PRODUCTION PROCESS OPTIMIZATION

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"Production process optimization"

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Preface

Dear reader,

I would like to present you my bachelor thesis, the last step within the Bachelor programme Industrial Engineering and Management. The content of the thesis is about a production process optimization at Royal Sens Rotterdam.

Firstly, I would like to thank Quadrum Capital for accessing a bachelor assignment. Secondly, I would like to thank Richard Versteeg for being my external supervisor at Royal Sens Rotterdam. Thank you for your time, effort and help while I was conducting my research. Furthermore, I would like to thank all the other colleagues at Royal Sens whom I have worked with.

Lastly, I would like to thank my first supervisor, Matthieu van der Heijden, for the detailed and valuable feedback that is used to improve my thesis.

Danny van der Wei

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Management Summary

Introduction

The research started with a wish namely using automation to improve the performance of the Cut & Stack production process. However, there were other issues detected which should be solved before automation options can even be considered. Still, automation options are analysed. The overall research question in the thesis is:

How should Royal Sens improve the performance of the Cut & Stack production process?

The following indicators were determined to measure the performance improvement.

- Throughput (products)
- Production costs
- Product quality
- Earning before Interest, Taxes, Depreciation and Amortization (EBITDA)

The last indicator is, obviously, the most interesting due to two main reasons: private equity is involved and, it gives a quick indication of the impact from the improvements on the future cashflows. The thesis is divided into two main parts. Firstly, the current situation is analysed and secondly a four-step improvement plan is introduced to improve the overall performance of the Cut & Stack production process. The conclusions introduced after the analyses of the current situation are used as input for the improvement plan.

Current situation

The Cut & Stack production process has four product lines however product line four is not included in the scope of the research because it is already fully automated, and Royal Sens wishes to automate another part of the production process. The Cut & Stack production process is divided into three sections. The first section includes jogging, cutting, and bundling. The second section represents the step where the bundles are sorted, this step is done manually. Lastly, the packaging and control step are taken together in section three. The current performance of the previously determined indicators is analysed and there are some main conclusions that are stated below.

- The cycle time at product line three is much lower than on product line one and two since product line three has one additional automated cutting step. The cycle time is 43% lower comparing it to P02 and 20% lower comparing it to P01.
- The product lines designed to produce Cut & Stack labels are also used to prepare a different product namely Die-Cut labels. 65% of the total amount of produced sheets is used for Die-Cut labels at product line one in 2019.
- The variable energy and maintenance costs per hour are higher for product line three than for product line one and two due to the additional automated step. The difference is exactly 50%.
- Most of the client complaints originate at the manual step of the product lines so section two, this decreases the product quality.
- Royal Sens creates its own bottleneck, the control step, because there is no constant producing flow caused by the multiple actions the employee must perform in section two of the product line.
- If the producing flow is constant than the cutting step determines the actual output with one exception, when the number of bundles in one pack is equal to one.

- The optimal situation is that the output of the total product line is dependent on the cutting step because it maximizes the production flow which maximizes throughput (products).

Improvement plan

The conclusions previously described are used as input for the four-step improvement plan. Furthermore, two critical assumptions were made and should be taken into account while reading the improvement plan. The assumptions are: “Sales is not a bottleneck at Royal Sens” and “The printing department does not become a bottleneck”. These assumptions are verified with employees of Royal Sens and are considered reasonable. The four-step improvement plan should be implemented in the recommended order because some steps cannot be implemented without the previous steps.

Step 1: Separating the processes
Step 2: Constant production flow
Step 3: Automate cutting the width at product line two
Step 4: Automating “section two” of the production processes

The first improvement step, separating the processes, is focused on relocating the Die-Cut labels back to their original production process. This enables Royal Sens to produce more Cut & Stack labels. Moreover, it creates more clarity within the planning department and factory. One additional cutter must be hired to implement this improvement step. The concrete improvements are stated in Table 1 below.

The second step, constant production flow, is concentrated on eliminating the bottleneck. As concluded in the previous part, Royal Sens creates their own bottleneck because the employee at section two has multiple tasks. For eliminating the bottleneck in both product lines, two employees need to be hired. However, it also creates additional improvement opportunities that are described in improvement step three and four.

The third improvement step, automate cutting the width at product line two, is focused on increasing the throughput (products). This enables Royal Sens to produce at a higher speed. The necessary investment is around 187,500 euros. However, after calculating the theoretical throughput (products), this should be payed back in around two months. Important to note is that after this step, product line two only can produce standard Cut & Stack labels. So, every Cut & Stack label with different characteristics should be produced on product line one which is possible in terms of capacity.

The last step, automating section two, is concentrated on improving the reliability of the production process. It automates the manual step within the Cut & Stack production process. The necessary investment is around 375,000 euros. The payback period for this investment is around 5 years which is, in my opinion, not worth it.

Overall, the plan improves the performance of the Cut & Stack production process. However, Royal Sens needs to decide how many steps they want to implement within their process.

Table 1: Impact of four-step improvement plan on indicators

Improvement steps	*Throughput (products)*	*Production costs*	*Product quality*	*EBITDA*
▪ *Separating the processes (1)*	+ 25%	+24%	-	**17%**
▪ *Separating the processes (1)* ▪ *Constant producing flow (2)*	+25%	+27%	+51%	**16%**
▪ *Separating the processes (1)* ▪ *Constant producing flow (2)* ▪ *Automate cutting the width at P02 (3)*	+75%	+63%	+51%	**45%**
▪ *Separating the processes (1)* ▪ *Constant producing flow (2)* ▪ *Automate cutting the width at P02 (3)* ▪ *Automate section two (4)*	+75%	+60%	+99%	**46%**

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1. Company introduction

1.1 Background information

Royal Sens is an A-brand organisation when it comes to labelling. It has four locations in three different countries with factories in Enschede and Rotterdam. Royal Sens specializes in wet glue labels and packaging materials, these are produced for multiple famous brands such as Coca Cola and Heinz. Royals Sens employs around 190 full-time employees (FTE's) and generates approximately 40 million euros revenue per year so they are an important player in the labelling market. The labelling market is dominated by Royal Sens for over 100 years. It is traditionally a family business however it has been recently sold to private equity. This allows Royal Sens to make huge investments and rapid changes to increase their revenue and productivity. Obviously, the main interest of private equity is reselling the organisation. The value of Royal Sens will be rated by their Earnings before Interest, Taxes, Depreciation, and Amortization (EBITDA) so this should be included in the research.
Royal Sens is an organisation that creates high end products which means that product quality is extremely important. Furthermore, the consequences of wrongly producing labels can be severe since they are liable for huge claims when labels are printed wrong or labels are mixed in wrong packages. So, product quality is one of their core values and must be considered in this optimization project. In addition to producing high value end products, Royal Sens tries to be flexible and adaptive. Royal Sens tries to ensure every revenue stream, so they seek to adapt their product to the customer requests. Therefore, Royal Sens mostly produces per order, they only produce for stock for their bigger clients, for example Coca Cola. Nevertheless, this stock is produced with the confirmation of the customer so this does not increase risks since the products will be sold.

The conclusion can be made that Royal Sens produces highly customizable products and has the philosophy that they should adapt to their potential customers.

1.2 Production process

This research will take place at the factory in Rotterdam where Royal Sens produces two kinds of labels, labels made of plastic and wet-glue paper labels. The production process of plastic labels is excluded from this research since this process is much smaller. The exclusion of this production process does not influence the research because the processes of producing paper and plastic labels are completely independent.

The process of producing wet-glue paper labels has multiple components, a graphical overview is made to better understand this production process and can be seen on the appendix[1]. The production process starts in the printing department where the programmed labels are being printed on raw material, in almost every case paper. Royal Sens uses different types of raw materials however this does not influence the remaining actions in the process. The labels are printed per order at pallets, pallets are used to transport the product through the factory and to the customer. After printing the labels, the pallets are transported to the post-printing department where they need to dry for at least 24 hours. Royal Sens uses a push system in the printing department while the post-printing department uses a pull system. This way of working can result in a rapid increase of intermediate stock but according to Royal Sens, intermediate stock is not a problem. In addition to this, the printing department produces in three shifts, whereas the post-printing department has two. This difference can be explained through the different types of handlings and processing speeds.

[1] *Appendix A: Graphical overview wet-glue paper labels*

After the drying period, one of three processes begin. Which process is dependent on the product requirements and the wishes of the customer. The different production routes are:

1. Specials
2. Die-cut paper labels
3. Cut and Stack labels

These are independent producing routes which means that there is a possibility to focus on one at the time per order. The procedure of producing Cut & Stack and Die-Cut labels is almost identical whereas Die-Cut labels can have different and trickier forms like ovals or circles. Cut & Stack labels are always rectangular or square shaped.

Specials are extremely difficult to produce since these have the requirement to be stacked in a particular order. Examples of these different labels are included in the appendix[2]. This research is going to focus on the Cut & Stack process because these labels have the highest share in the total amount of sales and Royal Sens believes that this part should be optimized. However, the reason for this scope will be explained in the problem identification.

[2] *Appendix B: Label examples*

2. Problem identification

2.1 Initial issue

The chief financial officer (CFO) of Royal Sens believes that especially the Cut & Stack production process is outdated and therefore has a large share in the total amount of production costs, Royal Sens wishes to improve this process. He also mentioned the huge difference in production costs in Enschede and Rotterdam where the production costs in Enschede are significantly lower. This difference is because the production processes in Enschede are more automated than in Rotterdam. Furthermore, the Cut & Stack production process in Rotterdam is mostly operated by flex workers because Royal Sens has a lot of issues with attracting the right people for their tasks. Furthermore, the turnover rate of employees is much higher which results in a lot of training time. In addition to this, Royal Sens has troubles with the performance of these employees. So, the initial issue of Royal Sens is that the production process of the Cut & Stack labels is outdated, and they believe this makes the process inefficient. As said before, Royal Sens is recently bought by private equity which means that the key performance indicator (KPI) Earnings before Interest, Taxes, Depreciation and Amortization (EBITDA) is important so the determined problems should have a relationship with this KPI. EBITDA is a popular KPI for private equity because it shows a quick estimate of what the operating future cash flow will look like

2.2 Actual problem

The core problems are determined with the help of several interviews. From conducted interviews another problem became apparent, which can be directly linked to both initial issues namely product quality. As said before, Royal Sens believes in the importance of high product quality. Several employees that were interviewed believe that the product quality can be higher in the Cut & Stack process. They believe that the product quality decreases because employees at the product lines make mistakes. This has a negative influence at the EBITDA because, according to the employees that were interviewed, low product quality results in losing recurring revenue which decreases the future EBITDA. This means that product quality needs to be considered in this research. The problems that occur in the Cut & Stack production process, their relationship with each other and the relationship with the EBITDA are stated in the problem cluster on the next page.

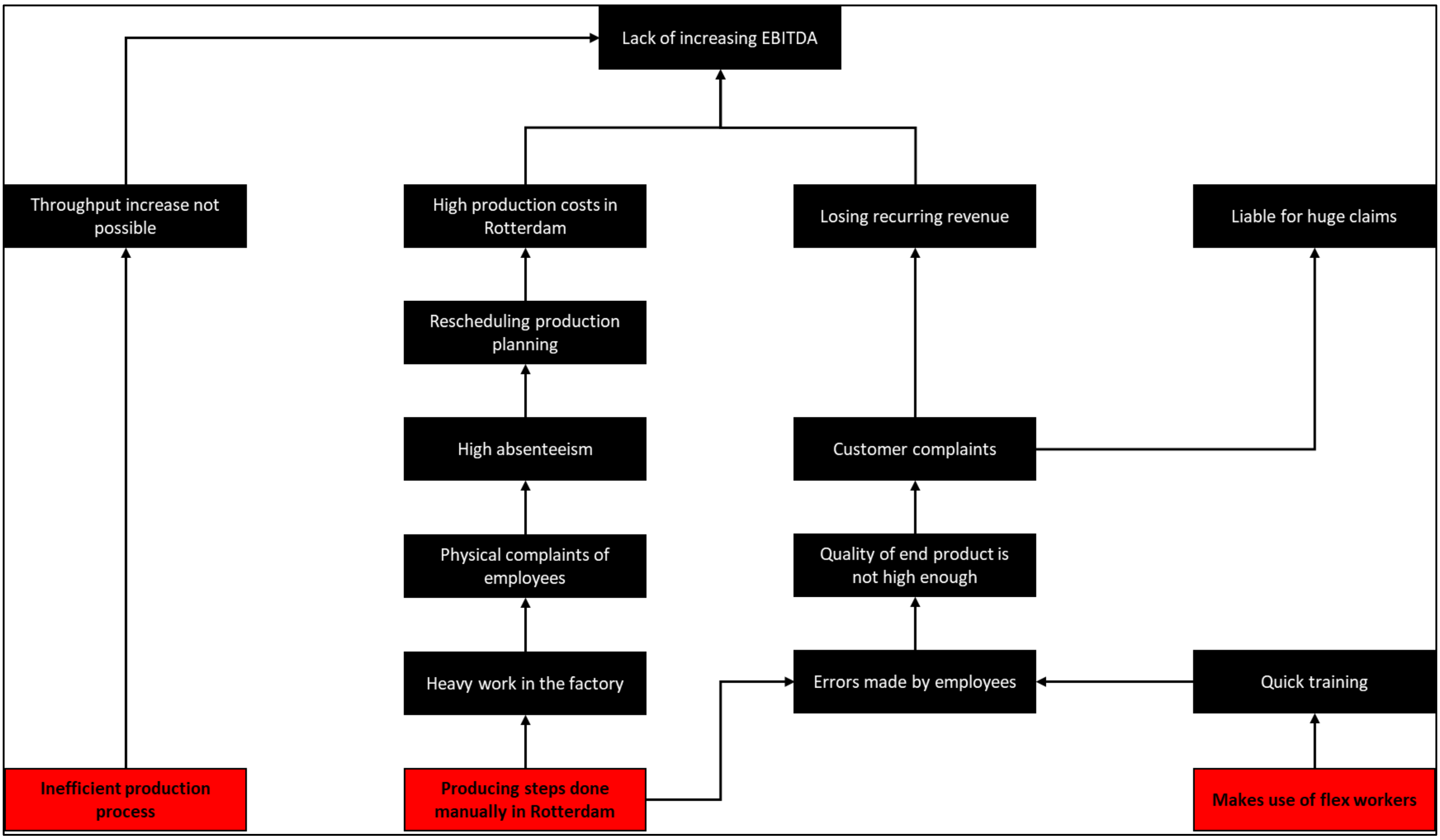

Figure 1: Visualization of core problems

So, there are three core problems within the Cut & Stack process namely inefficient production process, production steps are done manually, and Royal Sens makes use of flex workers. All of these have, indirectly, a negative impact on EBITDA. As mentioned before, EBITDA is a very important KPI especially since private equity has influence.

As previously mentioned, Royal Sens has two factories in Rotterdam and Enschede where the production process in Enschede is more automated, resulting in lower production costs since the personnel costs can decrease with implementing automation. Furthermore, automation brings consistency because Royal Sens is less dependent on employees and sickness. Also, the repeating costs of employing and training new personnel should decrease with implementing automation. Royal Sens would like to automate the Cut & Stack production process however it is not possible to copy the process in Enschede because, the production processes are different since the process in Enschede is focused on Die-Cut labels. So, Royal Sens sees that automation and robotization works in Enschede and they want to know how they should implement automation or robotization in the Cut & Stack production process in Rotterdam. Obviously, before automation or robotization can even be considered, it should have a direct link with the determined core problems.

Starting with the core problem producing step are done manually in Rotterdam. Since steps are done manually some work within the production process is considered heavy. Heavy work in the factory results in physical complaints from the employees. As can be seen in the problem cluster, complaints of the employees are not beneficial for the overall performance of the production process. With automation or robotization, the activities that are performed in the factory could be made lighter, or even erased. This should result in less complaints which leads to less sickness which has an impact on costs and therefore on the EBITDA. Moreover, automation and robotization has to potential to eliminate jobs.

The second core problem is defined as follows: the Cut & Stack production process is inefficient. The process was developed over 15 years ago which means that it rather old. Some employees within the factory believe that it is inefficient, the reason for this fact is: there is congestion within the product line. So, an in-depth analysis of the product lines must be made. Nevertheless, automation and robotization could help with solving this problem. This seems like a main core problem due to the fact of the importance of an efficient product line. The overall throughput of the product line is limited due to inefficiency which decreases the potential EBITDA.

Royal Sens makes use of flex workers which is the last core problem. According to Royal Sens, these flex workers make mistakes which results in low production quality and, as previously mentioned, product quality is very important to Royal Sens. Automation and robotization can be more reliable than people since the activities are performed by machines that are programmed to consistently do the same actions. Thus, automation or robotization should have a positive impact on the product quality. Furthermore, combining the opportunity to eliminate jobs and the production costs is interesting since Royal Sens can structurally decrease their production costs with automation. This is also resulting in a structural EBITDA increase.

Overall, automation and robotization do link with the determined core problems and can have a positive impact. So, in terms of the core problems, automation and robotization is a great idea of Royal Sens. However, robotization can require a huge investment which is a bottleneck for a lot of organisations. But private equity creates the opportunity to automate because it creates a lot of investment power.

To conclude, automating the Cut & Stack production process is directly linked with the problems Royal Sens faces. Furthermore, it should have a positive impact on the production costs and product quality. This means that automating the process is a legitimate option and Royal Sens would like to have help with implementing it and would like to have an analysation of where and which type of machine would be an option.

2.3 Research question

As previously described, Royal Sens wishes to automate their Cut & Stack production process. This is a viable option however other improvement steps should also be considered. Moreover, one of the determined is an inefficient production process which could be solved through automation however maybe some other actions are also helpful. So, the overall Cut & Stack production process is going to be analysed. Nevertheless, automation options should still be investigated. Because of this reasoning, the research question is formulated as follows:

How should Royal Sens improve the performance of the Cut & Stack production process?

This research question is in line with the wishes of Royal Sens, the established relationship with the core problems and the wish to automate steps within the process. The research question will be measured by three indicators namely:

- Throughput (products)
- Production costs
- Product quality
- Earnings before Interest, Taxes, Depreciation and Amortization

The throughput should be considered because it gives a clear indication about the total amount of products Royal Sens produces or can produce with their current process. Obviously, producing the Cut & Stack labels is costly so the production costs are analysed as second indicator. The production costs are made up of variable production costs and constant production costs which includes the current used staff at the product line. Lastly, as mentioned before, product quality is highly important for

Royal Sens so the improvement in product quality should be considered while computing an improvement plan. Moreover, all the suggested improvement steps are going to compared to the possible EBITDA increase because, as mentioned before, private equity is one of the stakeholders during the research.

