Continuous Improvement in a Transformation Process

The Case Study of Renova, Fábrica de Papel do Almonda S.A

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Abstract. The highly competitive environment in which companies operate nowadays leads to an increase in the efficiency and effectiveness of their operations. Without compromising quality standards, which in many cases are increasingly demanding, companies aim to achieve high production levels, by reducing the various types of waste and, thus, reducing costs. As a utility product, the tissue paper market is positioned not only as a highly competitive market, but also as one in which innovation is difficult to achieve. It is in this context that Renova, the Paper Factory of Almonda S.A., a Portuguese company based in Torres Novas, operates in the tissue paper market, its main focus. To overcome high competitive pressures, Renova differentiates itself by developing an extensive range of products with high quality standards. Therefore, consumer interest in this varied range of products translates into successive (format) changes. The high set-up times of the H07 line (Renova Plant 2), one of the lines with the greatest production capacity of the company, are one of the greatest contributors that lower operational indicators below the internally proposed objective - working coefficient and productivity. Additionally, after careful analysis, it was possible to conclude that the levels of waste should also be reduced. Thus, in order to solve the identified problem, a review of the relevant literature was carried out, where Theory of Constraints and continuous improvement tools such as RCA, SMED, 5S and Heijunka are addressed. Finally, based on a review of the literature presented, a three-phase multi-methodology was developed. This method presents itself as a continuous improvement solution for the H07 line, combining the different tools mentioned. Applying simultaneously the Theory of Constraints and Lean, the first phase aims to identify the causes and restrictions of the problem (RCA); the second phase corresponds to the implementation of the improvements (SMED, 5S and Heijunka); and finally, in the third stage, if the objective is not reached until then, the restriction is elevated by means of an investment in the identified bottleneck. By applying all the measures and phases proposed, it is possible to achieve a quarterly gain for the H07 line of approximately 556 hours of production and a reduction of more than 15 thousand tons of paper. This is the approach presented in the scope of this dissertation with the objective of increasing the operational efficiency of the H07 line.

Keywords: Continuous Improvement, Theory of Constraints*, Lean*, *Root Cause Analysis*, 5S, SMED, *Heijunka.*

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1. Introduction

Nowadays, the paper industry faces the challenges of a new technological era like never before, and with this, its genesis changes continuously. Printing paper, one of the most commercialized products in this industry, faces an ever lower demand. Consequently, productive efforts have turned to another product which, on the other hand, due to the growth of emerging nations, sees its demand increase year after year - tissue paper. In recent years, after a period of stagnation in the tissue paper market, when the growth rate of sales volume in 2009 was 1.2% (Esko, 2016), a growth of 4% per year has been observed, a trend which is expected to continue.

Represented in more than 60 markets worldwide, including emerging ones, Renova's strategy has been to strengthen not only its position in the national market, where it has a market share of around 30%, but also to branch out internationally, especially in Europe. Currently, the Portuguese company sees in the international market a key factor for success, resulting in approximately half of its annual results. In 2015, the company recorded a record operating profit in the order of 124 million euros. In this manner, Renova is able to remain competitive in an innovative way and obtain admittedly positive results. Since it is an industry that requires high investments to make significant improvements in production, process improvement plays a key role. In addition, the Portuguese company is not positioned at the level of others in the market, which means that capital-intensive investments, even if they exist, are even more difficult to achieve. As such, the study of continuous improvement herein proposed proves to be of the utmost importance, since the improvements to be implemented implify significantly lower costs and will allow the implementation of more efficient and effective processes, fundamental for the competitiveness of the company in the market in which it is inserted.

2. Methodology

The H07 line, one of the main and most recent transformation lines of the Portuguese company, is responsible for the production of hundreds of different references. However, according to the operators and management team of the transformation line, its operational efficiency has been hampered by the high setup times and high levels of waste. In order to analyze the problem in the context of continuous improvement, the following 3-phase multi-methodology is proposed (see Figure 1):

Phase 1 - Identification of system constraints
First, as suggested in 5FS[1], the system constraint must be identified. For this purpose, the analysis of the productive flow will be considered. Complementarily, the RCA tool will be applied in order to identify the causes that lead to the previously found restriction. For this, the qualitative method that supports the RCA can be applied, presented in the literature review of this project, "5 Whys".

