Optimisation of Planned Downtime Events

A study of the product to product changeover process at the Coca-Cola manufacturing plant in Jordbro

Nils Sjöqvist
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by

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Abstract

This thesis evaluates the product to product changeover process of the line S10 at the Coca-Cola European Partners manufacturing plant in Jordbro, Sweden. The target has been to propose improvements to reduce the total planned downtime by 10%. The total planned downtime in March of 2019 was 4449 minutes.

Secondary data has been used to identify the current situation. A study visit took place at the Coca-Cola European partners manufacturing facility in Dongen, the Netherlands, to serve as inspiration. Single Minute Exchange of Dye (SMED) methodology was applied to improve the most frequent planned downtime event (PDT event), which was performed 22 times during March of 2019 at an average of 72.8 minutes. The theoretical improvement for PDT event CIP programme 1, by applying SMED methodology, is estimated to roughly 16 minutes. This theoretically saves 8% of the total planned downtime for March of 2019.

The same solutions from the SMED methodology could be applied to other PDT events, which would increase the number of events from 22 to 27. This would theoretical save 9.6% of planned downtime for March of 2019.
# Sammanfattning


Sammalösningsförslag från SMED metodologisknäskunna tillämpas på andra omställningsprocesser, vilket skulle öka antal processer från 22 till 27. Teoretiskt sätt skulle detta reducera den totala ställtiden för mars 2019 med 9,6%.
Acknowledgements

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I would like to thank Ann-Sofie Slots for showing me the manufacturing facility in Dongen, the Netherlands during my study visit and for providing me with their data.

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## Abbreviations

<table>
<thead>
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<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>CCEP</td>
<td>Coca-Cola European Partners</td>
</tr>
<tr>
<td>CIP</td>
<td>Cleaning in Place</td>
</tr>
<tr>
<td>CP</td>
<td>Crew Performance (equivalent to OEE)</td>
</tr>
<tr>
<td>E60</td>
<td>CP of the first sixty minutes after a PDT event</td>
</tr>
<tr>
<td>OEE</td>
<td>Overall Equipment Effectiveness</td>
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<td>PDT</td>
<td>Planned Downtime</td>
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<td>RFT</td>
<td>Right First Time</td>
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<td>SMED</td>
<td>Single Minute Exchange of Dye</td>
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1 Introduction

This chapter presents the scope and background for the thesis.

1.1 Background

The Coca-Cola European partners manufacturing plant at Jordbro has six production lines. One of these is line S10 which produces PET bottles in the sizes 1/1,5/1,75 and 2 litres. The line produces a variety of products, such as Coca-Cola, Fanta, Sprite and more. This results in many changeover events, which are called Planned Downtime Events (PDT events) or product to product changeover events. The line is manned around the clock every day of the week, which means that a shortened duration of necessary PDT events would result in gained productive manufacturing time.

1.2 Purpose

The purpose of this thesis is to contribute to the optimisation of the product to product changeover efficiency.

1.3 Goals

The goal of this thesis is to propose changes in the product to product changeover process of the line S10, so that the total PDT event duration is optimised by 10%.

1.4 Methods

In order to identify the current situation, secondary data was used. Control charts are used to interpret datasets on product to product changeovers. OEE was used to evaluate line performance. “7+1 wastes” was used to categorise waste activities.

To methodically propose changes in the product to product changeover process, SMED methodology was used. Furthermore, a study visit was performed at the production site at Dongen in the Netherlands to serve as inspiration for solutions that could be applied in Jordbro, Sweden.

1.5 Delimitations

This thesis only has to study the changeover events at line S10 at the Jordbro manufacturing plant. Suggested changes in the process of PDT events do not need to be implemented. Only the PDT event process of the critical machine will be studied.
2 Theoretical Framework

Several concepts are described in this chapter in order to understand the scope of this thesis. The described concepts provide a basis for methodical problem solving later on in the thesis.

2.1 Overall Equipment Effectiveness

Overall Equipment Effectiveness (OEE) measures the percentage of manufacturing time that can be counted as productive. OEE consists of three components which are availability, performance and quality (Bellgran and Säfsten, 2005). Availability is determined by the ratio between planned uptime and actual uptime. Performance is calculated as ideal cycle time multiplied by the total count of produced products which is then divided by actual run time. Quality takes into account the products that do not meet quality standards. Which is presented as the total percentage of products that did meet quality standards. OEE is then calculated by multiplying the ratios of availability, performance and quality. OEE, as well as each of the three components, can never be greater than 100%. The formula is as follows:

\[
\text{Availability} = \frac{\text{Planned Production Time} - \text{Stop time}}{\text{Planned Production Time}} = \frac{\text{Run Time}}{\text{Planned Production Time}}
\]

\[
\text{Performance} = \frac{\text{Ideal Cycle Time} \times \text{Total Count}}{\text{Run Time}}
\]

\[
\text{Quality} = \frac{\text{Good Count}}{\text{Total Count}}
\]

\[
\text{OEE} = \text{Availability} \times \text{Performance} \times \text{Quality}
\]