2.4 Scope of the research

The research is going to focus on the post-printing department. The department where the products are finished into sellable products. The Cut & Stack process consists of four product lines however the focus will lay on the first three because product line four is almost fully automated. In addition, some actions on product line one to three are done manually which is disadvantageous for the production quality, production costs and throughput with are the focus of this research. Therefore, the research is going to focus on product line one to three in the Cut & Stack production process with throughput, production costs and quality in mind.

2.5 Structure of the report

The main-structure of the report is divided into chapters which are focused on the current performance of the previously described indicator and the improvement steps Royal Sens should take to improve the performance of the overall Cut & Stack production process. The following research questions are computed to clarify the structure of the report and to answer the main research question.

Chapter three describes the theoretical background that is necessary to understand the analyses made in the chapters afterwards. The computed research question is.

- *How can the Theory of Constraints be used to analyse the Cut & Stack production process of Royal Sens?*

Chapter four is focused on analysing the current situation at Royal Sens. This includes an analysation of the previously described indicators. Furthermore, an in dept analysation of the bottlenecks within the production process is made which is used to improve the performance. This chapter is divided into two parts that answer different research question.

- *What is the current performance of throughput (products), production costs and product quality?*
- *What are the current bottlenecks within the Cut & Stack production process?*

Chapter five is concentrated on the development of the improvement plan. Every improvement step is compared to the performance of the determined indicators. Additionally, the improvement steps are compared to the potential EBITDA increase. Chapter five is derived into two research questions.

- *Which steps should Royal Sens take in improving the Cut & Stack production process?*
- *What is the influence of the improvement plan on the earnings before interest, taxes, depreciation, and amortization?*

Chapter six will be used to answer the main research question and explains the recommendation to Royal Sens.

3. Theory of Constraints

3.1 Introduction

This chapter is focused on the theoretical background that is necessary to conduct the following steps in the research. The chapter is going to focus on the Theory of Constraints (TOC). The theory about the TOC is necessary to be able to understand the analysis of the actual situation, this is also the reason that it is discussed before hand. The research question that is going to be answered is stated as follows:

How can the Theory of Constraints be used to optimize the Cut & Stack production process of Royal Sens?

3.2 Theory of Constraints in product line optimization

The Theory of Constraints is a management view that is first introduced by Eliyahu M. Goldratt in his book “The Goal” in 1984. The concept of the Theory of Constraints (TOC) can be summarized into two philosophies (Rahman, 1998) namely:

- Every system must have at least one constraint
- The existence of constraints represents opportunities for improvement

So, according to Goldratt, every system has at least one constraint that does not contributes to the determined goal. This statement is true because a real system such as a profit-making organization has a limit to the amount of profit they can produce. The literal definition of a constraint is stated as follows: “A constraint is anything that limits a system from achieving higher performance versus its goal” (M. E. Goldratt, 2012). In addition, these existing constraints should not be something negative because they represent opportunities to improve. This improvement is explained and elaborated in one of the key principles of the Theory of Constraints. Goldratt developed a system which enables organisations to implement continuous improvement into their processes. This step-by-step approach is derived into five steps which should all be executed to create to highest added value (E. M. Goldratt, 1990). The steps are:

Step 1: Identify the system’s constraint(s)
Step 2: Decide how to exploit the system’s constraint(s)
Step 3: Subordinate everything else to the above decision
Step 4: Elevate the system’s constraint(s)
Step 5: If in any of the previous steps a constraint is broken, go back to step 1. Do not let inertia become the next constraint.

These steps provide a clear schedule for continuous improvement. In addition to this step-by-step approach, Goldratt determined three core principles namely the drum-buffer-rope scheduling methodology (DBR), the thinking process (TP) and new managerial performance measurements. The drum-buffer-rope is mostly focused on scheduling problems within a production process. As said in the problem identification, the research is focused on the optimization of the physical product line, not the scheduling department. Due to this fact, the drum-buffer-rope scheduling methodology is not further discussed.

The implementation of the five focusing steps can be used in typical production environments. It can quickly result in more profit or an increase in productivity however, at some point the constraint will shift to market demand. To clarify, insufficient demand could be a constraint in a production environment. This makes the step-by-step approach more complicated because insufficient demand is a managerial or policy constraint. Therefore, Goldratt introduced a new way of dealing with management and policy constraints. Three questions should be answered while dealing with policy or managerial constraints. These questions are the bases for the thinking process developed by Goldratt. As stated before, the TP is one of the core principles of the Theory of Constraints. The developed questions and their purpose are stated in the table below.

Table 2: The thinking process (E. M. Goldratt, 1990)

Generic questions	Purpose
What to change?	Identify core problems
What to change into?	Develop simple, practical solutions
How to cause the change?	Implement solutions

The last principle that Goldratt developed, for analysing improving businesses, are new measurement indicators for managers. These measurements are specifically focused on analysing production processes and their added value. Goldratt argues that the main goal in most organizations is wrong (M. E. Goldratt, 2012). Most companies are focused on decreasing costs in the organization or on individual processes. According to Goldratt, this is not the goal of an organisation. The goal of every profit-making organisation is not cutting costs but, generating money. To measure this, two sets of measurements were developed namely global measurements and operational measurements. The global measurements can be expressed in the operational measurements; therefore, the operational measurements are discussed first.

Measurement 1: Throughput: “the rate at which the system generates money through sales (output which is not sold is not throughput but inventory)” (M. E. Goldratt, 2012)

Measurement 2: Inventory: “all the money invested in things the system intends to sell” (M. E. Goldratt, 2012)

Measurement 3: Operating expenses: “all the money the system spends in turning inventory into throughput” (M. E. Goldratt, 2012)

In addition to these operational measurements, three global measurements are determined by Goldratt. These are net profit, return on investment and cash flow. The relationship between the operational and global indicators are explained with the help of several situations where the operational indicators change. Furthermore, the effects on the global measurements are stated after these situations.

Situation 1: Increasing the throughput while maintaining the same inventory and operating expense levels.

Situation 2: Decreasing the operational expenses without harming the throughput and inventory.

Situation 3: Decreasing the inventory levels.

These situations influence the global measurements in various ways. The effects of these situations on are stated as follows.

Table 3: The effect of operational measurements on global measurements

	Situation 1	Situation 2	Situation 3
Net profit	Improvement	Improvement	Unchanged
Return on Investment	Improvement	Improvement	Improvement
Cash flow	Improvement	Improvement	Improvement

Traditional management philosophy emphasises the reduction of the operating expenses first, followed by increasing the throughput and lastly, reducing the inventory. Goldratt suggest that increasing the throughput first, followed by reducing the inventory and, finally, decreasing the operating expenses is far more beneficial in terms of the goal (E. M. Goldratt, 1990). The decision to put the measurements in this order is because the reduction of operating expenses and inventory is finite, namely zero, whereas throughput is not. Obviously, these indictors are different than traditional cost accounting systems. However, the traditional costs account methods can create mismatches between the goal of the organisation and managerial decisions (Maskell, 1991).

3.2 Conclusion

Overall, the Theory of Constraints is a continuous improvement cycle that focuses on the constraints in terms of a determined goal. The continuous improvement cycle can be used in several production environments while the three managerial questions can be used in every circumstance. Furthermore, the Theory of Constraints developed new indicators that should result in more clarity and insight into a profit-making organisation, mainly focused on the goal, generating money.

The research question stated at the beginning of the chapter is answered. The research question is described as follows.

- *How can the Theory of Constraints be used to analyse the Cut & Stack production process of Royal Sens?*

Two main concepts of the Theory of Constraint can be beneficial in the development of an improvement plan. Firstly, the thesis represents the first two question of the thinking process. The last part, implementation, is obviously not done by me due tot the timespan of the research. Furthermore, the oprational measurements are used within the analysis of the production costs. In this way, the improvement steps are measurable and clear which results in better recommendations.

4. Current situation

To answer the overall research question sub-questions were constructed, mentioned in section 2.5. This chapter is going to focus on the analysation of the current situation. Firstly, the research questions and their measurables are introduced in section 4.1. Secondly, an in-depth description of the Cut & Stack production process is given in section 4.2. Next, sections 4.3, 4.4, 4.5 and 4.6, explain the previously determined indicators throughput (products), production costs and product quality. The last part of the chapter is concentrated on the bottlenecks in the Cut & Stack production process, explained in section 4.7, and the overall conclusion of the analysis of the current situation and answers to the research question are given in section 4.8.

4.1 Introduction

This chapter is going to start with an in-depth description of the Cut & Stack production process. It describes every individual step and explains the already existing automated steps. Furthermore, this chapter is focused on the analysis of the current situation where the throughput (products), production costs and product quality are investigated. The first research question that is going to be answered in this chapter is stated as follows.

What is the current performance of throughput (products), production costs and product quality?

The throughput (products) is divided into three measurables namely production volume, cycle time and capacity distribution. The last three years are analysed for all measurables, the reason for this is that a three-year analysis is much more reliable than a one-year analysis.

The production costs are calculated according to the philosophy of the Theory of Constraints so the throughput (euros) and operating expenses are determined. The inventory measurable is not considered because inventory changes is outside the scope of the research. Moreover, the inventory levels within Royal Sens are not that interesting because Royal Sens produces almost every order on request, not for stock.

Lastly, the product quality is measured. Product quality is difficult to measure at Royal Sens so the product quality will be expressed in amount of client complaints. However, this is further explained in that part of the chapter.

The second research question is concentrated on an in-depth analysis of the current product line. It is focused on the current bottlenecks and their influence on the throughput (products) of the product lines. The formulated research question is as follows.

What are the current bottlenecks within the Cut & Stack production process?

4.2 In depth process description

As said before, the research is focused on the department where Cut & Stack labels are being made. These are made on four product lines; however, the research will be focused on product line one (P01), product line two (P02) and product line three (P03). Product line one and two are combined at the end. Whereas, product line three is completely individual. Moreover, the production process is divided into three sections. This creates clarity within the process and analyses. The first section includes jogging, cutting, and bundling. The second section represents the step where the bundles are sorted. Lastly, the packaging and control step are taken together.

There are multiple steps and actions that take place in producing Cut & Stack labels, in production line one, two and three. The individual steps of producing Cut & Stack labels are described below. Furthermore, a graphical overview is made and can be seen in Figure 2.

Every production process at Royal Sens starts with printing labels on raw material which makes the printing department crucial. However, the printing department is excluded within the research since it does not contribute to the determined core problems and Royal Sens wants to improve their post-printing department. The performance of the printing the department is fine and further capacity improvements are made so the printing department does not become a bottleneck in the system. This fact is further explained in chapter five. As mentioned before, the printing department uses a push system to create the production planning. This is in contrast with the post-printing department but should not be any problem because this fact is covered by the production planning of the post-printing department. The second part of the production process is drying since the intermediate product after printing has a twenty-four-hour drying period before it can be modified to the end-product. This can create a lot of mid-stock however Royal Sens takes it into account when developing the production planning for the post-printing department. The production planning for the post-printing department uses a pull system that uses the delivery date as input. Furthermore, there is a difference in the number of shifts each department uses. The printing department produces in three shifts of eight hours, whereas the post-printing department uses two.

The production process in the post-printing department starts with the process called “jogging”. jogging is a process where the stacks of sheets are divided into smaller stacks that are used to cut the labels in the right sizes. The stacks that Royal Sens uses mostly contain 1000 sheets of paper. The jogging process is done manually and is considered heavy by the factory employees. The jogging process is an individual step since it is done as preparation for P01, P02 and P03.

Secondly, the stacks are cut into the right measurements. This is done semi-manually which means that is has a significant impact on the production costs. In case of a new order, the employee has to re-program the cutting machine since every order has different sized labels so setup time is a factor. The cutting process is divided into two actions namely cutting the length and width. There is a clear difference between P01, P02 and P03, cutting the width is done automatically at P03 whereas it is done by hand on the other product lines.

Thirdly, the stacks are labelled with a 2D code. Royal Sens uses a trend system which is specifically developed for Royal Sens. This system uses 2D codes to locate a bundle within their production process. Moreover, the 2D code is also used to control the bundles. Royal Sens has two different bundle machines namely a single-bundle machine and a multi-bundle machine. The first one bundles one bundle at the time and the second machine can bundle up to six bundles at the same time. The multiple bundle machine is vulnerable for downtime. Royal Sens is not satisfied with this machine since it disrupts the flow of the production process.

The next step is sorting the bundles into packs. The number of bundles within one pack is dependent on the customers wishes. This step is tricky, and errors occur often because it is done manually. In addition, there are multiple different labels on one sheet of paper which makes the job even harder. So, sorting the labels into packs requires a lot of concentration.

The fifth step within the production process is packaging. Packaging the packs is performed by a machine. The employee puts the pack on the roller track into the machine. The package machine wraps the pack and the product continuous on the roller track.

The sixth step within the production process is the control step. The control step is done by a computer that checks the 2D code on every stack within a pack. There are two options, all the 2D codes match or they do not. The first option is the optimal situation which puts the package further into the production line. The second option is not sufficient to pass, so the system eliminates the package out of the process on a different roller conveyer. When this happens, the package must be reworked, so it goes again through the whole production process starting by the bundling step.

The last step is sorting the packages on the right pallets. As mentioned before, multiple different labels can be printed on the same sheet and produced at the same time. All the packs with different bundles of labels should be divided over different pallets. This step is also done manually which means that it is sensitive to errors.

As mentioned within the company introduction, Royal Sens produces high quality products and tries to be as flexible as possible. Examples of being flexible are; Royal Sens produces labels into cardboard boxes for some clients. Furthermore, Royal Sens also packages the packs in several ways. These adaptations create additional work which results in higher producing times. The special cases are not assigned to one specific product line however the special cases are not produced on P04 or P03 because of the automated lines. This means that P01 and P02 are affected by the special cases. Nevertheless, they are part of the process and should be considered while developing an improvement plan.

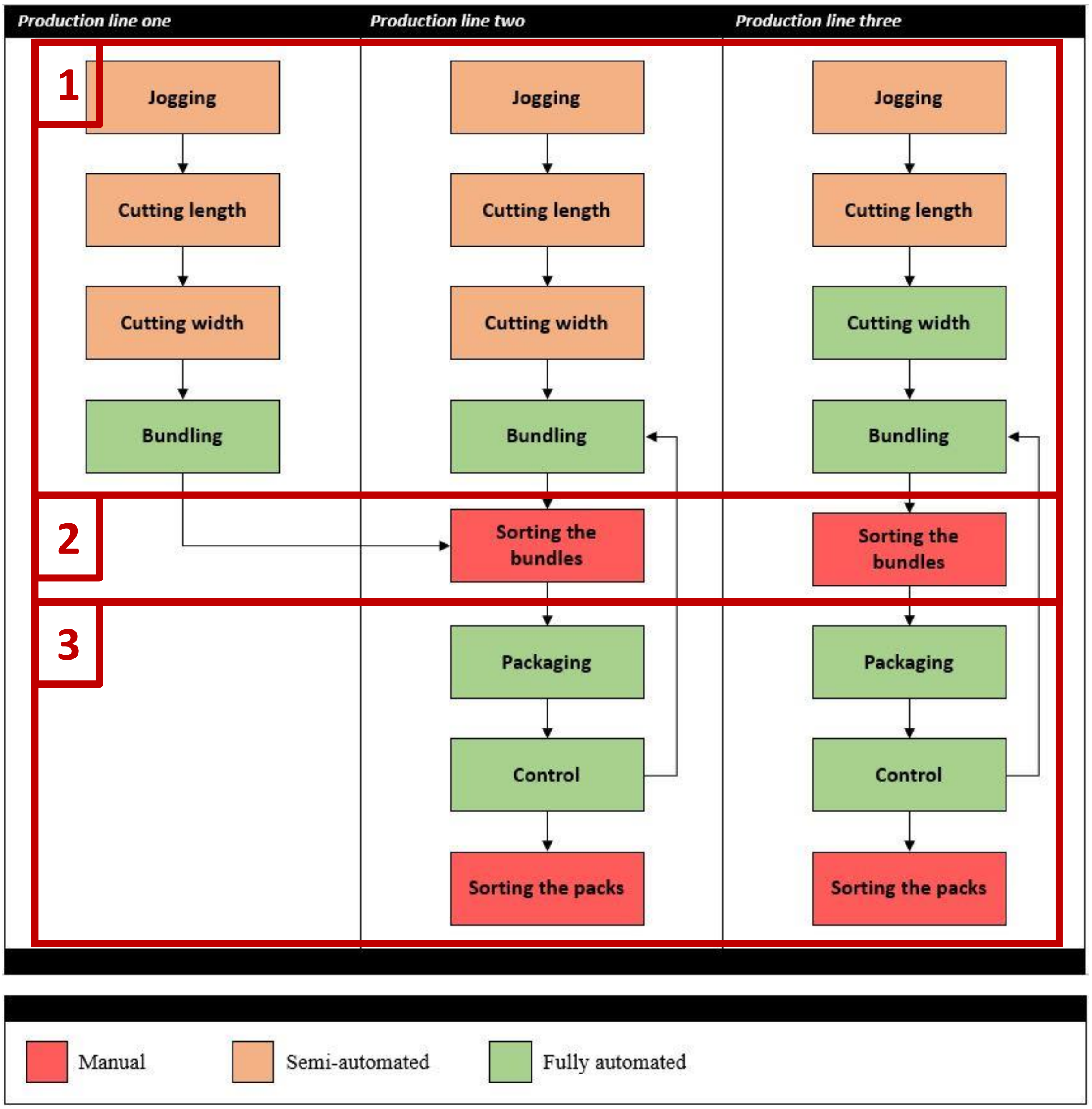

Figure 3: Flowchart of Cut & Stack producing process, sections included

4.3 Throughput (products)

4.3.1 Product volume, cycle time and capacity distribution

The next step within this chapter is to analyse the current situation starting with the throughput (products). As mentioned before, the throughput (products) is divided into three measurables: product volume, cycle time and capacity distribution.

The production volume is defined as the total amount of sheets of paper the product line processed in a specific period. The reason for this definition is that the processing speeds of the product lines also have this measurement.

