UNIVERSITY OF TWENTE.

Faculty of Behavioural, Management
and Social Sciences

Improving the factory efficiency of Bottling Line 2 at Grolsch

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BSc. Thesis
Industrial Engineering & Management
27 September 2019

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September 27, 2019

Preface

After spending my summer holiday at the Grolsch brewery, this thesis finalizes my research and my time working as part of the Packaging Department at Grolsch. Next to that, this thesis also marks the end of my bachelor Industrial Engineering & Management.

Not only have I been able to apply theoretical knowledge to a professional field for the first time in my IEM-career, I was also very fortunate to do this within the dynamic and very interesting environment at Grolsch.

For this opportunity and the guidance given during my time at Grolsch I would like to thank Daan Koelemeijer and Kasper Mayar, who were both very supportive and willing to help. They provided feedback when I needed it and could always make time for my questions.

I would also like to thank the operators working at Bottling Line 2, for always being willing to answer all my questions and helping me understand the bottling process. I really liked the enthusiasm that was present when the bottling line was explained.

Furthermore, I would also like to thank Marco Schutten for his guidance during the process. I am well aware of the fact that my planning, doing my research during the summer holidays, was not exactly standard procedure, so I am very grateful that it was possible to guide me and provide advice.

Next to my first supervisor, I would like to thank my second supervisor Engin Topan for taking the time to read my work.

Finally, I would like to thank any other persons that helped me in creating this thesis and I hope you will enjoy reading this thesis.

Tom van der Meer,
Enschede, September 2019

Management Summary

There are multiple bottling lines in place at the Grolsch brewery, which all bottle different kinds of beers in various containers. The performance of these lines is measured in the percentage of time this line would need for the production of the output compared to the total time it is available for production, the so-called *Factory Efficiency*. The operational side of this production line was performing up to the expectations of Grolsch, i.e., the machines did not break down too much. However, it is believed that there is more to gain on other aspects of the production. This would especially be the case at Bottling Line 2, a line that produces various different products. All these different product lead to a complex planning, and multiple changeovers and cleaning tasks.

The question that was the starting point of this research is: *"How can we improve on the factory efficiency of Bottling Line 2?"*

This research identifies the core problem with a problem cluster, in which we find changeovers to be an important factor in improving the efficiency. We then examined the current situation at Bottling Line 2, using multiple types of data. We also looked into literature to find relevant articles and case studies to help us create an optimal solution. The results of the observations are then listed, followed by an advice regarding changeover improvements.

This report contains advice on both the conversion of internal activities to external activities and on a policy regarding new bottles. A remark on the sustainability of the bottling line is also included.

It was observed that, even though changeover carts containing all necessities for the changeover are present within the company, these carts are not always used at the line when the changeover starts. Getting these carts takes 4 minutes and should be done while the machine is still running. The same goes for storing the labels and cleaning the parts of the machine; these activities should be executed as external activities that are performed after the changeover is finished.

Regarding the use of new bottles to compensate for the bottles that are not returned, there is a room for significant improvement. When new bottles have to be inserted, it should always be done during a changeover. This leads to time savings of more than 30 minutes (during the longest changeovers).

Since the machines at the line are not always necessary during a changeover, they should be on stand-by. At this moment, there are still machines performing tasks that require a lot of power (and therefore electricity) that are of no value. The example given is a mechanical arm that is

'taking out the bottles' of empty crates that run by it for more than one hour.

During this research it was also found that the operating standards that are used at this moment are not in line with the actual performance. This would be an interesting and valuable thing to re-evaluate.

Contents

Glossary

Concept	**Explanation**
BNR	“Bruine Nederlandse Retourfles” (Brown Dutch Return-bottle), a standardized bottle for the Dutch beer market. All brewers can use this bottle.
CIP	Cleaning in Place, the process of cleaning the machine parts of the bottling line in order to enable the bottling of new beer. There are 3 CIP-types: • Cold water CIP (20 minutes) • Hot water + acid CIP (60 minutes) • Alkaline + acid CIP (120 minutes)
EBI	Empty Bottle Inspector, machine in the bottling line that inspects the clean empty bottles before they get filled. Bottles with damages are pushed out.
Etima	The labelling machine, all operators and other employees of Grolsch refer to this machine as Etima, an abbrevation of ’Etiketteer machine’ (Labeling machine).
Operating Standard	Terminology used within Grolsch to refer to the time that a certain changeover is scheduled to take. These standards are, for example, used in the planning.
SKU	Stock Keeping Unit, unique product. All unique configurations represent different SKU. For instance different types of beer or the same beer in different packaging options. Examples: • 24 bottles of Grolsch in a crate • Crate with 4 6-packs Radler • Box with 6-packs Grolsch
SMED	Single Minute Exchange of Die, a method to improve changeovers develop by Shigeo Shingo in 1985
Star Wheel	A wheel present in multiple bottling line machines, picks up bottles from the moving lines 

Chapter 1

Introduction

This chapter provides an introduction to the company Grolsch and the problem it encounters. Next, we identify the core problem and determine the problem-solving approach. The last section covers the structure of this report.

Contents

1.1 Introduction to Grolsch

Since founded in 1615, Grolsch grew to be one of the big brewers in the Netherlands. In 2016, Grolsch was acquired by Asahi, a Japanese brewer.
Since the beginning of the brand, the main product is regular 'Pilsner', which is still the most important product today. Next to this type of beer, numerous other beers are filled at the modern Grolsch Brewery that was built in 2003. At this modern facility, more than 650 people work to ensure that all products are produced correctly. Grolsch is active worldwide, selling 3.0 million hectoliter (300,000,000 liter) in over 60 countries in 2018 (Grolsch, 2019).

The product portfolio of Grolsch is already extensive, but this is set to increase even more. This increase is mainly due to the increasing popularity and demand for non-alcoholic and speciality beers (Grolsch, 2019). For 2019 the aim is to introduce a new beer every month (Packaging department, personal communication July 17, 2019), which, in combination with the increased popularity, will lead to an even more diverse portfolio.

Grolsch is striving to incorporate sustainability and corporate social responsibility (SCSR) in all of its actions. Many sustainability projects are currently in process or being developed; for instance, the first crate in the world made of 100% recycled consumer plastic and numerous other recycling efforts.

1.2 Management Problem

One of the problems Grolsch encounters, concerns the efficiency of their Bottling Line 2. In the brewery, there are eight lines in total, working with all different kinds of beers, containers and packaging options. In this report, we refer to Bottling Line 2 as Line 2. Line 2 mostly focuses on 'speciality beers', for example radlers, bock-beers and other seasonal crafts. Grolsch measures the performance of their lines by monitoring machine efficiency and factory efficiency; these concept are explained below. The last few months, the focus of the Operations Department has mainly been on improving the machine efficiency of the line, which did improve. Now, Grolsch feels that there is even more to gain by focusing on the factory efficiency of Line 2. The following definitions and Figure 1.1 provide a clear understanding of these concepts. The 'Total Time' is defined as the total time in the period we are looking at, for example 168 hours per week. When determining the 'Available Time', the planned downtime is subtracted from the 'Total Time', this includes, for example, the weekends in which there is no production planned. The 'Operating Time' consist of the time the machine is available for production of a product, this does not include time spent on processes such as changeovers and cleaning. The 'Production Time' is the time it would have taken to produce the amount of product when the line would be running full speed.

Factory efficiency measures the final production as a percentage of the time the line is available. This is the 'Production Time' compared to the 'Available Time'. The 'FE-losses' in Figure 1.1 represent times during which the machine is available, but not operating. These situations can have multiple causes, with the main causes at Grolsch being:

- Cleaning
- Changeover
- Starting up and shutting down (at the beginning and end of the week respectively)
- Planned maintenance

Machine efficiency measures the final production as a percentage of the time the machine it is able to operate. The 'ME-losses' from Figure 1.1 include all factors leading to speeds below the full speed, these mainly consist of different types of errors and malfunctions.

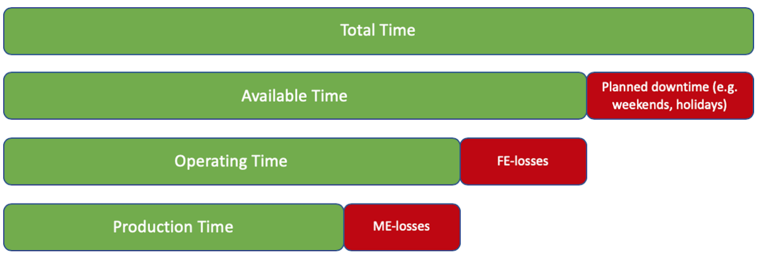

Figure 1.1: Illustration of the effect on production time

As Grolsch has focused on improving the Machine efficiency during the last months, minimizing the unexpected downtimes, the remaining time the machine is not producing at full speed should be studied. These are the 'FE-losses' in Figure 1.1 and the losses mentioned under factory efficiency.

How to improve on these factors is not known yet. This research will focus on the factory efficiency at Bottling Line 2 of Grolsch.