2.2 Cleaning in Place

Cleaning in Place (CIP) is an automatically performed method of cleaning, without dismantling or opening the system (Moerman et al., 2014). It is necessary for the food industry to frequently clean the plant equipment that comes into direct contact with food to get rid of residues. CIP is a necessity for the processing and bottling equipment at Jordbro to ensure product quality and hygiene. As it is not a viable option to disassemble all pipes, tubes and containers that the fluids move through for every product to product changeover. CIP gets rid of all remaining beverage inside the plant equipment to ensure that taste, quality and hygiene do not get affected. The line S10 uses three different types of CIP. The type of CIP that will be performed is dependent on the products that are produced before and after the CIP. The three CIP processes are:

- Cold rinse, which is the shortest in duration of the three. It is however not classed as a CIP.
- Hot CIP, which is a three-step process of cold, hot and cold rinsing.
- Caustic CIP, which is the longest in duration of the three CIP processes. It is a five-step process of cold, hot, cold, caustic and cold rinsing.
2.3 Lean Philosophy

Bergman and Klefsjö (2012) argue that the fundamental idea of Lean is to avoid all forms of waste and that the focus is on creating value for the customer. Everything and anything that does not create value for the customer must therefore be regarded as waste. Another keystone of the Lean philosophy is that one must strive for continuous improvement (Kaizen in Japanese), as no process can ever be declared perfect (Bicheno and Holweg, 2009). There is always room for some improvement, opportunities to cut down on waste.

2.3.1 7+1 Wastes

In order to know what waste (muda in Japanese) to cut down upon, it is important to define waste. Traditionally there were seven types of waste described by Shingo (1992) and the eighth one got added later (Bergman and Klefsjö, 2012). The wastes are described as follows:

- **Overproduction** refers to making too many products, making them too early or making them too fast.
- **Waiting** is described as products or employees waiting for the previous or next step to be finished.
- **Unnecessary transportations** of products and materials are counted as waste. While products are transported no value is added to them for the customer.
- **Extra processing** can be defined as unnecessary processes that should be eliminated or processes that can, and should, be optimised.
- **Excess inventory** are products that are waiting and therefore value is not being added. Inventory size should be managed to meet fluctuations in demand.
- **Unnecessary movements** do not add value and extend the lead time. Every unnecessary movement should be eliminated.
- **Defects** require the product to be reworked or discarded. A unit that produces defects needs quality control which also implies wasted resources.
- **Non-utilized talent** of employees is a waste of potential. Employees should actively be engaged in the process of continuous improvement.

2.3.2 Standardisation

Standardisation aims to create processes and procedures that are repeatable, reliable and capable (Bicheno and Holweg, 2009). Existing tasks could essentially remain the same but become simpler to conduct (McIntosh et al., 2001). Standardisation can also be related to the product itself, standard product features can sometimes be used to enhance changeover performance (McIntosh et al., 2001). There are three key aspects of standard work (Bicheno and Holweg, 2009):

- Standard work is not static.
- Standard work supports stability and reduces variation.
- Standard work is essential for continuous improvement.

Where possible, working procedures and equipment could be standardised in order to create repeatable, reliable and capable manufacturing. The notion that standard work is not static goes hand in hand with the idea of Kaizen (a process of continuous improvement). Standards are temporary best practice ways of conducting a task, that workers can refine (Clarke, 2005).
2.3.3 Single Minute Exchange of Die

Single Minute Exchange of Die (SMED) is a changeover time reduction method. SMED aims to reduce waste in the production system and to standardise changeover times (Lozano et al., 2017). A changeover occurs when a manufacturing unit or line changes production from one product to another. Changeover activity are all the activities and tasks that must occur for a changeover to be successfully completed (McIntosh et al., 2001). Changeover time is the time between the last good piece of one product until the first good piece of the next product (Karam et al., 2018). Another view according to Bicheno and Holweg (2009) on changeover is that a changeover also includes rundown and ramp-up times, which will affect the line performance. The classic SMED Shingo methodology is as follows (Bicheno and Holweg, 2009):

1. Identify and classify internal and external activities.
2. Separate internal activities from external activities. External or preparation activities should be maximised. Cut or reduce waste activities.
3. Aim to convert internal activities to external activities.
4. Optimise the remaining internal activities by engineering.
5. Minimise external activity time.

Internal activities are activities that take place during the changeover process that require the line or station to be at a complete stop, e.g. changing a tool. External activities are activities that can be conducted while the line or station is running, e.g. preparation activities.

