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Improving sawmill agility through log classification

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Abstract: *Sawmill production is characterized by divergent processes and coproduction. In this context, it is difficult for a production manager to establish a production plan which meets customer demand. This is one of the reasons why the North American lumber industry produces with a mainly make-to-stock strategy. The aim of this research is to evaluate the impact that a better classification of the raw material (logs) would have on sawmill agility. Using a mathematical model to create production plans, we evaluate the performance of the mill to meet the demand in light of the knowledge it has of the raw material.*

Keywords: *Agility in supply chain, optimization, timber industry, classification.*

1. INTRODUCTION

The process of softwood lumber production is one that shows interesting characteristics. Felled trees that have been limbed and cut to length arrive at a sawmill which then transforms this raw material (logs) into various products (lumber) of different standard[1] sizes and lengths. The sawing of a single log generates an assortment of different products (divergent process) simultaneously (coproduction).

In North America, there is generally little classification of logs prior to sawing, whether at the log yard (location where the logs are stored before entering sawmill) or along the forest roads.

The firm's ability to plan production in response to customer orders is therefore very limited and this is the primary reason why these businesses mainly produce with a make-to-stock strategy. It is thus difficult to satisfy a product order that constitutes a very small part of the business's production. For these products, it is not unusual to have to wait several weeks before a sufficient volume is available for sale.

A more efficient classification in the stock yard would make it possible to better identify the characteristics of the sawn wood and therefore better prepare for the quantity and the characteristics of the products to be made. By increasing the number of log categories, we become well placed for flexibility (i.e., able to adapt production according to customer demand). Using a pull production system, one could choose logs that are appropriate for the production of lumber that meets customer demand and by doing so, we would be able to meet this demand more quickly. However, the use of these methods would assume that there is an initial classification of the raw material. Such pull systems are already in use for the production of customized wood products (mainly hardwood), but not for the production of commodity softwood lumber.

The technical means for log classification are already available. For example, when the logs arrive in the yard, a 'log sorter' (industrial equipment for sorting logs) can be used to classify them according to physical characteristics. An alternative is to sort logs during forest operations: multi-purpose tree harvesters which are controlled by state-of-the-art computers already scan the trees before bucking them into logs (YOUSFI, 2010). Thus, classification can be performed helped by infotronic technology directly in the forest

Moreover, researchers have already developed production planning tools that allow determining, for each period, the type of logs that should be used

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[1] In North America, lumber dimensions are standardized and as such, they are considered commodity products.

considering customer demand (GAUDREAULT et al. 2010).

In the context of this research, we have therefore evaluated the impact of a better log classification in the perspective of a pull production system for softwood lumber. We measured the efficiency gained (the capacity to quickly meet customer demand) according to the number of log categories.

In Section 2, we introduce the basic concepts required to understand the context of the North American lumber industry. Then, in Section 3 we carry out experiments to evaluate the impact of log classification on the flexibility of the system. Finally, in Section 4 we make our concluding remarks.

2. BASIC CONCEPTS

2.1 Wood supply chain

In natural forest, each tree has different characteristics, e.g.,its diameter, height, sweep and even its density. Internal defects are also frequent. All these characteristics assure that no two trees are exactly the same. This continuous variation in the logs which arrive at sawmill causes problems from a planning point of view. Due to the log extraction process from the forest, and the variations in the raw material, the planning strategy of North American sawmills is driven by the supplier, which means the scheduler has to produce with whatever type of logs he receives without having total control over its supply. The Canadian wood supply chain is described in more detail by D'AMOURS et al. (2009).

In North America, when resinous trees are felled, a summary sorting is actually made in the forest. It is thus possible to see on the roadside a limited sorting of the logs which are sorted by assortment; similar length and diameters are stacked together according to their species. The raw material is then transported by trucks to different sawmills that have the right to receive logs from these harvesting areas. Upon arrival at sawmill, trucks unload in the yard in a few stacks, more or less sorted.

2.2 Sawing process

Logs are first stocked in the log yard. They then go into the sawing plant to be processed according to standard cutting patterns. Since North American lumber products are standardized (dimension, length and grades), logs are converted according to a push system in order to produce the range of products with the highest possible market value with an automation process (CID YANEZ et al. 2008).
Based on past production data, sawmills are able to estimate the quantities of each product that a log class can produce (GAUDREAULT 2009), as shown in Figure 1. This figure illustrates the impossibility of producing a particular product without getting some other products at the same time (coproduction), making it difficult to plan production according to customer orders. (CRAMA et al. 2001).

