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Title: **Coca-Cola Enterprises: Fit for the Future**

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Subject: Coca-Cola Enterprises: Fit for the Future

Coca-Cola Enterprises is one of the largest bottlers of Coca-Cola in the world, with multiple plants spread out over Western-Europe of which one is located in Dongen. One of the core competencies of CCE is always delivering the right product at the right time. Due to large fluctuations in demand, this causes a lot of changes in the production planning resulting in all sorts of sub-optimizations in the production process.

Currently, many decisions that have impact on potential changes in the production planning are made based on experience and gut-feeling since there is no insight in the extra costs that are being made.
The assignment is to identify, map and categorize all types of waste linked to changes in the production planning using the lean philosophy. All forms of waste will be expressed in costs and based on these costs several potential improvement scenarios will be developed in order to reduce waste and decrease total costs. These scenarios will be compared to the as-is situation in order to decide which strategy CCE should adopt concerning changes in the production planning.

The report should comply with the guidelines of the section. Details can be found on the website.

The professor,

Professor Dr. Ir. G. Lodewijks

Preface

With this report I will conclude my master thesis project and with that my master Mechanical Engineering: Transport Engineering & Logistics at the Technical University of Delft. Hereafter I shall obtain the title Master of Science.

First off, I would like to thank Coca-Cola Enterprises Dongen for allowing me to do my master thesis project at their production facility and giving me a beautiful insight in the workings of a production company. I was given the opportunity to perform this final assessment at the Coca-Cola Enterprises factory in Dongen, where all Coca-Cola's sodas for the Dutch market are bottled and was allowed a look at all phases of the process. I noticed firsthand the difference between efficiency en effectiveness and the struggle between sales and production.

I would not have been able to finish this report without the comprehensive help and cooperation of the employees of CCE, especially my supervisors Michael van Orsouw and Sjef van der Aa. They welcomed me from the very start, put trust in my work and were always willing to give me advice, guidance and created an enhanced insight in the complex production processes. The same goes for all other personnel at CCE, I received a very warm welcome and was always free to ask away, which was greatly beneficial to my research.

Furthermore, my gratitude goes to Dr. W.W.A. Beelaerts van Blokland for his extensive time during our meetings, helping me stay on track, his guidance and advice during the making of this report. My gratitude also goes out to Dr. B. Wiegmans for his sound advice, helping me see the problems at hand from another perspective and giving insight in the financial side of this report. Finally, I would like to thank Prof. Dr. Ir. G. Lodewijks, for his sharp insights, solid advice, time and trust in me.

The Hague, September 2014
Y.Y. Douma

Summary

The past few years characterize a significant decrease in the sales volume of carbonated sodas in the Dutch market. This decrease is clearly visible at Coca-Cola Enterprises (CCE), the biggest bottler and distributor of the product portfolio of the Coca-Cola Company in Europe. The Dutch market is primarily supplied by the Dutch CCE branch plant located in Dongen.

The annual sales volume of CCE in 2010 was around 50 million CCE cases, which is approximately 400 million liters of soda. The expected sales volume to retailers for 2014 is around 42 million CCE cases, a decrease in sales of approximately 15%. Next to the decrease in volume, retailers have become reticent in their communication around sales promotions, causing large fluctuations in the declining demand.

CCE Dongen produces over 180 Stock Keeping Units (SKUs), differentiated by a wide variety of flavors (Coca-Cola, Fanta, Sprite etc.) and different types of packaging (glass bottles, PET-bottles and cans). In order to cope with the market demands, changeovers on the production lines take place regularly.

The reduced sales and the demand fluctuations, in combination with an increase in the number of SKUs and a preferred reduction in lead-time has caused CCE Dongen, the commissioning company in this master thesis research, to rethink the way they manage their production processes in order to stay competitive.

Currently, CCE mainly focuses on the syrup yield of a production run, which is the ratio between the amount of finished products and the theoretically possible amount of finished product based on the syrup intake. Several other costs of production are left out of the equation, creating a distorted view of the costs. With the help of a variation of a yield management model, common in the aviation industry, the optimal batch sizes will be calculated for each product based on their demand. By means of lean thinking all forms of waste that occur during the production process have been identified and the costs of these wastes have been calculated. The types of waste and their respective costs that occur in the production process of CCE are:

Waiting: Waiting consist of the idle time during changeovers and the run-up loss, both of which are expressed in the cost of personnel and electricity.

Defects: The cost of defects is seen in the loss caused by syrup that stays behind in the piping during a changeover in flavor (i.e. from Coca-Cola to Fanta). As well as in the syrup yield since achieving the perfect mixing ratio requires some time, during which the target volume of finished product per liter syrup will not be achieved. The costs of syrup and syrup yield losses are the amount of extra used syrup multiplied by the price per liter.

Overproduction: Since CCE Dongen produces perishable products, batch sizes may never be bigger than the demand before the expiry date.

Inventory: When producing to stock, the inventory holding cost needs to be taken into account. This is a fixed price per pallet per week.

All costs that are caused by these forms of waste have been calculated or measured and have been transformed into a preliminary model. With the help of the production data of 2013, the renewed, optimal production costs have been calculated for several characteristic products. The products have been divided into three groups per line based on their demand: Bulk demand, Average demand and Minor demand. With the help of the model, and based on the demand of 2013, the optimal size of a batch based on the renewed production costs have been calculated. The change in batch size to achieve the minimal sum of waste is shown in Table 1.

Table 1: Optimal batch size compared to current batch size

	Bulk group	**Average group**	**Minor Group**
Line 3	Half	Equal	Equal
Line 4	Half	Equal	-
Line 5	Double	Double	Triple
Line 6	Double	Triple	Equal
line 8	Double	Triple	Equal

By choosing strategic batch sizes for specific product groups an enormous reduction in cost, potentially exceeding half a million euros, can be achieved. The increase in batch sizes for most product groups will cause higher inventory costs, but this is covered by higher yield performances. In addition, this will result in a reduction in the total amount of changeovers, reducing cost of waiting.

During the analysis of the changeover times, a comparison between the performances of the different team leaders has been made. In the worst case scenario, all changeovers were done by the poorest performing team leader and in the best case scenario all changeovers would have been done by the best performing team leader. By means of employing the right personnel that has been given adequate training, a cost saving of over € 80.000 per year can be realized. In addition, the reduction in idle time creates an additional 325 hours of production time per year and a more stable production planning is realized since fewer fluctuations in the changeover time occur.

In order to take full advantage of the renewed production cost optimization, an increase of the batch sizes is required. This is contrary to the common perception of Just-In-Time that a reduction of the batch sizes leads to a reduction in costs due to lower inventory holding costs. The larger batches are required due to the major impact the syrup yield results have on the feasibility of a batch, since they are very dependent on the run length. This strongly suggests that the point of minimum reasonable inventory has been surpassed. This shows the advantage of using yield management for batch size production companies, since this takes the advantage of larger batch sizes into account. Furthermore, the fast, fairly accurate and cheap method of modeling seen in yield management is ideal for a dynamic company facing products with fluctuating demands such as CCE.

Summary (in Dutch)

In de afgelopen jaren heeft er een forse afname van het totale verkoopvolume van koolzuurhoudende frisdrank voor de Nederlands markt plaats gevonden. Deze afname is duidelijk zichtbaar bij Coca-Cola Enterprises (CCE), de grootste bottelaar en distributeur van producten van de Coca-Cola Company in Europa. De Nederlandse markt wordt hoofdzakelijk aangeleverd vanuit de CCE productie locatie in Dongen.

Het jaarlijkse verkoopvolume van CCE in 2010 voor de Nederlandse markt lag rond de 50 miljoen CCE kisten, wat neerkomt op zo'n 400 miljoen liter frisdrank. Het verwachte verkoopvolume van 2014 ligt daar met 42 miljoen zo'n 15% onder. Naast de afname van het verkoopvolume worden retailers steeds terughoudender in de communicatie rondom verkoopacties, wat zorgt voor onzekerheden in de vraag en resulteert in grote fluctuaties in de marktvraag.

CCE Dongen produceert ruim 180 Stock Keeping Units (SKUs), die zich onderscheiden in smaak (Coca-Cola, Fanta, Sprite etc.) en in verpakking (glazen fles, PET-fles en blik). Om aan de vraag van de markt te kunnen voldoen, worden de productielijnen met regelmaat omgebouwd.

De verminderde verkoop en de fluctuerende vraag, in combinatie met de groei van het aantal SKUs en de gewenste reductie in de doorlooptijd heeft er voor gezorgd dat CCE Dongen, de opdrachtgever van dit onderzoek, haar productieprocessen moet herzien om concurrerend te blijven.

CCE focust momenteel hoofdzakelijk op de siroop yield van een productie serie. Dit is de ratio tussen het volume gereed product en het theoretisch haalbare volume gereed product gebaseerd op de siroop afname. Verschillende andere kosten van productie worden hiermee buiten beschouwing gelaten, wat een verstoord beeld van de werkelijke kosten geeft. Met behulp van een aanpassing op een *yield management* model, welke vaak gebruikt wordt in de luchtvaartindustrie, wordt de optimale batch grootte bepaald voor ieder product, gebaseerd op de marktvraag. In lijn met de lean filosofie worden alle vormen van *waste* geïdentificeerd en uitgedrukt in kosten. De volgende typen waste komen voor bij CCE Dongen:

Wachten: De kosten voor verloren tijd gedurende een wissel van de productielijnen en tijdens het opstarten, welke worden uitgedrukt in de kosten van personeel en elektriciteit.

