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Continuous improvement in a Paper Production Process: The case study of Renova

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Abstract

Being part of a market that has been growing in the last couple of decades, Renova, Fábrica de Papel do Almonda S.A. has the objective of differentiating from its competition not only by its innovating capability but also by constantly looking for efficiency and implementation of the best productive processes. This study has the purpose of proposing process improvements in two areas of the main factory of Renova: 1) the paper production process from the entry point of the pulp untill the paper reels; 2) Paper mills' programmed maintenance operations.
The successful implementation of the proposed process improvements could lead to an annual revenue increase of 148,776 euros.

Keywords: productive process, continuous improvement, lean, theory of constraints, SMED.

1. Introduction

The tissue paper market is a highly fragmented one, meaning that the top 10 producers combined make up less than 50% of the world's current production capacity. In this context, Renova is considered a small disruptive player that has the ability of differentiating itself from competition by means of innovation in a traditionally commoditized market. The company makes 130 million euros in annual revenue being the leader in the Portuguese market for domestic use and hygiene paper products with a 30% market share. Aside from that, Renova has been growing its presence in other markets all over the world, being present in over 60 countries at the moment and still growing. Its international business makes up for 50% of the annual revenue and the current objective is to make that piece grow in the following years. This paper focuses on the tissue paper manufacturing processes of one of the paper mills at the company's second plant (paper mill 6 - MP6) as well as on the scheduled maintenance stoppages processes for both mills at the site (paper mill 5 and paper mill 6 - MP5 and MP6). The study of these processes is done with the help of the Theory of Constraints (TOC) methodology integrated with a number of Lean tools. The objective is to reduce waste and improve productivity.

2. Theory of Constraints

2.1 The five focusing steps

Eliyahu Goldratt developed the Theory of Constraints, a management theory that focuses on optimizing a system by solving the point that is restricting it, in the beginning of the 1980's (Goldratt et al., 1984). The objective of the Theory of Constraints is to optimize a system that is composed by several dependent processes by eliminating its weakest links (Simsit et al., 2014). With this objective in mind, Goldratt suggested the use of Five

Focusing Steps - 5FS (Goldratt et al., 1984):

***Step1**: Identify the system's constraint.*

The first step focuses on analyzing the system in order to find the constraint, which is the process that limits the throughput of the system. In an industrial context this can be related with the underutilization of the available capacity of a machine.

***Step 2**: Exploit the system's constraint.*

After identifying the restriction the next step consists of deciding how to optimize this activity and therefore increasing its throughput. This optimization should be achieved using available resources and not by making new significant investments.

***Step 3**: Subordinate the system to previous decisions.*

After deciding on how to explore the identified restriction the whole system should be subordinated to the new capacity.

***Step 4**: Elevate system's constraint.*

In the case that it is not possible to pursue further system improvement and the identified constraint is still restricting the system, the other possible option is to elevate that constraint. At this point that means investing in order to increase capacity. This could be achieved by buying a new machine, for instance. It is also possible to opt not to elevate the restriction due to the unavailability of capital or because the payback time is expected to be too long.

***Step 5**: If the constraint has been eliminated, go back to step 1.*

After solving the first constraint a new restriction of the system should be found. This step promotes the constant search for improvement in the system, avoiding inertia. Pretorius (2014) identifies two complementary steps to Goldratt's methodology as prerequisites to the 5FS:

- Defining the organization's objective.
- Defining how each process will be quantified.

2.2 Comparison and integration of TOC with other continuous improvement methodologies: some examples

More recent studies have concluded that when compared to other methodologies such as Manufacturing Resource Planning (MRP), Lean Manufacturing or Just-in-time (JIT), the application of TOC may lead to better results while others point in the direction of integration: Izmailov (2014) studied the approach by one company in the automotive industry that integrated TOC with Lean manufacturing, improving its throughput by 6.6% and reducing annual overtime costs by $840,000. This improvement was only achieved due to the fact that the integration made it possible to identify restrictions that hadn't been identified in the previous 18 months when using just Lean methodologies. Dettmer (2001) also suggests that TOC and Lean are overlapping in many points, explaining that in some situations Lean may be used during Step 2 of TOC as a way of exploring the previously identified restriction. It is even suggested that the Lean tool SMED - Single Minute Exchange of Dies - could provide a way of improving throughput despite of being difficult to integrate these two solutions.

