CHALMERS
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Identifying and reducing converting paper waste

A case study at SCA's paper mill in Lilla Edet.

Master's thesis in the Master Degree Program Supply Chain Management

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2016
Report No. E2016:105

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Gothenburg, Sweden 2016

Acknowledgement

This master thesis was carried out in the spring and summer of 2016 as a final step in the master's program Supply Chain Management at Chalmers University of Technology. The supervisor for this thesis was Mats Winroth, Professor in Operations Management at the Department of Technology Management and Economics, Chalmers University of Technology.

I would like to thank my supervisor Mats for giving me the guidance and inspiration to conduct this report. Furthermore, I would like to thank the case company and their employees for supporting me in my case study and a special thanks to the lead team of L10/L12 and the operators.

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2016-09-23

Abstract

Sustainability is considered to be one of the key priorities for supply chains as it help companies in improving their financial performance and at the same time attract customers who value sustainability. Furthermore, companies implementing waste prevention programs draw the benefits of savings in material and supply cost, improving employee morale and complying with local or state solid waste regulations.

An industry that has been adapting to the increased awareness of sustainability is the tissue paper industry. The adoption includes for instance the introduction of products with 100 % recycled fiber, reduction of water used in the production process and the use of environmental labels.

This case study aims to further look into the sustainability work of a tissue paper manufacturer. In specific, the aim is to obtain a deeper understanding for the material efficiency of the production process and also identify and reduce the material waste in order to improve the efficiency.

After conducting quantitative data collection it was identified that the most significant material waste is found in the preparation stage of the incoming and consumed mother reels, the log rejecter stage and lastly the log saw stage. The three stages amount to about 85 % of the total material waste.

The root cause analysis identified inconsistent work by operators to increase the waste at the preparation stage and the log rejecter stage. Furthermore, technical constraints at the material supplier causes loose ends of the mother reels, which results in more waste at the preparation stage. Other causes that indirectly affect the log rejecter stage include the packaging machine's technical constraints as well as poor pallets provided by the Logistics department. Lastly, technical constrains in the log saw cause waste for itself and indirectly for the log rejecter stage.

In order to tackle the root causes standardized work should be employed alongside with an increased collaboration amongst the different stake holders of tissue paper manufacturer.

Keywords: tissue paper, converting process, paper waste, root cause analysis, sustainability work, waste management, waste reduction, waste prevention

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1 INTRODUCTION

This section presents the background of the thesis as well as problem analysis, research questions, purpose and delimitations.

1.1 Background

Over the past few decades globalization has challenged the traditional way of doing business. Increased competitiveness alongside with higher customer demands and market fluctuations have forced companies to adapt in order to survive. What was previously known as competing with brand versus brand or store versus store has now shifted into supply chain versus supply chain (Cooper and Lambert, 2000).

According to Chopra and Meindl (2013) sustainability is considered to be one of the key priorities for supply chains as it help companies in improving their financial performance and at the same time attract customers who value sustainability. Similarly, the U.S. Environmental Protection Agency (EPA) states that companies implementing waste prevention programs draw the benefits of economic advantages, with savings in material and supply cost, attracting new customers by strengthening the corporate image, improving employee morale and complying with local or state solid waste regulations (EPA, 1993). Thus, an increased amount of companies has started to monitor their sustainability performance which for instance include carbon dioxide emissions and energy and water consumption (Golicic et.al., 2010). The challenge is no longer on whether to implement monitoring of sustainability performance or not, but how to improve it. Epstein and Roy (2001) stresses that improving performance require managers to better understand the drivers of both costs and revenues and the actions that they can take to affect them, hence monitoring the performance is an essential tool.

Recently, the executive body of the European Union, the European Commission (EC) stated that the increased living standards of our societies have resulted in reaching all time high consumption and waste. This directly affects greenhouse gas emissions, pollution of air, soils and water (EC, 2010). Managing the waste properly has been a driving force for policy makers. Throughout the years government bodies like the EC and EPA have developed various action plans and frameworks that aim to make our societies to become sustainable and efficient with the use of energy and resources.

Both EC (2010) and EPA (1993) state that preventing the waste from occurring in the first place is considered to be the key for solving the waste issue and Lewis et. al. (2001) argue that eco-design plays a big role in accomplishing the waste prevention. With respect to the environment, the benefits of waste prevention include decreased demand of natural resources, reduced need of landfills and reduced pollution during production of certain products (EPA, 1993). Furthermore, companies implementing waste prevention programs draw the benefits of economic advantages, with savings in material and supply cost, attracting new customers by strengthening the corporate image, improved employee morale and compliance with local or state solid waste regulations (EPA, 1993).

An industry that has been adapting to the increased awareness of sustainability is the tissue paper industry. To become more sustainable the industry has responded with several actions, which includes for instance the introduction of products with 100 % recycled fiber, reduction of water used in the production process and treating wastewater biologically (Paulapuro, 2000). Tissue paper has been used for hygiene purposes for centuries and is today a well-established industry with both a consumer sector as well as an away-from-home sector and according to SCA (2016a) the industry is worth over 500 billion SEK. The production of tissue paper is known for its high demands of energy, virgin fiber pulp and water (Paulapuro, 2000). The majority of the raw material in paper making is wood and according to Lewis et. al. (2001) the global trend is going towards an increased reliance on plantations of intensively managed natural regeneration forests. Having a sustainable regeneration of the forest puts pressure on the tissue paper industry to have an efficient use of raw material in their production process. Like in any other industry, the benefit of improved production practices is a decreased demand of raw materials and hence reducing material costs (EPA, 1993).

With that in mind, this case study aims to further look into the sustainability work of a tissue paper manufacturer. In specific, the aim is to obtain a deeper understanding for the material efficiency of the production process and also identify and reduce the material waste in order to improve the efficiency.

1.2 Purpose, research questions

The purpose of the thesis is to, on a holistic level, identify the various activities that are present in the tissue production process and specifically detect and measure the material waste that occurs.

In order to understand the material waste on a more detailed level one must quantify where in the process the actual material waste occurs. Therefore, identifying waste parts in the production process and measuring material waste data during production will be done. In this sense the total material waste will be distributed into different parts of the process:

How is the total material waste distributed in the tissue production process?

Once the distribution of the material waste is known one is able to conclude where in the process the most significant waste is. The next step is to understand the underlying causes for this material waste:

What are the underlying causes for the most significant material waste?

The final step is to carefully analyze and decide upon what changes that should be made in the production process to significantly decrease or prevent the material waste. This will enable to set up a priority list of which parts of the process to work with:

What changes should be made in the production process in order to significantly decrease or prevent the material waste?

1.3 Delimitations

The case study is limited to the converting process of SCA's paper mill in Lilla Edet. The conclusions will mainly look into solutions that directly occur at the converting department. However, due to the strong interdependency optimization between the different departments some cross-border solutions will also be discussed, with the converting department as a reference point.

Since the converting department consists of several different lines that produces a wide range of products this study will only focus on the paper waste that is generated by one specific line. Furthermore, the waste data collection will only focus on toilet rolls for two product families. The line and the two product families have been carefully chosen through a dialogue with the case company. The material waste only includes soft paper waste, hence the waste from the paper core, glue and plastic for packaging are all excluded in this study.

The theoretical framework has been selected to reflect on the challenges of paper waste when converting the paper and investigates concrete ways of how an organization can work to reduce and prevent waste. Hence some parts of the theory are not fully developed as they lack of direct relevance for this study. In specific this refers to the definition of waste (which is defined below this section), as well as theory on standardization which focuses on standardized work, and the process of turning pulp into, (see sub-chapters 2.3.3 and 2.4). Furthermore, the root cause analysis of the paper waste (found in sub-chapters 2.3.2 and 4.3.1) is narrowed to the operations and work tasks of repetitive occurrence.

There are several definitions for waste, depending on the context. The recognized expert of Toyota's lean philosophy Mr. Shingo (1984) defines waste as everything that does not contribute to the value-adding of a product. According to Shingo (1984) there are seven different forms of waste which are overproduction, waiting, transportation, overprocessing, excess inventory, unnecessary movement and defective products. In recent years, advocates of the lean philosophy such as Petersson et. al. (2010) and Liker and Meier (2006) have introduced an eight waste form being "unused employee creativity", which is the result of organizations not engaging or listening to their employees.

Moreover, EPA (2016), through its "Resource Conservation and Recovery Act", defines solid waste as "any garbage or refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, resulting from industrial, commercial, mining, and agricultural operations, and from community activities".

Lastly, the European Union, henceforth EU, defines waste through its "Waste Framework Directive" as "any substance or object which the holder discards or intends or is required to discard" (EU, 2008).

As presented the word "waste" has a wide spectrum of meanings. In order for this thesis to obtain a constructive approach the meaning of "waste" has been narrowed. The paper waste in this study corresponds to the lean philosophy's waste form "defective products". In addition, by taking EPA's and EC's definitions of waste into consideration, and for the purpose of this thesis the word "waste" is defined as "the discarded paper, resulting during the converting process".

2 THEORETICAL FRAMEWORK

This section presents the theoretical framework that has been used with the objective to analyze and conclude the paper waste within the case company The section begins with introducing waste management from policy makers' point of view as well as from a lean philosophy point of view. Lastly, theory about tissue paper is presented which includes theory about the life-cycle, converting process alongside with tissue paper waste management.

2.1 Managing waste

Waste is a problem that is directly affecting greenhouse gas emissions, pollution of air, soils and water. Only in the EU the annual waste production is around three billion tons where household waste together with the manufacturing industry and the construction industry amount to almost 50 % of the total waste (EC, 2010).

The waste is expected to continue to grow as a result of increased consumption. This is enabled by improved living standard where the society is growing wealthier and consumers are buying more than ever before (Cohen, 2004). The number of products to choose from is all time high and is often recognized by relative short lifespans that are single-use and disposable products (EC, 2010). Another trend is the personal device industry where consumers have started to carry around one or multiple electronic devices and use them as part of their everyday life. The waste in today's society consists of a complex mix of materials that is very challenging to deal with, in specific plastics, precious metals and hazardous materials (EC, 2010).

To tackle the waste problem, government bodies like the EC and EPA have been developing sustainability action plans and frameworks as a directive for their member states. The aim is to protect human health and the environment, and to become sustainable and efficient with the use of energy and resources (EC, 2010). The EPA even goes a step further by stating that they (United States) take a leadership role in working with other nations to protect the global environment (EPA, 2016b).

Furthermore, EC, (2010) states how the view of waste have shifted from being an unwanted burden into becoming a valued resource that is collected, sorted, transported and traded amongst different stake holders. For instance, old phones can nowadays be traded in for cash or credit with the telecom company Vodafone (Vodafone, 2016). Similarly, Campbell (2016) explains how the fashion company H&M offers their customers vouchers when they bring a bag of unwanted clothes to the H&M stores. Since 2013 the company has managed to collect more than 25 000 tons of second hand clothes ensuring less ends up in landfills.

2.2 The five-step waste hierarchy

The corner stone of EU's waste management is the so called "Waste Framework Directive" which presents a five-step waste hierarchy, see Figure 1. The goal is to move the waste management upward the waste hierarchy (EC, 2010). The waste hierarchy model is a well-established in the world and has evolved with several modifications in different regions, for instance EPA (2016c) uses four steps in there model and Ireland's Environmental Protection Agency, henceforth IEPA, uses six steps (IEPA, 2016). However the bottom line of the model still remains. The five steps of the model are explained below the figure according to EC's (2010) definition.

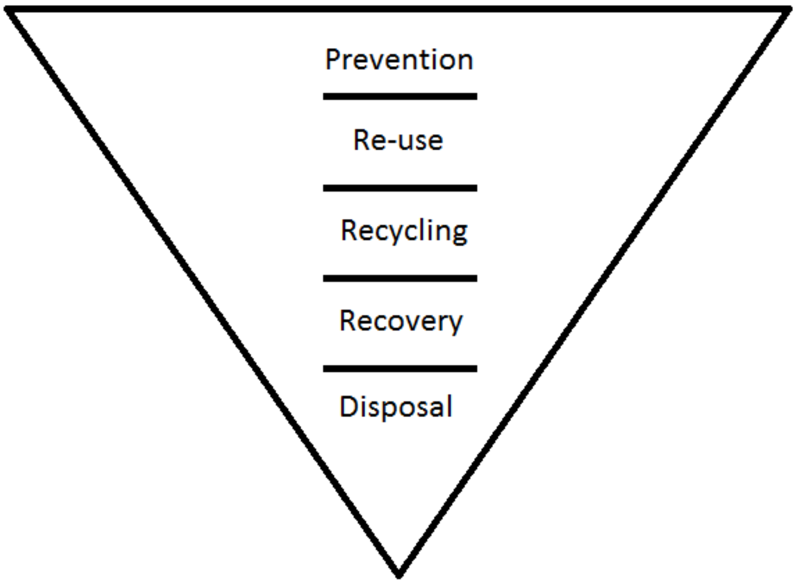

Figure 1: EU's five-step waste hierarchy (EC, 2010).

Step 1 – Disposal

The oldest way of dealing with waste is putting the disposal into landfills. This technique has shown to be very harmful for the environment as it can trigger the process of generating the greenhouse gas methane which equals 25 times the potent of carbon dioxide. A number of serious cases with methane, including explosions in landfills and release of toxic chemicals (due to breakdown of biodegradable waste) have made the policy makers of EU to act more restrictive toward landfills, for example restricting the amount of biodegradable waste allowed and requesting methane gas to be collected and used for the production of energy (EC, 2010).

Step 2 – Recovery

Recovery refers to the energy recovery that can be made out of waste. Modern waste plants have the ability to turn waste into electricity, steam, heating for buildings and fuel for some industrial processes. On the other hand, burning the waste incorrectly can cause damage on the environment and health due to the release of hazardous chemicals. Therefore, the burning of waste must only occur under controlled circumstances where plants are required to minimized the environmental and maximize the benefits. Even if energy recovery is better than disposal it is far from the most efficient way of managing waste.

Step 3 – Recycling

Recycling helps to decrease the pressure on landfills and also reduces the demand of raw materials extracted from the environment. Another benefit of recycling is the significantly reduced energy consumption compared to using raw materials. In order to maximize the quality and amount of products that can be produced out of recycled waste it is important to properly sort different types of waste. Therefore, recycling is very depended on how well companies and individuals keep up with sorting for instance glass, paper, plastics and metals.

Step 4 – Re-use

Re-using components and products have a great potential and is considered to be very sustainable. Products that have reached the end of their life cycle often consist of a significant amount of components that are still functioning, this includes for instance vehicles and electronic devices. Another good example is the second hand industry of clothes and furniture that generates jobs and is eco-friendly at the same time.

Step 5 – Prevention

On the top of the hierarchy is prevention, which stop the waste from occurring in the first place, what is not produced does not have to be disposed EC (2010).

2.3 Waste prevention techniques and tools

It is clearly stated by Berry and Rondinelli (1998) EC (2010), EPA (1992; 1993; 2016c), IEPA (2016) and Lewis et. al. (2001) that preventing the waste from occurring in the first place is considered to be the key for solving the waste issue.

"Truly effective environmental protection requires prevention of pollution rather than the control of wastes at the end of the pipeline". – Berry and Rondinelli (1998)

In addition, Lewis et. al. (2001) argue that eco-design plays a significant role in accomplishing the waste prevention. With respect to the environment Lewis et. al. (2001) presents the benefits of waste prevention to include less mining, extracting or harvesting for making basic materials, less energy for processing materials, fewer emissions and wastes during production and less energy needed for transporting products due to lighter weight. Furthermore, according to EPA (1993) companies that implement waste prevention programs draw the benefits of economic advantages, with savings in material and supply cost, attracting new customers by strengthening the corporate image, improving employee morale and compliance with local or state solid waste regulations.

