Optimization of Park Vehicle Circulation: The case study of Celbi

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Abstract

In a context of continuous improvement, any process within a company must be studied in order to identify potential improvements. These improvements can be, for example, in terms of operating costs, in terms of efficiency of operations or even in the level of service provided to customers and suppliers. In a pulp factory, ensuring a continuous flow of trucks arriving at the factory may be the key to maximizing this level of service, where a good management of the outdoor park can be considered a crucial element to ensure low truck waiting times at situations of peak activity with higher traffic. The present Master Dissertation seeks to optimize the flow of vehicles in the park, thus ensuring an improvement in the efficiency of the service provided in one of the main pulp production plants in the Iberian Peninsula. The work developed includes a review of the existing literature of case studies in similar industries, which will support the steps for the methodology to be adopted to solve the proposed problem, and which will be based on simulation. Subsequently, the Arena software will be used to evaluate the current system (identifying the bottlenecks) and the consequences of different gate management strategies at Celbi. Finally, the final results are presented and discussed with the intention of proposing a viable and efficient alternative solution that can not only improve the performance of the system, but also increase the level of supplier satisfaction.

Keywords: Logistics, Gate Management, Optimization, Arrival Flow, Appointment Systems, Vehicle Flow

1. INTRODUCTION

In an article published by Business Week in 1975, an analyst at consultant Arthur D. Little Inc. introduced the idea of a paperless office in such a way that, over the next few years, emerging technology would eventually replace paper in the workplace. The reality is that, despite the tremendous advancements made possible by the technological era, paper remains very much a part of our everyday lives, not just in the production of conventional office paper, but also in the sheets of newspapers, magazines, and even printed currency.

With a high number of imports and exports, the paper pulp industry in Portugal has proven to be the star of the national stock exchange. This is a profitable industry for both companies and the economy, and it carries a significant weight in PSI 20, one of the key stock market indexes in the Portuguese capital market. In 2017, this sector was experiencing a darker period, shaken by the discussion of forest restructuring, where measures to slow down eucalyptus plantations were being discussed. These debates have also questioned investments in the sector in Portugal, putting companies' international competitiveness in jeopardy. Now, the pulp production industry is seeing new reasons to smile again, thanks to the appearance of new incentives for the end of single-use plastic, and contrary to more sceptical predictions, this is an industry that is still growing. Not only is there still a market for office paper, but also new packages are emerging that use this raw material because it is easy to recycle, making it more environmentally friendly.

Celulose Beira Industrial (Celbi) S.A., a company with a 50-year history whose key operation is the manufacture and sale of short fibre pulp, is one of the major players in this field in Portugal. This is a company based in Leirosa that is part of the Altri group, which, along with two other pulp production plants - Celtejo and Caima - makes this group one of the most important in Portugal, with a forest area of around 84 thousand hectares, a self-sufficiency rate of around 30%, and a nominal annual production capacity of around 1 million tons.

Celbi stands out from other companies in the same industry due to its self-sufficiency, as it is able to generate all of the electric energy it requires for its pulp manufacturing operations. This self-sufficiency is achieved by cogeneration, in which combustible plant components that are not used in the manufacture of paper pulp (lignins) are burned to generate steam, which is then used to power an industrial generator. At the same time, Celbi trades energy (purchases and sales) with EDP through its thermoelectric facility, which produces electric energy from forest biomass that can then be pumped into the national grid.

These are some of the factors that, when combined with good quality in the type of eucalyptus used, ensure Celbi's paste has good strength, opacity, and porosity. As a result of its efficiency in the production of paper pulp (production in closed processes and with a high degree of self-sufficiency), Celbi is a reference not only in Europe but also globally, with an annual capacity production exceeding 700 thousand tons.

However, there is always room for improvement, which is why all processes within a company should be examined in order to identify areas where improvements can be made, such as in terms of operational costs or efficiency. In this sense, Celbi took on the challenge of reducing park waiting times for timber supply trucks. This is mostly a seasonal operation, with a high volume of deliveries during the summer, resulting in an overabundance of vehicles in the park. As a result of this accumulation, there can be problems with other operations, as well as a rise in business expenses and the use of time and resources that could be used in a more productive way.

The aim of this dissertation is to conduct a detailed examination of the company's current strategy for vehicle circulation in the park, as well as all relevant logistics and operations. Given that this work has a significant impact on many of the operations that take place within the factory, there is a need to implement a logistical planning methodology that allows different scenarios to be tested and analysed in order to develop a new park management policy. With this goal in mind, it is essential to idealize a simulation model based on discrete event simulation. The simulation will allow the key bottlenecks in the current system to be identified, as well as the results of the various scenarios presented.

The application of the developed methodology is expected to allow for the drawing of conclusions in order to improve park circulation flow and, as a result, avoid vehicle accumulation situations.