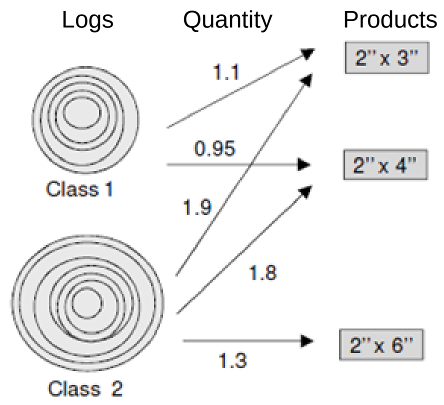

Figure 1 : Example of a production matrix, adapted from GAUDREAULT et al. (2010)

In an extreme situation where we have only one class of logs, the plant will produce the same mix of products during each production shift. So, for a given product, the sawmill will obtain approximately the same volume of each product during each shift.

For some marginal products (which correspond to a small percentage of the mix of products), it can take several weeks before a volume sufficient to be sold becomes available in stock.

With a larger number of log classes (i.e. assuming that log classes group the logs together according to their physical characteristics), it becomes possible to control and decrease the number of different lumber products created. Indeed, as can be seen in figure 2, the number of different products obtained during a given shift will be decreased if only one log class is sawn at time *t* rather than an equal quantity of unsorted logs. With a larger number of log classes, we can select the raw material that allows producing the right products (the one satisfying the demand of the particular period) and avoids having too many undesired co-products.

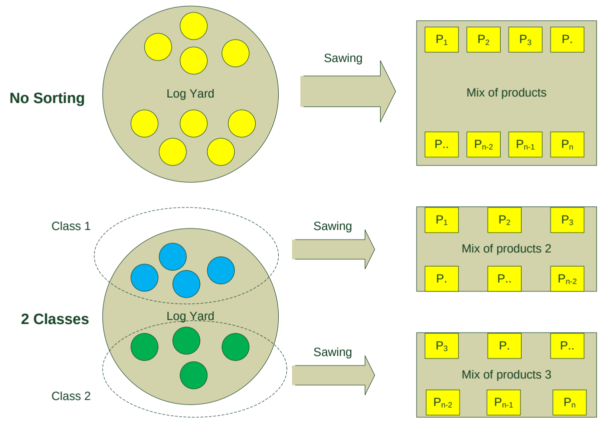

Figure 2 : Effect of log sorting on the mix of products

2.3 Lumber production planning

Among those authors who have worked on the specific problem of softwood lumber production planning, MANESS et al. (1993) have proposed a mixed programming model that simultaneously determines the optimal bucking and sawing policies based on demand and final product price (integration of stem bucking and log sawing). This model was later modified to handle several periods (MANESS et al. 2002). These works focus on the identification of new cutting patterns/policies.

Taking a more global view of the supply chain, SINGER et al. (2007) recently presented a model for optimizing planning decisions in the sawmill industry. They modeled a simplified internal supply chain, including two transformation stages and two inventory stages. The objective was to demonstrate how collaboration can benefit the partners, by transferring timber and using the competitive advantages of each.

GAUDREAULT et al. (2010) have presented a mathematical model used specifically to plan the sawing operations. This multi-period model decides the volume $\left(QC_{l,t}\right)$ of each log class $l \in \mathbf{L}$ to be consumed at each period t. In short, the objective is to satisfy the demand in the best possible way (minimizing lateness). Parameters define the capacity $\delta_{l,m}$ used each time a log from a given class is consumed and the quantities of each finished product that is expected when a volume from a given log class is processed $\left(\rho_{l,p}\right)$. The model also defines setup constraints. Although the model allows detailed operations planning and scheduling, it can be used for aggregated (tactical) planning purposes if setup constraints are relaxed.

A stochastic adaptation of this model that takes variability into account was published by KAZEMI-ZANJANI et al. (2010).

Even though planning models exist, it is difficult for sawmills to implement these tools because log sorting at sawmills is almost non-existent. Therefore, there is no planning decision to be made other than to decide to produce or not and the capacity to plan according to customer orders is thus quite limited in practice.