"Pollution prevention is a powerful business strategy because it encourages the efficient use of raw materials and reduces the costs of waste" – Berry and Rondinelli (1998).

Furthermore, material efficiency can be linked to the discussion on costs of poor quality. Sörqvist (1998) and Bergman and Klefsjö (2010) estimate a manufacturer's cost of poor quality to be worth around 10-30 % of its total sales. According to Bergman and Klefsjö (2010), the costs of poor quality include internal failure costs as well as external failure costs, where the former consists of e.g. costs of rework, scrapping and production standing still. The latter includes all the failure detected after the delivery to the customer, such as complaints, warranties and loss of goodwill. Furthermore, Bergman and Klefsjö (2010) argue that the costs of poor quality outnumbers the cost of quality, therefore manufacturers should invest in maintaining the quality of their products and processes and thus prevent the need of rework or compensations in different forms. To maintain quality Juran (1951), Oakland (2008) and Klefsjö (2010) discusses the rise of appraisal costs and prevention costs. Appraisal costs are those that can be linked to checking if the quality is fulfilled, for instance sampling of products and raw materials. Prevention costs are those that occur with preventing defective products from occurring in the first place, e.g. educating the work force on quality management and establishing supplier audits. Preventing the occurrence of poor quality can also be linked to the lean philosophy's root cause analysis and standardized, which are presented in sub-chapters 2.3.2 and 2.3.3.

2.3.1 Source reduction

In order to achieve waste prevention EPA (1992) has introduced the source reduction model, which focuses on improving both the product as well as the production process, see Figure 2.

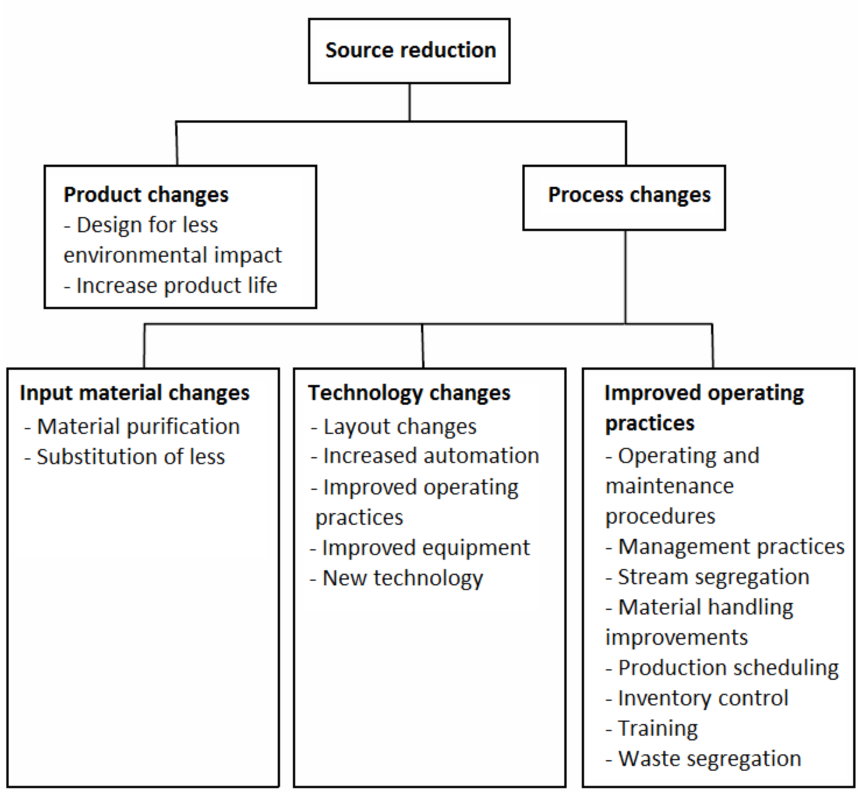

Figure 2: EPA's source reduction model (EPA, 1992).

EPA (1992) stresses that the environmental impact of a product is, to a large extent, determined during its design phase, therefore the product changes should focus on preventing the waste from production, consumption and ultimately the disposal of the product. Furthermore, as shown in Figure 2, EPA (1992) divided the process changes into input material, technology and improved operating practices, where the latter is argued to be less expensive to implement and quicker compared to the others. In addition, Bruzelius and Skärvad (2004) distinguish change between incremental changes and structural changes. The incremental changes are linked to adjusting and improving the organization's established framework, e.g. products and routines. The improvement work is built upon history, and these types of changes are usually done in a smaller scale and thus possess a relative small risk. In contrast, structural changes are usually done in a large scale where the organization makes something radical, e.g. new organizational structure and new technology. These types of changes have great potential, however a relative high risk compared to incremental changes. In conclusion, Bruzelius and Skärvad, 2004 states that structural changes are more difficult to realize than incremental changes.

Moreover, both product changes and input material changes can further be linked to Lewis's et. al. (2001) four design strategies for source reduction, which are (1) simplify the product and eliminate unnecessary components, (2), use the minimum amount of material required to meet performance requirements (3) avoid unnecessary packaging and (4) use strong and lightweight materials.

Regarding technology change, even though improving technology can contribute to various benefits such as e.g. reduced labor cost, reduced scrapping and increased quality, Shingo (1984) and Liker and Meier (2006) argue that companies often end up with high investments in wrong technologies. Before investing in technology, Shingo (1984) states that one must know the difference between simplification of work and improvement of technology, where the former should be the reference point for the investment. In addition, Liker and Meier (2006) state that one should approach the technology as a support to the process rather than replacing the process with technology. Furthermore, before a successful improvement can take place Shingo (1984) stresses the importance of critically examining the existing manufacturing method as other methods may generate various benefits (as mentioned above). As a first step Shingo (1984) recommends to obtain a clarification of how the product should look like and how it should be produced. As a second step the author argues that one should analyze the current manufacturing method from two perspectives, which are on one hand the possibility of improving the conditions of the production technology (e.g. temperature, cutting speed etc.), and on the other hand look into improvements of the production technique (e.g. fast drying and vacuum forming). Liker and Meier (2006) conclude that even if innovative products and process technologies are Toyota's success the most important factor for the success is the people. This is explained by the fact that the people are the core in creating and implementing these innovative products and process technologies (Liker and Meier, 2006).

As for improved operating practices, Shingo (1984) stresses the importance of increasing the time efficiency. The author makes a distinction between necessary operations and unnecessary operations, where the latter is seen as non-value-adding and should therefore be eliminated. Shingo (1984) further divides the necessary operations between those of repetitive occurrence and those of random occurrence. Within the operations of repetitive occurrence the primary operation is found alongside with its help operations, and preparations before and after the primary operation. Shingo (1984) argues that improving the primary operation is a matter of looking into its processing technology and aspects of mechanization. Regarding improvements of help operations the author recommends simplifications and automatization of machine feed as well as the assembly and disassembly of work objects. For the improvement of preparations before and after the primary operation Shingo (1984) argues that using the SMED method (Single digit-minute Exchange of Die method) would significantly decrease the downtime of the production equipment. The SMED method will not further be explained as it is out of the scope for this thesis, for more information about the method see Shingo (1984).

Lastly, Shingo (1984) divides operations of random occurrence to be either personal time or non-personal time, where both should be minimized. However, decreasing personal time is complex as it depends on psychological and physiological factors Shingo (1984). Regarding non-personal time Shingo (1984) distinguishes operation downtime and shop floor downtime where the former is specific for an operation while the latter is common for all operations. According to Shingo (1984) operation downtime could be reduced by introducing automatization of e.g. lubrication, cutting oil and cutting dust. Similarly, for the downtime of shop floor Shingo (1984) proposes automatic feeding of input material as well as the automatic storage of finished goods.

2.3.2 Root cause analysis

As presented in the previous sub-chapter Shingo (1984) argues that increased time efficiency is an important aspect of improving operating practices. However increasing time efficiency does not necessarily include the reduction of defective products (and increasing material efficiency). Instead, Shingo (1984) suggests that defective products should be approached with finding and eliminating the root cause, this is also supported by Petersson et. al. (2010). In addition, Epstein and Roy (2001) stresses that improving performance require managers to better understand the drivers of both costs and revenues and the actions that they can take to affect them. Finding the root cause can be achieved by using the so called "five-why method", a method that simply applies the question "why?" five times on a problem to reach the root cause of it. However, in order to achieve an effective root cause analysis Liker and Meier (2006) points out the importance of firsthand observation since problem causes based on assumptions and secondary sources increases the likelihood of poor results. Furthermore, to maximize the results Liker and Meier (2006) argues to narrow down the possible causes and prioritize the most significant ones. In addition, Petersson et. al. (2010) presents the so called "Pick chart" where p stands for possible, i for implement, c for challenge and k for kill. The chart is used as tool to prioritizing deviations and thus the root cause. As seen in Figure 3 the x-axis represents the effect, which refers to the effect of solving the deviation, while the y-axis represents the effort that is required to solve the deviation.

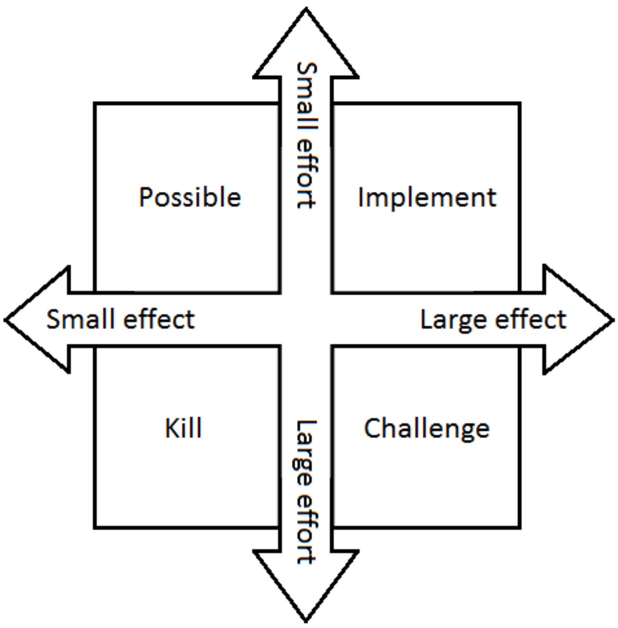

Figure 3: Pick chart (Petersson et. al., 2010).

When the solution has large effect and small effort it should be prioritized and implemented. If the solution has both small effect and effort it is labeled as "Possible", meaning that it is not of priority however it should be implemented when possible. On the other hand, when the solution has both large effect and effort then it is considered to be a “Challenge”, which may require extensive support to achieve the implementation. Lastly, if the solution has small effect and large effort it is labelled as “Kill” and should not be implemented as the effort is not worth the effect.

2.3.3 Standardized work

Liker and Meier (2006) state that the objective of standardization is to provide products with the highest quality in parallel with the lowest cost and shortest time possible. The authors point out how organizations tend to have significant waste caused by random activities and inconsistent work methods. Thus, eliminating this waste can be achieved by eliminating or reducing the variation within the process. Variation and standardization are the antithesis of one another, by standardizing one could realize a distinction between standard method (normal) and the nonstandard method (abnormal) and therefore enable eliminating or reducing variation (Liker and Meier, 2006). While there are several types of standardization this section will henceforth only focus on standardization work (as stated in the delimitations).

From a lean philosophy perspective Liker and Meier (2006) argue that standardized work should be considered as the key for continuous improvements, an argument that is also validated by Emiliani (2007), Petersson et. al. (2010) and Liker and Franz (2011). Furthermore, Petersson et. al. (2010) states that standardized work describes the best currently known and agreed way to perform a certain activity.

According to Liker and Meier (2006) standardized work has three requirements before it can be realized, (1) the work task must be repeatable. Unrepeatable tasks and tasks with “If, then” terms are difficult to standardize unless there are very few of them. (2) The production line and the equipment has to be reliable, it is difficult to standardize work in an environment with a lot of interruptions and downtime. (3) Quality issues must be minimal, if workers would often have to correct or scrap defective products it would be difficult for them to see the true image of work.

Petersson et. al. (2010) recommend the workforce to create their standardized work themselves since getting it put together by someone outside the process, e.g. manager or consultant may lead to resistance and a lack of understanding. The people that work in the process are the experts of the process and know what is relevant for the standardized work, this will assure the correct level of detail for the workforce as well as their approval. However, Petersson et. al. (2010) states that just because the authority is given to the workforce for creating the standardized work it does not mean that the management has no control of the way the work is performed. In fact the management should be present and supporting the workforce in the improvement work. Liker and Meier (2006) states that workers should not be left out alone with the process improvement as they may feel dumped on, the last thing the management team wish is to have a workforce that views the process improvement as something negative or stressful.

Petersson et. al. (2010) argue that a successful approach is to have a set up where the workforce proposes the standardized work to the management which approves before implementation. This also requires the management team to train their employees to understand why standardized work is important. Both Petersson et. al. (2010) and Liker and Meier (2006) state that management should show patients and support towards the workers as implementing standardized work takes time. In the case where variation reappears after implementation Petersson et. al. (2010) states that one should ask if the work was performed according to the standard. If the answer is no, then more training is need. If the answer is yes then it is a hint that the current standard is not good enough.

2.4 Tissue paper and the converting process

Tissue paper is creped soft paper used for hygiene purposes and includes products such as kitchen towels, industrial wipes and toilet paper. According to numbers from the hygiene and forest products company SCA (2016a) the global market for tissue is worth over 500 billion SEK with an annual growth of 4 % where the main players include SCA, Georgia-Pacific, Hengan, Kimberly-Clark and Sofidel. The market place is divided between a consumer sector as well as an away-from-home sector, henceforth AfH. AfH refers to tissue sold to bulk customers such as airports, hospitals, industrial environments, restaurants and offices. The tissue products come with different quality requirements which are for instance absorbency, appearance, basis weight, brightness, softness, stretch, thickness and tensile strength. This affects the length and the number of layers (one-ply, multi-ply) of the end product (Paulapuro, 2000). Figure 4 displays the simplified life-cycle of paper products.

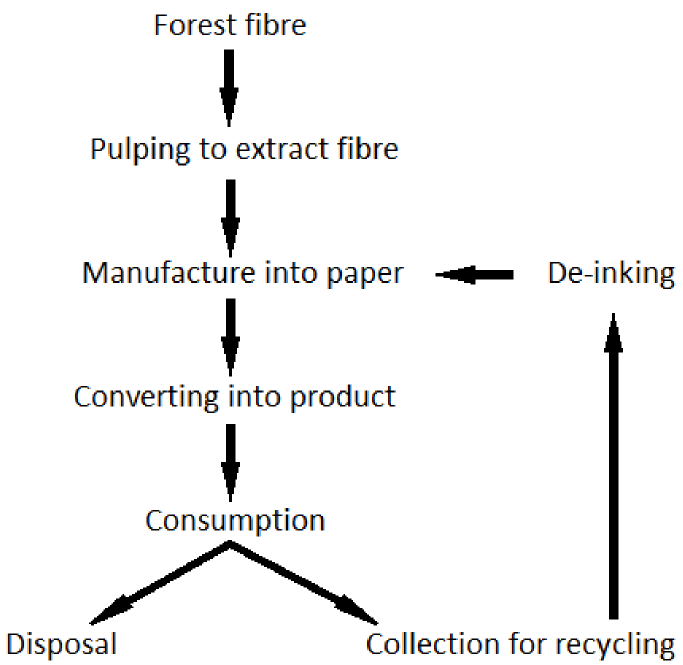

Figure 4: Simplified life-cycle of paper products (Lewis et. al., 2001)

The raw material of tissue paper is a mix of agents and pulp. The choice of agents usually depends on the quality requirements of the end product. The most common agents include wet strength size which increases the wet strength, pigments which give the paper a specific color, and brighteners that control the shade of the paper (Paulapuro, 2000).