2. CASE STUDY CHARACTERIZATION

Celbi is designed in such a way that it can ensure a constant flow of vehicles while still optimizing the amount of space used, as seen in Figure 1. Thus, the factory consists of: an area dedicated to the production of paper pulp, where we can see unloading tables for the wood shredders; a gate for trucks to enter and exit; two spaces where the ergotests tanks are located; a train line that transports some of the wood used in the process; a WasteWater Treatment Plant (WWTP) dedicated to the treatment of wastewater; an industrial biomass furnace for electricity generation; as well as many areas spread across the park for the storage of various types of wood according to their classification and origin. These wood storage areas are referred to as lots.

As a result, each vehicle that enters has its own pre-determined route, with a maximum capacity of 15 to 20 trucks inside the factory. This measure prevents vehicle collisions and increased vehicle congestion, which may result in longer waiting lines at different operations. Depending on the raw material it transports, each vehicle follows a different set of routes and operations inside the plant, but there are certain steps that are common to all.

Upon arrival, all drivers must collect a card, that it will be required to pass in each station inside the factory, allowing Celbi to keep track of the various waiting times between operations. After collecting the card, the driver must wait in an outside parking lot for his call to enter the plant. This call is made in the order in which each truck arrives.

Once the driver is called, he must drive his truck to the main entrance, where he will be weighed so that the transported weight can be calculated using the truck's tare. The truck is automatically rejected if the weight does not correspond to the agreed-upon weight. This preliminary weighing is essential because it helps to estimate the amounts that will be stored or transferred directly to the production line's tables.

At the same time, an inspection of the transported wood is carried out to ensure that the wood species matches that specified in the purchasing contract, as well as to search for foreign bodies (such as metals) mixed with the wood. If the wood species is not the right one or if there is an excessive number of foreign bodies, the truck will also be rejected.

Following the initial inspection and weighing process the truck must follow the indicated route where, depending on the consumption needs and the type of raw material, it can unload directly on the unloading tables of the production line or at the required storage site.

Having unloaded the truck, the driver must proceed to clean his vehicle to remove any remaining materials (such as dust and branches). Following this, the truck proceeds to the exit, where it will be weighed one last time before leaving. This final weighing is used to measure the net transported weight, by simply deducting the tare value of the truck from the gross weight previously observed. The driver will have to pass his card one more time at the exit, and with this last registration, the total time spent inside the factory can now be calculated.

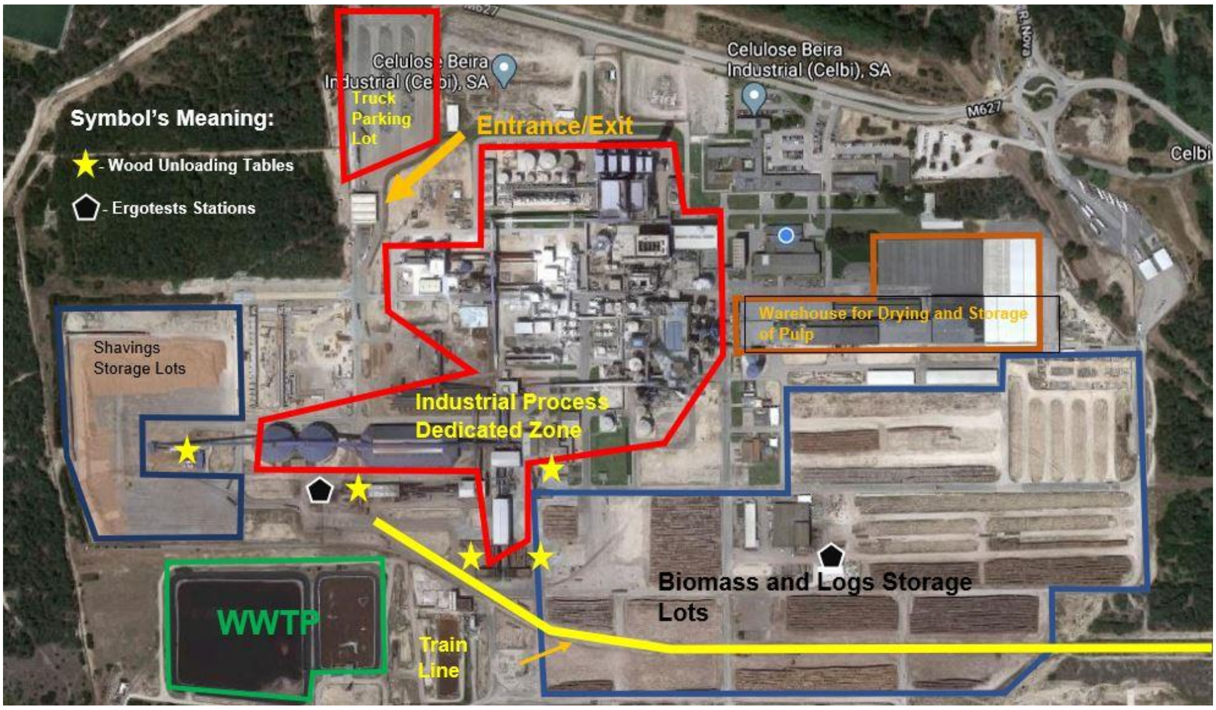

Figure 1: Celbi plant.