Phase 2 - Implementing Improvements
In the second phase, using the DBR concept explained by the Theory of Constraints[2], improvements should be applied. Namely, in the drum machine or equipment corresponding to the identified bottleneck - thus preventing it from stopping. Initially, the improvement process should focus on the application of the 5S tool, organizing the workplace and making it fit for greater process efficiency. Afterwards, household leveling (Heijunka[3]) should be standardized and SMED should be applied, aiming not only to reduce times of change, but also to reduce the frequency of such changes. In this way, considering the 5FS, the system is submitted to the aforementioned decision.

Phase 3 - Increase of restriction and new procedure
Finally, if the improvement proposals do not increase the efficiency of the system under the present conditions and the constraint persists, the option to raise it remains. That is, investments in equipment, labor or facilities should be weighted so as to increase capacity at the identified bottleneck. Once the investment has been completed, or if the operation of the identified restriction has been improved, a new stage may become the restriction of the system, and the proposed multi-methodology should be re-applied.

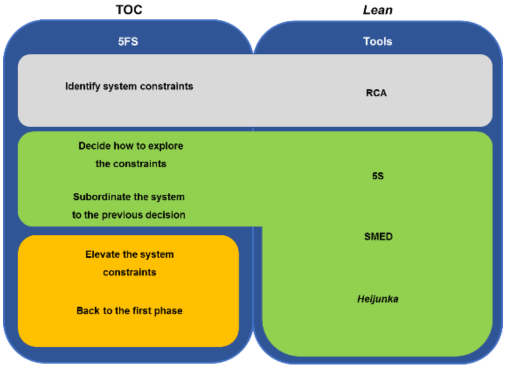

Figure 1: Three-phase multi-methodology.

3. Identifying system constraints

3.1. OEE

The Overall Equipment Effectiveness (OEE) is calculated as follows:

$$\boldsymbol{OEE} = \text{Availability x Performance x Quality}$$

where,

$$Availability = Working\ coefficient$$

$$= \frac{Run\ time}{Planned\ production\ time}$$

$$Performance = \frac{Productivity}{Maximum\ attainable\ productivity}$$

$$Quality = 1 - Waste$$

Table 1: OEE – H07 line

	2nd T 2016	3rd T 2016	4th T 2016	1st T 2017	Goal
Availabity	63%	60%	59%	60%	64%
Performance	58%	61%	54%	56%	56%
Quality	91%	92%	90%	91%	92%
OEE	33%	34%	29%	30%	33%

According to Frost and Sullivan (2005)[4], operational excellence is achieved at an OEE value of 85%. Individually, Availability should be at 90%, Performance at 95% and Quality at 99%.

Although these percentages can be used as a reference, the reality on line H07 is quite different from what would be desirable. However, the strategic goal of Renova is to maintain a high number of different references in line H07 which in turn imply changes. As so, despite the improvements proposed in this dissertation, an objective in the order of 85% is not considered feasible.

3.2. Root Cause Analysis

As proposed in the methodology presented, the causes for the problem identified in the previous section - the reduced OEE - were identified from a logical sequence of questions, using the "5 Whys" technique.
According to interviews with area managers and operators, the high setup times are the main cause for such a low availability and therefore OEE. However, Renova categorizes its stop times as follows: change times, set times and maintenance times.
According to Allahverdi and Soroush (2008)[5], the setup times must correspond to all the time consumed since the production of the last product is finished until the first units of the next one are produced with the established quality standards. Thus, contrary to what is considered in Renova, the tuning times must be integrated in the accounting of the setup times, because they contribute the most to the longer stopping times. Since these individualized records are available, the tuning times are based on this information and are thus presented in the year 2016 in the 3 sections of line H07 most affected by the changes (winder, packer and bagger). (see Table 2)

Table 2: Tuning times for the 5 most produced references

	Adjustment time (hours)		
Reference	Winder	Packer	Bagger
KISS 32rl Br 5N	0,667 H	4,150 H	-
KISS 32rl Br	3,500 H	9,917 H	-
4FLS déco 12rlx5 branco	0,917 H	4,250 H	0,500 H
KISS (48+24) rl Br	0,250 H	7,583 H	1,250H
KISS (36+36) rl Brc	0,583 H	2,500 H	0,167 H
TOTAL	5,917 H	28,400 H	1,917 H

Since a high asymmetry is observed in the total time consumed per section regarding the tunings, the following Pareto analysis is presented (see Figure 3).