There are three different forms of pulp that is used in tissue production being virgin fiber pulp, recycled fiber pulp and pulp mix which combines the previous two. Virgin fiber pulp is primary pulp, meaning that the fiber has not been used previously in production. In contrast, recycled fiber has already been used in other products and requires de-inking before usage. Recycled fiber pulp consists of two main grades which are so called selected or ordinary. Selected recycled fiber pulp is paper recovered of better quality like office paper while ordinary recycled fiber pulp is paper recovered from household waste such as newspapers and magazines (Paulapuro, 2000).

Similar to agents, the choice of pulp mix depends on the quality requirements of the end product. The two extremes of the end product are either made out of 100 % recycled fiber or 100 % primary fiber where the premium products relate to the latter (Paulapuro, 2000).

Once the pulp is selected the tissue paper is produced in a process consisting of three sections which are forming, pressing and drying. In the beginning of the process the material mix consists of 99.8 % water and after the drying it goes down to 4-8 %. As a final step the paper is winded on a core and becomes a reel, so called “Mother reel”. Mother reels usually have a width between 3 – 5 m and is the input material of the converting process displayed in Figure 5 (Paulapuro, 2000).

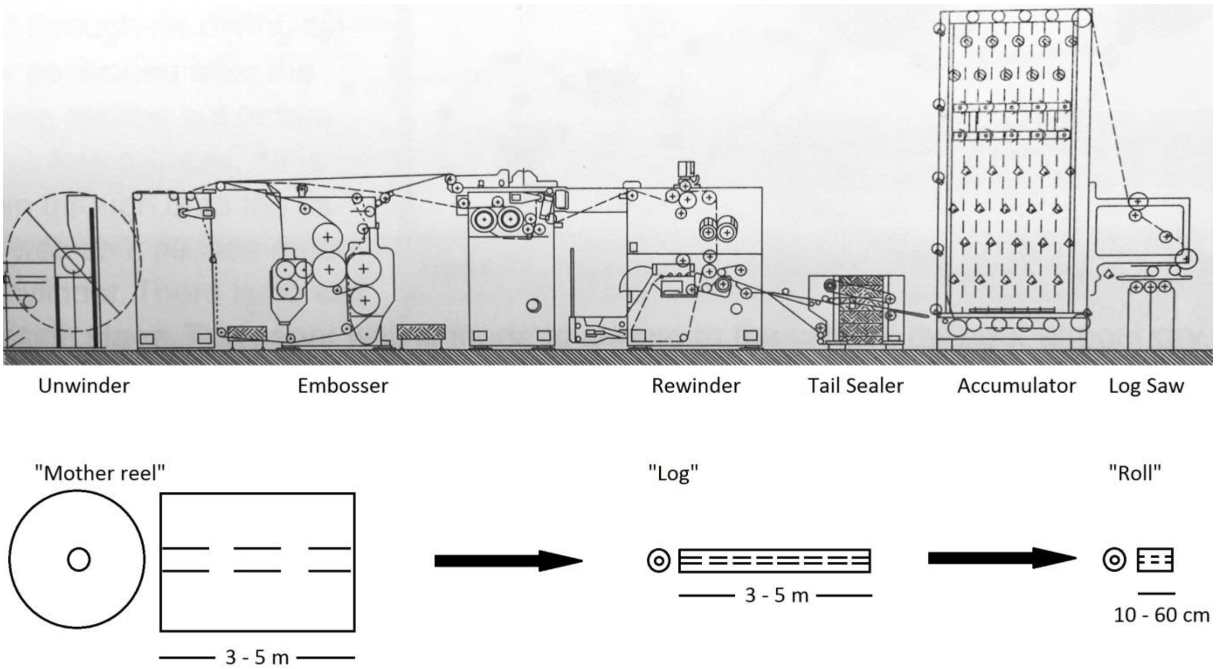

Figure 5: Tissue paper converting process, modification from Paulapuro (2000).

The converting process starts with unwinding the mother reel at the unwinder. The next stage is the embossing where rubber and steel cylinders press the piles together. This is done in order to increase the softness and absorbency of the end product. Moreover, the embossing also includes cylinders that are able to decorate, laminate, print and stretch the end product. Lastly, before entering the rewinder stage the paper may be perforated by perforation knives that simplify the separation of sheets. In the rewinder stage the paper is winded on to a new core that gives the final circumference and diameter which is usually set by a certain number of sheets or meters that is put on the core. The core together with the paper is referred to as a “log”. Once the log is created it goes through the tail sealer stage, where the end of the log is sealed. The log then enters the accumulator that works as a buffer to mitigate disturbances in the process. Finally, the log enters the log saw which cuts the log in the desired width and becomes the end product, a roll. The rolls are usually around 10-60 centimeters depending on what kind of product it is. The rolls are then going through a packaging machine that wraps the rolls with plastic or paper and can also be packed in sacks or corrugated board boxes to meet the customer and transportation requirements. The end of the life cycle includes the consumption of the tissue paper and since it is biodegradable the used tissue paper can be utilized Paulapuro (2000).

2.5 Tissue paper and waste management

As a result of the increased awareness of sustainability companies within the tissue paper industry have responded with several actions, which includes for instance the introduction of products with 100 % recycled fiber, reduction of water used in the production process and treating wastewater biologically (Paulapuro, 2000). Moreover the industry has embraced the use of environmental labels which helps consumers, companies and other organizations to choose products that are conscious of the environment Norden (2014). Examples of independent environmental labels include the EU flower, the Forest Stewardship Council (FSC) and the Nordic Swan. Furthermore, Paulapuro (2000) highlights three points of tackling waste caused from producing tissue paper, which are (1) the choice of raw materials and supplies, (2) the manufacturing process and (3) the use of products. In the first point Paulapuro (2000) puts emphasis on procurement with sustainably forest growth and forest management. As for the second point Paulapuro (2000) suggest to tackle the tissue-paper process emission by recycling process wasters, treating wastewater biologically, reducing the amount of water for the process, use environmental-friendly fuels and use filters to remove impurities from the flue gases. Lastly, for the third point Paulapuro (2000) argues that the consumers have the responsibility of using the most suitable product for their purposes which is argued to cut the consumption as well as the waste volumes. Moreover, from an eco-design point of view Lewis et. al. (2001) present five design strategies, which are:

1. Choosing paper that is elemental or totally chlorine-free.

2. Specify use of unbleached paper wherever possible.

3. Match the brightness of paper with its intended purpose (prevents over-specification).

4. When possible replace wood fiber with non-wood fiber, e.g. kenaf and hemp.

5. Use paper manufactured from recycled material.

3 RESEARCH METHODS

This chapter presents the methods that have been used for this thesis. The methods have been selected according to a scientific approach where the key has been to collect and work with relevant data to ultimately meet the requirements of a master thesis. Firstly, the scientific methods used for the case study are presented. Secondly, the method of the data collection and analysis is presented. Lastly, reliability and validity is discussed.

3.1 Hermeneutic method

There are several different scientific approaches that can be used. The differences are in some cases significant while in other cases rarely noticeable. According to Patel and Davidson (2003) the hermeneutic method is based on analyzing and understanding the conditions of the human existence through interpretation. The authors continue with stating that the hermeneutic scientist uses the holistic view as its reference point which allows a wider understanding of the defined problem. This understanding is then used as a tool for the scientist's interpretation (Patel and Davidson, 2003).

Wallen (1996) explains that the hermeneutic method can be seen as a theory of communications and understanding and states four key points of the method to be:

1. Interpretation of the meaning of actions, experiences, symbols and texts.

2. The interpreter has a pre understanding in forms of linguistic and cultural unity.

3. The interpretation switches between sub perspective and holistic perspective.

4. The interpretation has to be carried out in relation to a context.

Furthermore, Patel and Davidson (2003) argues that the hermeneutic scientist shifts between the subjective point of view (interviewer) and the objective point of view (interviewee), resulting in understanding the problem from different perspectives.

Arguably, the hermeneutic method fits this case study since the author, with the academic background, has a pre understanding for the concept of waste. Alongside with data collection in forms of theoretical review, interviews and measuring waste, the understanding will be further developed.

3.2 Abductive method

The method of relating theory to reality is one of the most discussed problems within the scientific world. According to Patel and Davidson (2003) there are generally three types of methods that a scientist can use to relate theory and empery to one another. These methods are deduction, induction and abduction and are defined by the authors as:

Deduction - Uses already established theories and reasoning in order to conclude single observations. The use of deduction strongly dictates what kind of information that should be gathered. In that sense the subjective thoughts of the scientist are relatively small, resulting in constraining the potential of new and interesting findings (Patel and Davidson, 2003).

Induction - Differs drastically from deduction. The method leads the scientist on the exploring path where the defined problem is studied without having the established theories as reference point.

Instead, through the gathering of information during the study, a new theory is formed. On the other hand, even though the established theories are not used to form the outcome of the study, the persona of the scientist will. The inductive scientist has own conceptions and ideas that will, in one way or another, affect the creation of the new theory (Patel and Davidson, 2003).

Abduction - The method that combines both deduction and induction.

The conditions of the case study, with having to break new ground in identifying paper waste combined with the already establish waste theories, makes it suitable to use abduction as the method. Hence, the reference point for this study is divided between established theories on waste management (deduction) and gathering information along the way combined with the author's academic background (induction).

3.3 Theoretical review

The theoretical review has been an essential part of this case study. Wallen (1996) divides theory between (1) concepts, (2) context and structures, (3) models and (4) explanations. Concepts are the cornerstone of theories and characterize events, phenomena and objects that are grouped after similarities and differences. Context and structures are explained by Wallen (1996) that every theory as a link between different phenomena or a structure in which they are ranged, where the purest form is an axiomatic system of theorem. Regarding models the author explains them to generally be a simplification which focuses on the most significant part of a theory. Lastly, explanations are used by Wallen (1996) in a context to distinguish theories from descriptions by stating that theories consist of explanations.

Throughout the case study concepts with different context and structures alongside with models and explanations have been gathered in forms of articles, literature and reports that discuss waste management. The theory has been gathered from the Chalmers library as well as the internet.

3.4 Qualitative data collection

The decision of performing qualitative interviews is based on Patel and Davidson's (2003) argument that it enables the interviewee to develop authentic answers and a deeper understanding is obtained compared to for instance "yes" or "no" answers obtained from standardized methods like surveys.

Moreover, Rosengren and Arvidson (1983) stress the importance of choosing interviewees from various groups to obtain credibility of the data. Therefore, interviewees of the case study included operators, process engineers and operations managers, which all work or have previously worked at L10.

The choice of operators intended to get a deeper understanding of the activities on the line. Secondly, the choice of process engineers was made in order to grasp the data of waste and the calculations. Lastly, the operations managers were chosen to understand what the management expects from working with waste and what deliverables they expect from the case study.

The interviews helped to define the various wastes that occur in the converting process. Furthermore, brainstorming helped to develop a method for measuring the actual waste, see sub-chapter 3.5. Case study method. In a later stage brainstorming was also used for ideas that could improve the product and process to reduce waste. Moreover, the interviews contributed in securing the quality of the case study method as all the different functions (operators, engineers, managers) had their say on the method.

3.5 Quantitative data collection

The quantitative data collection was the most challenging part of the case study as it had many different aspects to take into consideration. This can be directly linked to Eriksson and Wiederheim-Paul (2001) argument of data collection having interdependency between cost, quality and availability. The authors stress that it is rather impossible to choose a method that gathers data and at the same time achieves lowest cost, highest quality and in the fastest possible way. As a first step Eriksson and Wiederheim-Paul (2001) recommends to look into already existing data to get an overview of the research area and how the data collection has been treated previously. This will help to give an orientation for the own data collection (Wiederheim-Paul, 2001).

The case study's interdependency between cost, quality and availability made the data collection challenging to achieve as all three factors had significant importance. Regarding the cost, all data collection was expected to be carried out during regular working conditions, no extra resources were set aside. To achieve proper analysis of the waste the quality of the data collection had to include a breakdown both in terms of the distribution of the total waste in the process as well as how much of the total waste that could have been prevented. Lastly, the availability depended on the order frequency of the product families alongside with the availability of at least two volunteers in addition to the four operators on the line.

With respect to Wiederheim-Paul (2001) recommendation on looking into the already existing company data together with the theoretical review, the observations on the line and the interviews the case study method for the quantitative data collection was formed, henceforth the case study waste data method.

When developing the case study waste method the purpose was to fill the gaps that occur with using the case company's waste data method which are (1) waste is not measured but based on a theoretical value and (2) the distribution of waste in the converting process is not measured. Therefore, case study method is focusing on displaying the total waste with relative high accuracy and precision compared to the case company method as well as the distribution of waste in the converting process. A comparison of the two waste data methods is displayed in Table 1.

	Input (kg)	Output (kg)	Waste (kg)	Waste (%)
The case study's waste data method	Output + Waste	Output quantity of rolls (q) * Weighted paper weight per roll (grams/q)	Weighted paper waste	Waste / Input
The company's waste data method	Weighted mother reels by supplier	Output quantity of rolls (q) * Specification paper weight per roll (grams/q)	Input – Output	Waste / Input

Table 1: Comparison of case study method and company method.

Where:

Output quantity of rolls (q) =
Quantity of finished pallets registered by a clock at the palletizing
* Quantity of packages per pallet
* Quantity of rolls per package

Weighted paper weight per roll (grams/q) =
Average of the sample weighting of rolls.

The relative high accuracy of the case study method is enabled by weighting the paper waste on a calibrated scale by the converting line. In contrast, the company method obtains the waste weight through by subtracting the theoretical output weight from the input weight which is weighted by the mother reel supplier. In addition, notorious inaccuracy of the input weight has been reported due to a lack of calibration of the supplier's scale. Therefore, in order to receive more accurate results the case study waste data method assumes the sum of the weighted waste and the weighted output to represent the input weight. To obtain a waste percentage the waste weight is divided by the assumed input weight. The calibrated scale that weighted the waste had an interval scale of 0,2 kg which has relative high precision compared to the supplier's scale which has 1 kg.

According to Rosengren and Arvidson (1983) the measure of central tendency of interval variables should be performed by using the average value. Hence, the output weight of the case study method is based on the quantity of finished products multiplied by an average sample weight of the product. The average sample weight is based on sample weighting and was set to occur every fifteenth minute during the waste measures with five rolls in each sample. Compared to the waste weight, the sampling of rolls included a significantly lower weight, hence a calibrated scale with an interval scale of 0,001 g was used for the roll sampling. Furthermore, the sampling also included measuring the roll width to be able to deduct the roll core weight, which is not considered to be paper waste. In order to deduct the roll core weight the weight and width of 10 log cores are collected to obtain an average value of a core's weight per length unit.

