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Efficiency analysis in highly automated mass production

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Preface

The master thesis is the final chapter of the studies at the faculty of engineering at Lund University. 4.5 years of preparations in forms of exams is concluded with this practical course where we are allowed to use our knowledge in the real world.

The company kind enough to teach us about how it all works in practice is Rexam. Along with professor Jan-Eric Ståhl, our supervisor at the department of production and materials engineering at LTH, they have taught us valuable lessons and made us slightly better prepared for what is about to come.

We would like to thank the people at Rexam for their kindness and cooperativeness during the time we spent at their company. They made us feel more than welcome and the time at Rexam has made us more comfortable for our future work life. Special thanks to our supervisor at Rexam, Henrik Lidman, who have helped us from before day one. He has, despite obvious lack of time, been able to provide us with all the tools we needed to perform this study. Simultaneously he has been successful with keeping our and his own mood on top at all occasions.

We would of course also like to thank Professor Jan-Eric Ståhl for sharing his vast knowledge with us. He is the reason that we had the opportunity to work with this interesting task at Rexam and the cause of our peculiar interest in the manufacturing industry.

Finally, we would like to convey our gratitude to our friends and families. Without your support, in all weathers and way beyond this thesis, this master thesis and our degree in industrial engineering would not have been.

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Abstract

Rexam Beverage Can Fosie manufactures cans for beverages. The number of produced cans in production line 1 is not as high as it should be when comparing to the other 3 production lines. The overall efficiency is low but the cause of the problem has not been found.

To solve the problem the first step is to map the line efficiency as careful as possible. As the provided statistics is not fully accurate, lots of assumptions are made on the way to find a reliable statistic overview. When the statistics is properly gathered, tools are used for the analysis. The tools are the *production performance matrix*, *empirical distribution functions*, the *cost model* and theory from lean production.

Since the knowledge of the real production efficiency is accurately introduced in this study, this mapping turned out to be valuable. The statistics displayed for each part of the production line showed the efficiency losses in a new way. Spoilage, downtimes and pace losses are sorted out for each machine in the line. The results from the use of the tools confirmed the accuracy of the statistical overview.

The results showed that there is a lot of waiting time in the bottleneck of the line. The theory from lean production tells us that the bottleneck is not supposed to wait. To increase the number of produced cans in production line 1 the machine with the slowest pace must be running more often and with higher efficiency.

The results also show that the short waiting times in the bottleneck represent a large fraction of the total waiting time. The recommendation is therefore to reduce the amount of short stops as a first step. This reduction can be reached by creating a buffer for the bottleneck, a buffer located at the available space before the bottleneck.

The results are a recommendation which, if implemented, will increase the line efficiency. Rexam has also got a new valuable tool in the template which sorts out the efficiency statistics in detail. Hopefully, the tool will be used as guideline when implementing the suggested changes in the line.

Table of Contents

List of Figures

List of Tables

1 Introduction

This chapter aims to give understanding about the study. The company and its present situation is presented along with the purpose of the study.

1.1 Rexam PLC

Rexam is a global consumer packaging manufacturer. Rexam has 1 business area, beverage cans. The other division, plastic packaging for healthcare applications, was sold off in spring 2014. Before the divestment of the healthcare division the beverage can division accounted for 90 % of the sales. Rexam has a broad history in the consumer packaging industry with customers in the beauty industry and production of glass and plastic bottles before focusing solely on beverage cans. The company is the largest manufacturer of beverage cans in Europe and South America and the second largest in the US. Rexam has 67 manufacturing sites in 24 countries and employ 8000 people on average. The revenue in 2012 was 4312 million £. Rexam's history dates back to 1881 when William Vansittart Bowater began operating as a paper wholesaler to the UK's newspaper industry. In 1995 the company changed its name to Rexam from its previous name Bowater PLC.

Rexam has 4 core values. The idea behind these values is to express what they stand for as a business and what they expect from their employees (Rexam PLC 2014):

- Continuous improvements.
- Recognition.
- Teamwork.
- Trust.

1.2 Rexam Beverage Can Fosie

Rexam's history in Sweden dates back to March 1919 when AB Plåtmanufaktur was founded through a merger of 3 small sheet metal packaging manufacturers (Tranemo Bibliotek). The company was later renamed PLM AB and in 1999 Rexam acquired PLM. PLM made its first beer can in 1955 for AB Stockholms bryggerier. The beer was sold under the Three Towns brand name. The site at Fosie industriområde in Malmö opened in 1980 and has 4 highly automated production lines. It produces beverage cans for the Scandinavian markets. The site produces about 2 billion cans per year and 2 sizes of cans are produced, 50 cl and 33 cl. The site has 250 employees with approximately 200 working in the production.

1.3 The present production

1.3.1 Front end

1.3.1.1 Cupper

The production process of a beverage can begins with aluminium sheets rolled up on large coils, see **Figure 1.1**. The coils can weigh up to 10 tonnes and the length of the aluminium sheet is about 8 kilometres (Lidman 2014).

Figure 1.1. *The aluminium coils.*

The first step in the process is a large punching press called a cupper. The aluminium sheet is fed into the cupper which punches out cups that are wider and lower than a can, as in **Figure 1.2**. In the 50 cl lines the cupper punches out 11 cups with every stroke and in the 33 cl lines the number of cups produced in each stroke is 12. The left over material gets compacted and then sent away for recycling (Lidman 2014).

Figure 1.2. *The 50 cl can in comparison to the cup.*

1.3.1.2 Bodymaker and trimmer

In the bodymaker the cup gets its shape and starts to look like a beverage can, see **Figure 1.3**. In the bodymaker the cup is forced through 2 or 3 rings, depending on the size of the can. Each ring has a smaller diameter than the ring before and this stretches out the can and increases the length while the thickness of the walls is decreasing, this process is called ironing. After the last ring the bottom is pressed against a tool which forms the base of the can. The can is forced through the rings and pressed against the base forming tool in 1 continuous punch stroke (Lidman 2014).

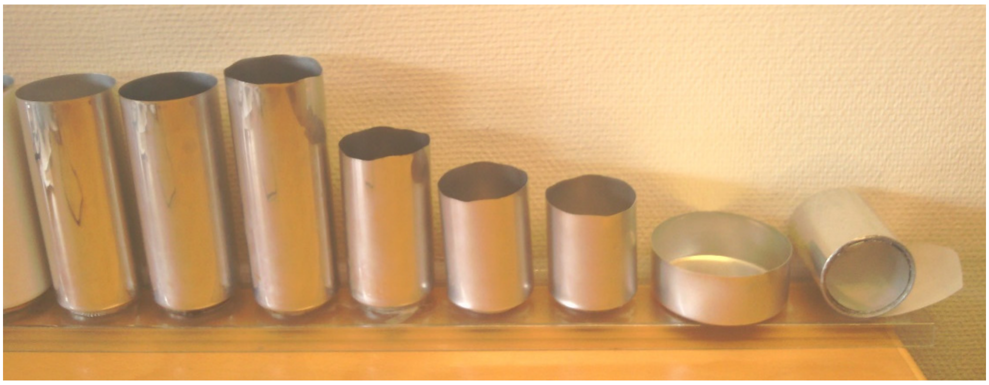

Figure 1.3. *The cup (second from the right) is transformed in the bodymaker. The most left can is the resulting product.*

To prevent the aluminium from being torn apart on the process, lubricant is added to the can before the ironing. The lubricant also helps cooling down the aluminium as heat is produced due to the friction caused when the can is forced through the rings (Lidman 2014).

Because sheet aluminium is an anisotropic material, ears are formed at the top of the can when it is formed in the bodymaker. The third can from the left in **Figure 1.3** shows an example of ears. The trimmer, located immediately after the bodymaker, cuts off the top of the can, leaving the upper wall straight and all cans get the same height. The cut off material is collected and recycled (Lidman 2014).

1.3.1.3 Washer

The bodymakers leave lubricant on the cans which need to be removed. This is done in the washer. The washing process contains 7 steps to ensure that the cans are properly clean and all traces of lubricant are removed. In the first 2 steps the cans are washed with surfactants and then hydrofluoric acid etches the can at 58 °C. The etching of the cans makes it easier to colour them in the next step of the process. After cleaning and etching, the cans are rinsed with water and finally dried in an oven (Lidman 2014).

1.3.2 Printer

In the printer the can gets its label. This is the point in the production line where the cans get its unique appearance. After this point, the can cannot be reprinted and used for another batch. The material can still be recycled when scrapped, but printed cans that are not needed cannot fill another purpose. This is the point where the number of cans produced in a batch must be controlled.

The printer is also the point of the line that should be deciding the overall production line pace. In other words, this is supposed to be the bottleneck of the production line (Lidman 2014). A rule of thumb in the can making industry says that the printer should run at 85 % of the capacity of the bodymakers. There always has to be a bottleneck in the production, and due to the printers deciding nature this is the natural bottleneck for this line.

The label is set by printing plates which print the desired colours to the can via a printing blanket by pressing against the can while they are both spinning around its own axis. Every selected colour has its own printing plate and the cans encounter all the plates in less than a second. When the can has received its colours from all the blankets, it is brought to an oven which dries the ink (Lidman 2014).

Before the printer, all the cans have the same appearance. After the printer, the procedure for the can making is very similar for all types of cans. It is in the printer the cans get unique. That also makes the printer the point of editing. When a new batch, with new label design, is about to be produced the printer demands manual work. The printing plates have to be changed and the inkers have to be emptied, washed and refilled with new colour. In addition, all the cans with the old label design downstream in the line needs to be emptied from the line to secure that the different labels are not mixed together. This change of label takes about 8 minutes and appears as downtime (Lidman 2014).

In production line 1 there are 2 printers available. The 2 printers do not operate at the same time but allows the label change to be done as an external setup. The reason for having 2 printers in line 1 is that this line produces most of the smaller batches and thereby requires more set-ups. The manual setup work can be made while the line is still running through the other printer. The exception is the emptying of the cans downstream. When changing the label with 2 printers, the line still has to be emptied to avoid mixed pallets (Lidman 2014).

1.3.3 Back end

1.3.3.1 Inside coating

To avoid the beverage from reacting with the aluminium, the inside of the can is coated. This is done by spraying the inside of the can with a thin layer of lacquer. (Lidman 2014). The coating is slightly adapted to the type of beverage it is supposed to contain, for example cider is more corrosive on the aluminium and requires a slightly thicker layer than beer which is less corrosive. The setting is done manually but the computer executes the work in no time (Lidman 2014).

The inside coating in the line is done by 7 sprayers, called IC-sprays, working simultaneously. Each sprayer has 2 nozzles, one for spraying the bottom of the can and the other for spraying the inner walls (Lidman 2014).

1.3.3.2 Necking

The final shape of the can is created by necking the can. The upper neck of the can is folded to fit the cap. This has been done at the second can from the left in **Figure 1.4**. The cap of the can is attached after the beverage has been filled in the can. The caps are manufactured by other Rexam plants which only produces the caps. The shaping of the neck is the final producing step of the production line at this location (Lidman 2014).

Figure 1.4. *Labelled cans before and after necking.*

1.3.3.3 Final inspection

The finished can is carefully tested and inspected before packed. It has to be made sure that the can fulfils the demands set on it. The size and mechanical properties of the cans are tested in an off line quality test equipment and the solidity of every can is controlled by a light test. The light is sent in to the can and the refraction of the light is used as an indicator. Cans that fail the light test are rejected and sent to recycling (Lidman 2014).

On periodically set occasions a sample is also taken to test the internal lacquer distribution. The cans are filled with a salt liquid to control the cans reaction with this liquid. This is called a metal exposure test. If the values are too high, the production is stopped and controlled (Lidman 2014). This brings comprehensive losses in terms of downtime and spoilage. It is still nothing compared to the losses it might bring if not tested. The quality of the cans is always the most important issue for the company (Lidman 2014).

1.3.3.4 Palletizing

When the cans are finished and inspected it is time to pack the cans for shipping. This is done by stacking the cans on to pallets. 1 pallet can house up to 6000 cans. The cans are stacked by the palletizer before the pallets are shipped to the customer or sent to the warehouse inventory (Lidman 2014).

1.3.4 Conveyors and accumulation tables

Between all the steps in the process there are different means of transportation solutions to carry the cans. The most common is conveyor belts or mass conveyers, they carry several cans in width, see **Figure 1.5**.

Figure 1.5. *Empty conveyor belt.*

The mass conveyors also act as accumulation buffers between the steps in the process, as in **Figure 1.6**. Another mean of transportation is single-filers, they are located immediately prior to many machines and their purpose is to feed the machine cans in a single row (Lidman 2014).

Figure 1.6. *Conveyor belt acting as accumulation buffer.*

Between the washer and the printers there are 2 accumulation tables. The purpose with the accumulation tables is to handle the flow of cans in case there is a disturbance in the production. If the printer stops all previous steps does not stop immediately, therefore there needs to be a buffer to store the cans before the printer starts again. The accumulation tables are also a safety measure since there must be space available to completely empty the washer in case of a longer stop in the production. There are also 2 accumulation tables between the IC-sprays and the necking. At Rexam the accumulation tables are called BD-tables. BD stands for Bi Directional with the implication that they can move in 2 directions, depending on if they are loading or unloading cans (Lidman 2014).

Between line 1 and line 2 there is a cross-conveyor which can be used to transfer cans from one line to the other. The cross-conveyor is used to even out shortages and overproduction in the lines. If the printer is shut down in one of the lines and the accumulation tables and conveyors are full the front end can continue producing cans. These cans can be transferred to the other line to avoid unnecessary shut down of the bodymakers. The cross-conveyor is located between the washer and the printer. There is also a possibility to transfer cups immediately after the cupper between the 2 lines (Lidman 2014). However, the cross-conveyer and cup transfer makes the analysis of the production data more difficult. The transferred cans give one line more spoilage and the other less spoilage than they actually have. A solution to this problem is to add the numbers from the 2 lines and look at the spoilage in the front end simultaneously for both lines.

1.4 Background

The 4 production lines at Rexam Fosie are highly automated and works with high speed every hour of the week. It is therefore vital that every part of the production lines is able to produce with the highest possible efficiency. Factors which may reduce the efficiency of the lines are plenty though.

2 of the main factors which affect the efficiency are rejection- and downtime rates. Those 2 factors have been considerably high at production lines 1 and 2 at Rexam Fosie for a long while. The high values cause a negative impact on the overall efficiency of the production lines. The rejected cans are wasted parts which in theory just as well could be undone and the downtime is of course a waste of valuable production hours.

The high rate of automation makes every part of the line dependant on the others. A rejection or a minute down in one part affects the whole line (Ståhl 2013). This fact is not only making every factor more important but is also making the production line very complex. The many different parts of the production line are all needed though, due to the complex nature and the several steps involved in making a sufficient product.

To calculate exactly how the downtimes, the rejections and many other factors contribute to the overall efficiency demands a lot of information and effort. Therefore, it is still unknown how each factor affects the others. Efforts to find the source of the problem have been made at Rexam Fosie, without satisfying progress. The many dependencies and the complexity demands not only several calculation steps but also practical testing of the calculated theories. In other words, this is a time consuming matter.

Rexam Fosie has a well-developed information gathering system. Plenty of data has been collected and is available. The great extent of the data gathered brings possibilities to find the causes for the efficiency loss. This large amount of information also demands a lot of work to be put in sorting and selecting the needed data. This is another time consuming matter which makes the problem even more demanding.

Rexam Fosie is a “Business to Business” company which produces for a high customer demand. The aim of the company is to produce as much as possible. Wasted material and time is a loss to the company, the customers, the environment and all other stakeholders. The efficiency is vital and always desirable to improve.

1.5 Problem discussion

The overall efficiency of production line 1 is, in comparison with the other lines, not as good as it can be. The downtime- and rejection rates are eye-catching as the source to the problem but might not be the solution due to the dependency and the complexity in the production. Therefore, the problem in focus is the overall low efficiency in line 1.

1.5.1 Purpose and Deliverables

To improve the efficiency in production line 1 by:

- Performing an analysis of the efficiency and the production.
- Analysing the production pace of the production lines.
- Mapping the utilization in the specific machines which forms the production lines.
- Finding the causes to the efficiency loss.
- Suggesting activities to improve the efficiency and evaluate those by testing.

1.5.2 Objective

To improve the overall production in line 1 with 5 %. The improvement should increase the production by 50 million cans per year.

1.5.3 Focus and Delimitations

- The study focuses on the efficiency in line 1. The other 3 lines are used only as reference.
- The study focuses on efficiency in terms of losses in the production. No factors before or after the production are considered. This means factors like material purchasing, administration and warehousing are not considered.
- The automation level or batch sizes are not included in the study. The study focuses on the present production situation.

2 Theory

In this chapter the theoretical framework used in this study is presented. Theories and approaches used in production development and to analyse production lines are described. The chapter also discusses the Lean production concept and some of the tools and mindsets needed to practice a Lean production.

2.1 Lean Production

2.1.1 Introduction

The lean production concept was developed by Toyota during the years following the Second World War. There are a number of reasons why Toyota and other companies in Japan could not use the concept of mass production that manufacturers in America used. Among these reasons are the high cost of raw materials, Japan has to import most of the materials since the country only have a few sources of raw material of their own, and a low internal demand following the economic crisis after the war. Because of this Toyota realized that if they were going to compete with the west they had to reduce their costs and this should be achieved by minimizing waste in the production. The reduced costs together with a higher level of quality on their products and the ability to react to the customer demand of more individualized products made Toyota successful during the late 1970s and 1980s. The success of the Japanese industry made manufacturers in the west interested in lean production (Chiarini 2013).

A simple way to describe lean production is to say that it is to minimize waste. One of the problems with using the lean production concept is that many companies who tries to implement lean in their production only use some of the tools, for example 5S and Kanban (Liker 2009). To be successful in implementing lean the organizational culture of the company must change and everyone, from the top managers to the operators on the factory floor, has to work with and think about possible improvements to eliminate waste (Modig & Åhlström 2012).

2.1.2 Types of waste

In their effort to eliminate waste Toyota defined 7 types of non-value adding activities to focus on. The 7 types of waste are not isolated to the production. They also appear in product development and in administration. The 7 types of waste: (Liker 2009).

- *Overproduction.* Producing details when there is no demand for them. This is considered to be the worst type of waste since it causes all the other types of waste as well.
- *Waiting.* Employees are waiting for something to happen, i.e. waiting for material, spare parts or the step ahead of the in the process.
- *Transport.* Moving work-in-process or finished goods to and from buffers and warehouses.
- *Over Processing.* Unnecessary moments when producing a detail. This could be the result of a poorly made process development or when a product is manufactured with a higher level of quality than necessary.
- *Inventory.* Too high levels of inventory including raw materials, work-in-process and finished goods.
- *Motion.* Non-value adding working moments, e.g. when an employee has to walk away from their work station to fetch a tool and then return to the work station to complete the working moment.
- *Defects.* Production of defect details which has to be scrapped or reworked.

2.1.3 Inventory

Lean production is closely linked with reduced inventory levels. The idea behind this is that buffers in the production are used to prevent disturbances to spread in the line. When the inventory level is gradually reduced, the problems and disturbances that are hidden by the buffers become visible (Alles, Datar & Lambert 1995). When the problems are discovered you solve them and then continue to reduce the inventory level to find new problems. This concept is often explained by using a lake as comparison. When the water level (inventory) is reduced, rocks (problems and disturbances) are exposed. (Ståhl 2010).

However it is still important to not reduce the inventory level too much. According to Obermaier and Donhauser (2012) companies with least inventory are also low performing. Higher inventory levels help firms to avoid splitting orders and thus reduce the number of costly setups thereby achieve more smooth production levels and a better flow in their processes. Buffers are also needed to secure acceptable service levels on uncertain markets with variation in supply and demand

2.1.4 Gemba

The meaning of Gemba is to go to the location where the activities are taking place. One of the reasons to do this is to see what is actually happening on the factory floor and with this knowledge be able to identify waste and areas of improvement. Gemba can also be described as the opposite to the more traditional management style, sitting at the office discussing and using tools for simulations and information gathering. The Gemba concept can be defined with 4 facts (Bicheno, Anhede & Hillberg 2006):

- Go to the actual place of work. This is usually the factory floor but could also be at the office or other areas worth studying.
- Study the ongoing processes, just by looking at what is going on around you.
- Notice what is happening.
- Gather information.

2.1.5 Bottlenecks

According to Modig & Åhlström (2012) a bottleneck is a sub-stage which limits the flow in the production line. The bottleneck in a production line is easily identified as the stage with the longest cycle time or the stage with the slowest flow. There are 2 key characteristics that define a bottleneck:

1. Because the bottleneck has the slowest flow in the line, and the stages earlier in the process therefore produce material faster, there is always a queue of material immediately prior to this stage.
2. The stages following the bottleneck will have a slower pace than they ideally could have. Because of this they will have more downtime and/or pace loss compared to if they could have been fully utilized.

If there is a situation where the stages prior or after the bottleneck has a lot of downtime or other disturbances it is usually a good idea to have buffers so that the slowest working stage always has material to work with when the stages upstream or downstream the line do not function properly. However, using buffers does not solve the actual problem and it is usually better to find the cause of the downtime or disturbance and eliminate this. (Ståhl 2010)

2.2 Production Performance Matrix

The production performance matrix, referred to as PPM, is a tool which is helpful when identifying the factor of an issue. Factors and result parameters is combined in a matrix where the total contribution of those factors and parameters can be displayed. In the left column are the factors, they are divided into 8 different groups from A to H (Ståhl 2013).

A. Tools and tooling systems.
B. Workpiece materials.
C. Process and process data.
D. Personnel and organization.
E. Maintenance and service.
F. Special factors.
G. Peripheral equipment.
H. Unknown factors.

In the top row are the result parameters: quality, downtime, production rate and environment and recycling. If an employee causes a stop in a production cell, the length of the stop should be added to the cell in the matrix in the intersection of factor D and result parameter downtime. The right column and last row are used to summarize column by column and row by row to see the total impact of individual factors and result parameters.

Table 2.1 is a visualization of the PPM.

There are a number of different applications to the PPM (Ståhl 2013):

- Monitor the ongoing production to find critical production segments that need improvement.
- A tool to use when new production systems are under development, the insights gained from analyzing an existing system can be valuable input.
- Assess possible improvement to the production system e.g. change of tools and tool systems and new equipment.

Table 2.1. *Basic structure of the Production Performance Matrix.*

Factor groups A-G and H	**Downtime parameters** S	**Quality parameters** Q	**Processing rate parameters** P	**∑ Factor groups**
A. Tools and tooling systems				
B. Workpiece materials				
C. Process and process data				
D. Personnel and organisation				
E. Maintenance and service				
F. Special factors				
G. Peripheral equipment				
H. Unknown factors				
∑ Result parameters				

2.3 Cost model

In this section the cost model for calculating the cost for producing 1 detail is presented in Equation 2.1. The model includes material cost, equipment cost when producing, equipment cost during downtimes and payroll costs. (Ståhl 2010).

$$k = \frac{k_B}{N_0}\left(\frac{N_0}{1-q_Q}\right) + \frac{k_{CP}}{60N_0}\left(\frac{t_0 * N_0}{(1-q_Q)(1-q_P)}\right) + \frac{k_{CS}}{60N_0}\left(\frac{t_0 * N_0 * q_S}{(1-q_Q)(1-q_P)(1-q_S)} + T_{su} + \frac{1-U_{RB}}{U_{RB}} * T_b\right) + \frac{k_D}{60N_0}\left(\frac{t_0 * N_0}{(1-q_Q)(1-q_P)(1-q_S)} + T_{su} + \frac{1-U_{RB}}{U_{RB}} * T_b\right) \quad \textit{Equation 2.1}$$

Cost term b represents the material cost per produced detail and is denoted k_b. The rejection rate is taken into account and the cost for the scrapped details is allocated to the finished details. If there is any interest to study the cost connected with material waste, an additional factor can be added to the cost term. This term is the material waste factor q_B, calculated as in $q_B = \frac{m_{tot} - m_{det}}{m_{tot}}$ Equation 2.2.

$$q_B = \frac{m_{tot} - m_{det}}{m_{tot}} \quad \textit{Equation 2.2}$$

In $q_B = \frac{m_{tot} - m_{det}}{m_{tot}}$ Equation 2.2 m_{tot} is the total quantity of material including material that is removed from the detail during the production process and m_{det} is the material of the finished detail.

Cost term c1 refers to the cost of the equipment used when processing a detail. The factor k_{CP} is the hourly cost of machinery when the equipment is running. This machinery cost includes the initial investment, the cost for the area taken up by the machine, maintenance costs and variable machine time costs. The variable machine time costs includes the costs that are directly related to that the machine is running, for example electricity and tools. k_{CP} does not include payroll costs. The product t_0*N_0 represent the total time to produce 1 batch.

Cost term c2 refers to the cost of the equipment during downtimes and switchovers. The factor k_{CS} includes the same parameters as k_{CP} except for the variable machinery costs.

Cost term d refers to payroll costs. Since these costs remain the same whether the equipment is running or not, this cost term includes processing time, downtime and switchovers. The factor k_D is the payroll expenses, the wages to the employees are included together with insurance costs and vacation pay. Costs related to staff facilities and possible management or specialist costs directly linked to a production segment should also be taken into account. It is a serious mistake to include all the overhead costs when calculating k_D as they are not directly linked to the production. According to Ståhl (2013) k_D‘s maximum value is about 2.5 times the gross wages involved.

2.4 Empirical distribution functions

The empirical distribution function describes the behaviour of the studied object. This model is used when searching the pattern of breakdowns. The breakdowns are often presented as downtime (DT) or time between failures (TBF). The DT is the length of a downtime and the TBF is the time passing from one downtime to the next one (Ståhl 2013).

The DT or the TBF is sorted from shortest to longest time value. Those values are then weighted as a fraction of the total sum of DTs or TBFs. The weight of a DT or a TBF is translated to a number which makes the sum of the times equal to 1. As these values are plotted the y-axis shows the accumulated weight of the values smaller than the time displayed on the x-axis.

The plot shows the empirical distribution function of the object. This distribution can then be analysed by comparing it to one or multiple known distributions. Those known distributions are in terms of DT or TBF often exponential distributions or Weibull distributions. By matching the empirical distribution function to a couple of known distributions with adapted parameters, the empirical distribution function can be broken down into known distributions. Thereby the empirical distribution function will become a combination of a couple of known distributions.