3. LITERATURE REVIEW

According to the author's review, the literature on park management for the pulp industry is non-existent. The majority of current wood industry literature discusses log-sort yards, which are separate distribution centres dedicated to the purchase of large quantities of wood, storage, and eventual sale to interested industries and factories. Although they are not pulp mills like Celbi, the two businesses share several similarities, especially in terms of log handling activities such as loading, transporting, and unloading, as well as storage.

For detailed literature reviews on the field of log-sort yards, highlighting the most relevant features, constraints, and objectives used by the different papers and other relevant sources, we refer the reader to three comprehensive surveys: Dramm & Jackson (2000), Ehrhardt et al. (2010), and Dramm et al. (2011). In these articles the authors look at the best practices and policies in terms of layout and material handling in log-sort yards that allow for lower operating costs while ensuring a smoother flow of products.

Ehrhardt et al. (2010) also discuss the introduction of Radio Frequency IDentification technologies (RFID) in the log and biomass supply chains. The potential applications of this type of technology in the wood distribution industry are discussed in this article, specifically in the identification of logs in order to fit important information such as quantity, consistency, and provenance. Until now, information has been exchanged on paper, which requires time and resources (namely human resources to interpret, translate, and integrate into the different computer programs) that could be used in other ways. This form of technology can significantly increase the initial check-in time of trucks about to enter the factory and the check-out time of trucks leaving, allowing for a more continuous flow at the entrance and exit in the case of Celbi.

While many of the problems portrayed are specific from the pulp industry, it is clear that they do not discuss appropriate or unique issues of park management operations. The next step was to look into how this management was being done in other industries, for example the seaport industry.

According to Li et al. (2018) and Nafarrate et al. (2017), seaports are coastal infrastructures that involve a variety of services and equipment for loading and unloading containers arriving on ships. A seaport, according to Azab & Eltawil (2016), has two interfaces: the sea or sea-side interface and the land or land-side interface. The cargo is unloaded and loaded from / to the ships at the land-side interface, and then temporarily stored at the shipyard. Cargo delivery and delivery operations on trucks and trains are part of the land interface. The issues addressed in this sector are somewhat more complicated than those discussed in the forest products industry, due to the two interfaces shown in Figure 2 and their separate activities.

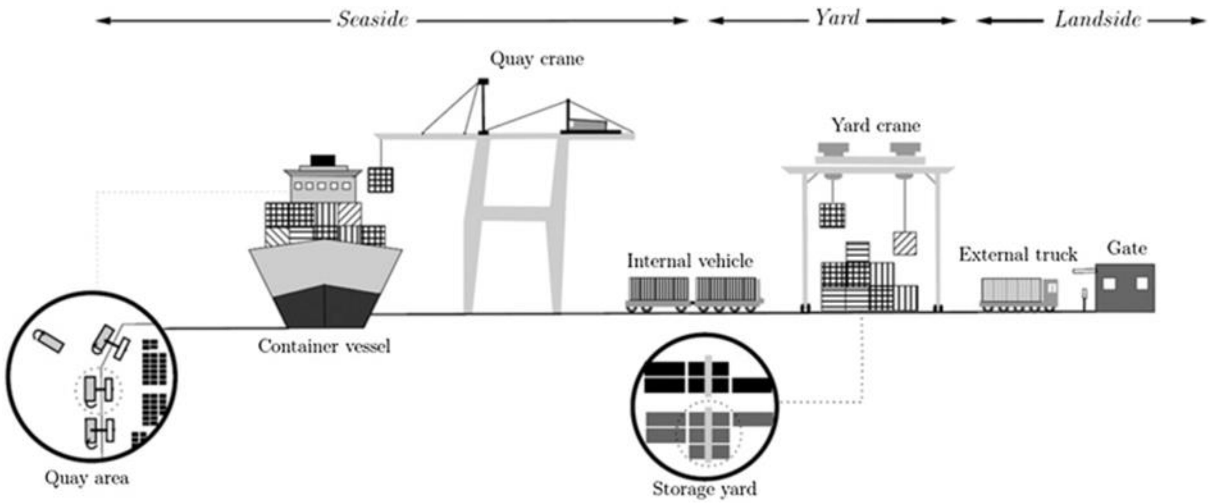

Figure 2: Seaport and its interfaces.

Due to similarities with operations carried out at the Celbi factory, the study focused more on the land-side and surrounding operations. In many ways, the goal is similar: to increase the rate of equipment usage and achieve high customer satisfaction (in this case, the transport companies). Customer satisfaction is achieved by serving each driver in the quickest and most cost-effective manner possible. To put it another way, we want to reduce what is known as Truck Turn Time, which is described by Huynh (2009) as the total time spent by a truck from the time it arrives at its terminal until it departs.