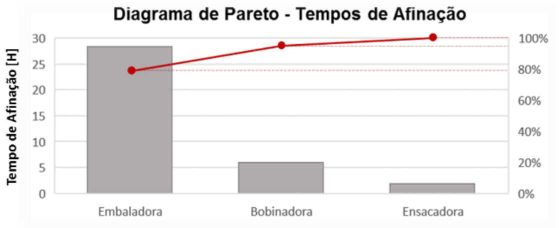

Figure 2: Pareto Diagram - Tuning Times.

From this analysis, it is possible to observe that a single section of the three most critical in the tuning process, accounted for 78.4% of the total time consumed for this purpose. Once the impact of the high tuning times on set-up times (which negatively impact the OEE value of the H07 line) has been established, it is possible to identify the packer as the bottleneck of this system.

4. Implementation and proposed improvements

4.1. Improvement of setup times

4.1.1. SMED - Packer

In an industrial reality coinciding with the innovation that the tissue paper sector requires, the Portuguese company opts for a differentiated production of references in small lots. Thus, in the application of the SMED[6] tool is a logical basis to optimize the section by this most affected principle, the packer.

In a first phase, the changing process was mapped. For this, the changing of formats between the references of the articles Renova SkinCare Plus 6rlsx10 and Renova Deco 9rlx5 white was studied. These have different sizes in terms of their primary packaging and different graphics in the film used, which makes them suitable for this analysis. The second phase is characterized by the classification of internal and external setup operations. Finally, the third phase deals with the transformation of internal setup operations into external setup operations.

As an example, a set of tests has been developed on the correct placement of the combs in the packer. This step is essential for them to be able to drive each roller in a centered way. Despite the existence of a metric scale that estimates the correct distance between each comb, it is not easy to use nor reliable. Thus, the position of the combs is directly confronted with a set of rolls that simulates the dimensions of the next format

The production of easy-fitting polyethylene gauges has been suggested to simulate the next format. In this way, the teams will not have to wait for the new format to be produced in order to create the test set, also guaranteeing greater accuracy in the set of combs. Since the shape of each package is influenced by each roll, it is important to consider the different possible combinations between diameter and width for each article reference. In total, operators should have a set of 4 gauges from each of the 20 possible combinations, properly arranged in a location close to the packer. With this improvement suggestion, the process efficiency is increased to about 2 minutes and 24 seconds - the sum of the times of the respective tasks.

4.1.2. 5S

According to the 5S flowchart, the need for each tool and, subsequently, its value, is evaluated. We proceeded to the 5 stages (Sort, Set in Order, Shine, Standardize, Sustain) assuming as fundamental the transition of only the tools considered fundamental in the Sort phase for a tool cart, as well as the creation of a cleaning checklist. These procedures should be standardized and management teams should promote the maintenance of the routines created.

4.1.3. Heijunka

In this section, the achievement of a production leveling of the ten most ordered references in the year 2016 was intended. The aim is to reduce the frequency at which the changing processes occur, as well as to reduce the dimension of each change (product families). Thus, a weekly scheduling that aims to respond exactly to demand and does not causing peaks and productive breaks in line H07 is proposed. The leveling of production is presented for line H07 in this dissertation in the following 4 phases:
Phase 1 - Analysis and constitution of the leveling model: once the identified bottleneck is the packer, the decision criteria focuses only on the changing processes affecting this section of the H07 line. The following criteria, validated by Renova representatives were used: the width of the primary packaging, the length of the primary packaging, the depth of the primary packaging, the type of film and the presence of a handle.

Phase 2 - Product family formation: To define the most relevant attributes for product family formation, as explained by Bohnen, Maschek and Deuse (2011)[7], a measure of proximity has to be calculated. The following model is proposed to obtain a measure of proximity between products:

$$\begin{cases} d(X_j, X_l) = \sum_{i=1}^{p} X_i \\ X_i = 1, \qquad x_{ji} - x_{li} \neq 0 \\ X_i = 0, \qquad x_{ji} - x_{li} = 0 \end{cases}$$

Where, X_j and X_l are the two objects of study, that is, two different formats; $X_i$is the binary variable that translates the existence of equality for each of the criteria established between the different objects of study; p is the number of attributes previously defined; representing x_{ji} and x_{li} the value of the attribute i for the objects j and l, respectively. In sum, the value of the proximity measure $d(X_j, X_l)$ is 5 when there is no similarity between the two products for the parameters considered, which in turn is reflected in a demanding and time consuming change process; and the value of $d(X_j, X_l)$ is 0 when for the selected criteria there is no need for any process of change at the level of the packer.