Every part of the broken down distribution represents a distribution of a downtime cause. Those plots can be compared and the causes for the downtimes can be found, analysed and rated by impact. One of the adapted parameters mentioned is the weight of the known distribution in the empirical distribution functions. This weight shows the impact that distribution have got on the total empirical distribution function.

To get a fair result it is important to gather a large amount of DT points or TBF points. A too small number of points cannot display a fair pattern of the behaviour.

2.5 Balance loss

It is very difficult to control the machines in the line to operate with the same lead time. There is always a slowest working machine. That machine is called the bottleneck and sets the overall pace for the whole production line. The other machines will have to wait for the bottleneck to perform its operation. There is a balance loss in the line created by the different lead times in the machines (Ståhl 2010). The balance loss corresponds to the total waiting time for the production line. The balance loss D, as in $D_{line} = 1 - E_{line}$ Equation 2.3, is defined as the difference between the real line efficiency E and the full efficiency, when all the machines operate at the same pace.

$$D_{line} = 1 - E_{line} \qquad \textit{Equation 2.3}$$

The real line efficiency is defined as the relation between the total real lead time and the total theoretical lead time. The real line efficiency is defined as E_{line} in $E_{line} = \frac{\sum_{i=0}^{n} t_i}{n \times t_0}$ Equation 2.4.

$$E_{line} = \frac{\sum_{i=0}^{n} t_i}{n \times t_0} \qquad \textit{Equation 2.4}$$

Where t_i is the lead time for machine i in a production line with n machines and t_0 is the lead time for the slowest operating machine (Ståhl 2010).

3 Method

In this chapter, alternative methods and techniques are described. Further, the method of choice is defined. The approach for the work is presented, including descriptions of the different steps taken.

The design of the method can be either fixed or flexible (Höst 2006). The design choice is based on the methods used but can, as the name of the designs indicate, be changed during the work. A flexible method allows changes in the method while a fixed design has to be set before the work has started (Höst 2006). A fixed method might be needed to perform when the aim is information gathering. To find the right information the right questions have to be asked. Therefore, it is in this case vital to have a fixed method before the information gathering has started. The flexible design is suitable when the aim is to solve a problem. If the method for solving a problem was known before the start of the project, it would not be that much of a problem. Therefore, the method needs to be adjusted during the project to find the solution to the problem. Of course, a framework for the method needs to be set before the start of a project with flexible design. A framework is needed as a guide for how to proceed, and without a method to start with there would be no method to change during the project.

The method of choice is based on the goal and character of the project. The different aspects of a project are as follows (Höst 2006).

- *Descriptive.* The studies are mainly for finding out and describe how something works or is done.
- *Exploratory.* The studies are used to profoundly understand how something works or is done.
- *Explanatory.* The studies search causes, connections and explanations to how something works or is done.
- *Problem solving.* The studies want to find the solution to an identified problem.

In a project there can be combinations of the different types of studies. For example, to find a solution to a problem the cause of the problem needs to be identified. If this cause is unknown, it needs to be found by explanatory studies. In the same way, the understanding needed to find the explanation can be gained by descriptive or exploratory studies. Each type of study is connected to a method, as presented below (Höst 2006).

- *Survey.* The method compiles and describes the present situation for the studied object. This is often a step towards describing a wide matter. Usually, this is done by descriptive studies and the design is fixed.
- *Case study.* In depth studies of one or several cases where the object is affected as little as possible. In this method the purpose is exploratory and the design is normally flexible.
- *Experiment.* Analysis comparing different options. Factors are isolated and manipulated to compare the different impacts. An explanatory study is compatible to a fixed design.
- *Action research.* A carefully monitored and documented study which wants to find the solution to a problem. A problem solving method which often demands a flexible design of method.

Combinations of the different methods are, as described with previous examples, allowed and often needed. There is also a choice when it comes to which kind of data that is needed. The data can be either quantitative or qualitative. The quantitative data can be counted or classified and handled by statistical analysis. Qualitative data consists of words and descriptions and has to be analysed by sorting or categorisation. In cases of complex problems, a combination of the 2 types of data might be needed (Höst 2006). Another way to categorize the data used in the study is to look at the data source. Lekvall and Wahlbin (2001) make a distinction between primary and secondary data. Secondary data is already collected and can be found in existing statistics and in databases with production data. Primary data on the other hand is data that needs to be collected directly from the source.

The purpose of this study is to solve an identified problem. Therefore, the method for this study is mainly action research. Due to the complex nature of the production line and the lacking knowledge of the problem cause, other methods will also be needed. The quantitative data needs to be analysed by experiments to make up a knowledge base for the problem solving.

Based on the method and the theory, tools are chosen. The tools used should be fitted to be helpful for fulfilment of the purpose. With a flexible method design, more tools might be added during the process if the need appears. Tools might also be adapted to be of better usage.

3.1 Project method

To proceed in the project it is important to setup a strategy, aiming towards the mission of the project. Through the way a lot of tools will be needed to fulfil every step of the overall strategy. Each tool with its own contribution to the overall result. The overall project method is of strategic nature and is used as a base showing which tools that will be needed on the way. The task of the project method is to secure that the work that is put in the different parts of the project always contributes to fulfil the common objective.

The overall project method in our case is set up as follows:

1. What? Formulate the problem.
2. Where? Find the location of the problem.
3. How? Find the effects of the problem.
4. Why? Find the cause of the problem.
5. Test and analyse the results.

The overall method of the project is closely connected to the purpose of the project. It is a frame needed to hold the right line. Therefore, the first step is to connect with the purpose. The steps are based on the nature of the project and the providing company. The company's production lines are highly automated and complex, including several production steps. The second step of the overall method is to break down the complex production line into units. This makes the complexity easier to understand and provides numerous possibilities to connect each unit to another. It displays a map of the production line units which makes it possible to rank either effects or causes of the problem.

The third step is to find and rank the contributions of the problems and to sort out efficiency losses after size and impact. This provides a guideline for which efficiency losses to put main focus in. The most important step is of course to find the cause of the problem. The size of the effects may not be representative for the impact of the different causes. It is not the main causes but the main effects which shows in the results. Still, it is always in the cause of a problem where it is possible to find the solution. It is important though that the solutions are tested and analysed to show the effects on the overall result. Iterations are of great importance to find the vital causes and its contribution to the results. Especially the question “Why?” should be iterated at several occasions.

3.2 Tools

The approach for using the experimental tools is taken according to Laws method (Law 2009). This method is used as fixed to keep track when working with the tools, the work should always aim for its purpose. Laws method is slightly adapted for each tool, to fit in the process.

Laws method:

1. Formulate the problem.
2. Collect information/data and construct an assumptions document.
3. Is the assumption document valid?
4. Program the model.
5. Is the programmed model valid?
6. Design, conduct and analyse experiments.
7. Document and present the simulation results.

The formulation of the problem is the line of argument when attempting each tool. The assumptions document is needed to validate the collected information before performing the analysis. The results from the experimental tools should be documented for use in the action research part of the study.

3.2.1 Statistical overviews

To reach an understanding of how the production lines are running, statistical overviews could be done. The overview should show the losses in efficiency for each cell of the different production lines. By choosing, excluding and gathering information about the process, an overview is made.

The statistical overviews should be used to learn about the production layout by displaying the layout as a statistical map. It is, of course, also useful to use as a rough information gathering system showing the narrow locations of the efficiency problems. The efficiency factors taken into consideration in those models are production spoilage, downtime and pace. Every factor is combined with the different steps of the production lines to create a line performance matrix. The cells of the matrix form a statistical overview displaying 3 kinds of efficiency for every production step.

The overviews are performed according to the work-structure presented by Law (2009). As the overviews are rough models of the production, with less consideration for details, most of the work for those models is to be done in the iteration part of the structure. These models are not only to get a statistical overview but also to gain basic knowledge of how the production lines work. The formulation of the problem needs to be consulted for every obstacle appearing in the data collection phase to avoid unnecessary work. For every new piece of basic information an iteration also has to be made back to the collecting of information and assumptions. Most of the workload though lies in the validation of the assumptions, where every new-found piece of information can change an assumption rapidly.

In the formulation of the problem the basic goals of the project is consulted. This model is the first step of the method used for finding causes of efficiency loss in the production lines. In this first step, the aim is to locate the points of the line where the impact of the problems is most visible, i.e. where the efficiency losses take place. This formulation of the problem is always consulted in iterations as the statistical overview should show information needed to visualize the efficiency loss only.

The majority part of the workload for statistical overviews lies in gathering information and constructing an assumptions document. The overviews should be a first narrowing of the information flow, which means that the basic information about the production of this product, the company, the machinery and the statistics measuring needs to be gathered at this point. As the production is advanced and complex, this is a demanding step including several methods and iterations. The methods consists of learning to understand the wide statistics gathering programs provided by Rexam (VISCAN, TPS, QSA), finding and evaluate old approaches to solve the problem, understanding the production methods, watch and follow the production routines, interview the internally experienced in every area of the company, check the sanity of the measuring and much more. Every new piece of information must be evaluated with consideration to the formulation of the problem and the sanity of the information. As a consequence of the information gathered, assumptions have to be made to include, exclude or edit the information. The assumptions can be used to fit the information to the formulation of the problem. Assumptions are based on the usefulness, sanity and vitality of the information received. Once again, new information can prove assumptions inaccurate, which bring new iterations.

The programming of the statistical overviews is made in Microsoft Excel and VBA to gain complete overview-templates designed to fit and sort the information directly imported from VISCAN. Most of the validation of the programme model contains of corrections, completions and simplifications of the programming and the plot design. In other words, the validation of the assumptions is the step of the structure where the most vital changes are done.

The step design, conduct and analyse experiments mostly consists of finding adequate data to use in the simulation. The right data is vital for achieving useful information from the model. Data has to be of satisfying amount but also of a width possible to handle. Too much information brings too many questions to be answered but less information does not give an enough accurate description of the situation wanted in the overview. When designing and analysing the experiment, factors like major maintenance periods and holidays also needs to be considered.

The documentation and presenting of the results of this method is automatically done by the programmed template. The template does not only consist if macros for sorting and calculating, but also of plots which displays the results. In the results the narrow location of the efficiency losses should be visualised. This method consists of a lot of work itself but can be valuable in the next steps of the project by narrowing the search for the cause of the problem to production line locations and specific types of efficiency losses. The results of this method are to be used in the next steps of the project as guidelines.

3.2.2 Production Performance Matrix

The production performance matrix is used to rank the different efficiency losses and its causes. The efficiency losses is divided into spoilage, downtime and reduced pace. Every contribution to the efficiency loss in the production line is linked to a type of efficiency loss and a cause. This tool can display how much impact every cause has got on overall efficiency.

One of the most difficult steps when using this tool is in the information gathering. The information is easy to collect, the hard part is to know which information to collect. The data needs to be representative for the production, but also possible to fit as input in the PPM. The company's information gathering system does not provide a feasible solution in itself, the information needs to be adjusted and picked manually from several sources. Another issue is in the several assumptions needed. Detailed knowledge of the company and the production is a demand to make the PPM a useful tool. An option is to make comprehensive research which brings numerous assumptions, but that brings a lot of insecurity to the outputs. Therefore, expertise assistance is needed to narrow down the width and number of the assumptions. The consulting experts are needed in order to link the efficiency loss to the right cause.

When adding data of different efficiency losses, it is important to consider the units of the different losses. The downtime for example is measured in time units, while the spoilage is shown as number of spoiled cans. The losses in pace are in the information gathering system displayed as percent of the nominal pace. To compare those 3 types of efficiency losses, the units need to match. Therefore, the losses have to be translated into percentage loss of total production and total production time. This is not a perfect solution though. 2 efficiency losses of the same percentage size might vary in overall impact. The impact is also affected by the other production line units and the location of the efficiency loss. For example, a pace loss of 2 % in the fastest running production line unit does not affect the overall production as much as a same size loss in the bottleneck-unit. In the same way spoilage of 3 % in the first production step does not cost as much as spoilage of 3 % in finished inventories. Mix those 2 examples together and it is easy to find that the efficiency losses are hard to add and compare fairly. 3 % reduction in pace might not impact the overall efficiency while a 3 % spoilage in the finished inventories always is a hard blow to the efficiency. This issue is taken care of with other tools, e.g. the cost model.

The programming of the model cannot be prepared more than construction of an input sheet. Due to the availability of data, the input needs to be done manually for each case. Each type of efficiency loss is put in, sorted and linked to a cause in the matrix sheet. This needs to be done manually for each unit of the production line. The lack of possibilities of programming a template which automatically sorts the inputs makes this method very demanding. Due to limited time it will not be possible to attempt this tool throughout the whole production line.

The experiments using this tool will be performed as one of the final steps of the project. The difficulties in fitting the model to the input make it vital to have a comprehensive base of information about the efficiency losses before this tool is used as a way to link the losses to its causes. It can only be done for a few points of the production line, knowing which points to use are therefore critical. The analysis of the given results is also demanding and needs to be done carefully, with iterations where the results are tested with possible improvement rate as output.

3.2.3 Cost model

The cost model is the tool that transforms the efficiency loss into costs. It is useful to calculate how the improvements might be valuable for the company. It can also be used as a tool to rank the different improvement suggestions, using the most important unit for the company.

During the project, the purpose of the cost model is to measure the efficiency in terms of economy. As mentioned earlier, an efficiency loss might be more or less valuable depending on where in the production line it occurs. This tool sets all efficiency losses to the same unit and makes them possible to compare fairly. It is a useful tool when it comes to selection of different improvement proposals. The cost is always the deciding factor and it is the only unit comparable to the investment costs needed.

The data for the cost model has to be collected from several sources. The different costs have to be valid and are provided by the economy staff of the company. The information has to be considered and checked for sanity. For example, the depreciations method might need to be controlled. The machine park is old, the way to depreciate the machines might cause unfair conditions when comparing the old machines to investments in new.

The deciding parameters are of great importance, they will be selected carefully from the information gathering system provided by the company. Those efficiency parameters are treated and adapted from other tool as the statistical overviews and the PPM. The assumptions for those important parameters are thereby already made.

The deciding part when using this tool is the validity of the inputs. The model is easily programmed to transform the input to output. The calculations have to be adapted to the situation at the company and the information available. The model will have to be simplified with fair assumptions to make the model useful and, at the same time, valid.

The experiments are designed using the results from other tools. The cost model should be used to compare the improvement possibilities found in the other tools and to show the gains in executing the suggested improvements. The cost model experiments should be selected when the suggestions are found. The results from this tool should be a theoretical result showing the possible efficiency improvements in the production.

3.2.4 Empirical distribution functions

The distribution functions are a helpful tool to find patterns in downtimes and time between failures. By using this tool the recurring downtimes can be identified. Those downtimes are of great interest for the study as they represent more efficiency loss than randomly occurring downtimes. They are also caused by a factor that hopefully can be identified by studying the occurrences. The purpose of using this tool is to identify the main causes of efficiency loss.

The information is collected from the information gathering system. As this tool demands accuracy it is important to select the right points of interest. This is done by using the statistical overviews. The information in the chosen points should consist of downtimes or times between failures. Corrections and exclusions have to be made to the information. For example, many registered downtimes have lengths of less than a second. The efficiency is not affected by those values. To obtain a usable plot those values have to be excluded.

The model is programmed by creating a suitable template where the formulas and the distributions are prepared. The input values should be easy to put in this model and the plot should be displayed. To match the empirical distribution functions to analytic functions, manual work is needed.

The experiments should be selected by using the statistical overviews. The template is used to obtain plots of the empirical distribution functions chosen. To analyse the experiments, the plots are used and matched with known distributions. When the matching distributions are found, the work continues by finding the causes creating those distributions. There might also be gains in comparing this tool’s results regarding different machines in the production line. Finding patterns between the downtimes in different machines might be valuable for the study.

The documentation is an important part of this tool. The results from this tool in combination with other tools should be used to pick out the main causes of efficiency loss in the production line. The results can also be used to confirm the observations gained from the other tools. The results from this tool are presented as matched plots and analysis of the causes.

4 Calculations

In this chapter the calculations and adaptions in the chosen tools are presented. The assumptions taken are presented along with the choice and corrections of indata. This chapter describes the usage of tools in detail.

To fit the tools and models to the project they all have to be more or less adjusted. During the project some tools might turn out useless according to the updated situation created by the new information gained. Those models will be adjusted or taken out of consideration, as presented in this chapter.

The level of calculations in the different models may vary. In some models the calculations are trivial and in others there is a demand of more advanced calculations and numerous assumptions. Those will be presented tool by tool in as much detail as possible.

4.1 Statistical overviews

The statistical overviews are made to gain an overall understanding over the efficiency in the production line. The efficiency numbers used are spoilage, pace and downtime. Those efficiency numbers are calculated in each machine of the line where it is possible with the available information. Altogether, those numbers form a matrix displaying the efficiency for each part of the production line. The matrix is also converted into several plots to make the information easier to analyse. The plots are presented in further detail later. The calculations in this model with its assumptions are presented here.

4.1.1 Spoilage

The information gathering system VISCAN provides statistics for the spoilage in every machine in the line. The statistics are based on sensors counting the number of cans entering and exiting machines. The spoilage presented is the difference between the numbers. There is no information on how the cans are lost, just where. The number of cans spoiled on the conveyors, which represents the majority of the lead time, is counted as the difference between cans exiting the previous machine and the number of cans entering the succeeding machine. The only information of how the cans are spoiled is found in another information gathering system, TPS. The information in this system is based on samples and does not show where in the line the spoil occurred. There is also a count of the number of waste bins used along the line. The completed pallets with issues are traced to a cause, but this is also a method with incomplete information. The aim of the statistical overviews is to map the efficiency in the different parts of the line. Therefore, the spoilage data used in this tool is the data from VISCAN. This data provides the information needed and is not less trustable than the other spoilage tracing systems. Calculations have been made to compare the systems, showing that the chosen indata is trustworthy. The chosen indata provides information of where in the line the spoilage takes place. The information about how the spoilage appears is left out in this tool but used in the PPM and the empirical distribution functions tool.

The spoilage in each cell are presented in spoilage percentage. The number of spoiled cans is calculated as the difference between cans in and cans out of each machine or conveyor. The spoilage percentage is calculated as this difference divided by the number of cans put into the same machine, see $Spoilage\ \% = \frac{Cans\ in - Cans\ out}{Cans\ in}$ Equation 4.1. Note that the denominator in this equation is the input to the current machine and not input to the line. This makes the percentage representative in each machine or conveyor of the line. It also provides the possibility to sum the percentage units for the whole line.

$$Spoilage\ \% = \frac{Cans\ in - Cans\ out}{Cans\ in} \qquad \textit{Equation 4.1}$$

At 2 points in the beginning of the line there is possibility to transport cans between the lines 1 and 2, as described in section 1.3.4. This possibility creates insecurity regarding the spoilage in this part of the line. A lost can might not be spoiled but transported to the other line to support the supply in that line. Therefore, the part of the line where this cross-conveyor is located is calculated as 1 point of spoilage. The inputs of cans at this point are set as the accumulated inputs of the 2 lines. At the same way, the output of cans at the end of this point is set as the output from the 2 lines added. This forced adding of points creates an information gap in the statistic overview. This point of the line will be more closely investigated with other tools.

4.1.2 Pace

In a highly automated production line, each machine or conveyor is dependant of the pace of the others. It is important to keep track of the pace in each part of the production line. The pace can be continuously adjusted if this option is allowed in the machine. In the machines which allows this, the pace loss can be calculated as an efficiency loss. In the machines with fixed pace, the pace loss is of course equal to 0. Its nominal pace is important though, to use in comparisons with the actual pace of the other machines.

The average pace in a machine or in a conveyor is calculated as cans per minute (CPM). The number of minutes is given from VISCAN as the sum of the different types of run modes. This number of accumulated operation time together with the number of produced cans gives the pace in cans per minute as in $Average\ pace = \frac{Produced\ cans}{Operational\ time}$ Equation 4.2.

$$Average\ pace = \frac{Produced\ cans}{Operational\ time} \qquad \textit{Equation 4.2}$$

To calculate the efficiency loss in pace, the average pace is compared to the nominal pace, given by Rexam. The calculations are done according to $Pace\ loss\ \% = 1 - \frac{Average\ pace}{Nominal\ pace}$ Equation 4.3.

$$Pace\ loss\ \% = 1 - \frac{Average\ pace}{Nominal\ pace} \qquad \textit{Equation 4.3}$$

In the model, the nominal pace is used as a parameter in several calculations across the production line. Therefore, it is easy to change in the input cells. Note that this calculations displays the pace loss as loss of pace when running. The loss when the pace is 0 is defined as downtime loss. This makes those 2 kinds of losses possible to add up.

4.1.3 Downtime

If a machine is down, there will be no production. It is vital to keep the machines up and running. When the machines go down, because occasionally they will, it is important to find out why they are going down. The downtime calculations include categorization to different kinds of downtime modes to answer this question. The overall downtime in the statistical overview is set as the sum of all types of downtimes, including machine faults, standby and manually operated stops. The overall downtime in each machine is calculated as the downtime divided by the overall time period, in other words the sum of the different modes. Computation carried out in terms of $Downtime\ \% = \frac{Downtime}{Downtime + Operational\ time}$ Equation 4.4.

$$Downtime\ \% = \frac{Downtime}{Downtime + Operational\ time} \qquad \textit{Equation 4.4}$$

The categorization of different kinds of downtime gives an important input to the project. They are treated separately as an adjusted version of the production performance matrix and are considered in that chapter.

An issue when it comes to the downtime can be found in the printer area. The production line is built up with 2 printers, running separately. When a printer is down due to the operational mode of the other printer, it cannot be seen as downtime. This cell of the statistic overview matrix must be adjusted to gain proper downtime statistics. The data system does not specifically show when this is the case, it has to be corrected in the model. The assumption used by the company expertise (Rosendal 2014) is to exclude 2 certain downtime modes shown for the printer. This assumption brings a slight uncertainty but makes the statistics as proper as possible. The 2 modes assumed being representative for this printer mode is therefore excluded in the statistics to gain accurate numbers. The printer area turns out to be a vital part of the production line, the impact of this assumption should not be underestimated.

4.2 Bottleneck

According to the theory, it is important to know where the bottleneck of the line is located. The maximum pace of the bottleneck is the maximum pace of the production line. Calculations have been made to find the pace of each production point in the pace calculations. When searching for the bottleneck, this pace loss is not included. The bottleneck appears when using the nominal pace. A modification to the nominal pace is made though, to fit the production line. The production line consists of old machines and breakdowns are not unusual. Those breakdowns, mostly caused by machinery faults, have been excluded to receive the true pace potential of the units in the production line. These breakdowns can probably be avoided only by replacing the old machines. By excluding those breakdowns when searching the bottleneck, the real numbers of the machine capacity appears. The real capacity is referred to as maximum potential in Equation 4.5.

$$Maximum\ potential\ (CPM) = Nominal\ pace\ \times (1 - Breakdown\ rate) \quad \textit{Equation 4.5}$$

The machine with the slowest potential pace is the bottleneck of the production line. This machines pace is also the overall pace for the production line and therefore the machine that can increase the production rate.

To compare the machines in a plot, the potential paces are recalculated to percentages. The machine with the highest pace is set to 100 %, the other machines are set as percentages in comparison to that.

4.3 Balance loss

In the production line of interest, the lead times in the machines are very short. The paces of the machines are not referred to as time in operation but in cups per minute. The calculations used to translate the unit cups per minute to lead time, or time in operation, are trivial but explained by Equation 4.6.

$$Lead\ time\ in\ machine\ (minutes) = \frac{1}{Machine\ pace\ (CPM)}$$ *Equation 4.6*

This translation of the units is not necessary for the results of the calculations. The balance loss can also be calculated with the input unit cups per minute. To adapt the model to be suitable for calculations with CPM as an input, there is change to be made in the formula for the real line efficiency. The fastest lead time is the shortest time while the fastest pace is the highest CPM. Therefore, the equation is turned upside down as in $E_{line} = \frac{n \times p_0}{\sum_{i=0}^{n} p_i}$ Equation 4.7.

$$E_{line} = \frac{n \times p_0}{\sum_{i=0}^{n} p_i}$$ *Equation 4.7*

Besides the change of place between the numerator and the denominator, the lead time t is changed to the pace p in $E_{line} = \frac{n \times p_0}{\sum_{i=0}^{n} p_i}$ Equation 4.7. p_0 is the pace of the slowest working machine expressed as CPM. The formula for the balance loss in Equation 4.8 does not need any change.

$$D_{line} = 1 - E_{line}$$ *Equation 4.8*

4.4 Conveyors

The lead-time for completing a product is essential for using theoretical models to calculate production costs and track production obstacles. Due to the fact that the detailed lead-time is not a part of the company's information handling system, this needs to be done manually. In fact, there is an absence of information considering not only the lead-times but the overall transportation of material in the production lines. The lead-times in the different processing steps is known from the pace of the processing machines, easily calculated from the given dimension *cups per minute*. The processing time though is a small part of the total lead-time, which mainly consists of transportation time. This absence of information includes not only transportation times but also the capacity of the transportation in terms of pace, size and spoilage. The latter is partly considered from count of waste bins positioned along the conveyors. In accordance to the project method, this needs to be done in order to find the location of the problem. The lead-time is also vital to display the monetary effects of the efficiency loss in the different steps of the production line.

The method for gathering significant information of the transportation is by manual measuring. The capacities of the conveyors is calculated from the length and width of the conveyors, measured with a foot rule and calculated with $Conveyor\ capacity =$ Equation 4.9.

$$Conveyor\ capacity = \frac{Conveyor\ length\ \times Conveyor\ width}{(Can\ diameter)^2} \qquad \textit{Equation 4.9}$$

The pace of the conveyors expressed in cups per minute is calculated from the width and speed of the conveyors and the width of a can, as in Equation 4.10. The speed is measured by a speed measuring tool and/or a stopwatch. The width is now known from previous measuring with foot rule. The conveyor speed is measured as distance per time unit.

$$Conveyor\ CPM = Conveyor\ speed \times \frac{Conveyor\ width}{(Can\ diameter)^2} \qquad \textit{Equation 4.10}$$

The lead-time of each conveyor is calculated from the measured speed and length of every conveyor with $Conveyor\ lead\ time = \frac{Conveyor\ length}{Conveyor\ speed}$ Equation 4.11.

$$Conveyor\ lead\ time = \frac{Conveyor\ length}{Conveyor\ speed} \qquad \textit{Equation 4.11}$$

In this calculations, the impact of the assumptions are not as deep as in many other tools used. Assumptions mainly have to be made about how trustworthy the measuring tools are. Tools which can be controlled to a certain accuracy. The width and length of the conveyors are of course fixed values, while the pace of the conveyors may vary. This may also be controlled, as a suggestion by consulting the line-control department.