The question Grolsch asks is: *"How can we improve the factory efficiency of Line 2?"*

1.3 Core problem identification

The main goal Grolsch envisions is the improvement of the factory efficiency since it is expected there is a lot to gain there. The standard processes that are of high importance to this are, according to Grolsch (from the Data Warehouse and Packaging Department):

- Cleaning
- Changeover
- Starting up and shutting down (at the beginning and end of the week respectively)
- Planned maintenance

The core problem identification is illustrated in Figure 1.2. After some conversations with Grolsch employees, it came up that there are no brewery-wide standard procedures. One reason is that there are different machines at every line and each machine operates differently. Not only is every line within the brewery different, at every line multiple different teams operate. Due to this fact, these procedures are carried out in different ways by different people. Furthermore, the duration of the changeover, differs from time to time. This variance in changeover time makes it very hard for the planners who have to make a weekly production schedule since they have no precise estimate of how long these changeovers take. These planners use operating standards that might not be on point, which leads to stops being either too long or too short, which both negatively influences the results of the planning. The term 'operating standards' is used within Grolsch to refer to the standard time a changeover is expected to take.

Another observed problem is the communication between operators at the line. It might happen that one operator has already finished the changeover at his/her machine, but other operators are not aware of this. This would lead to unnecessary waiting and therefore lost production time.

Other moments the machine stops are due to maintenance at the line, during which there can be no production. However, too little maintenance would lead to even more stops and lost production time. Maintenance planning is an essential aspect regarding factory efficiency.

Figure 1.2 illustrates the factors of importance. Here, the overarching problem, a sub-optimal FE, is marked with a red border and the main problems leading to this are has an orange border.

The problem on top, the changeover, is chosen as main topic for this research as this enables the most useful results. This is based on both the problem analysis and advice from Grolsch. According to Grolsch maintenance and machine performance should be left out of the scope.

1.4 Problem Solving Approach

The approach to improving the factory efficiency and being able to give a well-educated advice consist of multiple steps. These steps are globally in chronological order; however, there is a continuous cycle between the first stages as collecting and analysing different types of data are relevant at many moments.

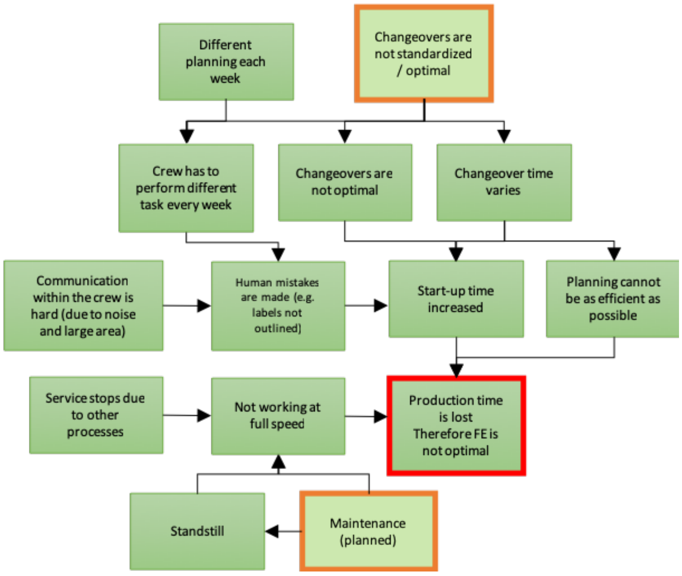

Figure 1.2: Core Problem Identification

Understanding the process The first step is to thoroughly understand how changeovers work and what processes take place. Observing the changeover, interviewing relevant employees and reviewing available documentation enables this understanding.

Observation Observing the changeovers at Line 2 was done multiple times as it was mentioned that every shift executes the changeover slightly different, leading to different performances. Keeping track of what actions are performed, by whom, how long they take and in what order tasks are carried out enables a good view of the changeover. Making as many comments as possible enables objective comparisons of the multiple observations.

Interviews The operators working at the line experience the changeovers every day and therefore provide valuable insights. These interviews also provide a good opportunity to verify theories and hypotheses and collect information about them. In situations where observations are not sufficient to fully understand the changeover, unclarities are addressed in an interview.

Analyse Data After collecting various types and an extensive amount of data, analysis can start. Within this data, we see where the most time is lost, where the most time is to be won and what can be learned from other lines and teams. Best practices for all elements of a changeover can be determined and analysed.

Applying literature Devising a proper advice for the changeovers at Line 2 requires a deep understanding of the changeover process and lean techniques. Lean techniques in general will help to understand efficiency improvements and the literature research about topics as Single Minute Exchange of Die (SMED) can be applied to the results found by observing, interviewing and analysing.

Constructing advice When all data is collected and analysed, we use this to devise a better changeover strategy for Line 2. This advice will incorporate everything from the theory out of the literature to the data collected on the work floor at Grolsch. This advice should have concrete recommendations to improve the changeover that are realistically applicable.

Deliverables The data analysis of the performance of Line 2, together with documented best practices and, of course, advice on how to improve the factory efficiency at Line 2 at Grolsch will be one of the deliverables. The findings in the literature and their applicability to Line 2 at Grolsch, that can be extended to other lines and companies, are also included in the report.

1.5 Report Structure

The problem-solving approach mentioned will serve as the basis for this report. Each chapter will provide insights into the problem and work towards solutions and improvements. Table 1.1 displays the structure of this report and an overview of the sub-questions that will be answered in each chapter. Each chapter will feature a short introduction to improve the readability and understanding of the chapter.

Chapter	Contents
Chapter 1	**Introduction to the problem and the company**
Chapter 2	**What is the current situation at Grolsch?**
	What does the production process at Grolsch look like?
	What are moments that the line does not produce?
	How does a changeover work?
	What is the current changeover performance?
Chapter 3	**What literature that is relevant to this research is available?**
	What is the lean methodology?
	What is known about changeover improvements?
	Is there literature available that is applicable to this case?
	What is known about sustainability in regard to changeover improvements?
Chapter 4	**What are the main results of the observations?**
	How is a changeover conducted at the line?
	What activities can be converted from internal to external?
	Which other procedures can be improved to achieve a faster changeover?
Chapter 5	**What would be the best strategy for Grolsch?**
	How can Grolsch improve on the changeover performance of Line 2?
Chapter 6	**Conclusion and Discussion**

Table 1.1: Structure of this report

Chapter 2

Current Situation

This chapter provides a detailed overview of the current situation at Grolsch. First, we look at the entire production process that takes place at Grolsch, after which we zoom in to the bottling line and discuss the stops of Line 2. Then we look at the procedures at the line and the sustainability performance. We then look at the way changeovers are conducted in the current situation. After that, the performance of these changeovers is evaluated, comparing the performance over SKUs and comparing the actual time it took to the expected time.

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2.1 Production process at Grolsch

This section describes the production process at Grolsch, from brewing the beer to shipping it to the buyers.

2.1.1 Brewing

Beer consists of 4 main ingredients: barley, hops, yeast, and water. The first step in brewing consists of cleaning the barley and allowing germination. Since barley is a grain, soaking it in water for some days and leaving it dry afterwards will start germination. This process will ensure the availability of the required proteins and enzymes. The barley seeds are then heated up to stop the germination process and to roaster them. A higher temperature here, will result in darker seeds and therefore, darker beer. After the seeds are dry, they get crushed to separate the useful inside from the outside that has no further use in the brewing process. Next, the barley is soaked in warm water for about an hour to enable enzymes to transform parts of the barley into sugar.

The water is then drained, leaving a sticky and sweet mash that is called wort.

The wort is then boiled for 2-3 hours while hops are added. The boiling enables the extraction of hop flavours and deactivates the enzymes. After this, the hops and proteins are filtered out and the fermentation takes place. A yeast that is unique for Grolsch beer, then transforms the sugars into alcohol and CO2. After this, the product is stored in large tanks for some weeks, allowing the yeast and resin to sink. This will lead to a clear product that can be stored. After the primary fermentation, the beer is transferred to the so-called bright beer tanks where it is stored until it is bottled. In these tanks, the beer further clarifies and matures.

2.1.2 Bottling line

At the bottling line, there is a supply of bottles and crates from the warehouse, both new and return bottles arrive here. At the beginning of the line, bottles are taken out of the crates, and both are cleaned. Empty bottles are inspected to see whether they are still safe to use. These bottles then arrive at the filler, just like the beer that is guided there as well. Pipelines from the bright beer tank guide the required beer to the filler. Here the bottles are filled, and crown caps are placed on the bottles. After the bottles are pasteurized and labelled, they are packed in the required configuration and leave the line in crates.

2.1.3 Warehouse

In the warehouse, both empty and full bottles and crates are stored. Trucks deliver crates with empty bottles collected from consumers and these crates are supplied to the right bottling line when needed. The crates with full bottles are picked up at these lines when a pallet of crates is filled and trucks deliver these new crates to the buyers. The safety stock per product ranges from four days to six weeks.

2.2 Allowed stops and areas of interest

Since we aim to improve the factory efficiency, the focus is to minimize the time spent on allowed stops. We analyse these allowed stops for the period between July 2018 and June 2019. Figure 2.1 shows the data for the allowed stops during these months. In this section, we discuss the different kinds of stops.

As can be seen, the most significant contribution to the time spent on allowed stops is the cleaning process. Since the cleaning is standardized (with standard programs) and should be done very precisely and well due to hygienic standards and requirements, this process is left out of the scope.