There are two approaches to the problem of truck turn times and park queues.

The first approach involves expanding the existing infrastructure, by increasing the number of machines or the amount of space available for operations. This is a riskier solution from an economic standpoint, as it entails larger investments that, when weighed against the effects on truck turn times, may not be worth it.

The other solution is the implementation of a Truck Appointment System (TAS) to stage truck arrivals and thereby reduce peak operation. In this method, the transportation companies schedule the working hours of the trucks in advance, giving each driver a time for arrival at the seaport, and the terminals, in exchange, plan the allocation of required equipment for each time.

When discussing the issue of truck congestion at seaports, Huynh (2009), Guan & Liu (2009), and Huynh & Walton (2005) discuss how these companies can split the workday and thus achieve various periods with specific times for the arrival of groups of trucks or, in the most extreme case, for each truck. These intervals should not only prevent the issue of waiting lines by phasing the arrival of each vehicle, but they should also ensure that resources and facilities are used to their full potential.

Azab & Eltawil (2016) investigated the impact of various truck arrival patterns on truck turn times using a discrete event simulation model. This research led them to the conclude that, by phasing truck's arrivals, significant reductions in waiting times can be achieved without raising terminal resources or reducing the number of trucks scheduled to arrive.

Huynh (2009) evaluated the impact of two scheduling techniques on resource utilization in seaports and truck turn times. A simulation model was used to compare the results.

According to Chen et al (2011) this TAS can also be achieved by charging higher fees to transportation companies who choose to operate during peak hours. This way, it is possible to manage truck arrivals and phase them during the day.

Due to the inability to extend its operating area, Celbi sees this solution as a way to reduce traffic congestion in the factory park without having to make large investments in new infrastructure and resources.

The author chose to create a simulation model that would recreate the flow of vehicles within the Celbi factory since most of the literature on seaport gate management uses simulation to test their various theories and policies.

4. MODEL DEVELOPMENT

Throughout this chapter, we attempted to describe the model that best addressed the work's goal and that will serve as a study base for testing and analysing the performance of various scenarios aimed at reducing the cycle time of factory trucks.

Firstly, the problem in question was formulated and the scope of the model, that is, the entities, processes, and time space to be considered, were defined. The simulation model to be developed is linked to all of the logistical steps that a wood transport train or truck would go through, from its arrival at the factory to the transport and unloading of the wood at the designated site before the vehicles leave. This chain of events has a direct effect on the amount of time each truck spends inside the factory, which is the subject of this project.

Subsequently, there was a need to define the time space that would be used. Based on the data analysis, it was determined that June is the most critical month, and that activity levels often drop on weekends. Furthermore, as shown in Figure 3, which depicts the number of trucks per hour for the month of June 2020, different times of the day have varying levels of operation. Thus, a 24-hour cycle from Monday to Friday was considered for the simulation, with changing levels of operation depending on the time of day, which will be expressed in the frequency of arrivals of the various vehicles.

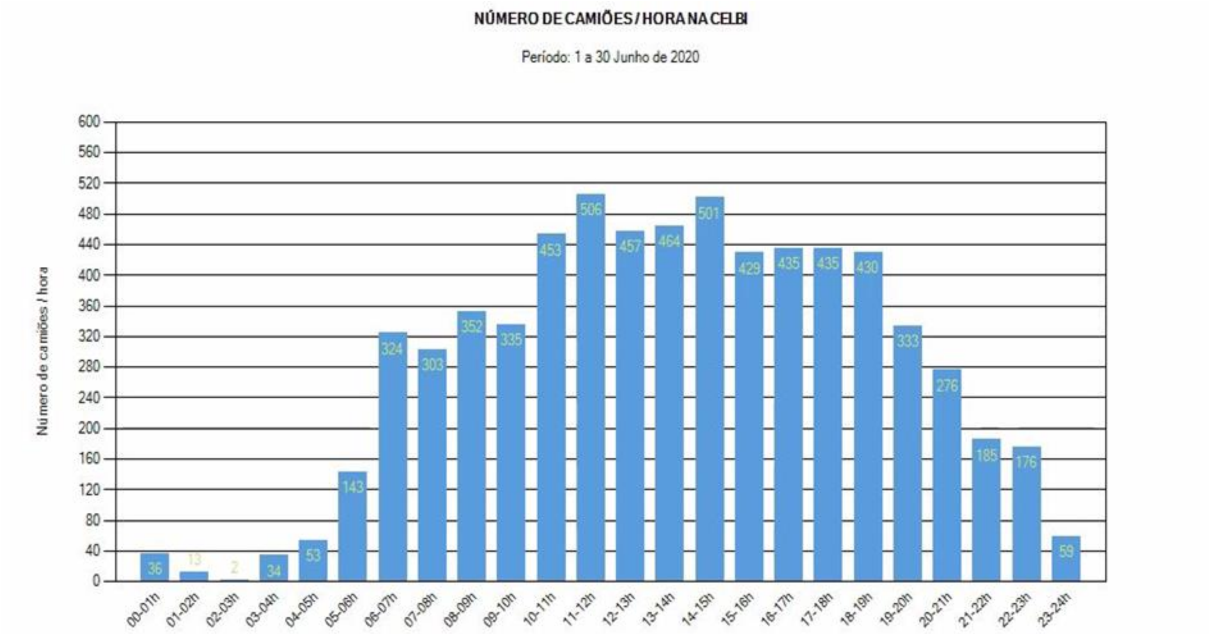

Figure 3: Trucks per hour at Celbi for the month of June 2020.