2.4 Control Chart

According to Wheeler (1993) raw data must be analysed, interpreted and assimilated before it can be useful. This means that gathering large amounts of data across a manufacturing system can only be useful if the data is analysed, interpreted and assimilated. It is always important to present data graphically (Bergman and Klefsjö, 2012). According to Bergman and Klefsjö (2012) a control chart is used to interpret that variation in a process is stable, to notice when a change has occurred and to determine that the change has resulted in an improvement. The control chart is also recognised as one of the seven quality control tools. Wheeler (1993) argues that every data set contains noise and that a control chart can be used to distinguish signals from noise. A control chart does this by calculating an upper- and/or lower control limit. An example of a control chart is shown in Figure 1. If a point of data has a higher value than the upper control limit (UCL) or a lower value than the lower control limit (LCL), this is a signal: the process is not under control. In addition to control limits, either the median or the average of the data set is calculated and represented as a centreline in the chart. A process is regarded as not under control when:

- A data point is not within the UCL and the LCL.
- Seven consecutive data points are either under or above the centreline.
- Seven consecutive data points are either trending up or trending down.
- Obvious patterns occur that suggest unusual behaviour.

If a process is regarded as not under control, the data point(s) that show an out-of-control behaviour should be investigated.
A widely used variant of control chart is the XmR control chart. An example of an XmR control chart is shown in Figure 2. This variation of control chart consists of two charts. The X chart that represents the collected data set, with UCL_X, LCL_X and a centreline. And the moving range (mR) chart that represents the difference of value of a data point between the previous data point in order to observe relative variation easily. The mR chart only shows an UCL_r because the values are absolute differences.

The formulas that are needed to create an XmR chart using the average and median moving range are as follows:
2.5 Bottleneck & Critical Machine

A bottleneck limits and determines the throughput of a supply chain. This is a result of the fact that the capacity of a bottleneck is lower than the capacity (Jonsson and Mattsson, 2016), before and/or after the bottleneck. It is important to focus capacity improvement efforts on these bottlenecks (Bergman and Klefsjö, 2012).

In order to visualise the capacity of machines or machine groups a *V-curve* can be used, see Figure 3. The machine that has the lowest capacity (Machine 3) is called the critical machine. The machines before and after the critical machine are designed to have a higher capacity, to absorb fluctuations in production.

![Figure 3: V-curve - basic example](image-url)
3 Current Situation

This chapter consists of what the current situation is at the production line s10 regarding machines, Planned Downtime events and the problem areas.

3.1 Production Line S10

The line s10 produces a large variety of PET bottle sizes (1/1.5/1.75 and 2 litres) and many beverage products that have their own bottle colour, bottle cap, bottle design and label. Bottles can be packaged as single bottles on display tray or as multipacks. The produced bottles exit the line stacked on either full-sized EURO pallets or half-sized EURO pallets. A large number of machine groups are required to produce the bottled products. Data is collected in real-time for each of the main groups individually. This data is then visualised in a digital tool called LineView. On the line S10 the main machine groups are:

- **Preform-blower and oven** that heat the PET pre-forms and blow them to size inside a mould.
- **Filling machine** that fills the bottles with beverage and screws on the cap.
- **Labelling machine** that applies labels to the bottles.
- **Display tray machine** that washes the incoming display trays.
- **Variopac** packages several bottles, multipacks, in shrink wrap plastic.
- **A handle machine** applies handles to the shrink-wrapped bottles.
- **MP filler** stacks the multipacks onto pallets.
- **Palletizers** Robot1 and Robot2 stack bottles onto display trays, stack the bottles and trays onto pallets and then they apply plastic film and straps around the pallet.
- **UTM1 and UTM2** are the output machines that sort the pallets to be picked up by the warehouse trucks.
- **Conveyor belts** move the bottled products between machines.

An overview of the line can be found in Appendix 1. The V-curve of these machine groups is visualised in Figure 4. The filling machine is the critical machine on the production line s10.

![Figure 4: Line S10 V-curve](image-url)
3.2 Syrup room

The preparation of all beverages for all lines is performed by one department at the Jordbro production facility, the syrup room. There the concentrate, water and sugar are mixed before sending the beverage to a specific line. The beverage is carbonated in a tank at the line. The preparation department controls the flow of beverage to the filling machine and controls the fluids that are needed for CIP processes. It is the syrup room that keeps track of remaining beverage volumes, sends signals for upcoming product to product changeovers and regulates the CIP process.

3.3 Planned Downtime Events

A PDT event is needed to prepare the line for a different product. This can be a different bottle size, bottle colour, beverage change, bottle cap change and label change or any combination of the mentioned changes. The process of a PDT event is visualised in Figure 5. The moment the process of a changeover event starts is about an hour before the planned start of the PDT event. The filling machine operator orders caps, labels and containers for the next production run. The operator also prepares the fixtures that need to be swapped inside the filling machine. When there are only 20’000 units left to be bottled (A in Figure 5), another series of preparation activities are performed. The cap alarm (B in Figure 5) is initiated by a call from the syrup room when the production is down to a predetermined number of units, depending on the bottle size. The filling machine operators now take the final steps in preparing the machine for the PDT event. When the production stops (C in Figure 5), the line is emptied. The filling machine is prepared for CIP. When the filling machine is ready for CIP, the filling machine operator calls the preparation department to let them know they can start the CIP process. When the CIP process is done, the syrup room calls the filling machine operator. A few units are then bottled of which some are sent to the lab in order to validate that the beverage meets the standard values. When the lab confirms that the values are in order, production can start (D in figure 5). All necessary fixtures, guides and machine programmes are able to be changed on the line during the PDT event (C till D in figure 5). The efficiency of the production after a PDT event is defined by the OEE of the first sixty minutes, this is called E60 (D till E in figure 5). Ideally the E60 value should be close to the total average OEE of a production run, but in it is often lower in reality.