In the weekends there is no production, therefore every Friday the lines are shut down, and on Monday they are started up again. These times are represented by the shutdown and the start-up time, respectively. The start-up and shutdown times that occur during changeovers are included in the changeover and not classified separately. Like the cleaning, these start-up and shut down times at the beginning and end of the week are assumed to be fixed in this research.

Some minor loss (in this period 0.16%) occurs as a result of team changes that take more time than usual.

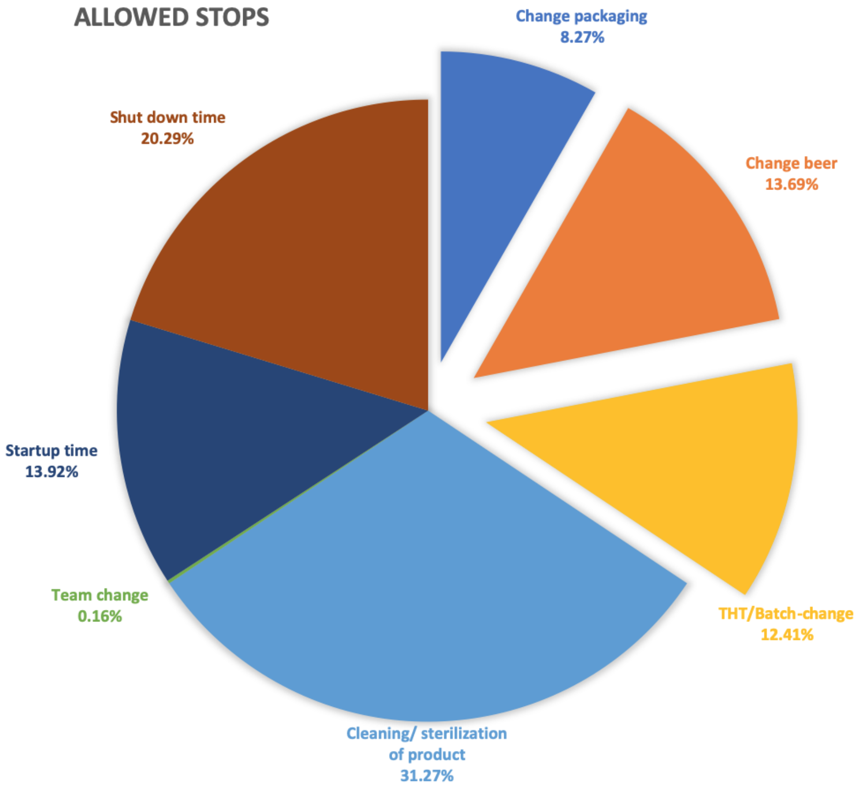

Figure 2.1: Allowed stops between July 2018 and June 2019

The three elevated part in the chart are all sub-categories of 'changeovers', which in total accounts for 34.37% of the allowed stops. Improving the changeover time will lead to a reduction in the time spent on allowed stops. Therefore this will lead to an increased factory efficiency, which is what Grolsch aims to achieve. To see whether an improvement in changeover time is possible, the performance concerning these allowed stops is analysed.

We can see in Figure 2.1 that there are three kinds of changeover stops. Changeovers concern different types of beer, packaging or THT/Batch (THT stand for 'tenminste houdbaar tot', Dutch for 'best before').

The central aspect of the beer change is the actual change of beer, but next to this, there is always a CIP (Cleaning in Place) executed to clean the tanks. Within a change of package (or container) the same beer in the same bottle is packed in another fashion, for example, packing radlers in six-packs instead of crates. The THT/Batch code is used in scenarios when there is a need for a small gap on the production line to distinguish between different batches of the same beer. This could be the case for promotional campaigns, where some beers might have various labels, caps or something alike.

2.3 Operational Procedures

In this section, we discuss the current procedures in place at Line 2. We discuss the way teams work during the week, the standard procedures and the capacity strategy.

2.3.1 Shifts

A team of operators operates a bottling line. Every 8 hours the team changes, with the same team working on the same part of the day for a week. The next week, all teams get a new shift, this is the shift that is before their previous shift (i.e. morning-shift changes to night-shift, night to afternoon, and afternoon to morning). So in three weeks, all three shifts have been covered by a team, and the cycle starts over again. A team always works at the same line and is therefore familiar with the workings and procedures of this specific bottling line.

There are seven different roles at the production line where each team member knows what to do. Most team members have one position they are trained for, while some might have the skills to operate on two or more positions. One team member has a free role in assisting where necessary. There are workplaces at the (de-)stacker, bottle washer, filler, labeller, crate checker, packer and the free role. The operator at the (de-)stacker position works near the mechanical arms that handle the pallets of crates going in and out of the bottling line, while the operator at the crate checker position works near the crate washer and bottle inspector.

Figure 2.2 shows an overview of the layout of the bottling line. The positions are located at the corresponding machine.

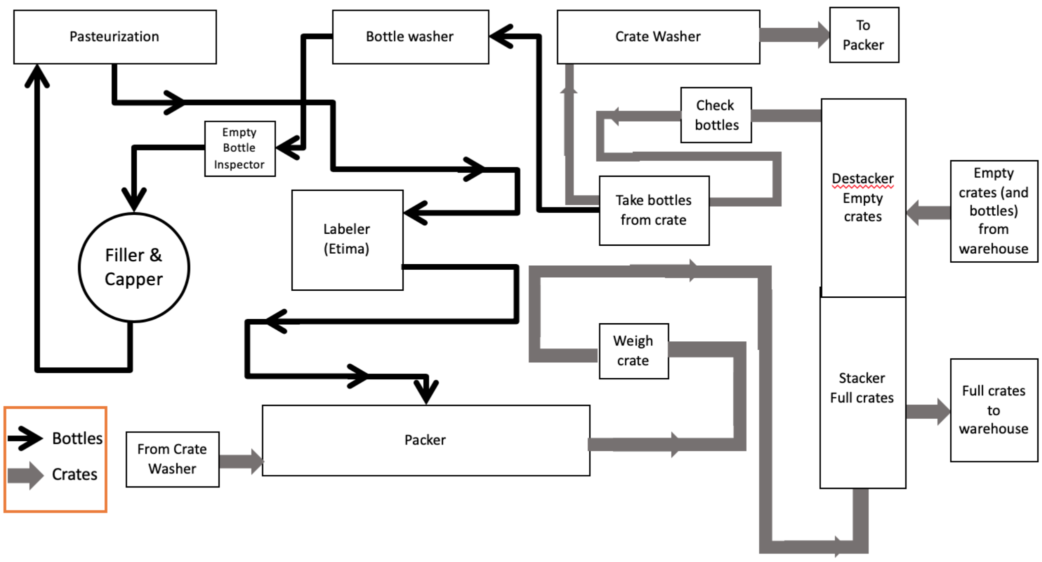

Figure 2.2: Layout of Line 2 at Grolsch

2.3.2 Standard procedures

For Line 2, there are no documented standard procedures. Other lines do have such documents, but as an operator of Line 2 mentioned: "it is all in our heads". This is an interesting situation since multiple shifts are working on the same line every day. In the current situation, this could lead to inconsistent changeovers due to differences in practices. One operator mentioned that he spends the first part of the shift on fixing problems of the previous shift. An effort was made in the past to design such a standardized document, however, this project was never finished due to unforeseen circumstances regarding the leading person within this project (K. Mayar, personal communication, July 9, 2019). The documents created before this were examined, in combination with conversations with operators, to get acquainted with the changeovers as executed at Line 2.

2.3.3 Buffer Strategy

Within the production of Line 2, the capacities of the different machines are based on the so-called buffer strategy. This means that the bottleneck machine (in this case the filler) should be operational as much as possible. The machines just before and after the filler have a higher capacity to ensure the filler does not stop because there is no supply of empty bottles on one hand or a full line in front of the filler on the other. Härte (1997) referenced to the graphical representation of this as the V-graph. An example of a V-graph of a bottling line can be seen in Figure 2.3. It is not possible for other machines to compensate for lost production time on the bottleneck machine; therefore these losses directly result in total production losses.

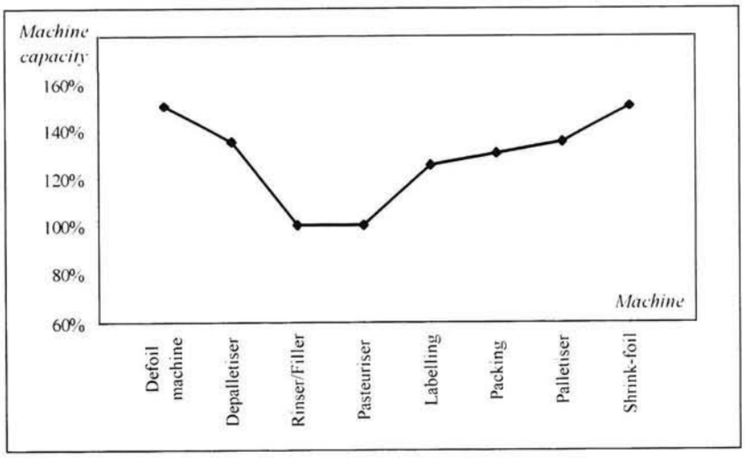

Figure 2.3: A V-graph of a bottling line, from Härte (1997)

2.4 Sustainability

Globally, and within Grolsch, it should be taken into account that sustainability plays an increasingly bigger role in the processes. Therefore one of the main targets for improving the sustainability of the brewery in 2019 is further improving the efficiency of the production lines and optimizing the bottle- and crate washing machines. Currently, numerous sustainability indicators serve as important KPIs. These include total heat produced, total electricity consumed, total water used and the total energy in the process. The KPI performance values are based on the performance in the past and the desired improvements. These four factors are measured and evaluated continuously.