Defecten: Het verlies van siroop die achterblijft in de leidingen wanneer een wissel van smaak plaatsvindt alsmede de siroop yield wanneer deze lager is dan de doelstelling. De kosten hiervoor zijn de prijs van de siroop per liter vermenigvuldigd met het extra verbruikte volume.

Overproductie: Aangezien CCE Dongen werkt met bederfelijke producten mag de batch grootte nooit meer zijn dan de vraag tot de houdbaarheidsdatum.

Voorraad: Aangezien CCE Dongen op voorraad produceert, moeten de kosten voor het houden van voorraad meegenomen worden. Deze kosten zijn een vaste prijs voor een pallet per week.

Alle kosten die veroorzaakt worden door deze vormen van waste zijn berekend of gemeten en getransformeerd in een preliminair model. Aan de hand van de productiedata van 2013 zijn de herziene optimale productiekosten berekend voor verscheidene karakteristieke producten. Deze producten zijn onderverdeeld in drie categorieën, gebaseerd op de vraag: Bulk, Gemiddelde en Minimaal. Met behulp van het model, en gebaseerd op de vraag van 2013, zijn de optimale batch groottes bepaald volgens de herziene productiekosten. De acties die CCE moet ondernemen ten aanzien van de batch grootte is te zien in tabel 2.

Tabel 2: Verandering van huidige naar Optimale batch grootte

	Bulk group	Average group	Minor Group
Lijn 3	Halveren	Gelijk	Gelijk
Lijn 4	Halveren	Gelijk	-
Lijn 5	Verdubbelen	Verdubbelen	Verdrievoudigen
Lijn 6	Verdubbelen	Verdrievoudigen	Gelijk
Lijn 8	Verdubbelen	Verdrievoudigen	Gelijk

Het strategisch kiezen van de juiste batch grootte voor specifieke producten leidt tot een substantiele reductie in de kosten. Deze besparing kan oplopen tot ruim boven de half miljoen euro. De grotere batches zullen zorgen voor hogere voorraadkosten, maar deze worden gedekt door de kostenbesparing door de verbeterde siroop yield resultaten. Bovendien zal het aantal wissels van de productielijnen afnemen en dus de kosten voor wachten.

Gedurende de analyse van de gebruikte tijd voor een wissel van de productielijnen, heeft de auteur gekeken naar de verschillen van functioneren tussen de teamleiders. In het slechtste scenario werden alle wissels uitgevoerd door de minst presenterende teamleider, terwijl in het beste scenario alle wissels werden uitgevoerd door de best presterende teamleider. Door het juiste personeel, dat adequate getraind is, in te zetten kan ruim € 80.000 op jaar basis bespaard worden. Tevens geeft dit een reductie in de wachttijd van 325 uur op jaarbasis en een stabielere productieplanning aangezien er minder afwijkingen in de wisseltijden zullen optreden.

Om volledig profijt te hebben van de optimalisatie van de herziene productiekosten zullen de meeste producten in grotere batches geproduceerd moeten worden. Dit in tegenstelling tot de *lean* gedachte dat kleinere batches positievere resultaten opleveren. De grote batches zijn nodig vanwege de grote impact die de siroop yield resultaten hebben op de totale productiekosten, aangezien deze afhankelijk zijn van de lengte van een productie serie. Dit geeft het voordeel van *yield management* aan voor productie bedrijven die in batches produceren aangezien dit het voordeel van grotere batches meeneemt in het model. Tevens is de snelle, redelijk accurate en goedkope wijze van modelleren, gebruikt in *yield management*, een ideale methode voor dynamische bedrijven die onderhevig zijn aan een fluctuerende vraag, zoals CCE Dongen.

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List of abbreviations

BIB	-	Bag in Box
CCC	-	Coca-Cola Company
CCE	-	Coca-Cola Enterprises
CIP	-	Cleaning In Place
DOS	-	Days of Sale
JIT	-	Just-In-Time
LU	-	Line Utilization
MES	-	Manufacturing Execution System
MRI	-	Minimum Reasonable Inventory
OEE	-	Overall Equipment Effectiveness
PET	-	Polyethylene terephthalate
RGB	-	Refrigerated Glass Bottles
SKU	-	Stock-keeping Unit

Table of Contents

1. Introduction

This master thesis focuses on optimizing batch size control for fluctuating demand at Coca-Cola Enterprises (CCE) Dongen, with the objective of reducing production costs. CCE Dongen is part of CCE, a group of bottlers of Coca-Cola products. This means that CCE and CCE Dongen alike are affiliated with The Coca-Cola Company (CCC).

1.1 *Company overview*

1.1.1. *Coca-Cola Company: Birth of an iconic brand*

Coca-Cola is an iconic brand with a worldwide reputation of producing first class sodas. Worldwide around one billion sodas are sold per day. A selection of the brand portfolio of Coca-Cola is shown in Figure 1, which also shows the percentages of the total sales volume of the represented products.

Figure 1: Brand portfolio, from: (CCE, 2010)

Coca-Cola was developed by a pharmacist called Dr. John Pemberton in 1886 in Atlanta, where he first produced and sold a syrup for fountain drinks. In 1899 Tennessee businessmen Benjamin F. Thomas and Joseph B. Whitehead secure exclusive rights to bottle and sell Coca-Cola in most of the U.S. and with another Tennessee businessman, John T. Lupton, they begin granting bottling franchise rights to other entrepreneurs that were also willing to produce Coca-Cola. In 1901 the first franchise began operations, serving parts of Tennessee. It is only until 1919, just after the First World War, that the first Coca-Cola bottler opens its doors in Europe nearby Paris.

1.1.2. *Coca-Cola Enterprises Europe*

In the seventies, over 400 different bottlers of Coca-Cola exist in North America alone. Slowly, consolidation of these bottlers began with the goal of increasing efficiency and in 1986 Coca-Cola Enterprises was listed at the New York Stock Exchange after a merger of The Coca-Cola Company own bottling facilities, the John T. Lupton franchises and BCI Holding Corp's bottling holdings. After several acquisitions, CCE managed to set foot on land in Europe and bought the Coca-Cola bottling operations in Dongen. Soon after, many other European countries follow (CCE, 2010).

The Coca-Cola Enterprises headquarter is located in Atlanta, right next to the Coca-Cola Company's headquarter but most of its activities take place in Western-Europe. There are 17 European manufacturing sites divided over 6 countries, as depicted in Figure 2.

	HQ	Manufacturing
	Brussels	Antwerp Chaudfontaine Gent
	Paris	Clamart Dunkirk Grigny Toulouse Marseille
	Uxbridge	East Kilbride Edmonton Colwall Milton Keynes Morpeth Sidcup Wakefield
	Rotterdam	Dongen
	Oslo	Oslo
	Stockholm	Stockholm

Figure 2: Coca-Cola Enterprises European sites, from: (CCE, 2010)

Since Coca-Cola Company hand-picks their bottlers, there is a strong link between CCC and CCE. This does mean that CCC has a strong say in the operations of CCE. Since Coca-Cola is a premium brand, they desire premium service. Therefore, the bottlers of Coca-Cola products are required to maintain a customer service level of over 99%. Furthermore, the finished products is sold for a fixed price, ruling out the possibility to steer demand via dynamic pricing

1.1.3. *Coca-Cola Enterprises Dongen: Coca-Cola in the Dutch Market*

The Dutch market is primarily supplied from the CCE branch plant Dongen, near Tilburg. This branch plant houses around 400 employees of which approximately half is working in manufacturing operations. The factory runs 24/5 with a rotating three shift team and has eight operational production lines that are capable of producing around 180 SKUs. These SKUs include a variety of flavors and packaging. The production lines in Dongen are capable of producing 330 ml cans, the characteristic glass 200 ml glass bottle, a variety of PET bottles and the Bag In Boxes (BIBs) for catering services as can be seen in Figure 3.

Cans 330 ml	***RGB Bottles 200 ml***	***PET Bottles 0,5L 1L 1,5L 2 L***	***Bag in Box***

Figure 3: CCE Dongen products, from: (Wholesale; systems; Unknown; Adatum)

Since CCE Dongen is part of the CCE Europe group, it is required to fulfill certain protocols and to achieve the goals set by CCE Europe. Examples of these goals are customer service level, line utilization and production costs. Although all European branch plants are part of CCE Europe, a certain degree of competition does clearly exists, making each branch plant hesitant in sharing demand as to reduce demand peaks.

In short, the premium brand status of Coca-Cola products forces CCE to have high customer service levels and does not allow for demand control via dynamic pricing. In addition, a competitive environment exists between different branch plants of CCE. This forces the research to focus solely on CCE Dongen

1.2 *Necessity of the research*

The necessity of this research is twofold; first there are the changes that the market is undergoing and already underwent whilst second there are the large fluctuations in demand.

1.2.1. *Necessity: Market Changes*

Nowadays, companies have to compete simultaneously on price, product quality, product differentiation, delivery performance and even rapid product development (McIntosh, Culley, & Mileham, 2001). This is caused by the fact that customer requirements have changed drastically over the past few decades. Customers desire lower costs, higher quality, better delivery performance and a wider variety in choice of products (Sherali, Goubergen, & Landeghem, 2008). Especially price and product quality play an important role in the market CCE is in since Coca-Cola is a premium brand.