Figure 5: Planned Downtime Event - General Process
Each individual machine group is required to be able to adapt to each specific product variant. The required changes to the machines during a changeover event is dependent upon what products are produced before and after the changeover event. The duration of a PDT event can therefore vary, depending on how many and which changes need to occur. Standard PDT event durations are defined, See Table 1. The PDT event duration is not set by an addition of all the standard durations of each performed PDT category. The planned duration of the PDT event is set by the activity that takes the longest amount of time.

### Table 1: Standard PDT times

<table>
<thead>
<tr>
<th>PDT Category</th>
<th>Target (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shift cleaning</td>
<td>15</td>
</tr>
<tr>
<td>Sign Off</td>
<td>280</td>
</tr>
<tr>
<td>CIP Programme 1, Cold</td>
<td>60</td>
</tr>
<tr>
<td>CIP Programme 1, Cold (Light)</td>
<td>80</td>
</tr>
<tr>
<td>CIP Programme 2, Short Hot</td>
<td>90</td>
</tr>
<tr>
<td>CIP Programme 3, Long Hot</td>
<td>90</td>
</tr>
<tr>
<td>CIP Programme 3, Long Hot (Light)</td>
<td>110</td>
</tr>
<tr>
<td>CIP Programme 4, Caustic</td>
<td>180</td>
</tr>
<tr>
<td>Change of bottle cap</td>
<td>10</td>
</tr>
<tr>
<td>Change of PET bottle pre-form type</td>
<td>30</td>
</tr>
<tr>
<td>Change of bottle size</td>
<td>180</td>
</tr>
</tbody>
</table>

### 3.4 Problem Area – PDT Duration

A problem area is defined in this chapter and its relevance is motivated.

In March of 2019, the line S10 saw a total of 4449 minutes of total planned and external downtime. The data from LineView of March is presented in Figure 6. The most frequent PDT Event is CIP Programme 1, which was performed 22 times during March of 2019. CIP Programme 1 showed a total of 301,7 minutes of over target downtime (PDT duration over 60 minutes per event). This resulted in a negative contribution of 0,88% to the CP value of March, because of CIP Programme 1 over target downtime alone.
In order to determine if the CIP Programme 1 duration is under control, a control chart was made for all 22 CIP Programme 1 PDT event durations of March 2019, see Figure 7. All values are within the control limits. The average duration is 72.8 minutes. Eight concurrent data points (8 till 15) are below the centreline, which would indicate that the process is not under control. The values of the eight datapoints are close to the goal. Six events are below the goal of 60 minutes. The black dots represent events during daytime shifts, which show an average duration of 70.6 minutes. The green dots are weekend shifts and show an average duration of 59.7 minutes. The yellow dots are night-time shifts and show an average of 91.3 minutes. The shortest duration of a single event during March was 52.2 minutes.

If the data points for the night-time shift are excluded from the control chart, the process does seem to be under control, see Figure 8. Since the average of the night-time shift datapoints are substantially higher, the average PDT duration of CIP Programme 1 with these data points excluded is then 67.4 minutes. Also, the control limits are narrower, because the value range of the data points is narrower. The goal is 60 minutes and there are six datapoints below 60 minutes, which indicates that there is a potential to improve this process and bring it closer to the set goal.

3.4.1 Changeover Effectiveness
In order to determine the effectiveness of the changeover process for the 22 datapoints of March 2019, the E60 values need to be evaluated. E60 values are currently not being
monitored, but they can be traced back manually in LineView, see Figure 9. Data points 5 and 7 do not have any E60 values, because there was no production demand after the changeover. The maximum value of E60 is 100% (1,0). The UCL was calculated to 9,5 and the LCL to 0,25. The average value of E60 for this data set is 0,60 and the lowest value is 0,29. Even though the last 5 data points show a downward trend, it is not yet seven consecutive data points. Therefore, the process seems to be under control. The interval of the datapoints is however very large, which indicates a potential for improvement.

![Figure 9: Control Chart, CIP Programme 1 E60 - March 2019](image)

The correlation between E60 and PDT duration can be seen Figure 10. The trendline illustrates a weak positive correlation coefficient of 0,22. This means that PDT duration has a weak positive correlation towards the outcome of E60. A short PDT event might indicate the crew trying to rush the procedures in order to meet the goal of 60 minutes, which may lead to a weak run-up efficiency. The correlation is however too weak to conclude that PDT duration has a large influence on E60, and that other factors might have a larger influence.