2.5 Operation and Changeover

Between the SKUs produced at Line 2, there are different adjustments required in the bottling line when changing from the production of one to another. A changeover consist out of a combination of changes at the following aspects of the bottling line:

- Filler & Capper
- Crate and bottle input
- Labeler
- Packer

The product combination between which the changeover is conducted determine the presence and duration of the different changeover elements. The changeover time that is taken into account when scheduling production is calculated based on operating standards. These are pre-defined timespans in which particular actions should be completed. The next sections highlight these machines that are points of interest during a changeover.

2.5.1 Filler and capper

Operational This part of the bottling line is responsible for filling the bottles with the right type of beer and closing them with the corresponding crown cap. Bottles enter the filler on a line where a star wheel (Figure 2.4) picks them up and places them in the filling wheel. After one round in this wheel, the bottles are filled and then go through the capper. The bottles now move on to the next step in the process.

Figure 2.4: An example of a star wheel

Changeover There are either one or two steps that have to be completed to convert the filler from one product to the other, depending on the type of bottles used. The execution of a CIP is independent of the type of changeover; the CIP always takes place. However, the duration and type of CIP does vary. When the new beer uses another bottle than the previous, the star wheel has to be replaced with one corresponding with the dimensions of the new bottle. Twice per 24 hours, the filler needs to be cleaned with a gel. Operators try to combine this with a changeover to minimize the time lost on this. Figure 2.5 illustrates this changeover.

2.5.2 Crates and bottles

Operational The different SKUs produced at Line 2 use three kinds of bottles, the Kornuit-bottle, the Grolsch-bottle (internally called the Apollo-bottle) and the BNR-bottle. The first two refer to the corresponding beer that is filled in them, while the latter stands for "Bruine Nederlandse Retourfles", Brown Dutch Return bottle, a standardized bottle for the Dutch beer market.

Five different types of crates transport the beers: crates for Radler, for Grolsch pilsner, for Kornuit pilsner, for De Klok pilsner and a crate for all the other types of beer. Empty bottles are

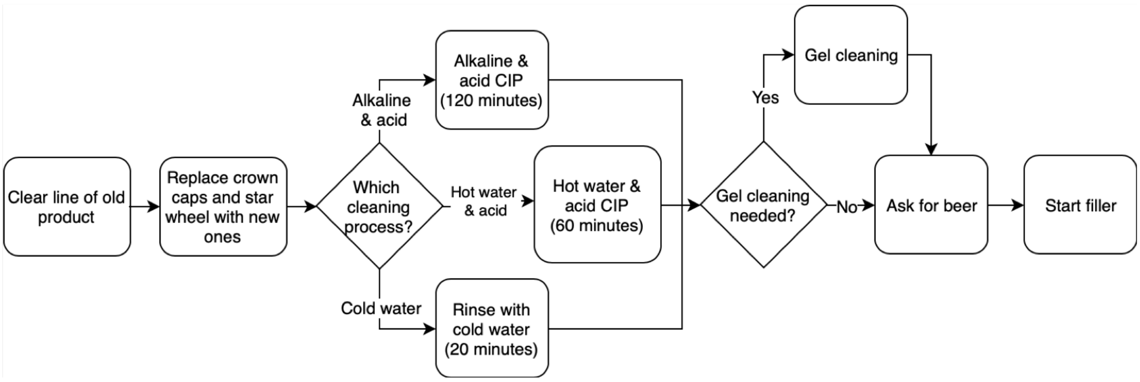

Figure 2.5: The changeover procedure at the filler

taken out of the crate, after which the crate goes through a washing machine, is filled with full bottles and transported back into the warehouse.

The route of the crates is a lot shorter than the route the bottles take, and involves fewer steps. Since the crate process is a lot quicker, the first crates of a new batch arrive at the packer before the first filled bottles. The first empty crates are stacked on pallets and transported to the warehouse. These crates are replaced on the line when the end of a batch is near. At that moment the last bottles will arrive at the packer and need to be put into a crate. This is illustrated in Figure 2.6. In general, there are a factor 20-30 more bottles present on the line compared to the capacity of the crates present on the line at the same moment.

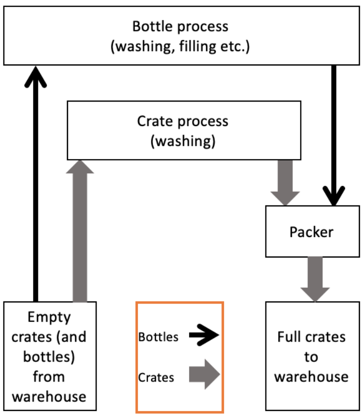

Figure 2.6: Schematic display of the bottle and crate processes

Changeover When a new SKU requires a different type of bottle, and therefore crates, the entire bottling line has to run empty. The reason for this is that the different bottle types come in different crates, and there is only a capacity of about 250 crates from the point where the bottles are taken out to where they are filled with full bottles again. The empty crates that were stacked on pallets should be used before the new bottles and crates are put onto the line. Otherwise, the bottles of the previous batch would end up in the crates of the next batch.

New bottles Since customers do not always return bottles, for example due to breaking, there might not be enough return bottles. In this case, new bottles will be used. These are taken from pallets near the pasteurizer and transported to the bottle washer. Here, these bottles mix with the return bottles. The number of new bottles put into circulation is shown in the confidential Appendix.

2.5.3 Labeling machine (Etima)

Operational This machine glues one or more labels onto the filled bottles. On Grolsch and Kornuit bottles, only one label is placed on the neck of the bottle, while on BNR bottles, three labels are placed; on the neck, front and back of the bottle. Labels are placed using rotating stamps that apply the labels, and brushes that fold the label around the bottle.

Changeover When there is a changeover between a Grolsch and a Kornuit bottle, the changeover entails replacing the old labels with the labels of the new product and adjusting the machine to the size of the new bottle. When there is a changeover to or from the BNR-bottle, there are two additional sets of stamps and brushes that have to be placed or removed to accommodate for the extra labels on this bottle. Parts that are removed during the changeover are cleaned and glue residue is removed by rinsing the parts on the floor using hot water. These parts are then placed on the so-called changeover car and driven to storage. This procedure is illustrated in Figure 2.7.

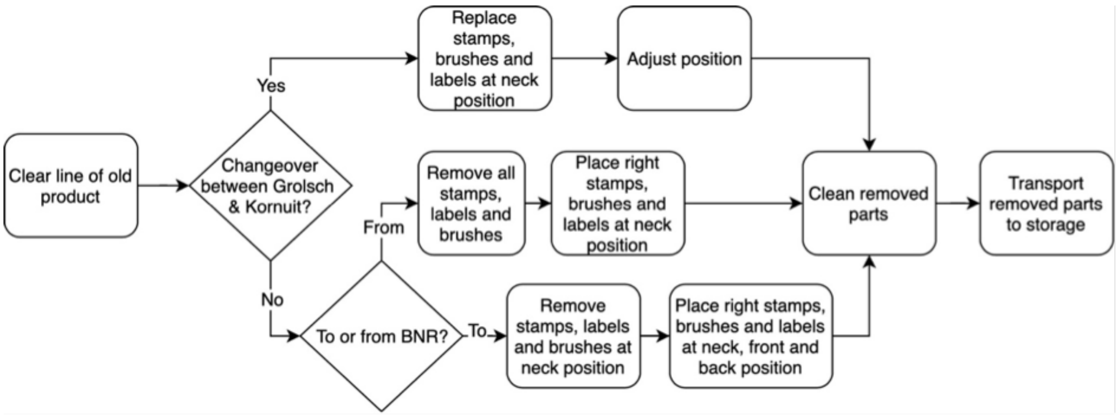

Figure 2.7: Changeover procedure at the labeler

2.5.4 Multi-packer

Operation When all bottles are filled and labelled, the multi-packer ensures that the bottles end up in a crate in the right way. As it name suggests, it can pack the bottles in different configurations. Bottles can either be packed loose in a crate or packed in a carton as a six-pack. These six-packs are also stored in crates in the warehouse. So at the end of the line, bottles are always in crates. There are two parallel paths in the machine; one for six-packs and one for the loose bottles.

Changeover The packer is the last part of the bottling line where the changeover occurs since this can only start when all the bottles of the previous batch are packed in crates. It is not possible to change parts in one path while the other path is running, so the machine has to stand still for the parts to be replaced. When changing the bottle type, the clamps that picks up the bottles from the line need to be changed. If the new product is packed in a six-pack configuration, there should be cartons supplied to the machine so that these will fold over and under the six bottles.