2.4 Methods for logs traceability and sorting

In order to sort logs, several solutions can be considered. When a sorting machine in the log yard is used, it can allocate each log to a stocking bin representing one class. Using this system makes possible a careful sorting of each log which will often be sorted according to its specie, diameter and length.

Another option would be to use the data collected within the on-board computers of the tree harvesters. YOUSFI (2010) mention several potential uses for those data. Indeed, during tree harvesting, logs are automatically scanned by the harvesters. As the characteristics of each timber can be recorded, it is conceivable to use a sorting which would directly be done in the forest.

The large European project named Indisputable Key (UUSIJARVI 2003) which groups together 28 partners from five different countries has worked for more than three years on log traceability methods between forests and sawmill in the European context. Each log could receive a unique ID in the forest which would then allow the log to be identified in the sawmill (HAKLI et al. 2010). Researchers on this project have been able to show different methods to trace logs along the whole supply chain (for more information, see UUSIJARVI 2010).

However, investing in such methods is expensive. These sorting systems are not used in the North American softwood lumber industry. It is clear that sorting, without any purpose, involves really high investment costs, but GOULET (2007) has shown that substantial productivity benefits on sawing units can be achieved with log sorting. These benefits come from the fact that a mix of compatible logs allows maximizing the usage rate of the different machines. However, the objective of their work was not to measure the gain in the ability of the plant to meet customer demand. The next section aims to answer that question.

3. EXPERIMENTATION

The following experiment aims to measure the flexibility of a plant regarding its level of raw material characterization.

In our base scenario, we suppose that the plant does not do any log sorting. We had access to data concerning a sample of 949 logs considered representative of a sawmill supply. Log characteristics are known (large end and small end diameter, length, volume, taper and sweep). A harvester or a log sorter could give the same information.

For each of these sample-logs, we simulated sawing operations using the Optitek simulator. Optitek has been developed by FPInnovations (see FORINTEK CANADA CORP, 1994). This simulator, used in many research projects (like GOULET 2006 or ZHANG 2005), allowed us to determine the mix of products obtained by the plant when no sorting is done. figure 3 shows the product distribution in this generated mix. Some products are frequently produced while others are seldom produced.

In practice, the performance obtained depends on the demand profile that the plant has to face. We will measure these indicators for three different products (see figure 3):

- The product having the median frequency (2x4 grade 1 length 7 ft) ;
- The product having the average frequency (2x3 grade 2 length 8 ft);
- The product having the largest quantity produced in our standard mix of product (2x4 grade 1 length 10 ft).

