims at the strategic role of a log yard within a network of yards in order to improve inventory management and the coordination of inter-yard exchanges. More specifically, the objectives of the research are to better identify the appropriate strategies for managing a log yard network, to provide full visibility of the network under study, and to study the effect of inter-yard exchanges, following different strategies and using performance indicators such as inventory status, occupancy rate, and the number of trucks exchanged.

This research has shown that certain inter-log exchange strategies result in a reduction in travel distances. In addition, this project allowed the establishment of a dashboard that will allow managers to have a better understanding of the dynamic of their log yard network when making decisions.

To achieve this goal, a three-phase methodology was used. In phase 1, simulation was used to design an abstract model reflecting the current state of a real network of three log yards and their three sawmills. Data collection from an industrial partner and the use of certain assumptions were necessary to establish this simulation model. In phase 2, the experimentation of different coordination scenarios within the log yard network was performed and the results obtained from the simulations were analyzed. In phase 3, the results were synthesized and integrated in a dashboard, and recommendations were made based on the study. The following sections will summarize these three phases.

2 METHODOLOGY

Since there seems to be limited work related to a log yard network and a coordination strategy for such a network, this research aims to further investigate this subject through a real case study. The problem addressed in this research is the following: based on the assumption that a log yard network needs to communicate and coordinate to better manage its operations, how can we implement a management and coordination system between the different links of such a network?

To answer this question, a four-step methodology was followed. A search of the scientific literature relevant to the project was first conducted, with the goal of better understanding log yards and how coordinating a network of yards can positively impact the value chain. This literature search was conducted using several available databases, including Engineering Village, Web of Science, and Google Scholar. In the end, 21 articles were selected. These references allowed us to answer some thematic questions concerning the functioning of log yards and the management of operations in a single log yard, but also demonstrated that there is very little research on the management of a network of log yards.

Afterwards, the study of a real log yard network was initiated. It is a network owned by a company with several mills in Quebec, Canada. One sub-network of this company was studied. It consists of three log yards adjacent to three sawmills. Those are, namely the St-Just de Bretenières sawmill, St-Pamphile sawmill, and St-Hilarion sawmill [LeBel et al., 2020].

To have a better understanding of this network, its mode of operation was studied. These log yards are supplied by trucks from various forestry areas (referred to as «sectors»). Each of these yards is adjacent to a sawmill that produces lumber at a stable rate with a defined capacity. Each log yard typically processes one or more types of wood. A type of wood is defined by the species, length, and diameter. Even if they receive different types of wood, the company's yards will generally only keep the type of wood processed by the sawmill, with some exceptions. The other types of wood will be sent to other yards that handle the product in question. So, there is an exchange of logs that will be created, though there is no wood exchange between two logs that process the same type of wood.

A simplified diagram in Figure 1 shows the case study. The simulation model is based on this network with its characteristics and specificities.

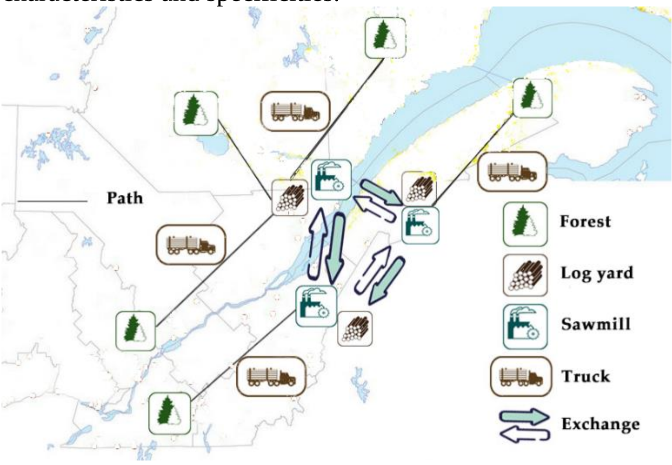

Figure 1. Log yard network studied

On the one hand, the St-Hilarion yard, located on the north shore of the St-Lawrence River, processes "stud" (8 to 10 ft. logs) and receives about 88% of "stud" and 12% of logs (12 to 16 ft.). On the other hand, the yards of St-Just-De-Bretenières and St-Pamphile, located on the south shore of the river, process mostly logs from 12 to 16 feet, but can also process shorter length (and sometimes "stud)." They receive about 12% "stud" and 88% logs (12 to 16 feet). The forest supply areas are located in southern Quebec, Canada and in Maine, United States, mainly. The sawmills where the wood is processed are adjacent to the log yard. In terms of log supply, the oldest log in the yard is generally used to feed the mill first.