In addition, the cycle time per product is calculated. The cycle time is defined as the number of minutes that is needed to process one stack of paper where the stack consists of 1000 sheets of paper. The definition is used because it is the most accurate information. The cycle time is the time between start processing the order and the completion of the order. The formula used to compute the cycle time is stated in the appendix[3]. As seen before in the Theory of Constraints, the throughput (products) increases when the cycle time of the products decreases (E. M. Goldratt, 1990). So, the cycle time is a crucial indicator for a throughput analysis.

The production volume per year per product line is given in the figure below.

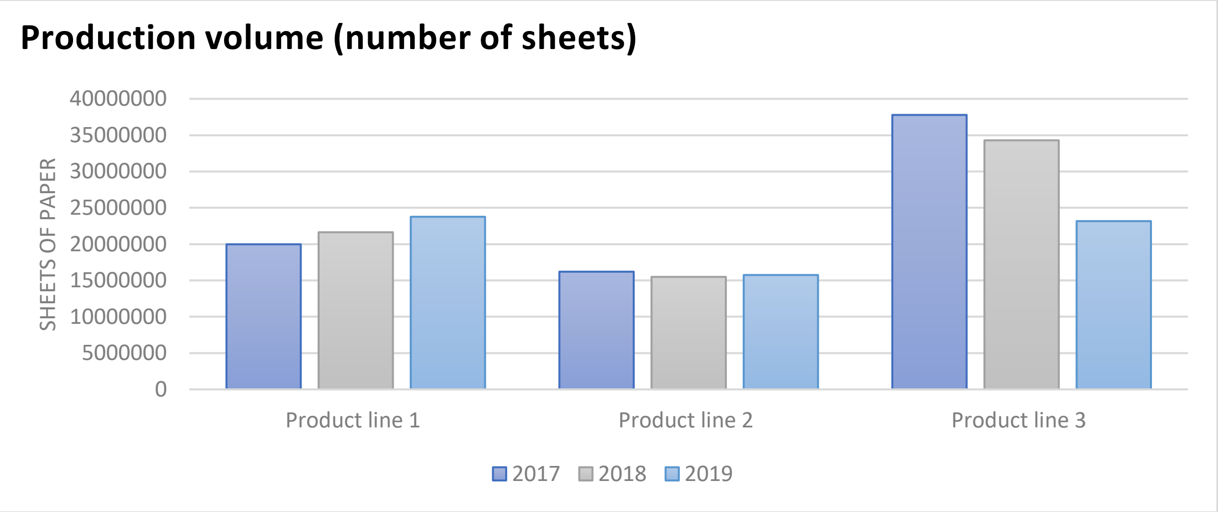

Figure 4: Production volume per product line per year

A trend that should be considered and pointed out in the total amount of produced products decreased for P03. This decrease is unexpected since it is the second largest product line in the factory of Rotterdam, only product line four (P04) is larger. The drop is due tot the fact that P03 uses the multi-bundle machine which has a lot of troubles with producing quality intermediate products. The reworks percentages are high at the bundle machine in P03. Furthermore, Royal Sens relocated a part of the production volume to Enschede, because it is a better fit in that factory, which is also one of the reasons that the production volume decreased significantly in 2019. As mentioned before, Royal Sens has one additional Cut & Stack production line, product line four (P04), which is outside the scope of the report. However, it is important to note that this product line produces in night shifts in 2019. So, P04 has a larger producing share in 2019 than in 2018 which is also a reason that the production volume at P03 decreases drastically. The total amount of products produced at the production lines decreased with 12% from 2018 to 2019.

[3] *Appendix P: Formula cycle time*

The second measurable that is investigated considering the throughput analysis is the cycle time. The time that a product spends in the system, where the product is defined as a stack of 1000 sheets of paper. The average cycle time in 2019 per product line is given in the figure below.

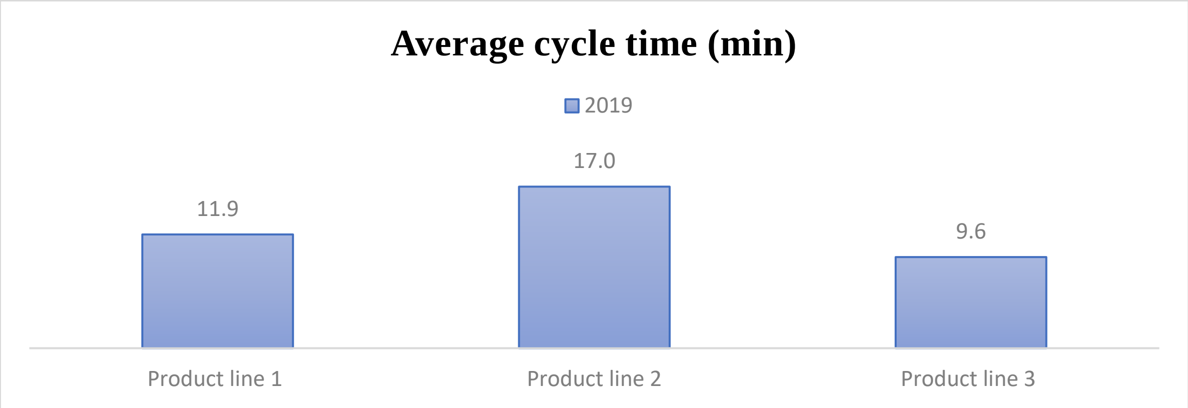

Figure 5: Cycle time per year per product line

It is interesting to note that the cycle time of P01 and P02 is relatively high in comparison with P03. P03 is the best performing product line whilst it has a lot of breakdowns. The reason for this significant difference in cycle time is that the one of the cutting steps within P03 is fully automated namely “cutting the width”. This increases the setup time however it also improves the overall producing speed, more on that fact is explained within the bottleneck analysis.

The last measurable that is calculated for the throughput (products) is the capacity distribution of the product lines. As mentioned before, Royal Sens produces three different product types namely Cut & Stack labels, Die-Cut labels, and Specials. These products are in principal the same, the labels are printed on paper in the printing department. However, the post-printing processes are significantly different. This means that these product types have different post-printing production processes. Still, some of the Die-Cut labels are produced on production lines that should produce Cut & Stack labels. This is interesting since it means that the amount of produced Cut & Stack labels is limited because some capacity is used for Die-Cut labels.

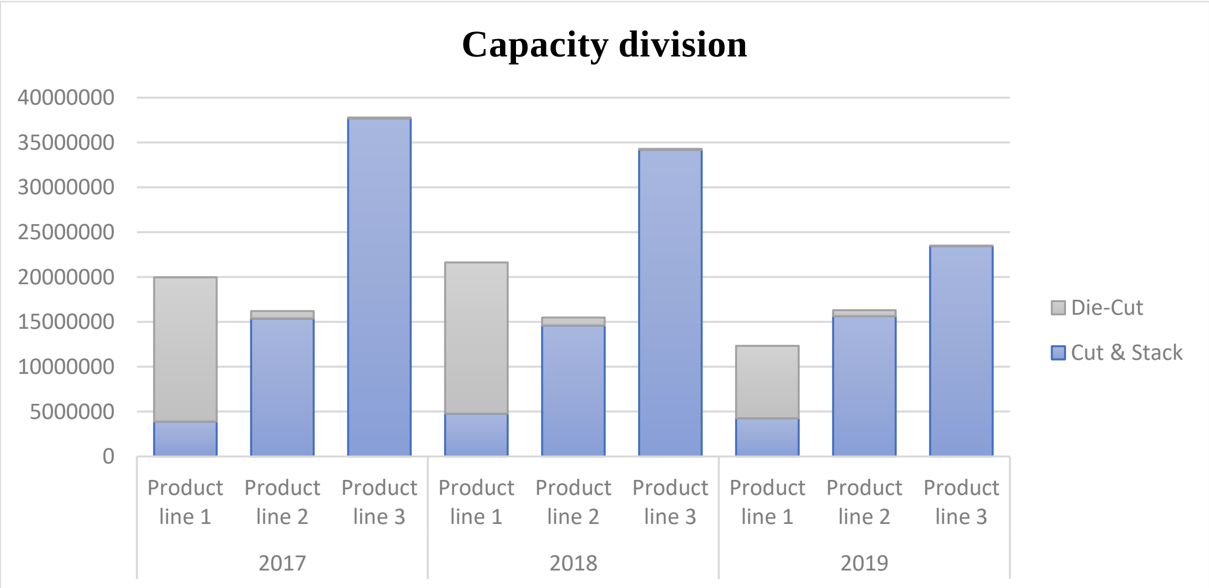

Figure 6: Capacity distribution per product line per year per production volume

The first thing that should be pointed out is that a lot of processing hours are used for Die-Cut labels which is a different product. There is a small decrease in 2019 however this is probably because the overall production volume is lower. P01 is further investigated since a lot of its capacity used to prepare Die-Cut labels. The exact percentages are:

Table 4: Percentage capacity used for preparation Die-Cut Labels

Year	Percentage Die-Cut labels
2017	80%
2018	78%
2019	65%

So, the conclusion can be made that there is a lot free capacity in P01 because the Die-Cut labels should be produced in their own production process. Furthermore, the product line developed for preparation of the Die-Cut labels (P06) is not being used while P01 is producing. This is because both producing steps are done semi-automated and Royal Sens has not enough experienced personnel to run both product lines at the same time.

4.3.2 Conclusion

There are two main conclusions out of the analysis of the throughput (products) that are highly important as input for the improvement plan:

- The cycle time at P03 is much lower than on the other product lines since the step “cutting the width” is fully automated. The cycle time is 43% lower comparing it to P02 and 20% lower comparing it to P01.
- The product lines designed to produce Cut & Stack labels are also used to prepare Die-Cut labels. 65% of the total amount of produced sheets is used for Die-Cut labels at P01.

4.4 Variable production costs

The second indicator that is investigated are the production costs. As mentioned in chapter three, the TOC developed operational and global cost accounting measurements. The cost accounting method, introduced by the TOC, is used to calculate the throughput in sales which also covers the variable production costs. Important to notice is that the determined throughput within this chapter is clearly different than the throughput established in product volume. The calculated throughput within this chapter is purely used as cost accounting method that analyses the current production processes and it's financials (E. M. Goldratt, 1990).

The throughput is defined as; "the rate at which the system generates money through sales". The formula introduced by Goldratt is stated as follows:

$$Throughput\ (euros) = generated\ sales\ (euros) - variable\ costs\ (euros)$$

Equation 1: Throughput (euros)

The purpose of determining the throughput is to create a clear overview of the overall variable costs that are made in this part of the production process. Moreover, the throughput (euros) is extremely convenient while computing the improvement steps and their impact on the EBITDA.

4.4.1 Generated sales

The generated revenue at P01 and P02 are almost identical in 2017 and 2018. There is a slight sales increase of 3,4% which is positive and in line with the overall revenue increase of Royal Sens. However, comparing the overall results of 2018 to 2019 shows a decrease in revenue of 25%. The revenue decreases from 13,7 million euros to 10,3 million euros which can be seen in figure five below. This decrease is surprising since the overall revenue of Royal Sens increased with 4%. The increase is mainly due to the fact of growing interest in plastic labels and Die-Cut labels. Furthermore, products that were produced at P01, P02 and P03 were relocated to another factory namely Enschede. So, the revenue still exists however on another product line.

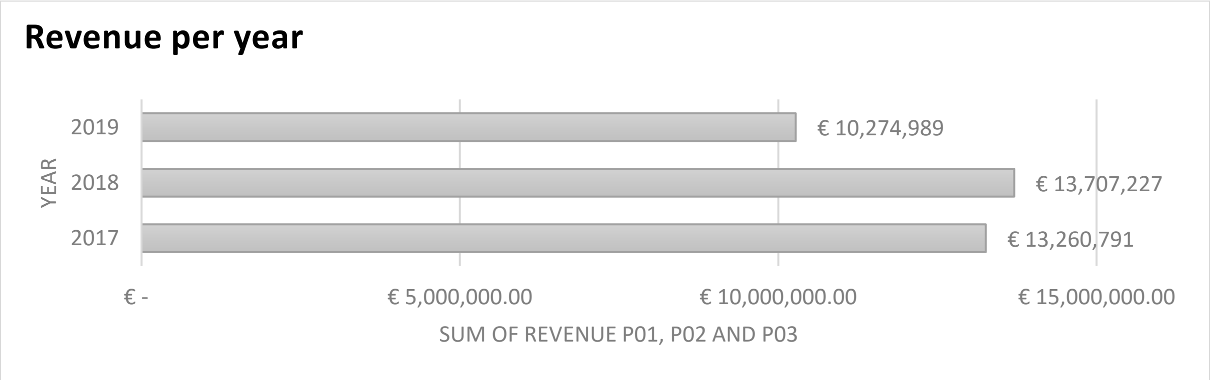

Figure 7: Summation of revenue of P01, P02 and P03 per year

The second step in calculating the throughput in sales over the last three years is determining the variable costs at P01, P02 and P03. The definition used for variable costs is: “costs that are dependent on production volume”. Royal Sens has several costs items that are in line with this definition. The next costs items are included:

- Raw materials
- Energy consumption
- Maintenance
- Additional personnel

All the in-depth graphs and calculation of the variable costs can be seen in the appendix[4]

4.4.2 Raw materials

Obviously, the raw material costs are dependent on the production volume which categorizes them as variable costs. The raw material costs cannot be improved other than renegotiating the contracts with suppliers, but this is not within the scope of the research. However, the costs of raw materials should be included in the throughput calculation.

4.4.3 Energy consumption

Energy consumption is dependent on the product volume since the machines do not consume energy when they are not operating. The total energy costs are determined with the costs of working one hour. The costs per hour are shown in the table below.

Table 5: Energy costs per hour per product line

Product line	Costs per hour
P01	€ 2,72
P02	€ 2,72
P03	€ 4,08

As said before, the total energy costs are dependent on the total amount of operating hours. So, these are determined and multiplied with the cost per hour. This calculation is done for the last three years. One clear note that can be seen out of the table, the costs per hour for P03 are much higher than for P01 and P02. This fact should be considered while developing the improvement plan.

4.4.4 Maintenance

The maintenance costs are calculated in the same way as the costs for energy consumption. Every product line is assigned with cost per hour. The reasoning for this is that maintenance is dependent on the number of products the machine produces which means that it is dependent on the production volume. The maintenance costs per operating hour are stated in the table below. Just as for the energy costs, P03 has the highest costs per hour which can create additional problems when developing improvements.

Table 6: Maintenance costs per hour per product line

Product line	Costs per hour
P01	€ 2,72
P02	€ 2,72
P03	€ 4,08

[4] *Appendix I: Variable costs calculations*

These costs are, just as previously, multiplied with the total amount of operating hours per year which creates a clear overview of the actual maintenance costs that can be seen in the appendix.

4.4.5 Additional personnel

Royal Sens uses a standard team within the factory however this team is extended with additional employees when it is extremely busy. Some Cut & Stack labels have a high throughput rate namely the product with less than 20 labels per sheet. In this case, it is necessary to use additional staff. These costs should be considered as variable costs.

4.4.6 Throughput (euros)

The determined variable costs are subtracted form the determined sales in 2017, 2018 and 2019 which gives us the throughput in sales. The throughput calculation is going to be used to analyse an automation implementation. The costs of printing the labels is not included in this calculation since it is not part of the scope whilst the total revenue is assigned to the product lines. Nevertheless, the throughput calculation can be used to analyse the automation solutions since the production costs in the printing department will not change due to automating a part in this product line. So, the production costs in the printing department are a constant. The calculated throughput is stated in the table below.

Table 7: Overview throughput (euros) calculation

	2017	2018	2019
Sales	**€ 13,260,791**	**€ 13,707,227**	**€ 10,274,989**
Raw material	€ 3,799,730	€ 3,770,952	€ 2,808,947
Energy	€ 43,226	€ 43,388	€ 38,277
Maintenance	€ 80,164	€ 80,244	€ 68,130
Additional personnel	€ 17,340	€ 14,358	€ 13,664
Total variable costs	**€ 3,940,460**	**€ 3,908,942**	**€ 2,929,018**
Throughput	***€ 9,320,331***	***€ 9,798,285***	***€ 7,345,971***
% Sales	***70%***	***71%***	***71%***

4.4.7 Conclusion

Overall, the variable production costs look normal, there are no significant problems or outcomes. Nevertheless, they are highly important for further analyses within the report. Important information that should be considered while computing an improvement plan is, the increase in energy and maintenance costs at P03 stated in Table 5 and 6. Furthermore, as mentioned before, some production volume is moved to Enschede. An obvious result is the decrease in revenue in 2019.

4.5 Operational expenses

The next operational measurement that is calculated and explained are the operational expenses. Operational expenses are defined by Goldratt as: "all the money the system spends in turning inventory into throughput". There are a lot of activities that can be seen as operational expenses however only the operational expenses important for P01, P02 and P03 are described. The determined operational expenses are costs for regular staff and depreciations.

4.5.1 Regular staff

As mentioned before, Royal Sens uses the same team in the factory, independent on the production volume. The staff that is used consists of three joggers, three cutters and two splitters.

Table 8: Overview of regular staff used at P01, P02 and P03

Product line	Staff	Costs per year per employee
P01	Jogger	€ 37,000
	Cutter	€ 45,000
P02	Jogger	€ 37,000
	Cutter	€ 45,000
	Splitter	€ 37,000
P03	Jogger	€ 37,000
	Cutter	€ 45,000
	Splitter	€ 37,000

4.5.2 Depreciation

Depreciation is considered a cost; however Royal Sens does not have any depreciation costs at this moment. Royal Sens depreciate all their machines in ten years which means that all the equipment in Rotterdam factory is older than that. So, this indicates that the production process is outdated which is in line with the determined core problems.

4.5.3 Conclusion

The Cut & Stack production process still uses employees which is costly for Royal Sens and. The costs for employees are recurring, which means that Royal Sens pays these costs every period for multiple years. As mentioned in the problem identification part, this could be one of the reasons to fully automate one of the manual steps within the process. However, the profitability and value of this decision should be investigated. The improvement plan explains this step further and in more detail.

The depreciation costs are interesting since Royal Sens does not pay it anymore. This implies that the machines used at the production lines are old. Due to this fact, more breakdowns and other failures can occur. One clear note, depreciation should not be considered while computing the EBITDA calculation so, it does not contribute to the current or theoretical EBITDA.

4.6 Product quality

The last indicator that is going to be analysed in the current situation is product quality. Product quality is measured in the total amount of complaints from clients. However, not all complaints are related to the Cut & Stack products or even to P01, P02 and P03. So, only the critical complaints related to our scope are investigated.