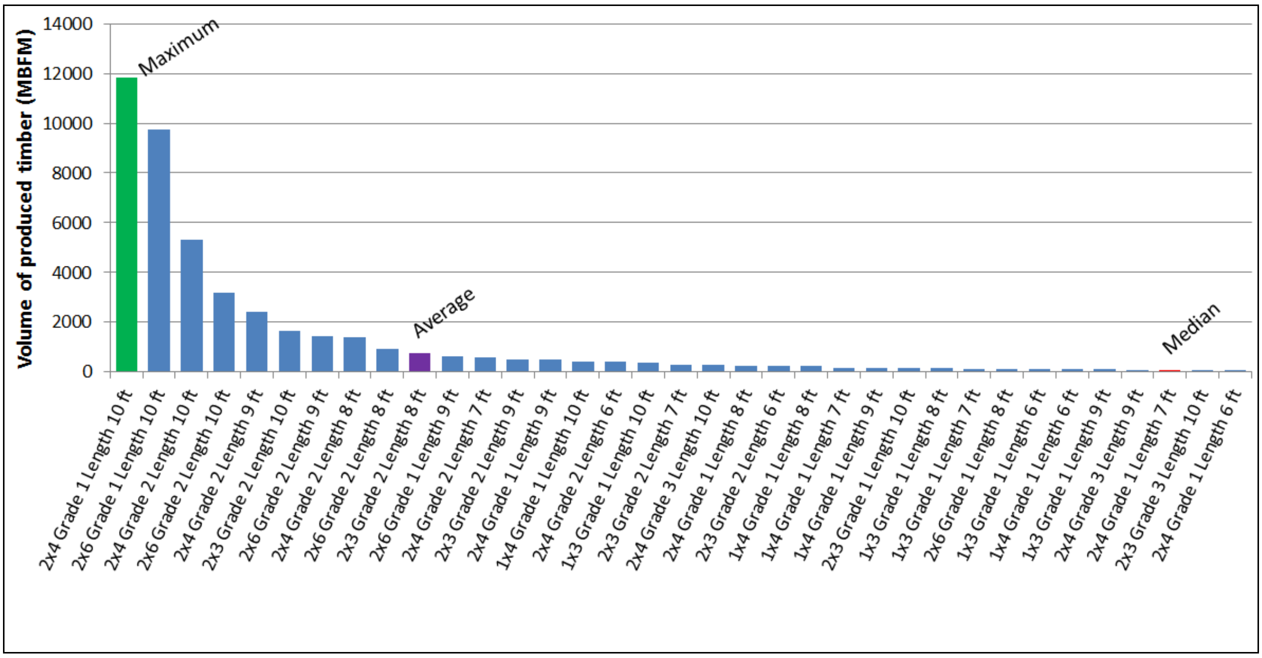

Figure 3 : Distribution of the annual production by products, only the first 35 products (from 64) are shown

We then simulated orders arrival of truck load volumes (32 MFBM[2]). With these (still supposing that our plant is consuming unsorted logs), we measured the following parameters: (1) time required to produce an order, (2) log volume required to fulfill this order and (3) total volume of finished product obtained during this period (due to the coproduction phenomenon, it is not possible to produce only the ordered product).

Thereafter, we took the same measures, but in the extreme situation in which 949 log classes would exist (each being represented by one of our sample-logs). The mathematical model described in Section 2.3 is then used to plan the production in order to meet the demand (Optitek gives us the mix of products that each log generates according to its characteristics, which defines the parameters of the model).

Figure 4 shows that in order to meet a standardized order of the product which corresponds to the median production of our sawmill, we can decrease the effort needed by 98% (logs volume to consume, total volume of finished products obtained and production time needed[3]) when 949 log classes are used when compared to the situation with no classification.

[2] The MFBM, *Thousand board-feet* is the unit of measure for the volume of lumber used in North America.

[3] In our study, we considered the processing time to be proportional with the log volume. Industrial partners validated it as being precise enough for a preliminary study.

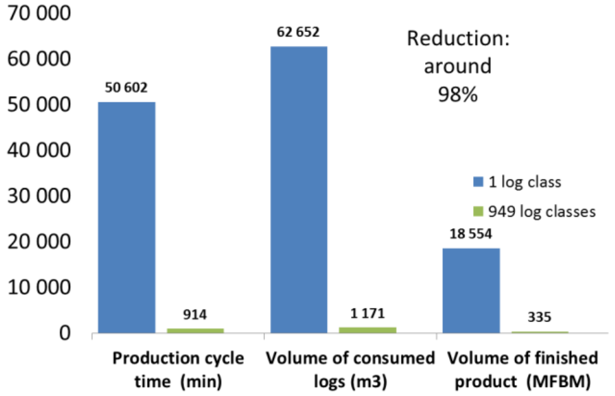

Figure 4 : Production time, volume of consumed logs and volume of generated products needed in order to meet a standardized order (1 truck) of the product: 2x4 grade 1 length 7 ft (median of the production), 1 log class compared with 949 log classes

This potential is also very high for the product corresponding to the production average: more than 85% (Figure 5). Finally, for the product most produced this reduction is around 70% (Figure 6). Indeed, it appears that the lower the quantity of the product is in the standard mix, the higher the reduction potential is.

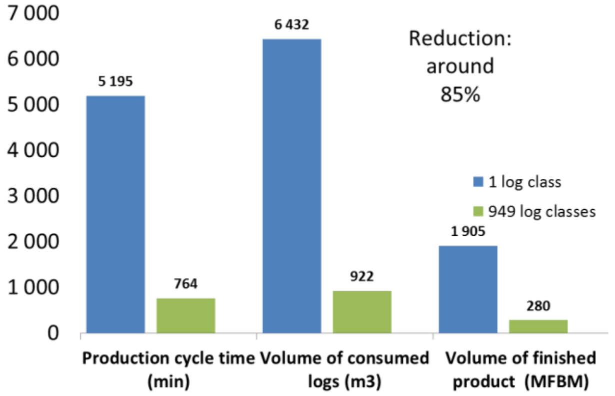

Figure 5 : Volume of consumed logs and of generated products in order to meet a standardized order (1 truck) of the product: 2x3 grade 2 length 8 ft (average of the production), 1 log class compared with 949 log classes

Then we tried to evaluate how many log classes would be necessary (still in comparison with a base case where the raw material is not sorted) to attain a given performance level. We split up our log sample in order to create some sets (log classes) of the same size. The criteria used for log sorting is the large-end diameter (extreme part of the log with the largest diameter), a basic characteristic well known within the industry.