The calculating in the model is done by a simple template in Excel. The formulas presented above are programmed to display the preferred information about each conveyor in order of appearance. This gives a detailed statistical overview for these parts of the production line, needed due to the present information gap.

This model of new information gathering can be used to display efficiency losses in the transportation parts of the production line. It may of course also be used to gather information needed in other models.

4.5 Choice of time period

The models described so far are tools used to gather and display information as preferred. The next step is to use those models to find suitable statistics to investigate further. In the upcoming models, the statistical data from the information gathering system is used as an input. Those models are designed to analyse the statistics. Therefore, it is vital at this stage to choose the right statistics to analyse.

Due to the high amount of statistics available, it is not possible to use statistics representing a wide extent of time as input in the models. The tools and models are not powerful enough and the workload would be unnecessarily high compared to the benefits it might bring. The width of the statistics must be narrowed. At the same time, the statistics that is to be analysed must be representative.

The method to choose the right time period for the statistics is the same throughout the project. The choice of period may vary though, to make it suitable for its tool. The statistic overview model is used to display a wider time period of statistics and compare its values to a shorter time base. For example, if the aim is to find a representative time period of a day that day is chosen by comparing its values to the values of a month. The day with the most similar values in comparison to the month is picked as a representative time period. The statistics from that day is used as input in tools where one day is a suitable time period. When deciding which day to pick as most representative, the purpose must be considered. For example, if the aim is to study the spoilage in the front end of the production line the decision should be based on those values.

The comparison can be made manually by considering the plots displayed in the statistical overviews. The same method can also be used when deciding which efficiency values to prioritize in further studies.

4.6 Production Performance Matrix

The implementation of the production performance matrix is different from the original model. This is because of the difficulties to find the causes for the spoilage. The sorting out of the downtimes is already done by the company's information gathering system, sorted into the general causes. Considering the workload needed to sort out the information in a more preferred way, the best way to perform the PPM is by using this pre-sorted information. This is not the preferred way to perform a PPM and may therefore not be expressed as such. The theory is taken from the tool though and this version has turned out to be valuable for the study.

The PPM in this study consists of downtime with different causes, sorted by causes and locations. The causes are general, but still provide the big picture and a valuable extension to the statistical overviews. The downtimes are set as breakdowns, manual stops and standby. The standby stops are defined as waiting time for the previous machine or waiting time for the succeeding machine. The accumulated downtime for the causes shows the contribution from the different causes. The downtime causes sums can be compared to each other as well as to the sums of overall operational times, received in the statistical overviews.

4.7 Inventory gains model

The calculations presented in this subsection treat the model used for visualising the gains in extended inventory. The model emerges from the results of the other tools and models. It is a model developed specifically for this study, using parts from several presented theories. The results of the study are the background for this model and therefore the model is treated in detail in the end of chapter 5. The calculations are presented here though.

The aim is to compare the waiting time in the bottleneck with the time of emptying an inventory placed prior to the same machine. The waiting time consists of standby, downtime and pace loss. The pace loss is translated to downtime by changing the pace from 85 % of nominal pace to 0 % of nominal pace as in Equation 4.12. The 15 % is the pace loss when the bottleneck is set to low speed. The loss translated to downtime minutes is there by 15 % of the time period when the machine is set to low speed. The 15 % used as a transformer is the highest pace loss possible for the machine. The machine might also run in low speed mode with less pace loss (Lidman 2014). The 15 % is used to simplify this model. It also prevents the results from being too optimistic.

$$Minutes\ of\ pace\ loss = Low\ speed\ setting\ length\ \times 0{,}15$$ *Equation 4.12*

The pace losing periods and the standby downtime periods is now expressed in the same unit. The same unit is preferred also for the buffer. The buffer is calculated from the area of the conveyors and buffer tables prior to the bottleneck. This area is transformed into number of cans in buffer with Equation 4.13.

$$Cans\ in\ buffer = \frac{Buffer\ area}{Can\ diameter^2}$$ *Equation 4.13*

From the number of cans in buffer, the dimension is set to minutes by using the nominal pace of the bottleneck expressed in cans per minute according to

$$Minutes\ of\ buffer = \frac{Cans\ in\ buffer}{Nominal\ pace\ of\ machine}$$ Equation 4.14.

$$Minutes\ of\ buffer = \frac{Cans\ in\ buffer}{Nominal\ pace\ of\ machine}$$ *Equation 4.14*

Now, the 3 factors are expressed in the same unit. It is possible to compare the buffer level to the downtimes. By using this model, the buffer level needed to prevent a waiting stop can be found. If the waiting stop is shorter than the time it takes to empty the buffer, that stop can be prevented.

The sum of the downtimes that can be prevented by keeping a buffer is recalculated to percentages of total downtime. This is displayed against the inventory level needed in a diagram.

5 Results and Analysis

In this chapter the outputs from the tools are presented and analysed. The results from the tools provide valuable information that all together helps with finding the solution to the study. The results are analysed one by one in this chapter, summarised and concluded in the chapter Conclusion.

The different tools and models are all small steps taken aiming at the same goal, to find the solution to the efficiency problem in line 1. All together they will hopefully provide enough information to visualise the cause of the problem. To reach that goal, the results from the tools need to be analysed one by one.

The time period used for the data input to the tools differs. The time period used is presented and the choice of time period is explained for each resulting output.

5.1 Bottleneck

Even though the information, about the printer is supposed to be a bottleneck, is given there is a point in controlling this information. To know which machine that is the bottleneck in the production line is vital for the analysis of the results. The bottleneck is decisive for the overall efficiency in the production line.

To find the bottleneck, the pace of the different steps of production line is used. The numbers are taken from the statistical analysis, read section 5.3.2. For reasons explained in the same section, the production steps used in this analysis is the steps with automatically adjustable pace. The nominal paces for those production steps are used.

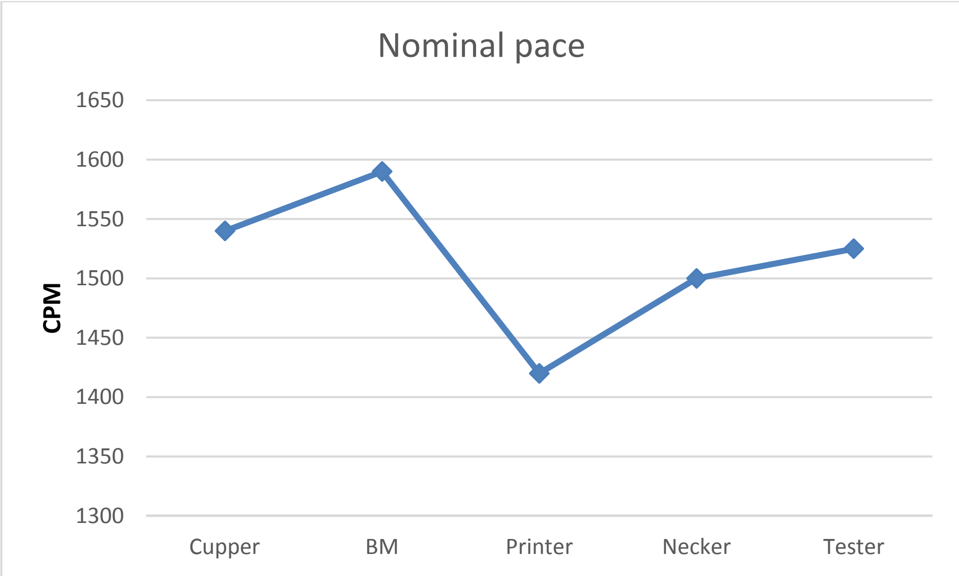

Figure 5.1. *Nominal pace of the machines in the line to display the location of the bottleneck.*

The plot in **Figure 5.1** displays how the machine with the lowest nominal pace acts as a bottleneck in the production line. The printer is supposed to be the bottleneck, which it also is according to **Figure 5.1**. The pace as percentages of the fastest working machine in the line is shown in **Table 5.1**. The machine with the highest nominal pace seems to be the bodymaker (BM), it is therefore seen as 100 % in **Table 5.1**.

Table 5.1. *Nominal paces in the 5 machines as CPM and as percentages of fastest working machine.*

	Cupper	BM	Printer	Necker	Tester
Nominal Pace	1540	1590	1420	1500	1525
	97 %	100 %	89 %	94 %	96 %

The bottleneck is supposed to have a capacity of about 85 % of the fastest working machine (Lidman 2014). It seems to be slightly higher in this case.

The machines in the production line are from the 1980s (Lidman 2014). There is downtime in every machine caused by machinery fault. A lot of this downtime is hard to avoid with the old machine park. To investigate how this factor affects the average pace capacity of the machines, the downtime caused by machinery fault is reduced from the nominal pace. With this adjustment, the plot for showing the bottleneck gets a very different appearance. This is an interesting way of searching the bottleneck due to the nature of the machine park. As the machines are operating today, the adjusted numbers does actually provide a fair view of the real pace capacity of the machines. The machinery fault is of course nothing to exclude from the report, but in this phase this method gives a proper view of the present situation.

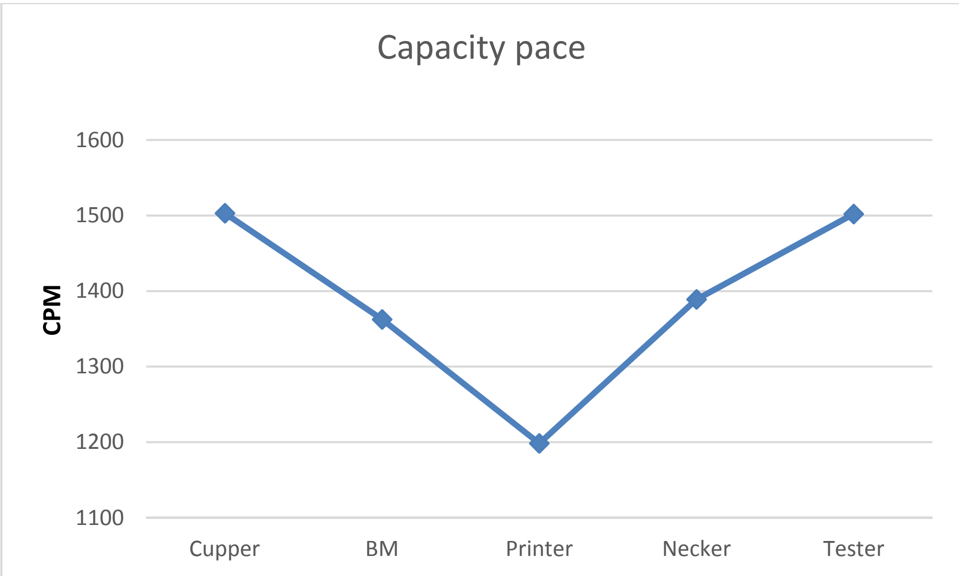

Figure 5.2. Pace of the machines when machinery fault is considered.

The machinery fault percentages are taken from the statistical overviews. The nominal pace is reduced by this percentage, given the new capacity shown in **Figure 5.2**. The bottleneck is still located in the printer but note that the pace compared to the fastest working machine is now much lower, see

Table 5.2. Also note that the bodymaker is now not the fastest working machine. Comparing the pace of the bodymaker in **Table 5.1** and

Table 5.2, the bodymaker is significantly slower when considering the downtime caused by machinery fault.

Table 5.2. *Nominal pace of the machines reduce by machinery fault 2013-09-09 – 2013-10-13.*

	Cupper	**BM**	**Printer**	**Necker**	**Tester**
Machinery Fault	2.4 %	14.3 %	15.6 %	7.4 %	1.5 %
Capacity Pace	1503	1363	1198	1389	1502
	100 %	91 %	80 %	92 %	100 %

The new numbers show that the bodymaker and the printer are relatively slower than expected. When planning and controlling the production, the pace of the printer is assumed to be 85 % of the pace of the fastest running machine. This new knowledge might be a factor worth considering. The actual capacity of the printer is actually less than expected, which puts even more demand on this bottleneck.

It might also be interesting to compare the appearance of the bottleneck curve to lines with better results. The statistical overviews provide the possibility to easily perform a comparison. One of the best running lines with available statistics is line 4 at Rexam Fosie. This line is used in comparisons, the differences might show the cause of the low efficiency in line 1. Another interesting comparison to be made is the one with another time period in line 1. There are time periods when the results in line 1 are significantly better than the average results. To compare the good time periods with the average, interesting observations may appear. The curves of the nominal paces at different time periods in line 1 will look the same, therefore the comparison is made with the capacity pace.

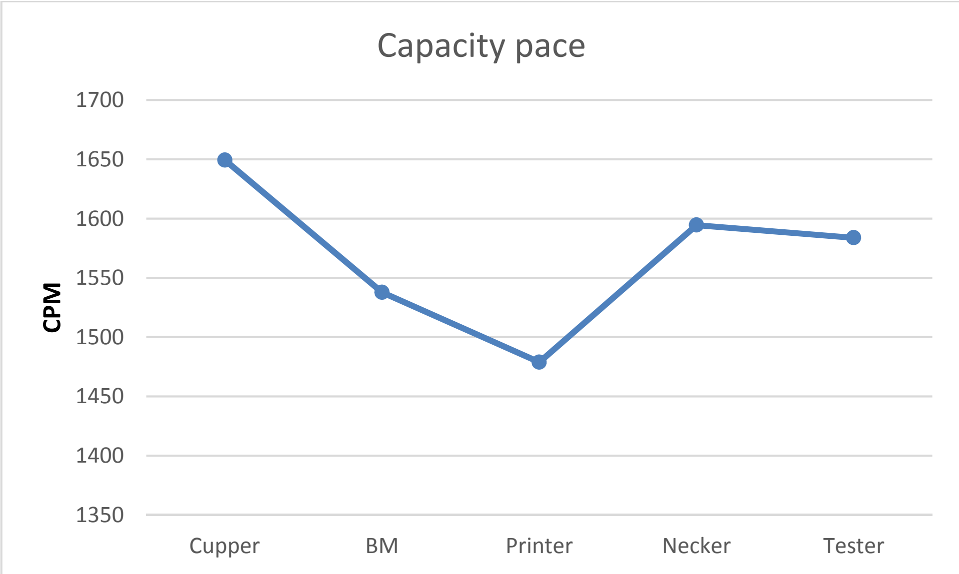

Figure 5.3. *Capacity pace in line 4, machinery fault 2013-09-09 - 2013-10-13.*

Table 5.3. *Capacity in line 4, machinery fault 2013-09-09 - 2013-10-13.*

	Cupper	BM	Printer	Necker	Tester
Nominal Pace	1680	1680	1630	1670	1720
Machinery Fault	1.8 %	8.5 %	9.3 %	4.5 %	7.9 %
Capacity Pace	1649	1538	1479	1595	1584

The appearance of the bottleneck curve for line 4 is different from line 1, see **Figure 5.3**. The printer is still the bottleneck, but its capacity is higher in comparison to the bodymakers. The last 2 points in **Figure 5.3** has a very special appearance, but it should not affect the efficiency of the line as it does not affect the bottleneck. The most significant difference between line 1 and the more effective line 4 is the faster nominal paces.

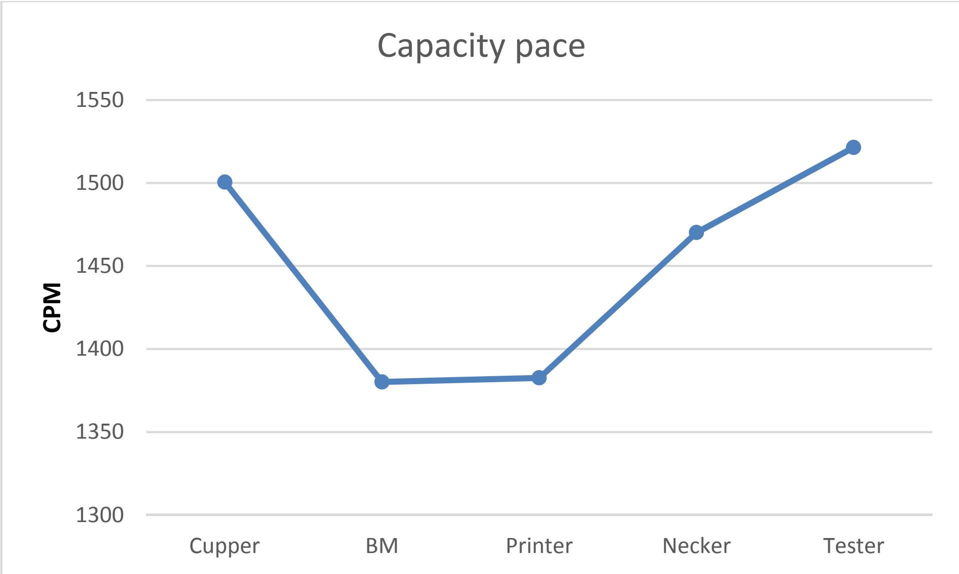

Figure 5.4. *Capacity pace in line 1, 2014-04-21.*

Table 5.4. *Capacity in line 1 with machinery fault from 2014-04-21.*

	Cupper	BM	Printer	Necker	Tester
Nominal Pace	1540	1590	1420	1500	1525
Machinery Fault	2.6 %	13.2 %	2.6 %	2.0 %	0.2 %
Capacity Pace	1501	1380	1383	1470	1521

The curve in **Figure 5.4** has a different appearance in comparison to the average curve for the same line in **Figure 5.2**. The printer was not the bottleneck this day. The bodymakers and the printer are running with the same capacity pace. This is mostly because of the low machinery fault in the printer, see **Table 5.4**. To get better efficiency results with lower machinery fault is not surprising, that is probably the explanation to the better results. It is still exciting results that should be considered.

5.2 Balance loss

To make the balance loss results comparable to the results from the bottleneck model, the balance loss calculations is done with the same numbers as used in the bottleneck model. The balance loss is calculated for the 2 cases where the input is either the nominal pace or the pace when considering the downtime caused by machinery faults. The balance loss calculated from nominal pace is calculated as:

$$E_{line} = \frac{5 \times 1420}{\sum 1540 + 1590 + 1420 + 1500 + 1525} = \frac{7100}{7575} = 0{,}94$$

$$D_{line} = 1 - 0{,}94 = 0{,}06$$

Balance loss calculated when considering downtime caused by machinery fault:

$$E_{line} = \frac{5 \times 1198}{\sum 1503 + 1363 + 1198 + 1389 + 1502} = \frac{5990}{6955} = 0{,}86$$

$$D_{line} = 1 - 0{,}86 = 0{,}14$$

The results from the balance loss calculations show that there is a significant difference between the different ways to consider the losses. The nominal pace is the base for the production calculations at the company but there is a critical change of situation when considering the downtimes caused by machinery fault. This does help explain why the situation in the production line is difficult to control. When analysing the results from the waiting time calculations, this is a factor worth remembering. The production controlling is based on numbers which do not represent the real situation.

To increase the output from line 1 the 2 printers could run at the same time. This will however affect the line efficiency and balance loss. Balance loss calculated from nominal pace:

$$E_{line} = \frac{5 \times 1500}{\sum 1540 + 1590 + 2840 + 1500 + 1525} = \frac{7500}{8995} = 0{,}83$$

$$D_{line} = 1 - 0{,}83 = 0{,}17$$

Balance loss calculated when considering downtime caused by machinery fault:

$$E_{line} = \frac{5 \times 1363}{\sum 1503 + 1363 + 2396 + 1389 + 1502} = \frac{6815}{8162} = 0{,}83$$

$$D_{line} = 1 - 0{,}86 = 0{,}17$$

The results from the calculations show that the efficiency will drop drastically, this is because of the overcapacity in the printers which cause a lot of idle time in that station. On top of this the downtime caused by setups will increase because the setup on one printer can no longer be done while the other one is running.

5.3 Statistical overviews

The statistical overviews provide numerous results and are due to that presented stepwise. The results are summarised after all the steps are presented. The time period used as input for this tool should be as large as possible to be representative. The model does not restrict the amount of indata. Restrictions consists of factors as major maintenance and holidays when the line is put down for a longer period of time. The time period chosen should not include any of those factors. The choice of time period is the longest possible coherent time period without any of those major stops. The resulting choice of time period consists of 4 weeks in late 2013.

5.3.1 Spoilage

The loss in terms of spoilage is presented in percentages of the total production input. The spoilage in the front end (FE) is the total spoilage in the front ends of line 1 and 2, due to the cross conveyors.

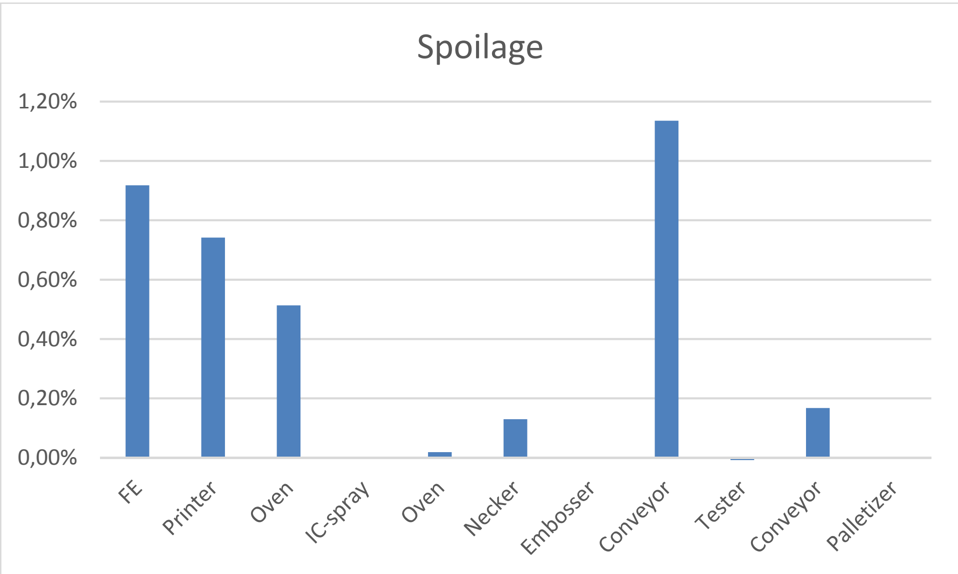

***Figure 5.5**. Spoilage over the production steps in Line 1, 2013-09-09 – 2013-10-13.*

The plot is generated from the spoilage matrix which is presented in full in Appendix A. **Table 5.5** is an assembly of highlighted numbers from that matrix.

The column total is the total of all points and not just the 3 points presented in **Table 5.5**.

Table 5.5. *Assembly of highlighted figures from the spoilage matrix.*

	FE	Printer	Conveyor	Total
Spoilage	0.92 %	0.74 %	1.14 %	3.58 %
Difference To Goal	-0.62 %	0.16 %	-1.14 %	-0.38 %

As seen in **Figure 5.5** the points with the most spoilage is the front end, the printer and the conveyor between the necker and the tester. The overall spoilage in line 1 is 3.58 %, as seen in **Table 5.5**. The spoilage in the printer can be explained by the changes of print and is needed to secure the esthetical quality of the can (Lidman 2014). It is not inaccurate according to the company's spoilage goals, (see **Table 5.5**) and does not need further study. The spoilage in the front end and the conveyor is too high and should be investigated further. The overall spoilage is high but should be analysed in relation with the other efficiency losses. This analysis is done when all the losses have been presented separately.

On some locations in the line there is more than 1 machine available. The machines on the same location are performing the same tasks. In **Figure 5.5** and **Table 5.5** the statistics for those locations are shown as an average for the machines at the locations. In **Table 5.6** the separate spoilage statistics for the 2 printers are presented.

Table 5.6. *Spoilage statistics in the 2 printers separately, 2013-09-09 - 2013-10-13.*

		Printer 1	*Printer 2*	*Average*
L1	*In*	17 814 320	22 438 135	40 252 455
	Out	17 949 866	22 000 600	39 950 466
	Spoiled cans	-135 546	437 535	301 989
	Spoilage %	**-0.33 %**	**1.07 %**	**0.74 %**

The average spoilage in line 1 is compared to the spoilage in line 4 (**Figure 5.7**) and the spoilage in line 1 (**Figure 5.6**) from a time period with better production results.