![Figure 10: Correlation Between CIP Duration and E60](image)
3.5 Right First Time

The rate of right first time, of the filling process is currently not being focussed upon and data is therefore not collected. Lab tests are performed when the filling machine is ready to produce, the crew is waiting for test results at this point. This process typically takes 12 minutes. Which means that 12 minutes of production time is lost. According to LEAN philosophy, this process could be seen as waste in the form of waiting and extra processing (Chapter 2.3.1). A focus should be on doing things right the first time, so that controlling the process is unnecessary. During the study visit at the manufacturing plant in Dongen, the Netherlands it became clear that their production lines do not wait on lab tests after a PDT event. The possibility for the line s10 at Jordbro to implement right first time is further explored in this chapter.

3.5.1 Calculation of Needed Right First Time

In order for it to be economically justifiable to eliminate lab tests after a PDT event, the RFT rate needs to be above the point of break-even ($RFT_0$). A rough estimation of what that point of break-even is, can be made. During March of 2019 the line had an up-time availability of 87.1% which translates to 648 hours of available production time. The total produced amount was 9,227,612 units. This is 14,240 units/h. This is far below the maximum capacity of the critical machine (36,000 units/h). 14,249 in one hour equals 2848 units in 12 minutes. The company estimates that the material costs (PET, labels, caps, plastic, etc.) for 2848 bottles roughly equals 1400 SEK. The costs for the beverage for these bottles are estimated to roughly equal 6000 SEK. The cost for destruction of bottles is about 1 SEK/unit, which is then 2848 SEK if the bottles cannot be sold. The cost of running a line is roughly 3000 SEK/h, which equals 600 SEK in 12 minutes.

The yield/litre for Q1 of 2019 for was roughly 0.83 EUR/litre (9 SEK/litre) on average for all products across CCEP. There are high margin products and low mar margin products, large PET is a low margin product. The estimation of yield/litre for large PET is 5 SEK/litre. It is then assumed that this translates from 5 SEK/unit to 10 SEK/unit, depending on the size of the bottle.

The point of break-even ($RFT_0$) can then roughly be estimated by the economic loss when the bottles cannot be sold in relation to the economic win when 2848 bottles can be sold.

$$RFT_0 = \frac{\text{Cost when bottles cannot be sold}}{\text{Yield when bottles can be sold}}$$

$$RFT_0 = \frac{600 + 6000 + 1400 + 2848}{5 \times 2848} = \frac{10848}{14240} = 76,2\%$$

This corresponds to that roughly 76% of the production run-ups after a PDT event have to be successful in order for the change to have no economic impact. As can be seen in the formula, the average units produced per hour has a large impact on the point of break-even. It could be that the average produced units/h for March is not representative for the general average. The average for Q1 of 2019 was 14,887 units/h, which means that a slightly lower $RFT_0$ is possible.
3.5.2 Estimate of Current Right First Time

There is no data being collected on the current rate of RFT, but an estimation can be made. The syrup room keeps track of data for every start-up of a production run. Included in this data is CO$_2$ and BRIX values for every start-up. From the 1st of January till the 24th of March of 2019, there were 49 logged start-ups. CO$_2$ and BRIX values have set goals, depending on what beverage is being produced. For CO$_2$ the tolerances are ±0,25 deviation from the goal, and for BRIX this is ±0,15. The deviations can be seen in Figure 11, together with the upper limits (UL) and lower limits (LL) for the tolerances. The graphs show that 3 of 49 logged start-ups values were outside of the tolerances for BRIX and 4 for CO$_2$. Number 24 is outside of the tolerances for both CO$_2$ and BRIX. This means that of the 49 logged start-ups, 6 are outside of the tolerances. This translates to an estimated rate of RFT of about 87,8%.

Figure 11: CO2 and BRIX values - deviation from goal
4 Methodological Implementation and Analysis

This purpose of this chapter is to propose changes that improve the PDT event process, by implementing methodology.

4.1 Single Minute Exchange of Die – PDT Duration

The problem area described in chapter 3.4 is aimed to be improved with the help of SMED methodology. Since the filling machine is the critical machine, it is important that its downtime is minimalised. By decreasing the PDT duration of the filling machine, the availability increases which results in a higher OEE for the whole line. The PDT durations of CIP programme 1, Cold rinse, for March can be found in Figure 7. Relatively short time gains per event result in large time gains over a long period of time, since CIP programme 1 is a frequently performed PDT event. SMED is chosen because Lozano et al. (2017) have shown that SMED is successfully applicable in the food industry.

4.1.1 Identify and Classify all Activities

The first step in SMED methodology is to identify all the activities that are performed (Bicheno and Holweg, 2009). Those activities are then categorised as internal activities, external activities and waste activities. A document describing all PDT event activities for the filling machine is present on the line (see Table 2). Activities 1 through 8 are performed while the filling machine is still running, so they are classified as external activities. Activities 1 through 35 are currently performed as internal activities. However, activity 17 can be performed as an external activity after the filling machine has started producing again at step 35. Activity 17 is therefore categorised as an external activity. Activity 33 can also be performed as an external activity after step 35 because it serves as a quality check of step 22 and 26. The classification is visualised in Figure 12. Waste activities are blue, internal activities green and external activities red.