The conceptual model was then developed, with the help of the Activity Cycle Diagrams (ACD) of each entity (as shown by the example of Figure 4), as well as the data that had been collected and handled. In order to achieve results that were compatible with the reality and that would accurately reflect the system to be simulated, some Celbi engineers and other instruments, such as the Work Breakdown Structure (WBS), were used in the data collection process. From the data, we obtained the values of the times to be used in all processes and movements, as well as the values of the arrival frequencies of each entity and the different capacities at the various stations.

With the ACDs of each entity and the process of collecting and analysing data completed, the Arena software modules and its graphical interface were used to create the representative model of the real system. The model verification and validation stage were crucial in ensuring the model's integrity in this case. Since there are no clear formulas for validating a simulation model, it must be done continuously as the model is being developed, with the goal of ensuring that it is accepted by a vast number of professionals who work in the factory, ensuring this way, that the model is not out of touch with reality.

Finally, the key performance indicators (KPIs) were identified, these are measurable/quantifiable parameters that serve as tools for measuring the performance levels of a particular entity or process. The literature revealed that the truck turn time (cycle time) and the rate of resource usage are the two most commonly used performance metrics. With that in mind, and in order to protect Celbi's interests, it was decided that these would be the indicators used in this project.

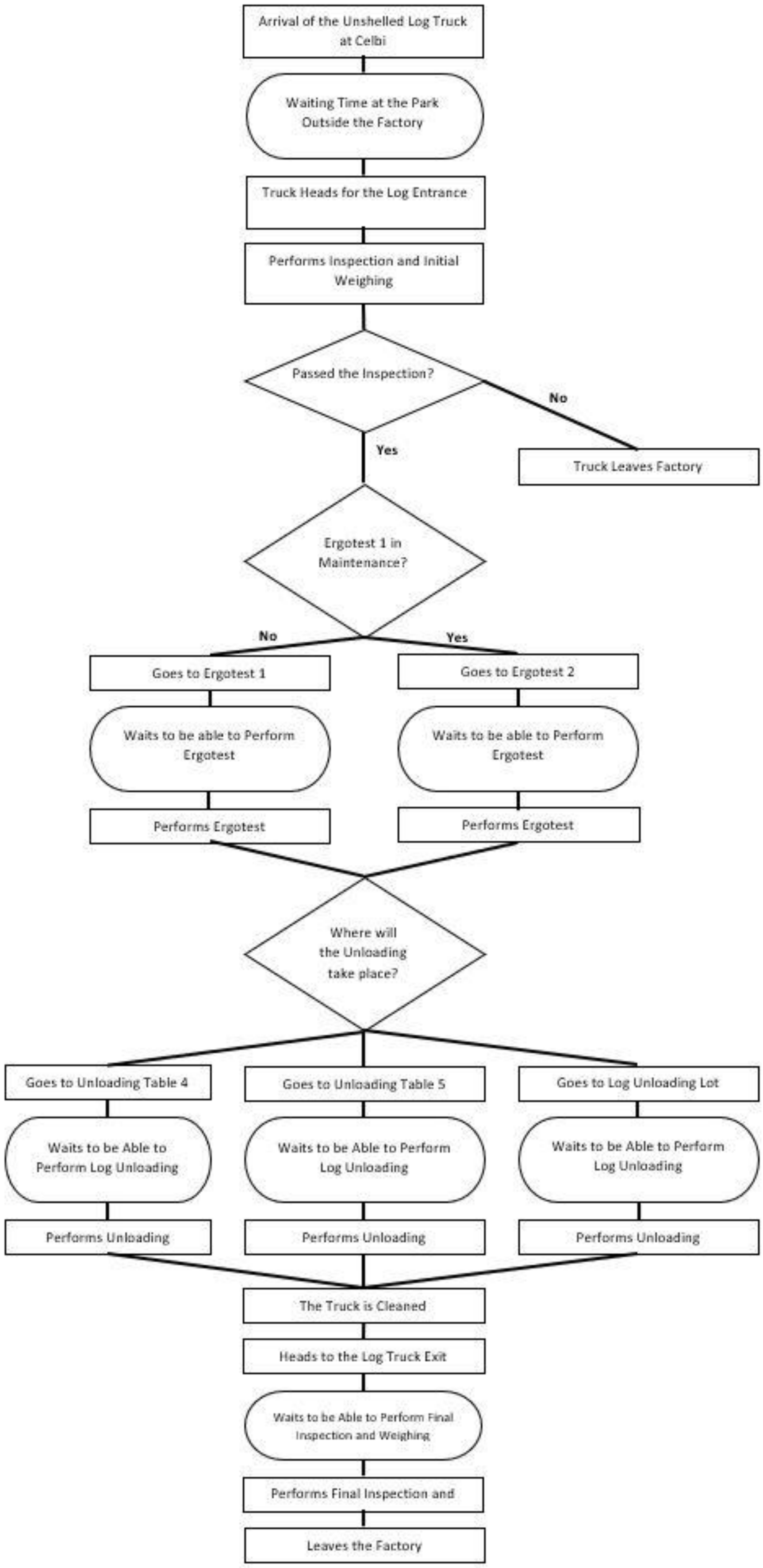

Figure 4: Activity Cycle Diagram for the unshelled log trucks entity.

5. ANALYSIS AND DISCUSSION OF RESULTS

Following the construction and validation of the simulation model, this chapter attempted to evaluate various scenarios based on the applications outlined in the literature review as well as Celbi's suggestions. Initially, an overview of the system that represents the current reality of the vehicle flow at Celbi (the base scenario) was carried out in order to identify bottlenecks and, therefore, possible areas for improvement.

From the analysis of the base scenario, it was possible to identify several issues in the current framework that need to be addressed, namely the waiting time in the entrance park, which accounts for approximately 66% of the cycle time for the log trucks, making it the most significant bottleneck in the model and thus reinforcing the significance of the dissertation's theme.