The data collection was carried out on two products during regular production runs, meaning that no production changeovers or planned stops occurred at the time. In order to obtain the required quality of data the whole process had to be monitored during the data collection which is very resource intensive. Hence, the execution of the data collection was limited to aim for an input weight of 5000 kg each for the two products. The limitation almost enabled to start and finish the data collection within a regular 8 hour work day, however it became slightly longer for one of the products which lasted about 12 hours.

Extensive planning and preparation was a pre requisite for the execution of the data collection. Logistics had to be prepared in forms of containers, pallets, pallet collars and scale as well as the preparing the personnel that were helping during the execution of the data collection. The method of the data collection was revised several times by the input of the interviewees as well as testing the method on a smaller scale.

The choice the products was based on the annual volume and product complexity. The chosen products each belong to product families that represent a significant volume of L10's annual production. This enables to draw more general conclusions of the waste as the product family involves a greater volume compared to only looking into an individual product. Regarding product complexity, the first product family is the most simple products produced on L10 consisting of only one ply. In contrast the other product is the most complex product with a total of three plies. Hence, the product families were defined as product family "Basic" and product family "Premium".

Due to the high complexity of product family "Premium" more variables had to be monitored during the data collection compared to product family "Basic". Therefore, the data collection started with product family "Basic". This experience allowed to evaluate the method and also make the adjustments that was needed to be able to perform the data collection on product family "Premium". The adjustment included rationalization of the weighting procedure since it was detected that the work load for the operators became too high when adding the data collection to their ordinary tasks. Therefore, instead of having the operators weighting and writing down the waste they spotted it was instead solely handled by the two volunteers and the author. The adjustment also allowed adding more detailed information about the underlying causes for the waste since the operators did not have time to register this after the weighting in order to support production to running. For more information about the two product families see sub-chapter 4.3.2.

3.6 Reliability

To further ensure the quality of the case study reliability is needed. High reliability is defined by Eriksson and Wiederheim-Paul (2001) as obtaining trustworthy and stable results from measure instruments and recommends the researcher to ask the question "would other researchers obtain the same results if they used the same method?". If the answer is yes then the reliability is high. Rosengren and Arvidson (1983) states that the reliability of a single measure can be affected by the random or rare features of e.g. a measure instrument, the human factor or the measured object. Furthermore, the authors argue specifically for interviews to be challenging since outer factors e.g. as noise and temperature can affect the answers of the interviewee, but also human factors like e.g.

illness or tiredness. Even though it is impossible to have some level of reliability Rosengren and Arvidson (1983) suggests tackling the problem with standardization, e.g. interview approach and instructions. Furthermore, both Rosengren and Arvidson (1983) and Wallen (1996) suggest repeated measure of the same object to ensure reliability.

For the case study's qualitative data collection the reliability can be questioned against Rosengren and Arvidson (1983) argument of outer factors as many of the interviews were conducted by a converting line which is a relative noisy environment. On the other hand, this a regular environment when working in the mill and the people are used to communication under these conditions. Moreover and most importantly, the interviews conducted on the converting line enabled the author to receive on spot demonstrations of the process and waste which is the backbone of this case study. Furthermore, as a response to Rosengren and Arvidson (1983) suggestion the interviewees were well informed on the purpose of the study.

As for the quantitative data collection the affected people were well informed with instructions on what to do when waste occurs. In addition, and Wallen (1996) suggestion on repeated measure had to be adjusted due to the resource constraint. The repeated measure was adjusted in the sense that all the values shown on the scale's display where first registered either on a piece of paper and then to the computer (product family "Basic") or directly to the computer (product family "Premium"), and then double checked by again looking at the scale's display.

3.7 Validity

Eriksson and Wiederheim-Paul (2001) define validity as the ability of a measure instrument to measure what it is supposed to measure, while Rosengren and Arvidson (1983) define validity as the absence of systematic errors of a measure. According to Rosengren and Arvidson (1983), the validity of new methods can be somewhat tricky to assure due to the lack of existing data. On the other hand, according to Wallen (1996) the question of validity can be approached with well-defined limitations of the object for the measure. Moreover the author suggests having a clarified link between the theoretical variables and what should be measured.

The interviews conducted for this case study had a great impact on securing the validity as the interviewees helped to develop and made sure that the case study waste data method measured what it intended to. The case study method intended to measure the paper waste and the distribution of paper waste in the process, hence it was weighted and registered for which part of the process it belonged. Furthermore, as the limitation of the case study only include paper waste all the measured waste that included core paper, being log waste and roll waste, was deducted by the using the mentioned sampling values.

Furthermore, as previously mentioned the case study waste data method was developed from the company's waste data method with the purpose was to fill the gaps that occur with using the established method. As a response to Wallen's suggestion (1996) the two methods were carefully compared to clarify the link between the theoretical variables in the company's waste method and the measuring of waste for the case study method. In that sense the validity of the case study waste data is relatively higher when comparing to the company's waste data.

4 RESULTS

This chapter presents the results of the data collection. Firstly, a background of the company and the paper mill will be presented. The end of the chapter presents specific results from converting line 10 where the waste data is displayed alongside with the root cause of the waste.

4.1 Company background

The history of the paper mill in Lilla Edet dates back to 1881. Throughout the years the mill has evolved in various constellations and since 1986 the mill belongs to SCA. SCA is a company which develops and produces personal care, tissue and forest products and employs around 44 000 people and have sales in 100 countries, which amounted to 115 billion SEK in 2015 (SCA, 2016b).

SCA is Europe's largest private forest owner and puts a lot of emphasis on sustainability. All SCA's forests are FCS-certified. FCS stands for Forest Stewardship Council and is a global, not-for-profit organization dedicated to the promotion of responsible forest management worldwide (FSC, 2016). Furthermore, SCA's sustainability targets include for instance reducing CO2 levels from fossil fuels, increasing production of wind power on SCA forestland and employing mechanical and biological water treatment plants on all pulp and paper mills (SCA, 2016c).

Over the past few years the company has experienced an increase of external monitoring where high rankings in sustainability performance is an essential part of attracting customers and investors. SCA's sustainability effort has earned the company a place in Dow Jones' 2015 Sustainability Index, which is considered to be one of the world's most prestigious sustainability indexes (SCA, 2016d).

Regarding SCA's business area Tissue, the sales amounted to 64 billion SEK in 2015 with production at 58 mills in 20 countries. The market is divided between a consumer sector and AfH sector where SCA's is the market leader in Afh with the global brand Tork, which alone generates some 10 billion SEK annually. In the consumer tissue sector the company is on a second place globally and at the same time by far number one in Europe with a market share twice as big as the second largest player. Production is divided between SCA's own brands and retailer's brands, so called "private label", in total sales they represent 64 % and 36 % respectively (SCA, 2016a).

4.2 Edet mill

One out of five rolls on the European market originates from a SCA mill and many of them come from the tissue mill in Lilla Edet. Currently, the number of employees at the mill is 430. The mill has a production capacity of 100 000 ton per year which consists of mainly kitchen paper and toilet paper in various forms as well as industrial rolls. The sales and marketing department is located in Gothenburg, which together with SCA's customers are the most important stakeholders when it comes to what kind of products that should be produced. The mill produces both consumer tissue and Afh products with both SCA brands as well as private labels. SCA's consumer tissue brand is the well-known Edet, which is one of the oldest brands in Sweden and the AfH brand is, as previously mentioned, Tork.

Simplified, the organization of the mill is divided into four different departments, which in the process order are (1) Powerplant and Site Infrastructure, (2) Papermaking and DIP/Pulp, (3) Converting and (4) Logistics. The first department provides the mill as well as the surrounding community with power. The second department produces the paper, which includes everything from preparing and mixing the ingredients for the papermaking to producing the mother reels. The third department converts the mother reels into rolls, which are eventually packaged and palletized. The department consists of 10 converting lines. The forth department includes an international distribution center (IDC) where the stock keeping of finished products take place. Figure 6 presents the organization chart of the Edet mill.

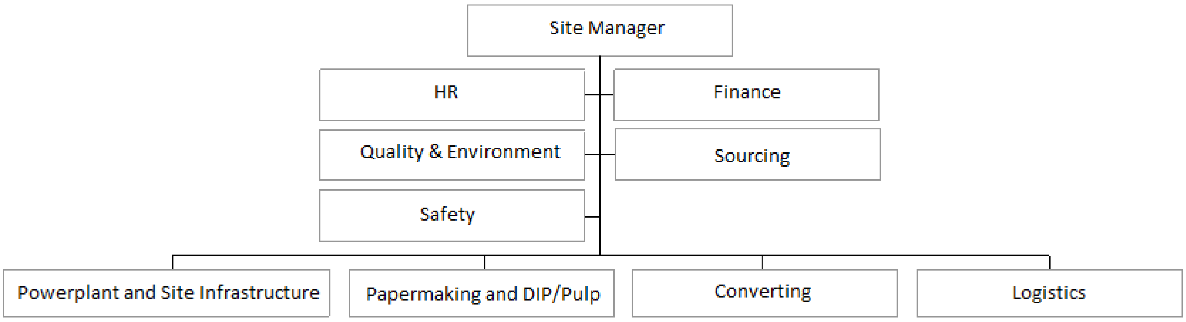

Figure 6: Organization chart Edet mill.

The mill operates according to ISO standards and is certified with ISO 9001, ISO 14001 and ISO 50001. The most recent major sustainability project was carried out in the autumn of 2015 when nearly 25 million SEK were invested in a water reduction program. The outcome of the program included 30 % annual reduction of water consumption (from 3 billion cubic meters to 2 billion cubic meters), contributing to increased environmental performance with better water treatment as well as cost reductions in water and energy consumption (SCA, 2016c).

Another successful example of the sustainability work is when the mill a few years ago shifted from generating disposal of bi-products into landfills to starting using it for heating and eventually selling the ashes. The resulting ashes are considered to be valuable material in other industries. The raw material used in the mill's production is 86 % recovered paper and the remaining 14 % is virgin fiber. The bi-product of recovered paper is generated by a screening of unwanted impurities which creates a so called "sludge". The burn of sludge generates steam for drying the paper as well as electricity and heat for the mill and the community. The bi-product of burning sludge is sludge ashes and amount to some 25 000 tons annually. The ashes have been proven to reduce energy consumption and emissions when used as a binder when producing asphalt. Other applications of the ashes include construction material for forest roads and replacing lime to raise the pH level of farm soil. The ashes are considered to be environmental friendly alternative to the traditional materials and has been certified with KRAV which is a Swedish ecological certification standard (SCA, 2009).

The mill uses several key performance indicators, KPIs, that are clustered into five major groups being safety, quality, delivery, cost and morale. Safety is the top priority with the aim of having zero workplace accidents. The relevant KPI for this case study is the converting tissue waste which falls under the cost cluster. The unit of the measure is percent (%) and the level of detail includes mill, converting, converting product group and converting line and is reported on a monthly basis. The company's method for calculating the paper waste can be found in sub-chapter 3.5, Table 1.

The current desire at the mill is to reduce the converting line waste. The upper management suspects a significant difference between the input of paper in the converting department and the output of finished products that goes to the IDC. As a result, the converting lead team at L10 has been given the task to investigate the possibilities of reducing the paper waste. Currently, the paper waste in the production process is based on reports with theoretical values on the output data, which may differ from the reality. Furthermore, these reports only show the total waste, hence creating difficulties in tracking and tracing where in the process the waste occurs. In order to get a better overview of the paper waste the converting lead team has set the project deliverables to:

1. Identifying paper waste on the converting line.

2. Perform actual weighting of paper waste and compare with the established method.

3. Analyze correlations/deviations for paper waste of different product families.

4. Analyze reasons for paper waste and propose actions to reduce it.

The results of the two first deliverables are presented further on in this chapter while the two last deliverables are part of the discussion chapter as well as the conclusion chapter.

4.3 Converting line 10

The management of L10 is shared with converting line 12 (L12) as both converting processes are very similar. The lead team consists of a Resource Support Team (RST) leader, a process engineer and a maintenance leader. The RST leader is the head of the lead team, responsible for personnel and performance and reports to the converting manager. The process engineer supports the RST leader with analyzing production disturbance and improving the process. The maintenance engineer, together with a team of one automation technician and one mechanic, supports the RST leader with maintaining the line to avoid break downs. Figure 7 presents the organization chart of L10.

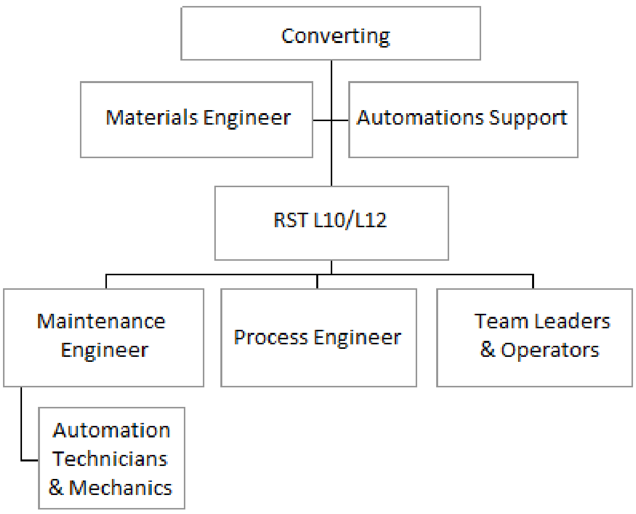

Figure 7: Organization chart line 10.

The production line is operated by four operators and two operators at the palletizing. The operators work five shifts and the production is running all year around except for Christmas Eve. Each morning at 08:00, Monday through Friday, the lead team of L10 has a start-up meeting together with the subordinates of the maintenance engineer and the team leader for the current shift. The meeting goes through the previous day's performance, stop codes and the operators' log book. Based on this information the lead team divides the needed tasks for the day. The duration of the start-up meeting varies, but is usually between 30 minutes to an hour.

In 2015 L10's net production of finished products was around 15 000 tons, representing 15 % of the total volume carried out in from the converting department for the same period. The finished products include consumer size kitchen towels and toilet paper serving both the consumer tissue market and the AfH market.

As explained in the theoretical framework the converting process consists of the following stages: unwinder, embosser, rewinder, tail sealer, accumulator, log saw and packaging. Henceforth, the word "converting machine" will include the three first stages mentioned above (unwinder, embosser and rewinder). In addition, in front of the unwinder stage L10 has a preparation stage for the incoming and consumed mother reels. Moreover, after the packaging stage there is a sack machine which can wrap the packages if needed. Conveyer belts from both the packaging machine and the sack machine connects the palletizing where the products are put on pallets.

L10 consist of automatic processing with manual feeding of the input material (the mother reels). The mother reels have a specification width of 341 cm and generally have a diameter around 190 cm which includes the 30 cm mother reel paper core diameter. Incoming mother reels generally weights around 2000 kg. During the production of rolls the operators conduct sampling once every hour to ensure the quality of the roll by e.g. measuring the width, weight and thickness. The operators are also responsible for replenishing the input material (core paper) for the core machine, which is located next to the converting machine and produces the roll core paper that is used in the creating the logs in the rewinding stage.

4.3.1 Product families for waste data collection

As mentioned in sub-chapters 1.3 and 3.5 the waste data collection was narrowed to toilet rolls for two product families, being product family "Basic" and product family "Premium". Table 2 displays a comparison of the two product families in terms of product features and production characteristics.