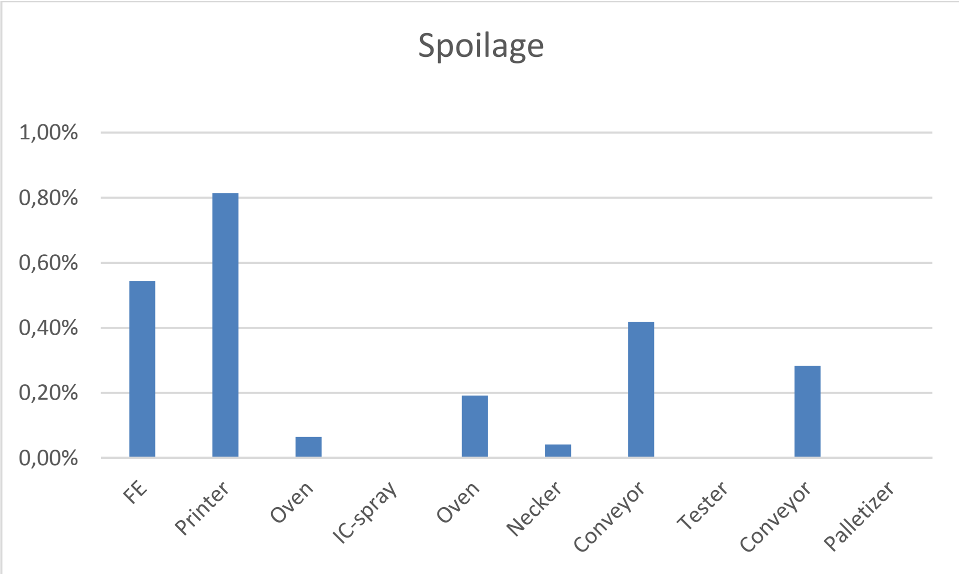

Figure 5.6*. Spoilage in Line 1 2014-04-21.*

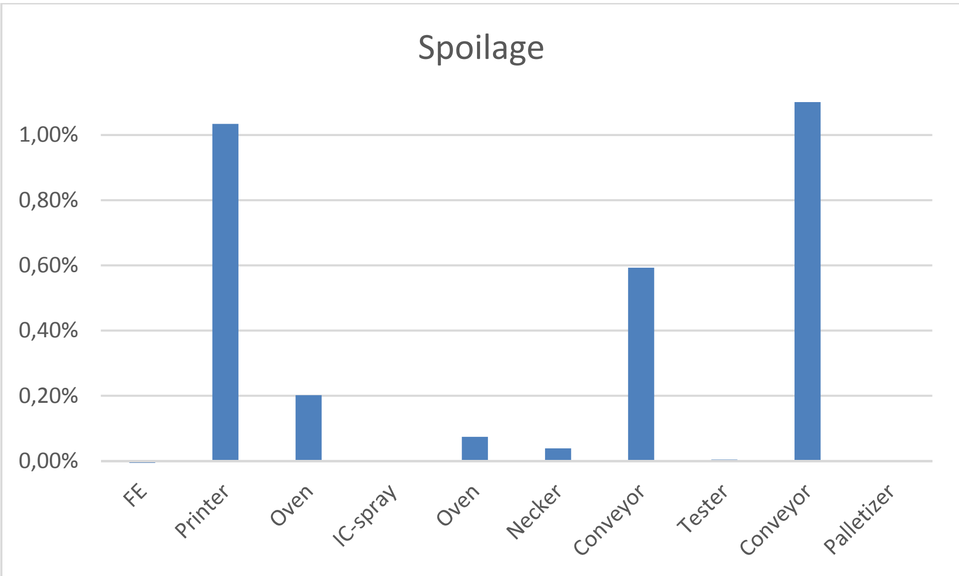

Figure 5.7*. Spoilage in Line 4 2013-09-09 - 2013-10-13.*

The matrices from where **Figure 5.6** and **Figure 5.7** are generated are available in Appendix A. It is hard to say that the spoilage contributes to the total production efficiency in wide extension. The point of interest is in the conveyor between the tester and the palletizer. The spoilage in this area seems to be high in all the spoilage plots. This is probably not the real case, there have to be something wrong in the statistics.

5.3.2 Pace

The pace loss is presented as percentages lost in comparison to the nominal pace. The pace loss is only calculated for the machines with flexible pace. The machines and conveyors with fixed pace does of course not suffer from pace loss when operating. Pace loss when down are referred to as downtime.

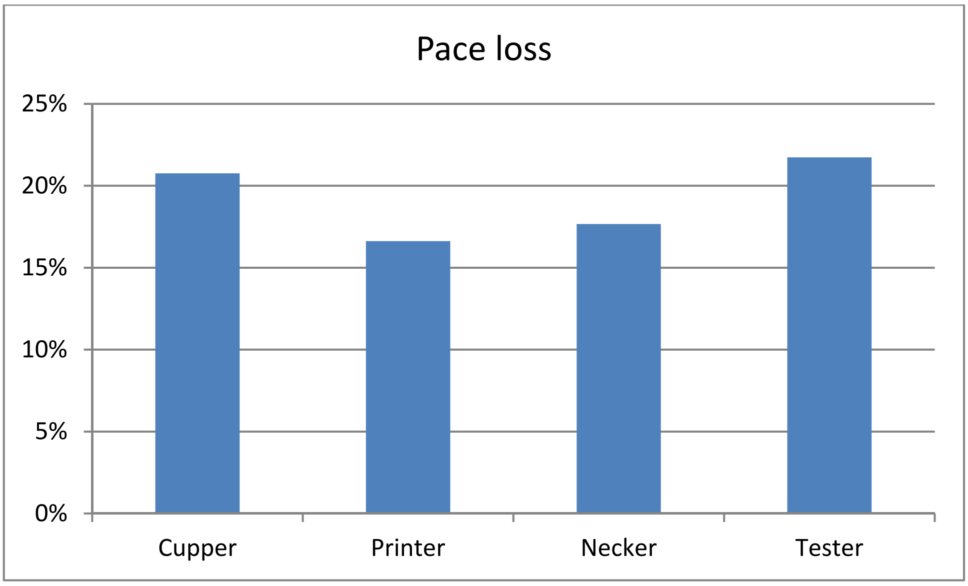

Figure 5.8. *Pace loss in the production steps with flexible pace in Line 1, 2013-09-09 – 2013-10-13.*

Figure 5.8 is generated from the matrix of the pace loss over the production line, see **Table 5.7**. The table is based on numbers from the company's information gathering system VISCAN. The efficiency loss in pace is recalculated as the displayed lost cans due to pace loss in the system does not seem accurate. The cans lost are recalculated as the difference between the number of produced cans and the nominal production possible with nominal pace. The nominal pace is thereby critical as indata. This nominal pace is often modified by the operators though, especially in the printer. The modification is done to fit the nature of the ongoing production and the estimation is based on the experiences of each operator. In the printer there is a limitation which makes the printer go down when operating in less than 85 % of its nominal pace. This is often considered by the operators when setting the maximum pace of that machine. There are batches of cans with special production demands that make the average production pace for those batches slower. To prevent the printer from going into standby too often the nominal pace for those batches are set slightly lower than the average. Because of all this, it is hard to set fixed nominal paces for the production. To ensure that the numbers of the efficiency losses are not exaggerated, the input of nominal pace in the calculations are set as slightly lower than it could be. In other words, the efficiency losses in **Figure 5.8** and **Table 5.7** are probably even higher than shown.

Table 5.7*. Pace loss matrix with input and output at the points with flexible pace in Line 1, 2013-09-09 - 2013-10-13.*

		Cupper	***Printer***	***Necker***	***Tester***
L1	*Normal pace (h)*	233:15:04	408:06:47	536:11:48	547:36:29
	Reduced pace (h)	322:53:28	158:32:06	0:00:00	0:00:00
	Total operational time (h)	556:08:32	566:38:53	536:11:48	547:36:29
	Produced cans	40718854	40252455	39733631	39218399
	Pace (CPM)	1220	1184	1235	1194
	Nominal pace (CPM)	1540	1420	1500	1525
	Cans lost	10668687	8025959	8524069	10887738
	Pace loss	**20.76 %**	**16.62 %**	**17.66 %**	**21.73 %**

When analysing the pace loss and its causes, there seems to be only one reason why the pace is low. The machines does not lower their pace themselves to improve can or production quality. Problems in the production like spoilage or machine breakdowns does not cause pace loss but downtime. The only reason for the pace loss seems to be waiting time. The machine is waiting for the succeeding or the preceding machine. This actually seems to be the case. When comparing to the results from the balance loss model, the pace loss caused by waiting time should not be this high. Just those results tell us there is a waiting problem in the line. Still we have not yet presented the results for the downtime and the standby. It is especially concerning that the printer is waiting for other machines, the bottleneck should not be waiting at all.

There are 2 printers in production line 1. Separate pace loss statistics is presented in **Table 5.8**.

***Table 5.8**. Pace loss matrix for the 2 printers in line 1, 2013-09-09 - 2013-10-13.*

		Printer 1	Printer 2	Average
L1	*Normal pace (h)*	198:43:59	209:22:48	408:06:47
	Reduced pace (h)	61:55:10	96:36:56	158:32:06
	Total operational time (h)	260:39:09	305:59:44	566:38:53
	Produced cans	17814320	22438135	40252455
	Pace (CPM)	1139	1222	1184
	Nominal pace (CPM)	1420	1420	
	Cans lost	4393273	3632686	8025959
	Pace loss (%)	**19.78 %**	**13.93 %**	**16.62 %**

The average pace in line 1 is compared to the pace in line 4 (**Figure 5.10**) and the pace in line 1 (**Figure 5.9**) from a time period with better production results. The pace loss matrix for line 1 is shown in **Table 5.9** and for line 4 in **Table 5.10**.

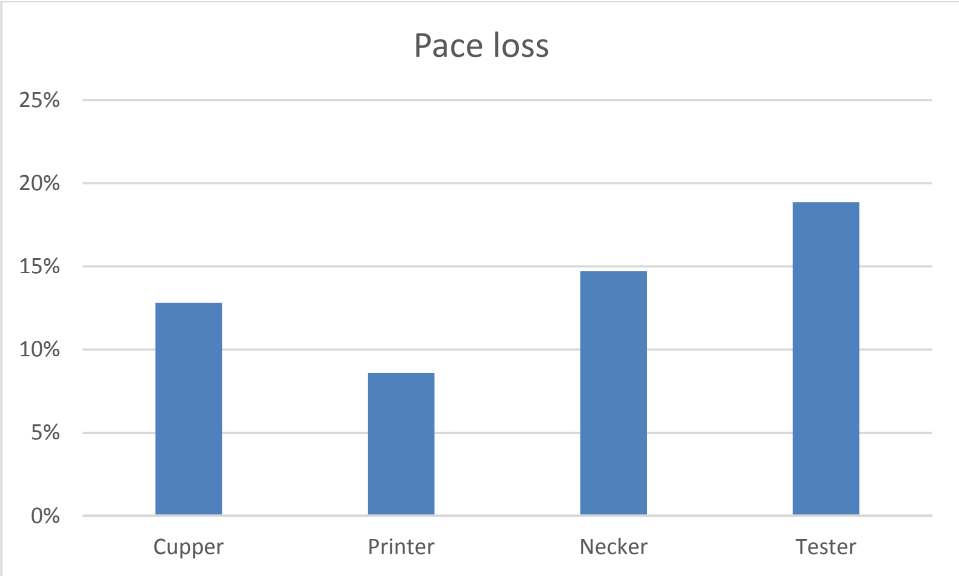

Figure 5.9. *Pace loss in line 1 2014-04-21.*

Table 5.9. *Pace loss matrix for line 1 2013-04-21.*

		Cupper	***Printer***	***Necker***	***Tester***
L1	*Normal pace (h)*	13:22:04	16:36:34	21:25:07	22:02:09
	Reduced pace (h)	8:42:57	4:45:00	0:00:00	0:00:00
	Total operational time (h)	22:05:01	21:21:34	21:25:07	22:02:09
	Produced cans	1778931	1663221	1644172	1635986
	Pace (CPM)	1343	1298	1279	1237
	Cans lost	261595	156604	283503	380293
	Pace loss (%)	**12.82 %**	**8.61 %**	**14.71 %**	**18.86 %**

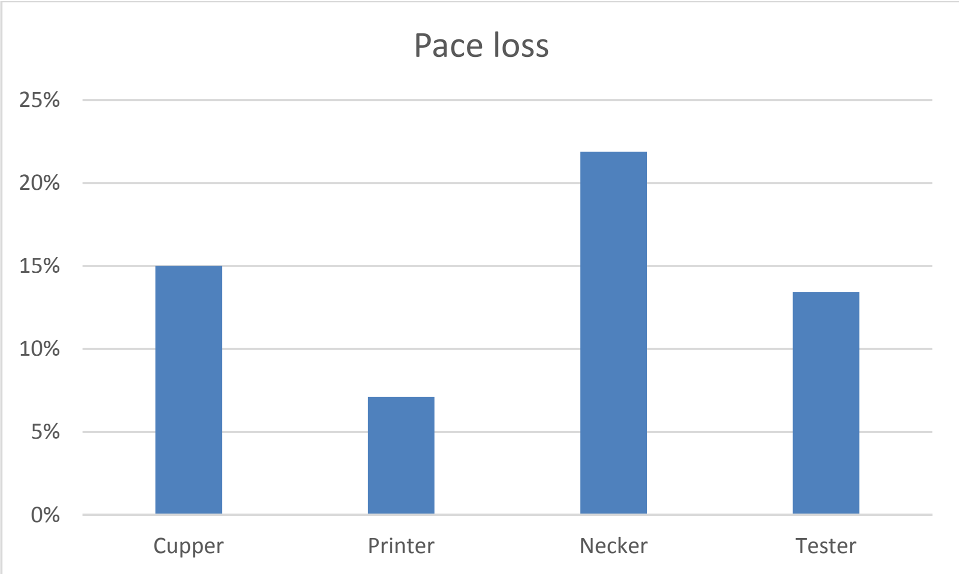

Figure 5.10. *Pace loss in line 4 2013-09-09 - 2013-10-13.*

Table 5.10. *Pace loss matrix for line 4 2013-09-09 - 2013-10-13.*

		Cupper	***Printer***	***Necker***	***Tester***
L4	*Normal pace (h)*	500:15:35	392:45:42	1114:05:14	544:23:21
	Reduced pace (h)	80:38:13	153:19:52	0:00:00	0:00:00
	Total operational time (h)	580:53:48	546:05:34	1114:05:14	544:23:21
	Produced cans	49757712	49610086	48958348	48644063
	Pace (CPM)	1428	1514	732	1489
	Cans lost	8796672	3797788	62673192	7536899
	Pace loss (%)	**15.02 %**	**7.11 %**	**21.88 %**	**13.42 %**

Table 5.11 *Pace loss matrix for the 2 printers in line 1, 2014-04-21.*

		Printer 1	**Printer 2**	**Average**
L1	*Normal pace (h)*	11:38:06	4:58:28	16:36:34
	Reduced pace (h)	2:48:44	1:56:16	4:45:00
	Total operational time (h)	14:26:50	6:54:44	21:21:34
	Produced cans	1147354	515867	1663221
	Pace (CPM)	1324	1244	1298
	Nominal pace (CPM)	1420	1420	
	Cans lost	83549	73054	156604
	Pace loss (%)	**6.79 %**	**12.40 %**	**8.61 %**

Table 5.12*. Pace loss matrix for the printer in line 4, 2013-09-09 - 2013-10-13.*

		Printer
L4	*Normal pace (h)*	392:45:42
	Reduced pace (h)	153:19:52
	Total operational time (h)	546:05:34
	Produced cans	49610086
	Pace (CPM)	1514
	Nominal pace (CPM)	1630
	Cans lost	3797788
	Pace loss (%)	**7.11 %**

The comparison shows that it is possible to improve the efficiency in terms of pace loss. Line 4 is compared during the same time span and even though the nominal pace is 210 CPM more the printer only has a pace loss of 7.11 % as seen in **Table 5.12**. The 33 cl can is indeed easier to manufacture but there is probably still more to it than that in terms of the physical layout of the conveyors and accumulation tables and in line control.

5.3.3 Downtime

The downtime numbers are presented as percentages of the total time. The total time includes downtimes and operational times. As supposed to in the statistical overviews, the downtimes for the different machines in the production line are shown.

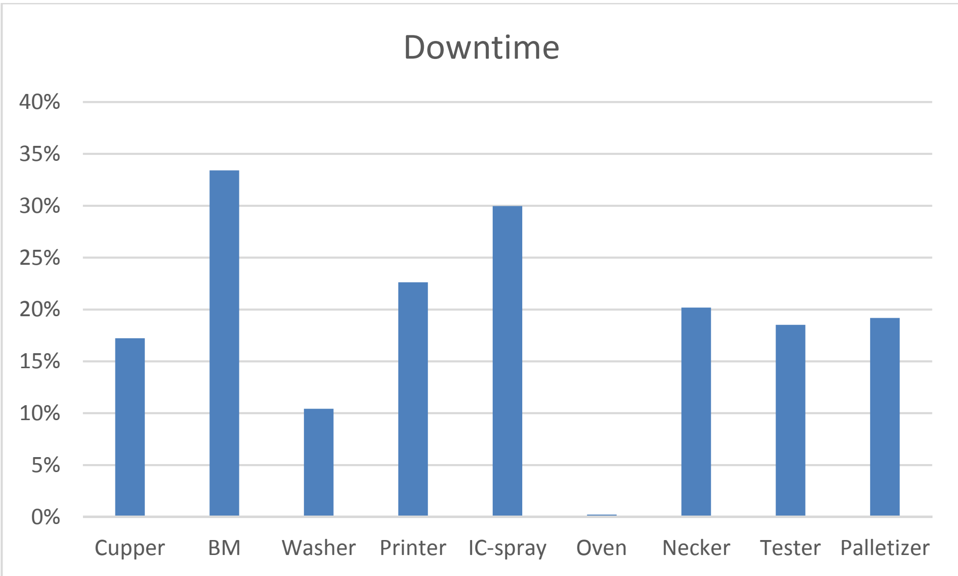

Figure 5.11*. Downtime for the machines in line 1, 2013-09-09 - 2013-10-13.*

The plot in **Figure 5.11** is generated from the matrix consisting of the different states supported in the information gathering program VISCAN. The complete matrix can be found in

Appendix B. All states with a pace equivalent to 0 are referred to as downtime. The separate numbers for the 7 bodymakers, the 2 printers and the 7 inside coating sprayers (IC-spray) can also be found in

Appendix B. The numbers for those machines in this plot are the average numbers for all the machines at the station.

The downtime values in **Figure 5.11** are generally high values. The highest downtime ratio is in the bodymakers and the inside coating sprayers. The fact that those stations consists of 7 machines each should not affect the values as it is shown as an average percentage. The cause of the high downtime must be something else. To find out about why the machines are down, a Production Performance Matrix is used.

The average downtime can be compared to the statistics with better production results. The comparison is made with the line 4 average statistics (**Figure 5.13**) and a time period with good results in production line 1 (**Figure 5.12**).

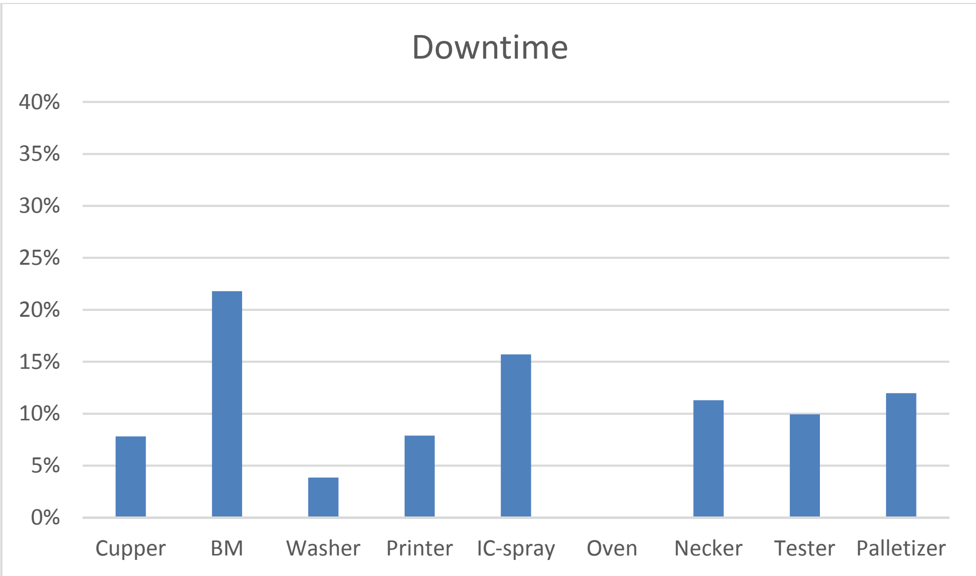

***Figure 5.12**. Downtime in Line 1 2014-04-21.*

The downtimes in **Figure 5.12** are significantly lower than the average for production line 1. This indicates that the downtime is essential to the total production efficiency. Which kind of downtime that is lower at this productive day must be investigated further in the PPM. The numbers generating the plot in **Figure 5.12** can be found in

Appendix B along with downtimes for the separate machines.

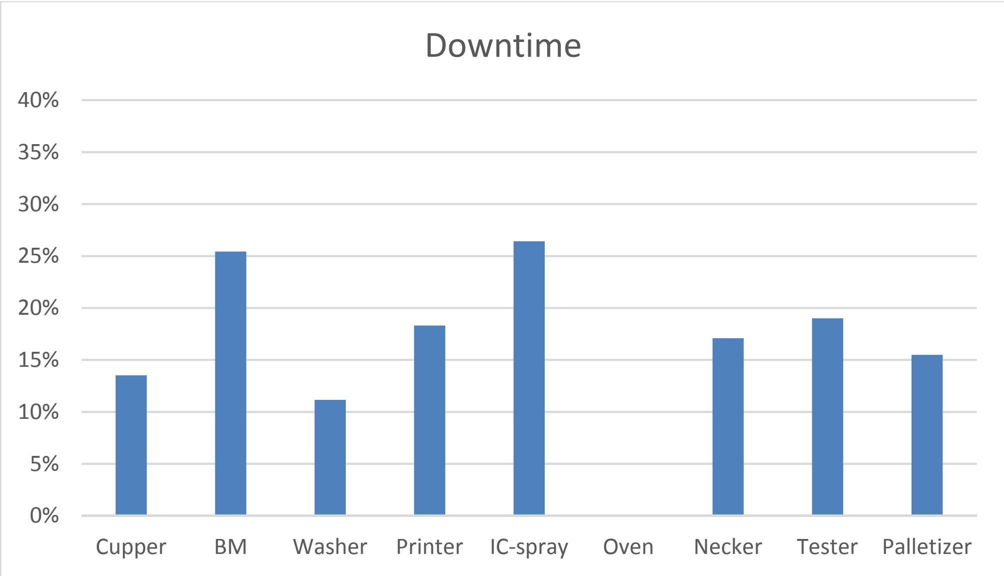

Figure 5.13. *Downtime in production Line 4, 2013-09-09 - 2013-10-13.*

Figure 5.13 shows that the average downtimes in line 4 are slightly lower than in line 1. The big difference between those 2 lines does not seem to be found here though. For complete matrix of the downtime in line 4 including the downtime in the separate machines see

5.3.4 Complete statistical overview

To visualise the results of the statistical overviews, all the efficiency losses are put together in a plot showing the different losses.

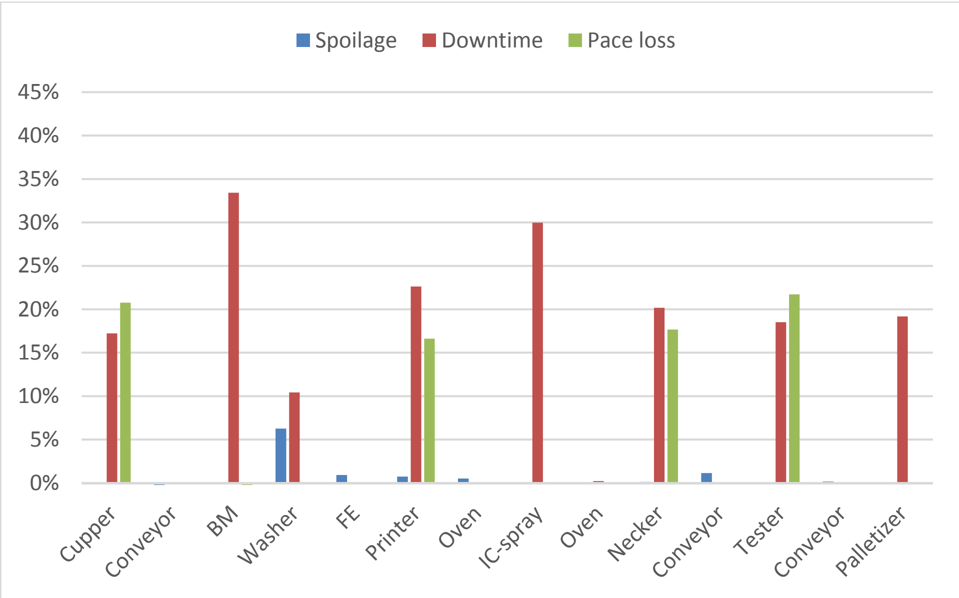

***Figure 5.14**. Different efficiency losses plotted from the statistical overviews, 2013-09-09 - 2013-10-13.*

Figure 5.14 shows that the spoilage losses is small in relation to the downtimes and the pace losses. The downtimes and the pace losses should be the prioritised objects for further investigation. To find out which machines to investigate further, the efficiency losses are stacked in **Figure 5.15**.

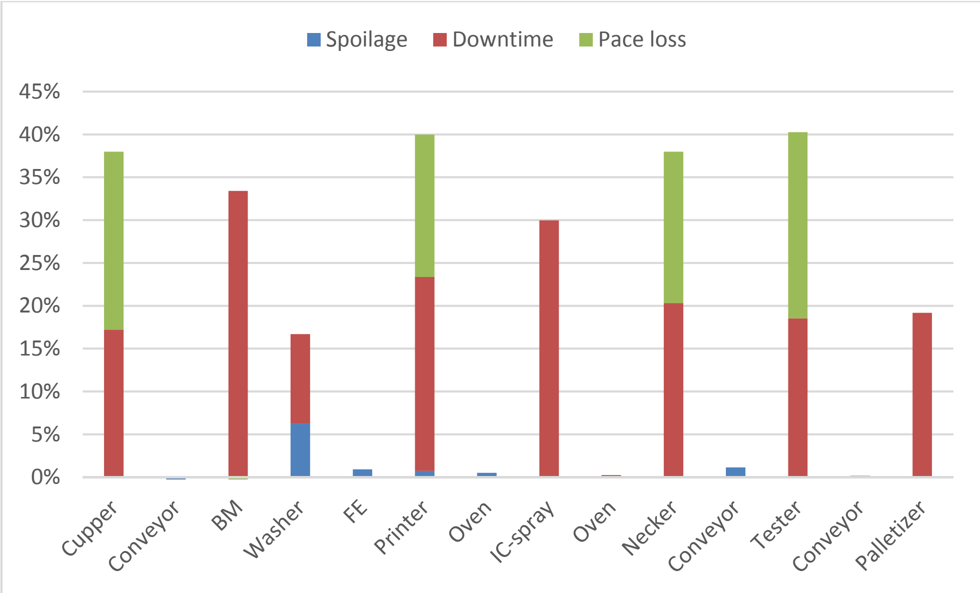

Figure 5.15*. Different efficiency losses plotted from the statistical overviews stacked, 2013-09-09 - 2013-10-10.*

The results can be compared with the accumulated results of the line 4 average (**Figure 5.17**) and the better producing time period in line 1 (**Figure 5.16**).