It was also possible to see an instantaneous utilization rate at log unloading tables 4 and 6 falling below what would be required for a month of higher activity at the plant, justified by the distance from these stations to ergoteste 1 and, in the case of table 4, also by the fact that it can only receive unshelled wood logs.

From studying the base scenario, it was possible to identify two possible paths for the solutions that would be presented. One focusing more upstream of the factory entrance, attempting to manipulate truck arrivals, and the other downstream of the entrance, attempting to change the operations inside the factory, in order to accelerate truck flow and avoid congestions and delays.

This led to the testing of five scenarios, from which it was possible to identify two solutions that could be useful in the future. The first approach (Scenario 3) aims to phase truck arrivals during the day in order to minimize activity peaks and valleys. As seen in Table 1 there was a strong reduction of about 86.20% in park waiting time for the log trucks and 65.65 % for shavings or biomass trucks, making this the best scenario for the purposes of this Dissertation.

However, the author realized that would be more useful to study this same scenario but in a more realistic context (Scenario 3.1.), where there is still a gap, although smaller, between the level of activity at night and the level of activity during the day (Figure 5). Describing, this way, a situation in which Celbi tries to distribute the arrival flow of trucks throughout the day, but some transportation companies still prefer to deliver during the day.

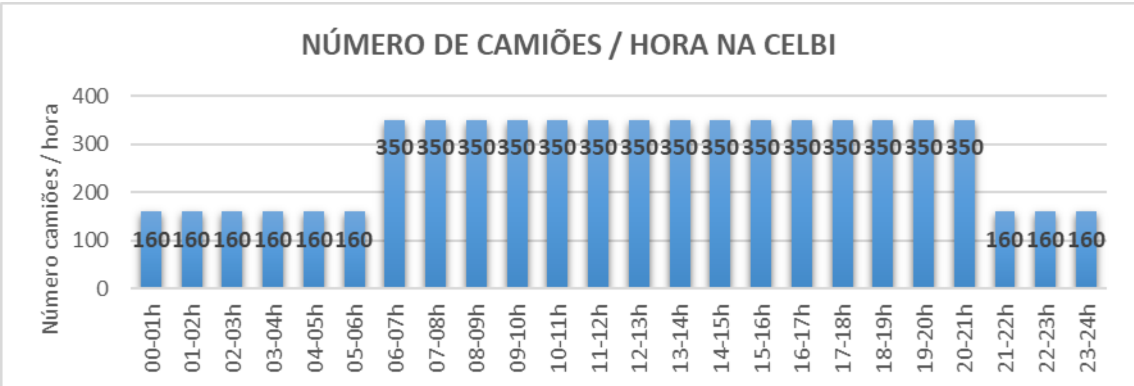

Figure 5: New levels of activity for Scenario 3.1.

This scenario, as seen in Table 2, also achieved very good results, showing a decrease in entrance park waiting time of 53.52% for log trucks and 49.51% percent for shavings or biomass trucks.

The other approach that stood out, aims to install Radio Frequency Identification (RFID) readers at the factory's entrances, ergotests, and exits in order to minimize the time spent at these stations (Scenario 2). This approach proved to be very promising, as it reduced cycle times for all entities while also reducing entrance park waiting times by about 77.67% for log trucks and 61.94% for shavings or biomass trucks (Table 3). However, it is important to be mindful of the negative impact that this new technology may have on the unloading tables because, with faster entries and ergotests, there may be an accumulation of vehicles in later stations, as shown by the increased waiting time at all log unloading stations. This situation can be avoided by restricting the entry of new vehicles into the facility.