	Product family "Basic"	Product family "Premium"
Product features	The rolls have one ply and are relatively compact, heavy, long and thin. Consists of 100 % recycled fiber pulp, labelled Nordic Swan.	The rolls have of three plies and are relatively short, soft and thick as well as light in weight. Consists of virgin fiber pulp, labelled Nordic Swan.
Unwinder stage	During production only one unwinder is running.	During production three unwinders are running in parallel.
Embosser stage	The paper does not go through any value-adding in the embossing stage.	In the embossing stage the paper goes through cylinders that bulks, laminates, decorates.
Rewinder stage	The paper is rewinded on logs and cut once the logs are fully winded.	Before the logs are winded and cut, perforation is added on the paper.
Tail sealer stage	Generally all logs are successfully sealed.	Generally all logs are successfully sealed.
Accumulator stage	Due to the relatively heavy logs the accumulator cannot be fully utilized. Hence it takes relatively short time to make the accumulator full (which generates stops).	Since the logs are relatively light in weight the accumulator can be fully utilized. It takes relatively long time to make the accumulator full (which generates stops).
Log saw stage	Due to the relatively compact logs the log saw cannot be fully utilized. The capacity of the log saw is to cut four logs in parallel, however it can only cope with cutting two logs in parallel for product family "Basic", hence creating a bottleneck. Furthermore, the log saw has challenges with cutting the rolls in the desired width.	Since the logs are relatively soft the log saw can be fully utilized by cutting four logs in parallel, thus having a relatively high throughput.
Packaging machine	Due to the relatively compact and heavy rolls the technical solution is relatively highly dependent on the rolls having the specification values (right quality).	Due to the rolls being relatively soft and light in weight the settings of the technical solution is relatively independent from rolls having the right quality.
Palletizing	Similarly to the previous section, the technical solution at the palletizing is relatively highly dependent on the rolls having the right quality.	The current path of the conveyer belt that transports small size three-ply packages is a bottleneck as they are frequently queuing to enter the package feeder of the palletizing machine.

Table 2: Characteristics of the product families.

4.3.2 Identified paper waste parts of L10

Throughout the process twelve different parts have been identified where paper waste occurs, which are displayed in Figure 8. The twelve parts are individually explained below the figure.

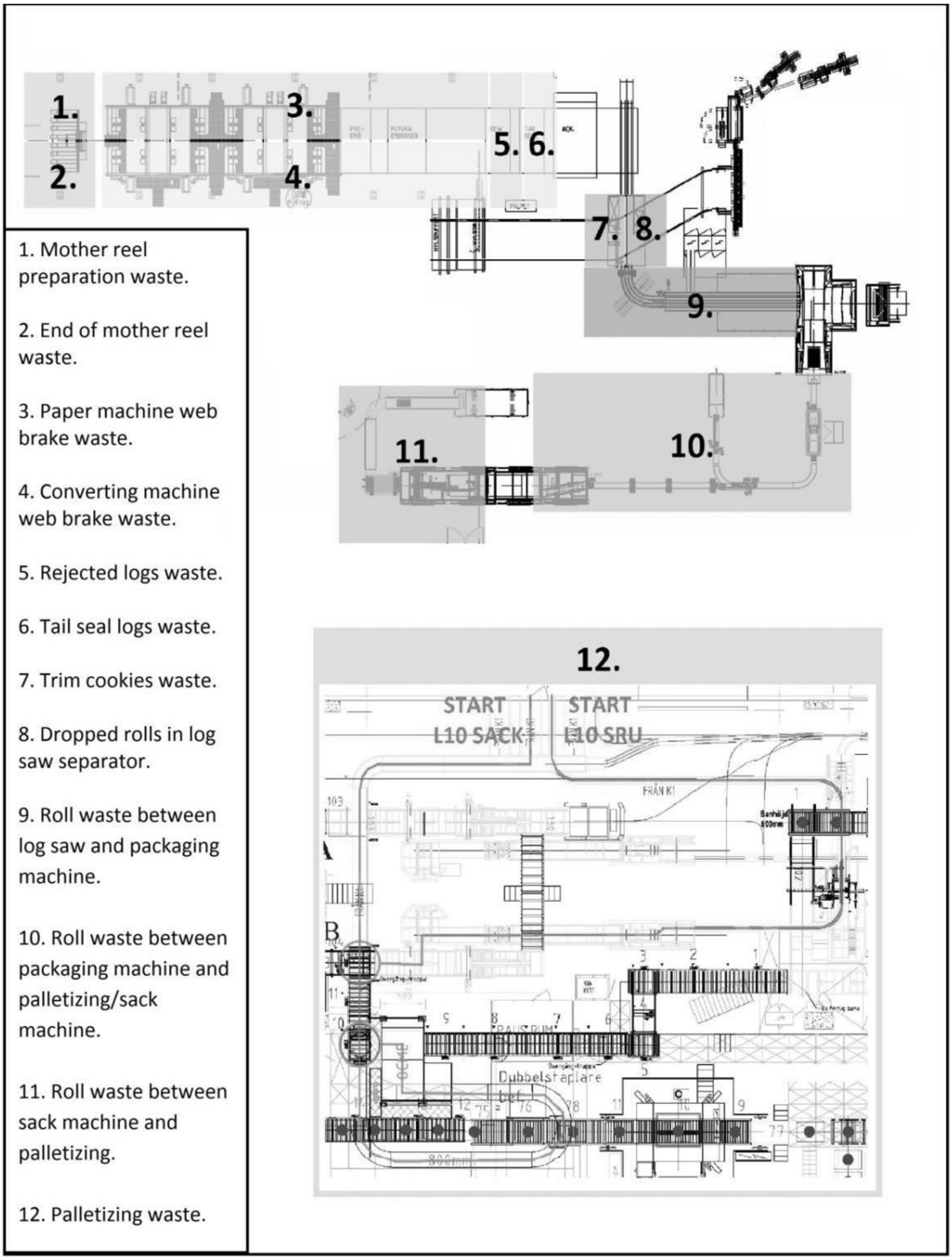

Figure 8: Identified paper waste parts of L10. (Note that the palletizing is located one floor below L10 (for more information see Part 12 below the figure).

Part 1 – Mother reel preparation waste.

Each time a mother reel has been consumed in one of L10's three operating unwinders the operators replenish it with a new mother reel. This starts with the operators placing an order through the mill's material requirements planning (MRP) system. The new mother reel is then automatically delivered by a self-going truck, so called “AGV”, from the warehouse to L10’s preparation stage for the incoming and consumed mother reels, which is located in front of the unwinder (see 1. and 2. in Figure 8). The mother reels arrive at L10 sealed with tape in a spiral. This is the case since it simplifies the handling of the mother reels prior to they L10. Before the new mother reel is put into the unwinder the operators rip off its first few layers of paper. This gives the mother reel a good and straight start of the paper and is then taped on the end of the paper from the unwinders previous mother reel. After this is done the unwinding can start again.

The paper that was ripped off is the so called “mother reel preparation waste” and is recycled by going into a solver and is eventually used for producing new mother reels. Currently, there is a recommendation on how to minimize the number of layers that needs to be ripped, however this is just a recommendation rather than a standard.

By observing the work of operators, two types of behavior have been detected at this part, (1) some operators treat every mother reel individually and inspect it before choosing how many layers to rip off and (2) some operators treat every mother reel equally and rip off the same amount of layers no matter what the quality of it is. Clearly, some operators rip off more layers than others.

Furthermore, observations detected that the handling of mother reels before entering the preparation stage at L10 caused additional waste. This can be divided between automatic handling (AGVs) and manual handling.

For the automatic handling the observation showed that at least one of the AGVs that supply L10’s mother reels have a metal piece sticking out from the middle of the truck. This creates a hole in the outer layers of the mother reel, which results in the operators having to rip of more paper than usual. Another case of error which includes AGV is when the truck drops of the mother reel at the preparation stage where the mother reels gets damaged due to lack of order at the drop off area. The operators have access to an instruction for how the drop off area should look like and mostly it is fulfilled.

Lastly, damages caused by manual handling have been identified to include mother reels being squeezed by the fork of the truck when picking up the mother reel. Moreover, damages of mother reels have been identified when in transit due to lack of caution. Manual handling of mother reels occurs when e.g. there is a shortage or breakdown of AGVs.

Part 2 – End of mother reel waste.

When the consumption of a mother reel is starting to reach the mother reel core the operators begin to decrease the speed of the unwinding to avoid a web breaks (web brakes are further explained in Part 3). The paper on the mother reel tends to be more loose (unstable) the closer it is to the core, hence the operators stop the unwinding completely before it reaches the core. There is no current standard procedure on when to stop the unwinding, every operator have their own way off determining how far they will unwind the mother reel. When the operators finally stop the unwinding they replace the old mother reel with a new one (as explained in Part 1). The old mother reel is taken to the mother reel preparation stage where the operators cuts off the remaining from the core, which becomes the so called “end of mother reel waste” and is recycled in the solver.

When the paper is gone from the mother reel core the operators are instructed to examine the core for defects and sort out the bad ones, while the good ones are re-used by Papermaking and DIP/Pulp department (henceforth PM) when producing new mother reels. Even though there is an instruction on sorting out bad mother reel cores many operators are not doing it and explains that the focus is on keeping the production running. The issue with reusing bad cores is that PM is unable to produce proper mother reels. The winding close to the core gets even more unstable with more paper being loose than usual. This results in the operators at L10 having to stop the unwinding earlier than usual which means more paper waste.

In addition, it has been observed that there is a variation of loose ends even for the mother reel cores that meet the quality requirements. Further investigation show that PM's current technical solution for producing the mother reels cannot avoid the variation of loose ends, however it can be reduced by using only good cores.

Part 3 – Paper machine web brake waste.
Web breaks mean that the paper from the mother reel brakes somewhere in the converting machine and cause unplanned stops. Web brakes are generally very time consuming as it usually includes time spent on finding the error and also time spent on fixing it, and in worse case also time spent on waiting on experts to come and solve the problem. When web brakes occur the operators need to enter inside of the converting machine (restricted area) and manually thread the paper so that it gets through all the cylinders. For the operators this often includes work in uncomfortable positions as there is a lack of space inside of the converting machine, there is always a safety risk connected to stepping inside of the restricted area.

The so called "paper machine web brake waste" refers to the waste of the web brakes caused by PM in form of a splice in a mother reel. At PM splices are caused by web brakes during the production of mother reels. Simplified, the procedure at PM when web brakes occur: in the case when a significant amount of paper has been winded on the mother reel then instead of scrapping there are two options, (1) either the mother reel it is sent to the stock keeping and then used by the converting or (2) if there is space for addition paper on the mother reel another round of paper is winded on it. The second option is done in order to utilize the production, both at PM and the converting department, as mother reels with bigger diameters equals to less replenishments. Furthermore it utilizes the space for the stock keeping. However, the drawback of the second option is that it generates the splices. As explained in Part 2 the paper closest to the core (the start of PM's winding) tends to be more loose, in the same sense the splice area of the mother reel is loose. Hence, the operators at L10 need to perform the preparation explained in Part 1 twice on mother reels with splices. In other words, preparation is done the first time when ripping of the first layers of the incoming mother reel and the second time when ripping of the splice.

When a mother reel has a splice the standard procedure is to mark the location of the splice on the side of the mother reel before it leaves PM, which is done by workers at the department. Later when the mother arrives to the converting the operators at L10 will then see the marks and thus know when to reduce the speed of unwinding and eventually stop the unwinder to avoid a web brake. The splice is then ripped off and recycled by the solver. When the mother reel is cleaned from the splice the unwinding continuous until it is consumed (as explained in Part 2).

Mother reels with splices are rare, but when they occur they usually cause paper waste that is out of proportion for L10 regular production conditions. To avoid misleading waste values for the converting department the L10's operators are instructed to conduct reclamation on splices through the MRP system, in this way the waste is moved from the converting department to PM. The MRP system has a built in formula that can calculate the partial weight of a mother reel (in this case the weight of the splice). The formula is based on the mother reel's specification grammage, specification thickness and specification width. The operators need to fill in the start diameter and end diameter of the mother reel's sought partial weight. Figure 9 presents the formula in specific, where the dark grey area represents the mother reel's sought partial weight, while the light grey area represents the rest of the mother reel.

Partial weight of mother reel (kg)
= Specification grammage (g/m2) * Specification width (m) * Paper length (m) / 1000

Where:

Paper length (m) = pi/4 (Do^2 - Di^2)/t

Do = Outer diameter

Di = Inner diameter

t = Specification thickness

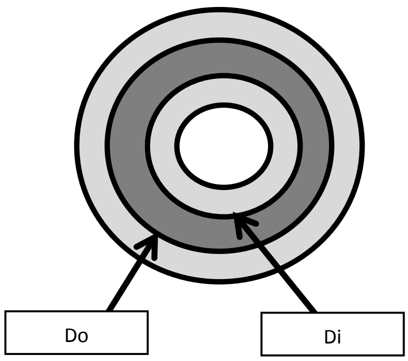

Figure 9: Calculating partial weight of mother reel.

Furthermore, the most rare splices are the so called "undetected splices" where paper contains holes that are small enough to not cause web breaks when winded on to the mother reels at PM, hence the defect pass through PM unnoticed. However, the holes in the paper are big enough to cause web brakes in the unwinding at L10, resulting in threading the paper manually all over again.

Even though there is an instruction for operators to conduct reclamation on splices, far from everyone do it. When asked upon why the operators state that reclamations are not considered being important for the daylily work as the priority is to have the production running. Furthermore, some operators are not familiar with how to conduct reclamations.

Part 4 – Converting machine web brake waste.
The so called "converting machine web brake waste" is the waste of web brake waste caused by the converting machine itself. When the converting machine drags the paper to hard, the paper breaks. When these types of web brakes occur the operators usually readjusts the settings in either the unwinding, embossing or rewinding, or a combination of them. According to the operators the

converting machine web brakes tend to occur more frequent than paper machine web brakes, especially during the set-up of new production orders.

However, in many cases it is a difficult to decide whether a web brake in the converting machine was caused by PM or the converting department. Many web brakes occur when the converting machine is unwinding the paper in speeds of over 500 meter per minute, making it hard to know what went wrong.

Part 5 – Rejected logs waste.
Between the rewinder stage and the tail sealer stage there is a so called “log rejecter” that is activated by the operators whenever they perform quality checks of logs or to scrap logs for not meeting the quality requirements. The so called “rejected logs waste” refers to all the logs that come out of the log rejecter. The log rejecter is activated every time during the change of mother reels to take out the log which contains the tape that connects the paper from the old mother reel with the paper from the new mother reel. In the same sense, each time when web brakes occur the current log that is winded needs to be rejected.

Furthermore, specifically for multi-ply products the log rejecter is activated each time after a stop of the converting machine, which generates so called “start-up logs". This is explained by the fact that the laminating cylinder that glues the plies together does not function before the converting machine reaches the speed of 50 meters per minute. Hence, every start-up log has insufficient lamination and has to be rejected. All the rejected logs are recycled by the solver.

After further investigation of the converting machine stops a distinction is made between planned stops and unplanned stops, where the former includes e.g. maintenance while the latter includes breakdowns of the converting machine and other disturbances in the process. It has been observed that during regular production unplanned stops are frequently caused by the packaging machine as well as the palletizing. Specifically for the packaging machine two main causes have been identified, being the package handles and the settings of the package machine. The package handles are added to the package from a separate plastic film which tends to get stuck in the packages machine and create stops. Furthermore, for the production orders with small size packages the handles become a bottleneck. This is a fact since the operators need to decrease the speed of the packaging machine for the handles to properly stick to the packages. The other main cause is the packaging machine’s settings can randomly change 10-20 mm when running. This causes stops and forces the operators to readjust the settings.