There are three types of complaints that relate to the scope in this research. The complaints are stated below.

- Mixed label
- Wrong sticker
- Package

Royal Sens categorizes each complaint in minor, major or critical complaints. A package complaint is considered a major complaint whereas mixed label and wrong sticker are critical complaints. Mixed label and wrong sticker problems can create huge troubles which is already mentioned in the problem identification part. Because of the huge problems that occur when making such a mistake, the norm is set to zero. The actual complaints in 2019 are stated in the figure below.

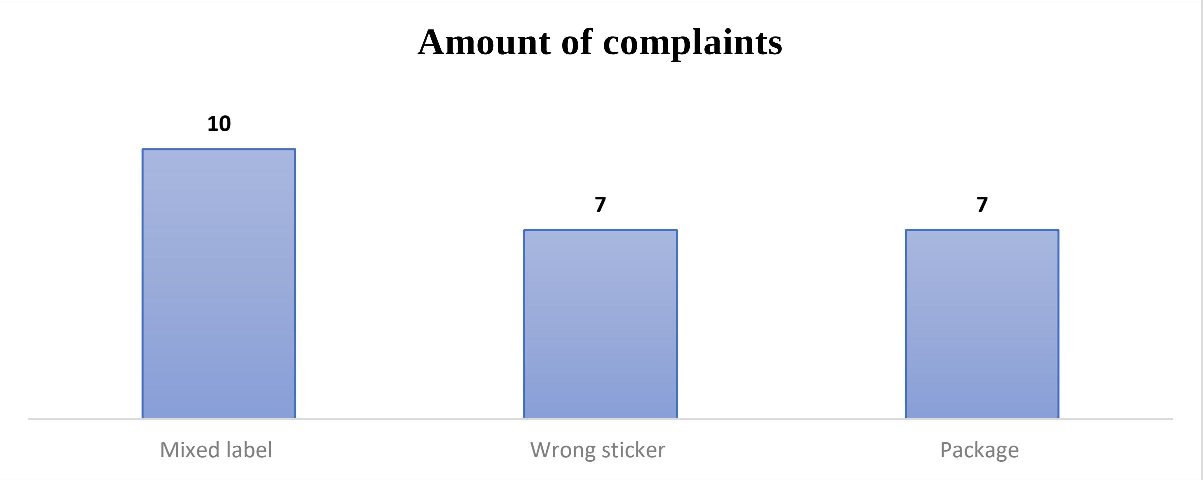

Figure 8: Amount of complaints

As can be seen that the norm is not met in 2019. There were some mix labels and wrong sticker problems. These mistakes are made in the manual steps of P01, P02 and P03. Mixed label mistakes are made by the action "sorting the bundles" in section two, and the wrong sticker mistake is made at the end of the product lines. So, improving the product quality is possible through automation which is line with the wishes of Royal Sens. However, automation should not be an improvement in itself since its rather costly to implement an automation option only for product quality.

4.6.1 Conclusion

The product quality norm is not met which implies that Royal Sens has difficulties with producing quality products. However, the norm that is set is zero which is, obviously, difficult to achieve. 12% of the total complaints in 2019 are critical complaints, these complaints should have been solved before Royal Sens delivered the product. So, the most important aspect of the product quality is that most of the product quality issues occur in section two of the product line. Which is the section where the step is done manually. This is one of the main conclusions used for one of the improvement steps.

4.7 Bottleneck analysis

The bottleneck analysis is the last step in the analysation of the current situation. The bottleneck analysis is performed with the Theory of Constraints in mind. The TOC explains that the slowest producing step of a system is the step that determines the actual production speed of the whole production process (M. E. Goldratt, 2012).

4.7.1 Introduction

The Cut & Stack production process is not a straightforward process which results in difficulty in developing a bottleneck analysis. The main reason is that the product changes during the process. The product starts as sheets of paper. After the cutting step, the products are bundles whereas the end-product are packs. Because the product changes, the bottleneck changes dependently on the product characteristics. As mentioned before, Royal Sens is focused on flexibility and quality. So, there is no standard product that is produced. This fact is used within the bottleneck analysis. All the individual processing speeds are given in the appendix[5].

4.7.2 Bottlenecks

As mentioned before, the bottleneck changes depending on to the product characteristics specifically the number of bundles in one pack. The range varies for P01, P02 and P03. At P01 and P02, the range of the number of bundles in one pack is from 1 to 16 whereas the range for P03 is from 1 to 9 bundles in one pack. The product changes from bundles into packs in section two of the product line, the package step. So, the output of section two of the product line is compared with the maximum capacity of section three of the product line. The maximum capacity of section three of the product line is dependent on the control step because this step has the lowest capacity[6].

Table 9: Bottleneck P01, P02

Number of bundles in one pack	Output section two (packs per hour)	Capacity section three (packs per hour)
1	366	225
2	183	225
3	122	225
4	92	225
5	73	225
6	61	225
7	52	225
8	46	225
Etc.		

[5] *Appendix T: Capacity and processing speeds per station*
[6] *Appendix T.3.2: Control step*

Table 10: Bottleneck P03

Number of bundles in one pack	Output section two (packs per hour)	Capacity section three (packs per hour)
1	320	200
2	160	200
3	107	200
4	80	200
5	64	200
6	53	200
7	46	200
8	40	200
Etc.		

As can be seen in the tables above, for both product lines, section three becomes a bottleneck when the amount of bundles in one pack is equal to one which is 4.9% of the orders at P01 and P02 and 5.4% of the orders at P03. However, this reasoning only holds if the production flow within the product line is not interrupted, which is not the case at Royal Sens.

To explain, the actions that are performed in section two of the product line are done manually which is stated in Figure 2. The employee performs three actions.

- Sorting the bundles
- Sorting the packs
- Controlling the label

"Sorting the packs" even requires the employee to leave to another part of the product line. These actions take time which creates two additional problems within the product lines: intermediate stock builds up and it is likely that the number of reworks increases.

Intermediate stock builds up because section one of the product line is still producing while the employee does other tasks. The result is that the employee must get rid of the intermediate stock after the employee comes back. However, the remaining steps of the product lines do not have the capacity to handle the intermediate stock[7]. Royal Sens created a system with mirrors[8] to prevent congestion in the system however, the cause of the problem is never investigated. Moreover, because the employee must perform other tasks, the number of reworks is likely to increase[9].

The reason for this fact is that sorting the bundles is a difficult task which requires a lot of concentration and the employee must perform other tasks that require concentration as well. Moreover, the rework due to mistakes adds up to the rework that already must be done. To explain, the bundling machine has a mistake rate. P01 and P02 are working almost perfectly fine in terms of rework namely on average 0.75% of the total producing time whereas the time lost for reworks at P03 is 3.6% of the total producing time. So, the amount of rework can add up quickly. Besides, as mentioned before, section two of the product line is also the step where most of the mistakes occur.
So, Royal Sens creates their own bottleneck namely section three of the product line, in detail, the control step. This bottleneck is created because the flow of the product lines is interrupted. This is not optimal because maximizing the product flow results in lower cycle time and an optimal throughput

[7] *Appendix K: Relationship between intermediate stock and number of minutes not a t the station*

[8] *Appendix C: Mirrors at the product line*

[9] *Appendix U: Indication rework*

(products) level (E. M. Goldratt, 1990). This means that the optimal situation for P01, P02 and P03 is that the output of the whole production process is dependent on the cutting step in section one.

4.7.3 Conclusion

So, three main conclusions can be made from the bottleneck analysis.

- If the producing flow is constant than the cutting step determines the actual output with one exception, when the number of bundles in one pack is equal to one.
- The optimal situation is that the output of the total line is dependent on the cutting step because it maximizes the flow and creates improvement opportunities.
- Royal Sens creates its own bottleneck, the control step, because there is no constant flow caused by the multiple actions the employee must perform in section two of product line.

4.8 Answers to research questions

There are two sub-research questions answered in chapter four of the report. The following research question were computed.

- *What is the current performance of throughput (products), production costs and product quality?*
- *What are the current bottlenecks within the Cut & Stack production process?*

Conclusion were made at the end of every part within the analysis of the current situations. The following most important conclusions were made and used as input for the improvement plan.

- The cycle time at P03 is much lower than on the other product lines since the step "cutting the width" is fully automated. The cycle time is 43% lower comparing it to P02 and 20% lower comparing it to P01 *(see section 4.3.1 – Figure 5).*

- The product lines designed to produce Cut & Stack labels are also used to prepare Die-Cut labels. 65% of the total amount of produced labels is used for Die-Cut labels at P01 in 2019 *(see section 4.3.1 – Table 4).*

- The variable energy and maintenance costs per hour are higher for P03 than for P02 and P01. The difference is exactly 50% *(see section 4.4 – Table 5 and 6).*

- Most of the client complaints originate at section two of the product lines *(see section 4.6).*

- If the producing flow is constant than the cutting step determines the actual output with one exception, when the number of bundles in one pack is equal to one *(see section 4.7.2 – Table 9 and 10).*

- The optimal situation is that the output of the total line is dependent on the cutting step because it maximizes the production flow *(see section 4.7).*

- Royal Sens creates its own bottleneck, the control step, because there is no constant flow caused by the multiple actions the employee must perform in section two of product line *(see section 4.7.2).*

5. Improvement plan

This chapter explains a four-step improvement plan that can be followed to improve the Cut & Stack production process. Firstly, an introduction and the sub-questions are explained in section 5.1. Obviously, some assumptions are made before developing the improvement plan, these assumptions are described and explained in section 5.2. The improvement plan is explained after the assumptions, starting with improvement step one which is explained in section 5.4. Every step is compared to the previously determined indicators. At the end of the chapter, the overall EBITDA impact of the improvement plan is computed in section 5.8 and the research questions are answered in section 5.9.

5.1 Introduction

This chapter is going to describe a step-by-step approach to improve the Cut & Stack production process. The first part of the chapter is going to focus on the improvement steps with the following research question in mind.

Which steps should Royal Sens take in improving the Cut & Stack production process?

The step-by-step plan is derived into four steps. The improvement steps are firstly analysed with the previously determined indicators throughput (products), production costs and product quality. The production costs include the variable costs and operating expenses mentioned within chapter four.

As mentioned before, Royal Sens wishes to automate a step within their product line, so automation is also included within the improvement plan. However, before automation can even be an option, other issues must be resolved. These are less costly and can have the same impact furthermore one of the improvement steps is necessary as preparation for other improvement steps.

The second part of every section is going to compare the individual improvement step with the possible EBITDA increase. The research question that is going to be answered is stated as follows.

What is the influence of the improvement plan on the Earning before Interest, Taxes, Depreciation and Amortization?

5.2 Assumptions

Two assumptions are made while developing the improvement plan. These are verified with employees of Royal Sens and are considered reasonable; a small explanation is given.

Assumption one: “Sales is not a bottleneck at Royal Sens”

Sales is not a bottleneck so every capacity increase in production can be sold by Sales. At this moment specifically due to Covid-19, Royal Sens has much more orders. Royal Sens produces around 10-15% more in this period. Moreover, Royal Sens is growing in terms of overall sales. The overall sales increased almost 5% from 2017 to 2019 (*Financial report Royal Sens Q4 2019.xlsx*, 2019). This assumption is also discussed with Royal Sens and they find it also reasonable.

Assumption two: “The printing department does not become a bottleneck”

This means that there is always enough input for the post-printing department. As mentioned before, the post-printing department gets its input from the printing department. This means that the output of the post-printing department is dependent on the output of the printing department. Royal Sens just bought an additional printer which increases the output of the printing department. So, the assumption is reasonable to make.

5.3 Improvement plan

The improvement plan consists of the following four steps.

Step 1: Separating the processes
Step 2: Constant producing flow
Step 3: Automate cutting the width at P02
Step 4: Automate section two

The improvement steps should be executed in this recommended order because some steps are necessary for other steps. For example, step three can only be executed if step two is implemented. The improvement steps are determined with the conclusions mentioned at the end of the analysation of the current situation. Theses conclusions are used as input for the improvement plan. Every improvement step is explained in detail further in this chapter, where the impact of every individual step on the previously determined indicators is discussed.

5.4 Improvement step one: Separating the processes

As concluded in the analysis of the current situation, the product lines that should produce Cut & Stack labels are also used to prepare Die-Cut labels. Due to this decision the producing hours that can be used to produce Cut & Stack labels is significantly lower, so capacity of the product lines is used for the wrong product. As can be seen in previous chapters, in 2019 65% of the total amount of produced sheets which is equivalent to 50% of total producing hours, is used to prepare Die-Cut labels. Moreover, only the cutting step is used while preparing Die-Cut labels so this results in downtime for the remaining production steps at P01, P02 and P03. Furthermore, Die-Cut labels have their own process namely, P05 and P06 are specifically built to prepare Die-Cut labels. Unfortunately, P06 is not fully occupied because Royal Sens does not have enough experienced personnel. However, out of interviews with the Manager Operations, attracting personnel is his main priority right now. He believes that the workforce is back to normal by the end of September.

The proposed capacity distribution is shown in the figure below. The actual producing hours of P06 in 2019 were 661 hours while 3640 producing hours were budgeted, this concludes that there is enough capacity to transfer all the preparation work to P06. One additional assumption is the basis for this improvement step, that the workforce will be at a normal level by the end of September.

Situation 2019		
	Total hours	**Die-Cut**
P01	3166	1586
P02	4799	225
P03	3749	1
P06	661	661

Proposed situation		
	Total hours	**Die-Cut**
P01	1580	0
P02	4574	0
P03	3748	0
P06	2473	2473

Figure 9: Graphical overview of new situation for P06

The total hours are computed from the delivered data sheet. The total hours of 2019 are used since those are most relevant in this case because these are the producing hours from last year. Relocating the workload from P01, P02 and P03 to P06 does not contribute to the variable production costs because, as previously mentioned, all the variable costs are dependent on the production volume which is not changing. However, the operating expenses are going to increase because one additional cutter must be hired.

Dividing the Die-Cut and Cut & Stack production process creates clarity and better insight which is useful for further performance analyses. Furthermore, it results in rest in the workplace. The workload will be more organized, and this creates much more clarity in the factory as well. Furthermore, the freed-up capacity can be used to produce additional Cut & Stack labels so this improvement step results in a throughput (products) increase. However, all the additional production hours also influence the variable costs as mentioned in the previous chapter. The EBITDA calculation is made in the next section. Concluding, after this improvement step the throughput (products) is going to increase, the production costs are increasing whereas the product quality stays the same. The throughput (products) is measured in the potential amount of bundles the cutting step can produce. The reason for this, is that the output of the cutting step are bundles.

Table 11: Improvement step one in terms of indicators

Indicator	Change	Difference
Throughput (products)	Increases	25%
Production costs	Increases	24%
Product quality	Unchanged	-

The percentage increase in throughput (products) and production costs are determined through comparing the current situation and the proposed situation earlier described in this section. The details of this calculation can be seen in Appendix M*:* Calculation improvement step one.

The conclusion can be made that improvement step one improves the throughput (products) however it also increases the overall production costs with 24%[10]. However, in terms of potential EBITDA improvement the improvement step shows clear results. This is covered in the next section.

[10] *Appendix M.5: Overview of throughput (products) and variable costs*

5.4.1 EBITDA change

Improvement step one increases the overall capacity for the Cut & Stack products with only one investment, an additional cutter. The potential throughput (euros) increase is calculated[11], an overview is given below. The details of this calculation can be seen in Appendix M. The calculation already includes the variable production costs increase. The potential throughput (euros) increase is also the total EBITDA increase because all the other costs are constant such as overhead costs.

Table 12: Potential throughput (euros) increase improvement step one

	Potential throughput increase (euro)
P01	€ 505,611
P02	€ 230,732
P03	Negligible

The EBITDA impact and the impact on the Profit and Loss statement is stated in the table below.

Table 13: EBITDA and P&L impact of improvement step one

	P&L change		*Impact on EBITDA*	
Operational expenses	+	€ 45,000	-	€ 45,000
Potential throughput (euros)	+	€ 736,342	+	€ 736,342
Potential EBITDA impact improvement step one: Separate processes			+	**€ 691,343**

5.4.2 Conclusion

Improvement step one is focused on increasing clarity within the overall production process. Moreover, it increases the overall capacity for Cut & Stack products that results in additional possible throughput (products). Also, only the cutting step is used when preparing Die-Cut labels at P01, P02 and P03 which results in downtime for the other production steps.

Obviously, the throughput (products) increase has an impact on the variable costs furthermore the operating expenses also increases due to the additional cutter that is necessary. However, the overall performance improvement can be seen within the EBITDA calculation.

[11] *Appendix M: Calculation improvement step one*

5.5 Improvement step two: Constant producing flow

The second improvement step is focused on eliminating the bottleneck within the product lines. As concluded earlier, the bottleneck changes dependently on the product characteristics. The following bottlenecks were detected, section three (control step) and the cutting process. Concluded out of the analyse of the current situation, the output of the product lines should be dependent on the producing speed of the cutting step to maximize the producing flow. So, the only real bottleneck within the product line is the control step. As previously mentioned, the control step becomes a bottleneck because section two of the product line is not fully occupied. Eliminating the control step as bottleneck should be done by fully occupying section two of the product line. Fully occupying section two of the product line maximizes the flow through the product line which results in the potential to produce at the highest rate. This is in line with the theory introduced in chapter three (M. E. Goldratt, 2012).

As mentioned above, the control step becomes a bottleneck because section two of the product line is not fully occupied. This creates intermediate stock which is not manageable by section three of the product line. So, optimizing the flow eliminates the bottleneck for around 95% of the orders. The control step will be a bottleneck in the other 5% because the number of bundles in one pack is equal to one for these orders. Optimizing the producing flow has a second benefit namely, the product quality is likely to increase since the employee stays at their spot in the product line. So, sorting the bundles will be the only tasks which improves the concentration level and decreases the mistake rate. However, the actual difference in amount of complaints can not be measured within the timespan of the research. Nevertheless, Royal Sens can clearly see the impact in a longer period. An indication has been made for the product quality increase[12] however, the actual results can be seen on the long term. Furthermore, the number of reworks should decrease due to the additional employee. Obviously, the throughput (products) benefits from this fact.

The increase in throughput (products) is not measurable due to the lack of data, for example the number of minutes that the employee is gone to perform other tasks. However, theory states that an optimal producing flow results in the lowest cycle time that results in a throughput (products) increase (Dallery & Gershwin, 1992). The data can be obtained however this requires months of measuring which is not possible in the timespan of my research.