It is considered in this dissertation that the measure of proximity considered should respect the following criterion among all the products of a family: $d(X_j, X_l) \leq 1$. The following families of products have been defined:

- Family A: Kiss 32 rl 5N, Kiss 32 rl, Renova Top

- Family B: Kiss (48 + 24), Kiss (36 + 36)

- Family C: 4 FLS déco, Skincare

- Family D: RenovaOlé !, Renova Super

- Family E: XXL (24 + 8)

Phase 3 - Selection of families for production leveling: In this phase, the families of products previously considered are segmented according to two factors: the total volume produced in the year 2016 and the volume variations verified for each family. Thus, based on the analysis of phase 3 of Heijunka, it is possible to categorize the families obtained: in runners, there is a high production volume and a small variability in the production of lots; or in strangers, if they are produced in smaller volumes and have more variable production rates. Thus, in a comparative analysis, families A and B are considered as runners, the family C as strange and families D and E as runners/strangers (see figure 3).

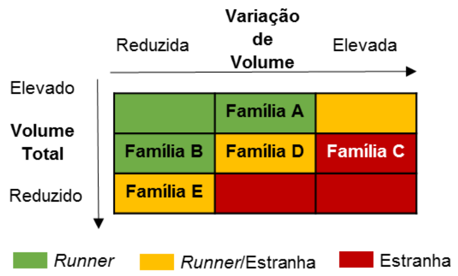

Figure 3: ABC Matrix of the H07 line.

Phase 4 - Scheduling of product families: When the change occurs within the same family (d (X_j, X_l) ≤ 1) the changeover time is approximately 0. Therefore, the goal of household scheduling is to promote the chained production of families and not to segment their production. Since the referred families are composed of the ten most produced references in Renova and that, except for the E family, and they were produced every month of the year in 2016, the following scheduling is suggested:

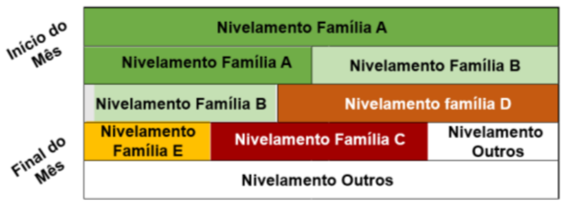

Figure 4: Production leveling of the H07 line.

According to the scheduling of the product families shown in Figure 4, a maximum of four changes per month will be necessary for the ten most produced references. Household scaling represents a potential gain of approximately 73 hours (50% of the total changeover time allocated to these products in 2016).

4.1.4. CHANGE OF THE PERFORATION DISTANCE

When the distance of the perforation has to be changed, one of the operators must move to the other end of the winder. The control system of this parameter does not work properly, requiring manual, estimated adjustments, on a basis of trial and error. On average, this highly inefficient process results in two trips to the tuning zone, averaging 40s each way. As so, the following improvements are suggested:
- The perforation adjustment knob must be placed on the operation panel and thus be close to the perforation test zone.
- In the area of the operation panel, the creation of a screen with real-time image of the perforation system would be favorable.

4.2. IMPROVEMENTS IN SHORT STOPS

4.2.1. TURNED ROLLS

One of the main causes of the reduced availability of line H07 comes from the wrong positioning of the product. Namely the rolls, which are driven to the wrapping machine via 4-way mats when leaving the cutting zone. These sequential carpets operate at different speeds, defined by and operator on the basis of trial and error. The difference in speed between carpets causes the rolls to turn. Whenever a paper roll turns, the entire section stops until one of the operators corrects the position of the roll and restarts the production process.
To this end, speed displays were installed in order to facilitate the synchronization of the speed of the mats. Additionally, other mechanical adjustments were performed. Both these measurements helped establish a less abrupt transition between mats, thus reducing the risk of rolls turning in this area. (Table 3)

Table 3: Impact of improvements.

	φ Turned Rolls/Hour	φ Stop time (min/Hour)
1st Test (control)	102	13.6
2nd Test (Displays)	26	3.5
3rd Test (Mechanical adjustments)	2	0.3

After implementing all the improvements suggested in this section, the average stop time per hour of production reached only 18 seconds.

4.2.2. PAPER BREAKS

In order to understand the impact that the difference between a marked or unmarked break can have on the operation of the H07 line, an analysis of the stopping times for each of the situations in the first half of 2017 was made (see table 14). As is apparent from its analysis, it is possible to conclude that, on average, the stopping time caused by an unmarked break is greater than 0.10 hours, that is, 6 minutes (the stopping time caused by a marked break). This will be the potential gain in the operation of line H07.