We first created three classes, then 10, 50, 95 and finally 214. Figure 7 presents the reduction of the total produced volume for a standardized order of each of the three studied products.

The curves are strictly decreasing, meaning that the higher the classes' amount is, the lower the produced quantity is, compared to the quantity produced with only one class of log, and so the greater the reduction is.

However it is the classes added first which are generally more profitable (i.e. the marginal gain linked to the addition of classes generally decreases with the increase of the number of classes).

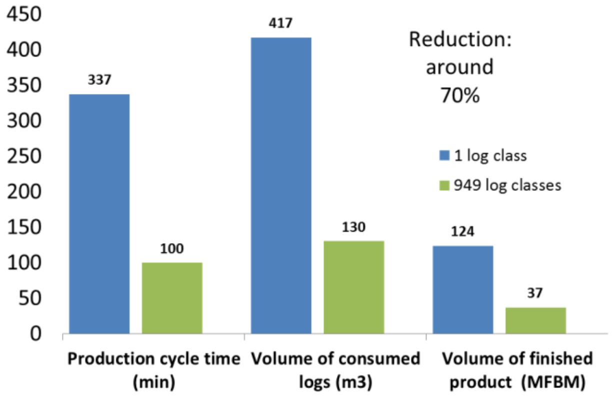

Figure 6 : Volume of consumed logs and of generated products in order to meet a standardized order (1 truck) of the product: 2x4 grade 1 length 10 ft (biggest quantity produced), 1 log class compared with 949 log classes

For the product 2x4 grade 1 length 7 ft (median of the production), three classes do not allow decreasing the volume produced. The highest gain for this product is located between 10 and 50 classes. We get a very high decrease for 10 classes for the 2x4 grade 1 length 10 ft (the most produced product), but, in order to have the same decrease with the 2x3 grade 2 length 8 ft (production average), we need more than 100 classes. However, for the 2x4 grade 1 length 10 ft the realized gain between 10 and 100 classes is comparatively very low. So the tendency depends on the product. But the gain between 250 and 949 classes is not significant considering the important number of additional classes.
Finally we studied the impact of disposing of an important log stock at the entrance of the sawmill (in the previous scenarios, we supposed that the plant was supplied weekly by its suppliers).