3. Lean Manufacturing

Lean Manufacturing is a methodology whose purpose is workflow improvement, minimizing setup times and minimizing waste. Womack and Jones (1996) defined three Lean principles:

- Value identification
- Waste elimination
- Flow generation

These principles are the guidelines for the creation and implementation of the different tools that have been developed over the years.

3.1 Lean tools

Some of the most common tools are, according to Feld (2000):

- *Total Preventive Maintenance (TPM)*: this tool focuses on preventing breakdowns as a way of avoiding the need for repairing. The workers visually check machines and tools and have the responsibility to report any malfunction they identify.
- *Single Minute Exchange of Dies (SMED)*: this tool reduces total setup time of a machine by converting internal setup time (work done while the machine is not working) in external setup time (tasks that can be done while the machine is working). (Shingo, 1985)
- *Total Quality Management (TQM)*: this continuous improvement system focuses on customers' needs. Its main components are the involvement of everyone in the company, teams dedicated to problem solving, use of

statistical methods and definition of long-term objectives.

3.2 Challenges and benefits of implementing Lean in continuous processes

According to Abdullah and Rajgopal (2002), the use of Lean tools in continuous processes has been much lower when compared to discrete processes. This can be explained by the characteristics of this industrial sector: the use of big non-flexible machines, high set-up times or the difficulty to produce small batches. This does not mean however that the use of Lean methodologies cannot bring added value to this kind of productive processes (Melton, 2005). An example of a successful use of SMED had place within the molding industry (Karasu et al., 2014) in which it was concluded that 50% of the inefficiencies were due to higher setup times than what was planned. After implementing SMED it was possible to reduce the setup time by 15 minutes from the initial 93 minutes. This shows that it is possible to achieve significant improvements with the use of this tool in particular. Melton (2005) defends that despite the difficulties in implementing Lean methodologies to continuous processes, it is becoming common to see these tools being used in industries such as the pharmaceutical or chemical.

3.3 Single Minute Exchange of Dies (SMED)

For the development of the study at the Renova factory, SMED in particular was of great use since its purpose is to reduce setup times. Its implementation can be divided in three phases:

Phase 1 - Actual state mapping: the process is analyzed, measuring the duration of tasks and registering the movements that are needed in order to complete them.

Phase 2 - Separation between internal and external activities: internal activities are the ones that can only take place while the machine is not running. External activities can take place while the machine is still working.

Phase 3 - Transferring internal activities to external: after the identification phase an effort should be made in the sense of transforming internal activities into external. In the case that it is not possible, parallelizing internal activities is one solution. Costa et al. (2013) suggests five preparation steps before the first phase of SMED:

1) Initial observation in which a tool check is made.
2) Talking to the workers in order to understand the problems they face during maintenance.
3) Video recording of every move and stage of the process.
4) Describing each activity, measuring distances covered by workers and registering the time they take to perform each activity.
5) Construction of a spaghetti chart in order to visualize more easily which are the most congested areas during maintenance.

4. Case Study

As a company that has been steadily growing in the last 10 years, Renova is currently at a point in which its productive capacity is at its limit. This work has the purpose of improving internal processes in order to make better use of the available conditions. It was decided that two different approaches were to be explored in order to achieve this objective:

- Studying the internal circuit of the paper mill 6 (MP6), looking for ways to make the operation more efficient.
- Studying the processes of programmed maintenance operations for paper mill 5 (MP5) and paper mill 6 (MP6) in order to minimize the waste of productive time.

The study of both TOC and Lean Manufacturing methodologies in the literature review was helpful in the work developed at the second Plant of Renova in Torres Novas, where the two most productive paper mills of the company are located.

4.1 Paper production process in MP6

The paper production process allows the transformation of the paper pulp that goes in the paper mill into tissue paper. The part of that process that has place inside the paper mill is presented in Figure 1.

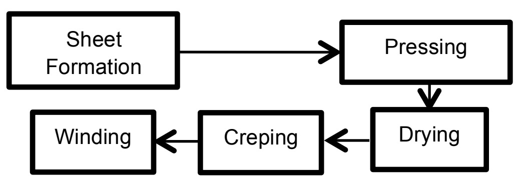

Figure 1- Processes inside MP6.