Table 4: Stopping times – Breaks.

	Total number	Total Stopping Time (Hours)	φ Stopping time (Hours)
Marked break	238	58.17	0.24
Unmarked break	76	25.75	0.34

4.3. Reduction of waste

4.3.1. Vacuum system

As soon as each roll leaves the accumulator and is sent to the cutting machine, it is subjected to the action of two electric saws that transform the single piece into a predefined number of rollers. However, since the size and weight of the rolls varies according to the format to be produced, the cutting zone needs an adjustment that must be made prior to the production of the next format. However, in the course of this dissertation, it was observed that this adjustment or indications for it did not exist.
Thus, in order to estimate the impact of the problem, the cut zone was analyzed during the production of the most produced roll format in the year 2016, Renova Kiss, with a diameter of 100 mm and a width of 95 mm. To this end, hourly quantification of rolls was carried out from the cutting zone through mats to the waste carts.
For two days an analysis was performed, which registered a value of 267 rolls/hour to be unduly sent to the waste carts.
This means that, in addition to product waste, there is a waste associated to the movement of the waste carts. It was estimated that they need to be emptied every 3 hours of production.
After a trial-and-error adjustment process of the vacuum values of the cutting machine, the position of the trimex (suction mats) and the pressure value, it was possible to arrive at a combination that resulted in minimal waste. In the same analysis period, the average number of rolls dropped in the cutting zone decreased to 68 rolls/hour.

4.3.2. Reuse of rolls with defective packaging

There is often a human-dependent tuning period to achieve the desired quality standards for the primary packaging. While this tuning period is taking place, several test containers are produced and analyzed by the operators. For the most part, especially at the beginning of tuning, primary packaging is defective. Test containers should be forwarded to the packer as raw materials.
However, the procedure described in this section is not strictly followed by the employees, and defective packaging goes to waste. Due to its inherent variability and error arising from the human factor, it is not possible to quantify exactly the impact of this action. Still, the recommendation for area managers to carry out training actions with the employees of line H07, sensitizing them to the issue of waste is pertinent. It is believed that in this way, the waste in line H07 can be reduced substantially.

4.3.2. Raw material quality standards

Reels of (textured) paper from the M7 machine have been used in grids. However, waste levels have increased significantly due to the omission of the embossing step in paper production, dry glue accumulation points, and paper shrinkage in the last production meter. Thus, in order to reduce the increase in waste found in line H07, it is fundamental to solve the problems identified in the production of the raw material essential for the transformation process, ie, paper reels.

5. Discussion

In this section, the results from the application and suggestion of improvements are presented and the potential increment of the OEE from their application is quantified. For the proposed analysis, the most recent available data for the first quarter of 2017 are considered. (Table 5)

Table 5: Initial situation

<table>
<tr><td>Production (ZUE)</td><td>Production Hours</td><td>Available Hours</td><td>Waste (ton)</td><td>Paper Consumption (ton)</td></tr>
<tr><td>630 825</td><td>1 152</td><td>1 911</td><td>215 736</td><td>2 358 870</td></tr>
<tr><td colspan="2">Productivity = 548 ZUE/h</td><td>1ºT 2017</td><td>Waste (%) = 9%</td><td>Working coefficient = 60%</td></tr>
<tr><td colspan="5">Availability = 60%</td></tr>
<tr><td colspan="5">Performance = 56%</td></tr>
<tr><td colspan="5">Quality = 91%</td></tr>
<tr><td colspan="5">OEE = 30%</td></tr>
</table>

Since the bottleneck of the system under study is the packer, more precisely in the respective setup times, the proposals for the changing process are firstly evaluated: SMED, 5S, Heijunka and optimization of perforation change. It is important to note that for the analysis under study, according to Renova internal data, in the

first quarter of 2017 there were 117 product changes in line H07. Secondly, the measures applied and suggested in the context of small stops are also presented and quantified in this chapter as to their gain for the operation. Finally, the operational impacts of measures to reduce waste are also quantified. It should be noted that in the case of operational gains related to the 5S application and increased raw material quality standards, only qualitative considerations are taken.
Table 6 summarizes the potential gain for the indicators related to the OEE calculation in the quarter:

Table 6: Operational gain – H07 line.