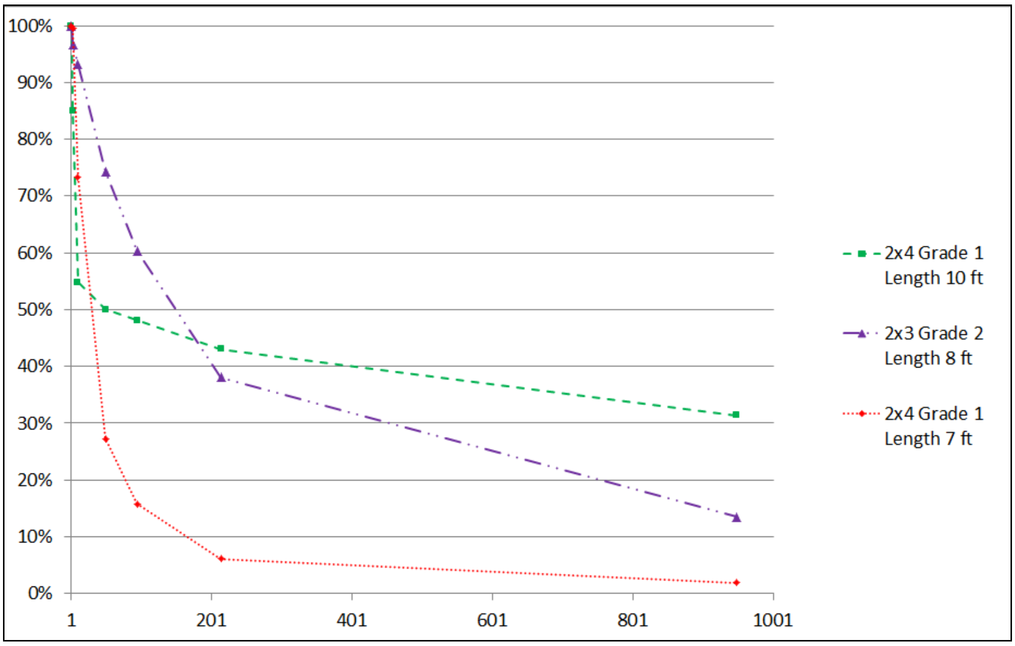

Figure 7 : Total produced volume for a standardized order of different products according to the number of log classes

Figure 8 presents the same metric as figure 7 but for one product. We added a second curve which shows the increase of the performance if the plant has a six-week stock of logs (representative of the Canadian forestry industry practices). It shows the inventory greatly reduces the volume we have to produce (with an increase of log stocks, we have more room available to select only the logs that best fit the demand).

The results are similar for the other products studied (even though not represented in the figure).

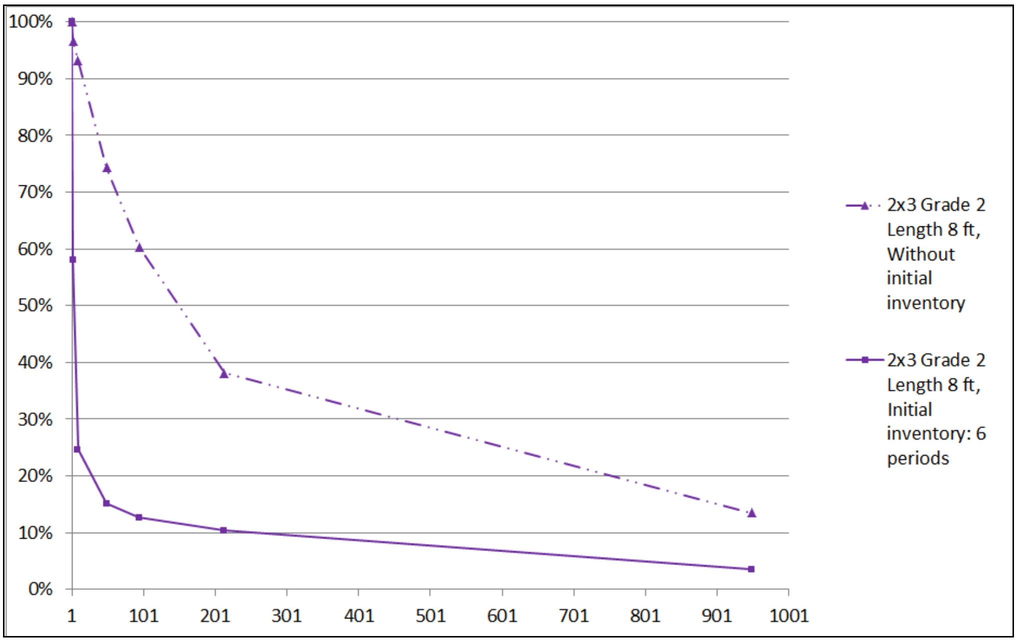

Figure 8 : Total volume we need to produce to satisfy a standardized order of 2x3 grade 2 length 8 ft (with and without initial inventory of logs), according to the number of log classes.

4. CONCLUSION

Log sorting clearly shows huge potential in terms of agility, although it is the first classes we create that generate the biggest improvement in agility.
Moreover, the higher the log inventory in the log yard is, the more the order would be able to be satisfied quickly with a smaller number of classes. Therefore, some tradeoff needs to be established.

Our results cannot serve as a prescription for the industry. A company could determine the products which should be produced on demand (rather than made to stock) and should determine the appropriate sorting strategy as well. As indicated, the question of stock levels for each log class should be an important element in this strategy.

In our study, we considered neither the costs generated by the sorting, nor the gains realized because of the finished product inventory reduction. We also did not take into account some eventual gains in productivity as announced by the work of GOULET (2007).

As part of our future work, we intend to develop the methodology that allows establishing a global strategy. In addition, we intend to evaluate more sophisticated criteria for the log sorting (more particularly sorting the logs according to their propensity to generate a similar mix of products).

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