The first stage that happens inside the machine is the sheet formation. After that the pulp is diluted to very low concentration, which is one of the reasons for the high consumption of water in this industry in particular, its projection onto the forming fabric takes place. The formation stage is one of the most important in paper production, since a good projection assures the correct deposition of fibers, while allowing for a good drainage of excess water. The pressing stage promotes some more water removal by mechanical means while promoting a better connection between fibers. The drying stage is the final stage for water removal, in this case by means of the heat generated by a big rolling cylinder - the yankee dryer. The paper is then released from the roll with the help of a creping blade, which gives the paper more volume and texture. The crepe is one of the characteristics that distinguishes tissue paper from other types of paper. In the final stage, the paper is wound into a 2.15-meter diameter reel. At this point the reel leaves the paper mill and follows its path along the production line. It is estimated that in regular working conditions the verified losses of raw materials are between 7% and 9%.

Applying TOC

Following the TOC methodology presented in section 2, the five focusing steps were applied to the analysis made to the production process of MP6. The methodology is schematically shown in Figure 2. Adding to the 5FS, the two other points defined by Pretorius (2014) - definition of the objective of the organization and deciding on how to measure - were also considered and identified. The objective of the organization is to improve its productive processes and its performance was measured in terms of wasted raw materials during the production of paper.

4.1.1 Identify the system's constraint

To identify the constraint, the circuit was studied in order to make it possible to design a procedure that would ensure control of the operation and the collection of data. The study required knowing every piece of equipment involved, from the pulpers that receive the paper pulp (raw material) to the centrifugal cleaners, refiners and the fiber recoverer (DAF). Since the circuit is quite big and the mill is working continuously, a test procedure had to be defined over a sufficiently wide period of time that could provide plausible results. It was defined that the test would have place during the production of a specific type of paper, composed by 80% recycled pulp and 20% virgin pulp. It ran over 10 hours and the amount of pulp inserted in the system was weighed beforehand as well as the produced paper reels which are weighed on a scale when they leave the mill (Table 1). In order to control more accurately how much pulp entered the system and how much paper was actually produced, the deposits had to be leveled to a certain point before starting the test by the workers of MP6 who then got those levels back to the initial situation before finishing the testing phase.

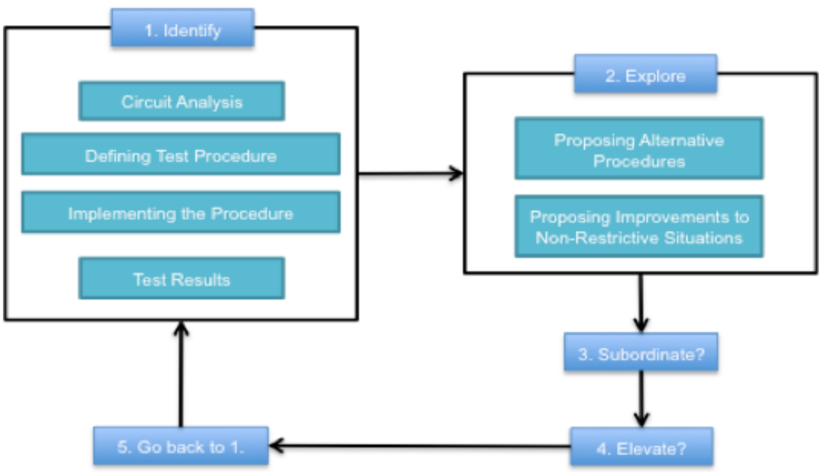

Figure 2 - TOC methodology applied to the study of MP6.

Table 1 - Dry fiber losses verified during the test period (10h).

Dry Pulp (In)	Paper Produced (Out)	Δ (kg)	Δ (%)
40555 kg	38050 kg	2505 kg	6.18%

This result was in line with what was expected (monthly average of 7% to 9%) since during the defined period the operation went almost perfectly and there were no stoppages. Out of these 2505kg (6.18%) of waste only 270kg (0.67%) were accounted for as waste at the final stage. In order to understand what are the origins of these losses of fiber, the purge systems of one of the pulp refiners, one of the cleaners, the sewer that leads to the water treatment station and the machine's headbox were also controlled. Figure 3 illustrates the variation of the consistency of samples retrieved from the purges of different equipment during the defined period. Analyzing this data it is easy to conclude that the refiner (RF603) was the most stable of the three. The other two - fiber recoverer (DAF) and centrifugal cleaner (DP604) presented variations that were later found to be connected with the time defined for automatic discharges. This led to the conclusion that the registered variations were related to the timing of the collection of samples. Since there are no reference values for this kind of analysis it was not possible to compare these to an optimal situation.