For many years, it was common policy for many food processing companies to produce in large batches to keep production costs low and to limit the number of changeovers. CCE Dongen was surely no exception to this way of producing. However, during the course of the past decade changes in the market occurred, although slowly but gradually growing in significance. These changes can be summarized under three main themes: Products, Retailers and Margins (Donk, 2001).

The first of these themes is the increase of types of packaging as well as the number of new products introduced. Secondly, there is the fact that retailers have changed their way of doing business and are reducing inventories, want faster replenishments and shorter cycle times forcing production companies to reduce lead times. Finally there is the fact that the retailers have small margins and that this has caused for many mergers leaving large firms that put great pressure on the prices paid to producers. All three of the above mentioned themes are visible at CCE, forcing them to reevaluate their production process.

The necessity of this research however does not only lay in the fact that the margins on the products of CCE are reducing but it also gives CCE the ability to perform a check-up on choices that have been made in the past and might be made in the future. Over the course of 2013 almost 700 changes to the initial production planning have been made. Of all these changes around 75% is due to changes in the demand, either being set by central planning in order to keep stock levels at reasonable levels or directly from sales in order to be able to deliver to the customer. As said before, since order time decreases, it is very likely that the number of changes in the production planning will increase even more so. This effect shows the necessity of the research and forces CCE to carry out the research as soon as possible.

The demands set by the market, especially in the fast moving consumer goods sector, forces many production facilities to become Just-In-Time (JIT) suppliers. However, a much seen strategy at many firms of a wide variety of industries is for production facilities to become JIT-suppliers by holding large stock levels as to be able to quickly deliver and still maintain economy of scale during production (Sarker & Parija, 1994). They hold this excessive finished goods inventory to become, although only theoretical, a JIT-supplier for their customers, unfortunately little has been done to investigate the economic impact of such a strategy.

At CCE this trend can be seen as well, coming from the mindset of producing in bulk, there still exists the urge to keep batch sizes as big as possible. This resistance to change is often seen in firms that have been in business for a long time and even more so at production plants of the size of CCE. Large firms tend to suffer from structural inertial forces when new operational practices need to be implemented (Shah & Ward, 2003). Therefore, insight in the expected production costs in necessary.

Literature has shown that many companies do not take cost of downtime into consideration and even if they do they tend to strongly underestimate the sum of all costs (Fox, Brammall, & Yarlagadda, 2008). Unfortunately, very little research has been done on this topic. Since downtime is a very important, if not the most important, cost of changeovers, this therefore gives an ideal opportunity for both the author as the employer to investigate the true cost of downtime. CCE currently has very little to no knowledge of the actual cost of a specific production run, only on the total yearly amount of cost, making it next to impossible to make accurate choices in the production planning.

More importantly so, the author strives to create a means for CCE to create accurate and valuable information about the choices made by sales and to give operations and manufacturing a go by for negotiating batch size and implementation of new products. The ever ongoing battle between sales and operations can be very dangerous and should be handled with great care (Shapiro, 1977).

At most organizations supply chain planning is a cross-functional effort. However, functional areas such as sales, marketing, finance and operations traditionally specialize in portions of the planning activities, which results in conflicts over expectations, preferences and priorities (Olivia & Watson, 2010). These problems are also clearly seen at CCE, where finance and marketing are even stationed at another facility, furthermore there also exists differences in expectations, preferences and priorities between CCE Benelux and CCE Europe.

The ongoing dispute between sales and manufacturing over the way the supply chain should be organized originates from the fact that the goals of both divisions are very different. The need for agility and leanness depends upon the total supply chain strategy, particularly by considering market knowledge and positioning of the decoupling point (Naylor, Naim, & Berry, 1999).

Where the sales division mainly focuses on selling the products at hand to the customer and fulfilling almost every possible demand the customer has they strive for a very agile supply chain. Sales strives for an agile supply chain because its capability of satisfying a fluctuating demand. On the other hand, manufacturing strives to keep production costs to a minimum which requires a high efficiency. At CCE, a high efficiency is with the current machinery only possible with a level schedule and as little as possible changeovers, thus manufacturing strives for a lean supply chain.

Traditionally so, the sales division tends to win the argument since they are the ones who make the money. By means of this research, the author strives to find a trade-off between these two strategies that is acceptable both for sales as for manufacturing by investigating the benefits and drawbacks of decisions and protocols in the production planning and giving the manufacturing plant in of CCE in Dongen a stronger position during negotiations due to a realistic estimate of costs and benefits.

Finding the optimal batch size is therefore something many companies struggle with, especially those that suffer from products with large demand fluctuations. Optimal batch size is a decreasing function of setup costs and so batch sizes optimally decrease as more flexible machines are introduced (Milgrom & Roberts, 1990). Most models however maintain a fixed set-up costs which fail to completely capture the nature of batching problems and a distinction should be made between lost productivity and losses caused by material losses (Karmarkar, 1987). By identifying all cost and transforming these into a mathematical model this problem can be overcome.

This means that, as for most FMCG companies, the market of CCE has changed significantly over the past decade which led to higher production costs. Therefore, CCE has to reevaluate its production planning process and properly adjust batch sizes to match the fluctuating demand. In order to do so, insight in the production costs is necessary

1.2.2. *Necessity: Demand fluctuations*

To get an understanding of the demand fluctuations of CCE's products and the accuracy of the demand forecast an analysis was done on the actual sales volumes and the expected demand. In addition, the author will check if these fluctuations significantly differ per product. In order to do so, three products have been analyzed. The first, Coca-Cola is a true bulk product that is sold in mass volume. The second is Fanta Orange, an average selling product and finally Fernandes Green Punch, which has a considerably lower sales volume.

When the actual sales volumes of 2013 are analyzed it is clear to see that the demand of the analyzed products shows several major varieties, but that in general are reasonable steady demand pattern can be noticed. As can be seen in Figure 4, there are three distinctive peaks in the demand of Coca-Cola, which are fairly easy to explain when looking at the time they occur.

The first peak in demand arises in the weeks before eastern, which is typically a time retailers have a sales promotion with Coca-Cola and when large volumes are sold. The second peak is just before the summer vacation starts and is simply a stock build-up for the summer time in which demand tends to be higher, which can be seen in the figure as well.

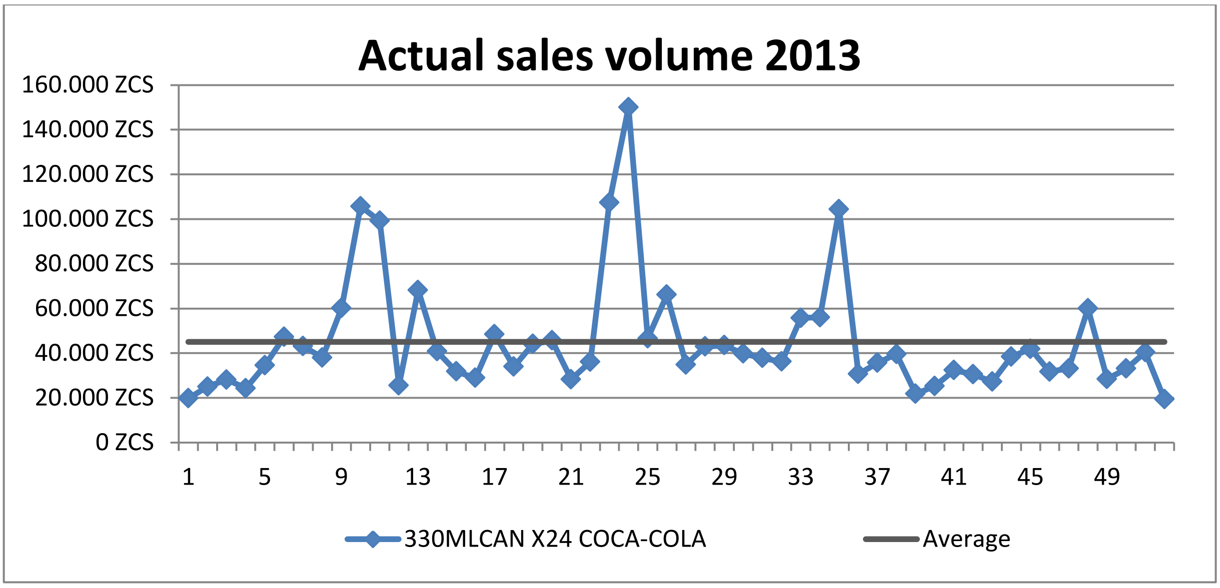

Figure 4: Demand pattern Coca-Cola 330ml 24-pack

The final peak is most likely due to a combination of a sales promotion and the sunny weather in that period (KNMI). Whilst the average sold volume over 2013 is around 45.000 cases per week, during winter time the average only lays around 25.000 cases and in summer around 40.000 cases.