Once the company's log yard network was well understood, the simulation model could be developed. Among the simulation software available on the market, Simio software, for which the university has a license, was chosen for this study. Simio is a 3D software based on discrete event flow simulation and allows to manage input data in several forms, different modeling approaches and experiments and scenario comparison.

Meetings with sawmill executives and managers were held to identify the characteristics of their storage and production systems and to collect the data needed to represent the log yard network. In addition, further meetings with researchers and research assistants were conducted to exchange ideas regarding the modeling.

The initial model consisted of the three log yards, the mills adjacent to the yards, and the forest harvesting areas. The study involved moving raw material from the forests to the yards using trucks over a full day. Then, under the scenario tested, the appropriate wood was stored in the yard for processing at the adjacent mill, while the other type of wood was sent out to the other yards in the network. Once the model was running correctly, validation was required to ensure similarity between historical values representing the reference and the values resulting from the model. Several modifications were required to adjust the initial model.

After a series of 20 replications of the theoretical model, the experiments of the different scenarios could be carried out and results obtained. These results represent the variation of the performance indicators of each log yard for a given scenario. An analysis of the results was then made to identify the strategies having the greatest effect on the performance indicators.
To evaluate the coordination strategies and conclude on the added value they bring to the log yard network, performance indicators were identified and monitored. The value of each indicator considered reflects the average of the values obtained for each replication. These indicators are as follows:

- Inventory: All the logs that are stored in the log yard, whether they are designated to complete the transformation process or to be transferred to another log yard.
- Inventory by type of wood: All specific type of logs in the log yard, either for processing or for transfer.
- Log Yard Occupancy Rate: The amount of space occupied in the log yard, which determines the amount of space available to receive more wood.
- Trucks exchanged between yards: The total number of loaded trucks entering and leaving between log yards in the network.
- Distances: The distances travelled by the trucks during the entire simulation.

The four steps of the methodology are illustrated in Figure 2.

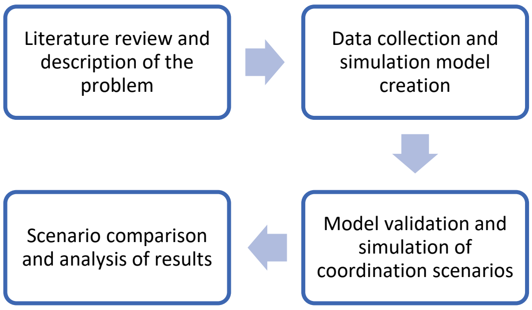

Figure 2. The research methodology

3 MODEL AND EXPERIMENTATION

3.1 Data collection

The data to be collected to build the simulation model were classified into five groups:

- The characteristics of the incoming raw material (volumes, frequency of trucks arrival, types of wood);
- Demand characteristics (production at the mill);
- Transportation characteristics (distances, load, and type of trucks);
- Raw material handling in the yard (loading/unloading time, waiting time);
- Forest areas and resources (equipment, employees).

To test different scenarios, it was first necessary to collect supply data, including the supply areas for each log yard, the types of wood harvested, the distances between the log yards and these areas, and the frequency of truck arrivals. The data collected refer to the supply history from July 2019 to June 2020. The data used in the study were obtained through our industry partner, some available daily, some others on an annual basis.
Some data were also obtained from the results of a survey of several log yards in the province of Quebec conducted by Trzcianowska et al. [2019]. The survey, which provides a general portrait and comparative analysis of several log yards, was conducted from March to August 2016. From these results, data corresponding to the operation of a log yard could be identified. These are measures of the area of the log yards and of the space allocated to storage, the amount of inventory present in each yard per month, the different types of trucks used, and the volumes per trip. In addition, wood processing data was shared by the partner. These are measures of wood processed per hour (MBFT/hour). Table 1 describes each type of data and its source.