As for the unplanned stop in the palletizing, three frequent causes have been identified. The first cause is the lack of quality of incoming pallets which are supposed to be used for the finished packages. Before the packages are built on pallets, the pallets arrive stacked in quantities of nine or twelve on a conveyer belt from the IDC (from where they are re-used). To ensure the pallets’ quality, the stacked pallets go through sensors before they are separated. The purpose of the sensors is to detect missing planks and uneven pallets. Together with the IDC (the supplier of the pallets) it is agreed that these problems may occur. In the case when the sensors detects missing planks or uneven pallets the conveyer belt stops and cannot start before the operators manually solve the problem. Generally, the palletizing stops are solved before they generate stops in the converting machine. Stops in the converting machine only occur if the time for solving the problem at the palletizing exceeds the time for filling up L10’s accumulator (L10’s buffer). However, the observations show that most of the palletizing stops that also generate stops in the converting machine are those that include uneven pallets in the stack. When further investigating the issue, it was concluded that the pallet stacks are very likely to get uneven during the transit from the pallet stacker until they reach the sensors. There is a significant distance from the point where the pallets are stacked to the point where the sensor examines them. Furthermore, the observations have detected that the sensors react (and stop the conveyer belt) when plastic or paper are hanging out of the pallets. This quality error is below what IDC has promised for their outgoing pallets.

The second cause of the three frequent causes identified for palletizing stops is specific for the production of one-ply products. Packages with one-ply rolls that possess a greater width than the specification width (9.8 cm) tend to get stuck in the package feeder of the palletizing machine. This causes stops both at the palletizing as well as at L10. The technical solution of the feeder is designed by using the package's specification width as a reference point. The technical solution includes a feature that can vertically move the feeder, which allows smaller variations of the rolls' width. However, the technical solution does not cope to move when packages with one-ply rolls enter the feeder due to the fact that these rolls are relative compact and heavy compared to the muli-ply products.

The third and last cause of the identified frequent causes for palletizing stops is a bottleneck specifically connected to small size packages that contain three-ply products. It has been observed that the packages are queuing to enter the package feeder of the palletizing machine. This is explained by the fact that three-ply products have a greater throughput compared to one-ply products and two-ply products. The current path of the conveyer belt that transports the packages into the package feeder is the bottleneck.

Besides the unplanned stops, the operators' behavior possesses a great potential of reducing the rejected logs waste. Currently, there are no instructions for the operators on how they should operate the log rejecter efficiently. By observing the operators during the production of three-ply products some operators rejected two logs per start-up while others rejected up to four logs per start-up. This is explained by the fact that operators with less rejected logs held the converting machine on a speed just above 50 meters per minute during the start-up. In contrast, operators with more rejected logs speeds up the converting machine more or less instantly to regular production speed. The problem with speeding up instantly to regular production speed is that all the mechanisms in the converting machine are not functioning straight away, which results in more paper waste compared to if the converting machine remained on a low speed (as explained above).

In addition, even though one-ply products do not have laminating and thus do not need to reject any "start-up logs" it has been observed that some operators reject logs for these products anyways. When asked why, the operators state that rejecting the first log for any product is an easier procedure than having an additional procedure for the one-ply products.

Part 6 – Tail seal logs waste.

The so called "tail seal logs waste" refers to waste caused by insufficient tail sealing which counts as defective logs and are usually taken out by the operators once they reach the accumulator stage. Sometimes unsealed logs can go through the accumulator stage unnoticed, and once they go into the log saw and come out as rolls on the other side the paper starts to unwind before and during packaging, which could, in worst case scenario, get shipped all the way to the customer and result in a customer complaint. All the detected waste at this part is recycled by the solver.

Part 7 – Trim cookies waste.
When the logs enter the log saw they are cut into rolls. For toilet products each log gives 34 rolls. However the first cut and the end cut of each log, so called “cookies”, are rejected by a separator in order to only deliver fine rolls to the customer. The separator includes a vacuum solution that holds up the rolls and transports them to the conveyer belt that goes into the packaging machine. The cookies on the other hand, fall down in a pipe and are sucked out to the solver where they are recycled.

In theory, each log should have a trim cookies waste of 2.29 %. This is valid under the circumstances that the log width is equal to the mother reel specification width (341 cm) together with the log saw cutting the 34 rolls according to their specification width (9.8 cm).

The importance of achieving specification values can be exemplified as: If the incoming mother reels have a greater width than the specification width the trim cookies waste becomes greater than 2.29 %. On the other hand if the incoming mother reels have a smaller width than the specification width the log saw will not be able to cut 34 rolls per log. Moreover, if the rolls have a greater width than the specification width they can create stops in the palletizing (as mentioned in Part 5) as well as unstable finished pallets. In addition, this affects the customer perspective. One hand customers are receiving more paper than what they pay for. One the other hand customers can complain that the rolls are too wide for their containers. Lastly, if the rolls have a smaller width than the specification width the trim cookies waste becomes greater than 2.29 %. Furthermore, customers are likely to complain.

Part 8 – Dropped rolls in log saw separator.
The so called “dropped rolls in log saw separator” refers to the waste caused by the inability of the separator to carry all rolls. The separator has different settings for different products and if the settings are not adjusted properly some rolls will start falling down and end up with the cookies. Generally, the vacuum solution has more challenges with holding up heavier rolls. Some operators argue that the current technical solution cannot fully avoid dropped rolls and thus needs to be replaced with better technology. On the other hand, some operators state that L10 can achieve the elimination of dropped rolls if the instructions for settings of the separator were revised and updated as they currently are poor.

Part 9 – Roll waste between log saw and packaging machine.
This waste refers to the rolls that come out of the log saw and do not meet the quality requirements. The rolls are manually thrown by the operators from the conveyer belt before reaching the packaging machine. Generally, the defective rolls at this part are either unsealed or dirty from dust caused in the log saw after maintenance. However, there are cases where defective rolls pass through unnoticed all the way from the converting machine. The rolls are thrown into green bins and once they are filled they are taken to the solver’s drop off point where they are recycled.

Part 10 – Roll waste between packaging machine and palletizing/sack machine.
All rolls that reach the final customer goes through the packaging machine that packages the rolls into plastic, also referred to as a “sales ready unit” (SRU). The packaging machine is able to pack the rolls in many different sizes depending on what the customer order. The minimum for toilet products are 4-packs. Some rolls that come out on the conveyer belt between the packaging machine and the palletizing/sack machine may not meet quality requirements for the same reasons as mentioned in previous parts. Additionally, if the packaging machine has issues with producing packages that meet the quality requirements then all rolls are recycled in the package regardless of the rolls meeting the

quality requirements. Generally, defective packages are caused by the package sealer not sealing or missing rolls during the buildup of a package which results in packages with missing rolls. Furthermore, break downs of the packaging machine have also been observed caused by the handle plastic that is attached to the package plastic. The recycling of rolls meeting the quality requirements is significant since it is rare that rolls actually become defective in the packaging processes. The operators state that they are contaminated and that it would take up too much time for the operators to put back the rolls one by one on the conveyer belt. According to the quality manager, the rolls meet the quality requirements as long as they have not been deformed in the defective package. When asked upon contamination, the quality manager replied that as long as the hands of the operators are clean, the rolls meet the quality requirements.

Part 11 – Roll waste between sack machine and palletizing.
Packages going out from the packaging machine are divided between two conveyer belts, one going straight to the palletizing as SRU and one going to the sack machine that wraps packages together in plastic sacks. Depending on the customer order production run can consist of solely packages or sacks, or both a so called "combi order". The waste at this part are those rolls that for some reason get deformed during the sack packaging process, which rarely happens. However, when it occurs all the rolls that were in the package are recycled, just as explained in previous part. In contrast, when a sack is defective the operators take it to the side and put back all the packages that are intact on the conveyer belt going into the sack machine, hence most of the packages are re-used in new sacks.

Part 12 – Palletizing waste.
As previously mentioned, the packages and sacks reach the palletizing on separate conveyer belts, in Figure 8 on the upper side of Part 12 the paths of the two conveyer belts begin, where the left one is for sacks, while the right one is for packages (SRU). Once the products reach the palletizing, which are located one floor under L10, they are automatically handled by two pallet machines where one builds pallets with packages and the other one with sacks. When a pallet has been built it is transported down to the next floor and at the same time registered into the system as a finished pallet. The number of finished pallets is used in the company waste data method to calculate the theoretical output (as explained in sub-chapter 3.5). In Figure 8 the two circles in Part 12's lower left corner represent where the pallets are registered as finished products, the upper circle is the for pallets with packages while the lower one is for the pallets with sacks. The pallets are then transported to the wrapping machine for stabilization and then sent for storage in the IDC. The so called "palletizing waste" refers to the defective packages or sacks that are detected at the palletizing before the pallets are registered as finished. In general, palletizing waste is rare for two main reasons (1) the packages or sacks are already detected at the previous parts of the process, (2) it is difficult for the operators to detect any defects that are not related to the plastics. In the case of defective sacks the intact packages are sent up to the converting for re-use. As for defective packages, the rolls are sent to the solver for recycling.

4.3.3 Total paper waste testing results

The collected data for paper waste testing is summarized by using both the case study method as well as the company method. Table 3 and Table 4 presents the total paper waste testing results, the former for product family "Basic" and the latter for product family "Premium".

Product family "Basic"	Input (kg)	Output (kg)	Waste (kg)	Waste (%)
Results based on the case study's waste data method	7407	7060	347	4,7
Results based on the company's waste data method	7336	6980	356	4,8

Table 3: Results of total paper waste for product family "Basic".

Product family "Premium"	Input (kg)	Output (kg)	Waste (kg)	Waste (%)
Results based on the case study's waste data method	5961	5694	267	4,5
Results based on the company's waste data method	6473	5652	821	12,7

Table 4: Results of total paper waste for product family "Premium".

As seen the results for product family "Basic" obtained almost the same waste percentage for both methods. In contrast, the results for product family "Premium" show a significant difference. Regarding the results based on the company method for product family "Premium" the input weight had to be adjusted by calculating and deducting partial weights of the mother reels. This was done due to the fact that the products within the product family are consists of three plies. This means that during the testing three mother reels were used in parallel (on different rewinders). Since incoming mother reels do not have the exact same diameter and weight each of them are consumed and replaced at different times, resulting in different mother reel combinations during the testing. In order to control the input value for the experiment a defined start and end of the input weight data was required.

Therefore, five mother reels were chosen to be part of the testing and were named A, B1, B2, C1, C2, where B1 and B2 was put into the rewinder 1, C1 and C2 into rewinder 2 and A into rewinder 3. Mother reel A was the reference point for the testing as it is the only mother reel that was entirely consumed within the testing and thus entirely included in the input data. As for mother reels B1 and C1 they were put into the rewinders before mother reel A while mother reels B2 and C2 were replaced B1 and C1 after they were consumed and thus B2 and C2 were still in their rewinders once mother reel A was consumed.

The counting of input data began once the mother reel A (the third in order after mother reels B1 and C1) was put into the rewinder. This means that the weights that were already consumed from the other two mother reels (B1 and C1) were deducted from the total weight of the mother reels, which was done by using the very same formula that the company uses for reclamation of splices, see sub-chapter 4.3.1, Figure 9. In the same sense, after the third mother reel A was consumed and replaced, the remaining weights of the two other mother reels (B2 and C2) were deducted by using the mentioned formula. For the specific calculations of the input data that was used for the company method, see Appendix 1.

As seen in Table 4, deducting the partial weight of mother reels used in the testing turned out to significantly affect the results of the company's method. This is further elaborated in the discussion chapter.

4.3.4 Distribution of total paper waste

The case study method enabled to break down the total paper waste into the twelve different parts of the process (shown in Figure 8). Figure 10 and Figure 11 display the distribution of waste, the former for product family "Basic" and the latter for product family "Premium".

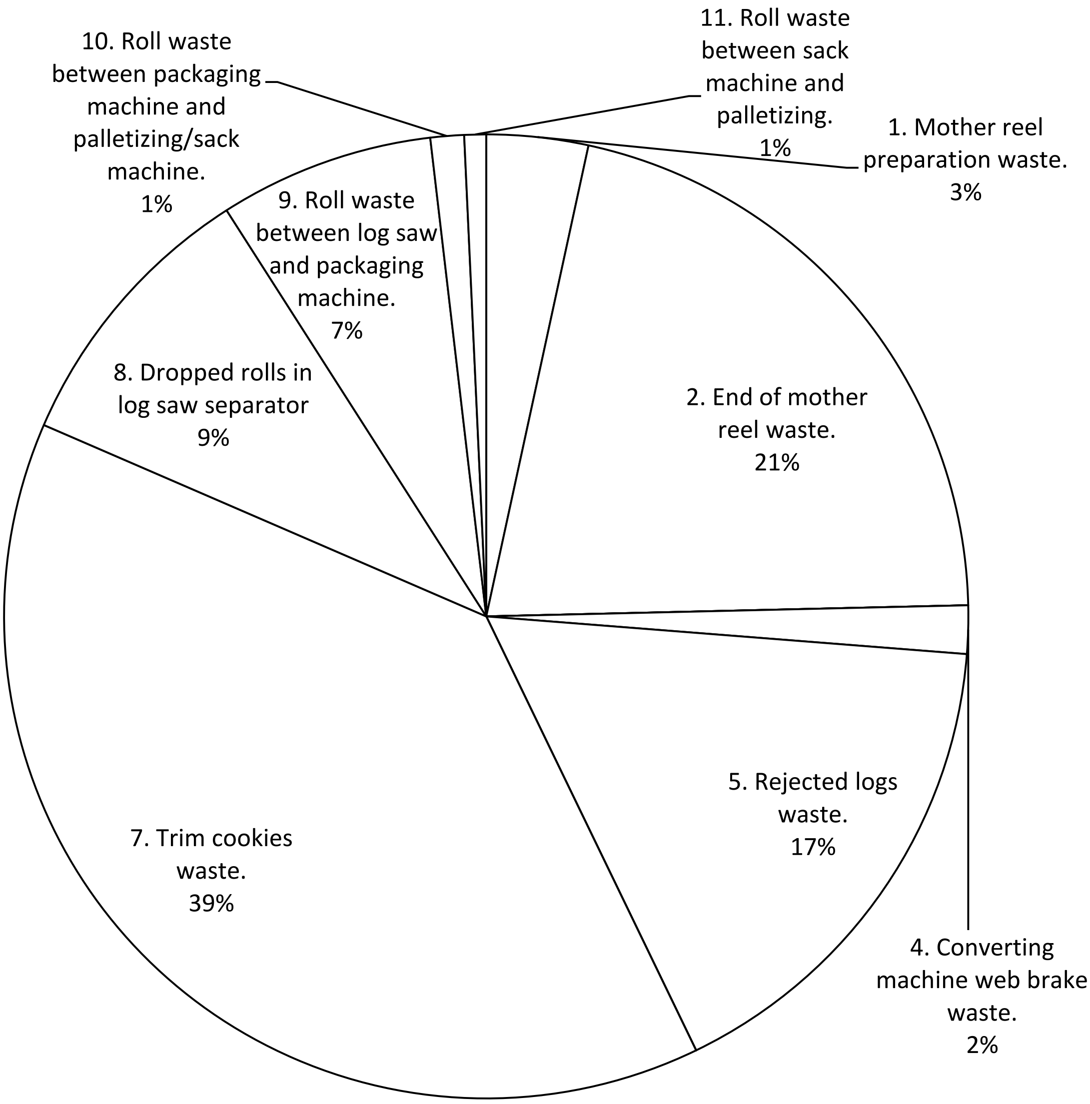

Figure 10: Distribution of paper waste for product family "Basic".