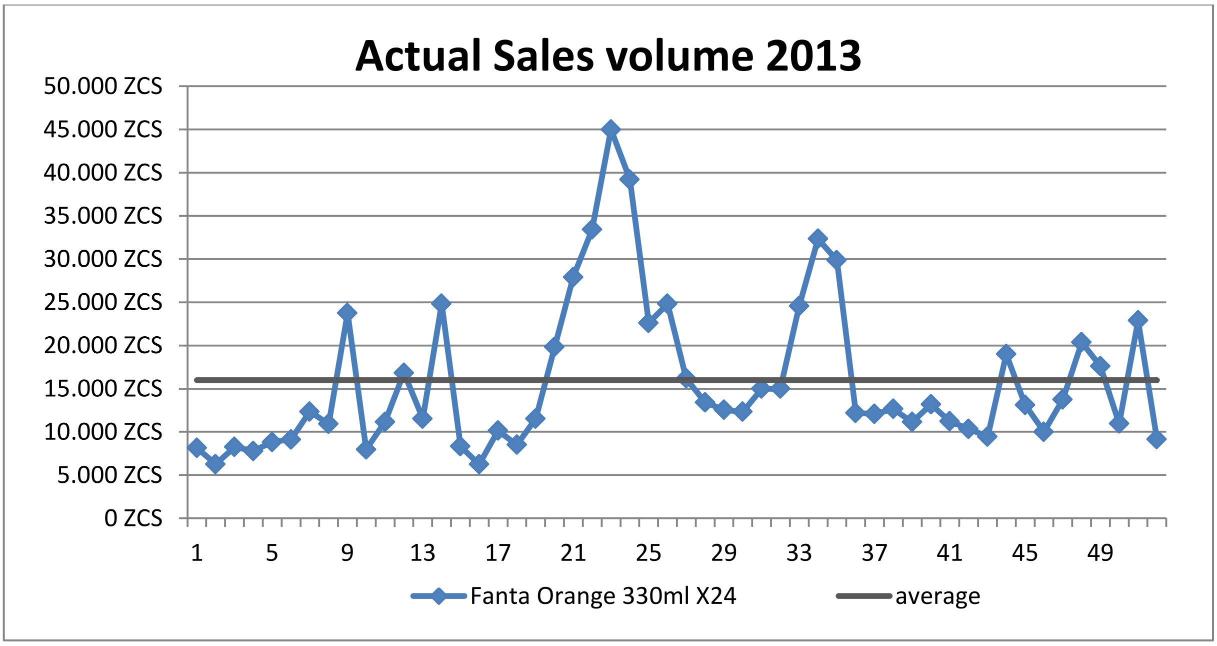

Figure 5: Demand pattern Fanta Orange 330ml 24-pack

As for the demand of Fanta Orange, the demand pattern is far more distorted as for Coca-Cola as can be seen in Figure 5. Although slightly more peaks occur as for the Coca-Cola demand, the peaks do occur at the same time: before Eastern, before summer time and at the end of summer. The demand for Fanta is much higher in summer time as it is in winter time, showing the importance of an dynamic model for optimizing batch sizes.

The final product that was analyzed is Fernandes Green Punch, which has a considerably lower sales volume with an average of only 3.000 cases per week, as shown in Figure 6. Once more, before Eastern, before summer and at the end of the summer three peak moments can be seen. Furthermore, just before Christmas a peak can be seen for Fernandes. Apart from the peaks, the demand for Fernandes shows a rather steady demand pattern.

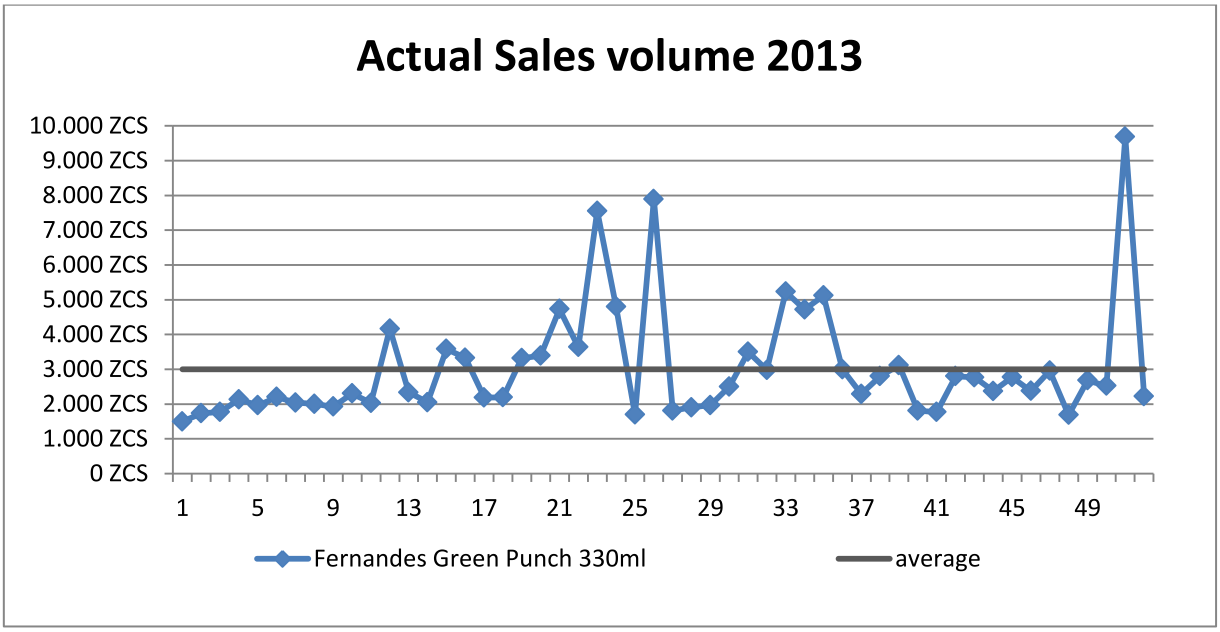

Figure 6: Demand pattern Fernandes Green Punch 330ml

In order to show the accuracy that the peaks in demand where predicted in the two week forecast, the demand accuracy has been calculated and is shown in Figure 7. The demand accuracy is the inverse of the absolute difference between the forecast and the actual sales divided by forecast, the formula is represented as follows:

$$FA = 1 - \frac{|F - S|}{S}$$

FA : Forecast Accuracy in percentage

F : $Forecast\ in\ CCE\ cases$

S : $Sales\ in\ CCE\ Cases$

The demand accuracy of the Coca-Cola, Fanta Orange and Fernandes Green Punch is given in Figure 7. As can be seen the accuracy of the demand forecast for Coca-Cola is reasonably high and stable at around 80%, the forecast for Fernandes and Fanta however show far less accurate results, causing for sub-optimization in the supply chain and creating extra pressure on the production planning.

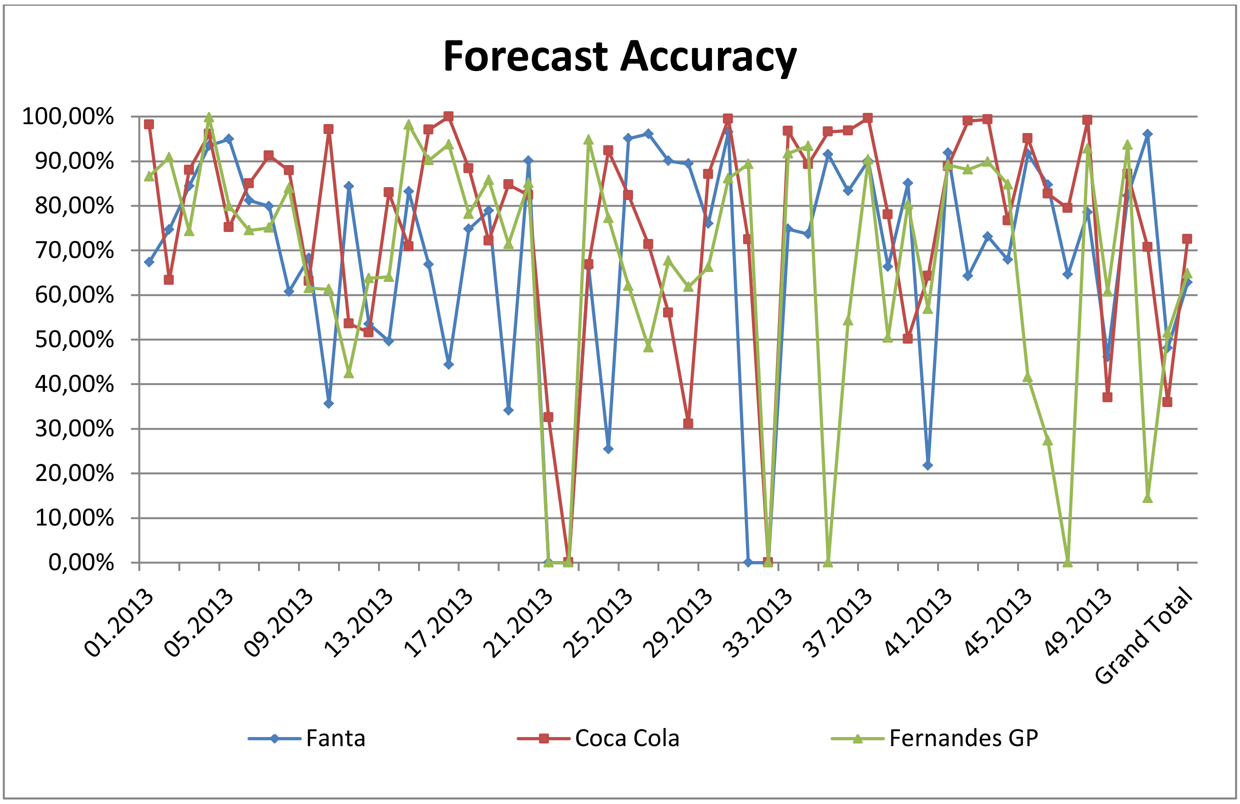

Figure 7: Demand forecast accuracy 2013

It is clear to see that the demand of Fanta and Fernandes consists of far more fluctuations as the bulk product Coca-Cola. Furthermore, the demand accuracy of these products is considerably lower. This has lead the author to believe that larger safety stock levels for these products might be necessary in order to always be able to fulfill demand. In addition, major differences in the demand in summer and winter time can be noted which is logical for a soda which in general tends suffer from seasonality in its demand.