Table 1. Data collected during the research to build the simulation model

Type of data	Unit	Source
Supply Sectors	-	FORAC's research professional
Quantities of wood delivered by sector	m^3/day - m^3/year	Lebel Group
Distances between areas and log yards	km	FORAC Research Professional
Inventory of log yards	m^3/month	Doctoral student at FORAC
Maximum storage capacity	m^3	Lebel Group
Sawmill production	MBFT/h	Lebel Group
Truck speed	km/h	FORAC research professional

3.2 Assumptions

To create the model, a few assumptions had to be made. They can be summarized as follows:

- The trucks supplying the log yards arrive according to a triangular distribution process to adequately model the daily distribution of arrivals. These distributions will be the same for the entire six-month simulation period.
- To simplify the model, two types of wood are considered, "stud" (8 to 10 feet) and logs (12 to 16 feet).
- The truck loads are considered standard loads of 39 m^3.
- The handling time (scaling, unloading) in the log yards is set to 15 minutes.
- The operating time of the sawmills is 12 hours (from 6 am to 6 pm).
- The order of priority is established according to the order of arrival; the older logs are prioritized to feed the sawmill.
- Backhauling is not considered.
- The geographic locations of the forest supply areas and the distances are estimated due to the vastness of the forest areas.
- The speed for trucks is set at 80 km/h.
- The truck load is homogeneous, i.e., only one type of wood per truck.

3.3 Model development

Once the data was collected and the assumptions made, the simulation model was created. Such a model was based on the modelling of incoming and outgoing flows within a network of log yards, using mathematical calculations and a probability distribution. Simio allowed the system to be visualized and different coordination scenarios to be applied by being able to virtually recreate this transfer of products from the forests to the yards and then to the mills.

In Figure 3, the different components of the model are presented graphically on the Simio interface. We can distinguish between "sources", which represent the supply sectors of the network, and "servers", which are the log yards with their storage areas. Other "servers", i.e., sawmills, are adjacent to these yards. Everything is linked by "paths" which are roads to ensure the movement of trucks while representing the distances that separate the log yards from the forest sectors and the distances between yards.

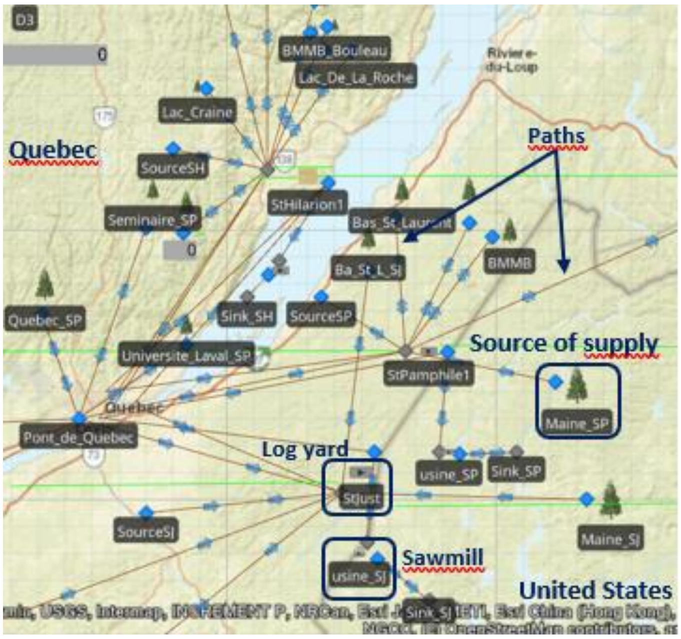

Figure 3. Simulation model components

The "source" which corresponds to the supply area feeds a log yard. "Entities" are created according to a triangular distribution process. The parameters of this distribution are deduced using the supply history provided by the company, i.e., the inter-arrival time of the trucks from the supply sectors is randomly generated by a triangular distribution with a mean, a minimum, and a maximum value. It is about several trucks loaded with wood and spread out throughout the day. The "entities" are these standard trucks loaded with 39 m^3 of wood moving at an average speed of 80 km/h.

Once the truck arrives at the sawmill, it must go through the unloading area if the yard entrance is empty. If not, it will need to wait in the queue represented in Simio by a green line at the entrance of each log yard. This unloading and handling operation takes about 15 minutes. Then, the delivered wood is stored in specific areas according to the type of logs. A counter is assigned to control the inventory accumulated based on the type of wood in the yard. This inventory then feeds the adjacent mill, which processes the logs at a steady rate. The "entities" that are not compatible with the mills are transferred to another sawmill. Another counter covers the incoming and outgoing flows in the different log yards. Finally, the "entities" are destroyed by the "sinks". To start the simulation, we had to reproduce the real initial conditions at the beginning of January, which coincides with the beginning of the simulation. Figure 4 shows the process steps of the simulation model.