Table 1: Results for Scenario 3.

Performance Indicator	Station	Base Scenario	Scenario 3	(S3-BS)	% of Difference
		Average	Average		
Waiting Time by Station (min.)	Hold 1 (Waiting Queue for Entrance of Log Truck)	123,16	16,9851	-106,17	-86,20%
	Hold 2 (Waiting Queue for Entrance of Shavings and Biomass Trucks)	4,5851	1,5800	-3,01	-65,65%
	Shavings Unloading table	5,7574	4,5775	-1,18	-20,50%
	Biomass Unloading Table 1	1,1485	0,5189	-0,63	-54,85%
	Biomass Unloading Table 2	0,2221	0,0915	-0,13	-58,53%
	Ergotest 1	1,3797	0,9979	-0,38	-27,54%
	Log Unloading Table 5	11,7698	10,4106	-1,36	-11,55%
	Log Unloading Table 6 West	8,2627	7,3044	-0,96	-11,62%
Number of Entities Waiting	Hold 1 (Waiting Queue for Entrance of Log Truck)	21,0212	2,9183	-18,10	-86,10%
	Hold 2 (Waiting Queue for Entrance of Shavings and Biomass Trucks)	0,3423	0,1176	-0,22	-64,27%
Rate of Instantaneous Utilization (%)	Log Trucks Entrance	84,72	85,71	0,99%	-
	Shavings and Biomass Trucks Entrance	37,27	37,17	-0,10%	-
	Shavings Unloading Table	47,66	51,69	4,03%	-
	Biomass Unloading Table 1	41,30	44,66	3,36%	-
	Biomass Unloading Table 2	24,04	22,81	-1,23%	-
	Ergotest 1	81,74	82,83	1,09%	-
	Ergotest 2	4,17	4,12	-0,05%	-
	Log Unloading Table 5	89,76	93,48	3,72%	-
	Log Unloading Table 6 West	80,03	81,12	1,09%	-

Table 2: Results for Scenario 3.1.

Performance Indicator	Station	Base Scenario	Scenario 3.1.	(S3.1-BS)	% of Difference
		Average	Average		
Waiting Time by Station (min.)	Hold 1 (Waiting Queue for Entrance of Log Truck)	123,16	57,2473	-65,91	-53,52%
	Hold 2 (Waiting Queue for Entrance of Shavings and Biomass Trucks)	4,5851	2,3136	-2,27	-49,51%
	Shavings Unloading table	5,7574	4,8842	-0,87	-15,11%
	Biomass Unloading Table 1	1,1485	0,7108	-0,44	-38,31%
	Biomass Unloading Table 2	0,2221	0,1432	-0,08	-36,02%
	Ergotest 1	1,3797	1,3403	-0,04	-2,90%
	Log Unloading Table 5	11,7698	11,2396	-0,53	-4,50%
	Log Unloading Table 6 West	8,2627	8,2245	-0,04	-0,48%
Number of Entities Waiting	Hold 1 (Waiting Queue for Entrance of Log Truck)	21,0212	9,8032	-11,22	-53,37%
	Hold 2 (Waiting Queue for Entrance of Shavings and Biomass Trucks)	0,3423	0,1724	-0,17	-49,66%
Rate of Instantaneous Utilization (%)	Log Trucks Entrance	84,72	85,32	0,60%	-
	Shavings and Biomass Trucks Entrance	37,27	37,25	-0,02%	-
	Shavings Unloading Table	47,66	50,33	2,67%	-
	Biomass Unloading Table 1	41,30	43,78	2,48%	-
	Biomass Unloading Table 2	24,04	22,99	-1,05%	-
	Ergotest 1	81,74	82,54	0,80%	-
	Ergotest 2	4,17	4,05	-0,12%	-
	Log Unloading Table 5	89,76	92,16	2,40%	-
	Log Unloading Table 6 West	80,03	81,66	1,63%	-

Table 3: Results for Scenario 2.