The fluctuating demand of CCE's products requires a dynamic solution to the problem, as the market is in continuous movement. In general, the higher the demand of a product, the more stable and better to predict the demand.

1.3 *Problem description*

The CCE branch plant in Dongen was initially built for high volume bulk production of sodas, as demand was high and kept on rising. This meant large batches were made to stock, stored in the warehouse for distribution to clients. CCE's clientele mostly consists of retailers such as Albert Heijn. Over the years, this situation slowly started to change. Although the number of SKUs has grown substantially to around 180, the total produced volume of soda, expressed in CCE cases, has reduced significantly.

1.3.1. *Reduction in sales volume*

This reduction started around 2010, back then the total volume produced and sold was around 50 million CCE Cases. In comparison, the expected sales volume for 2014 is approximately 42 million CCE Cases, a decrease of over 15% in the sold volume. The combination of the increase in the number of SKUs produced and the decrease of total volume sold has led to a reduction of the average batch size and an increase in the total number of changeovers. This makes for a far more complex production planning, leading to more downtime and less efficient production and thus higher production costs.

To make matters worse, retailers are becoming increasingly more reticent in their communication about sale promotions and volumes. Since the price elasticity of CCE products is very high, a sales promotion can cause up to three to four times the nominal amount of sales as seen in the demand fluctuations. This price elasticity in combination with the lack of communication leads to uncertainties in the demand forecasting which in turn causes quite a substantial amount of conversions in the production planning and thus a lot of extra changeovers in production.

Due to the shrinkage of the market CCE is forced to redesign her production process and to reevaluate the choices they make in order to stay competitive. If the market continuous to decrease, it can even be expected that some branch plants will need to shut down. This is another incentive for CCE Dongen to make sure that they are amongst the top performers as to minimize the chances of being let go.

The reduction in volume and the smaller batch sizes and the many changes in the production planning led to an increase in costs per CCE case; where the average cost per CCE case in 2010 was approximately € 0,64 it is expected that the costs per case, if no actions will be taken, will reach € 0,75 in 2014. In order to stay competitive, any further increase in cost per CCE case must be prevented.

1.3.2. *Production Planning at CCE Dongen*

Currently many orders are accepted without proper realization of the consequences for production, a common problem in many industries (Shapiro, 1977; Wezel, Donk, & Gaalman, 2006). If CCE wishes to reduce production costs, it will have to improve insight in the expected cost of a batch sizes. In order to do so, proper monitoring and control of the production costs is required and the impact of the batch size reduction of the different products needs to be identified.

The planning process of CCE is rather complex as many people are involved from transforming the retailers order into the production planning. Therefore, an overview of the process of transferring retailers orders into the actual production planning will be given and insight is given in the choices that are currently being made in the production planning.

From order to planning

The ordering process at CCE starts at the retailers, they have their own account manager that keeps track of their desires and needs and monitors their expected sales volume. This volume is in turn reported to the national account manager, who thus has an overview of the expected sales volumes of the Netherlands. The national account manager in turn reports to the demand planner, who creates an expected demand, based on the expected sales volume and other influencing factors such as the weather forecast. This in turn is reported to the European demand planners who create an overview of the demand of Coca-Cola products in all CCE countries. Important to notice is that all people currently involved are not working in Dongen and tend to be unaware of the actual production costs and constraints

The production planning gets its info from the Demand planners, both the National as European planners and checks the stock levels to see what needs to be produced in the upcoming weeks in order to meet demand and which products have priorities due to the risk of out of stock. The required volumes that need to be produced in the upcoming week are planned by the production planner, who decides the actual production planning of the factory. A graphical representation of the information flow of the demand is given in Figure 8.

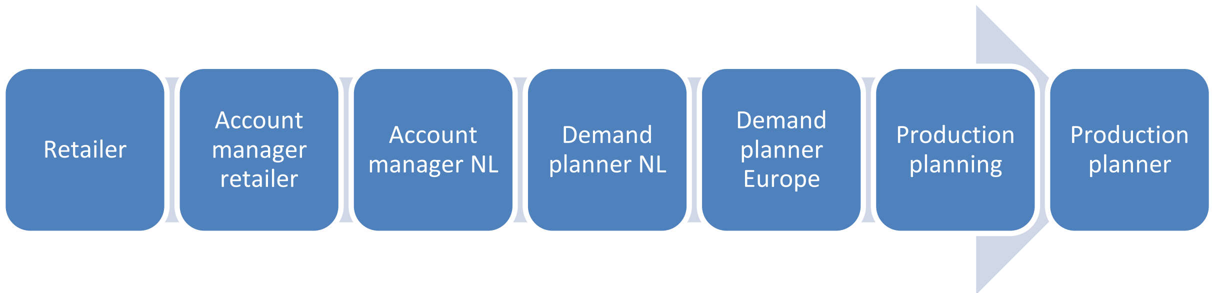

Figure 8: From order to production planning

Production process

The production processes for Coca-Cola will be described in short to get an understanding of the complexity of the process. Although each line is different, they do have a lot in common, a graphical representation coming from LineView showing production line 5, one of the PET-bottle production lines, is given in Figure 9. A detailed explanation of the production process can be found in Appendix B: Production process at CCE Dongen.

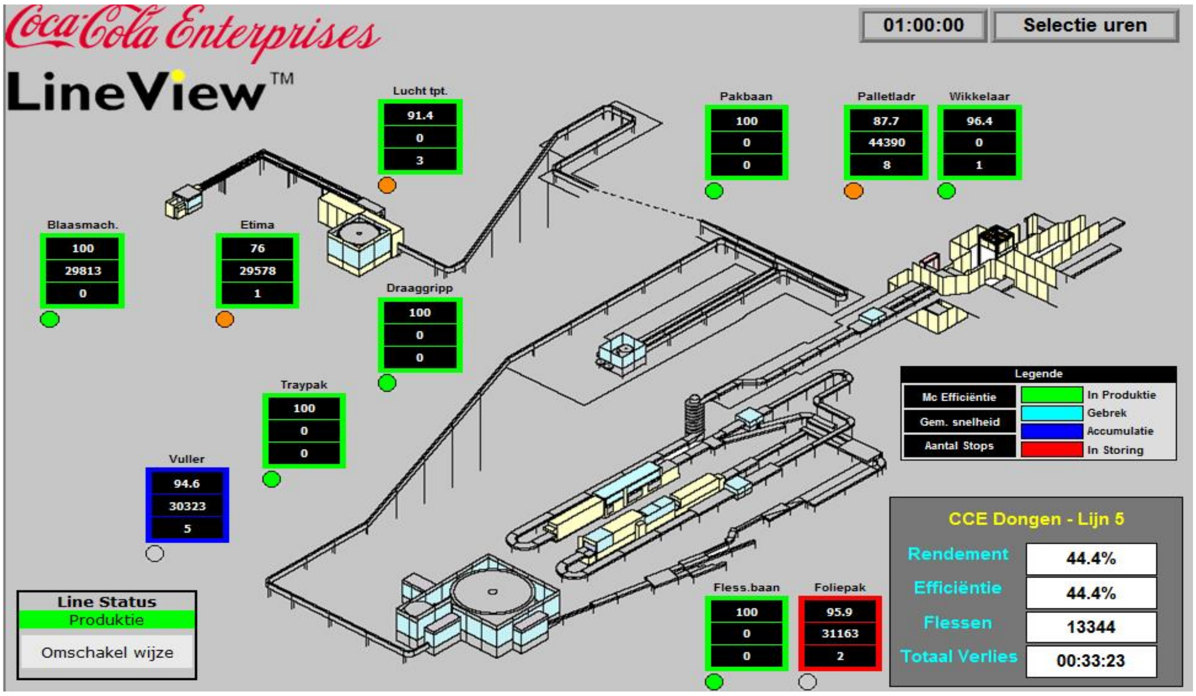

Figure 9: Line layout in lineview

The movement of the bottles can be followed with relative ease in this figure, when started in the upper left corner the bottle blower can be seen, after which the bottles go through a labeling machine and go in to the filler, which can be seen in at the bottom of the figure in the middle. Next the bottles are being packed in their designated packing and go off to the stacker which can be seen in the upper right part of the figure. Here the packages are stacked on pallets and transferred to the warehouse

Current batch sizes

Currently, the batch sizes of the production runs are mainly based on the required amounts according to the production planning. Although the production planner does have a little influence in the batch size and it is possible to disapprove a change in the production planning, this is seldom done. Quite basically put, CCE Dongen produces what it is told to produce and tries its best to do so in the most efficient way.