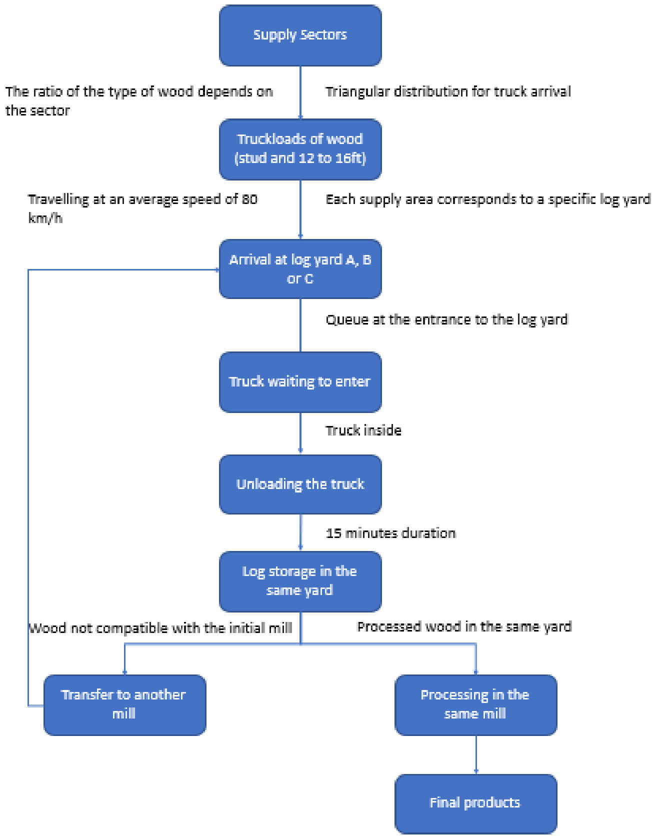

Figure 4. Simulation model operating process

3.4 Model validation

Several techniques can be used to verify a simulation model depending on the nature of the system under study and the availability of the data.

Therefore, the quality of the verification and validation process will determine the reliability of the model. Sargent [2013], identified several techniques for verification and validation of simulation models. These methods include:

- Comparison with other models: Various results of the simulation model being validated are compared to the results of other similar models.
- Event Validity: The occurrence of events in the simulation model is compared to the occurrence of events in the real system to determine if they are similar.
- Apparent Validity: People familiar with the system are interviewed to see if the model and its behavior are reasonable.
- Historical Data Validation: A portion of the historical data is used to build the model and the remaining data is used to determine if the model matches the real system.
- Predictive Validation: The model provides predictions of the system's behavior, and then comparisons are made between the system's behavior and the model's prediction to determine if they are identical.

In our case, the system studied is a network of three log yards belonging to the same company. Thus, given the accessible data and the available resources concerning this network, three validation techniques were applied. First, the validation of historical data was used. Our industrial partner and FORAC researchers provided us with several historical data concerning log yard supply, inventories, mill consumption, and inter-yard exchanges. These data were presented in the form of tables, texts, and surveys. Some of these historical data were used to set up the simulation model. For example, handling times in log yards were entered into the system directly from the data. All these data, which for the most part cover a period of one year, were also used as a reference to monitor the simulation and to determine if the model reflects reality. Then, as Sargent [2013] mentioned, predictive validation was applied. Indeed, in our model, parameters that are variable in time such as supply are simulated by triangular distributions that were introduced to the model. Thanks to these distributions, the model can provide some variable predictions from one replication to another, i.e., in one replication supply could be high and in another one it could be low, which will affect the whole wood flow in the model. This allowed us to make comparisons between the predictions obtained and the actual behavior of the system. After applying this technique, the differences obtained between the predictions and the actual state of the system were found to be minimal. Finally, the face validity technique was used to conclude the validation. Meetings with our industrial partner were held to validate the model and the system operation. The manager expressed his agreement with the results presented. As the work progressed, validations led to several changes in the model with new inputs and parameters. In the end, this led to a final version of the model on which different scenarios could be tested.

3.5 Scenarios tested

Once the model was established and validated by various verification techniques, it then became possible to introduce inter-yard exchange coordination strategies to measure the effects on the several performance indicators of the log yard network.

Figure 5 presents a study done by Vachon-Robichaud et al., [2014] showing the seasonal variability of supply truck arrivals. The differences are clear for the number of truck arrivals by season. In winter, which is the accumulation period, arrivals are high. There is then a noticeable decrease in arrivals during the spring thaw period when travel is limited. Then, in the summer, truck arrivals resume and stabilize.