2.6 Changeover performance

The vast amount of data that Grolsch collects enables an analysis of the changeover performance. The exact start and end times of changeovers are not present in the data, so these are extracted manually. The start of the changeover is defined as: the first moment the line stops and the classification is changeover related (all stops are classified in the data warehouse). The end is defined as: the moment the last step was finished, and the line started running again (most of the time after the beer arrived at the filler). We use the data from the months April, May and June 2019. Some changeovers that were in the data were left out of the analysis as there were external factors that influenced the changeover (e.g. beer was brewed too late and not yet ready), which made the data unfit for analysis regarding the changeover performance.

We compare the actual time it took to complete the changeover to the time the planning department expected it to take. The planning department uses the operating standards to account for the time the changeover takes. Figure 2.8 depicts the performance of the changeovers over the period from the beginning of April until the beginning of July 2019.

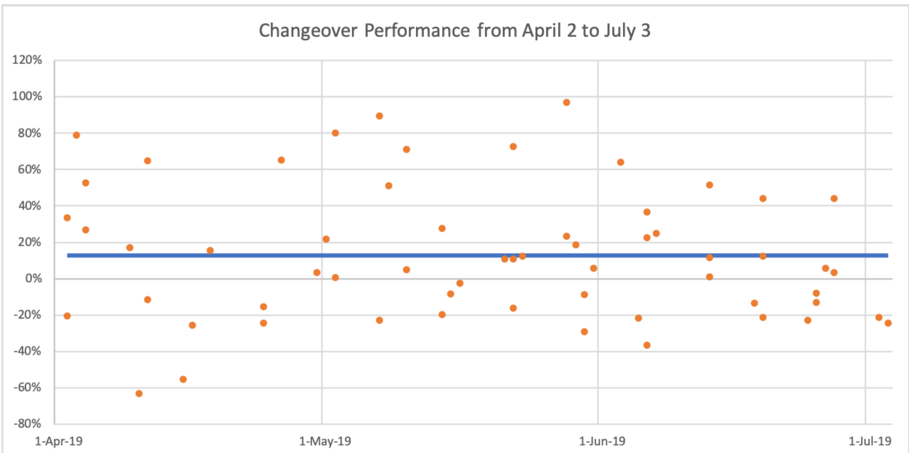

Figure 2.8: Changeover performance over a three-month period, the blue line is the average

On average, the changeovers take 13% more time than expected, this is shown by the blue line in Figure 2.8 In this figure we see that all the changeover performances differ from the expectations, the average of the absolute differences is 29.7%. So the average changeover the average changeover time deviates 29.7% from the expected time, the operating standard.

Operating standards define the expected changeover time, so grouping the performances by the expected time gives an overview of which changeover perform better or worse than expected. Figure 2.9 shows this analysis. During the 3 month period, 25 changeovers of 3 hours or more took place. However, in consultation with the packaging manager at Grolsch, it was determined that this period was rather chaotic regarding the planning and on a yearly base there are about 75 of these changeovers.

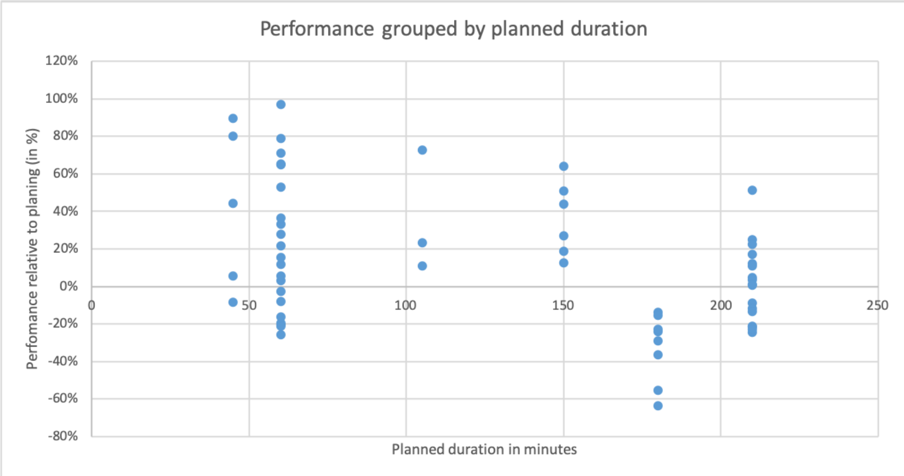

Figure 2.9: Changeover performance compared to planned duration

An interesting observation is that the changeovers with a planned duration of 105 or 150 minutes all take longer than expected, while all changeovers with an expected duration of 180 minutes are executed in less time.

The total changeover time is equal to the longest duration of a sub-step. For example in the case of a changeover that is planned to take 180 minutes, this is due to the fact that the operating standard at the packer for a changeover from 24 bottles loose in a crate to six-pack is 180 minutes.

2.7 Changeover performance per category

Product categories were devised according to the type of bottle, crate and package configuration. These factors influence the changeover procedure and should, therefore, be considered separately. The SKUs in each category are listed in Appendix **??**.

Product categories can be interesting if there is a constant over- or underperformance since operating standards should then be adjusted, or when there is a significant difference between the best and worst performance. In the last case, the changeover is not executed consistently, and there might be room for improvement there. The changeovers were filtered to the categories where a performance difference of at least 25% was visible; a significant impact that was determined together with the supervisors at Grolsch. Figure 2.10 illustrates the difference in changeover performance. The different changeovers are listed as 'from-to', so AKE-ASPe means a changeover from category AKE to category ASPe. Remarkable is the fact that changeovers between the same categories of product often deviate quite a bit from the planning (e.g. ASPe-ASPe, BSPi-BSPi).

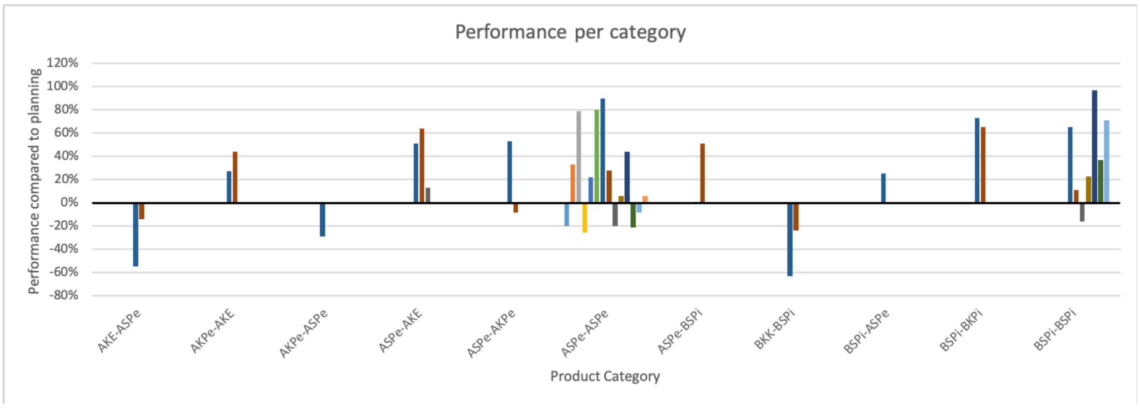

Figure 2.10: Changeover performance per category

Chapter 3

Literature Study

This chapter starts with the literature that is currently available about lean strategies and changeovers. After this, we look at changeover improvement methodologies, and then we link literature about sustainability to changeover improvements. Next, we elaborate on relevant cases, and we conclude with a final overview of our findings.

Contents

3.1 The lean methodology

When talking about process improvements, the term 'lean' inevitably arises. It is a methodology developed by Taiichi Ohno while working at Toyota and described by MIT-researcher Krafcik who coined the term lean (Krafcik, 1988). The complete method was then described in detail by Womack et al. (1990).

The lean methodology focuses on waste reduction in the production chain (Fullerton and Wempe, 2009; Poppendieck, 2011). In this context waste refers to steps that are not required to complete the process and do not add value. An essential aspect of this methodology is that every step in the production process should add value and that responsibilities should be transferred to the people directly involved (Dahlgaard and Dahlgaard-Park, 2006). Specialist tasks that do not add immediate value should be assigned to the production workers, as that eliminates the need for a dedicated specialist that does not add value. By shifting the decision-making and problem-solving processes to the 'people on the floor', these teams are empowered to spot problems when they occur and act accordingly (Bowen and Youngdahl, 1998).

A significant outcome of the implementation of the lean methodology is that it can combine both mass-production practices and specialized, flexible production practices. By using general-purpose machines to create multiple unique products, it enables a wide variety of product output, while still maintaining high production speeds (Bowen and Youngdahl, 1998).

Within the lean methodology, there are seven types of waste classified: overproduction, inventory, waiting, motion, transportation, rework and excess processing (Hines and Rich, 1997; Shingo and Dillon, 1989). Each of these wastes is generated in a different part of the production process. The waste classified as 'waiting' is created, amongst others, by changeovers. When changeovers take place, there is a period in which no production (value-adding) takes place, and workers wait for the changeover to finish (Hicks, 2007). In the next sections, we review the literature regarding changeover improvements.

3.2 Changeover improvement methodologies

When looking for literature on changeover improvements, every article is mainly about Single Minute Exchange of Die (SMED). This lean methodology is widely spread across the world and applied to various industries, and within the search for articles regarding changeover improvement, this was the only method we found. Some studies touch upon the importance of certain changeover aspects, such as the Cleaning In Place procedure (CIP) where operators no longer need to remove all machine parts to clean, but an automated system takes care of this more efficiently and more thoroughly (Memisi et al., 2015).