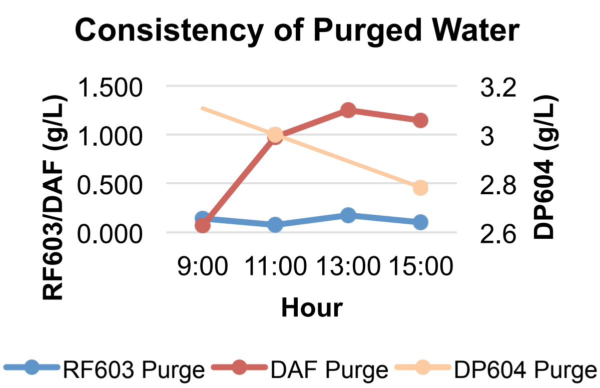

Figure 3 - Consistency of the purges of different equipment.

The next step was to calculate early retention rate of fibers. The values obtained from the control of the machine's headbox make it possible to calculate the fiber retention at the Sheet Formation stage (Equation 1).

$$Y = \frac{c_1 - c_2}{c_1} \times 100 \qquad (1)$$

In which Y is fiber retention, c_1 is consistency at headbox and c_2 is consistency of the water recovered after the pulp is projected on the forming fabric. This was identified as the restriction of the system since the fiber retention at this stage, with this particular type of paper was of, in average, 61.8% during the test (out of four tests). This means that almost 40% of the fibers have to be recirculated and reprojected on the forming fabric again, consuming extra energy in the process.

Finally the average consistency at the entrance of the water treatment station was also calculated. Combining this information with the average flow passing through this channel during the test it was possible to quantify the average loss of dry fiber at this point at 0.73% (296kg) of total, meaning there is still 4.78% out of the 6.18% whose origin was not identified.

It was concluded that at the end of the test the worker responsible for the operation of the mill wasn't able to go back to the initial situation of the deposits while guaranteeing good conditions of the operation. This translated into a deviation by excess of an estimated 770kg (1.90%) still inside the deposits. This means that the waste of 6.18% (2505kg) was overestimated by 1.90%. Table 2 summarizes the information regarding the origin of total registered losses. It can be easily concluded that true losses, apart from the 1.9% inside the deposits, are of 4.28% and that of these there are still 2.88% of unaccounted for losses. The origins of these losses were discussed with production managers from the company, having concluded that with such a big and complex circuit it is hard to keep every variable under control. The use o average values for calculations can explain some of this variability. However, the necessary investment to eliminate this would be too high for the sole purpose of testing, since this is not a problem during daily operations. Having this in consideration, the following step in the methodology is to explore the identified restriction.

Table 2 - Sources of the waste verified during the system analysis.

Initially Verified Waste	6.18%	2505kg
Production Waste	0.67%	270kg
Losses to water treatment facility	0.73%	296kg
Pulp still in the deposits	1.90%	770kg
Other losses	2.88%	1168kg

4.1.2 Explore the restriction

Two possible solutions were presented in order to explore the identified restriction.

4.1.2.1 Paper composition

After consulting historical retention records it was possible to relate retention rates with paper composition. Table 3 shows that the higher the percentage of virgin fibers in paper composition the higher, in average, is the retention rate. It was suggested to increase the percentage of virgin paper in the type A (the paper being produced in MP6 80% of the time and also during the test) in order to improve the operation's efficiency. It was not possible however to implement this measure since the production department made clear that changing the composition would change the type of paper being produced and therefore the use of the final product. Other than that, production costs would increase which at this point is not justified by any quality requirement.

Table 3 - Variation of retention and composition in different types of paper.