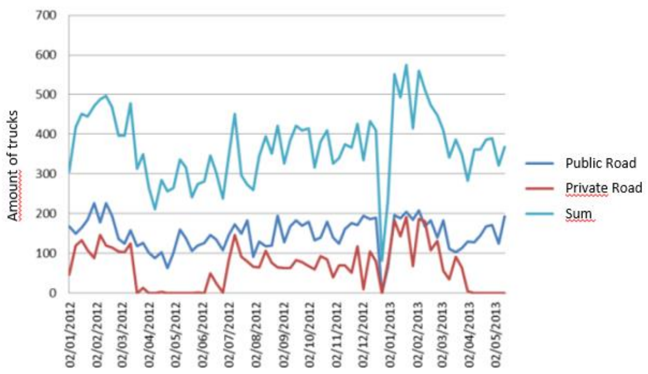

Figure 5. Seasonal variability of supply truck arrivals for one of the study plants, adapted to Vachon-Robichaud et al., (2014)

To simulate changes in the studied log yard network, we considered a few realistic proposals for the partner company.

Since truck arrivals from the forests are linked to seasonal road conditions as shown in Figure 5, trying to vary this parameter seems a bit complicated. Therefore, the idea of the scenarios is to vary the truck arrivals by inter-yard exchanges during the accumulation and thawing seasons. Therefore, the flow of truck arrivals from the forests is the same for the different scenarios.

The objective was to change the periods during which inter-yard exchanges are allowed. In the current situation, exchanges are not subject to a fixed and well-defined strategy. In fact, they are done on a case-by-case basis depending on the situation and condition of the yard. It is the decision makers, who are generally the yard managers, who decide when and how to make an exchange with another yard. The simulation is based on a six-month horizon divided into two parts, one covering the accumulation period and the other covering the thaw period. The 1st scenario therefore covers six months of wood exchanges, i.e., log yards transfer wood among themselves during both the accumulation period and the thaw period. In the 2nd scenario, inter-yard exchange occurs only during the accumulation period. Therefore, there is no wood exchange during the thaw period. In the 3rd scenario, no inter-yard exchange of wood is allowed during all the studied periods. Finally, in the 4th scenario, wood exchange is only allowed during the thaw period. Table 2 summarizes the four scenarios tested.

Table 2. Summary of the four scenarios tested

Scenarios	Inter-yard exchange	
	Accumulation period	Thaw period
S1	✓	✓
S2	✓	✗
S3	✗	✗
S4	✗	✓

4 RESULTS

4.1 Comparison of scenarios

After analyzing the results for each scenario individually, it became interesting to compare them with each other. The analysis carried out was based on performance indicators for the log yards and their evolution over time to identify the best solutions that could be interesting for industry. To do so, we first compared the evolution of the log yards' inventory for the four scenarios.

Figure 6 shows the evolution of the St-Hilarion yard inventory for the four scenarios. The best use of the space allocated to storage is in the 2nd scenario (inter-yard exchange allowed during the accumulation period only). On the one hand, the yard is sufficient at the end of the accumulation period to meet the mill's needs and to transfer wood to other mills. On the other hand, at the end of the simulation period, the stock occupies about 35% of the available space in the St-Hilarion yard. This quantity ensures the supply of the mill during the summer season. The only concern in this scenario is that the theoretical threshold of 100% storage space occupancy was slightly exceeded. Although the storage space of a log yard does not appear to be problematic, the use of our model becomes particularly interesting for such a context, since by ensuring a better visibility of the whole network, the use of the model could then allow to control the state of the inventories, the flow of incoming and outgoing trucks, and the consumption of the sawmills in real time. Using this tool, the problem of exceeding the occupancy rate could be avoided, whether by planning a reduction in truck arrivals, transferring logs to another yard, or modifying the mill's consumption rate.

Scenarios 3 and 4, which have in common the absence of inter-yard exchanges during the accumulation period, present a low inventory, leading to disruptions in the mill's performance during the summer period. The St-Hilarion yard would not be able to meet the needs of its adjacent mill and potentially would fail to respect its commitments to customers. This confirms that the St-Hilarion yard is highly dependent on supplies from other yards in the system during the accumulation period. In the same figure, we see that scenario 1 is similar to scenario 2 for the first three months. Then, in the second part of the simulation, the St-Hilarion yard receives additional "stud logs", preventing it from reducing its inventory for the summer period. Thus, the inventory is maintained at more than 50% in the summer. This excess inventory generates additional costs related to storage and handling, in addition to the potential degradation of log quality over the warm summer months.