During the testing for product family "Basic" no waste occurred for the following parts:

Part 3 – Paper machine web brake waste.
Part 6 – Tail seal logs waste.
Part 12 – Palletizing waste.

For a more detailed presentation of the waste data for product family “Basic” see Appendix 2.

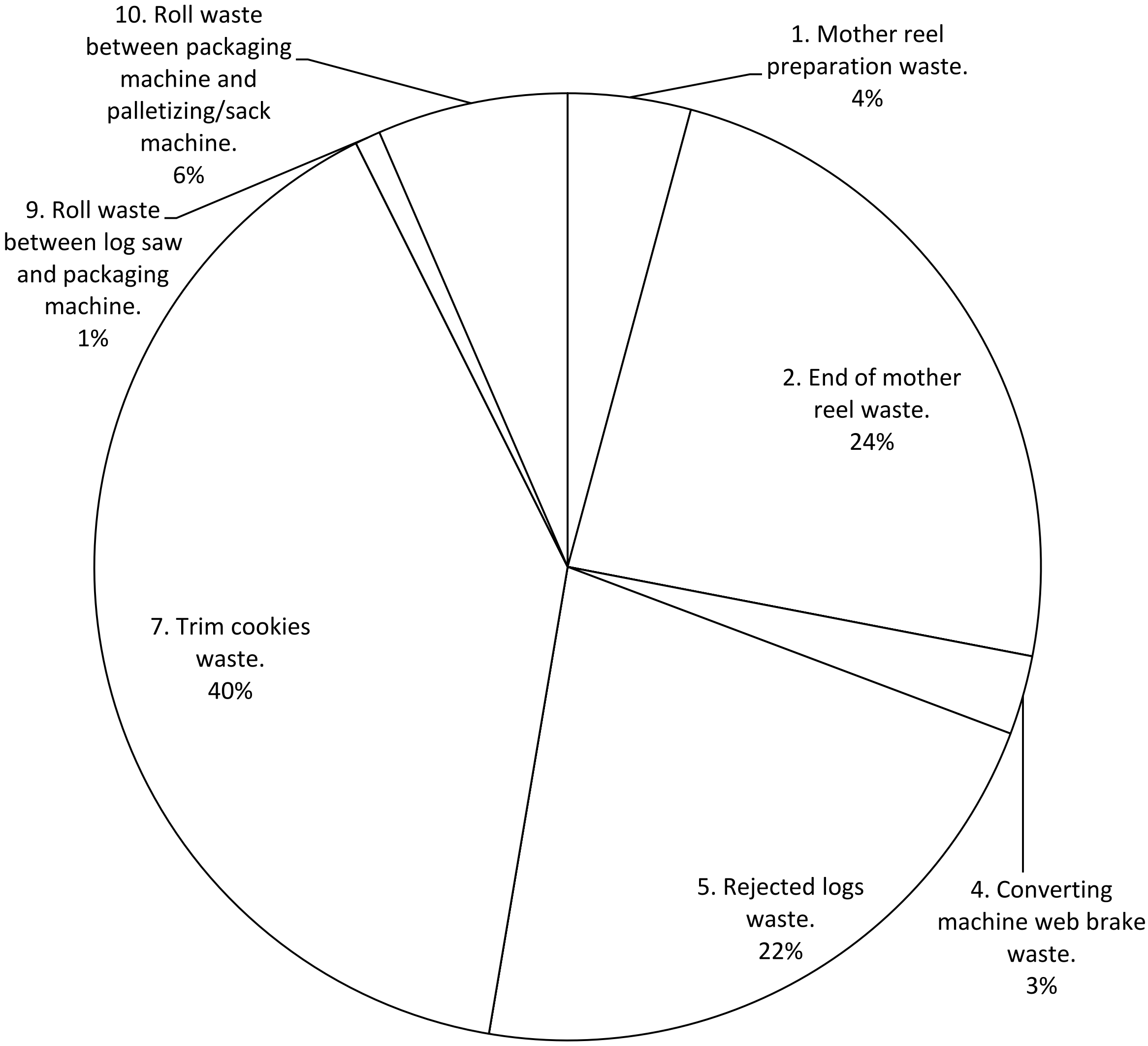

Figure 11: Distribution of waste for product family “Premium”.

During the testing for product family “Premium” no waste occurred for the following parts:

Part 3 – Paper machine web brake waste.
Part 6 – Tail seal logs waste.
Part 8 – Dropped rolls in log saw separator.
Part 11 – Roll waste between sack machine and palletizing.
Part 12 – Palletizing waste.

For a more detailed presentation of the waste data for product family “Premium” see Appendix 3.

4.3.5 Best case scenarios of paper waste

The case study method made it possible to develop a best case scenario for the waste data results by adjusting the raw data. Before adjusting the raw data assumptions were made by analyzing and discussing the results with the interviewees.

It was assumed that of those waste parts (shown in Figure 8) with paper waste caused by machine breakdowns, disturbance in the process as well as poor machine settings, poor mother reel quality, poor product quality (roll, package, sack) were able to be prevented and thus set to zero. This includes the following waste parts:

Part 3 – Paper machine web brake waste.
Part 4 – Converting machine web brake waste.
Part 6 – Tail seal logs waste.
Part 8 – Dropped rolls in log saw separator.
Part 9 – Roll waste between log saw and packaging machine.
Part 10 – Roll waste between packaging machine and palletizing/sack machine.
Part 11 – Roll waste between sack machine and palletizing.
Part 12 – Palletizing waste.

Hence, the remaining waste parts consisting of paper waste that could not possibly be prevented are the following:

Part 1 – Mother reel preparation waste.
Part 2 – End of mother reel waste.
Part 5 – Rejected logs waste.
Part 7 – Trim cookies waste.

The raw data for Part 1 and Part 2 were adjusted so that all mother reels in the testing obtained the same waste as the mother reel with the lowest value for that waste part. As for Part 5 the raw data was adjusted to only include the rejected logs caused by quality controls and change of mother reels. Lastly, Part 7 was set to obtain the theoretical value of 2,29 % which is optimal for quality purposes and prevention of process disturbance (as mentioned in sub-chapter 4.3.1). From the adjustment of the raw data, the weight of the reduced paper waste was added to the original output weight of the case study method, thus keeping the same input weight. Table 5 presents the best case scenario of the total paper waste for the two product families. Figure 11 and Figure 12 display the best case scenario of the total paper waste is distributed between four waste parts, the former for product family “Basic” and the latter for product family “Premium”. For a more detailed presentation of the best case scenario waste data for product family “Basic” and product family “Premium”, see Appendix 4 and Appendix 5. The best case scenarios will further be elaborated in the discussion chapter.

Table 5: Best case scenarios of the product families, total paper waste.

Best case scenarios of paper waste	Input (kg)	Output (kg)	Waste (kg)	Waste (%)
Product family "Basic"	7407	7145	262	3,5
Product family "Premium"	5961	5739	222	3,7

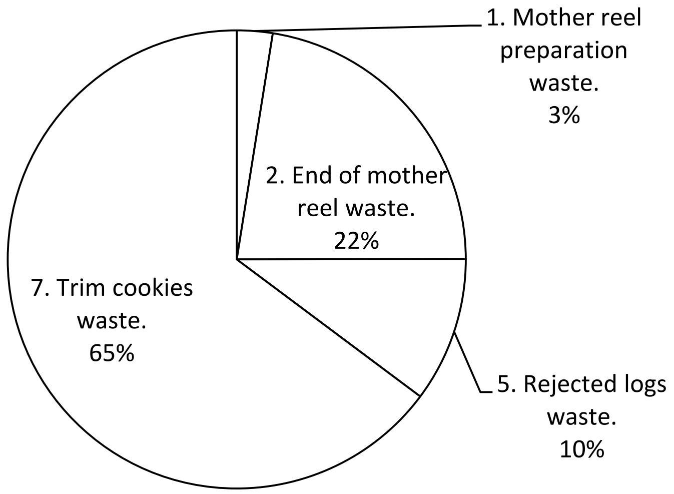

Figure 11: Best case scenario of product family "Basic", distribution of total paper waste.

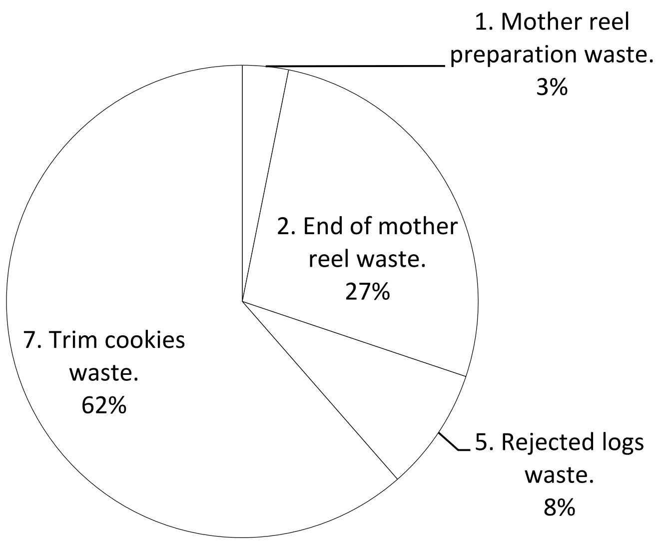

Figure 12: Best case scenario of product family "Premium", distribution of total paper waste.

5 DISCUSSION

This chapter discusses the theory and the results of the case study. Firstly, the sustainability work and waste management is discussed, followed by the paper waste results.

5.1 Sustainability & Waste Management

5.1.1 SCA group level & Edet mill level

When it comes to sustainability work SCA shows a high level of maturity. By living up to its ambitious sustainability targets, such as e.g. employing mechanical and biological water treatment plants on all pulp and paper mills, the company has earned certifications from Dow Jones' 2015 Sustainability Index, FCS, KRAV and the Nordic Swan. These type of certifications are also encouraged by Paulapuro (2000) and EC (2010). Moreover, SCA's deeply rooted sustainability image can be linked to EPA's (1993) argument of attracting new customers through the company image. In addition, one could argue that SCA's image is of high regard for the rising customer demands, as expressed by Cohen (2004). As for the Edet mill, the sustainability projects have been highlighted on the group level of SCA, which has given the mill additional exposure both externally as well as internally. In this sense, one could argue that the mill's sustainability image spans far beyond EPA's (1993) argument, e.g. SCA has recently experienced an increase of external monitoring from investors and thus. Furthermore, one could argue that a strong sustainability image also contributes to an attractiveness both amongst potential and existing employees. The leverage of internal exposure allows the Edet mill to use its image for e.g. the mill's identity and culture, and also to motivate the employees. Similarly, EPA (1993) discusses the improvement of employee morale, however EPA (1993) argues that it is obtained by the implementation of waste prevention programs rather than just having a strong sustainability image.

The mill's burning of bi-products for providing heat and electricity for itself and the surrounding community is an example of EC's (2010) statement of how companies have started to view waste as a valuable resource. Moreover, the mill sells the ashes for road construction, which indicates the great potential of waste and the rise of complete new, non-traditional, business networks. Furthermore, this example can be seen as an improvement according to the EU's five-step waste hierarchy where the mill went from disposal of bi-products to recovery for heat and electricity and eventually also re-using the ashes (EC, 2010). In addition, the mill's water reduction program shows how the company has taken counter actions on an issue that is well known about the tissue paper industry (Paulapuro, 2000). The program has contributed to an incredible 30 % annual decrease (ca 1 billion cubic meters) of water consumption as well as improved water treatment and cost reductions in water and energy consumption.

5.1.2 L10 level

The current waste management at L10 mainly consist of recycling the paper. The exception is the sack machine (Part 11) where packages are re-used in the case of defective sacks. While Shingo (1984) puts emphasis on completely atomizing the handling of waste most of L10's parts are manually recycled by the operators. This is done either directly into the solver drop off point or in the green bins (which eventually are emptied at the solver drop off point). L10's only automatic recycling takes place at the log saw (Part 7 and Part 8). The current layout makes it very difficult to atomize the recycling for the other parts of L10.

By linking the current waste management of L10 to EU's five-step waste hierarchy one could argue that the set up allows proper sorting, which is otherwise considered to be challenging (EC, 2010). Furthermore, it was discovered that L10 even has the potential of climbing from the recycling step to the re-use step in Part 10, which is the roll waste caused by defective packages. Currently all rolls in defective packages are recycled even if they meet the quality requirements. When asked upon this the operators presented two main argument being (1) the operators do not have time to rip packages and put the rolls back on the conveyer belt and (2) the rolls get contaminated when touched by the operators. The latter argument was shut down by the quality manager, hence the re-use of the rolls in Part 10 is a management related question.

Even though EC (2010) presents the benefit of lower energy consumption for recycled material compared to new raw material one could argue that recycling in the long run equals to a relative low material efficiency. Despite the fact that the waste was recycled one should keep in mind not only the material efficiency but also the production time and labor costs linked to the waste. As mentioned before, it is clearly stated by Berry and Rondinelli (1998), EC (2010), EPA (1992; 1993; 2016c), IEPA (2016) and Lewis et. al. (2001) that preventing the waste from occurring in the first place is considered to be the key for solving the issue of waste. Thus, the management should set the target for climbing the five-step hierarchy all the way to the prevention step. EPA's (1992) source reduction model (Figure 2) is a tool that can concretely help L10, together with the involvement of other stakeholders, to structure the work for achieving the prevention of waste. For the product changes and input changes emphasis is put on the other stakeholders since these changes are not on L10's table, nevertheless a vital part of L10's performance. Both EPA (1992) and Lewis et. al. (2001) highlight the design phase to be critical for the waste prevention. For L10 this is mainly a discussion that should be taken together with the Sales and Marketing department. A concrete example is the use of handles for small size packages for product family "Premium", which has been observed to frequently cause stops in the packaging machine. In the same sense the loose ends of mother reels should be discussed with the Papermaking and DIP/Pulp department. The discussion of technology changes and improved operating practices is presented in sub-chapter 5.2.2.

5.2 Paper waste results

The quantitative data collection was the most challenging part of the case study as it had many different aspects to take into consideration. However, at the same time it is the foremost contribution of this thesis as the actual paper waste weighting of L10's entire process was done for the first time through this case study. The case study's waste data method contributed with (1) displaying the total waste with relatively high reliability and validity compared to SCA's current waste data method as well as (2) displaying the distribution of waste in the converting process, which is a missing dimension in SCA's current method.

5.2.1 Total paper waste

The results of the total paper waste for both product family "Basic" and "Premium" show that the output weight of the case study method is higher relative to SCA's method. This means that the average weight per roll was higher than the roll's specification weight. In this case the customers get more than what they pay for. This can be linked to the fact that the average paper grammage of the finished rolls was higher than the specification value (and thus the incoming mother reels). In the case of product family "Basic" one could see that the paper waste percentages from the two methods are very similar. In contrast the paper waste percentage for product family "Premium" shows a significant difference where the value of SCA's method is over twice as big as the case study method. This explained by the fact that the input weight for SCA's method was calculated by using the very same formula that the company uses for reclamation of splices (see sub-chapter 4.3.1, Figure 9). When analyzing the formula one could see that 2 of the 3 factors are based on specification values, which are grammage and width. As mentioned previously the average grammage of the used mother reels is slightly higher than the specification value. Also, the formula does not take stretch into consideration. Also, it is well known that paper is a "living" material which has different levels of humidity throughout its life-cycle (Paulapuro, 2000).