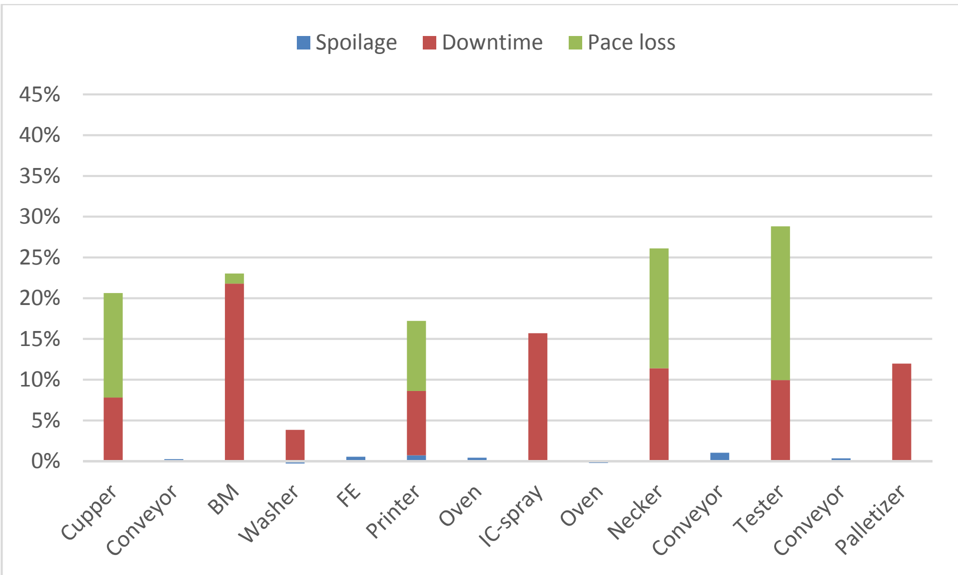

Figure 5.16*. Different efficiency losses from the statistical overviews stacked, Line 1 2014-04-21.*

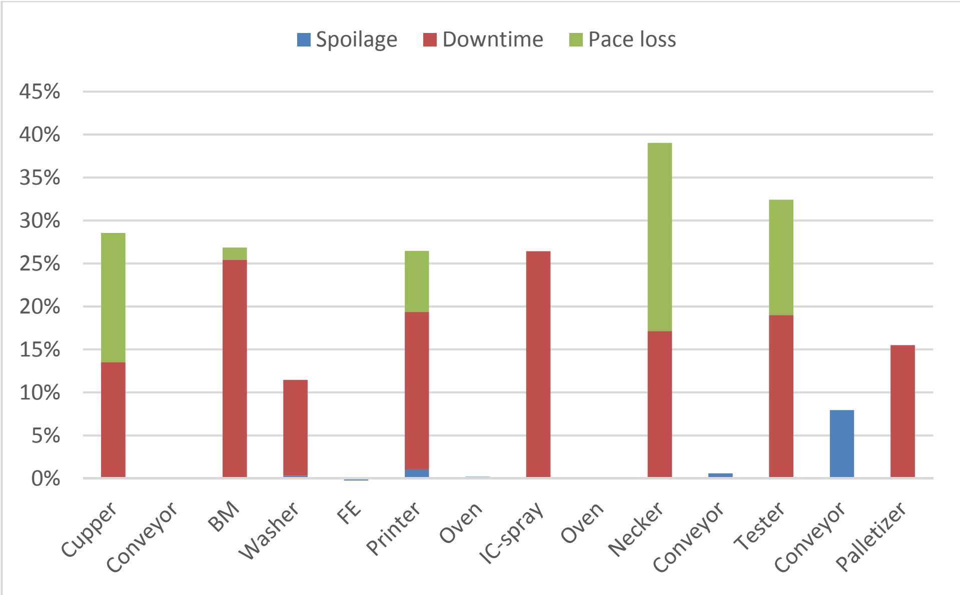

Figure 5.17. *Different efficiency losses from the statistical overviews stacked, Line 4 2013-09-09 - 2013-10-13.*

5.4 Production Performance Matrix

The production performance matrix is used to find the causes of the downtimes. The full PPM can be found in

Appendix C. The sums of the rows and the columns are presented in **Table 5.13**. The rows are set as the machines in the production line where the downtime is occurring. The columns are the different downtime causes machinery fault, standby and manual stop.

Table 5.13. *Resulting sums of the PPM for different downtimes, 2013-09-09 - 2013-10-13.*

	Machinery Fault	**Standby**	**Manual Stop**	**Sum**
Cupper	10:14:01	99:26:01	6:05:41	**115:45:43**
Bodymaker	67:48:51	127:38:17	27:36:56	**223:04:04**
Washer	17:28:59	52:37:36	0:00:00	**70:06:35**
Printer	18:11:58	51:42:46	1:43:14	**71:37:58**
IC-Spray	55:11:13	132:59:34	13:13:57	**201:24:44**
Necker	42:06:25	85:51:32	7:37:49	**135:35:46**
Tester	10:14:08	114:16:20	0:00:00	**124:30:28**
Palletizer	34:57:09	93:55:46	0:00:00	**128:52:55**
Sum	**256:12:44**	**758:27:52**	**56:17:37**	

To get a better overview of the results, the sums can be translated to percentages as in

Table 5.14. The percentages in the right column are the added percentages for the row. The values in the lowest row represent the sum of the columns. The other cells are the percentages of the total downtime.

Table 5.14. *Resulting fractions of the PPM for different downtimes, 2013-09-09 - 2013-10-13.*

	Machinery Fault	**Standby**	**Manual Stop**	**Fraction**
Cupper	1 %	9 %	1 %	**11 %**
Bodymaker	6 %	12 %	3 %	**21 %**
Washer	2 %	5 %	0 %	**7 %**
Printer	2 %	5 %	0 %	**7 %**
IC-Spray	5 %	12 %	1 %	**19 %**
Necker	4 %	8 %	1 %	**13 %**
Tester	1 %	11 %	0 %	**12 %**
Palletizer	3 %	9 %	0 %	**12 %**
Fraction	**24 %**	**71 %**	**5 %**	

Table 5.14 showing the sums recalculated to percentages provides a better overview of the downtimes. In this way the downtimes are divided into the cells as a fraction. To clarify the matter of how to read

Table 5.14, the sum of the percentages not written in bold is 100 %. The sum of the lowest row is also 100 %, so is the sum of the right column. 100 % is the total downtime of the period 2013-09-09 – 2013-10-13. One of the most obvious observations is that the standby represents 71 % of the total downtime. The standby is when a machine is waiting for another. Occasionally one single machine can cause all the others to wait, which causes multiples of standby. The number is still remarkably high, especially when considering that the pace loss also is caused from waiting for another machine. The matrix can also be displayed as a plot as seen in **Figure 5.18**.

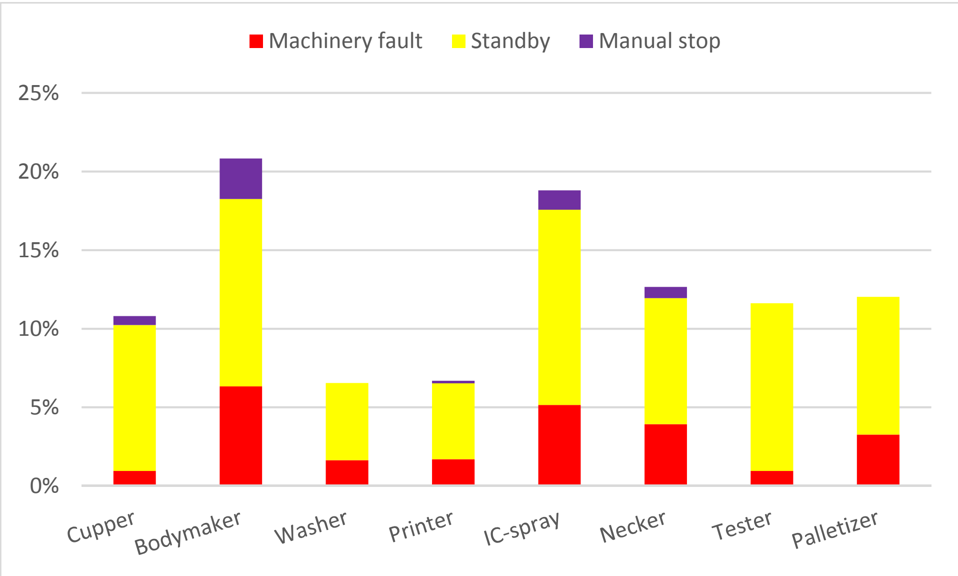

***Figure 5.18**. Downtime fractions generated from the PPM expresses as percentages of total downtime 2013-09-09 - 2013-10-13*

5.4.1 Additional details

It is possible to sort out the downtimes even more to get even more detailed information. On the locations where there is more than 1 machine operating, the detailed statistics can show if there is less or more issues in the different machines. A particular machine might cause the majority of the problem at the location. There are also 3 different modes for standby. The standby is registered as standby in, standby out or standby. Standby in is the state when the machine is waiting for cans. Standby out is when the machines are waiting to send the cans forward. The mode named simply standby represents the state when the machine is searching for the reason for a stop. It is just a few seconds of time used by the machine to find out if it is supposed to wait for the preceding or the succeeding machine.

For the next step the 3 states of standby are used to provide more detailed information. At the same time the percentages are recalculated. The following statistics show the different downtimes as percentages of the total production time and not only as percentages of the total downtime. This is done to provide more fair numbers and avoid misunderstandings.

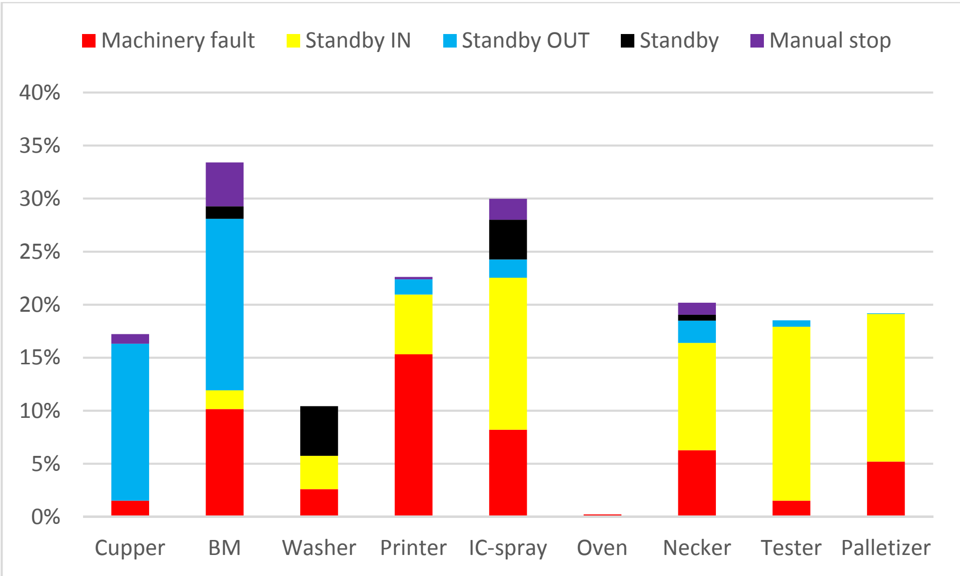

Figure 5.19. *Different downtimes as percentages of the total production time 2013-09-09 - 2013-10-13.*

The numbers in **Figure 5.19** are taken from the statistical overviews (complete matrix in

Appendix B) as that makes the calculations more comfortable. Unfortunately this cancels the edits made to the statistics in the PPM. The statistical overviews are done as a template which automatically sorts out the information unedited. The PPM is done end edited manually. The only edit made though is in the printer's machinery fault. A long downtime caused by machinery fault is excluded in the statistics for the PPM as that downtime seems to be caused by a mismatch in the setting. That downtime should not have been registered as such since the other printer was operating at the same time. In **Figure 5.19**, that downtime is included which explains the high amount of machinery fault. The interesting part of **Figure 5.19** is not the machinery fault though. It is the different standby modes that are of interest since that is the major difference from **Figure 5.18**.

The standby type upstream from the printer should be of type standby out as the printer acts as the bottleneck of the production line. Downstream from the printer the machines should be waiting to receive cans, the mode should be standby in. The main impression from watching the plot is that the machines are waiting for the correct direction according to the bottleneck theory. There is a collision though. The bodymaker is waiting for the printer to be available but the printer is also waiting for cans. The washer in between the machines is operating most of the time, it can actually be seen more as a conveyor rather than a machine in this case. The bodymaker and the printer should not be waiting for each other. Actually, the printer should not be waiting at all since it is a bottleneck. The only reason for the printer to wait is machinery fault in several bodymakers at the same time. It should be kept in mind that the printer is also waiting by reducing its pace when a few bodymakers are down at the same time. To put the printer down due to lack of cans is not an option until several bodymakers are out of function. To investigate this further, the 7 bodymakers will be studied separately. **Figure 5.20** shows the different types of downtime in the bodymakers as percentages of the total production time for each bodymaker.

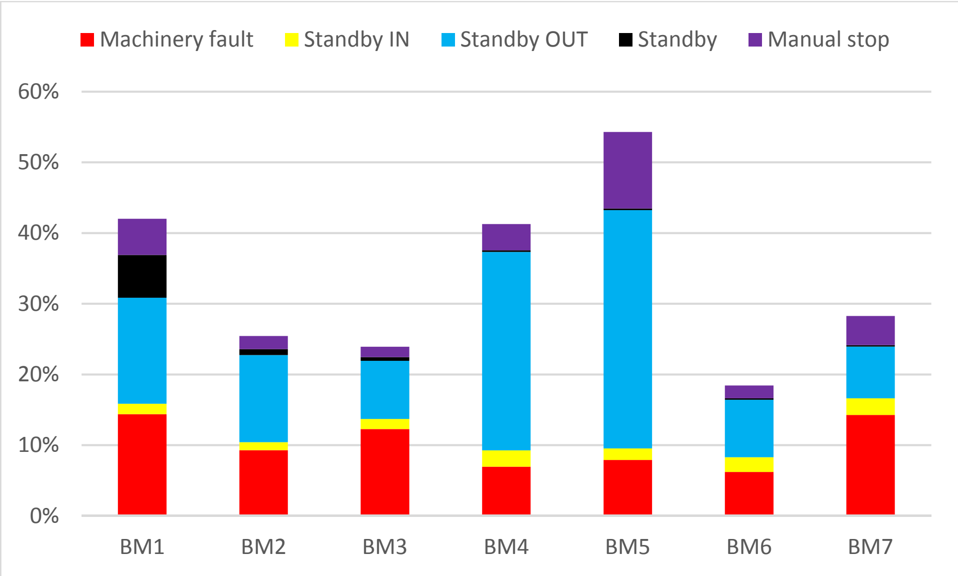

Figure 5.20*. Different downtimes in the 7 bodymakers 2013-09-09 - 2013-10-13.*

Figure 5.20 is plotted from the matrix treating the different downtimes in the bodymakers. The matrix can be found in

Appendix B along with the matrices for the 7 inside coating sprayers and the 2 printers.

It is hard to tell the correlation between the machinery fault in the bodymakers and the waiting time in the printer just by studying **Figure 5.20**. Other tools are needed to perform this analysis. The empirical distribution functions should be suitable to find an eventual connection. From the information received from the PPM it is obvious though that there is something wrong in the area between the bodymakers and the printer. The bottleneck should not be waiting, especially not at the same time as the preceding machine is waiting for the bottleneck. As another step to investigate this further, the large section of conveyors between those 2 machines is studied.

5.5 Conveyors

The conveyors, transporting the cans between the bodymakers and the printer, are many and include a few minor processing steps. Due to the results of the PPM this area is investigated further. The fact that the bodymakers and the printer seem to be waiting for each other might suggest there is something wrong in between those machines. The lead time for transport is definitely longer than the lead times in the machines, there is a lot of time for things to go wrong on the conveyors. The different paces and widths of the conveyors suggest there might be a bottleneck for the production line at some of the conveyors. The results from the PPM also suggest this might be the case.

The information gathering system VISCAN does not provide any information about the conveyors. The transport may also be the cause of spoilage, the statistics does not provide any information about that either. There are spoil bins located at some points of the conveyors which gathers the spoiled cans. Those bins are counted to keep track of the conveyor spoilage. These numbers are very hard to analyse though as the spoil in a bin may occur from several reasons. To find out more about the conveyors they have to be studied. The width, length and pace of the conveyors have been measured manually. Other interesting observations about the conveyors have also been made while performing the measuring. During this part of the study a Gemba based approach was used, see section 2.1.4. A lot of time was spent on the factory floor just looking at the flow of cans on the conveyors and how the machines in the line reacted to both even and uneven flow of cans. These observations confirmed the theory that one of the causes to the low efficiency was the area between the bodymakers and the printers.

Table 5.15. *Results of the manual measuring of the conveyors. The acc. columns is the accumulation downstream. LT=lead time.*

Mach. /Conv.	V (Cpm)	V (M/Min)	Width (M)	Length (M)	Cans /Conv.	Acc. Cans	Lt (Min)	Acc. Lt
BM	1600						0.000	0
Washer Inm. 1	3350	24.5	0.60	1.75	239	239	0.071	0.071
Washer Inm. 2	2537	18.6	0.60	5.60	764	1003	0.301	0.373
Washer Inm. 3	2445	15.4	0.70	5.40	860	1863	0.352	0.724
Washer Inm. 4	3362	15.6	0.95	2.50	540	2403	0.161	0.885
Washer Inm. 5	1845	7.4	1.10	5.15	1289	3692	0.698	1.584
Washer	1767	4.0	1.92	25.60	11198	14890	6.337	7.920
Bd.Bana 1	2743	20.1	0.60	2.85	389	15279	0.142	8.062
Bd.Bana 3			0.60	2.20	300	15579		8.062
Bd.Bana 4			0.60	4.90	669	16248		8.062
Bd.Bana 5			0.60	6.00	819	17067		8.062
Bidi-Table			1.88	21.50	9176	26243		8.062
Uv.Bana 1	2550	18.7	0.60	4.00	546	26789	0.214	8.276
Printers Inm. 1	2482	18.2	0.60	2.90	396	27185	0.160	8.436
Printers Inm. 2	2233	16.4	0.60	3.10	423	27608	0.189	8.625
Printers Inm. 3	2647	19.4	0.60	2.60	355	27963	0.134	8.759
Printers Inm. 4	2509	18.4	0.60	5.25	717	28679	0.286	9.045
Printers Inm. 5	2289	16.8	0.60	5.00	682	29362	0.298	9.343
Bidi-Table			2.40	6.60	3604	32965		9.343
Printers Inm. 5,5	2206	16.2	0.60	1.50	205	33170	0.093	9.436
Printers Inm. 6	2426	17.8	0.60	3.70	505	33675	0.208	9.644
Printers Inm. 7	2302	16.9	0.60	3.95	539	34214	0.234	9.878
Printers Inm. 8	3318	15.4	0.95	5.35	1156	35370	0.348	10.22
Printers Inm. 9	1812	8.4	0.95	4.15	897	36267	0.495	10.72
Printers Inm. 10	1877	8.7	0.95	3.00	648	36916	0.345	11.07
Pr 11 Inm.1	1680	8.7	0.85	2.20	425	37341	0.253	11.32
Printer 11	1420					37341		11.32
Pr 12 Inm. 1			0.95	3.00	648	37990		11.32
Pr 12 Inm. 2			0.95	5.00	1081	39070		11.32
Pr 12 Inm. 3			0.95	2.40	519	39589		11.32
Printer 12	1420					39589		11.32

The lead times for the machines are less than a second and in relation to the lead times of transport that is very short. In

Table 5.15 the lead times for the conveyors can be found. The accumulated lead times for the conveyors transporting cans between the bodymakers and printer 12 are more than 11 minutes. The conveyors with no specified lead times are buffer conveyors and are not needed when transporting the cans the shortest way. Those conveyors are alternative ways to transport the cans to gain extra buffer capacity. The lead times for those conveyors are not included in the accumulated lead time in

Table 5.15. They are included in the accumulated cans per conveyor though. This accumulation gives the potential buffer space available at the conveyors. Almost 40000 cans be held at the conveyors, waiting to enter the printer. The buffer capacity in the crossover between line 1 and line 2 is not included in

Table 5.15.

The CPM of the conveyors must be controlled to confirm that the conveyors do not act as bottleneck for the production line. The CPMs for the conveyors along with the nominal CPMs for the machines are plotted in **Figure 5.21**.

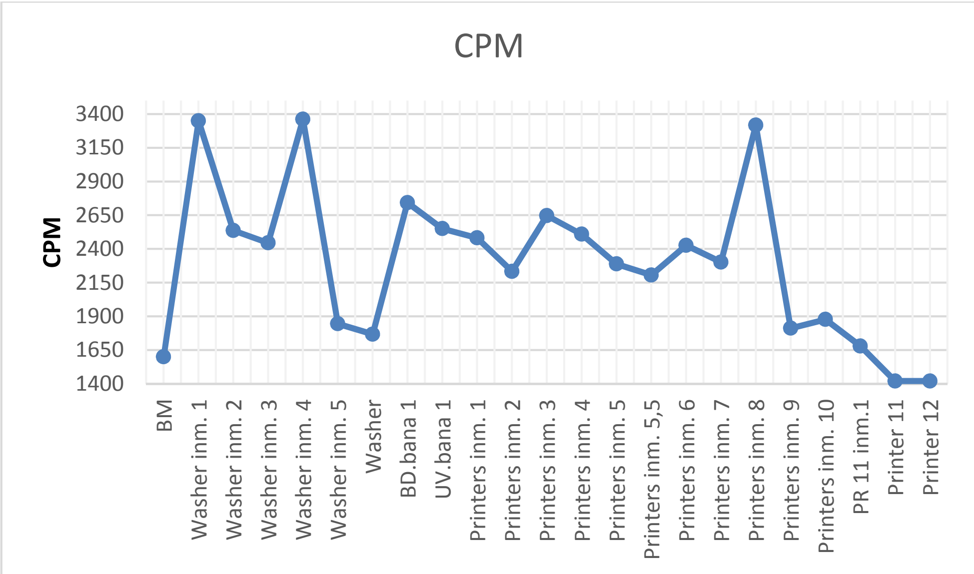

***Figure 5.21**. CPM in conveyors and machines from bodymaker to printer.*

The lowest point in **Figure 5.21** shows the bottleneck of the part of the production line between the bodymaker and the printer. The bottleneck in this area is the printer, just as when looking at all the machines in the production line. It can now be confirmed that the printer is the bottleneck and the conveyors do have enough capacity to feed the printer.

The appearance of the plot in **Figure 5.21** does show that the CPMs in the different conveyors are very irregular. This makes the flow far from even and might cause collisions and spoilage on the conveyors. The uneven flow also creates irregular drift in the printer, the conveyors creates spaces in the flow to the printer. This may cause waiting time and pace loss in the printer but also breakdowns. The conveyors should be pushing cans to the printer with even flow. The long lead time between the bodymaker and the printer does also create a problem by delaying the reactions between those 2 machines. The conveyors close to the bodymaker should transport the cans downstream as fast as possible to reach the printer with less delay. Of course, there is always the factor of spoilage restricting the pace of the transport.

The conveyors close to the printer should be slower to gather the cans and make the flow even.

5.6 Cost model

The information gathering for completing the cost model turned out to be too comprehensive. To get usable results from the cost model, the input numbers to the model must be precise. This numbers were too demanding to gather in the time period for the study. Therefore, the results from the cost model are of no interest and left out of the report.

5.7 Empirical distribution functions

The interesting points of the production line were picked out for being studied with the empirical distribution functions model. The choice is based on the level of interest in the points along with the availability of information. For example, the pace loss is not chosen to investigate with this model due to the lack of information available. The chosen points are marked with a number in **Table 5.16**. The number represents the number of downtimes included in the study.

Table 5.16. *Number of downtimes used for empirical distribution functions.*

	BM	Washer	Printer
Machinery Fault	342	54	133
Standby In		55	156
Standby Out	562		

The statistics for the downtimes at the points of interest are plotted to visualise the empirical distribution functions.