It is likely that the additional employee will not be productive the whole time, specifically when the cutter has to re-programme the cutting machines for a new order. Within this time, the employee can help empty the whole product line which is a requirement for starting a new order. Nevertheless, this step is necessary to drastically increase the throughput in products and euros in improvement step three. Moreover, according to Goldratt, “a factory where everyone always works is highly inefficient” (M. E. Goldratt, 2012).

Table 14: Impact on indicators

Indicator	Change	Difference
Throughput (products)	Increases	Not measurable*
Production costs	Increases	2,2%
Product quality	Increases	51%

**Reason is covered in text above*

[12] *Appendix S: Indication of product quality increase*

5.5.1 EBITDA change

The throughput (euros) increase will not be included in the EBITDA mutation. The reason for this decision is that the throughput increase cannot be made measurable. As mentioned above, the production flow of the product line should be optimal which can be achieved with additional employees. So, the operating expenses increase, however, one component of the variable costs is "additional personnel" mentioned in the cost's analysis. Additional personnel costs are described as, "the additional personnel needed when the number of labels per sheet is less than 20". This component of the variable costs is gone after implementing improvement step two because the additional employee will be standard at the product line. So, the EBITDA and changes on the Profit and Loss statement are stated below.

Table 15: Impact on EBITDA and P&L of improvement step two

	P&L change	***Impact on EBITDA***
Operational expenses	+ € 74,000	- € 74,000
Variable costs additional employees	- € 29,972	+ € 29,972
Potential EBITDA impact improvement step two: Constant producing flow		**- € 44,028**

5.5.2 Conclusion

Improvement step two is made to create a constant production flow in product line one, two and three. It creates addition improvement opportunities, an improvement in throughput (products) and possible product quality increase. However, the throughput (products) increase is not measurable. But, according to theory and clear logic it should perform better. The product quality increase is measured, as described earlier, in amount of complaints. The product quality increases mainly because the employee does not have to divide its concentration to multiple tasks.

The throughput (products) increase is not included within the EBITDA calculation because it is not measurable, so this improvement step costs money. However, this step is necessary for the third and fourth improvement step.

5.6 Improvement step three: Automate cutting the width at P02

Because of the previous improvement steps, the cutting speed determines the actual output of the whole product line in 95% of the orders. The only exception are orders with one bundle in one pack. The dependency on the cutting speed enables Royal Sens to increase their throughput drastically. The suggestion is to automate the step “cutting the width” in production line two. Automating the step “cutting the width” improves the producing speed of the cutting step which increases the overall producing speed of the product line with the same amount due to the fact that the cutting speed determines the overall output. The step can be automated with the same machine used at production line three. However, the amount of orders produced at P02 is much higher than on P03. This has an impact on the overall capacity since the setup time per order of P02 increases with the additional automation step. Additionally, the setup time is dependent on the amount of different sized labels at one sheet. The in-depth computed formulas to calculate the total setup time can be found in the appendix[13]. Furthermore, Royal Sens has the policy that the product line must be empty after every order. The impact of this policy should be considered since it takes around 7 to 8 minutes to clear the product line. This value is determined with the help of one of the team leaders in the factory. This policy should be included while developing the capacity comparison. So, the current capacity of the cutting step of P02 is compared to the potential capacity that includes the automation step.

The total setup time, number of bundles produced, producing speed, and producing hours for the current situation and the new situation are stated below.

Table 16: Overview comparison current and automated situation

	Number of bundles produced	Setup time (hours)	Producing speed	Producing hours
Current	556,298	567	165 bundles per hour	4,284
New	556,298	887	305 bundles per hour	3,056

The setup time in the new situation is much higher than in the current situation (56.4%) however, the overall producing hours is less which means that the additional automation step increases the capacity at P02. The capacity increase can be used to produce additional orders and bundles which results in higher throughput in products. Nevertheless, Royal Sens finds it interesting that the setup time per order increases and the overall producing time decreases. So, I made a graphical overview with a capacity comparison from P02 that can be seen in the appendix[14]. The break-even point in terms of producing capacity is at 5940 orders. So, if the amount of orders stays below this level than the number of produced products of the new situation will always be higher.

[13] *Appendix O: Information regarding the setup time and capacity formulas*

[14] *Appendix Q: Capacity break-even point*

The production costs, revenue, and throughput (euros) are also investigated. The specifics can be seen in the appendix N[15]. An overview is given below.

Table 17: Overview of throughput increase improvement step three

	Currently	New
Revenue	€ 3,743,723	€ 5,247,151
Variable production costs	€ 864,708	€ 1,210,591
Throughput (euros)	**€ 2,879,016**	**€ 4,036,559**

Table 16 clearly shows that the new situation decreases the amount of producing hours with 1228 hours. Assuming that Department Sales is not a bottleneck in this case, and these hours are used to process additional orders than the revenue increases significantly. Logically, the variable costs also increase however much less than that the revenue increases which can be seen through the throughput (euros). So, automating "cutting the width" at P02 has the potential to increase the throughput (euros) with 40.2% equivalent to around 1.2 million euros.

Important to note is that a change needs to happen in the planning department while executing this improvement step. The automated step is only able to produce sheets with a maximum number of different labels at one sheet equal to two. So, all the other varieties must be produced at P01 from now on. This is possible since P01 was not fully occupied, moreover, preparation of Die-Cut labels is done at another product line (improvement step one) which freed up some capacity. So, after this improvement step P02 and P03 should be used for standard forms of sheets while P01 should be used for flexibility, thus to produce products without standard characteristics.

Table 18: Impact on indicators

Indicator	Change	Difference
Throughput (products)	Increases	40%
Production costs	Increases	29%
Product quality	Unchanged	-

So, the throughput (products) increase drastically which also results in a clear EBITDA increase. However, the production costs also increase. Obviously, the variable production costs increase furthermore the operating expenses increase due to the additional depreciation costs[16]. The details of the overall calculation can be seen in Appendix N.

5.6.1 Payback period

This improvement step requires Royal Sens to make an investment into a machine. The machine is an "autocutter" which will fully automate the step "cutting the width". The initial investment will be around 150,000 euros, this is determined with the help of the Manager Operations. As mentioned above, the throughput (euros) increases with 40%. The payback period is computed with the help of the following formula.

$$Payback\ Period = \frac{Initial\ investment}{Net\ Cash\ Flow\ per\ period}$$

Equation 2: Payback period (Irfanullah, 2019)

The net cash flow per period is based on the calculation made previously in the chapter. The throughput increase is around 1.2 million euros which is also the net cash flow per period because all other costs, such as fixed and overhead costs, are constant. Moreover, depreciation does not contribute

[15] *Appendix N: Calculation improvement step three*

[16] *Appendix N.5: Overview throughput (products) and variable costs*

to the net cash flow per period. So, the net cash flow per period is equivalent to 1,178,806 euros per year.

The initial investment is set on 150,000 euros, however, an investment is always more expensive so a buffer of 25% is used resulting in an investment of 187,500 euros.
With this reasoning, the calculated payback period is 0,159 years so around two months. With this said, the investment in an "autocutter" at P02 is profitable after 2 months. Moreover, the producing flexibility of Royal Sens is not damaged since all the product types can still be produced on P01.

5.6.2 EBITDA change

This improvement step results in around 1.2 million throughput (euros) per year which results in an EBITDA increase with the same amount because every other costs are constant or stay the same and the impact of the variable costs are already included within the throughput (euros) calculation. Previously in the payback calculation, depreciation is mentioned. The depreciation should not be included in the EBITDA calculation, this can also be concluded out of the name of the indicator. So, the following EBITA mutations can be done after implementing improvement step three.

Table 19: EBITDA and P&L impact of improvement step three

	P&L change	***Impact on EBITDA***
Potential throughput (euros)	+ € 1,157,543	+ € 1,157,543
Potential EBITDA impact improvement step three: Automate cutting the width at P02		+ **€** 1,157,543

5.6.3 Conclusion

Improvement step three has a huge impact on the throughput (products) and production costs. The variable costs and operating expenses increase; however, the improvement step can still generate a lot of money which is shown in the EBITDA calculation. Moreover, the investment is paid back in a reasonable amount of time. One clear change that must be done within the planning department is, P01 should only be used for flexibility so products with different characteristics whereas P02 and P03 should be used for standard work. This is possible in terms of capacity[17].

[17] *Appendix O: Information regarding the setup time and capacity formulas*

5.7 Improvement step four: Automate section two

The last automation step is focused on automating section two of the product lines. Section two of the product lines consist of "sorting the bundles" which is done manually. Previously, some conclusions about section two of the product lines were determined:

- Section two develops a bottleneck namely the control step
- Section two creates most of the client complaints

The bottleneck that is developed by section two of the product line is solved in improvement step two. However, this is done with adding additional employees to the product line which has a negative impact on the production costs. However, it enables Royal Sens to implement improvement step three that results in a significant throughput increase. The next step is focused on automating section two. This should result in less production costs and a much more reliable production process. The additional automation step is not beneficial for the throughput in euros or in products since the flow in the product line is already optimized in improvement step two. However, it has a positive impact on the production costs and product quality. The product quality is measured in amount of client complaints, as previously mentioned. This fact is also used to create an indication[18].

5.7.1 The sorting machine

Obviously, I have not enough knowledge to design a sorting machine. Moreover, it is also not possible to compute the value of the investment. Therefore, I decided to contact an organization that specializes in robotization and automation projects. This company would like to be anonymous, so the name of this company is not used. The organisation helped with designing the machine and valuing the investment. The in-depth specifications of the machine are stated in the appendix[19]. Moreover, the reason why only one machine supplier is asked is given in Appendix R. The following information is necessary to understand the payback period calculation.

Table 20: Information sorting machine

	Producing speed	Investment	Percentage of orders
Option one	9 bundles per minute	€ 150,000	99.42%
Option two	15 bundles per minute	€ 150,000	99.42%
Option three	9 bundles per minute	€ 155,000	99.67%

As can be seen within the table above, three options were investigated. The first one is the standard option that is perfectly designed for the current situation. The second option includes improvement opportunities in terms of producing speed. However, this option is only necessary when the producing speed of the cutting step is further improved. Nevertheless, it does not increase the initial investment. The machine in the third option is larger which means that the machine can handle more orders in terms of bundle measurements. To explain, some bundles are to large to handle for the soring machine however, as mentioned before, the Cut & Stack products with different characteristics should be produced on P01.

5.7.2 Payback period

The payback period is calculated with the help of the same formula introduced in the previous chapter. As can be seen in the graphical overview and described in the in-depth analysis of the product line, both product lines have the manual step "sorting the bundles" so if Royal Sens wants to automate both steps than they have to invest in two of these machines. The sorting machine can be implemented in both product lines. Again, a buffer of 25% is added to the initial investment. The determined initial investment for option one and two is equivalent to 375,000 euro. For option three the initial investment would be 387,500 euro.

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[18] *Appendix S: Indication of product quality increase*

[19] *Appendix R: Details sorting machine*

The throughput of the product lines is not going to increase with this automation step. However, the recurring production costs are decreasing because less employees are needed to produce the product. The net cash flow per period is equivalent to the salary of two splitters which is a total of 74,000 euros. So, the payback period is as follows:

Option one and two: *5.06 years*
Option three: *5.11 years*

I believe that investing in a sorting machine is not worth it due to the fact of the long payback period. However, this automation step also increases the product quality and reliability. So, Royal Sens must choose between product quality and the initial investment.

Table 21: Impact on indicators

Indicator	Result	Difference
Throughput (products)	Unchanged	-
Production costs	Decreases	2,3%
Product quality	Increases	97%

5.7.3 EBITDA change

As mentioned before, this improvement step does not contribute to the throughput since the flow of the product line is optimized in improvement step two. However, the improvement step has impact on the operating expenses. The EBITDA and Profit and Loss mutations are as follows:

Table 22: EBITDA and P&L impact of improvement step four

	P&L change	*Impact on EBITDA*
Operating expenses	- € 74,000	+ € 74,000
Potential EBITDA impact improvement step four: Automate cutting section two		+ **€ 74,000**

5.7.4 Conclusion

Improvement step four is focused on the reliability and improvement of the product quality. Moreover, it reduces the amount personnel that is needed within the Cut & Stack production process which results in a decrease of the operating expenses. However, the depreciation costs are also included within the production costs indicator which means that the impact on the overall costs is 2.3%. The payback time is also relatively long if we compare it to the payback time of the investment in improvement step three. So, Royal Sens must make a decision between payback time and investment or reliability and product quality.

5.8 Overall EBITDA impact

The second research question that is answered within this chapter was stated as follows.

- *What is the influence of the improvement plan on the earnings before interest, taxes, depreciation, and amortization?*

At the end of every improvement step the EBITDA impact is mentioned. However, it is more interesting to know the overall impact of the improvement plan, not only the individual steps. Important to note is that the improvement plan needs to be executed in the recommended order since the steps depend on each other. However, it is not necessary that every improvement step is executed to show improvement. To explain, Royal Sens can decide to only execute step one of the improvement plan. I certainly believe that separating the processes (step one) is necessary for Royal Sens since it creates clarity and the product lines will only be used to produce Cut & Stack products. Furthermore, step two is necessary for improvement step three and four which is earlier explained in the report. So, the table below shows the potential EBITDA increase for different implementation options. The last option explains the impact of every improvement step, so it shows the impact of the whole improvement plan.

The EBITDA realised in 2019 is around 4 million euros (*Financial report Royal Sens Q4 2019.xlsx*, 2019). This number is used as comparison with the potential EBITDA. As mentioned before, the plan is a step-by-step plan, which, if more steps are executed, should be implemented in the recommended order.

Table 23: EBITDA improvement

Improvement steps	Change	Impact on EBITDA (euros)	% Improvement
▪ *Separating the processes (1)*	+	€ 691,343	***17%***
▪ *Separating the processes (1)* ▪ *Constant producing flow (2)*	+	€ 647,315	***16%***
▪ *Separating the processes (1)* ▪ *Constant producing flow (2)* ▪ *Automate cutting the width at P02 (3)*	+	€ 1,804,858	***45%***
▪ *Separating the processes (1)* ▪ *Constant producing flow (2)* ▪ *Automate cutting the width at P02 (3)* ▪ *Automate section two (4)*	+	€ 1,878,858	***46%***

Thus, the overall EBITDA has the potential to increase with around 1.8 million euros if the whole improvement plan is executed and the assumptions stated at the beginning of the chapter hold. Improvement step two, creating a constant producing flow, has a negative impact on the overall performance of the EBITDA, however, the step is used as preparation for improvement step three which has a huge impact. Overall, the improvement plan could help to improve the performance of the Cut & Stack production process.

5.9 Answers to research questions

The sub-research questions answered in chapter five are stated as follows.

- *Which steps should Royal Sens take in improving the Cut & Stack production process?*
- *What is the influence of the improvement plan on the earnings before interest, taxes, depreciation, and amortization?*

At the end of every improvement step conclusions were made. The following conclusions are highly important for Royal Sens to keep in mind.

- Two assumptions were made while computing the improvement plan, "department Sales is not a bottleneck and the printing department does not become a bottleneck" *(see section 5.2).*

- Royal Sens can take multiple actions to improve the Cut & Stack production process: separating the processes, constant producing flow, automate cutting the width at P02 and automate section two. These steps should be followed in the recommended order *(see section 5.3).*

- Improvement step one, separating the processes, is focused on increasing the Cut & Stack production capacity through relocating preparing Die-Cut labels back to their original product line. This creates clarity and capacity for Cut & Stack products *(see section 5.4).*

- Improvement step two, constant producing flow, is not beneficial for the overall EBITDA. However, it enables Royal Sens to further improve the product lines because this step eliminates a bottleneck. Improvement step three and four cannot be executed without this step *(see section 5.5).*

- After improvement step two, the overall output will be dependent on the cutting step which is optimal *(see section 5.5).*

- Improvement step three has the largest impact on the overall EBITDA. However, after this step product line two can only be used to produce standard Cut & Stack products. P01 should be used as flexible product line *(see section 5.6).*

- Improvement step three does need an investment however this is payed back in a short time specifically two months *(see section 5.6.1).*

- Improvement step four requires a huge investment with a long payback period. Royal Sens must decide between payback time and reliability and product quality *(see section 5.7.4)*.

- Improvement step one and three have the largest impact on the EBITDA and the performance of the Cut & Stack production lines *(see section 5.8).*

6. Conclusion

This chapter briefly explains the conclusions and recommendations for Royal Sens. The impact of the improvement plan on the indicators is analysed in this chapter.

The overall research question of the thesis is stated in the problem identification and is described as follows.

How should Royal Sens improve the performance of the Cut & Stack production process?

The following indicators are described and analysed to measure the overall research question.

- Throughput (products)
- Production costs
- Product quality
- Earning before Interest, Taxes, Depreciation and Amortization

The Cut & Stack production process is important for Royal Sens since it generates 25% of the overall revenue. As mentioned before, the capacity of the printing department is going to increase due to the newly acquired printer. This results in higher output and, logically, more input for the post-printing department. Therefore, the overall improvement plan is focused on capacity increase. Moreover, an in-depth analysis of the production process is made which resulted in some interesting conclusion that are stated at the end of chapter four and were used as input for the improvement plan. Furthermore, Royal Sens wishes to automate one of their steps within the Cut & Stack production process, so automation steps are also included. Answering the research question, "How should Royal Sens improve the performance of the Cut & Stack production process?" is done with a four-step improvement plan. The improvement plan is based on the conclusion made from the analysis of the current situation. The improvement plan consists of the following actions.

Step 1: Separating the processes
Step 2: Constant producing flow
Step 3: Automate cutting the width at P02
Step 4: Automating section two

The first step creates clarity and increases the capacity for Cut & Stack products. Moreover, it enables Royal Sens to perform further analyses on the individual production processes. So, after this step, P01, P02 and P03 are fully used to produce Cut & Stack products which what they were designed for.

The second step is highly important for Royal Sens. As concluded chapter four, Royal Sens develops its own bottleneck namely section three specifically, the control step. Furthermore, it is better that the overall output is dependent on the cutting step of the product line which results in a constant producing flow. Important to note is that if improvement step two is executed than the cutting step must always be occupied! According to Goldratt, an hour lost on the step that determines the overall output is an hour lost for the whole factory (M. E. Goldratt, 2012). Step two does not positively contribute to the EBITDA however the step is necessary to further improvements to the process otherwise every additional improvement does not have value since there is still a bottleneck in the system.