Therefore, the formula in Figure 9 is more suitable for calculating partial weight in theory rather than in reality. In addition, when comparing the output weight of the two methods they are very similar, which means that the error can be limited to only the input weight as the waste weight is based on the input weight and the output weight. As previously mentioned 5 mother reels were included in the testing of product family "Premium". The formula only affected the weight of the two starting and the two ending mother reels. Thus, the error caused by the formula could have been decreased by including more mother reels that are entirely consumed within the testing. However, this would mean a very resource intensive data collection as the testing of 5 mother reels took around 12 hours. Another option would be to have a built in scale in the unwinder, which is not the case with L10. The keep the reliability and validity the most important aspect of the case study method is to not compromise the regular production run in forms of e.g. additional stops and waste. Therefore it is highly disregarded to take out the mother reels from the unwinders for weighting since it would affect the reliability and validity as argued by Rosengren and Arvidson (1983), Wallen (1996) and Eriksson and Wiederheim-Paul (2001).

5.2.2 Distribution of waste and best case scenario

The distribution of waste for product family "Basic" and "Premium" (Figure 11 and 10) have been identified to have strong similarities but also some interesting differences. For product family "Basic" the waste in Part 8 stands out. The dropped rolls in the log saw separator is a well-known problem for heavy rolls, yet it occurs. Part 9 also showed relative high waste, this is explained by a breakdown of the log saw (unplanned stop). As for product family "Premium" Part 10 stands out, which was caused by the handles in the packaging machine. Note that almost all rolls that were recycled in Part 10 could have been re-used (this also applies for Part 10 of product family "Basic"). During the testings both product family "Basic" and "Premium" experienced a web brake (Part 4). However, these were considered to be randomly generated and thus difficult to further investigate.

The remaining parts for both product families show almost an identical pattern, which includes Part 1, 2, 5 and 7. After analysis of the waste results and discussions with the interviewees it was concluded that these four parts are considered to be the only ones where paper waste cannot be fully prevented. The exception is the sampling of rolls for quality purposes, also referred to by Juran (1951), Oakland (2008) and Klefsjö (2010) as appraisal costs.

For Part 1 this is explained by the fact that the incoming mother reels are sealed by tape in a spiral, which in the best case scenario means the operators need to rip off the start of the spiral to obtain straight paper. As for the end of mother reel waste the current technical solution cannot consume the entire mother reel without causing web brakes. Even if the operators were to sort out the bad mother reel cores the technical solution still winds loose ends. On the other hand, the converting machine is manually stopped by the operators when they sense that a mother reel is consumed. It may be possible that an affordable investment automatization, most likely not entirely due to the loose ends, but less than the current situation. As for rejected logs waste, rejected logs with tape (mother reel changes) and quality control (appraisal costs). Part 7 is the only waste part that can be theoretically calculated and have the value 2,29 %. When comparing this number to the testing data both product families show a lower percentage, meaning that the rolls are wider than the specification width. This is also confirmed from the sampling of roll width made during the testings. The best case scenarios of the paper waste is far from what the reality has shown. Nevertheless, it is important to understand the gap between the two. For instance, with comparing the numbers one could understand that decreasing the waste with only one tenth of a percent is a very large step in reality. This is also realized by looking into the annual production figures. Furthermore one should keep in mind that this case study has been narrow to looking into two product families which together may represent a significant amount of L10 annual production, however at the same time this represent less than 15 % of the entire mill.

To conclude the root cause analysis, one should first and foremost focus on improving the operating practices, specifically this refers to decreasing the preparation waste of mother reels, improving the sorting of bad mother reel cores and decreasing the start-up speed of the converting machine together with preventing the rejection of good logs. In order to eliminate the inconsistent work, standardized work should be introduced. Currently there is a recommendation on how to rip of as little paper as possible from the mother reels. Furthermore there is an instruction for sorting of bad mother reel cores. These can be used as guidance, however as stated by Petersson et. al. (2010) the operators should preferably standardized the work, with the support from the managers (Liker and Meier, 2006). The implementation of standardize work is relative small in effort but at the same time large in effect.

Moreover, for the complex root causes collaborations between the different stakeholders are needed. In addition to what was mentioned in 5.1.2 L10 should also discuss the quality of pallets with IDC, and encourage caution amongst the truck drivers that transport the mother reels and make sure that the AGV park is up to date. Specifically for L10 one should look into the opportunities of improving the precision and accuracy of the log saw (including the roll separator) and the packaging machine.

6 CONCLUSION

In this chapter the conclusion of the case study is presented by answering the research questions.

How is the total material waste distributed in the tissue production process?

By observing the converting process during regular production runs, the distribution of the total material waste has been identified to be mainly divided between the preparation stage of the incoming and consumed mother reels, the log rejecter stage and lastly the log saw stage. The three stages amount to about 85 % of the total paper waste which in the chronological order are split into 25 %, 20 % and 40 %. The remaining 15 % are mainly divided between the converting machine and the packaging machine, but also the sack machine and the palletizing.

What are the underlying causes for the most significant material waste?

The underlying causes for the most significant material waste is the inconsistent work carried out by the operators, which is caused by lack of standardized work and affects the preparation stage and the log rejecter stage. Furthermore, technical constraints at the material supplier causes loose ends of the mother reels, which results in more waste at the preparation stage. Other causes that indirectly affect the log rejecter stage include the packaging machine's technical constraints as well as poor pallets provided by the Logistics department. Lastly, technical constrains in the log saw cause waste for itself and indirectly for the log rejecter stage.

What changes should be made in the production process in order to significantly decrease or prevent the material waste?

One should first and foremost focus on improving the operating practices, specifically this refers to decreasing the preparation waste of mother reels, improving the sorting of bad mother reel cores and decreasing the start-up speed of the converting machine together with preventing the rejection of good logs. The implementation of standardized work is relative small in effort but at the same time large in effect.

Moreover, for the complex root causes collaborations between the different stakeholders are needed. Collaboration with the Sales and Marketing department should be made in order to prevent unnecessary components, such as the handle for small size packages. Moreover, one should discuss with the Papermaking and DIP/Pulp department the opportunities of increasing the quality of the paper closest to the core in order to increase the consumption of paper per mother reel. Furthermore, the quality issue of pallets should be discussed with the Logistics department. In addition, one should encourage caution amongst the truck drivers that transport the mother reels and make sure that the AGV park is up to date. Specifically for L10 one should look into the opportunities of improving the precision and accuracy of the log saw (including the roll separator) and the packaging machine.

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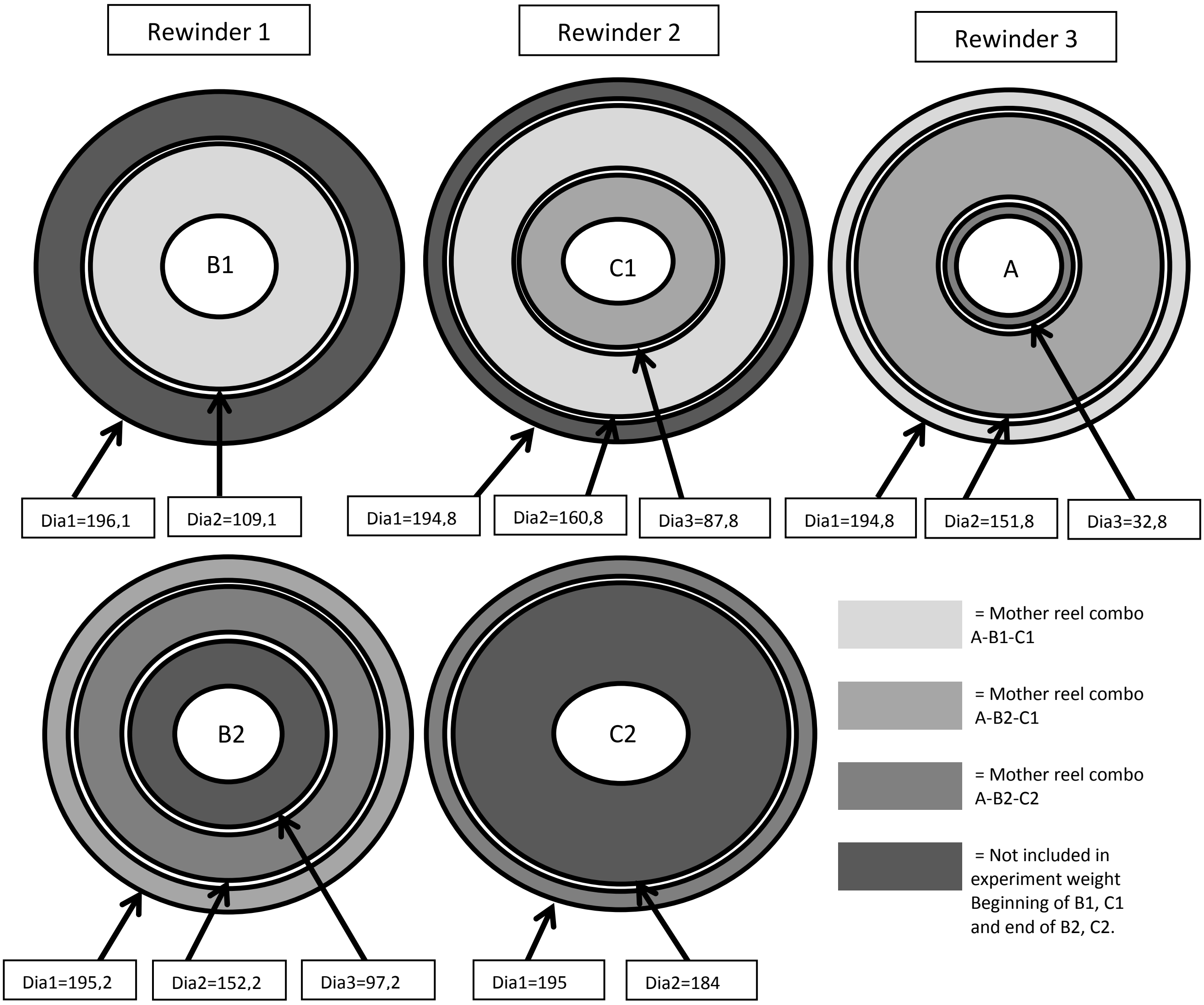
APPENDIX 1: Results of calculated input weight for product family "Premium"

The mother reel combinations of the experiment for product family "Premium" are presented below, including diameters (Dia) presented in centimeters. The mother core diameter equals to 30 cm and has to be deducted when using the displayed diameters below. Due to company policies, the specification values used for calculating the partial weight of the mother reels are not shown in detail.



Mother reel ID for waste data collection	Measured Total mother reel weight (kg)
A	2025
B1	2488
B2	2438
C1	2463
C2	2384

Mother reel combo A-B1-C1

	Weight of mother reel consumed until this combo (kg)	Mother reel weight for this combo (kg)
A	-	464
B1	840	1648
C1	399	340
A, B1, C1	-	2452

Mother reel combo A-B2-C1

	Weight of mother reel consumed until this combo (kg)	Mother reel weight for this combo (kg)
A	464	480
B2	-	487
C1	739	1724
A, B2, C1	-	2690

Mother reel combo A-B2-C2

	Weight of mother reel consumed until this combo (kg)	Mother reel weight for this combo (kg)
A	944	1081
B2	487	110
C2	-	138
A, B2, C2	-	1330

Total input weight (kg)	6472

Appendix 2: Test results of waste data for product family "Basic"

Test result of waste data for product family "Basic".
Start of test: 11:20, 2016-04-29.
End of test: 15:45, 2016-04-29.
Location of test: Edet mill, converting line 10.

Location of waste	Actual weight paper waste (kg)	Actual paper waste of total input (%)	Distribution of waste (%)
1. Mother reel preparation waste.	11,8	0,16	3
2. End of mother reel waste.	73,6	1,00	21
3. Paper machine web brake waste.	0,0	0,00	0
4. Converting machine web brake waste.	5,6	0,08	2
5. Rejected logs waste.	57,5	0,78	17
6. Tail seal logs waste.	0,0	0,00	0
7. Trim cookies waste.	134,1	1,82	39
8. Dropped rolls in log saw separator.	32,8	0,44	9
9. Roll waste between log saw and packaging machine.	25,0	0,34	7
10. Roll waste between packaging machine and palletizing/sack machine.	3,9	0,05	1
11. Roll waste between sack machine and palletizing.	2,5	0,03	1
12. Palletizing waste.	0,0	0,00	0
Total	347	4,7	100

Appendix 3: Test results of waste data for product family "Premium"

Test result of waste data for product family "Premium".
Start of test: 07:30, 2016-06-15.
End of test: 17:30, 2016-06-15.
Location of test: Edet mill, converting line 10.

Location of waste	Actual weight paper waste (kg)	Actual paper waste of total input (%)	Distribution of waste (%)
1. Mother reel preparation waste.	11,2	0,19	4
2. End of mother reel waste.	63,6	1,07	24
3. Paper machine web brake waste.	0,0	0,00	0
4. Converting machine web brake waste.	7,2	0,12	3
5. Rejected logs waste.	58,5	0,98	22
6. Tail seal logs waste.	0,0	0,00	0
7. Trim cookies waste.	106,6	1,79	40
8. Dropped rolls in log saw separator.	0,0	0,00	0
9. Roll waste between log saw and packaging machine.	2,3	0,04	1
10. Roll waste between packaging machine and palletizing/sack machine.	17,4	0,29	7
11. Roll waste between sack machine and palletizing.	0,0	0,00	0
12. Palletizing waste.	0,0	0,00	0
Total	267	4,5	100

Appendix 4: Best case scenario of waste data for product family "Basic"

Best case scenario of waste data for product family "Basic".

Location of waste	Actual weight paper waste (kg)	Actual weight paper waste (%)	Distribution of waste (%)	Assumptions
1. Mother reel preparation waste.	**6,6**	**0,09**	**3**	**All mother reels from the test obtain the waste of the mother reel with the lowest value.**
2. End of mother reel waste.	**58,8**	**0,79**	**22**	**All mother reels from the test obtain the waste of the mother reel with the lowest value.**
5. Rejected logs waste.	**26,8**	**0,36**	**10**	**Based on only including log waste generated by quality controls and change of mother reels (mandatory waste).**
7. Trim cookies waste.	**169,6**	**2,29**	**65**	**Based on the mother reels having the specification width as well as the cut rolls having specification width.**
Total	**262**	**3,5**	**100**	

Appendix 5: Best case scenario of waste data for product family "Premium"

Best case scenario of waste data for product family "Premium".

Location of waste	Actual weight paper waste (kg)	Actual weight paper waste (%)	Distribution of waste (%)	Assumptions
1. Mother reel preparation waste.	**7,0**	**0,12**	**3**	**All mother reels from the test obtain the waste of the mother reel with the lowest value.**
2. End of mother reel waste.	**60,0**	**1,01**	**27**	**All mother reels from the test obtain the waste of the mother reel with the lowest value.**
5. Rejected logs waste.	**18,7**	**0,3**	**8**	**Based on only including log waste generated by quality controls and change of mother reels (mandatory waste).**
7. Trim cookies waste.	**136,5**	**2,29**	**61**	**Based on the mother reels having the specification width as well as the cut rolls having specification width.**
Total	**222**	**3,7**	**100**	