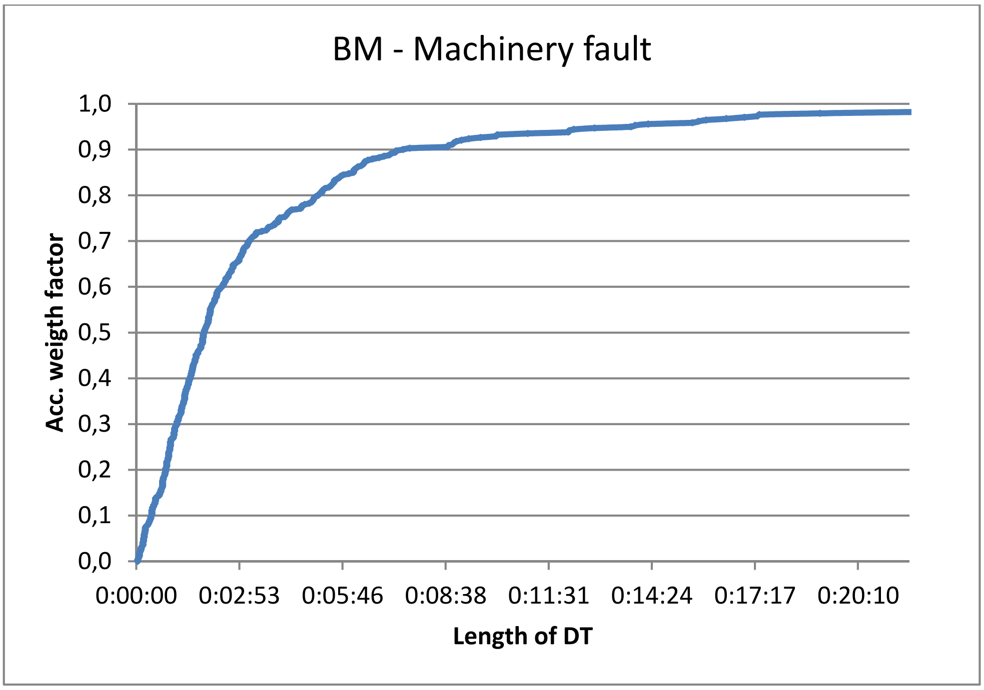

***Figure 5.22**. Machinery fault downtimes in bodymakers 2013-10-07.*

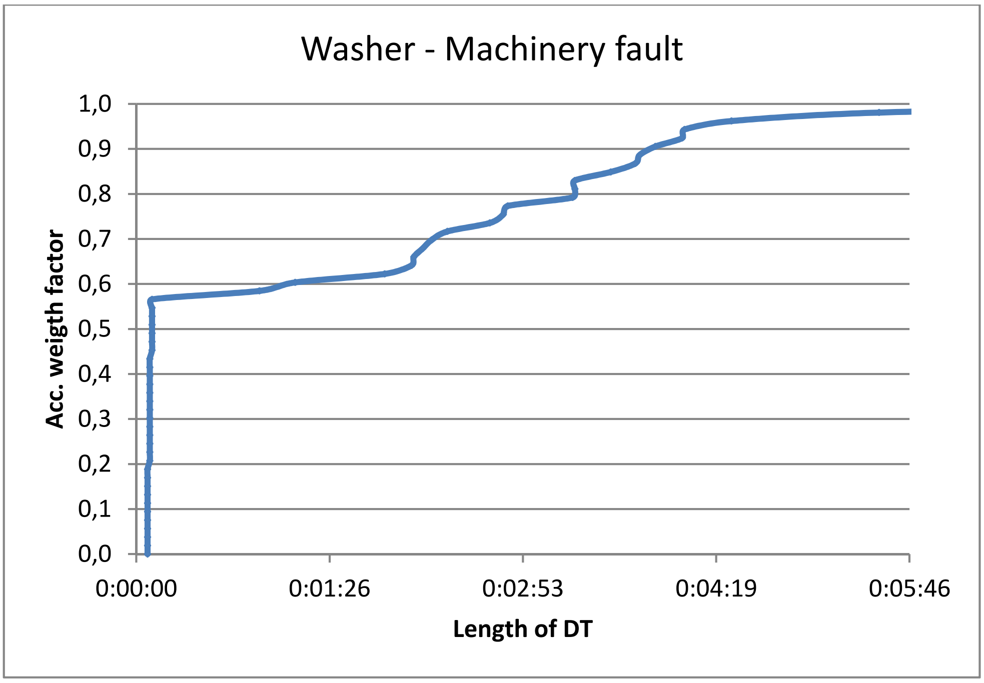

Figure 5.23. *Machinery fault downtimes in washer 2013-10-07 – 2013-10-08.*

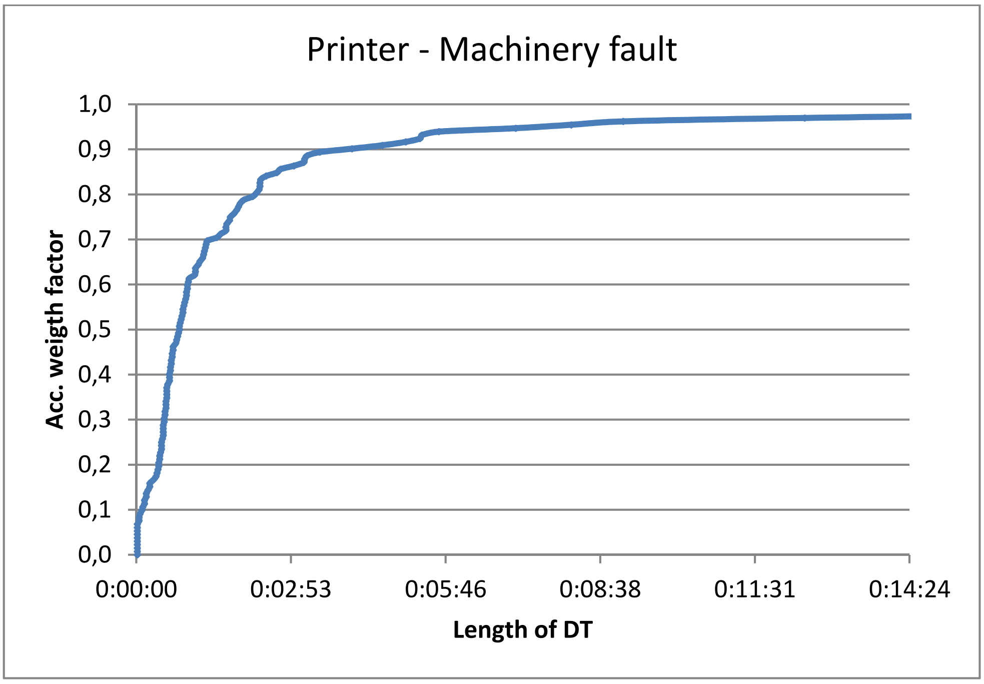

Figure 5.24. Machinery fault downtimes in printers 2013-10-07 – 2013-10-08.

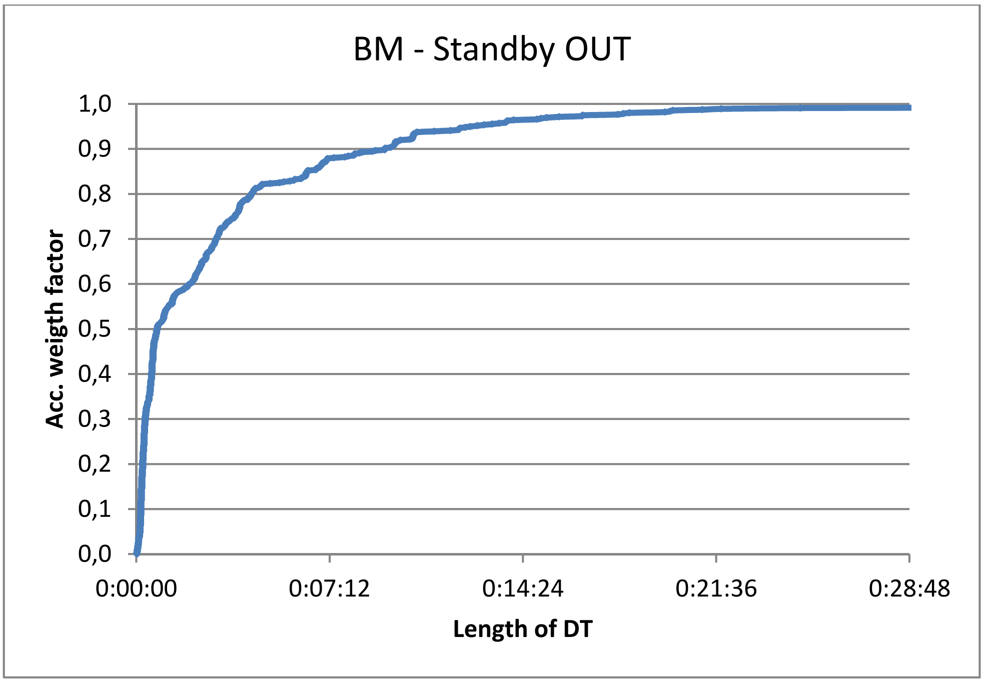

Figure 5.25. *Standby out downtimes in bodymakers 2013-10-07.*

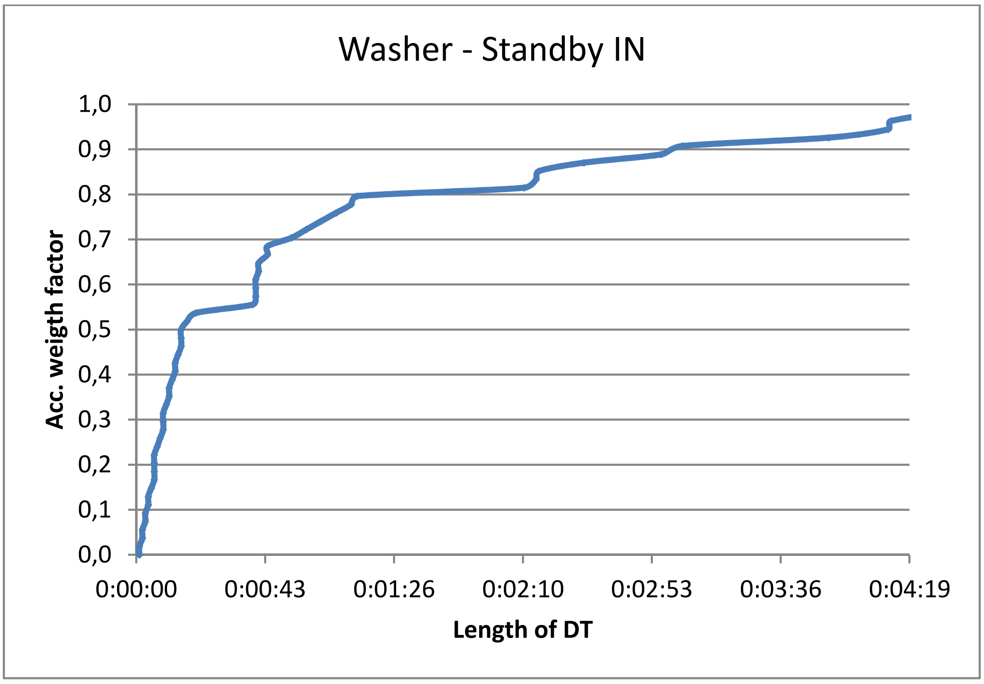

Figure 5.26. *Standby in downtimes in washer 2013-10-07 – 2013-10-08.*

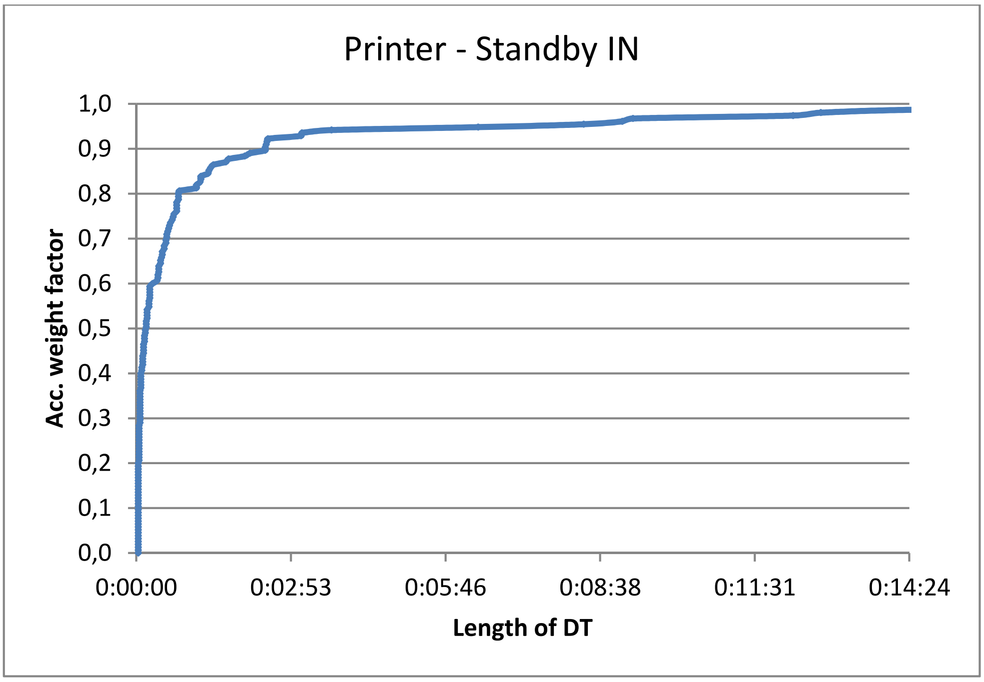

Figure 5.27*. Standby in downtime in printers 2013-10-07 – 2013-10-08.*

In **Figure 5.22-5.27** the downtimes used for the bodymakers are from 2013-10-07 and for the washer and the printer from 2013-10-07 – 2013-10-08. This irregularity is due to the number of downtimes registrered. In the washer and the printer the number of downtimes in 1 day are too few to analyse properly. The time period is chosen with the method described in section 4.5. The downtimes are adapted to be usable in the model by excluding the short downtimes. The definition of short downtimes is adapted to the available statistics and therefore different for the different machines and downtime categories.

This empirical distribution functions have been analysed by comparing to combinations of weibull- and exponential functions. The matches have been successfully found but not analysed further due to lack of information. The most interesting information gained from the usage of this tool is the large amount of short downtimes existing in all the analysed machines. A lot of very short downtimes are excluded from the plots to be able to receive plots that look anything else than a straight vertical line from the lines starting point. This indicates that there is a problem with numerous short stops in the production line. This problem is investigated further in section 5.8.

5.8 Inventory gains model

The results have shown that the bottleneck in the production line is waiting for cans. This should not occur for a bottleneck. The bodymakers must be able to deliver cans to the printer, but to help the bodymakers a can inventory can be created before the printer. This inventory will provide the bottleneck with cans when the bodymakers cannot, it will prevent the printer from going into waiting mode. It will also fill up the spaces created by the irregular paces of the conveyors. Fewer stops will make the printer run smoother and it will make the bottleneck more efficient. To calculate how much there is to gain in bottleneck efficiency by creating an inventory, this model is used.

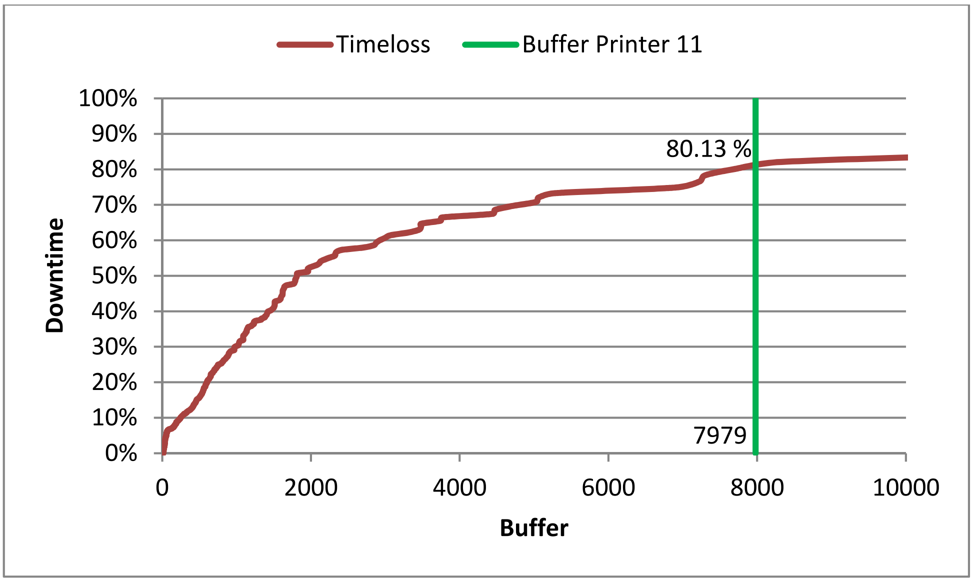

Figure 5.28*. Theoretical possible reduction of the waiting time in the bottleneck caused by creating an inventory in front of Printer 11. Downtime and pace data for 2013-10-07 - 2013-10-13.*

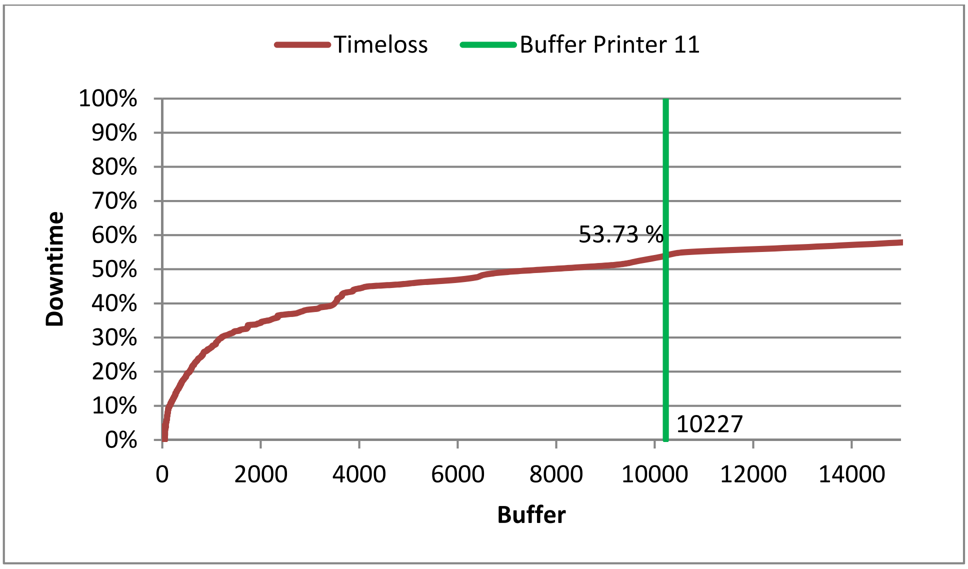

Figure 5.29*. Theoretical possible reduction of the waiting time in the bottleneck caused by creating an inventory in front of Printer 12. Downtime and pace data for 2013-10-07 - 2013-10-13.*

The plots in **Figure 5.28** and **Figure 5.29** show how much of the total waiting time in the printer that is theoretically possible to reduce by creating an inventory. The waiting time consists of standby downtime in the printers and the pace loss in the printers. The pace loss is recalculated to downtime by reducing the pace of each downtime to 0. This is done by using 15 % of the length of each pace loss. If a standby downtime or 15 % of the pace loss is shorter than the time it takes to empty the buffer, that downtime or pace loss can be avoided by keeping inventory. No average waiting time is used, the plots in **Figure 5.28** and **Figure 5.29** is showing the separate waiting times for the 2 printers. The y-axis shows the percent of the total accumulated waiting time for each printer which can be reduced by creating an inventory. The x-axis represents the inventory needed to reduce the waiting time, calculated by the nominal pace of the printer. The vertical green lines are examples taken from the recommendation.

The examples shows that an inventory of 7979 cans in front of Printer 11 can reduce the waiting time by 80 % and that a buffer of 10227 cans can reduce the waiting time in Printer 12 by 53 %. Those numbers demand that the buffer is filled up at the start of each downtime or reduced pace period. The possible reduction in waiting time shown is therefore probably slightly overestimated. Another factor that makes this number overestimated is that the present buffer is not 0 at all occasions. These results still show that there is a lot to gain by creating a buffer for the bottleneck. From previous results of the PPM, it is shown that the printer do wait a lot. In the same results it is also shown that the bodymaker is waiting for the printer. The waiting in the printer could be reduced by creating a buffer, this will also reduce the waiting time in the bodymakers. The existing waiting time in the bodymakers tells us that there is capacity available that could be used to fill up a buffer to the printer.

The main thing to consider when analysing the plots in **Figure 5.28** and **Figure 5.29** is the impact of the short waiting times. All the waiting times that demand a buffer less than 1450 cans are waiting times shorter than a minute. This short waiting times represents about 30 – 40 % of the total waiting time efficiency loss. On top of this they also create machinery fault losses. Those short stops can make a big difference if avoided. A buffer before the printer can make many of those short waiting times disappear.

6 Conclusion

The most important conclusions from the analysis are presented and clarified in this chapter.

The results all indicated the same issues in the production line. There is a lot of waiting time in the line. The waiting time is no real problem due to overcapacity in most of the machines. The real problem is that the bottleneck is waiting. The bottleneck is already the slowest running machine in the line and should not wait unless the rest of the line is out of order. The printer is according to the results the bottleneck of the production line. The results showing that the printer is waiting are concluded in **Table 6.1**.

Table 6.1. *Compilation of waiting time in the bottleneck.*

	Printer 11	**Printer 12**	**Average**
Pace Loss	19.78 %	13.93 %	16.62 %
Standby In	3.48 %	7.05 %	5.63 %
Standby Out	2.88 %	0.48 %	1.43 %
Total Waiting Time	26.18 %	21.46 %	23.68 %

Comparing to production lines with better results does prove the indications. The waiting time is not this high in lines with better production results. The difference between the waiting time percentages in the 2 printers may very well emerge from the extra buffer available for Printer 12. When running Printer 12 there are more conveyors than when running Printer 11. These conveyors are more often filled up than the last conveyors in front of Printer 11. This has been found by manual observations of the line. The extra buffer gives Printer 12 possibility to avoid some of the short waiting times.

By manual observations it has also been found that the printers seem to be better off when given the possibility to operate without interruptions. This indication is proven by the statistics. Printer 12 has more downtime from waiting than printer 11 and is also more often struck by machinery fault. The spoilage numbers indicates the same thing. Printer 12, which is more often forced to downtime waiting, has got a higher spoilage percentage.

Investigations of the conveyors shows there is nothing wrong with the transport between the bodymakers and the printer. The lead time is long and the pace does vary from conveyor to conveyor, but there is no bottleneck in the transport area. The area could be corrected on some points to facilitate the line controlling for this area, but the cause of the main issue is not to be found here. Comparing to the better producing line 4, the better line has less lead time and larger buffer.

The main issue seems to be the waiting time in the bottleneck. Besides that, the capacity of the bodymakers is not as high as expected. The machinery fault percent in the bodymakers is high which makes it necessary to run the bodymakers as much as possible when available.

According to the numbers in the results, there seems to be a lot of possible gains in holding a buffer in front of the printer. The compilation of numbers in **Table 6.1** together with the results from the inventory gains model gives us the total efficiency improvements in **Table 6.2**.

***Table 6.2**. Possible efficiency improvement in bottleneck with buffer.*

	Printer 11	**Printer 12**	**Average**
Total Waiting Time	26.18 %	21.46 %	23.68 %
Possible Reduction of Waiting Time	80.13 %	53.73 %	66.93 %
Efficiency Improvement	20.98 %	11.53 %	15.85 %
Total Waiting Time After Reduction	5.2 %	9.93 %	7.83 %

The trivial calculations in **Table 6.2** show that the reduction of the waiting time loss theoretically can result in a 15.85 % efficiency improvement in the bottleneck. This is an improvement that could increase the overall efficiency rapidly. The waiting time in the bottleneck after the reduction could be as low as 7.83 %, a significant improvement compared to the present waiting time percentage.

7 Recommendation

Here are the recommendations given to Rexam to increase the efficiency in line 1. The recommendations are based on the results from the analysis.

The main idea is to keep a buffer for the bottleneck of the line, the printer. This might be done by lowering the pace of the printer. The more preferred way though is to keep the front end running as much as possible, e.g. not putting the bodymakers in standby until it is actually needed. The goal should be to keep a buffer on the conveyors and accumulation table prior to the printer. One way to achieve this is to adjust the line control programming to fill up the conveyors with a buffer. The standby time and the efficiency loss in terms of pace in the printer should be reduced by doing this. This brings and demands less standby time in the bodymakers as well. Today the conveyors and tables between the washer and the printers are used as buffer to the bodymakers (and the washer of course, but it is the bodymakers that are put into standby to control the flow).

Another measure that could increase the efficiency is to change the speed of the conveyors to create a better push on the bottleneck printer. The first conveyors after the washer should be the fastest and the last conveyor before the printer should be the slowest. This creates a pressure of even can flow at the bottleneck and decreases the lead time before the buffer. This is already the model of the machines and the conveyors should be adjusted the same way. The pushing of the printer will be significantly easier if the possibility to change the pace of the bodymakers, washer and conveyors is installed. The bodymakers and washers could then slow down instead of being put into standby, which brings issues of restarts. The front end will also be able to push at the pace needed to fill the gaps on the conveyors instantly.

To increase reliability of the data used to analyse the production, Rexam should investigate why VISCAN sometimes deliver numbers that do not seem accurate, especially the spoilage that seems to occur on the conveyors between the machines. This problem can be caused by sensors not measuring accurate or by the way VISCAN calculates the numbers. Another problem that affects the production data is the incorrect downtime description on the printer. Due to the 2 printer setup in line 1, one printer is waiting while the other is running but there is specific downtime description for this type of waiting. Usually the printer is put in manual stop mode but it is also put in fault mode or standby. This disrupts the analysis of downtime data.

8 Discussion

In this chapter the recommendation is discussed. The counterarguments are presented and analysed. The discussion chapter works as a complement to the recommendation and increases the validity of the study.

Even though there seems to be a lot to gain by implementing the recommendation, it is not clearly the best option. There are practical issues arguing the sanity of the theory. The matter of validity for the numbers presented in the results has been taken care of with the analysis of the numbers. There are still wider practical aspects which may contradict the theoretical base for the recommendation.

One of the most significant differences between the theoretical numbers and the practical case is the matter of safety. This aspect has not been included in the calculations of the study and needs to be discussed. The safety aspect concerns both the line controlling and the buffer spaces.

8.1 Line controlling

The safety aspect creates problems in implementing the recommendation at the plant. It is easy to say that the bodymakers should operate until the suggested buffer is filled up, it is another thing to fit the line controlling with the idea. If the bodymakers produces cans to fill the conveyor space downstream, the conveyors might actually end up overloaded and cause lots of spoilage. Every little detail in the line controlling must be adapted to the new way of manufacturing. A small mistake might cause losses both in terms of spoilage and of injuries of the equipment.

To adapt the line controlling is of course a difficult task. A project like this will demand more resources than available today. A complete modification of the line controlling needs to be done at the same time. It will bring risks if trying to implement the changes step by step. The task should be performed as a project and the resources should be provided. It is a comprehensive change but the gains might very well exceed the invested effort.

8.2 Emptying of the washer

Cans standing still on the conveyors in the washer (including washer, oven and UV-conveyor) for too long will be lost as spoilage. There is also a safety aspect, it may cause fire or injure the equipment. Therefore, the possibility to empty the washer at all times is a vital demand.

The washer is emptied by transporting the cans downstream the production line, as the conveyors are not bi-directional. Conveyor or BD-table space needs to be available for receiving the cans from the washer at all times. This demand might actually be the source of the problem with efficiency loss in the bottleneck. The safety aspects prevents the line control from using those conveyors as buffer for the bottleneck, instead it is used as safety space for the washer.