Step three is focused on increasing the throughput for the standard Cut & Stack products. One huge investment is necessary to execute improvement step three however this investment is payed back within 2 months which was shown in section 5.6.1. This step also creates clarity in the factory and production planning because P02 can now only be used for standard Cut & Stack products. So, the Cut & Stack production process is now divided into two parts. P02 and P03 that produce standard Cut

& Stack products and P01 that should only produce Cut & Stack products with different characteristics[20].

Improvement step four is focused on fully automating section two of the product line. The production costs decreases however, again, a huge investment has to be made by Royal Sens. This investment is payed back in around 5 years which is rather long in comparison to the investment in improvement step three. Nevertheless, a reason to implement this improvement step is to increase the product quality and reliability of the product line. This decision must be made by the management team of Royal Sens.

The impact of every individual improvement step on the indicators is mentioned in the previous chapter. As mentioned before, Royal Sens can decide to implement every improvement step but also only improvement step one. Important to note is that the improvement steps should be executed in the recommended order. So, the table below shows the impact of every improvement step on the previously determined indicators. The first option shows the improvement of only implementing the step "separating the processes", the second option shows the results of implementing improvement step one and two, and so on. So, the last step shows the results of the whole improvement plan. The steps clearly show improvement. Important to note is that the product quality increase is almost 100%[21]. The reason for this is that improvement step four automates section two where the client complaints are originated.

Table 24: Overview of impact form the improvement plan

Improvement steps	*Throughput (products)*	*Production costs*	*Product quality*	*EBITDA*
▪ *Separating the processes (1)*	+ 25%	+24%	-	**17%**
▪ *Separating the processes (1)* ▪ *Constant producing flow (2)*	+25%	+27%	+51%	**16%**
▪ *Separating the processes (1)* ▪ *Constant producing flow (2)* ▪ *Automate cutting the width at P02 (3)*	+75%	+63%	+51%	**45%**
▪ *Separating the processes (1)* ▪ *Constant producing flow (2)* ▪ *Automate cutting the width at P02 (3)* ▪ *Automate section two (4)*	+75%	+60%	+99%	**46%**

As can be seen in the table above, the improvement plan increases the performance of the Cut & Stack production process. The throughput (products), production costs and product quality are specific for the Cut & Stack production process whereas the EBITDA difference is calculated for the whole organisation. The performance improvement of the whole improvement plan is high however some facts need to be considered.

- The assumptions made at the beginning of chapter six still need to hold. The following assumptions were made: "sales is not a bottleneck" and "the printing department is not a bottleneck".
- It is a four-step improvement plan which creates a compound effect that has a significant impact on the results.

The values reflect a calculated theoretical optimal situation. It is highly possible that the percentages are not met in real world. However, they clearly indicate that the improvement steps are the right course of action for improving the Cut & Stack production process.

[20] *Appendix O.2: Different product characteristics distribution*
[21] *Appendix S: Indication of product quality increase*

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Appendices

Appendix A: Graphical overview wet-glue paper labels

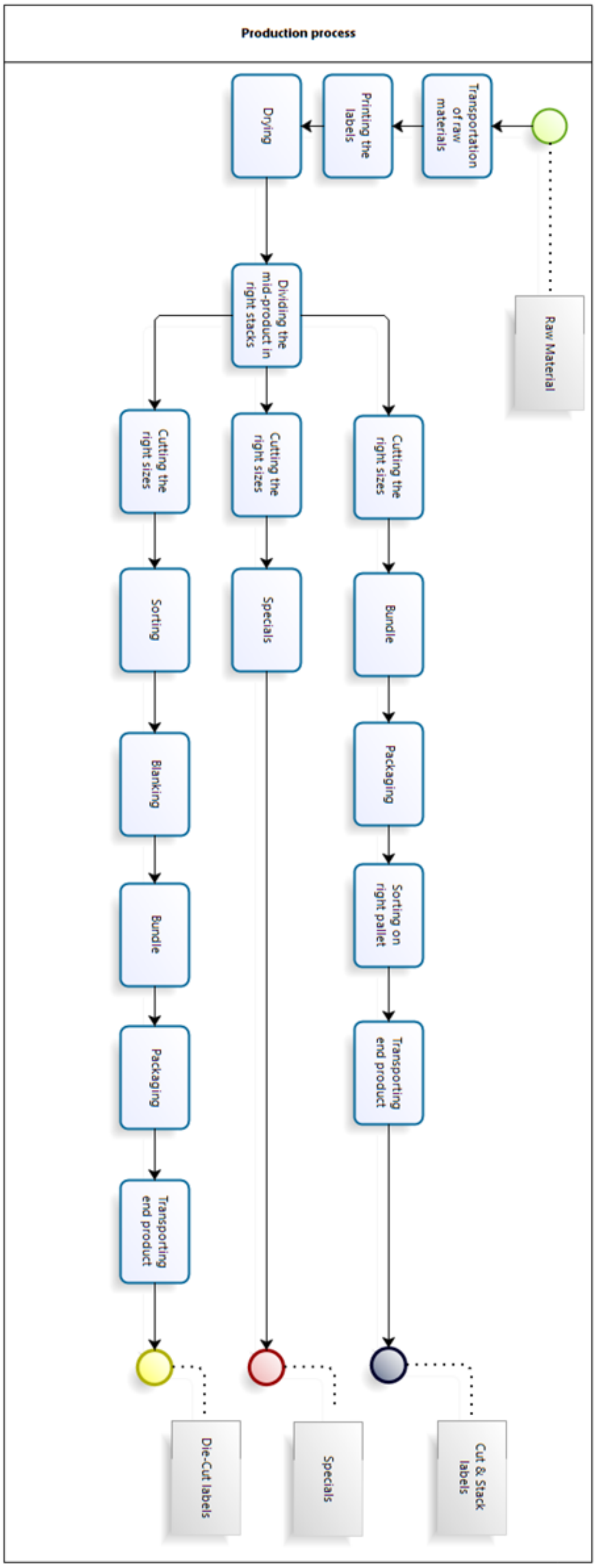

Figure 10: Graphical overview wet-glue paper labels

Appendix B: Label examples

B.1 Die-cut label

Figure 11: Die-cut label

B.2 Specials

Figure 12: Specials

B.3 Cut & Stack label

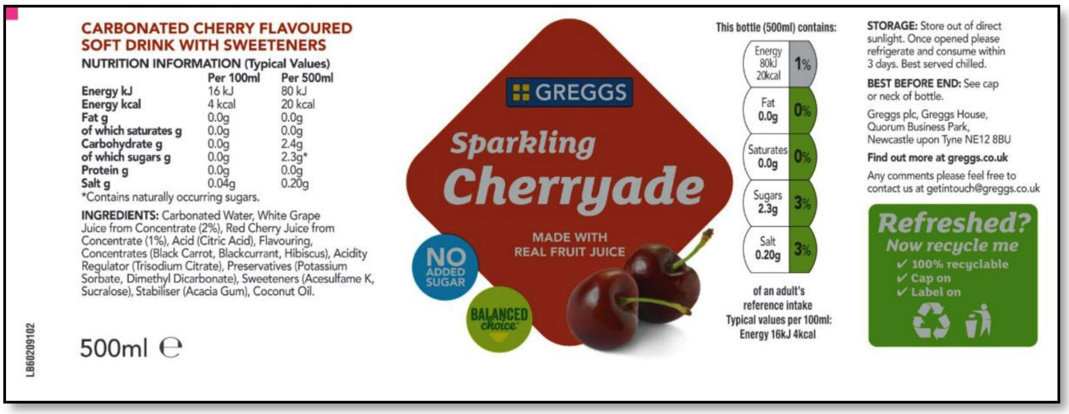

Figure 13: Cut & Stack label

Appendix C: Mirrors at the product line

Figure 14: Mirrors at the product line

Appendix D: Graphical overview of the Cut & Stack production process, sections included

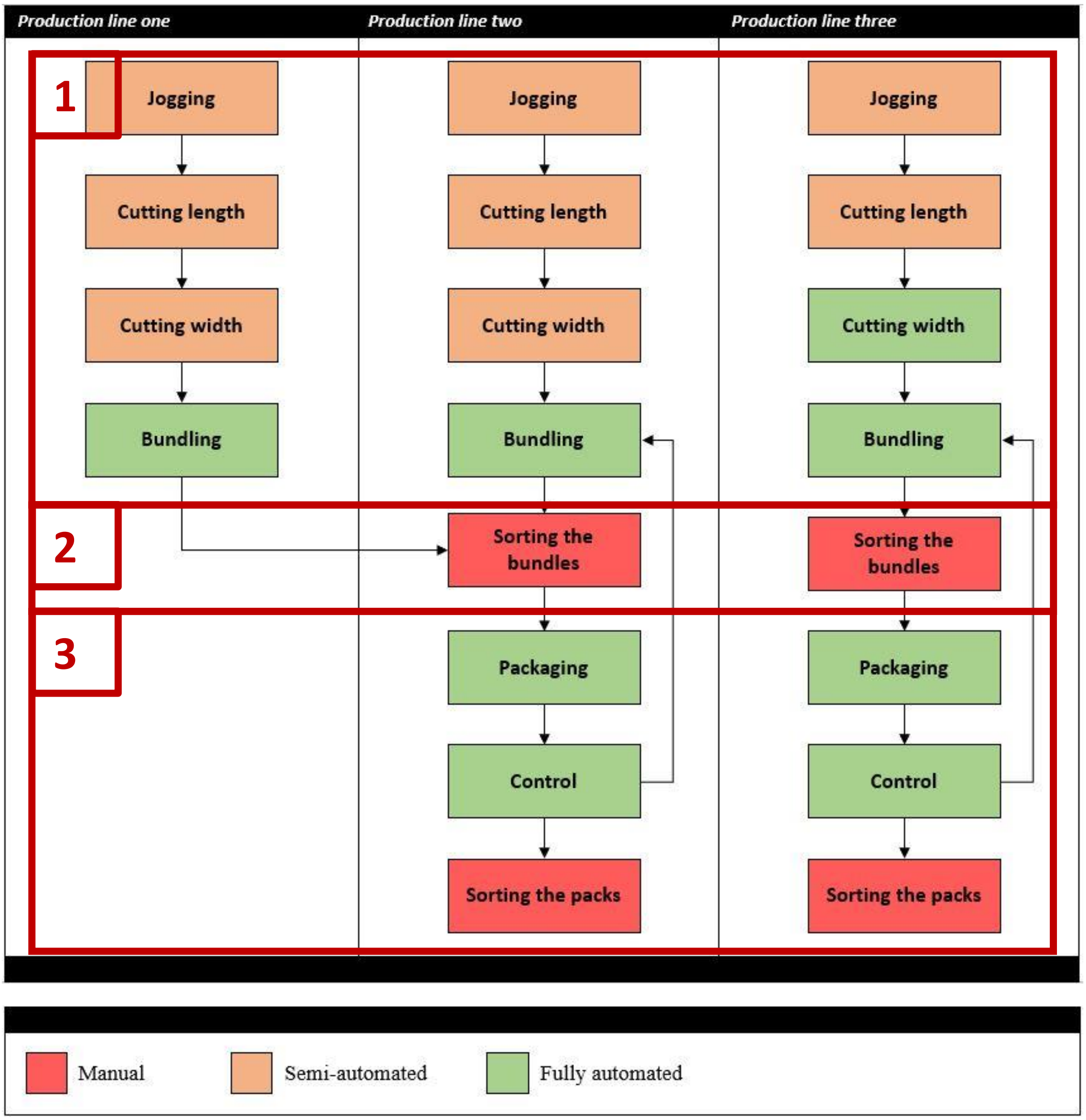

Figure 15: Graphical overview of the production process, sections included

Appendix E: Proof cutting speed

The Pearson correlation coefficient (PCC) is used to proof the non-existence of the relationship between variables. Royal Sens believes that the cutting speed and the of labels per sheet have a relationship with the producing speed of the cutting machine. So, two cases are investigated namely:

Case 1: *The producing speed of the cutting machines decreases when the amount of cutting lines increases.*

Case 2: *The producing speed of the cutting machines decreases when the number of labels per sheet increases.*

The PCC can be interpreted in three ways namely negative correlation, positive correlation, and no correlation between two variables. The interpretation is based on values. The table below sketches the values that represent the different outcomes (Yeager, 2020).

Table 25: Outcomes of correlation test

Outcome	Value
Negative correlation	-1
No correlation	0
Positive correlation	1

The analyses are made with the help of Excel and its data analysis tool. The analyses are made over a data set which combines the data out 2017, 2018 and 2019. The following tables were computed by Excel.

Case 1:

	Cutting lines	*Speed (bundles per min)*
Cutting lines	1	
Speed (bundles per min)	0.055201622	1

Figure 16: Case one values

The computed PCC value is 0.055 which is close to zero. This means that there is no correlation so no relationship between the amount of cutting lines and the producing speed of the cutting machines.

Case 2:

	Speed (bundles per min)	*Amount of labels per sheet*
Speed (bundles per min)	1	
Amount of labels per sheet	0.065805903	1

Figure 17: Case two values

The computed PCC value is 0.067 which means that the number of labels per sheet does not influence the producing speed.

So, both cases are not true which means that these assumptions made by Royal Sens are not correct.

Appendix F: Total amount of produced packs per year

	2017	2018	2019
Produced packs	763,395	832,389	561,258

Appendix G: Bundling speed calculation

The average producing speed after taking measurements is determined on 8 seconds for one bundle. The speed measured in bundles per hour is stated in the table below.

Table 26: Actual bundling speed without breakdowns

Bundling		
	P01	480
	P02	480
	P03	540

The breakdown percentage is significant for this machine since the bundle material is limited and should be replaced ones in while. The determined breakdown averages are mentioned in the table below.

Table 27: Average breakdown percentage of bundling machine

	Average BD% over all years
P01	4.21%
P02	3.18%
P03	3.62%

This means that the actual processing speed of the bundle machine is lower. The actual producing speed of the bundle step is determined and stated below. As can be seen in Table 26, the average breakdown on P01 and P02 is different however it is the same machine therefore the highest breakdown percentage is used.

Table 28: Bundles per hour per product line

Bundling		
	P01	460
	P02	460
	P03	520

Appendix H: Breakdown percentages

Table 29: Breakdown percentages

	Average BD% over all years (cutting)
P01	0.02%
P02	0.02%
P03	0.48%
	Average BD% over all years (bundling)
P01	4.21%
P02	3.18%
P03	3.62%
	Average BD% over all years (package)
P01	0.36%
P02	0.42%
P03	0.26%
	Average BD% over all years (control)
P01	0.12%
P02	0.33%
P03	0.44%