Type of Tissue	*Average Retention*	*Composition*
A	50.5%	20% Virgin 80% Recycled
B	69.2%	80% Virgin 10% Recycled 10% Waste
C	66.1%	70% Virgin 20% Recycled 10% Waste

4.1.2.2 Specifications of forming fabrics

Another way to explore the identified restriction is related to the type of forming fabric installed in MP6. The characteristics that are most important are the ability to retain fibers but also to drain excess water. These two parameters are in fact hard to balance, along with the resistance to wear. After comparing products from different manufacturers it was concluded that the technical differences between them are small and that usually this is a price-based decision. Prices float between EUR 9000€ and EUR 14000€ while the characteristics are relatively close between all the available options. One manufacturer in particular - Huyck-Wangner - guarantees that after the installation of their product it is possible for Renova to achieve an extra 10 ton of production a day. The cost of this forming fabric is only 15% more expensive than the actual being used, which would be easily be compensated since 10 extra tons translate into a EUR 9000€/day revenues - estimate based on the production revenue value of 900€/ton. This was not however tested since the installation and adaptation of new forming fabrics can take up weeks or even months until the mill is working correctly once more. Therefore it is extremely important to keep the forming fabrics clean and assuring that the operative conditions are always optimal.

4.1.3 Subordinate?

Being confronted with the impossibility to implement any of the suggested measures it is easily concluded that the system cannot be subordinated to these. The main objections with the implementation of any of the two proposed solutions had to do with feasibility. Despite this fact it is still considered that any of these two suggestions could translate into improvements in the efficiency of the operation.

4.1.4 Elevate?

Since it was not possible to submit the system to new conditions the next step is to elevate, which can be translated into making an investment. At this moment Renova is already investing in a new factory in France in order to increase its productive capacity. Based on that knowledge and on the fact that the paper industry is very capital intensive, it makes no sense to also invest in a mill that is already close to its productive limit. Nevertheless, the approach suggested in section 4.1.2 is still considered to be a valid one for the company.

4.2 Programmed maintenance operations for MP5 and MP6 - a Lean approach

Keeping in mind that the objective of the company is to increase global efficiency, some other ways of improving it were sought. The programmed maintenance operations for both the paper mills (MP5 and MP6) are also highly relevant to the productivity of the plant. Each machine stops at least once a month usually for a period between 8 and 12 hours. The purpose of these interventions is to make sure every equipment is working properly, preventing unexpected stoppages in production. It was found that this duration forecast was usually not met, being exceeded by over 2 hours in many cases.

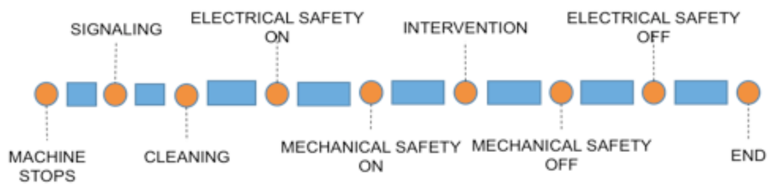

Figure 4 - Activity sequence during maintenance operations for MP5 and MP6.

Using SMED, a Lean tool described in the literature review section, the objective was to completely eliminate or at least minimize this delay.

4.2.1 Phase 1 - Actual State Mapping

The first phase of SMED implementation consist of describing the actual situation and identifying the activities of the process. There are usually three main teams involved in maintenance operations: Mechanical Maintenance (MTM), Electrical Maintenance (MTE) and Instrumentation (ITM). The Technical Office (GT) supervises and connects every department, making sure the same information is distributed to everyone on time. Figure 4 describes in a succinct way in which the activities precede each other during a programmed maintenance operation. The operation starts at 6 a.m. when the mill stops producing and the workers are supposed to clean the machine and the floor during the following hour. At 7 a.m. it is defined that electrical safety procedures should begin to take place, as well as the opening of records of those activities on SAP. At 8 a.m. every equipment should be in electrical safety, with all the records closed and ready for the mechanical work. However, this is not what happens. The restriction of this operation was found to be at this early stage of the process since the mechanical work would only start after 9:30 a.m. many of the times. The causes for this delay were then identified:

1) *Difficulties in the correct identification of the switches that electrically turn off each equipment.*

The lack of organization of the rooms in which the equipments are electrically turned off sometimes makes it confusing for the workers to perform this task - the switches are sometimes not correctly identified. Besides the lack of organization in the rooms, they have the need to ask directly to the operation's shift leader for which equipments should they turn off and in which room (BFA, BFB or BFE) those switches are located. This, combined with the fact that the lists of equipments are incomplete or, in some cases, wrong, makes this task somewhat inefficient. The combination of all these situations sometimes leads to movement waste of the workers as well as the time they spend inside the rooms looking for the correct switch.