From the measuring of the conveyors in this area, it has been received information about how many cans the conveyors and tables actually have capacity to house.
The information has been presented before but is re-ordered and presented in

Table 8.1 to display the solution to this safety issue.

Table 8.1. *Accumulated can capacity sorted for the different purposes.*

		CPM	Width	Length	Cans	Acc. cans
Cans to empty	Washer	1767	1,92	25,6	11198	11198
	BD.bana 1	2743	0,60	2,85	389	11587
	UV.bana 1	2550	0,60	4	546	12133
	Total					**12133**
Space for emptying	BD.bana 3	0	0,60	2,2	300	300
	BD.bana 4	0	0,60	4,9	669	969
	BD.bana 5	0	0,60	6	819	1788
	BD-table	0	1,88	21,5	9176	10964
	Printers inm. 1	2482	0,60	2,9	396	11360
	Printers inm. 2	2233	0,60	3,1	423	11783
	Printers inm. 3	2647	0,60	2,6	355	12138
	Printers inm. 4	2509	0,60	5,25	717	12854
	Printers inm. 5	2289	0,60	5	682	**13537**
Buffer Printer11	BD-bord	0	2,40	6,6	3604	3604
	Pre-crossover	2206	0,60	1,5	205	3808
	Printers inm. 6	2426	0,60	3,7	505	4313
	Printers inm. 7	2302	0,60	3,95	539	4852
	Printers inm. 8	3318	0,95	5,35	1156	6009
	Printers inm. 9	1812	0,95	4,15	897	6906
	Printers inm. 10	1877	0,95	3	648	7554
	PR 11 inm.1	1680	0,85	2,2	425	**7979**
Buffer Printer 12	Printer 11	1420				7979
	PR 12 inm. 1	0	0,95	3	648	8628
	PR 12 inm. 2	0	0,95	5	1081	9708
	PR 12 inm. 3	0	0,95	2,4	519	10227
	Printer 12	1420				**10227**
Buffer BM	Washer inm. 1	3350	0,6	2	239	239
	Washer inm. 2	2537	0,6	6	764	1003
	Washer inm. 3	2445	0,7	5	860	1863
	Washer inm. 4	3362	0,95	2,5	540	2403
	Washer inm. 5	1845	1,1	5,15	1289	**3692**

Table 8.1 shows that the cans needed to be emptied from the washer can easily fit on the first table and a few conveyors. There is lots of space still available for creating a buffer to the printers. The buffer sizes in

Table 8.1 are the same numbers used for calculating the gains in the inventory gains model, see section 5.8.

There is a lot of available space for creating a buffer for the bottleneck and this space should be used as such. This will increase the line efficiency significantly. Note that if somehow the space would not be enough there is always the possibility to use the cross conveyor to transport the cans from the washer on to line 2. The safety space issue should be no problem to solve. The safety should always be prioritized, but in this case the capacity of the line suffers from an underestimation of the space available.

9 Further studies

In this chapter, thoughts and ideas which did not fit in the project description or were scrapped due to lack of time are presented.

The next step in Rexam's work to improve their efficiency would be to try to implement the recommendations regarding change in line control presented in chapter 8. Further it would be interesting to evaluate how much an investment in pace-adjustable machines and conveyors which communicate with each other would increase the output in all the 4 lines.

To see how well Rexam Fosie performs, a study similar to this one, with the same measurements and tools, could be performed at other Rexam plants. Both newly built plants and plants with older machinery, like Rexam Fosie could be included in the study.

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Appendix

The appendix treats information that is excessive in other chapters but still should be included in the report to assure the information in the report. The context of the appendixes is found in the report where the text is referring to an appendix.

Appendix A

Spoilage in Printers

Spoilage in Line 1 2013-09-09 – 2013-10-13.

		Printer 11	***Printer 12***	***Average***
L1	*In*	17 814 320	22 438 135	40 252 455
	Out	17 949 866	22 000 600	39 950 466
	Spoil	-135 546	437 535	301 989
	%	**-0.33 %**	**1.07 %**	**0.74 %**

Spoilage in Line 1 2013-04-21.

		Printer 11	***Printer 12***	***Average***
L1	*In*	1 147 354	515 867	1 663 221
	Out	1 139 251	509 490	1 648 741
	Spoil	8 103	6 377	14 480
	%	**0.46 %**	**0.36 %**	**0.81 %**

Complete spoilage matrix

Spoilage in Line 1 2013-09-09 – 2013-10-13.

		CUPPER	CONVEYOR	BM	WASHER	FE	PRINTER	OVEN	IC	OVEN	NECKER	EMBOSSER	CONVEYOR	TESTER
L1	*In*	40 718 854	40 718 854	42 784 407	42 801 026		40 252 455	39 950 466	39 741 367	39 741 367	39 733 631	0	39 680 785	39 218 399
	Out	40 718 854	42 784 407	42 801 026	40 252 455		39 950 466	39 741 367	39 741 367	39 733 631	39 680 785	0	39 218 399	39 236 042
	Spoil	0	-2 065 553	-16 619	2 548 571		301 989	209 099	0	7 736	52 846	0	462 386	-17 643
	%	**0,00%**	**-5,07%**	**-0,04%**	**6,26%**	**0,92%**	**0,74%**	**0,51%**	**0,00%**	**0,02%**	**0,13%**	**0,00%**	**1,14%**	**-0,04%**
	Diff. goal	0,10%	5,07%	0,24%	-6,26%	-0,62%	0,16%	-0,11%	0,40%	0,38%	0,07%	0,00%	-1,14%	0,14%
L2	*In*	41 248 229	41 248 064	41 545 883	41 545 883		40 962 214	40 511 340	40 174 228	40 174 778	40 020 275	1 113 041	39 963 117	39 961 780
	Out	41 248 064	41 545 883	41 545 883	40 962 214		40 511 340	40 174 228	40 174 778	40 020 275	39 963 117	1 104 853	39 961 780	39 760 217
	Spoil	165	-297 819	0	583 669		450 874	337 112	-550	154 503	57 158	8 188	1 337	201 563
	%	**0,00%**	**-0,72%**	**0,00%**	**1,42%**	**0,92%**	**1,09%**	**0,82%**	**0,00%**	**0,37%**	**0,14%**	**0,02%**	**0,00%**	**0,49%**
	Diff. goal	0,10%	0,72%	0,00%	-1,42%	-0,82%	-0,19%	-0,82%	0,40%	0,03%	0,06%	-0,02%	0,00%	-0,39%
L1+L2	*In*	81 967 083	81 966 918	84 330 290	84 346 909		81 214 669	80 461 806	79 915 595	79 916 145	79 753 906	1 113 041	79 643 902	79 180 179
	Out	81 966 918	84 330 290	84 346 909	81 214 669		80 461 806	79 915 595	79 916 145	79 753 906	79 643 902	1 104 853	79 180 179	78 996 259
	Spoil	165	-2 363 372	-16 619	3 132 240	752 414	752 863	546 211	-550	162 239	110 004	8 188	463 723	183 920
	%	**0,00%**	**-2,88%**	**-0,02%**	**3,82%**	**0,92%**	**0,92%**	**0,67%**	**0,00%**	**0,20%**	**0,13%**	**0,01%**	**0,57%**	**0,22%**
	Diff. goal	0,10%	2,88%	0,12%	-3,82%	-0,72%	-0,02%	-0,47%	0,40%	0,20%	0,07%	-0,01%	-0,57%	-0,12%

Spoilage in Line 1 2014-04-21.

		CUPPER	CONVEYOR	BM	WASHER	FE	PRINTER	CONVEYOR	IC	OVEN	NECKER	CONVEYOR	TESTER	CONVEYOR	PALLETIZER	TOTAL
L1	In	1 778 931	1 778 931	1 771 565	1 771 565		1 663 221	1 648 741	1 647 586	1 647 586	1 644 172	1 643 432	1 635 986	1 635 906	1 630 861	1 778 93
	Out	1 778 931	1 771 565	1 771 565	1 663 221		1 648 741	1 647 586	1 647 586	1 644 172	1 643 432	1 635 986	1 635 906	1 630 861	1 630 861	1 630 86
	Spoil	0	7 366	0	108 344		14 480	1 155	0	3 414	740	7 446	80	5 045	0	148 07(
	%	**0,00%**	**0,41%**	**0,00%**	**6,09%**	**0,54%**	**0,81%**	**0,06%**	**0,00%**	**0,19%**	**0,04%**	**0,42%**	**0,00%**	**0,28%**	**0,00%**	**2,36%**
	Diff. goal	0,10%	-0,41%	0,20%	-6,09%	-0,24%	0,09%	0,34%	0,40%	0,21%	0,16%	-0,42%	0,10%	-0,28%	0,00%	0,84%
L2	In	1 609 707	1 609 707	1 605 572	1 605 572		1 707 009	1 695 170	1 688 099	1 688 099	1 691 521	1 689 888	1 673 008	1 672 536	1 666 833	1 609 70
	Out	1 609 707	1 605 572	1 605 572	1 707 009		1 695 170	1 688 099	1 688 099	1 691 521	1 689 888	1 673 008	1 672 536	1 666 833	1 666 833	1 666 83
	Spoil	0	4 135	0	-101 437		11 839	7 071	0	-3 422	1 633	16 880	472	5 703	0	-57 126
	%	**0,00%**	**0,26%**	**0,00%**	**-6,30%**	**0,54%**	**0,74%**	**0,44%**	**0,00%**	**-0,21%**	**0,10%**	**1,05%**	**0,03%**	**0,35%**	**0,00%**	**3,04%**
	Diff. goal	0,10%	-0,26%	0,00%	6,30%	-0,44%	0,16%	-0,44%	0,40%	0,61%	0,10%	-1,05%	0,07%	-0,35%	0,00%	0,16%

Spoilage in Line 4 2013-09-09 – 2013-10-13.

		CUPPER	CONVEYOR	BM	WASHER	FE	PRINTER	CONVEYOR	IC	OVEN	NECKER	CONVEYOR	TESTER	CONVEYOR	PALLETIZER	TOTAL
L3	*In*	47 985 936	47 985 936	48 703 593	48 703 593		48 669 426	48 152 670	48 051 677	48 051 677	47 933 009	47 890 564	47 557 998	47 536 644	42 793 627	47 985 936
	Out	47 985 936	48 703 593	48 703 593	48 669 426		48 152 670	48 051 677	48 051 677	47 933 009	47 890 564	47 557 998	47 536 644	42 793 627	42 793 627	42 793 627
	Spoil	0	-717 657	0	34 167		516 756	100 993	0	118 668	42 445	332 566	21 354	4 743 017	0	5 192 309
	%	**0,00%**	**-1,50%**	**0,00%**	**0,07%**	**-0,55%**	**1,08%**	**0,21%**	**0,00%**	**0,25%**	**0,09%**	**0,69%**	**0,04%**	**9,88%**	**0,00%**	**11,70%**
	Diff. goal	0,10%	1,50%	0,00%	-0,07%	0,65%	-0,28%	0,14%	0,35%	0,10%	0,06%	-0,69%	0,06%	-9,88%	0,00%	-9,40%
L4	*In*	49 757 712	49 757 712	49 764 401	49 764 401		49 610 086	49 095 600	48 995 156	48 995 156	48 958 348	48 939 093	48 644 063	48 641 960	44 686 217	49 757 712
	Out	49 757 712	49 764 401	49 764 401	49 610 086		49 095 600	48 995 156	48 995 156	48 958 348	48 939 093	48 644 063	48 641 960	44 686 217	44 686 217	44 686 217
	Spoil	0	-6 689	0	154 315		514 486	100 444	0	36 808	19 255	295 030	2 103	3 955 743	0	5 071 495
	%	**0,00%**	**-0,01%**	**0,00%**	**0,31%**	**-0,55%**	**1,03%**	**0,20%**	**0,00%**	**0,07%**	**0,04%**	**0,59%**	**0,00%**	**7,95%**	**0,00%**	**9,35%**
	Diff. goal	0,10%	0,01%	0,00%	-0,31%	0,65%	-0,23%	0,20%	0,40%	0,33%	0,11%	-0,59%	0,10%	-7,95%	0,00%	-7,05%

Appendix B

Downtime in Printers

Downtime in Printers Line 1 2013-09-09 – 2013-10-13.

		Printer 11	Printer 12	Average
L1	*Operating*	198:43:59	209:22:48	408:06:47
	Machinery fault	8:35:50	103:37:43	112:13:33
	Standby in	10:02:28	31:13:02	41:15:30
	Standby out	8:20:29	2:06:39	10:27:08
	Standby	0:00:00	0:00:00	0:00:00
	Low speed	61:55:10	96:36:56	158:32:06
	Manual stop	1:43:13	0:00:00	1:43:13
	Downtime total	28:42:00	136:57:24	165:39:24
	Downtime %	**9.92 %**	**30.92 %**	**22.62 %**

Downtime in Printers Line 1 2014-04-21.

		Printer 11	Printer 12	Average
L1	*Operating*	11:38:06	4:58:28	16:36:34
	Machinery fault	0:03:44	0:20:54	0:24:38
	Standby in	0:47:13	0:25:50	1:13:03
	Standby out	0:00:00	0:00:00	0:00:00
	Standby	0:00:00	0:00:00	0:00:00
	Low speed	2:48:44	1:56:16	4:45:00
	Manual stop	0:12:00	0:00:00	0:12:00
	Downtime total	1:02:57	0:46:44	1:49:41
	Downtime %	**6.77 %**	**10.13 %**	**7.88 %**

Downtime in Bodymakers

Downtime in bodymakers in Line 1 2013-09-09 – 2013-10-13.

L1	BM 11	BM 12	BM 13	BM 14	BM 15	BM 16	BM 17	AVERAGE
Operating	389:24:01	501:06:32	511:04:42	394:23:17	307:07:32	547:46:38	460:29:09	3111:21:51
Machinery fault	96:38:27	62:24:00	82:26:12	46:42:54	53:10:59	41:38:16	91:39:50	474:40:38
Standby in	9:55:21	7:38:27	9:40:51	15:35:21	10:53:36	13:59:44	15:03:32	82:46:52
Standby out	100:38:56	82:46:04	55:10:04	188:27:45	226:32:29	54:42:48	47:05:09	755:23:15
Standby	40:38:10	5:40:13	3:28:59	1:30:23	1:29:09	1:20:09	1:10:15	55:17:18
Low speed	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00
Manual stop	34:19:46	12:24:27	10:01:23	24:58:40	72:43:41	12:14:06	26:36:06	193:18:09
Downtime total	282:10:40	170:53:11	160:47:29	277:15:03	364:49:54	123:55:03	181:34:52	1561:26:12
Downtime %	**42,02%**	**25,43%**	**23,93%**	**41,28%**	**54,29%**	**18,45%**	**28,28%**	**33,42%**

Downtime in bodymakers in Line 1 2013-04-21.

L1	***BM 11***	***BM 12***	***BM 13***	***BM 14***	***BM 15***	***BM 16***	***BM 17***	***AVERAGE***
Operating	20:21:52	21:45:29	15:55:19	18:03:39	14:39:57	21:25:02	19:24:56	131:36:14
Machinery fault	1:07:55	1:06:55	2:07:31	1:43:53	3:45:54	1:19:36	3:05:52	14:17:36
Standby in	0:27:54	0:25:14	0:14:59	0:02:39	0:01:37	0:02:40	0:17:00	1:32:03
Standby out	0:28:20	0:24:59	5:15:50	3:12:50	1:05:36	0:22:24	0:17:11	11:07:10
Standby	1:35:31	0:01:43	0:03:48	0:02:09	0:02:33	0:01:36	0:01:20	1:48:40
Low speed	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00
Manual stop	0:03:17	0:20:19	0:21:17	0:52:18	4:29:32	0:49:45	0:58:38	7:55:06
Downtime total	3:42:57	2:19:10	8:03:25	5:53:49	9:25:12	2:36:01	4:40:01	36:40:35
Downtime %	**15,43%**	**9,63%**	**33,60%**	**24,61%**	**39,11%**	**10,83%**	**19,38%**	**21,79%**

Downtime in bodymakers in Line 4 2013-09-09 – 2013-10-13.

		BM 11	BM 12	BM 13	BM 14	BM 15	BM 16	BM 17	AVERAGE
L4	*Operating*	527:53:03	536:11:42	452:31:31	514:25:48	388:05:18	547:09:52	539:20:35	3505:37:49
	Machinery fault	47:57:07	31:29:32	38:22:56	36:46:45	17:39:32	46:59:47	22:24:59	241:40:38
	Standby in	4:07:13	6:51:30	9:12:49	8:14:22	6:40:40	6:02:24	8:23:38	49:32:36
	Standby out	79:02:42	59:15:31	156:36:08	76:53:38	248:42:50	60:17:56	60:26:28	741:15:13
	Standby	0:56:23	0:42:08	1:41:31	0:37:51	2:09:35	0:44:40	0:46:06	7:38:14
	Low speed	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00
	Manual stop	11:54:18	37:03:36	13:18:11	34:53:13	8:23:04	10:21:00	40:14:21	156:07:43
	Downtime total	143:57:43	135:22:17	219:11:35	157:25:49	283:35:41	124:25:47	132:15:32	1196:14:24
	Downtime %	**21,43%**	**20,16%**	**32,63%**	**23,43%**	**42,22%**	**18,53%**	**19,69%**	**25,44%**

Downtime in inside coating sprayer

Downtime IC-sprayers in Line 1 2013-09-09 – 2013-10-13

L1		**IC 11**	**IC 12**	**IC 13**	**IC 14**	**IC 15**	**IC 16**	**IC 17**	**AVERAGE**
	Operating	467:46:29	471:20:18	471:53:07	469:34:00	443:12:25	481:45:59	487:15:42	3292:48:00
	Machinery fault	57:56:38	53:48:08	54:32:01	51:11:50	88:16:01	43:38:23	36:54:39	386:17:40
	Standby in	96:34:27	96:33:44	95:22:31	96:57:13	93:37:40	97:28:22	97:10:43	673:44:40
	Standby out	11:58:15	12:03:23	12:10:16	11:37:59	9:39:51	11:10:29	12:15:50	80:56:03
	Standby	25:18:44	25:25:36	25:19:06	25:15:35	24:29:53	25:17:18	25:09:22	176:15:34
	Low speed	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00
	Manual stop	12:13:58	12:37:21	12:31:26	17:11:50	12:32:40	12:27:57	13:02:13	92:37:25
	Downtime total	204:02:02	200:28:12	199:55:20	202:14:27	228:36:05	190:02:29	184:32:47	1409:51:22
	Downtime %	**30,37%**	**29,84%**	**29,76%**	**30,10%**	**34,03%**	**28,29%**	**27,47%**	**29,98%**

Downtime in IC-sprayers in Line 1 2014-04-21.

L1		***IC 11***	***IC 12***	***IC 13***	***IC 14***	***IC 15***	***IC 16***	***IC 17***	***AVERAGE***
	Operating	0:00:00	20:12:25	19:43:41	20:26:31	19:34:51	20:38:06	20:34:34	121:10:08
	Machinery fault	0:00:00	0:42:17	1:07:27	0:27:35	1:29:53	0:12:35	0:19:14	4:19:01
	Standby in	0:00:00	2:32:10	2:34:54	2:32:06	2:21:37	2:36:17	2:33:16	15:10:20
	Standby out	0:00:00	0:01:10	0:01:10	0:01:09	0:00:00	0:01:09	0:01:10	0:05:48
	Standby	0:00:00	0:18:30	0:18:20	0:18:15	0:17:13	0:18:28	0:18:20	1:49:06
	Low speed	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00
	Manual stop	0:00:00	0:10:52	0:11:51	0:11:49	0:13:51	0:10:50	0:10:51	1:10:04
	Downtime total	0:00:00	3:44:59	4:13:42	3:30:54	4:22:34	3:19:19	3:22:51	22:34:19
	Downtime %	**#DIVISION/0!**	**15,65%**	**17,65%**	**14,67%**	**18,27%**	**13,87%**	**14,11%**	**15,70%**

Downtime in IC-sprayers in Line 4 2013-09-09 – 2013-10-13.

		IC 11	IC 12	IC 13	IC 14	IC 15	IC 16	IC 17	AVERAGE
L4	*Operating*	553:28:44	556:47:47	546:12:57	304:32:46	483:44:33	515:58:00	500:02:36	3460:47:23
	Machinery fault	48:49:04	0:18:11	0:16:27	0:12:26	50:27:55	47:09:06	57:45:12	204:58:21
	Standby in	48:46:14	96:26:24	113:09:19	103:13:00	49:15:45	50:00:12	78:00:13	538:51:07
	Standby out	19:37:00	17:08:26	11:25:29	18:23:20	49:47:58	19:10:26	19:35:11	155:07:50
	Standby	1:15:22	1:15:41	0:45:40	245:36:57	38:31:43	39:30:06	16:24:38	343:20:07
	Low speed	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00
	Manual stop	0:04:54	0:05:05	0:11:37	0:13:10	0:05:40	0:05:45	0:05:51	0:52:02
	Downtime total	118:32:34	115:13:47	125:48:32	367:38:53	188:09:01	155:55:35	171:51:05	1243:09:27
	Downtime %	**17,64%**	**17,15%**	**18,72%**	**54,69%**	**28,00%**	**23,21%**	**25,58%**	**26,43%**

Complete downtime matrix

Downtime in Line 1 2013-09-09 – 2013-10-13.

L1	CUPPER	BM	WASHER	PRINTER	IC	OVEN	NECKER	TESTER	PALLETIZER	TOTAL
Operating	233:15:04	3111:21:51	601:56:47	408:06:47	3292:48:00	637:36:37	536:11:48	547:36:29	542:59:01	9911:52:24
Machinery fault	10:13:50	474:40:38	17:28:47	112:13:33	386:17:40	1:26:01	42:06:07	10:14:03	34:57:07	1089:37:46
Standby in	0:00:00	82:46:52	21:07:56	41:15:30	673:44:40	0:00:00	68:03:42	110:12:48	93:33:50	1090:45:18
Standby out	99:26:00	755:23:15	0:00:00	10:27:08	80:56:03	0:00:00	14:02:03	4:03:30	0:21:52	964:39:51
Standby	0:00:00	55:17:18	31:29:34	0:00:00	176:15:34	0:00:00	3:45:42	0:00:00	0:00:00	266:48:08
Low speed	322:53:28	0:00:00	0:00:00	158:32:06	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	481:25:34
Manual stop	6:05:39	193:18:09	0:00:00	1:43:13	92:37:25	0:00:00	7:37:47	0:00:00	0:00:00	301:22:13
Downtime total	115:45:29	1561:26:12	70:06:17	165:39:24	1409:51:22	1:26:01	135:35:21	124:30:21	128:52:49	3713:13:16
Downtime %	**17,23%**	**33,42%**	**10,43%**	**22,62%**	**29,98%**	**0,22%**	**20,18%**	**18,52%**	**19,18%**	**26,32%**

Downtime in Line 1 2013-04-21.

		CUPPER	BM	WASHER	PRINTER	IC	OVEN	NECKER	TESTER	PALLETIZER	TOTAL
L1	*Operating*	13:22:04	131:36:14	23:13:12	16:36:34	121:10:08	0:00:00	21:25:07	22:02:09	21:36:42	371:02:10
	Machinery fault	0:33:17	14:17:36	0:07:39	0:24:38	4:19:01	0:00:00	0:21:00	0:03:26	1:11:27	21:18:04
	Standby in	0:00:00	1:32:03	0:40:03	1:13:03	15:10:20	0:00:00	2:02:00	2:22:08	1:44:52	24:44:29
	Standby out	1:15:29	11:07:10	0:00:00	0:00:00	0:05:48	0:00:00	0:06:33	0:00:16	0:00:00	12:35:16
	Standby	0:00:00	1:48:40	0:08:05	0:00:00	1:49:06	0:00:00	0:06:23	0:00:00	0:00:00	3:52:14
	Low speed	8:42:57	0:00:00	0:00:00	4:45:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	13:27:57
	Manual stop	0:03:35	7:55:06	0:00:00	0:12:00	1:10:04	0:00:00	0:07:49	0:00:00	0:00:00	9:28:34
	Downtime total	1:52:21	36:40:35	0:55:47	1:49:41	22:34:19	0:00:00	2:43:45	2:25:50	2:56:19	71:58:37
	Downtime %	**7,82%**	**21,79%**	**3,85%**	**7,88%**	**15,70%**	**#DIVISION/0!**	**11,30%**	**9,93%**	**11,97%**	**15,77%**

Downtime in Line 4 2013-09-09 – 2013-10-13.

L4	CUPPER	BM	WASHER	PRINTER	IC-SPRAY	OVEN	NECKER	TESTER	PALLETIZER	TOTAL
Operating	500:15:35	3505:37:49	596:42:27	392:45:42	3460:47:23		1114:05:14	544:23:21	568:17:21	10682:54:52
Machinery fault	7:42:01	241:40:38	10:12:24	11:50:14	204:58:21		60:30:40	53:11:46	32:28:06	622:34:10
Standby in	0:00:00	49:32:36	0:00:00	41:27:46	538:51:07		124:35:27	54:17:18	71:31:26	880:15:40
Standby out	78:34:35	741:15:13	0:00:00	19:00:39	155:07:50		34:43:52	13:02:59	0:12:42	1681:00:31
Standby	0:00:00	7:38:14	64:43:52	0:00:00	343:20:07		9:47:07	7:11:17	0:00:00	432:40:37
Low speed	80:38:13	0:00:00	0:00:00	153:19:52	0:00:00		0:00:00	0:00:00	0:00:00	233:58:05
Manual stop	4:32:28	156:07:43	0:00:00	50:07:09	0:52:02		0:13:31	0:00:00	0:00:00	211:52:53
Downtime total	90:49:04	1196:14:24	74:56:16	122:25:48	1243:09:27		229:50:37	127:43:20	104:12:14	3828:23:51
Downtime %	**13,52%**	**25,44%**	**11,16%**	**18,31%**	**26,43%**		**17,10%**	**19,00%**	**15,50%**	**25,96%**

Appendix C

Different downtime modes

Different downtimes in printers 2013-09-09 – 2013-10-13.