Appendix I: Variable costs calculations

I.1 Raw materials

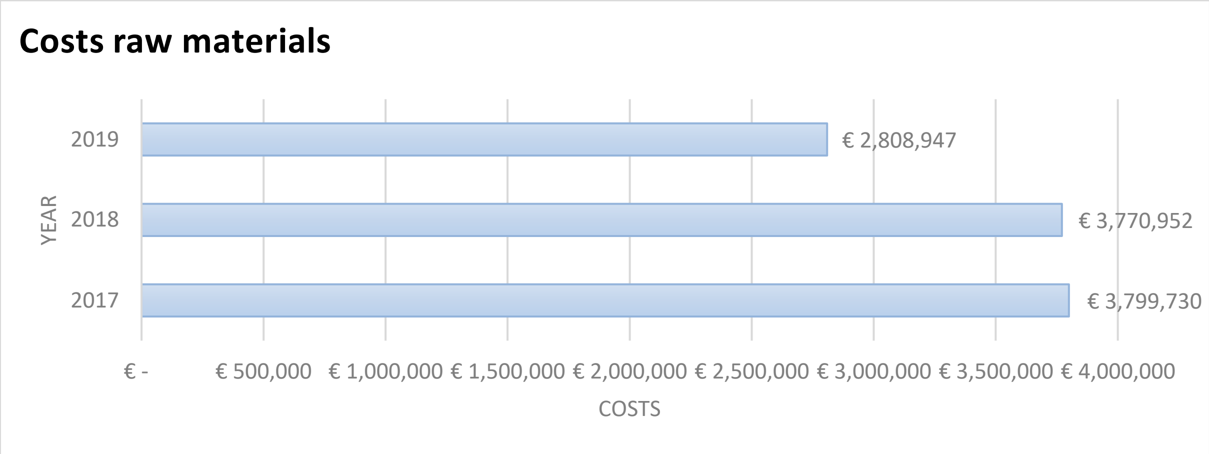

Figure 18: Overview raw material costs

I.2 Cost for energy consumption

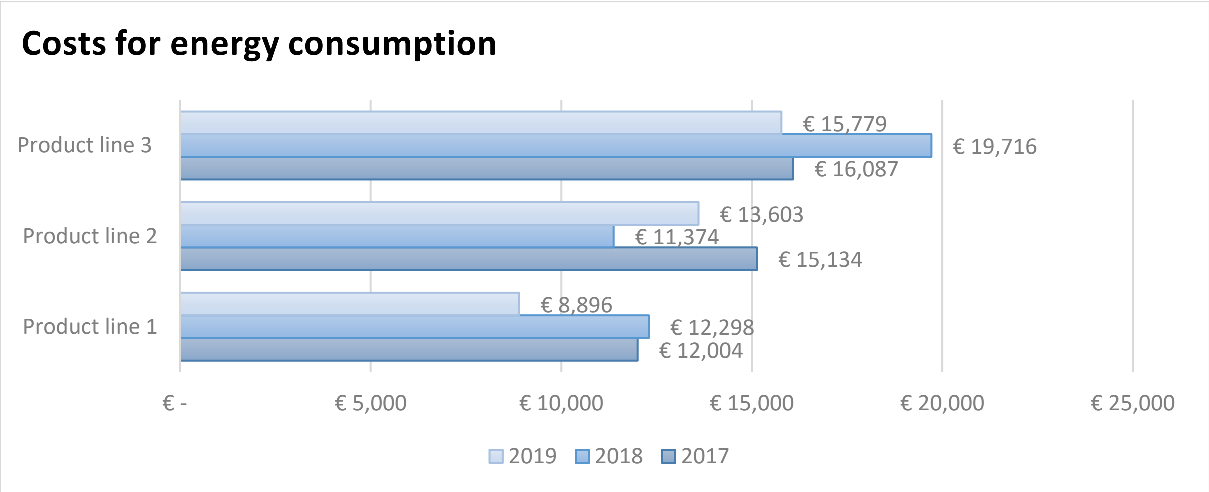

Figure 19: Overview energy consumption costs

I.3 Maintenance costs

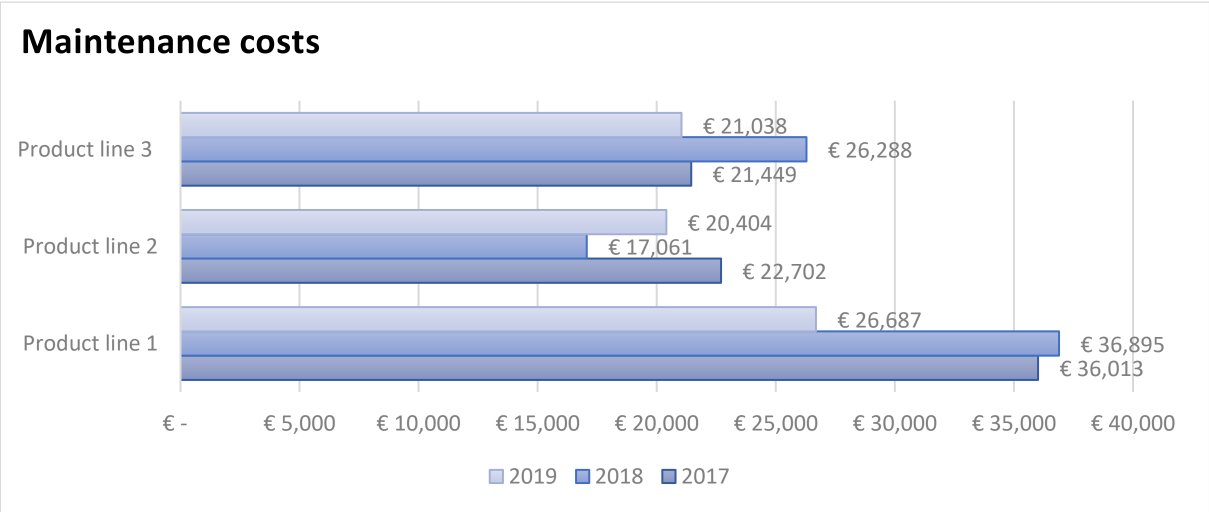

Figure 20: Maintenance costs

I.4 Additional personnel

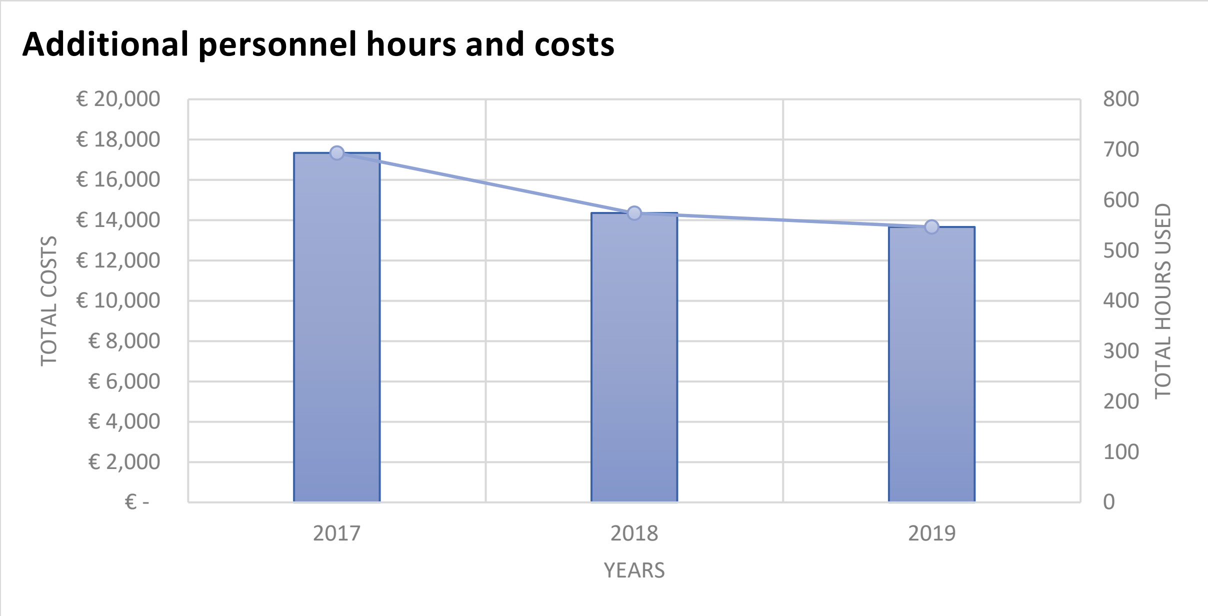

Figure 21: Additional personnel hours and costs

Appendix J: Control step as bottleneck

Figure 22: Visualisation of intermediate stock at control step

Appendix K: Relationship between intermediate stock and number of minutes not at the station

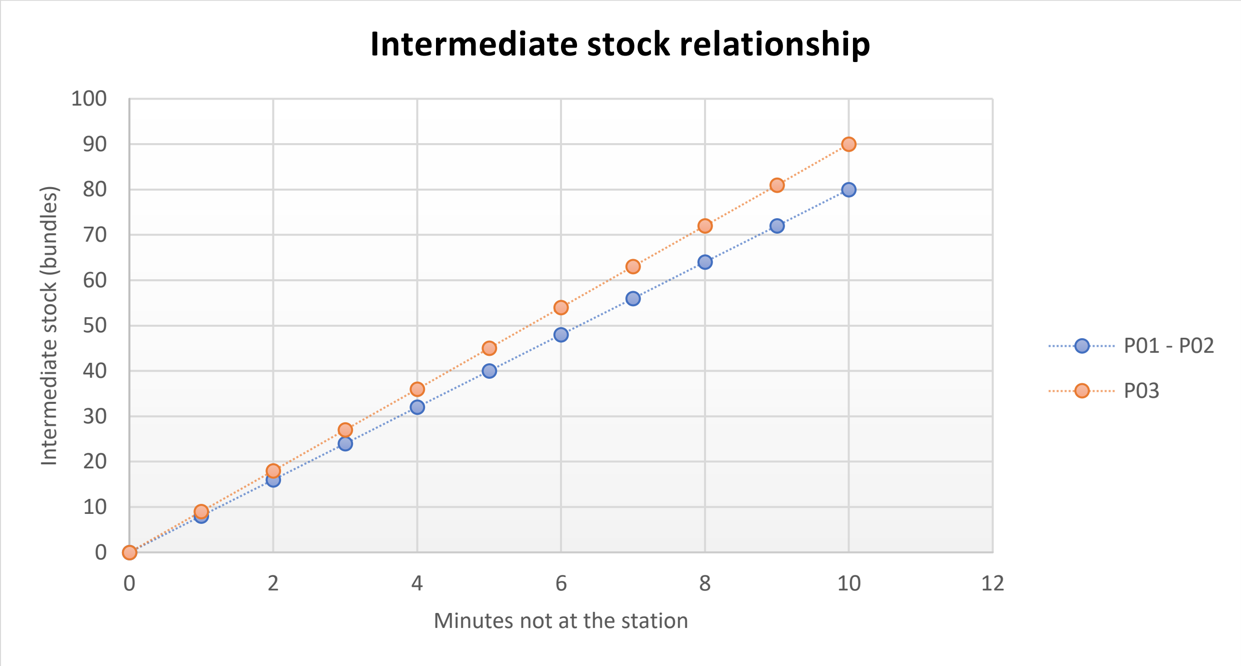

Figure 23: Relationship between intermediate stock and minutes not at the station

Figure 24: Intermediate stock at section two of the product line

Appendix L: Frequency bundles per pack

Table 30: Frequency bundles in one pack

Bin	Frequency	Cumulative %
1	540	4.87%
2	1502	18.43%
3	2682	42.64%
4	2362	63.95%
5	2963	90.69%
6	640	96.47%
7	78	97.18%
More	313	100.00%

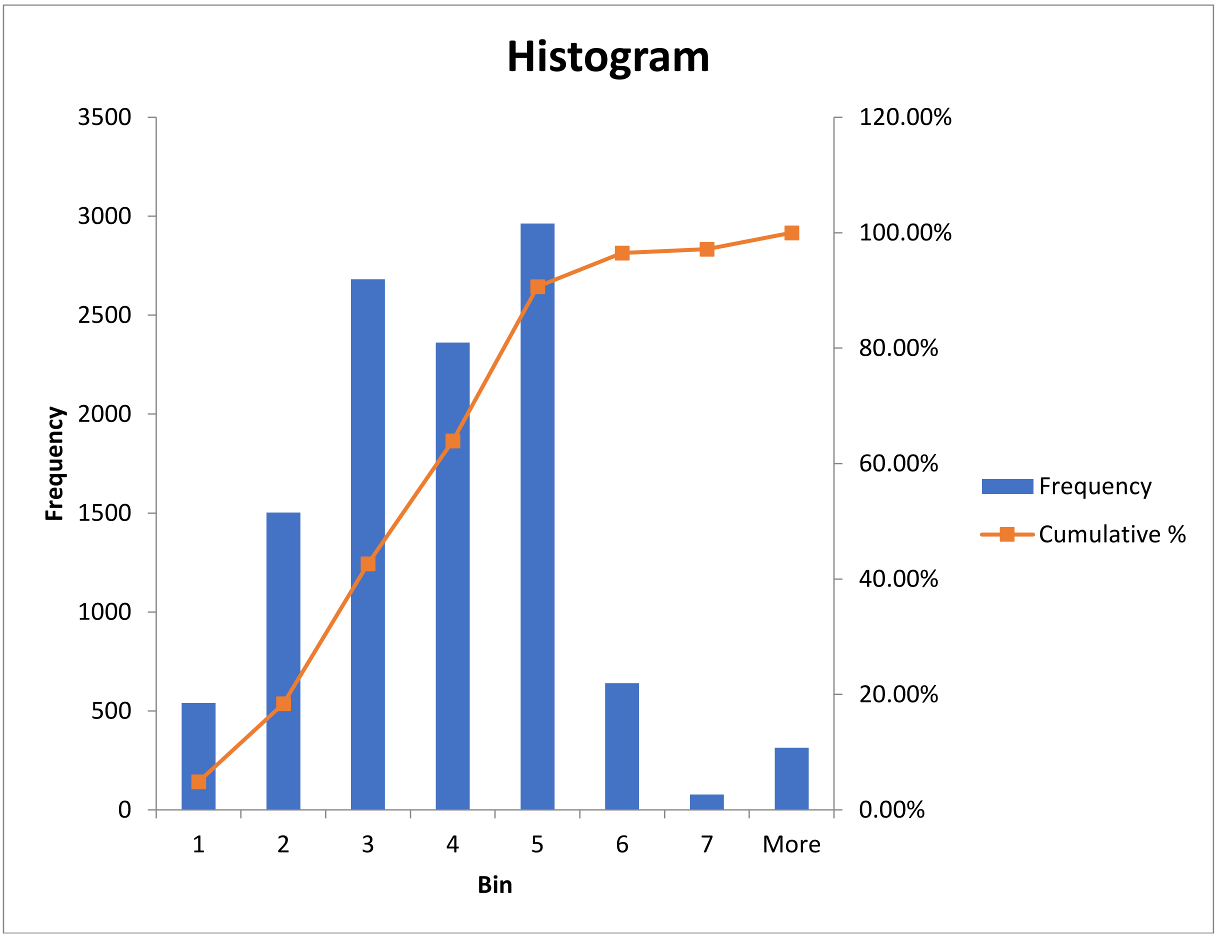

Figure 25: Histogram number of bundles in one pack (three years)

Appendix M: Calculation improvement step one

The breakdown time is not considered because the breakdown percentages are low which is stated in the appendix[22]. Furthermore, the additional throughput of P03 is not calculated because the values are neglectable.

M.1: Potential revenue calculation P01

Table 31: Potential revenue P01

Total amount of hours used P01	**3,166**
Total amount of hours used C&S	1,580
Total amount of hours used D-C	1,586
Total amount of orders	785
Total amount of bundles	149,916
Total revenue	€ 1,000,735
Average per order	€ 1,275
Average per bundle	€ 7
Average per hour	€ 633
Additional potential revenue	€ 1,004,536

M.2: Variable costs increase calculation P01

Table 32: Variable costs P01

	Per hour	Per order	Total
Energy costs	€ 2.72	0	€ 4,314
Maintenance costs	€ 2.72	0	€ 4,314
Additional employees	0	€ 17	€ 27,380
Raw materials	0	€ 294	€ 462,917
Total variable costs	€ 5.44	€ 312	€ 498,924

M.3: Potential throughput (euros) increase P01

Table 33: Potential throughput (euros)

Additional potential throughput (euros)	**€ 505,611**

[22] *Appendix H: Breakdown percentages*

M.4: Potential additional throughput (euros) calculation P02

Table 34: Throughput P02

Additional revenue	€ 275,625
Energy costs	€ 612
Maintenance costs	€ 612
Additional employees	€ 2,365
Raw materials	€ 41,303
Additional potential throughput	€ 230,732

M.5: Overview of throughput (products) and production costs

Table 35: Overview of throughput (products) and production costs

			Production costs difference
	P01	*P02*	*Total*
Current variable costs C&S	€ 253,280	€ 912,617	€ 1,165,897
New variable costs C&S	€ 507,521	€ 957,553	€ 1,465,074
Operating expenses current			€ 275,000
Operating expenses new			€ 320,000
Total expenses currently			€ 1,440,897
Total expenses new situation			€ 1,785,074
% Difference	100%	5%	24%
			Throughput (products) difference
	P01	*P02*	*Total*
Current throughput (bundles)	149,916	558,202	708,118
New throughput (bundles)	300,401	585,661	886,062
% Difference	100%	5%	25%

Appendix N: Calculation improvement step three

The breakdown time is not considered because the breakdown percentages are low which is stated in the appendix[23]. The impact of the total amount of different labels at one sheet (i) is included within the calculation.

N.1 Current situation 2019

Table 36: Current situation 2019

Production speed	**165**	***Bundles per hour***
Time needed to empty the line	0.125	*After every order*
	Hours	**Setup time (hours)**
Total orders with i = 1	2488	498
Total orders with i = 2	195	39
Total orders with i = 3	57	21
Total orders with i = 4	21	9
Summation		567
Total stand still due to emptying (hours)		345
Time produced (hours)		3372
Total production time necessary in 2019		4284
Revenue per hour		€ 874
Bundles per hour (inclusive empty / setup)		130

N.2 Automated situation

Table 37: Proposed situation

Production speed	**305**	***Bundles per hour***
Time needed to empty the line	0.125	*After every order*
	Hours	**Setup time**
Total orders with i = 1	2635	870
Total orders with i = 2	48	18
Total orders with i = 3	0	0
Total orders with i = 4	0	0
Summation		887
Total stand still due to emptying		345
Time produced (hours)		1824
Total production time necessary in 2019		3056
Revenue per hour		€ 1,225
Bundles per hour (inclusive empty / setup)		182

As can be seen in the tables, the automated situation is way quicker than the current situation. It decreases the amount of producing time with 1228 hours which also results in a revenue per hour increase. As mentioned before, the term throughput is used in two ways namely in product volume and

[23] *Appendix H: Breakdown percentages*

in terms of euros. The throughput in euros is investigated below. The conclusion out of this information is made in the actual text of the thesis.

N.3 Current situation (euros)

Table 38: Current situation throughput (euros)

Energy costs	**€**	**11,652**
Maintenance costs	€	11,652
Raw material	€	841,404
Total revenue	€	3,743,723
Throughput (euros)	€	2,879,016

N.4 New situation where the computed producing hours are used (euros)

Table 39: Throughput proposed situation

Situation with same hours produced		
Producing hours		4284
Bundles per hour (inclusive empty / setup)		182
Number of produced bundles		779700
Average revenue per bundle		€ 6.73
Total revenue		€ 5,247,151
Energy costs		€ 17,478
Maintenance costs		€ 17,478
Raw material		€ 1,175,635
Throughput (euros)		€ 4,036,560

N.5 Overview throughput (products) and production costs

Table 40: Overview throughput (products) and production costs

	Throughput (products)	
Producing hours	4,284	4,284
Producing speed (bundles per hour)	130	182
Produced bundles	556,920	779,688
% Difference		40%

Production costs	
	Total
Variable production costs current	€ 864,708
Variable production costs new	€ 1,210,591
Current operating expenses	€ 394,000
Deprecation	€ 17,500
New operating expenses	€ 411,500
Current production costs	€ 1,258,708
New production costs	€ 1,622,091
% Difference	29%

Appendix O: Information regarding the setup time and capacity formulas

O.1: Information setup time and capacity formulas

The following general formulas for P02 is computed to compare the capacity of the product line. Firstly, the formula for the total setup time is computed. As mentioned before, the setup time is dependent on the amount of different sized labels at one sheet. The following values were introduced:

Table 41: Frequency of different sized labels at one sheet at P02

	P02
One size (i = 1)	64%
Two sizes (i = 2)	25%
Three sizes (i = 3)	8%
Four sizes (i = 4)	2%

Table 42: Setup time per the amount of different sized labels at one sheet at P02 (hours)

	P02
One size (i = 1)	0.2
Two sizes (i = 2)	0.2
Three sizes (i = 3)	0.37
Four sizes (i = 4)	0.45

So, the total setup time is dependent on two main factors namely the different setup times and the frequency of producing different sized labels at one sheet. The formula computed for the total setup time at P02 is as follows:

$$Total\ setup\ time = A \sum_{i=1}^{4} S(i) * Q(i)$$

Equation 3: Total setup time

$Where$

$A\ =\ Total\ amount\ of\ orders$
$i = the\ amount\ of\ different\ sized\ labels\ at\ one\ sheet$
$S(i) = setup\ time\ dependent\ on\ i$
$Q(i) = frequency\ of\ amount\ of\ different\ sized\ labels\ at\ one\ sheet\ i$

The next step is to compute a formula that represents the capacity of the cutting step at P02.

$$y(A) = v\ (\ x - qA - Total\ setup\ time\ )$$

Equation 4: Capacity dependent on A

$Where$

$y\ (A) =\ The\ capcity\ of\ section\ one\ dependent\ on\ A$
$v\ =\ Average\ producing\ speed\ of\ cutting\ step\ (bundles\ per\ hour)$
$x\ =\ Amount\ of\ producing\ hours$
$q\ =\ Time\ necessary\ to\ make\ the\ product\ line\ empty\ per\ order\ (hours)$
$A\ =\ Total\ amount\ of\ orders$