The most crucial aspect that has to be looked at from a theoretical perspective is the general best practice for a changeover. Of course, every case is unique and even within Grolsch the changeover at Line 2 completely differs from the changeovers at other lines, but there is a lot of theory on improving changeovers. Virtually all the theory about changeovers is about the SMED-methodology (Yash and Nagendra, 2012; McIntosh et al., 2000; Bin Che Ani and Bin Shafei, 2014). Shingo (1985) created this SMED-methodology for improving changeovers and is much quoted in literature and business cases.

The most important part of this SMED-methodology is the separation of internal and external work during the changeover. Internal work can only be executed when the entire process/machine stands still. External processes can be executed when the machine is still running or when it is already running again. The SMED-methodology consists of 4 different stages, illustrated in Figure 3.1. These stages are (Shingo, 1985):

- Stage 0: This is the initial state of the system before any improvement techniques are used.
- Stage 1: In this stage, internal and external activities are separated and only during the internal steps the machine is not operative.
- Stage 2: In this stage, internal activities should be converted to external activities to reduce the amount of time the machine needs to stop production.
- Stage 3: Improving all the activities and processes (internal and external) by simplifying and streamlining them as much as possible.

Next to transforming internal activities to external activities, McIntosh et al. (2000) argue that fundamental design changes within the process can be of equal or more significance. However, in

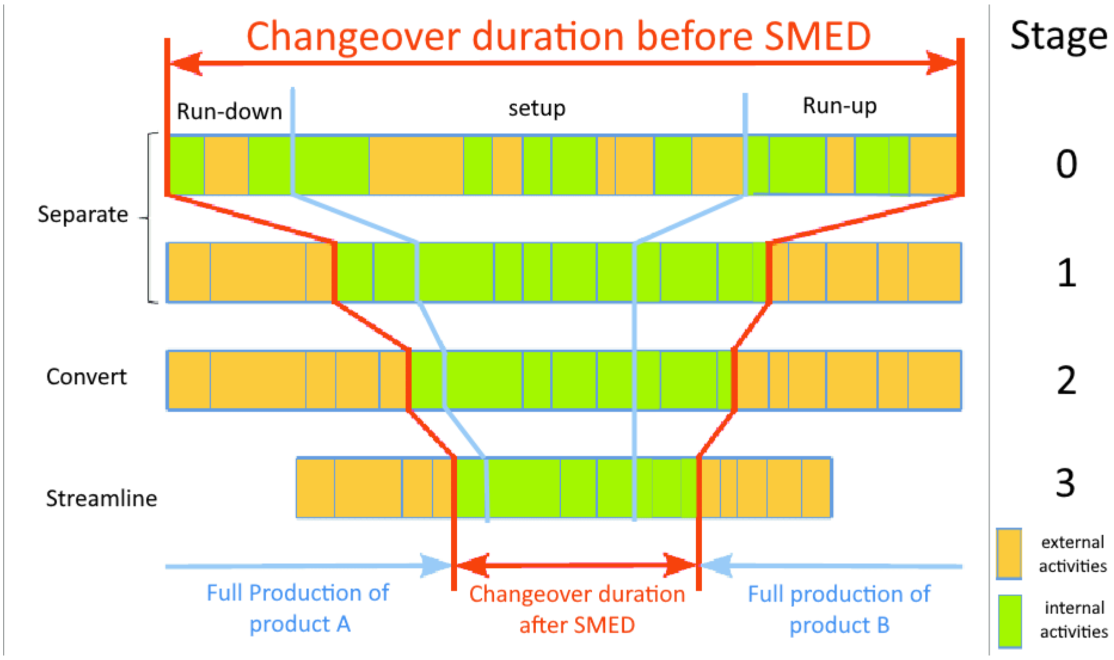

Figure 3.1: An illustration of the implementation of SMED, adapted from Lopes et al. (2015)

this research, fundamentally altering the layout and design of the bottling line is not a realistic option.

Yash and Nagendra (2012) conducted an extensive literature review on the principles of SMED, and the following conclusive points are provided:

- Maximum SMED-effectiveness requires training and awareness throughout the organization, from top to bottom.
- SMED can be applied to any industry
- Visual controls and 5S can help improve the power of SMED (The 5S methodology creates and maintains a well organized, clean, high quality and highly efficient workplace (Michalska and Szewieczek, 2007))
- Lean tools, such as SMED, should be combined with other improvement techniques for maximum efficiency. For example with computer methods and statistical analysis (Trovinger and Bohn, 2005; Alves and Tenera, 2009).
- Implementation of SMED leads, next to mechanical improvements, to procedural and organisational improvements and a reduction of the required human resources.

Constant monitoring and control are also mentioned as essential to good implantation of changeover improvements and are also vital to the sustainability of the improvements (Bin Che Ani and Bin Shafei, 2014).

3.3 Sustainability

Waste reduction, one of the main concepts of lean production (King and Lenox, 2000), intuitively could lead to a more sustainable production. Fliedner (2008) mentions that less time spent on changeover leads to lower energy and resource needs, an improvement in sustainability that can be attributed directly to SMED.

Within the production processes, a lot of steps consume energy even when paused. Some parts of the production line have to be kept at certain temperatures, which consumes energy even when there is no production. Reducing the time between products would lead to a more productive process with less waiting, and therefore a more sustainable production (Fliedner, 2008; Vinodh et al., 2011)

Improving sustainability has become an important part of the business model of present-day companies. Not only due to regulations and customer pressure, as Kaebernick et al. (2003) shows that using lean methods to eliminate waste in the production process enables the growth of business value.

3.4 Relevant cases

Application to the beverage industry seems to be relatively new territory for the SMED methodology. In our search we found some papers on optimizing the performance of a bottling line using simulation tools (Moerman et al., 2006; Sel et al., 2015), however, there was only one article found about the application of SMED to a bottling line (Lopes et al., 2015). In this section, we will first look at what was found to be important within the beverage industry, then we look at case-studies from the food industry that contain useful and applicable information, and we conclude this section by distilling general points of interest out of these (case) studies.

3.4.1 Beverage industry literature

Lopes et al. (2015) define some important factors concerning the changeover processes they analyzed at a beverage producing company.

- Well documented changeover procedure
- Well trained operators
- Standardized procedure
- Coordination during changeovers
- Availability of the correct tools needed during a changeover

Moerman et al. (2006) showed, with a simulation study, that focusing on the changeovers at a bottling line can lead to significant improvements. However, there was no mention of how to achieve this improvement. The factor mentioned by Lopes et al. (2015) can be applied to the bottling lines at Grolsch in this research. This research will expand the body of knowledge since there is not a lot of recent literature on the appliance of SMED to bottling lines.

3.4.2 Food industry literature

In the food processing industry, it was proven that applying SMED could lead to significant improvements (Gálová, 2018). In this case study, the focus point of the study was determined by analysing all stop types and changeovers; from this analysis, it was determined which changeover presented a valuable opportunity to improve.

Some aspects should be taken into account regarding changeovers in this particular sector. It is essential to consider that the cleaning processes are essential in the food industry and can take up to 25% of the time (Fryer et al., 2013). The same importance of cleaning is expected in the beverage industry.

3.4.3 General points of interest

One should also take into account that it is indicated that changeovers present a significant environmental and economic burden for companies in the personal care, food and drink industries (Gungor and Evans, 2018). The reason for this is that a lot of time, and therefore money, is spent on changeovers. The environmental aspects were also outlined in the previous section. Designing a protocol for cleaning and changeovers is semi-empirical, due to the unique nature of every process (Fryer et al., 2013). Therefore it is important to observe changeovers to create advice tailored to the production environment it applies to.

3.5 Concluding overview

When all research is combined, some key points regarding changeover improvements can be deducted. These are summarized in Table 3.1. In this table, the main concepts regarding the implementation requirements, results and important remarks regarding the Single Minute Exchange of Die method and changeover improvement are listed.

An improved changeover	
Implementation requirements	Well documented changeover procedure
	Well trained operators
	Standardized procedure
	Coordination during changeovers
	Availability of the correct tools
	Training and awareness throughout the organization
	Constant monitoring and control of implementation
Results	Mechanical, procedural and organizational improvements and a reduction in the required manpower
	Lower energy and resource needs
Remarks	SMED can be applied to any industry
	Visual controls and 5S can help improve the power of SMED
	Lean tools, such as SMED, should be combined with other lean tool for maximum efficiency

Table 3.1: Summary of literature findings

Chapter 4

Results

This chapter analyses the changeover process and possible improvements. First, we identify the most interesting observations made, after which we identify and separate the internal and external activities. Next, we identify internal activities that can be converted into external activities. Then we look at possible streamlining options for Line 2. This chapter end with a conclusion regarding the presented results.

Contents

4.1 Changeover observations

Observation of three distinct changeovers enables diverse data gathering over different teams. The most useful changeovers to observe are the changeovers where all elements of the production line need adjusting. In this case all separate changeover elements are present and can be studied. The observation sheets are added as confidential Appendices.

Within these changeovers, there were interesting observations made, the following key points that influence changeover performance were identified.