Figure 12: SMED - Step 1

Activity 32 is to produce approximately 40 bottles by starting filling machine. Activity 34 is to send a few of those bottles to the lab and wait for the bottles to be approved by the test results, this takes about 12 minutes. According to the concept of right first time, these activities should be regarded as unnecessary and therefore as a waste. In chapter 3.5 the estimated RFT of 87.8% shows that it is economically justifiable to not perform activities 32 and 34 as internal activities. This means that activity 32 can be scrapped. Activity 34 can then be performed after the production has started and is therefore classed as an external activity.
### Table 2: PDT Event Instructions Standard - Filling Machine

<table>
<thead>
<tr>
<th>Nr</th>
<th>When to perform</th>
<th>What to perform</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>At least 1 hour before PDT event</td>
<td>Order caps, labels, sorting and preform containers</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Prepare fixtures that need to be swapped</td>
</tr>
<tr>
<td>3</td>
<td>20,000 bottles left</td>
<td>Call to stop the preform feed from RVL</td>
</tr>
<tr>
<td>4</td>
<td>Cap alarm</td>
<td>Tape the cap octabin shut, lift it from the machine and prepare the return duct</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Lift the new capsule octabin on the machine</td>
</tr>
<tr>
<td>6</td>
<td>Preform blower stops the input of bottles</td>
<td>Call to the syrup room to confirm that the beverage tank is empty</td>
</tr>
<tr>
<td>7</td>
<td>Filling machine has slowed down</td>
<td>Put the blowing machine in solo drive</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>Empty the ring container in the filling machine</td>
</tr>
<tr>
<td>9</td>
<td>Last bottle out of the filling machine</td>
<td>Set LineView to PDT</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>Empty the capsule elevator</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>Take 8 bottles from the line for final test (6 without labels and 2 with labels)</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>Turn on CIP cups</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>Change the product filter (Fanta/Cola/Sprite)</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>Change fixtures inside the filling and cap machines</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>Start the CIP programme</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>Empty the preforms from the machines</td>
</tr>
<tr>
<td>17</td>
<td></td>
<td>Perform the final tests</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>Change the product type in Proficy</td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>Set flowliner 1 according to the colour marking</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>Change the conveyor belt programme</td>
</tr>
<tr>
<td>21</td>
<td></td>
<td>Call to initiate preform feed from RVL</td>
</tr>
<tr>
<td>22</td>
<td></td>
<td>Adjust the best before date laser</td>
</tr>
<tr>
<td>23</td>
<td></td>
<td>Set the checkmat values</td>
</tr>
<tr>
<td>24</td>
<td></td>
<td>Adjust conveyor belt and towers</td>
</tr>
<tr>
<td>25</td>
<td>CIP programme finished</td>
<td>Call the syrup room to fill the carbonation tank</td>
</tr>
<tr>
<td>26</td>
<td></td>
<td>Change filling machine programme and change best before date</td>
</tr>
<tr>
<td>27</td>
<td></td>
<td>Empty the cap chute</td>
</tr>
<tr>
<td>28</td>
<td></td>
<td>Open the new cap octabin</td>
</tr>
<tr>
<td>29</td>
<td></td>
<td>Set the pressco programme</td>
</tr>
<tr>
<td>30</td>
<td>Carbonation tank is filled</td>
<td>Check if the blowing machine is adjusted and remove solo drive</td>
</tr>
<tr>
<td>31</td>
<td></td>
<td>Set all machines to &quot;production&quot;</td>
</tr>
<tr>
<td>32</td>
<td></td>
<td>Send approximately 40 bottles through the filling machine</td>
</tr>
<tr>
<td>33</td>
<td></td>
<td>Check if the best before date is correct</td>
</tr>
<tr>
<td>34</td>
<td></td>
<td>Send bottles to the lab and perform start-up tests</td>
</tr>
<tr>
<td>35</td>
<td>Test results are OK</td>
<td>set LineView to &quot;production&quot; and begin producing</td>
</tr>
</tbody>
</table>
4.1.2 Separate Internal Activities from External Activities

The second step in SMED methodology is to separate the internal activities from the external activities, so that internal activities are grouped together (Bicheno and Holweg, 2009). Waste activities are also cut. This step is visualised in Figure 13. In the lower bar, the total internal activities are four activities less. Activities 32 and 33 are estimated to take about 1 minute each. Activity 17 is estimated to take about 2 minutes. Activity 34 takes about 12 minutes. This means that the total internal PDT duration will be shorter by about 16 minutes.

![Figure 13: SMED - Step 2](image)

4.1.3 Convert Internal Activities to External Activities

The third step in SMED methodology is to convert internal activities to external activities (Bicheno and Holweg, 2009). There is currently no internal activity that could be converted to be an external activity.