O.2 Different product characteristics distribution

Table 43: Frequency of different sized labels at one sheet in percentage of orders

	P01	P02	P03
One size (CS1)	66%	64%	98%
Two sizes (CS2)	25%	25%	2%
Three sizes (CS3)	7%	8%	0%
Four sizes (CS4)	2%	2%	0%

Appendix P: Formula cycle time

(Presentationeze, 2013).

$$Cycle\ time\ = \frac{1}{Throughput\ rate}$$

Equation 5: Cycle time

Where the throughput rate is defined as:

$$Throughput\ rate\ = \frac{Units\ produced}{Time}$$

Equation 6: Throughput rate

Appendix Q: Capacity break-even point

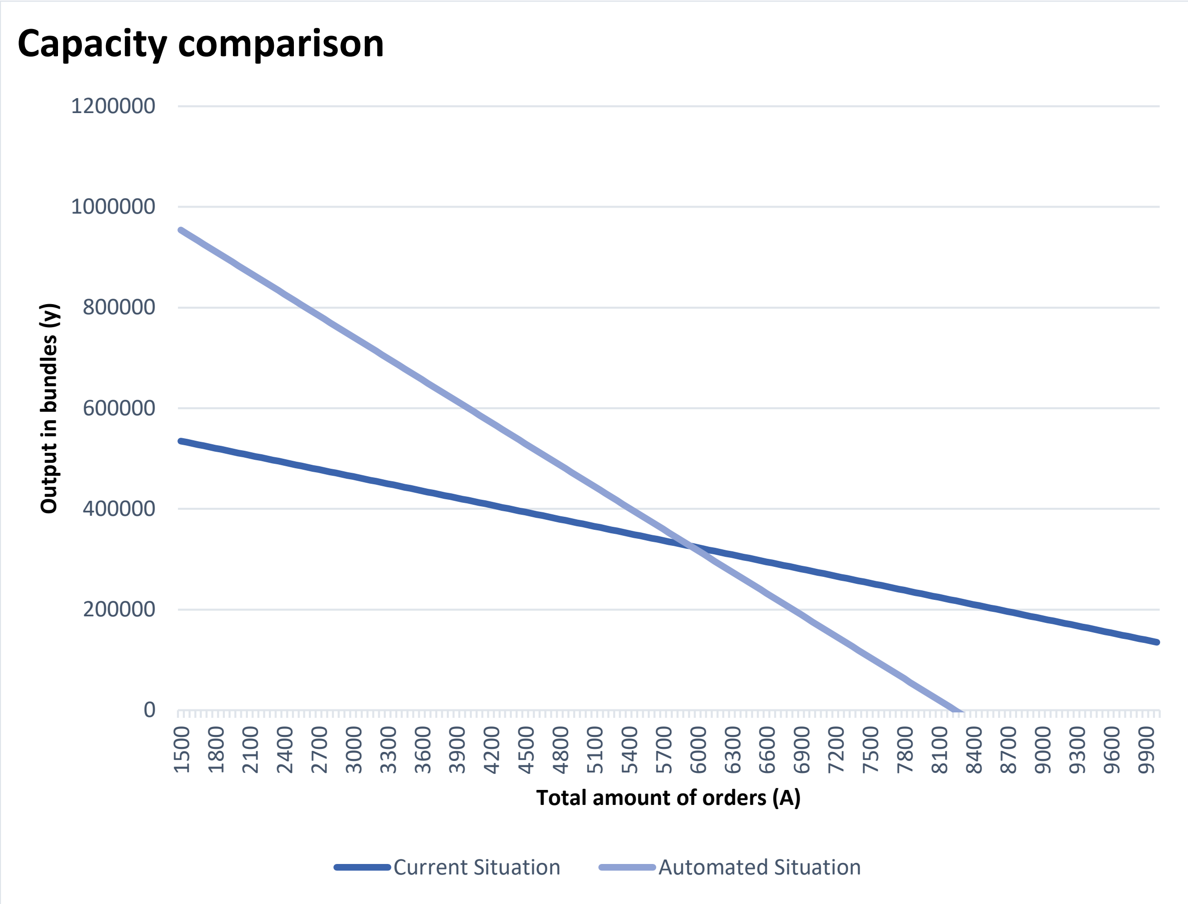

Figure 26: Break-even point capacity new and current situation

Appendix R: Details sorting machine

As mentioned before, the bundling step has a constant producing speed of eight bundles per minute at P02 and nine bundles per minute at P03. This is also the starting position for the sorting machine. So, the input for the sorting machine is set at eight and nine bundles per minute. I asked the organisation to evaluate three options.

Option one

Bundles per hour:	*540 bundles*
Bundles per minute:	*9 bundles*
Total amount of sorting spots:	*8 spots*
Width of the sorting spots:	*35 cm*
Length of the sorting spots:	*40 cm*

This option has more capacity than the output of the bundling machine at P02. However, it is necessary that the sorting machine can handle 9 bundles per minute at P03. The amount of sorting spots is derived from a rule that Royal Sens uses in the printing department. The maximum number of different labels at one sheet is eight which means that there will be never a situation with more than eight different bundles. The width and length are based on the maximum width and length of the produced bundles in 2019. When option one is implemented into the system around 99.42% of all the bundles can be produced that were produced in 2019.

Option two

Bundles per hour:	*900 bundles*
Bundles per minute:	*15 bundles*
Total amount of sorting spots:	*8 spots*
Width of the sorting spots:	*35 cm*
Length of the sorting spots:	*40 cm*

The second option is different in terms of bundles per minute. This option is created with growth opportunities in mind. As explained the cutting speed of the production process dependent the production speed of the whole production line because of the previous improvement steps. This could be the reason to further develop the cutting step. So, option two enables further optimization opportunities. The same percentage of bundles could have been produced as in option one.

Option three

Bundles per hour:	*540 bundles*
Bundles per minute:	*9 bundles*
Total amount of sorting spots:	*8 spots*
Width of the sorting spots:	*40 cm*
Length of the sorting spots:	*40 cm*

The third option is different in the width of the sorting spots. With this option, 99.67% of the bundles produced in 2019 could have been produced which is higher than the previous option.

This is the only machine-supplier that is asked to compute a machine and to calculate the investment. This is done because of some reasons, there was not enough time to contact more machine suppliers, the machine supplier that is asked to compute the investment has already knowledge about the production process. So, this enabled him to quickly compute a machine and investment calculation. Moreover, this thesis is focused on problem solving not finding the right supplier. Overall, it has to give an impression that can be used to make a decision.

Appendix S: Indication of product quality increase

S.1 Improvement step two

The product quality is measured in the amount of complaints that are divided into three main complaints namely mix label, package, and wrong sticker. Section two of the product line is operated by one employee which must perform multiple tasks.

- Sorting the bundles
- Sorting the packages
- Controlling the label

With improvement step two the employee at section two of the product line only has two tasks. Sorting the packs is eliminated which results in much more concentration while sorting the bundles. The complaint mix label and package are originated at this section of the product line. So, because the employee has 33% more concentration these amount of complaints will reduce with 33%. Furthermore, the additional employee that is hired is fully responsible for the task soring the package which means that the mistake rate should be zero. However, it still performed by humans, so the improvement is set at 95%.

Table 44: Current amount of complaints improvement step two

	Current amount of complaints
Mix label	10
Package	7
Wrong sticker	7

Table 45: Possible amount of complaints after improvement step two

	Possible amount of complaints
Mix label	6.7
Package	4.7
Wrong sticker	0.35

So, the amount of complaints decreases with around 51% which also means that the product quality increases with 51%.

S.2 Improvement step four

The amount of complaints after improvement step two are as follows.

Table 46: Possible amount of complaints after improvement step two

	Possible amount of complaints
Mix label	6.7
Package	4.7
Wrong sticker	0.35

The automation step should decrease the number of mixed labels to the norm, namely zero. The same goes for the package complaint. The wrong sticker complaint will still be an issue because this step is performed by hand within the Cut & Stack production process.

Table 47: Possible amount of complaints after improvement step two and four

	Possible amount of complaints
Mix label	0
Package	0
Wrong sticker	0.35

So, the amount of complaints decreases with around 97% which also means that the product quality increases with 97%.

S.3 Overall

Table 48: Current amount of complaints

	Current amount of complaints
Mix label	10
Package	7
Wrong sticker	7

Table 49: Possible amount of complaints after improvement step two and four

	Possible amount of complaints
Mix label	0
Package	0
Wrong sticker	0.35

Overall, the improvement of the product quality is almost 99%. Note, this is only an indication of the situation since the actual data is not available.

Appendix T: Capacity and processing speeds per station

T.1 Section one

T.1.1 Jogging

Starting with the process, Jogging. As previously mentioned, jogging is the process of dividing the sheets of paper into similar stacks. Royal Sens understands that this first step should not be bottleneck which means that Royal Sens decided that this should always be executed. The jogging process has similar inputs and outputs, sheets of paper.

***Input**:* *Sheets of paper*
***Output**:* *Sheets of paper divided into stacks of 1000 sheets*

The actual producing speed over the last three years are not available due to the fact it is not measured and saved by Royal Sens. However, Royal Sens developed a theoretical processing speed so the processing speed that should be achieved. This speed is pinned on 12.000 sheets of paper per hour which is equivalent to 12 stacks per hour.

T.1.2 Cutting process

The second step within the production process is the cutting process. There are two different cutting processes namely the process on P01 and P02 with in contrast the steps performed on P03. P03 has additional automated step, cutting the width. So, the producing speed on P01 and P02 is different and probably slower than the production speed measured at P03. Nevertheless, the input and output of this step is the same for all product lines.

***Input**:* *Sheets of paper divided into stacks of 1000 sheets*
***Output**:* *Bundles*

The producing speed will be measured in two variables namely in sheets of paper per hour and bundles per hour. The reason for these measurements is that the steps within the producing process should be compared with the same indicator.

According to Royal Sens the cutting speed is dependent on several factors including the number of labels per sheet. Because, the number of labels per sheet determines the amount of cutting lines the cutter must make. However, clear correlation analysis shows that this is not the case which means that this relationship is not considered while computing the cutting speeds. The calculation for this conclusion can be seen in the appendix[24]. The average cutting speeds per product line per year are computed and stated in the tables below.

[24] *Appendix E: Proof cutting speed*

Table 50: Sheets per hour per product line per year

	2017	2018	2019
P01	5640	5703	4232
P02	5173	5061	4824
P03	11442	9638	10332

Table 51: Bundles per hour per product line per year

	2017	2018	2019
P01	186	183	138
P02	153	155	165
P03	318	263	305

As mentioned before, the product lines are used to prepare Die-Cut labels however the calculated processing speeds only take the production hours specifically used for Cut & Stack labels into account. The setup time is excluded in the producing speed determination. As can be seen in the tables, the number of sheets that are produced in an hour is lower than the output of the jogging process. This implies that the cutting process is not dependent on the step before but on its own producing speeds.

The setup times are analysed individually per product line since the setup time is different for P01, P02 and P03. The setup is dependent on the amount of different sized labels at one sheet. If the amount of different sizes labels is higher than the setup time is higher. The maximum number of different labels at one sheet is four which occurs not that frequently.

Table 52: Setup times per product line per amount of different sized labels at one sheet (hours)

	P01	P02	P03
One size (CS1)	0.2	0.2	0.33
Two sizes (CS2)	0.2	0.2	0.37
Three sizes (CS3)	0.37	0.37	-
Four sizes (CS4)	0.45	0.45	-

The frequency of these situations is also calculated which is shown in the table below. The different setup times and their frequency are used to calculate the capacity in one of the improvement steps.

Table 53: Frequency of different sized labels at one sheet in percentage of orders

	P01	P02	P03
One size (CS1)	66%	64%	98%
Two sizes (CS2)	25%	25%	2%
Three sizes (CS3)	7%	8%	0%
Four sizes (CS4)	2%	2%	0%

T.1.3 Bundling

The next step within the production process is bundling. The production speed of the bundling step is determined with the help of taking measurements by hand. The output and input of this step is the same namely bundles.

Input: *Bundles*
Output: *Bundles*

The performed measurements determine the amount of bundles the machine produces within a minute. The bundling step has a constant production speed which is 8 bundles in eight seconds. This number is used to calculate the total amount of products the machine bundles within an hour. However, this assumption only holds if the machine is one hundred percent occupied. So, the breakdown percentage over the last three years is determined and used to calculate the producing speed for the bundling step. The calculation can be seen in the appendix[25].

Table 54: Bundles per hour per product line

Bundling		
	P01	460
	P02	460
	P03	520

As can been seen in both tables, the bundle machine should be able to handle the flow of goods coming out the cutting machine. However, in some instances this is not the case. So, the individual bundles per order per year are investigated. This resulted in a percentage that the bundle processing speed is higher than the bundle machine.

Table 55: Percentage bundle machine as bottleneck

	% above processing speed bundle machine
2017	1.542%
2018	1.623%
2019	1.175%

Moreover, the rework rate at the bundling machine at P03 is significantly higher than the bundling machine used at P01 and P02. Number of hours used for rework is around 3.6% of the total amount of productive producing time. Whereas, the other bundling machines uses much less hours for rework namely 1% at P01 and 0.5% over the last three years. This means that the bundling machine at P03 has a lot of difficulties with developing quality products that can be used further in the process. According to Royal Sens, the reworks has a significant impact on the motivation level of the employees which has a lot of impact on their productivity. However, this is not investigated since it lays outside the scope.

To conclude the first automated part, the overall producing speed of this part in the product line is determined by the cutting machine since this step is the slowest step in the system. There is enough capacity in the bundle machine to handle much more than the cutting step produces as output. This means that the bundle step has unnecessary idle time.

[25] *Appendix G: Bundling speed calculation*

T.2 Section two

T.2.1 Sorting the bundles

The second part is the manual action, sorting the bundles. An actual processing speed of this step cannot be computed since it is dependent on the employee. However, an overview of the tasks and the occupation of section two can be used to develop conclusions. There are three actions that the employee must perform namely:

- Sorting the bundles
- Sorting the packs (last step of production process)
- Control the label

All these actions take time where "sorting the packs" even requires leaving to another place in the production line. So, this employee does a lot of actions which means that the room for error and ineffectiveness is high because the employee must choose which action to do at which specific time. The production flow is interrupted because the employee must perform multiple actions. This is clearly not in line with theory explained by Goldratt, he mentioned that the flow of a product line is crucial (E. M. Goldratt, 1990). Since, maximizing the product flow results in a lower cycle time and an increase in throughput.

In addition, the producing speed of this step is dependent on the number of labels per sheet. A lot of labels per sheet results in a lot of searching and investigating the labels since the labels must be sorted per variety. A lot of labels per sheet also increases the difficulty of the handling which results in more rework. The rework is difficult to measure so an indication is made:

The amount of packs that had to be reworked is measured. The amount of packs is measured by hand and is done for three days.

Table 56: Overview of rework

	P02	P03
Day one	141	214
Day two	91	18
Day three	248	Maintenance

The input and output for this part are the same namely bundles. However, the output is sorted.

***Input**:* *Bundles*
***Output**:* *Bundles sorted per variety*

So, this step interrupts the production flow because the employee must do other actions. This means that there is intermediate stock when the employee comes back. The intermediate stock is difficult to get rid off since the remaining production steps are slow. More on that fact is explained further in the chapter. As mentioned before, sorting the bundles is difficult to execute which increases the mistakes and reworks. Furthermore, as mentioned in the product quality part in the previous chapter, most critical client complaints are originated in this part of the product line. Overall, this step is critical for the product line and has a significant impact on the determined cycle time in the previous chapter. Optimizing the flow of the product line should decrease the cycle time which increases the overall throughput in production volume and in sales.

T.3 Section three

T.3.1 Packaging

The remaining steps after sorting the bundles per variety are packaging and controlling the labels. These processing speeds are measured in the total amount of packs produced per hour. The breakdown is not included since the breakdown percentages are low which means that the number are negligible. The breakdown numbers can be seen in the appendix[26]. Starting with packaging. As can be seen in Figure 2, the P01 and P02 are combined in this step which means that P01 does not have an individual processing speed, so the remaining product lines are P02 and P03. Moreover, the used machine for packaging are the same in both lines which means that the producing speed of this step should be the same for P02 and P03. This step is also used to modify the product which means that the input and output is different.

***Input**:* *Bundles sorted per variety*
***Output**:* *Packs*

The measured maximum speed for the packaging step is stated in the table below.

Table 57: Packs per hour per product line

Package		
	P02	342
	P03	342

T.3.2 Control step

The second last step in the production process of Cut & Stack labels is the control step. The control step consists of two actions namely controlling the bundles within the pack and printing a label which is placed on the pack. The control step is not the same for both product lines since P03 has one additional function. In my opinion, the additional step is unnecessary since it adds no value and delays the process. The input and output of the control step is the same namely packs.

***Input**:* *Packs*
***Output**:* *Packs*

The processing speed of the control step is stated below.

Table 58: Packs per hour per product line

Control		
	P02	225
	P03	200

It is rather interesting to note that the production speed of the control step is significantly lower than the packaging step. This means that the package step must wait for the control step, this is also visible in the product line and can be seen in the appendix[27]. So, the system cannot make more than 225 packs on P02 and 200 pack on P03 per hour.

[26] *Appendix H: Breakdown percentages*
[27] *Appendix J: Control step as bottleneck*

Appendix U: Indication rework

The following information is necessary to compute an indication of the amount of rework. The original information is stated in the previous appendix[28].

The amount of packs that had to be reworked is measured. The amount of packs is measured by hand and is done for three days.

Table 59: Measured rework

	P02	P03
Day one	71	107
Day two	46	9
Day three	124	Maintenance

Table 60: Second needed for every individual rework step

Step	Seconds needed for one product
Bundle	7.5 seconds per bundle
Package	10.5 seconds per pack
Control	5.8 second per pack

The number of seconds needed for one product is computed out of the individual processing speeds. As can be seen, the total amount of seconds needed to re-bundle the full pack is dependent on the total amount of bundles in that pack. For this indication, 5 bundles per pack are used since this characteristic occurs the most[29]. So, the total amount of minutes lost at the days that were measured are.

Table 61: Total minutes lost per day

	Minutes lost
Day one	159
Day two	49
Day three	111

Thus, the conclusion can be made that rework within the product line has a huge impact on the overall output of the system because almost all of the time that is needed for rework can not be used to produce the actual product.

[28] *Appendix T: Capacity and processing speeds per station*
[29] *Appendix L: Frequency bundles per pack*