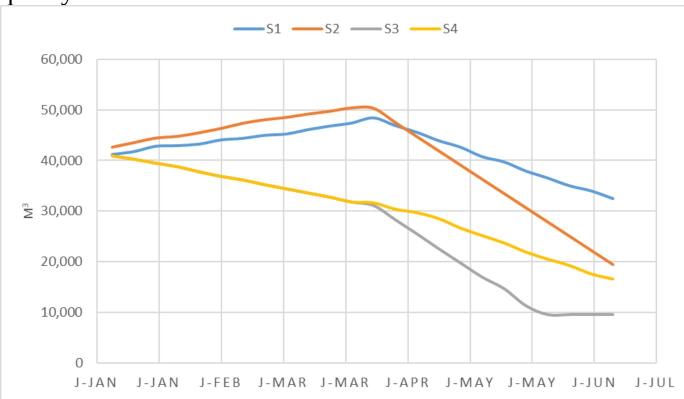

Figure 6. Comparison of the evolution of the St-Pamphile yard inventory for the four scenarios

Figures 7 and 8 show the evolution of the inventories of the St-Pamphile and St-Just log yards for the four scenarios tested. Results for these two yards are similar. On the one hand, they are almost saturated at the end of the accumulation period, for scenarios 3 and 4, with about 80% of 12-to-16-ft logs in their inventories and about 20% of "stud". On the other hand, at the end of the simulation in late June, scenario 1 reaches an inventory of about 35% of available stock.

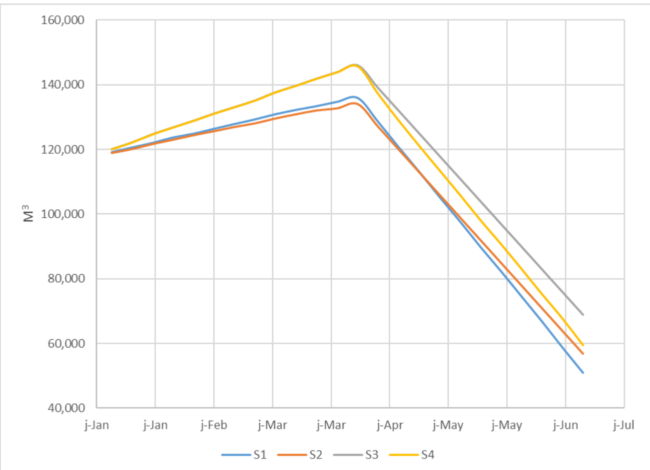

Figure 7. Comparison of the evolution of the St-Pamphile yard inventory for the four scenarios

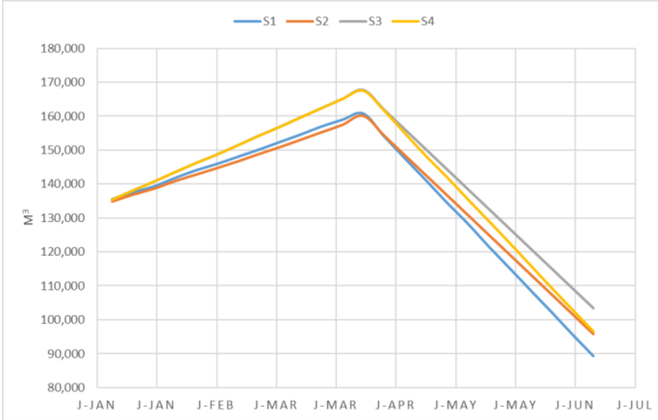

Figure 8. Comparison of the evolution of the St-Just-de-Bretenières yard inventory for the four scenarios

Inter-yard exchange has a significant effect on trucking distances. Managers are always looking for the right compromise between supplying their yards and truck movements. For this reason, it is interesting to evaluate the truck travel distances in each scenario. In Figure 9, we can see that with Scenario 3, involving no inter-yard exchanges, the best result in terms of truck travel costs is achieved since trucks are limited to the forest-to-mill route. Next come scenarios 2 and 4, which allow interchanges for 3 months of the simulation period only, either at the beginning or at the end of the simulation. And finally, scenario 1 corresponds to the longest distances since this scenario allows inter-yard exchanges throughout the simulation. This distance indicator is important but should not be studied in isolation from the other indicators which concern inventories, sawmill consumption, and the number of trucks arriving.