		Printer 11	***Printer 12***	***Average***
L1	*Operating*	68.68 %	47.27 %	55.73 %
	Machinery fault	2.97 %	23.39 %	15.33 %
	Standby IN	3.47 %	7.05 %	5.63 %
	Standby OUT	2.88 %	0.48 %	1.43 %
	Standby	0.00 %	0.00 %	0.00 %
	Low speed	21.40 %	21.81 %	21.65 %
	Manual stop	0.59 %	0.00 %	0.23 %
	Total run time	**90.08 %**	**69.08 %**	**77.38 %**
	Downtime	**9.92 %**	**30.92 %**	**22.62 %**

Different downtimes in bodymakers 2013-09-09 – 2013-10-13.

L1		***BM 11***	***BM 12***	***BM 13***	***BM 14***	***BM 15***	***BM 16***	***BM 17***	***AVERAGE***
	Operating	57,98%	74,57%	76,07%	58,72%	45,71%	81,55%	71,72%	66,58%
	Machinery fault	14,39%	9,29%	12,27%	6,96%	7,91%	6,20%	14,28%	10,16%
	Standby IN	1,48%	1,14%	1,44%	2,32%	1,62%	2,08%	2,35%	1,77%
	Standby OUT	14,99%	12,32%	8,21%	28,06%	33,71%	8,15%	7,33%	16,17%
	Standby	6,05%	0,84%	0,52%	0,22%	0,22%	0,20%	0,18%	1,18%
	Low speed	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
	Manual stop	5,11%	1,85%	1,49%	3,72%	10,82%	1,82%	4,14%	4,14%
	Total run time	**57,98%**	**74,57%**	**76,07%**	**58,72%**	**45,71%**	**81,55%**	**71,72%**	**66,58%**
	Downtime	**42,02%**	**25,43%**	**23,93%**	**41,28%**	**54,29%**	**18,45%**	**28,28%**	**33,42%**

Downtime in inside coating sprayers 2013-09-09 – 2013-10-13.

L1		IC 11	IC 12	IC 13	IC 14	IC 15	IC 16	IC 17	AVERAGE
	Operating	69,63%	70,16%	70,24%	69,90%	65,97%	71,71%	72,53%	70,02%
	Machinery fault	8,63%	8,01%	8,12%	7,62%	13,14%	6,50%	5,49%	8,21%
	Standby IN	14,38%	14,37%	14,20%	14,43%	13,94%	14,51%	14,47%	14,33%
	Standby OUT	1,78%	1,79%	1,81%	1,73%	1,44%	1,66%	1,83%	1,72%
	Standby	3,77%	3,78%	3,77%	3,76%	3,65%	3,76%	3,74%	3,75%
	Low speed	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
	Manual stop	1,82%	1,88%	1,86%	2,56%	1,87%	1,86%	1,94%	1,97%
	Total run time	**69,63%**	**70,16%**	**70,24%**	**69,90%**	**65,97%**	**71,71%**	**72,53%**	**70,02%**
	Downtime	**30,37%**	**29,84%**	**29,76%**	**30,10%**	**34,03%**	**28,29%**	**27,47%**	**29,98%**

Complete PPM

Line 1

Machine	Downtime Description	Mach. fault	Stand by	Manual stop	∑	% of machine	% of line
Cupper		**10:14:01**	**99:26:01**	**6:05:41**	**115:45:43**		**11%**
	Ban krock station #1	0:03:09			0:03:09	0%	
	Ban krock station #11	0:03:19			0:03:19	0%	
	Ban krock station #8	0:42:06			0:42:06	1%	
	Coil slut alarm	0:09:52			0:09:52	0%	
	Fel coilbredd station # 11	0:03:29			0:03:29	0%	
	Ingen coil loop alarm	0:05:47			0:05:47	0%	
	Interlock skrotlarm	0:20:44			0:20:44	0%	
	Lubricator larm	0:11:15			0:11:15	0%	
	Luft fel PS 1,2,3,4	0:40:33			0:40:33	1%	
	Nödstopp intryckt	0:00:43			0:00:43	0%	
	Synk koll CH1 låg hastighet top stopp	0:03:26			0:03:26	0%	
	Synkl koll CH 4 verktygskontroll	0:01:00			0:01:00	0%	
	Verktygskrock station #10	0:18:46			0:18:46	0%	
	Verktygskrock station #11	0:20:25			0:20:25	0%	
	Verktygskrock station #3	0:02:03			0:02:03	0%	
	Verktygskrock station #5	2:22:36			2:22:36	2%	
	Verktygskrock station #7	1:53:22			1:53:22	2%	
	Verktygskrock station #9	1:28:31			1:28:31	1%	
	Vertygskrock station #1	1:05:19			1:05:19	1%	
	Vertygskrock station #2	0:17:36			0:17:36	0%	
	Top stopp			6:05:41	6:05:41	5%	
	Standby Backup		99:26:01		99:26:01	86%	
Bodymaker		**474:41:55**	**893:27:58**	**193:18:34**	**1561:28:27**		**21%**
Bodymaker #11		**96:38:45**	**151:12:31**	**34:19:51**	**282:11:07**	**18%**	
	BM Huvudmotor	0:27:57			0:27:57	0%	
	BM kort burk	49:39:51			49:39:51	18%	
	BM krock i utmatning	4:04:20			4:04:20	1%	
	BM lågt flöde dragolja	1:03:23			1:03:23	0%	
	BM lågt lufttryck	3:16:34			3:16:34	1%	
	BM skydd öppet	7:59:07			7:59:07	3%	
	Nödstopp Intryckt / Ingen Kontrollspänning	0:26:20			0:26:20	0%	
	Okänt fel	15:46:12			15:46:12	6%	
	Trimmer krock	1:27:49			1:27:49	1%	

	Trimmer krock i fallränna	1:40:02			1:40:02	1%
	Trimmer krock i utmatning	10:13:54			10:13:54	4%
	Trimmer krock inmatning	0:00:43			0:00:43	0%
	Trimmer skydd öppet	0:32:33			0:32:33	0%
	BM Topstop			30:27:59	30:27:59	11%
	CupMatning Manuelt Av Från FLC			3:51:52	3:51:52	1%
	Standby		40:38:11		40:38:11	14%
	Standby Inmatning		9:55:22		9:55:22	4%
	Standby Utmatning		100:38:58		100:38:58	36%
Bodymaker #12		**62:24:08**	**96:04:48**	**12:24:30**	**170:53:26**	**11%**
	BM kort burk	30:24:05			30:24:05	18%
	BM krock i utmatning	4:20:25			4:20:25	3%
	BM lågt flöde dragolja	5:35:50			5:35:50	3%
	BM lågt lufttryck	0:03:16			0:03:16	0%
	BM skydd öppet	0:06:55			0:06:55	0%
	Nödstopp Intryckt / Ingen Kontrollspänning	0:26:32			0:26:32	0%
	Okänt fel	10:24:14			10:24:14	6%
	Trimmer krock	1:29:28			1:29:28	1%
	Trimmer krock i fallränna	3:26:27			3:26:27	2%
	Trimmer krock i utmatning	3:22:00			3:22:00	2%
	Trimmer krock inmatning	2:27:12			2:27:12	1%
	Trimmer motor	0:00:33			0:00:33	0%
	Trimmer skydd öppet	0:17:11			0:17:11	0%
	BM Topstop			8:32:46	8:32:46	5%
	CupMatning Manuelt Av Från FLC			3:51:44	3:51:44	2%
	Standby		5:40:14		5:40:14	3%
	Standby Inmatning		7:38:28		7:38:28	4%
	Standby Utmatning		82:46:06		82:46:06	48%
Bodymaker #13		**82:26:23**	**68:19:59**	**10:01:27**	**160:47:49**	**10%**
	BM Huvudmotor	1:32:44			1:32:44	1%
	BM kort burk	43:53:51			43:53:51	27%
	BM krock i utmatning	17:51:08			17:51:08	11%
	BM lågt flöde dragolja	3:14:06			3:14:06	2%
	BM lågt lufttryck	0:03:44			0:03:44	0%
	BM skydd öppet	0:10:13			0:10:13	0%
	BM smörjfel	0:01:06			0:01:06	0%
	Nödstopp Intryckt / Ingen Kontrollspänning	0:30:22			0:30:22	0%

	Okänt fel	11:40:21			11:40:21	7%
	Trimmer krock	0:03:28			0:03:28	0%
	Trimmer krock i fallränna	2:09:50			2:09:50	1%
	Trimmer krock i utmatning	1:03:54			1:03:54	1%
	Trimmer krock inmatning	0:09:54			0:09:54	0%
	Trimmer motor	0:00:11			0:00:11	0%
	Trimmer skydd öppet	0:01:31			0:01:31	0%
	BM Topstop			5:44:49	5:44:49	4%
	CupMatning Manuelt Av Från FLC			4:16:38	4:16:38	3%
	Standby		3:29:00		3:29:00	2%
	Standby Inmatning		9:40:52		9:40:52	6%
	Standby Utmatning		55:10:07		55:10:07	34%
Bodymaker #14		**46:43:04**	**205:33:33**	**24:58:43**	**277:15:20**	**18%**
	BM ingen synk	0:01:23			0:01:23	0%
	BM kort burk	25:00:10			25:00:10	9%
	BM krock i utmatning	4:48:00			4:48:00	2%
	BM lågt flöde dragolja	0:18:14			0:18:14	0%
	BM lågt lufttryck	5:07:38			5:07:38	2%
	BM smörjfel	0:11:12			0:11:12	0%
	Trimmer krock i fallränna	3:26:48			3:26:48	1%
	Trimmer krock i utmatning	3:39:26			3:39:26	1%
	Trimmer krock inmatning	0:00:27			0:00:27	0%
	Trimmer motor	3:27:22			3:27:22	1%
	Trimmer skydd öppet	0:42:24			0:42:24	0%
	BM Topstop			19:49:13	19:49:13	7%
	CupMatning Manuelt Av Från FLC			5:09:30	5:09:30	2%
	BM låg inmatning		4:07:15		4:07:15	1%
	Standby		1:30:23		1:30:23	1%
	Standby Inmatning		11:28:09		11:28:09	4%
	Standby Utmatning		188:27:46		188:27:46	68%
Bodymaker #15		**53:11:07**	**238:55:19**	**72:43:45**	**364:50:11**	**23%**
	BM kort burk	23:13:09			23:13:09	6%
	BM krock i utmatning	5:33:07			5:33:07	2%
	BM lågt flöde dragolja	0:30:22			0:30:22	0%
	BM skydd öppet	1:42:26			1:42:26	0%
	Nödstopp Intryckt / Ingen Kontrollspänning	0:15:36			0:15:36	0%
	Trimmer krock	3:44:35			3:44:35	1%

	Trimmer krock i fallränna	7:36:55			7:36:55	2%
	Trimmer krock inmatning	0:01:50			0:01:50	0%
	Trimmer motor	10:13:06			10:13:06	3%
	Trimmer skydd öppet	0:20:01			0:20:01	0%
	BM Topstop			57:55:03	57:55:03	16%
	CupMatning Manuelt Av Från FLC			14:48:42	14:48:42	4%
	Standby		1:29:10		1:29:10	0%
	Standby Inmatning		10:53:38		10:53:38	3%
	Standby Utmatning		226:32:31		226:32:31	62%
Bodymaker #16		**41:38:28**	**70:02:46**	**12:14:09**	**123:55:23**	**8%**
	BM kort burk	31:57:03			31:57:03	26%
	BM krock i utmatning	3:10:12			3:10:12	3%
	BM lågt flöde dragolja	0:17:24			0:17:24	0%
	Trimmer krock	0:07:38			0:07:38	0%
	Trimmer krock i fallränna	1:54:45			1:54:45	2%
	Trimmer krock i utmatning	1:21:38			1:21:38	1%
	Trimmer krock inmatning	0:02:44			0:02:44	0%
	Trimmer motor	2:15:17			2:15:17	2%
	Trimmer skydd öppet	0:31:47			0:31:47	0%
	BM Topstop			7:30:55	7:30:55	6%
	CupMatning Manuelt Av Från FLC			4:43:14	4:43:14	4%
	BM låg inmatning		2:24:01		2:24:01	2%
	Standby		1:20:10		1:20:10	1%
	Standby Inmatning		11:35:46		11:35:46	9%
	Standby Utmatning		54:42:49		54:42:49	44%
Bodymaker #17		**91:40:00**	**63:19:02**	**26:36:09**	**181:35:11**	**12%**
	BM ingen synk	12:54:16			12:54:16	7%
	BM kort burk	61:27:46			61:27:46	34%
	BM krock i utmatning	4:36:12			4:36:12	3%
	BM lågt flöde dragolja	0:22:52			0:22:52	0%
	BM lågt lufttryck	0:03:48			0:03:48	0%
	BM skydd öppet	0:28:17			0:28:17	0%
	Nödstopp Intryckt / Ingen Kontrollspänning	0:02:38			0:02:38	0%
	Trimmer krock i fallränna	1:08:12			1:08:12	1%
	Trimmer krock i utmatning	2:35:49			2:35:49	1%
	Trimmer motor	7:52:57			7:52:57	4%
	Trimmer skydd öppet	0:07:13			0:07:13	0%

	BM Topstop			21:28:27	21:28:27	12%	
	CupMatning Manuelt Av Från FLC			5:07:42	5:07:42	3%	
	BM låg inmatning		4:57:39		4:57:39	3%	
	Standby		1:10:18		1:10:18	1%	
	Standby Inmatning		10:05:55		10:05:55	6%	
	Standby Utmatning		47:05:10		47:05:10	26%	
Washer #1		**17:28:59**	**52:37:36**	**0:00:00**	**70:06:35**		**7%**
	Avställd arbetsbrytare M32 blow off fläkt	0:04:49			0:04:49	0%	
	Drifttryck M26 behandlingspump steg 4	0:00:00			0:00:00	0%	
	Fel flöde di-vatten steg 6	0:19:16			0:19:16	0%	
	Fotocell krock inmatning ugn	0:23:31			0:23:31	1%	
	Krock behandling steg 4	3:28:05			3:28:05	5%	
	Krock steg 2 tvätt	0:20:53			0:20:53	0%	
	Krock steg 3B	7:39:30			7:39:30	11%	
	Krock steg 5B	0:02:55			0:02:55	0%	
	Krock steg 6	0:56:12			0:56:12	1%	
	Låg nivå steg 7 U33	0:26:17			0:26:17	1%	
	ME pump M40 steg 7	0:06:36			0:06:36	0%	
	Obekant fel	1:01:05			1:01:05	1%	
	Washer matta klar för drift	1:47:36			1:47:36	3%	
	WasherUtmatning Full	0:52:14			0:52:14	1%	
	Interlock från ugn brännare från		0:25:09		0:25:09	1%	
	Interlock från ugn temp ok		1:05:41		1:05:41	2%	
	Interlock från washerinmatning. Låg nivå		21:07:57		21:07:57	30%	
	Interlock washer start/stop		29:58:49		29:58:49	43%	
Printer		**18:11:58**	**51:42:46**	**1:43:14**	**71:37:58**		**7%**
Printer #11		**8:35:55**	**18:23:01**	**1:43:14**	**28:42:10**	**40%**	
	Driftfel Huvuddrivmotor.	0:00:11			0:00:11	0%	
	Dörr (Gs3A) Till Kedjebur 1:A Vån Öppen.	0:01:43			0:01:43	0%	
	Fel Flöde Ov-Lack (Fs1)	0:53:03			0:53:03	3%	
	Främre Skydd (Gs1) Öppen.	0:11:39			0:11:39	1%	
	InmatningsKrock Ellerl Dåligt Burk Flöde	2:50:40			2:50:40	10%	
	Okänt fel	0:00:04			0:00:04	0%	
	Ov-Drive Eller Ov-Pump Ej I Drift	0:00:55			0:00:55	0%	
	Singelfiler Stopp Från Linjekontroll	4:23:59			4:23:59	15%	
	Transfer I Av Läge Under Drift.	0:05:32			0:05:32	0%	
	Unloaderkrock PRX8.	0:08:09			0:08:09	0%	

	H-Drivning Stopp Påverkad.Tryck Återställning Sys			1:43:14	1:43:14	6%	
	Låg InmatningFrån Givare I Inmatningsbana.		0:57:59		0:57:59	3%	
	Standby Inmatning		9:04:31		9:04:31	32%	
	Standby Utmatning		8:20:31		8:20:31	29%	
Printer #12		**9:36:03**	**33:19:45**	**0:00:00**	**42:55:48**	**60%**	
	Fel strömriktare	0:00:36			0:00:36	0%	
	Huvudmotor klar för drift	2:06:54			2:06:54	5%	
	Ingen burk överföring	0:00:58			0:00:58	0%	
	Inmatningsfel	5:20:35			5:20:35	12%	
	Nödstopp	0:00:52			0:00:52	0%	
	Okänt fel	0:01:58			0:01:58	0%	
	Overvarn aggregat i läge för auto körning.	0:22:00			0:22:00	1%	
	overvarnish start	1:17:23			1:17:23	3%	
	Smörjfel av kuggar	0:03:06			0:03:06	0%	
	Ugn ingen låga	0:03:39			0:03:39	0%	
	Unloader krock/bandbrott	0:18:02			0:18:02	1%	
	Låg InmatningFrån Givare I Inmatningsbana.		0:13:14		0:13:14	1%	
	Standby Inmatning		30:59:51		30:59:51	72%	
	Standby Utmatning		2:06:40		2:06:40	5%	
IC-spruta		**386:18:34**	**930:56:58**	**92:37:37**	**1409:53:09**		**19%**
IC-Spruta #11		**57:56:45**	**133:51:30**	**12:13:59**	**204:02:14**	14%	
	Huvudmotor ej startad	47:51:26			47:51:26	23%	
	Krock utmatning microbrytare	1:45:17			1:45:17	1%	
	Krock utmatningsbana	7:44:20			7:44:20	4%	
	Minne inget spinn	0:09:15			0:09:15	0%	
	Nödstopp	0:05:41			0:05:41	0%	
	Obekant fel	0:18:33			0:18:33	0%	
	Rotationsmotor ej startad	0:02:13			0:02:13	0%	
	Manuelt Stopp			12:13:59	12:13:59	6%	
	Låg inmatning		3:30:22		3:30:22	2%	
	Standby		25:18:45		25:18:45	12%	
	Standby Inmatning		93:04:07		93:04:07	46%	
	Standby Utmatning		11:58:16		11:58:16	6%	
IC-Spruta #12		**53:48:18**	**134:02:48**	**12:37:23**	**200:28:29**	**14%**	
	Huvudmotor ej startad	49:15:11			49:15:11	25%	
	Krock utmatning microbrytare	0:19:04			0:19:04	0%	
	Krock utmatningsbana	3:07:58			3:07:58	2%	

	Minne inget spinn	0:17:40			0:17:40	0%
	Nödstopp	0:11:51			0:11:51	0%
	Obekant fel	0:32:06			0:32:06	0%
	Rotationsmotor ej startad	0:04:28			0:04:28	0%
	Manuelt Stopp			12:37:23	12:37:23	6%
	Låg inmatning		1:56:12		1:56:12	1%
	Standby		25:25:37		25:25:37	13%
	Standby Inmatning		94:37:34		94:37:34	47%
	Standby Utmatning		12:03:25		12:03:25	6%
IC-Spruta #13		**54:32:08**	**132:52:00**	**12:31:27**	**199:55:35**	**14%**
	Huvudmotor ej startad	46:02:21			46:02:21	23%
	Krock utmatningsbana	5:21:38			5:21:38	3%
	Minne inget spinn	0:12:09			0:12:09	0%
	Nödstopp	0:15:38			0:15:38	0%
	Obekant fel	0:18:19			0:18:19	0%
	Oljetryck fel	2:15:45			2:15:45	1%
	Rotationsmotor ej startad	0:06:18			0:06:18	0%
	Manuelt Stopp			12:31:27	12:31:27	6%
	Låg inmatning		2:09:44		2:09:44	1%
	Standby		25:19:08		25:19:08	13%
	Standby Inmatning		93:12:50		93:12:50	47%
	Standby Utmatning		12:10:18		12:10:18	6%
IC-Spruta #14		**51:11:58**	**133:50:53**	**17:11:52**	**202:14:43**	**14%**
	Huvudmotor ej startad	48:52:52			48:52:52	24%
	Krock utmatning microbrytare	0:22:25			0:22:25	0%
	Krock utmatningsbana	0:38:09			0:38:09	0%
	Minne inget spinn	0:31:24			0:31:24	0%
	Nödstopp	0:25:53			0:25:53	0%
	Obekant fel	0:14:57			0:14:57	0%
	Rotationsmotor ej startad	0:06:18			0:06:18	0%
	Manuelt Stopp			17:11:52	17:11:52	9%
	Låg inmatning		2:07:09		2:07:09	1%
	Standby		25:15:37		25:15:37	12%
	Standby Inmatning		94:50:06		94:50:06	47%
	Standby Utmatning		11:38:01		11:38:01	6%
IC-Spruta #15		**88:16:09**	**127:47:29**	**12:32:43**	**228:36:21**	**16%**
	Huvudmotor ej startad	73:04:42			73:04:42	32%

	Inget vakuum	0:12:29			0:12:29	0%	
	Krock utmatning microbrytare	3:50:27			3:50:27	2%	
	Krock utmatningsbana	8:41:08			8:41:08	4%	
	Minne inget spinn	0:28:10			0:28:10	0%	
	Nödstopp	0:10:08			0:10:08	0%	
	Obekant fel	1:46:55			1:46:55	1%	
	Rotationsmotor ej startad	0:02:10			0:02:10	0%	
	Manuelt Stopp			12:32:43	12:32:43	5%	
	Låg inmatning		2:08:17		2:08:17	1%	
	Standby		24:29:54		24:29:54	11%	
	Standby Inmatning		91:29:27		91:29:27	40%	
	Standby Utmatning		9:39:51		9:39:51	4%	
IC-Spruta #16		**43:38:29**	**133:56:16**	**12:27:59**	**190:02:44**	**13%**	
	Huvudmotor ej startad	42:15:43			42:15:43	22%	
	Krock utmatningsbana	0:46:16			0:46:16	0%	
	Minne inget spinn	0:05:10			0:05:10	0%	
	Nödstopp	0:13:30			0:13:30	0%	
	Obekant fel	0:15:00			0:15:00	0%	
	Rotationsmotor ej startad	0:02:50			0:02:50	0%	
	Manuelt Stopp			12:27:59	12:27:59	7%	
	Låg inmatning		3:17:47		3:17:47	2%	
	Standby		25:17:20		25:17:20	13%	
	Standby Inmatning		94:10:39		94:10:39	50%	
	Standby Utmatning		11:10:30		11:10:30	6%	
IC-Spruta #17		**36:54:47**	**134:36:02**	**13:02:14**	**184:33:03**	**13%**	
	Huvudmotor ej startad	35:35:26			35:35:26	19%	
	Inget vakuum	0:04:41			0:04:41	0%	
	Krock utmatningsbana	0:41:35			0:41:35	0%	
	Minne inget spinn	0:04:50			0:04:50	0%	
	Nödstopp	0:12:25			0:12:25	0%	
	Obekant fel	0:15:50			0:15:50	0%	
	Manuelt Stopp			13:02:14	13:02:14	7%	
	Låg inmatning		2:04:31		2:04:31	1%	
	Standby		25:09:23		25:09:23	14%	
	Standby Inmatning		95:06:16		95:06:16	52%	
	Standby Utmatning		12:15:52		12:15:52	7%	
Necker #11		**42:06:25**	**85:51:32**	**7:37:49**	**135:35:46**		**13%**

	Avlossa krock port	0:20:01			0:20:01	0%	
	Huvudmoter ej startad	1:48:48			1:48:48	1%	
	Krock i verktyg	7:17:14			7:17:14	5%	
	Obekant fel	0:46:52			0:46:52	1%	
	Synkfel PROX7 transfer sensor#1	23:52:22			23:52:22	18%	
	Tappad burk i module#1	2:48:41			2:48:41	2%	
	Tappad burk i module#10	0:08:26			0:08:26	0%	
	Tappad burk i module#11	0:05:14			0:05:14	0%	
	Tappad burk i module#12	0:18:23			0:18:23	0%	
	Tappad burk i module#13	0:22:46			0:22:46	0%	
	Tappad burk i module#2	0:00:53			0:00:53	0%	
	Tappad burk i module#4	0:00:26			0:00:26	0%	
	Tappad burk i module#5	0:06:35			0:06:35	0%	
	Tappad burk i module#6	0:06:06			0:06:06	0%	
	Tappad burk i module#8	0:17:39			0:17:39	0%	
	Tappad burk i module#9	1:12:15			1:12:15	1%	
	Tappad burk i utmatning	0:08:48			0:08:48	0%	
	Utmatning backup	2:24:56			2:24:56	2%	
	Manuelt Stopp			7:37:49	7:37:49	6%	
	Låg inmatning		0:38:38		0:38:38	0%	
	Standby		3:45:44		3:45:44	3%	
	Standby Inmatning		67:25:06		67:25:06	50%	
	Standby Utmatning		14:02:04		14:02:04	10%	
LjusTester #1		**10:14:08**	**114:16:20**	**0:00:00**	**124:30:28**		**12%**
	Fel luftryck	0:03:57			0:03:57	0%	
	Hög Kassation	3:54:03			3:54:03	3%	
	Ic-Lack Pressco	5:08:50			5:08:50	4%	
	Krock utmatning	0:54:10			0:54:10	1%	
	Lamphus öppet	0:08:28			0:08:28	0%	
	Nödstopp ok / Manöverspänning på	0:04:40			0:04:40	0%	
	Standby Inmatning		110:12:49		110:12:49	89%	
	Standby Utmatning		4:03:31		4:03:31	3%	
PallPackare #1		**34:57:09**	**93:55:46**	**0:00:00**	**128:52:55**		**12%**
	Skydd/Ljusridå	10:14:02			10:14:02	8%	
	Fel packnings mönster	24:35:05			24:35:05	19%	
	Fel toppram lift plattform 2	0:08:02			0:08:02	0%	
	Standby Inmatning		93:33:52		93:33:52	73%	

Standby Utmatning		0:21:54		0:21:54	0%
∑	**994:13:09**	**2322:14:57**	**301:22:55**		
%	27,48%	64,19%	8,33%		