4.1.4 Optimise the Remaining Internal Activities

The fourth step in SMED methodology is to optimise the remaining internal activities (Bicheno and Holweg, 2009). This often requires engineering solutions (Bergman and Klefsjö, 2012). For example, the filling up of the carbonation currently takes 8 minutes. A solution could be engineered, so that this time would be reduced. The same goes for the other internal activities, they could be engineered to be more effective. Another example of an engineered solution is to put a second carbonation tank in place that could be filled with the new beverage, while the first carbonation tank is not yet depleted. This would save the 8 minutes duration of filling up the carbonation tank. However, it would be complex to put another carbonation tank in place because of the importance that every single tube needs to be cleaned by CIP. It would also be a costly investment, since it would require a carbonation tank, pumps, tubes, electronics and more to operate. If the 8 minutes win of every PDT event is worth the investment, and what the time of return-on-investment is, would need to be calculated. These kinds of highly engineered solutions are not within the scope of this thesis.

4.1.5 Minimise external activity time

The final step in SMED methodology is to make the external activities more effective (Bicheno and Holweg, 2009). For example, testing by the lab and waiting for the results takes roughly 12 minutes. When the test results indicate that the units are not within the values of tolerance, 12 minutes of produced products would need to be scrapped. However, if this time would be less than 12 minutes, the number of produced units would be less. And therefore, also the financial loss. This would make immediately producing bottles, instead of testing in the lab first, more justifiable.

4.1.6 Results

Table 3 is a proposal of how the PDT event instructions document (Table 2) would change if the solutions described in this chapter are implemented. An example of how the PDT event activities of the filling machine could be carried out by two operators is shown in Figure 14. The letters and numbers in this figure correspond with Table 3. The estimation is that the internal PDT event duration is reduced by about 16 minutes.
<table>
<thead>
<tr>
<th>Nr.</th>
<th>Activity to Perform</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td><strong>1 Hour Before PDT Event</strong></td>
</tr>
<tr>
<td>1</td>
<td>Order caps, labels, sorting and preform containers</td>
</tr>
<tr>
<td>2</td>
<td>Prepare fixtures that need to be swapped</td>
</tr>
<tr>
<td>B</td>
<td><strong>20'000 Bottles Left</strong></td>
</tr>
<tr>
<td>3</td>
<td>Call to stop the preform feed from RVL</td>
</tr>
<tr>
<td>4</td>
<td>Tape the cap octabin shut, lift it from the machine and prepare the return duct</td>
</tr>
<tr>
<td>5</td>
<td>Lift the new capsule octabin on the machine</td>
</tr>
<tr>
<td>C</td>
<td><strong>Blower Stops Infeed of Preforms</strong></td>
</tr>
<tr>
<td>6</td>
<td>Call to the syrup room to confirm that the beverage tank is empty</td>
</tr>
<tr>
<td>7</td>
<td>Put the blowing machine in solo drive</td>
</tr>
<tr>
<td>8</td>
<td>Empty the ring container in the filling machine</td>
</tr>
<tr>
<td>D</td>
<td><strong>Last Bottle Out</strong></td>
</tr>
<tr>
<td>9</td>
<td>Set LineView to PDT</td>
</tr>
<tr>
<td>10</td>
<td>Empty the capsule elevator</td>
</tr>
<tr>
<td>11</td>
<td>Take 8 bottles from the line for final test (6 without labels and 2 with labels)</td>
</tr>
<tr>
<td>12</td>
<td>Turn on CIP cups</td>
</tr>
<tr>
<td>13</td>
<td>Change the product filter (Fanta/Cola/Sprite)</td>
</tr>
<tr>
<td>14</td>
<td>Change fixtures inside the filling and cap machines</td>
</tr>
<tr>
<td>15</td>
<td>Start the CIP programme</td>
</tr>
<tr>
<td>16</td>
<td>Empty the preforms from the machines</td>
</tr>
<tr>
<td>17</td>
<td>Change the product type in Proficy</td>
</tr>
<tr>
<td>18</td>
<td>Set flowliner 1 according to the colour marking</td>
</tr>
<tr>
<td>19</td>
<td>Change the conveyor belt programme</td>
</tr>
<tr>
<td>20</td>
<td>Call to initiate preform feed from RVL</td>
</tr>
<tr>
<td>21</td>
<td>Adjust the best before date laser</td>
</tr>
<tr>
<td>22</td>
<td>Set the checkmat values</td>
</tr>
<tr>
<td>23</td>
<td>Adjust conveyor belt and towers</td>
</tr>
<tr>
<td>E</td>
<td><strong>CIP Finished</strong></td>
</tr>
<tr>
<td>24</td>
<td>Call the syrup room to fill the carbonation tank</td>
</tr>
<tr>
<td>25</td>
<td>Change filling machine programme and change best before date</td>
</tr>
<tr>
<td>26</td>
<td>Empty the cap chute</td>
</tr>
<tr>
<td>27</td>
<td>Open the new cap octabin</td>
</tr>
<tr>
<td>28</td>
<td>Set the pressco programme</td>
</tr>
<tr>
<td>F</td>
<td><strong>Carbonation Tank Filled</strong></td>
</tr>
<tr>
<td>29</td>
<td>Check if the blowing machine is adjusted and remove solo drive</td>
</tr>
<tr>
<td>30</td>
<td>Set all machines to &quot;production&quot;</td>
</tr>
<tr>
<td>31</td>
<td>set LineView to &quot;production&quot; and begin producing</td>
</tr>
<tr>
<td>G</td>
<td><strong>First Bottle Out</strong></td>
</tr>
<tr>
<td>32</td>
<td>Check if the best before date is correct</td>
</tr>
<tr>
<td>33</td>
<td>Send bottles to the lab and perform start-up tests</td>
</tr>
<tr>
<td>34</td>
<td>Perform the final tests (of previous production run)</td>
</tr>
</tbody>
</table>