2) *The startup phase of the maintenance process.*

The fact that only the operation's shift leader can open records on SAP creates a lack of resources since this worker is also responsible for cleaning. The impossibility for him to perform two tasks at the same time delays the operation right from the start and creates a long queue of workers who are waiting for him and for everyone else who precedes them. This is considered the bottleneck of the process, meaning that from the perspective of TOC the restriction to the system is identified. It was observed that it is impossible to complete the cleaning stage in only one hour, meaning that when the first MTE (electrical) worker is ready to start his work there is no one responsible available to help him. This delay then propagates over the duration of the process since when the MTM (mechanical) and ITM (instrumentation) workers get there at 8 a.m. they have to wait for the MTE records to be cleared on SAP. The fact that all the MTM and IMT workers get to the control room at the same time also creates a queue that makes the process even less efficient at this point. By observing several different situations it was concluded that this stage alone could generate a delay of 1.5 hours, which represents and extra 12.5% in the case of a 12 hour programmed stoppage.

3) *SAP records are too complex and provide non-relevant information.*

The records on SAP are too complex and the information they ask for and provide is too generic, which not only originates more delay as it also makes the process less clear for everyone involved. The person who opens the records has to mannualy simplify each and every one of them, making this a time consuming activity. This problem is not as critical as the prior but the total waste can be estimated in 30 minutes by the end of the process.

4.2.2 Phase 2 - Internal versus External activities

After defining the initial situation, the second step of SMED consists of identifying the tasks that can only be performed after the mill has stopped and the ones that can be performe outside that period of time - either prior to the stoppage or after (Table 4).

Table 4 - Internal activities of the programmed maintenance process.

Internal Activities	Description
Cleaning	Manual task under the operation's shift leader's responsibility.
Signaling	Signaling the area being intervened. This sinalization gives safety instructions.
Identification of the equipments to leave in safety conditions	Reviewing of the list of tasks for the stoppage. The operation's shift leader informs the MTE workers of which equipment must be turned off.
Electrical Safety On	Electrical workers turn off and signal the equipment in the proper rooms.
SAP Record	The equipment is registered in SAP as 'safe to work on'. Activity performed by the operation's shift leader together with the MTE worker.
Opening MTM/IMT work logs on SAP	This activity can be performed either by the operation's shift leader but also by each MTM or IMT worker independently. The operation's shift leader only needs to be informed that the record was opened.
Intervention	Maintenance intervention in the equipment performed by the assigned worker from MTM, MTE or IMT.
Electrical Safety Off	MTE workers take the equipment off safety mode, go back to the control room and inform the operation's

The fact that it was not possible to identify any external activity means that there is room for improvement in the process.

4.2.3 Phase 3 - Transfer of internal activities to external activities: How to explore the system's restriction.

This step of the methodology can be compared to the second step of the TOC, which validates the theory of using these two approaches simultaneously.

Table 5 gives an insight on the values used to estimate improvements that could be achieved with the implementation of suggested measures.

Table 5 - Production and revenue figures for both paper mills.

	M5	*M6*
Work coefficient	≥ 96%	≥ 96%
Net monthly production	2725 ton/month	2575 ton/month
Net hourly production	3925 kg/h	3700 kg/h

In this stage it is studied how it is possible to mitigate the problems identified in section 4.2.1:

1) Difficulties in the correct identification of the switches that electrically turn off each equipment.

Despite being a simple task, this is one of the most important activities during the entire process. Therefore there was a need to eliminate uncertainty in order to guarantee the safety of everyone involved and avoid wasting time. This was achieved by:

- Checking every switch for every equipment by shutting them down and back up during one stoppage. This way it was possible to verify if the name in the tags of every switch corresponded to the correct equipment.
- Cross-referencing the tags in the switch rooms with the names and its references of the equipment in the controller as well as the description in SAP. It was defined that the equipment names and references in the controller had priority over the tags and SAP because it was harder to reprogram it only to change these. After identifying several tagging errors it was decided that all the tags in the three rooms would be substituted by new ones. This would have an estimated cost of EUR 1000€.
- Finally, checking and correcting the equipment lists that are available inside each switch room. This solved the problem of having different sources providing different information. The purpose was to avoid the waste of time inside the rooms looking for the right reference or equipment name and the waste of going back to the control room to ask the operation's shift leader for help. In addition, the reference and location (which room is the switch at) of each equipment is to be added to the

lists of maintenance tasks that are distributed to every stakeholder the day before the stoppage. This allows for the MTE workers to be able to immediatly identify the equipment they are supposed to turn off and where they can do that.