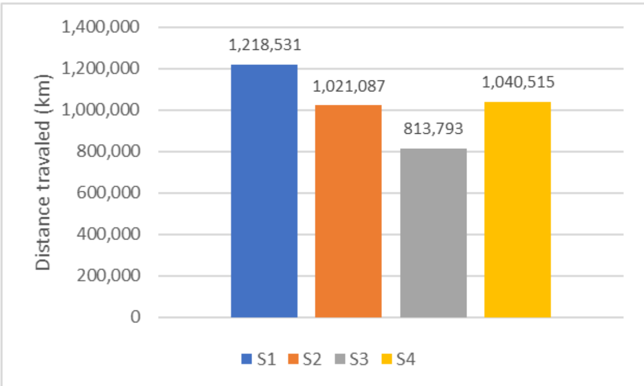

Figure 9 : Total distances travelled by trucks in the different scenarios

5 Performance Indicators and Dashboard

In this section, we will highlight the results of the simulation model through a dashboard developed to point out actual measures, target values, performance indicators and bottlenecks or risk points associated with the system under study. This additional tool supports the goal of improving inventory productivity and utilization by managing the log yard supply network through information sharing capabilities.

After selecting the desired parameters, the corresponding information is displayed on the dashboard. In Figure 10, the dashboard presented corresponds to the St-Pamphile yard. First, the table allows us to identify the logs by forest of origin to better manage the flow and quality of logs. Then, we can observe the total inventory by type of wood (two types of logs in this case) in real time during the selected day. This dashboard also allows us to follow the evolution of the hourly filling rate of the yard per m^3/h. Thus, the manager will have a better idea of the speed at which operations are carried out in the log yard. Monitoring of the mill consumption is also possible at any time through the tracking of the daily transformation by product. Setting goals over a defined period at the very beginning allows for monitoring the satisfaction of sawing needs, yard filling and to verify whether the goals are being met. In addition, a history of inter-yard exchanges is presented on the dashboard by providing the number of trucks entering and leaving for exchange during the selected period. The average of these inter-yard exchanges is also visible on the graph, which makes it possible to adjust the entries and exits of trucks loaded with wood.

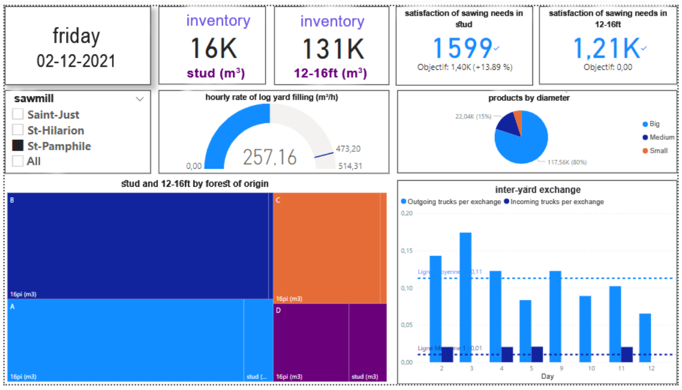

Figure 10. Dashboard for St-Pamphile yard

The display of all the log yards in the network is also possible and we therefore obtain a dashboard that presents the different performance indicators for the entire network, as shown in Figure 11. Thus, it is possible to have a global vision of the whole network in order to adjust the inventories, the production and the inter-yard exchanges by considering the state of the whole network. The dashboard can be validated by checking the balance of the inter yard exchanges, i.e., the number of outgoing trucks must be equal to the number of incoming trucks within the network. In a 2nd interface (Figure 12) and from the processed data, the follow up of the utilization rate of the storage space in the log yard is accessible. The manager can therefore control the occupancy rate of the yard by adjusting the incoming and outgoing flows to better exploit the available space. In addition, it is also possible to control the distances travelled per day. The monthly distances travelled can be deduced, and by superimposing the data of the current month with the previous month(s), the evolution and the variation of the distances are more visible and therefore new measures can be taken. Through this dashboard, it is also possible to check the availability of the trucks since all the trips are recorded and their entries or exits are tracked in real time. Thus, inter-yard exchanges can be scheduled in advance according to the available trucks. Also, another important piece of information that shows the significance of the inter-yard exchanges in the network is provided by this tool. It is the average daily rate of incoming trucks per interchange and the same indicator for outgoing trucks per interchange. It is an average over the entire period defined at the beginning of the dashboard. This indicator shows whether the actions followed by the manager are in line with the strategy and policy for interchanges.