There are some suggested limitations to the batch sizes which have been created during the last couple of years, which are based on experience instead of solid arguments. For example, one of the boundaries is that a production run may never be less than an hour, for it is impossible to get proper yield results. If CCE wants to be able to properly arrange its production planning process, it will have to aware of the consequences of the choices they make. This means they will have to set out clear ground rules based on facts.

In order to compensate for the production costs, CCE works with a scrap factor that allows for a certain loss in efficiency per line. The scrap factor is depending on the product since the proportional filling losses per product deviate. As can be seen in Table 3, the scrap factors are rather straight forward and might give a distorted view of reality since they do not take into account the type of product nor the run length. This method however is slightly outdated and originates from a time of large volumes and fewer SKUs.

Table 3: Scrap factors

Size	Scrap factor
BIB	1,0125
0,2L	1,0075
0,5L	1,005
1L	1,002
1,5L	1,002
2L	1,002
0,33L	1,005

In conclusion, the increase in SKUs and decrease in sold volume have caused higher production costs. The current production planning process is outdated and is steered on volumes stated by sales rather than solid arguments. Currently CCE lacks the information to create these solid arguments. Thus, the problems this research addresses is creating insight in the cost of production and giving CCE Dongen the tools to optimize their batch sizes based on these costs.

1.4 *Research Goal & Research Question*

A substantial amount of research has been done on optimizing supply chains and improving production planning, however most if not all research is done from a strategic or tactical level instead of an operational level. Furthermore, very little literature exists, with the exception of Van Wezel and Van Donk, about the necessity of adequate batch sizes in the food processing industries in order to achieve efficient production.

This research is therefore carried out from an operational production perspective and aims to create insight in the costs inflicted by the reduction in batch sizes, sudden changes in the production planning and of downtime. By creating a more complete insight in the cost of production runs, this research will give CCE Dongen the tools to further optimize production by optimizing batch sizes to reduce production cost and add a new dimension to the yield management currently used at CCE. The focus of yield management lays in boosting revenue and taking away a large amount of guesswork (Kimes, 1989)

To create the insight in the costs that occur due to the fluctuations in demand and last minute changes a complete understanding of the costs of downtime is required, a cost that is quickly overlooked or misjudged in many industries and therefore should be studied in great detail (Fox, Brammall, & Yarlagadda, 2008). The costs inflicted by changes in the production planning are investigated since it is believed that this is one of the reasons of the increasing costs per CCE case, apart from the reduction of total volume.

Based on the author's results, improvements will be presented in order to reduce the cost per CCE case. Furthermore, the research will give CCE Dongen the possibility to make funded choices about whether or not changes in the production planning are worth the effort. In the end, the author will bring forth a strategy to reduce costs of production by means of a preliminary model, whilst keeping track of the principles that Coca-Cola stands for. This can be done by improving production control, which is the coordination of supply and production activities in manufacturing systems to achieve a specific delivery flexibility and delivery reliability at minimum costs (Bertrand, Wortmann, & Wijngaard, 1990).

To limit the increase of the cost per CCE case, an improvement of efficiency and effectiveness of production will be essential. Efficiency can be defined as doing things right, whereas effectiveness is doing the right thing (Wiegmans & Donders, 2007). For CCE this means efficiency is producing sodas with a minimum amount of waste and effectiveness is producing the sodas that the customers desire at that exact time.

The question the author aims to answer with this research is the following:

How to optimize batch sizes at CCE Dongen from a production yield perspective facing fluctuating demand conditions?

By answering this question the author aims to realize a cost minimization and profit maximization without losing any flexibility and gaining control of production. Flexibility can be seen as the ease to alter the production planning and control as the influence CCE Dongen has on the batch sizes and order of the products that are to be produced.

1.5 *Scope of the research*

With the given boundaries in mind, the scope of this research is on the manufacturing plant of CCE in Dongen, no other production plants have been taken into account. The reduction in production costs per CCE case is only sought in improving production performance by changing the way CCE handles their production planning.

The author has chosen to only take into account those cost that can be directly linked to a production run and that are dependent of the size of a production run in order to be able to express the differences in costs between production runs instead of the actual total amount of the made costs. Due to the timespan of the project, the author deemed it impossible to take into account all other costs. This means that depreciation of the machinery and facilities is not taken into account, since they are irrelevant of batch size and number of production runs. Furthermore, labor cost of office personnel is also left out of the scope.

The management of capacity in a manufacturing firm is often divided into three stages, ranging from long-term capacity planning to short-term capacity planning control and execution and in-between is intermediate capacity management which is related to rough-cut capacity planning (Olhager, Rudberg, & Winker, 1999). This research will mainly focus on short term and intermediate capacity planning.

1.6 *Report outline*

To further guide the reader trough the report an outline of the upcoming chapters and their content is given. The report continues a theoretical background research, where the author identified ways to improve production performance in production industries (2.1). Next, the potential contributors to the production costs are identified with the help of lean thinking (2.2) and all forms of waste according to the lean philosophy that can be identified at CCE Dongen will be presented (2.3)

Following the production waste analysis is presented in chapter 3. The identified forms of waste will be expressed in terms of cost, first the cost of waiting will be analyzed (3.1) and thereafter the cost caused by defects (3.2). The cost of overproduction will then be discussed (3.3) as well as the costs of inventories (3.4).

Chapter 4 discusses the proposed model. First by showing the way the yield results are transformed in formulas in order to use them in the model (4.1). Second by showing the design of the model (4.2) and next the batch sizes of the 2013 were compared to the optimal batch sizes based on the production costs (4.3). This chapter is concluded with a mean to reduce the costs of waiting and reduce fluctuations in changeover time (4.4).

The fifth chapter addresses the implementation of the proposed model and the way CCE should handle peak demands (5.1). Furthermore, a recommendation is given in ways to reduce the batch sizes whilst staying competitive.

The report ends with a conclusion of the results and further recommendations (6.1) and a discussion of the research done (6.2). The literature that has been used for this research can be found in the references and the appendixes show the data that has been used.

1.7 *Methodology*

As a prerequisite for this research the current processes at CCE Dongen had to be investigated. This investigation showed large fluctuations in demand and an incomplete image of the production costs, which lead to the following main research question:

How to optimize batch sizes at CCE Dongen from a production yield perspective facing fluctuating demand conditions?

In order to answer the main research question and optimize batch sizes for CCE Dongen, several sub-questions will need to be answered.

- How was production performance improved in other industries?
- Which forms of waste can be identified in the production process at CCE Dongen?
- Which forms of waste are relevant to this research?
- What are the costs of the relevant forms of waste?
- How can these costs be predicted via a model?

Once these questions are answered, a preliminary model will be developed that calculates the expected cost of a production run based on the found costs of waste. This requires that the empirical data obtained in the analysis will have to be expressed in a mathematical manner in order to be usable in the model.

With the help of the model the cost of production of the actual batch sizes of several characteristic products will be calculated as well as the minimal production cost achieved with the optimized batch size. In order to take the fluctuating demand into account this is done for the entire year 2013. The as-is situation will be compared to the optimized batch sizes to show the cost saving potential and to give CCE target values for their batch sizes.

2. Theoretical background of the research

By investigating the way other companies have improved production performance, a theoretical background of the research was established. Possible ways to improve production performance are discussed and the most suitable for CCE is chosen. All potential variables that influence the production costs are investigated and the ones that are relevant are discussed in further detail.

2.1 *Improving production performance in production industries*

In order to gain insight in the problems at hand in a time-efficient way a theoretical background research has been done, focusing on solving production planning issues in a wide variety of industries. Firstly in a very broad perspective by considering the entire supply chain and afterwards gradually zooming in on solving the problems at hand from a production perspective. This has been done in order to get the required understanding of typical supply chain and production planning issues and as to as well as to take learning from other industries as to not having to reinvent the wheel making it possible for the author to focus on other problems at hand.

There are several possible ways of tackling the problems at hand which can be learned from viewing other industries that cope with similar problems. These will be discussed and arguments will be given whether or not this is a possibility for CCE. Some of these possible solutions will be off limit due to the company's policies or will be almost impossible to realize in a company such as CCE, as will be explained in the upcoming chapter. Others however might prove to be very effective.

A trend that is being noticed all over the world is that the mass production model is being replaced by a vision of a flexible multiproduct firm that emphasizes quality and speedy response to market conditions while utilizing technologically advanced equipment and new forms of organization (Milgrom & Roberts, 1990) Nowadays, it is more and more realized that a supply chain needs to be adapted to the circumstances and the business conditions. In supply chains that are dominated with shared resources are hardly feasible and in order to gain an effective and efficient supply chain a very good co-ordination of the production capacity is required (Donk & Vaart, 2005).

In order for the supply chain to function in an optimal way, the sales division has to be familiarized with the limitations of production and distribution and the financial impact certain decisions have on the production costs. Furthermore, a fast and correct supply of information such as a sales forecast is essential in gaining an advantage over competitors by shortening the lead time and in preventing unnecessary costs (McClain & Thomas, 1977; Cachon & Fisher, 2000).

Whilst sales desires smaller batch sizes and shorter lead times as to be able to realize the wishes of the customers, production has to make a tradeoff between the productivity losses from making to small batches and the opportunity costs of tying up capital in inventory when large batches are produced (Karmarkar, 1987). All awhile making sure that the production cost stay at a minimum. In order to do so, clear insights in these costs is required as this is something that CCE currently lacks.