4.1.1 Multipacker already adjusted

Within the changeovers, the multipacker usually takes a long time to change from the loose configuration to a six-pack configuration, while the other way around does not take that much time. To shorten changeover time, preparations for the next changeover are already executed when this changeover goes from six-pack to loose. This way, the next changeover takes less time. This is a best practice currently applied during some changeovers, this method should be used whenever there is the possibility.

4.1.2 Communication not optimal

During the observations, it happened on multiple occasions that actions could have been performed earlier, but the operator was unaware of the actions and progress of other operators. For example in the changeover of 17 July, the operator at the filler waited with requesting the beer because he thought the bottles would still take some time to leave the bottle washer, however, these were in the washer for quite some time already. The request could have been made twenty minutes earlier, in this case the filler was not working during this time. During the changeover of 6 August, the crates that were supplied from the warehouse were standing there untouched for twenty minutes because the inexperienced operator did not know he could put them on the line already.

4.1.3 Waiting for bottles at the filler

In the V-shape production setup (see Subsection 2.3.3), the bottleneck machine must be producing most of the time. At Grolsch, the bottleneck machine is the filler and this machine should be stopped as little as possible. During the CIP and the request for beer the filler has to stand still as it cannot produce while these tasks are performed. However, after these actions are performed, the filler was idle during both of the observed changeovers (40 minutes & 2 hours and 43 minutes). The only reason the filler is not working during this time is the fact that there is no input of empty bottles.

4.1.4 Sustainability

On the part of sustainability, there are some improvements visible. Machines that keep on running even if there is no need for it for quite a while. For example, the mechanical arm that takes bottles out of the crates when they enter the line was performing this operation on empty crates for about 2.5 hours. This served no purpose and added no value to the production line. On these occasions, this machine could have been set to not moving.

4.1.5 Etima

The duration of the changeover at the Etima (label machine) was quite long during both the observations. There are quite some improvements possible on this part. However, during the observed changeovers, the changeover at the Etima never was the bottleneck for the entire changeover, as other parts took longer than the changeover at the Etima. When other solutions are implemented to reduce changeover time, there is time to win at the Etima as well. The calibration test did slow down the production process, as this was done while there were bottles waiting in front of the machine. Nevertheless, an operator mentioned (in an interview) that this calibration could only partially take place before that. This because the glue distribution can only be confirmed when there are quite some bottles that have passed the Etima. This led to a start-up speed of about half the average production speed.

4.2 Separating activities

During the observations, the activities were classified as internal or external, this was done in the observation sheets. One of the main principles of SMED is the identification of the type of activities. The internal and external activities should be separated to enable efficient changeover. The main external activities that were observed were:

- Retrieve new labels and place them near Etima
- Retrieve changeover cart for the Etima
- Retrieve new star wheels and place them near the filler
- Bringing new crown caps to the line with a forklift

These were not always performed before the changeover started. For example, during the changeover of August 6, the changeover cart for the Etima was fetched when the Etima was already stopped. This way, the external activity was executed between internal activities. By separating these activities, and performing the external activities while the line is still running, less time is wasted during the actual changeover.

4.3 Converting internal activities

Applying SMED and improving changeover performance includes the conversion of internal activities to external activities. During the changeover observations, it was indicated which activities classify as internal. These activities have been analyzed based on their potential to be converted from internal to external activities. The activities that might be converted are listed in Table 4.1 on the next page.

As can be seen in this table, these conversions focus on the Etima. During the observations, there were multiple possible improvements for this machine observed. At the filler most processes are automated, and at the packer the changeover was done beforehand. Improving the changeover at the Etima would improve the changeover performance of the line in general. However, it should be noted that the Etima is not always the major bottleneck and therefore other improvements should be explored as well. This is done in the next section.

4.4 Streamline activities

When internal activities are converted to external, the most time in a changeover is gained by streamlining the current process. Within the changeover observations, and after talking to multiple operators at the line, one major issue arose regarding the general changeover procedure: the flow of empty bottles to the filler. Most of the time the filler is ready after the CIP and beer request and has to wait for the new bottles to arrive at the filler. Important to note is that this is the case during the longest changeover, where the complete configuration of the new product is different than the previous product. The supply of bottles to the filler is a main point of interest with room for improvement.

Activity	Convertible?	Details
Storing Etima stickers for later use	Yes	At this moment, the stickers are stored while the changeover is in progress. The stickers are counted and the inventory levels are updated. This could be done after the changeover is finished. In that case the labels only have to be put away for later use during the changeover.
Cleaning Etima parts	Yes	During the observations parts that were taken of the machine were cleaned before the new labels were put into place. By postponing the cleaning tasks, it is possible to first prepare the machine for the next batch.
Getting the right tools and necessities	Yes	Multiple times during the changeover, operators go and get some tools that they could have taken earlier. For instance the changeover carts, crown cap crate and new labels.
Testing the label calibration at the Etima	Partially	Monitoring the placement of the newly inserted labels takes place when the new batch of bottles has already reached the Etima. Using different methods to test this would enable the calibration to be done before the bottles arrive at the Etima. However, whether the glue dispenser is working properly can only be tested when the line is running.
Cleaning the inside of the EBI, filler and Etima	No	Cleaning of these machines (removing caps, glue or broken glass) can only be done while there is no production. This is due to safety constraints and accessibility.
Replacing machine parts at the filler and Etima	No	The parts that are replaced during a changeover are in use while the production is running. It is not possible to replace these without stopping the machine.

Table 4.1: Convertible internal activities

4.4.1 New bottle usage

As can be seen in Figure 4.1, the filler has to wait a considerable amount of time after the CIP and the request for beer are completed. As soon these processes are completed it can start to fill bottles again, however, there are no empty bottles at this machine yet. Since the filler is the machine at the lowest point in the capacity graph of the bottling line, this machine should experience minimal downtime. These gaps between CIP and filling only occur during certain changeovers, in these cases the changeover time would significantly decrease when the filler is active sooner after the CIP. The gap in time between the CIP and the request for beer is a period in which no production takes place and no value is added.

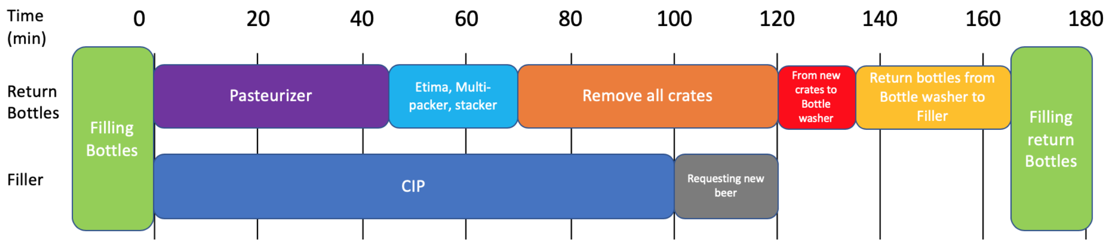

Figure 4.1: Illustration of the changeover process during a changeover with an acid & alkaline CIP (observed August 15)

To decrease changeover time in these situations, new bottles could be used specifically during these changeovers. If there would be bottles at the filler when the filler completes the CIP, in this case there would be a 45-minute increase in production time. This would require 45 minutes worth of bottles. In this new situation the filler is not standing still while waiting for the arrival of the return bottles. This is illustrated in Figure 4.2

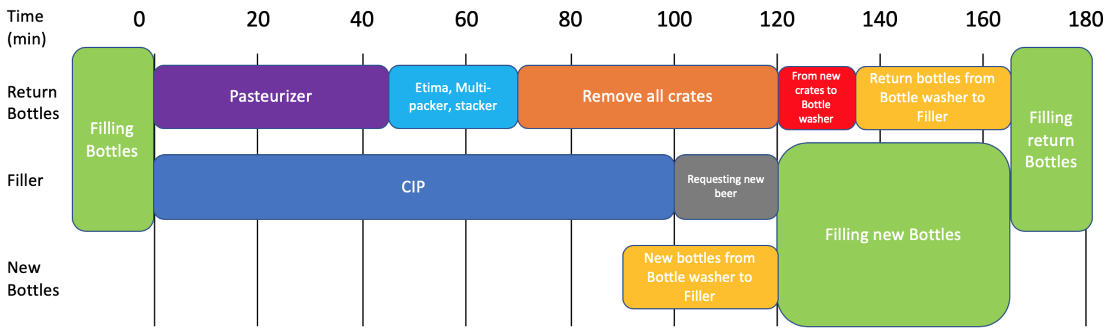

Figure 4.2: Illustration of the same changeover process when using the 'new-bottle'-strategy

4.5 Conclusions

As observed, there are some flaws in the changeover procedures. Observations identified room for improvement at the Etima and the filler, while there was also a possible improvement on the topic of sustainability. We also identified best practices regarding the multipacker that was already changed over to the next product during multiple observations. Table 4.1 lists the activities during a changeover and whether they are suitable to be converted. We concluded with a new policy regarding the use of new bottles in the process that could lead to a great reduction in changeover time. In the next chapter these results will be converted into recommendations to Grolsch.

Chapter 5

Recommendations

In this chapter the results from the previous chapters will be converted into recommendations for the company Grolsch on how to improve the factory efficiency. These recommendations are made on the topics of converting activities, a new bottle policy and the topic of sustainability.