Performance Indicator	Station	Base Scenario	Scenario 2	(S2-BS)	% of Difference
		Average	Average		
Waiting Time by Station (min.)	Hold 1 (Waiting Queue for Entrance of Log Truck)	123,16	27,4972	-95,66	-77,67%
	Hold 2 (Waiting Queue for Entrance of Shavings and Biomass Trucks)	4,5851	1,7449	-2,84	-61,94%
	Ergotest 1	1,3797	1,5415	0,16	11,60%
	Ergotest 2	0,5229	1,3262	0,80	152,99%
	Log Unloading Table 4	1,2736	4,3087	3,04	238,69%
	Log Unloading Table 5	11,7698	14,8241	3,05	25,91%
	Log Unloading Table 6 East	1,6837	12,2964	10,61	630,16%
	Log Unloading Table 6 West	8,2627	12,4805	4,22	51,07%
	Wood Logs Lot	1,6430	1,7170	0,07	4,26%
	Log Trucks Exit	5,6306	1,1975	-4,43	-78,68%
	Shavings and Biomass Trucks Exit	0,6318	0,1339	-0,50	-79,14%
Number of Entities Waiting	Hold 1 (Waiting Queue for Entrance of Log Truck)	21,0212	4,7091	-16,31	-77,59%
	Log Unloading Table 4	0,0259	0,0959	0,07	270,27%
	Log Unloading Table 5	0,9471	1,1253	0,18	19,01%
	Log Unloading Table 6 East	0,0576	0,4138	0,36	625,00%
	Log Unloading Table 6 West	0,6352	0,9148	0,28	44,08%
	Log Unloading Lot	0,1396	0,1558	0,02	-14,33%
Rate of Instantaneous Utilization (%)	Log Trucks Entrance	84,72	51,32	-33,40%	-
	Shavings and Biomass Trucks Entrance	37,27	22,33	-14,94%	-
	Saída de Rolaria	84,48	51,27	-33,21%	-
	Saída de Aparas e Biomassa	29,79	14,88	-14,91%	-

6. CONCLUSIONS AND FUTURE WORK

With Celbi's main goal of being the best European producer of short fibre pulp, there is a constant need for growth and improvements. For this reason, this dissertation proposes a simulation model and two possible solution approaches to help with the problem of long waiting times at the entrance of Celbi's factory and, therefore, improving the flow of vehicles. Despite its limitations, the proposed final model is consistent with the conceptual model designed and accurately represents the real system.

The developed model is useful for detecting bottlenecks and evaluating potential scenarios. This way, Celbi now has another tool at its disposal to support decision-making, demonstrating once again that simulation is something worth investing in.

From this study it was possible to conclude that the two best alternatives would be the introduction of RFID technology in strategic locations of the factory and the execution of agreements with the transportation companies in order to phase the arrival of the trucks as much as possible throughout the day.

Opportunities for future work to be developed fall into three categories: simulation model improvements, WBS complements, and cost analysis.

Regarding the model improvements, the different factory operators and their job shifts can be included in the simulation, as well as the internal vehicle movements, i.e., the subcontractors responsible for transporting the wood from the lots to the unloading tables.

For the WBS complements, Celbi should include the categorization of data by raw material transported, as well as the separation of data with respect to transport times, waiting times and processing times at each station.

Finally, a cost-benefit analysis of the two scenarios recommended in this Dissertation should be included, in order to conclude more accurately which scenario is the most effective for the proposed challenge.

7. BIBLIOGRAPHY

Azab, A. E., & Eltawil, A. B. (2016). A simulation based study of the effect of truck arrival patterns on truck turn time in container terminals. *Proceedings - 30th European Conference on Modelling and Simulation, ECMS 2016*, *2*(Cd), 80–86.

Chen, X., Zhou, X., & List, G. F. (2011). Using time-varying tolls to optimize truck arrivals at ports. *Transportation Research Part E: Logistics and Transportation Review*, *47*(6), 965–982. https://doi.org/10.1016/j.tre.2011.04.001

Dramm, J. R., Govett, R., Bilek, T., & Jackson, G. (2011). *Log Sort Yard Economics , Planning ,. October*.

Dramm, J. R., & Jackson, G. L. (2000). Is it Time to Revisit the Log-Sort Yard ? *Proceedings, Wood Technology Clinic and Show Conference*, *1*(1).

Ehrhardt, I., Seidel, H., & Doden, N. (2010). Potentials for Savings by Implementing RFID and Telematic Technologies in the Timber and Biomass Supply Chain. *Agronomy Research*, *May*, 47–59.

Guan, C. Q., & Liu, R. (2009). Modeling gate congestion of marine container terminals, truck waiting cost, and optimization. *Transportation Research Record: Journal of the Transportation Research Board*, *2100*, 58–67. https://doi.org/10.3141/2100-07

Huynh, N. (2009). Reducing truck turn times at marine terminals with appointment scheduling. *Transportation Research Record: Journal of the Transportation Research Board*, *2100*, 47–57. https://doi.org/10.3141/2100-06

Huynh, N. N., & Walton, C. M. (2005). Methodologies for reducing truck turn time at marine container terminals. In *Center for Transportation Research The University of Texas at Austin*.

Li, N., Chen, G., Govindan, K., & Jin, Z. (2018). Disruption management for truck appointment system at a container terminal: A green initiative. *ELSEVIER*, *61*(Transportation Research Part D), 261–273. https://doi.org/10.1016/j.trd.2015.12.014

Ramírez-Nafarrate, A., González-Ramírez, R. G., Smith, N. R., Guerra-Olivares, R., & Voß, S. (2017). Impact on yard efficiency of a truck appointment system for a port terminal. *Annals of Operations Research*, *258*(2), 195–216. https://doi.org/10.1007/s10479-016-2384-0