2.1.1. *Just-In-Time*

A much seen production philosophy to deal with this problem is Just-In-Time or JIT which strives for shorter lead times and less inventory costs. Under JIT, a plant is designed for efficient change-over performance processes to keep set-up times and thus costs low and thereby allow small batch sizes and small inventories (Houghton & Portougal, 1997) One of the problems of implementing JIT techniques in process industries is the fixed capacity due to capital-intensive processes or recourse constraints (Mirsky, 1993).

Since CCE encounters substantial fluctuations in demand, production capacity is not always able to fulfill demand. The fluctuations in demand are caused by seasonality since more sodas are being sold in summer time, but more importantly so short term fluctuations are being caused by sales promotions at retailers and due to weather conditions.

In order to be able to meet demand without having major overcapacity during normal demand, planning is necessary in order to smooth production runs. How much capacity to install and how much inventory to hold are among the most fundamental decisions that must be made in manufacturing organizations and seasonal demand is one of the factors that greatly complicates these decisions (Bradley & Arntzen, 1999).

From a market perspective there exists a trend that most process industries tend to move away from make-to-stock and towards a make-to-order strategy while offering a more diversified, customized line of products (Crama, Pochet, & Wera, 2001). This trend is also visible at CCE, however there is still a long way to go before a genuine make-to-order strategy is realized. All though many process manufacturers are very concerned with JIT and material planning issues, the primary concern still remains the efficient use of equipment, in particular because of the importance of set-up times and costs and of capital investments.

2.1.2. *Yield Management*

Yield management is a method for managing capacity in such a way that maximum profit is realized (Kimes, 1989). The goal of yield management is boosting revenue by modeling the predicted outcome, thus reducing the amount of guesswork. Since CCE currently plans based on experience and guesswork, implementing yield management could just be the ideal way of improving production efficiency. However, this does require some alterations in the way yield management is envisioned currently.

In the aviation industry, yield management focuses on gaining the maximum profit by adjusting the ticket prices based on dynamic pricing. A more popular way of explaining yield management in the aviation industry is: "selling the right seats to the right customers at the right time" (Smith, Leimkuhler, & Darrow, 1992). In the hotel business a similar business model for the booking of hotel rooms is utilized. In both cases, a model helps in achieving the optimal results by predicting the expected outcome, usually based on prior experiences.

In order for yield management to work for CCE the focus will still lay on maximum profit per CCE case, but this will be realized by minimalizing the production costs per CCE case instead of maximizing the sales. Normally, the question yield management aims to answer is "how much should one sell at what price?" (Kimes, 1994). In the case of CCE the question yield management should answer would be "How large should the batch size of a specific product be based on the given demand?". To be able to answer this question and to minimize the production cost, all factors that contribute to the production cost need to be identified. Furthermore, in order for yield management to work an estimate of the expected production cost is required and the ability to predict the production cost via a model is essential.

One of the key characteristics of the yield management problem is that it has to be solved repeatedly, preferably every time new information is known. Because of this, any solution method must be fast, fairly accurate and not too expensive. Optimality is desired, but may not be as important as solving the problem quickly with a fair degree of accuracy (Kimes, 1989). The same goes for CCE, every time a new order comes in, they must be able to quickly get an understanding of the approximate batch size, with the lowest production costs. Thus stressing the need for knowledge of the contributors to the production costs and being able to model their behavior.

As such, many industries suffer from the changes in the market of which a common solution is Just-In-Time production. However, the fluctuating demand and high customer service level make this very hard to implement. Therefore, the focus lays on a variation of yield management in order to boost revenues. This however requires clear insight in the production cost and the ability to model these cost.

2.2 *Lean thinking: Waste occurring in production industries*

With the help of lean thinking, it is possible to identify the different factors that contribute to the production costs. Taiicho Ohno, the former Toyota executive and by many seen as the birthfather of lean production, stated that in order for a company to become lean it has to eliminate all forms of "muda" (Womack & Jones, 2003`; Womack, Jones, & Roos, 1990). Muda is the Japanese word for waste, which can be found everywhere in the production process. According to Ohno seven different types of deadly wastes exist: Defects, Inventories, Motion, Overproduction, Over-Processing, Transport & Handling and Waiting.

Defects

Whenever a defect occurs, this means that either the products will have to be destroyed or rework is necessary. In both cases additional work is required, resulting in higher labor cost and more time of "work-in-progress".

Inventories

Inventory, either as raw material or finished product is seen as a form of waste as this is a capital outlay that has not yet produced any income. This is a very dangerous, as reducing inventory levels to rapidly will greatly increase the chances of running out of stock, or having delays in production due to a lack of raw materials.

Motion

Every form of movement, either of the product that is being made or of the employees that does not add value is considered as waste. If an employee has to walk from one machine to the next or has to search for a tool he requires, the time that the employee is walking or searching he is not performing any actual work and it is therefore idle time and thus waste. A great deal of motion can be prevented by adopting the 5 S-method (Michalska & Szewieczek, 2007) which is already done by CCE. Waste due to motion is left out of the scope of the research.

Overproduction

Producing more than is required by customers at that time is overproduction. This is often seen in production companies that work with large batches, such as CCE. Often, a little extra is produced just in case, which in turn causes extra inventory.

Over-processing

Doing extra steps in the production process or making the product overly complex without the customer desire for it is a form of waste since additional work is done and quite often extra materials are required that do not bring any added value to the product. This type of waste is mostly seen in the high tech market

Transport & handling

The transport of work-in-process during production or finished products to storage is considered as waste as well and should be minimized for two simple reasons. The first reason is transport requires time, during this time no value is added. The second reason is that during transport the chance of inflicting damage to the product is much higher which leads to defects which are as explained before a form of waste on itself. Reducing the waste of transport would require major alterations in the lay-out of the production line and is therefore left out of the research.

Waiting

Every time a person or machine has to wait for someone or something before they can complete their task, valuable production time is lost. During a changeover of a production line, waiting occurs.

With the help of lean thinking contributors to the production costs have been identified. The four types of waste that are most likely to give the biggest contribution to these costs at CCE are: Waiting, Defects, Overproduction and Inventories

2.3 *Waste occurring at CCE Dongen*

The only types of waste that will be taken into account in this research are therefore Defects, Inventories, Overproduction and Waiting. These are discussed in the order that they arise in the production process. Before a production run waiting exists during the changeover time, during production defects cause additional waste. If a production run is too long, overproduction will become a problem and inventory levels will rise.

2.3.1. *Waiting*

One of the more silent types of waste is waiting, since this is far harder to detect but it occurs throughout the entire process. At CCE waiting can be caused by an activity upstream that does not deliver on time. For example when the filler does not produce on full capacity due to a breakdown, the packing unit and stacker will have to wait as well even though they do not experience any difficulties. Waiting can also be caused due to missing information (Hicks, 2007), for example before the weekly production planning can be made the planner needs the expected demand.

Idle time due to changeovers

The first type of waste that occurs is one of the more obvious, since if a changeover is done the lines will not be able to produce, stoppage or setup time can therefore be seen as waiting. Setup time is, in general, the time required to prepare the necessary resources to perform a task (Allahverdi & Soroush, 2008) .The costs of the idle time due to changeovers exist in principle of idle personnel and electricity. The costs of goods not sold will not be taken into account since stoppage does not immediately leads to empty shelves since there is currently a large overcapacity. If this would not be the case, the costs of missed sales should be taken into account as well and stoppage would become even more costly.

Run-up & Run-down losses

In order to be able to do some of the changeovers, the lines need to be completely empty. This means that every time a changeover is required on a line, a certain amount of time before the changeover can be done and after the changeover is finished the line will not be able to run on its full capacity. The run-up and run-down times are highly dependent of the type of changeover that is done. In general, the more complex a changeover is the longer the run-up time required since there is a bigger chance of errors.

2.3.2. *Defects*

Defects in products are waste as well, even though it might be possible to restore the defects before they arrive at the customer this still requires extra work and it is therefore waste. If the products has defects that only show when the customer uses it, this can lead to even more damage, since this might change the consumer's view of the products. At CCE everything is done to make sure customers are not confronted with defects such as caps that are screwed on too tightly, not properly filled bottles or wrinkled labels. If something goes wrong in production the batch is being blocked as to prevent it from going to customers, this does mean a lot of extra work is required which once again means a lot of waste.

Yield

CCE already uses the term yield, although vastly different as in yield management. The current meaning of yield is a percentage that states the actual amount of product made versus a benchmarked value per liter syrup. The longer a production run is, the higher the potential yield since negative run-up effects have time to flatten out. If a run is shortened, because of less demand or because a different SKU requires more time, the yield of the production run will most likely be lower and thus the financial gain of this run. The yield is affected by multiple variables such as the start & stop losses, tuning of the machinery during production, rejects and the brix value. Once a production line is up and running, the amount of failures tends to be much lower, which makes a higher yield possible. In mathematical terms, the syrup yield is calculated as follows:

$$Yield = \frac{L_{product}}{L_{syrup}} * mixing\ ratio$$

$$L_{product} = Liters\ of\ finished\ product$$

$$L_{Syrup} = Liters\ of\ syrup$$

Currently, the main focus point in the steering of the production processes at CCE Dongen is the production yield. This is however calculated after the production run has been finished and it is therefore useless for the yield management model. It is therefore essential to not only calculate the cost of syrup yield, but also develop of formula with which the yield can be predicted.