Figure 14: SMED – PDT Activities Performed by Two Operators
4.2 Study Visit – Dongen

A study visit at the manufacturing plant in Dongen, the Netherlands was performed on the 30\textsuperscript{th} of April. The manufacturing plant in Dongen is a substantially larger manufacturing site than the site in Jordbro, Sweden. The plant has multiple lines that are able to produce large PET products. These production lines practise the concept of \textit{right first time}. This means that bottles are not sent to the lab before a production series is started.

The PDT events are differently defined at the manufacturing plant in Dongen. One of their PDT processes is called Blow&Go, where the system gets cleaned by blowing \textit{CO}_2 through the pipes and containers. A general rule of thumb is that changeovers from clearer beverages to darker beverages may be eligible for a Blow&Go, provided that the changeovers are between Light products or between products containing sugar. A Blow&Go is shorter in duration than a cold rinse. The goal of a Blow&Go is 20 minutes, the average for line 4 in Dongen for 2018 was 31 minutes. A Blow&Go also saves a lot of water compared to a cold rinse. The ability to perform a Blow&Go between production runs is limited. However, the few instances it saves time involve large time savings.
5 Results and Conclusion

SMED methodology was applied to the PDT event process of CIP programme 1, cold rinse. This resulted in an altered standard work procedure that shortens the PDT event of a cold rinse by 16 minutes at the line s10. The target of this thesis was to cut the total PDT time of the line s10 by 10%. The line s10 saw a total of 4449 minutes of PDT event duration during March of 2019. 22 CIP programme 1 events were performed with an average of 72.8 minutes. Had these 22 PDT events been 16 minutes, that would have saved 352 minutes. This would roughly translate to 8% PDT duration cut for March of 2019.

However, the proposals in the SMED methodology can be applied to all CIP programmes. It would have no impact on the PDT events sign-off and change of bottle size. This would increase the number of events from 22 to 27, saving 432 minutes. Which translates to roughly 9.6% of theoretical PDT event time savings for March of 2019. If a 16 minutes shorter duration is an accurate estimation, needs to be tested. The results of such a test will provide a more accurate estimation of time savings on total PDT events duration.

5.1 Reliability and Validity

A few things can be said regarding the reliability and validity of the results of this thesis. The line data that was used for this thesis were values for March. This thesis has not in-depth studied if the dataset for March is representative. The possibility therefore exists that the results are skewed compared to a broader time span. There may well be more effective methods of evaluating product changeover processes than the methods used in this thesis, those methods could have led to different results. The rate of RFT, point of break-even for RFT and estimated time winnings have been roughly estimated in this thesis. A deeper multiple factor analysis of these values would most likely result in different, more accurate, estimations.

5.2 Recommendations

New duration targets should be determined. Determining a goal should be done carefully, people can distort data in order to meet a certain goal (Wheeler, 1993). LineView is easily manipulated, because the filling machine operator determines when the line is shown in LineView as PDT or production. Too short PDT event durations could possibly result in a lower E60 value, due to a weak correlation (see Figure 10). E60 values should be actively tracked in order to analyse how effective the PDT event process has been. The current estimation of RFT for the filling machine on the line s10 is 87.8%. This is higher than the calculated 76.2% needed to skip lab testing before beginning to produce. In order to provide a better estimation of RFT, data must be collected. The importance of this is to ensure that the rate of RFT improves, but also that the concept of RFT is economically justifiable.

Many of the findings in this thesis on the production line s10 are most likely able to be applied to other production lines at the Jordbro manufacturing plant as well. This should be evaluated. The study visit to the manufacturing facility in Dongen, the Netherlands has showed that other PDT events, such as Blow&Go, could be performed in order to shorten the PDT event duration. A study that explores the implementation of Blow&Go at the manufacturing plant in Jordbro could be useful.
References


CLARKE, C. 2005. Automotive Production Systems and Standardisation From Ford to the Case of Mercedes-Benz, Heidelberg : Physica-Verlag HD.


WHEELER, D. J. 1993. Understanding variation : the key to managing chaos, Knoxville, Tenn., SPC Press.
Appendices

Appendix 1 – Overview of Line S10