Contents

5.1 External activities

As mentioned in Section 4.3, there are some internal activities that can be converted to external activities during the changeover. The following activities are currently executed as internal activities, while transforming them into external activities will, ultimately, lead to an improved changeover efficiency.

5.1.1 Preparing for the changeover at the Etima

Action Since it was observed that preparing for the changeover is not always done correctly, operators should be reminded of the fact that they need to prepare the changeover in advance. Even though the use of changeover carts was implemented in production routines, during the observed changeovers there were moment the operators went to get these while the machine was not running anymore. This is an example of the importance of sustaining changeover improvements. The new labels should also be near the Etima before the changeover starts, as this is also not always the case.

Expected benefit Each action that is executed before the changeover saves time. So therefore, converting internal activities to external improves the changeover at the Etima. The savings are shown in Table 5.1. These savings are based on both conversations with operators and observations.

Item to retrieve before changeover	Time saved in minutes
Etima Changeover cart	4 minutes
New labels	2 minutes

Table 5.1: Expected improvement

5.1.2 Storing the Etima labels

Action At this moment, the Etima labels that remain after a production batch, are stored during the changeover. These labels are counted and wrapped before they are placed in the box. By putting these labels aside and doing the counting and storing after the changeover is complete, the changeover can be executed quicker.

Expected Benefit The time that is currently spent on storing the labels differs per changeover, as it is dependent on the number of remaining labels. However, each changeover approximately 3 to 5 minutes are spent on the counting and storing of the labels. Taking this out of the changeover process, thus speeds up the changeover.

5.1.3 Cleaning Etima parts

Action Cleaning the parts of the Etima that are covered in glue, before they are put away on the changeover cart should be done after the entire Etima changeover is finished. This is not yet done consistently and therefore time is lost during this cleaning.

Expected Benefit For this improvement it is harder to define an exact number of minutes that would be the result of this. The reason for this is that the cleaning is only partially done during the changeover now. It is hard to pinpoint an exact improvement, however, there are definitely some minutes to gain.

5.1.4 Calibrating the Etima

Action By using test bottles to check the label alignment after the replacement of different Etima parts, this can be done before all the bottles arrive at the Etima. These test bottles can either be dummy-bottles or real bottles that are taken out of the production process.

Expected Benefit This improvement converts the time that is normally used to test the calibration from internal to external. This testing can take up to 5 minutes. Now the operator can immediately start the production at the Etima at a 'warm-up speed' to the the glue distribution.

5.2 New bottle policy

Action The policy on new bottle usage should also be considered for optimal changeover improvement. Using new bottles during a changeover eliminates the time that the filler is waiting for bottles. During these changeovers new bottles should be used in such a fashion that they will bridge the gap between when the filler is ready and when the first return bottles arrive.

Expected Benefit The potential time savings of this policy differ per changeover, since this is dependent on multiple factors that differ in time per changeover. The most significant savings can be achieved in changeover towards the Apollo-bottle, the reason for this is that the number of new Apollo-bottles used per month at Line 2 is a lot higher than the number of new Kornuit and BNR-bottles. Therefore, the changeovers to Apollo bottles can make use of this strategy more. However, we can design a formula that applies to all changeovers. Regardless of what changeover we consider, there are 3 elements that always take place: Cleaning the filler, the CIP and requesting the beer. Gelling the filler only happens during a part of the changeovers. When we consider these elements we have the minimal required changeover time. Subtracting this from the total changeover time (operating standard) gives the potential saving that can be achieved.

$$Saving = Operating\,Standard - Filler\,cleaning\,time - CIP\,time - Request\,beer - Potential\,gelling$$

During the observed changeovers this could have saved a significant amount of time, shown in Table 5.2. During the changeover at August 6, there would have been an improvement, however, it is not possible to determine the extent of this improvement due to some malfunctions that occurred during this changeover. During the 3 months that were observed, 25 changeovers of 3 hours or more took place, these months were considered chaotic in terms of planning. Therefore, the total per year is expected to be below this average. This new policy would save about 40 minutes per changeover.

Observed Changeover	Potential time saving
July 17	35 minutes
August 6	Not possible to determine due to breakdown
August 15	45 minutes

Table 5.2: Potential savings using the 'new-bottle' strategy

5.3 Sustainability

On the topic of sustainability there is also an improvement possible, this especially on the topic of saving electricity. It was observed that during the phase in which empty crates are put on the line (explained in Subsection 2.5.2), the machine that removes bottles from the crates was still operational and working. This mechanical arm was still making the movement associated with removing the bottles from the crate, while the crates were empty. This movement is unnecessary during this phase. It is advised to look into the possibility of preventing this machine to work during this phase.

Chapter 6

Conclusion and Discussion

In this chapter the main points of this research are summarized, this will be done in Section 6.1. There is also room to discuss the issues that were encountered during the research as well as potential improvements that could have been made to the method. These are covered in Section 6.2. The last section identifies interesting topics for further research.

Contents

6.1 Conclusion

We started this research by defining the core problem of the current situation at Grolsch. Initially, we found that the performance of Line 2 was below what was believed to be possible. The performance in this case refers to the so-called factory efficiency, the ratio of productive time to the total time that is paid for. During the core problem identification we found that sub-optimal changeovers affected the performance significantly. The improvement of these changeovers was, therefore, determined to be the focus of this research.

The analysis of the current situation in Chapter 2 mapped the operational and changeover activities currently in place at Line 2. To obtain a scientific basis for our improvement, literature regarding the process of changeovers was collected in Chapter 3. Results of the observation, SMED and the research were presented in Chapter 4 and the proposed improvements were listed in Chapter 5.

The improvements given in Chapter 5 can be divided in three categories. Advice is given on the following topics:

- Possible conversions from internal to external
- New bottle policy
- Sustainability

Implementing these changes within the production process at Grolsch will lead to quicker changeovers and therefore increased efficiency of Bottling Line 2.

Regarding the conversion of activities from internal to external the most important aspects were during the preparation of the changeover, when operators should make sure that they have the changeover cart and the labels ready for the upcoming changeover.

Another activity that can be executed as external activity is the cleaning of the Etima parts. The glue residues are now cleaned while the changeover is in progress, however, this is also possible to do when the rest of the changeover is finished.

We also discussed a new policy regarding the use of new bottles. This new policy, if implemented correctly, has significant potential regarding the efficiency of the changeovers and the bottling line in general. Instead of just using these bottles at 'random' moments, it would save a vast amount of time if these bottles were used at specific moments during the changeovers. The new bottles should be used to bridge the time between the moment the filler is ready and the arrival of the first return bottles at the filler. The potential savings of this method are given by the following formula:

$$Saving = Operating\,Standard - Filler\,cleaning\,time - CIP\,time - Request\,beer - Potential\,gelling$$

In the observed changeovers, this policy would have led to over 30 minutes of extra production time.

The sustainability aspect of the bottling line during the changeover was also observed and one major issue and potential improvement stood out. One very large machine, a mechanical arm, is operating while this is not necessary for a significant part of the changeover. This leads to unnecessary use of electricity. Turning this machine off or putting it on standby would be an improvement to the sustainability of the production line and would contribute to the sustainability goals that are set for the entire production process of Grolsch.

6.2 Discussion

In this section, we discuss factors that might have influenced the results and what could have been done differently.

6.2.1 Observations

The importance of observations in this research was significant. In this research, 3 changeovers have been observed and logged. In a more extensive research, it would be wise to observe more changeovers to account for the fact that different teams might execute various changeovers in a slightly different fashion. However, in the course of this research there were quite some production issues that resulted in Line 2 standing still for a significant portion of this research (more than a week in the middle of this research).

During these observations there might have been small details that have been overlooked that could have been interesting and important to the research. It is also important to note that as with all observations, the importance of actions is in the eye of the beholder. In an ideal scenario every activity, no matter how small, of an operator would be logged. However, in this research there were not enough means and time to observe in this fashion.

6.2.2 Changeover duration from data

In the data collection, the changeover times were not directly present in the data. Assumption were made (based on advice of Grolsch employees) which stop-classifications were assigned with the beginning of the changeover and which one signalled the end of the changeover. If there would be a more extensive research focused on changeovers at Grolsch, one could create a system were operators indicate the start and end of a changeover.

6.2.3 Type of Changeover

In this research the observations focused on the largest changeovers in which all elements that could occur during a changeover were present. However, one part of the changeover might not represent a bottleneck during a changeover that takes this long, while being a major bottleneck in a short changeover.

During the research there were some factors outside the scope that were noticed and that might have positive influence on the performance of the packaging lines at the Grolsch brewery.

6.3 Further Research

This research also identifies possible directions for future research within Grolsch. The main points that would benefit from extra research are listed and explained below.

6.3.1 Re-evaluate Operating standards

It would be wise to re-evaluate the operating standards that are currently used in the production planning. Currently there are some changeovers that constantly over- or underperform in regard to the expected changeover time. Re-evaluating these standards would lead to more realistic planning and therefore a more optimal use of the available resources.

6.3.2 Setting machines to stand-by

It was observed that some machines do no always add value or sometimes perform unnecessary activities during the production time. Looking into the possibilities to set these machines on a stand-by mode or turning them off altogether might be an interesting approach to save energy and therefore money.

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