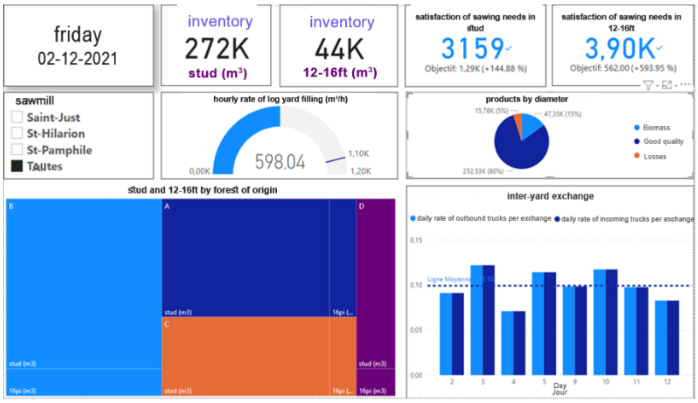

Figure 11. Dashboard for the entire network

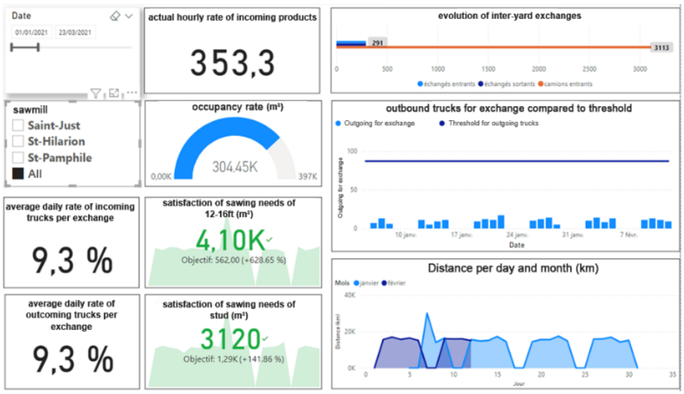

Figure 12. Interface of the dashboard which targets transportation activities

Such a dashboard could therefore be used to provide better visibility on each of the network's log yards and on the network. To fully exploit this tool, it is preferable to link it to the simulation model. Thanks to its forecasting capabilities, the simulation model will provide a prediction of the network evolution that will be highlighted in the dashboard. The latter will therefore reflect what is happening in the log yard network by analyzing the data generated by the simulation while highlighting the performance indicators. The results of the simulation would be sorted and then processed in order to design the full dashboard, which would give more flexibility in the yards management. This dashboard could also be used as a database for future research and for statistics since it documents all operations within the network. It also complements the simulation model as it allows for a better visualization of the effect of different yard management strategies on the system.

6 CONCLUSION

The objective of this research was to propose a simulation model capable of reproducing the current situation of a log yard network and to test various coordination scenarios to identify the best inter-yard exchange strategy for managers. The research also aimed to develop a dashboard that could provide better visibility on the entire network in real time.

Four scenarios with different inter-yard exchanges schedules were tested for a period of six months. An analysis of each scenario showed the evolution of some performance indicators such as inventory and inter-yard exchanges. Then, a comparison of the scenarios for the same performance indicator was performed, to identify the advantages and disadvantages of each scenario. Results showed that it was possible to increase the overall performance of the log yard network following a well-defined strategy. The challenge is to find a good compromise, as these improvements could have negative effects on other aspects of the network. For example, by reducing travelling distances through reduced inter-yard exchanges, there will be additional costs for storing and handling both types of wood in the same yard or managing a shortfall in inventory. In the opposite situation, additional costs are related to the additional truck trips for the inter-yard exchanges.

A dashboard was also established. It offers global visibility of the network with its different performance indicators in real time. Through a simple interface, the manager can choose the parameters to indicate the date, the yard, and the period for which he wants to display the information. He can also choose to display the information for all the log yards together. Through the dashboard, the manager will be able to ensure that he reaches his targets in terms of inventory, wood processing, inter-yard exchanges, and distances traveled since the interface of the dashboard provides a comparison between the current state and the target value.

The research is based on a case study. Thus, this study was limited to a network of three log yards. Other yards could have their own complexities and give different results. In addition, the results could be different if the financial factor was considered. For example, it would be possible to convert changes in yard inventories, sawmill production, and truck movements into costs. This would make it possible to measure the benefits of each scenario, which is necessary to ensure the validity of the proposed strategies.

To follow up on the results of this research, various avenues could be explored. A comparative study between the management of a log yard network equipped with a dashboard accessible to managers and another network without such a dashboard could be conducted to further study the effects of such a dashboard on the performance of a network of log yards. A more complex network as well as a larger number of products could also be investigated. Competition between the resources to be transported and stock capacity could furthermore be a challenging aspect to look at.

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