Projected results

The above mentioned suggestions could bring in an extra yearly revenue of EUR 24840€ (Table 6).

Table 6 - Projected increase in revenue after the implementation of the previous waste minimization solutions.

Total time wasted in worker movement per stoppage	**7.62 min**
Total time wasted inside switch rooms per stoppage	30 min
TOTAL TIME WASTED	37.62 min
Productive gains (ton paper per year)	27.6 ton/year
Extra Revenue (€/year)	**24840 €**

2) The startup phase of the maintenance process.

Having identified the restriction of the system, it was decided that the organization of the shift team that is responsible for the startup phase of the process had to change. Therefore, the following measures were implemented and tested in a real situation:

- The main reason for the verified delay was the lack of human resources, namely the fact that there is only one person authorized to open SAP records for the electrical activities. This is the same person that is responsible for cleaning the mill and surrounding area. In order to solve this it was tested a solution in which there are two operation's shift leaders simultaneously working from 7 a.m. to 8.a.m instead of just one. This allows one of them to focus on cleaning while the other one helps the MTE worker opening SAP records and getting every equipment electrically secured on schedule.
- Another tested modification was the inclusion of one worker of the Technical Office (GT) at this early stage. This person was in the control room at 8 a.m. ready to help the operation's shift leader opening the SAP records of the MTM and IMT workers' tasks in another computer. This immediatly helped relieve the strain on the system by forming two queues instead of just one. In both these cases the activities were not externalized but rather parallelized in order to achieve productive time gains.

3) SAP records are too complex and provide non-relevant information.

The SAP records for the test were prepared the day before by the GT in order to simplify them and eliminate the need to process excessive information during the operation. This can be considered an externalization of the activity, although not completely. The activity stil has to be performed during the maintenance but the time consuming part of it was done before. This procedure is to be implemented to every SAP record for every equipment of both mills.

Achieved Results

With the implementation of the measures mentioned in points 2) and 3) it was possible to spend less 1.25 hours at this stage. It is fair too estimate that in perfect conditions, and after some practice, it would be possible to achieve a gain of 1.5 hours. Table 7 shows the projected revenue that can be generated in one year after integrating these measures in the the standard procedure for programmed maintenance stoppages. The costs of implementation are related to overtime expenses of the workers who come earlier during stoppage days. The revenue is calculated based on the premises that there are two machines and each machine stops for programmed maintenance around one time per month.

Table 7 - Projected generated after the implementation of measures from points 2) and 3).

	TOTAL
Annual Productive Gains (ton/year)	138 ton
Extra Annual Revenue (€/year)	124200 €
Cost of Implementation (€/year)	264 €
Increase in annual revenue (€/year)	**123936 €**

In total, the implementation of every suggestion could generate an increase in annual revenue of EUR 148776€/year which represents 0.26% more in revenue of the production of both mills. During the elaboration of this work it was assumed that any increase in throughput would translate directly into revenue since the plant is at its limit capacity at the moment.

5. Conclusions and Future Work

To conclude this paper it is important to emphasize that the objective of reducing waste and increasing productivity was achieved. The study of the pulp circuit of MP6 recurring to the TOC methodology promoted the identification of a process that restricted the system - fiber retention at the headbox. Two solutions were proposed in order to explore that restriction although it was not possible to implement or test any of these due to practicability issues. Despite the fact that not every suggested measure was fully implemented or tested, it was possible to reduce wasted time. This resulted from the use of the Lean tool described in section 4.2, SMED. During the analysis of the programmed maintenance operations three issues were identified: lack of human resources, lack of organization in the early stages of the maintenance process and excessive bureaucracy in SAP records. These problems were solved, resulting in a possible increase in 1.5 hours of productive time for each stoppage, which is translated into an increase in annual revenues of EUR 148776€. These results support the fact that it was possible to achieve waste reduction and therefore an increase in productivity.

As for the future, it is suggested the study of the variation of paper composition in order to understand if increasing the percentage of virgin fibers for this type of paper is a viable option for Renova. It is also advisable to encourage the development of Lean initiatives by everyone at the plant, as well as the continuous use of the TOC methodology as a way of looking for improvements in internal processes.

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