	Improvement	Operational gain
Setup measures (117 changes in the H07 line in the 1st trimester of 2017	SMED	16.73 min/setup x 117 *setups* ≈ 1957 min ≈ **32 Production Hours**
	5S	-
	Heijunka	≈ 50% Total times; Changes = 184.13 x 0.5 = **92 Production Hours**
	Perforation	≈ 20% x 117 *setups* x Tuning time = 0.2 x 117 x 160s ≈ **1 Production Hour**
Measures for short stops	Turned Rolls	13.3min/h x Available hours = 13.3 x 1911≈**423.6 Production Hours**
	Breaks	76 Unmarked breaks x 0.1h = **7.6 Production Hours**
Measured for the reduction of waste	Vacuum system	(267 – 68) rolls/h x Production Hours x 66 g =199 x 1152 x 66 = **15 130 ton**
	MP Quality	-

Given the potential gains from the measures presented in this dissertation, it is possible to conclude that, if they were applied in full, for the first quarter of 2017 it would have been possible to account for approximately 556.2 hours of production of line H07 and reduce the waste by about 15 130 tons of paper. In order to give expression to the presented hypothesis, table 7 shows the alternative scenario of the referred quarter if the proposed measures had been applied. Since the variability of formats in the transformation line under study is significant (over one hundred), it is not possible to extrapolate a new value to the production volume (ZUE) with the proposed measures. Thus, although the productivity of the line under study tends to increase with the observed operational gain, a fixed value of productivity is considered for this analysis, equal to that previously obtained.

Table 7: Impact of improvements

Production (ZUE)	Production Hours	Available Hours	Waste (ton)	Paper Consumption (ton)
-	1 708	1 911	200 606	2 358 870
Productivity = 548 ZUE/h		1ºT 2017	Waste (%) = 8.5%	Working coefficient = 89%
Availability = 89%				
Performance = 56%				
Quality = 91.5%				
OEE = 46%				

In this analysis, it is considered that, through the implemented and suggested improvements, the performance value does not decrease. However, given the variability of product, the potential increase of this indicator (performance) is assumed, without defensively implemented improvements.
Notwithstanding this limitation, the hypothetical increase in availability by 29% and the reduction of waste by 0.5% with the measures proposed in this paper would lead to a potential increase in OEE for the period considered in the order of 16%. It is important to note that the value obtained, OEE = 46%, is substantially higher than the target value for line H07, OEE = 33%, which would allow for the first time to achieve the proposed objectives for line H07.
Finally, this analysis also allows to conclude that the line of transformation under study, according to the application of all proposals for improvement of this dissertation, would be similar to Renova's most operationally efficient line, line H05 - OEE = 40%.

6. Conclusions and Future Work

The printing paper market is becoming less attractive due to a marked decline in demand. The same does not happen with the tissue paper market. Driven by a worldwide population growth, the tissue paper market assumes itself as the most important paper market of today. In this context, Renova is positioned in the Portuguese market as a market leader, and in dozens of other markets with a growing preponderance over the last few years. In the last decade, the turnover of the Portuguese company has exceeded, in most cases, the 100 million euros. Given the attractiveness of the market described, the number of competitors tends to increase, which leads to Renova's bet on the innovation and quality of its products. To do this, from the processing lines of its factories, its products are diversified and differentiated from the competition. The high degree of product differentiation, as well as the high number of references produced, means that the processing lines undergo successive stops and adjustments. Consequently, in order to avoid high capital intensive investments, this dissertation is proposed as part of the continuous improvement for one of the most operationally inefficient lines, line H07.
Based on a careful bibliographical review, the 3-phase multi-methodology, a combined approach of Lean and TOC tools, was then presented, which was considered essential to explore the operational problem described above.

After applying the multi-methodology proposed in this dissertation, it was possible to quantify a quarterly gain for line H07 of approximately 556 production hours and a reduction of more than 15 thousand tons of paper, which represents an increase of 29% of availability and a 0.5% decrease in waste generated, respectively. In summary, the final value of OEE obtained by applying the three-phase multi-methodology and its proposals is 46%. This value is higher than the target value for line H07, which is around 33%. Therefore, it is concluded that the operational gain resulting from the application of the content of this dissertation is in line with that which was initially proposed, surpassing it in some cases.

It is important to note that, as described in this dissertation, only some of the proposed measures were implemented, namely the transformation of internal setup tasks into external setup in the packer change (SMED); the synchronization of the mats to the exit of the cutting machine (Rolls-Royce); and adjustments made to the vacuum system. In addition, as future development, in order to reach the potential operational gain presented in this dissertation, the application of the remaining suggested measures is recommended (change of the perforation system, 5S, repurposing of rolls with defective packaging and paper breaks/raw material quality standards),

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