The general opinion at CCE is: as long as the yield results are positive we are doing a good job. Although this is partially true, this does mean that many other costs, such as the cost of idle time during a changeover, are currently left out of the equation. By leaving certain costs out of the equation, it might very well be possible that a distorted view of the maximum realized profit is created. Thus stressing the need for a more complete view created with yield management.

It is the researcher's expectation that the yield per run length should show a logarithmic trend, slowly increasing towards a boundary value, with a steep increase in the first hours that slowly flattens as the run length increases since the biggest gain in yield can be made in the first hours of production. Therefore a formula will be derived per line that, based on the gathered data, gives the possibility to predict the yield results of the production lines depending on the size of the batches.

The formulas will be a logarithmic function with an upper limit as the yield is not capable of passing a given amount since that would mean the product would be rejected. The fit of the logarithmic function with the acquired data will be tested with the root squared method, to gain insight in the goodness of fit. The root squared method gives the coefficient of determination of the function denoted R^2. The coefficient of determination gives an estimate of the goodness of fit of the used formula and can be interpreted as the fraction of uncertainty explained by the fitted model (Cameron & Windmeijer, 1997; Bardsley, Bukhari, & Ferguson, 1995).

In order for successful implementation of yield management at CCE, the syrup yield will have to be predicted with a fair degree of accuracy and ease, thus stressing for an accurate and easy to use formula.

Start & Stop losses

When a change in flavor is done, the pipelines need to be rinsed. The rinsing is required to prevent mixing of the different syrups and to eliminate the chance of development of micro-organisms. This does mean that any syrup that is still in the pipelines will be lost. There is syrup lost at the beginning and end of a production run. The loss in the beginning of a run is due to the fact that there will still be some water in the piping which will mix with the syrup and will render the syrup useless. At the end of the run water will be pumped in the piping in order to get the last syrup out, this happens until too much water has mixed with the syrup rendering it once again useless. Depending on the current and to-be syrup this requires a specific type of rinsing. Usually, a simple rinsing is sufficient but in some cases a CIP has to take place, where lye, a solution sodium hydroxide in water, is used to erase any possible micro-organisms.

2.3.3. *Overproduction*

The first type of waste is overproduction, simply producing more than is required to fulfill the customers demand. To ensure no overproduction takes place constant interaction with customers is essential, since one needs to know the expected demand of its customers in order to minimize the chance of overproduction. Since CCE works with perishable products, overproduction could lead to products becoming overdue and thus unable to sell which can lead to a significant cost.

Since products expiring are extremely costly, overproduction is seen as a fixed boundary of the problem. Especially since CCE aims for a high customer satisfaction and the customer wants the longest possible shelf time. Therefore, the batch size may never be bigger as a the demand for one third of the expiry date.

2.3.4. *Inventories*

Keeping stock is, according to Ohno, a form of waste. This goes for both inventory of raw materials as well as inventory of finished products. Therefore, lean thinking means to try to get rid of all inventories. In the case of CCE this about quite some struggle since they strive for lowering their inventory levels, but they also wish to maintain a high customer service level that forces CCE to have some inventory as to be able to always fulfill demand.

The inventory holding cost will be calculated as to be able to find the break-even point between inventory holding cost and the gain of longer production runs. In the case of CCE a fine line between the waste due to defects and the waste due to inventory exists, since increasing batch sizes will reduce defects but will increase the waste of inventory. Therefore, the optimum of the sum of these two types of waste has to be found.

2.4 *Conclusion of the theory*

As mentioned in chapter 1, very little is known of the actual costs of production prior to the production run. Furthermore, the current production performance is only measured based on the syrup yield results, which are calculated once the run is finished. Several ways to improve production performance have been investigated such as the Just-in-Time philosophy and yield management.

The yield management model, common in the aviation industry, shows true to potential to be used for dynamic companies such as CCE since it strives for optimality in a fast and cheap way. More importantly so, it searches for an optimum by taking into account the beneficial effects of larger batch sizes, which are considerable at CCE. By means of the yield model, the minimal total sum of the cost of waste can be found. In order to do so, all costs need to be identified and their behavior needs to be known.

With the help of lean thinking all forms of waste that occur in the production process at CCE have been identified. Before production starts waiting occurs, during production defects in the product arise and when a batch size is too big the chance of overproduction arises, which in turn will lead to higher inventory costs.

Therefore, the next steps in the research are identifying the costs of the waste as well as their behavior in order to be able to predict those costs. By means of this costs, create a yield management model with which the minimal sum of the production costs for specific batch sizes can be optimized and compared to the actual batch sizes in 2013.

3. Production waste analysis

In order to categorize all forms of waste in a proper fashion the costs linked to each form of waste has been identified, all of these costs will now be measured, determined and analyzed.

Each type of waste that has been identified will now be expressed in costs, these costs will be calculated and a mathematical representation of the costs will be given as to be able to predict the cost of a production run with the help of a preliminary model.

Two different types of cost structuring can be identified (Allahverdi & Soroush, 2008). First there is the fixed costs, which are not affected by the event duration and only by its occurrence and secondly there are the variable or the per event costs which are dependent on the duration of the event. With the sole exception of the start/stop losses, all costs are variable as they are all dependent on the duration of the event.

3.1 *Cost of Waiting*

Waste due to waiting consists of two different types of costs: Idle time due to changeovers and Run-up costs. The idle time is caused by a changeover being done on the production line and Run-up costs are caused by the fact that it takes a little time before a line is back on full capacity after a shutdown.

3.1.1. *Idle time due to changeovers*

The first type of waste that can be seen as waiting is the idle time due to changeovers; the costs are a combination of the idle time of the personnel working on the line and the electricity for heating en light. As can be expected, this cost is variable and is fully dependent on the time of the changeover. The costs of the personnel is, based on an estimate of the financial department, set to € 30,- per hour per person. As for the electricity, MES allows us to check the actual used amount of energy per given time. In order to have an understanding of the energy usage during downtime, the energy usage during cleaning at the end of the week has been used as a reference. The average usage of electricity when a line is down is around 150 kwh, and with a electricity price of, according to the data found in MES, € 0,0687 per kwh this results in a total of € 10,31 per hour for electricity.

$$Cost_{stoppage} = H(n * p + e)$$

$$H = Hours$$

$$n = amount\ of\ workers$$

$$p = costs\ per\ person\ per\ hour$$

$$e = electricity\ cost\ per\ hour\ during\ downtime$$

The next step is to calculate the actual time of stoppage that occurs when a certain changeover is done on a given line. In order to do so, all changeovers that have been filled in by the team leaders and done over the course of 2013 have been analyzed. Although this offered more than enough data for the author to do a solid analysis the team leaders have not been all too consistent in filling in the information and this consistency greatly differs per team leader and thus also per line. This inconsistency is best seen at the data of line 8. For example line 8 has no data of changeovers in January and February and for the rest of the year it quickly became clear that many changeovers that took place were not filled in by the team leaders causing a large difference.

The analysis done resulted in an average time per line per changeover and the average LU in the first hour following the changeover. The results of this analysis will now be discussed in further detail.

The type of changeover that has to take place depends on a large variety of factors, if a flavor change has to be done and what the current and to be flavors are, the size and shape of the bottle, and the size of the packing. In order to know the correct way of rinsing between two flavors, a CIP-matrrix is used. The CIP-matrix varies per line, since not every line uses the same range of flavors. In order for the reader to get an idea of the working of a CIP-matrix, the matrix of line 3 will be discussed. A representation of this matrix is given in Figure 10. Considering line 3 has a small variety of flavors, this CIP-matrix is not very complex.

In the case of the line 3 CIP-matrix there are 7 different options for the type of rinsing that has to take place. A brief explanation of the meaning of these values in the CIP matrix is given in Table 4. As can be seen a differentiation between light and products that contain sugar is made in the rinsing process. This is due to the fact that it is absolutely not allowed to have any sugar in the light products and therefore the piping and filler need to be rinsed extra carefully. Furthermore, some products are not allowed to have a runtime above 72 or 144 hours due to the chance of development of micro-bacteria in the piping. Therefore a CIP has to take place in order to rule out any change of contamination of the sodas.

Table 4: Explanation of CIP-matrix values

144	If production run exceeds 144 hours, CIP is required. Else single rinsing
72	If production run exceeds 72 hours, CIP is required. Else single rinsing
72,1	If production run exceeds 72 hours, CIP is required. Else double rinsing
CIP	CIP is required
CIPL	CIP for light products is required
CC	Single rinsing is required
CCL	Single rinsing for light products is required

		COKE	PUNGENT			FANTA			NON-Preserved			SPRITE
	VAN / NAAR	Coca-Cola	Ginger Ale	Schweppes Tonic	Kinley Tonic	Fanta Orange	Schweppes Bitter Lemon	kinley Bitter Lemon	Coca-Cola light	Coca-Cola Zero	Nestea Lemon	Sprite
COKE	Coca-Cola	144	CIP	144	144	CC	CC	CC	CCL	CCL	CC	CC
PUNGEN	Ginger Ale	72	72	72	72	72	72	72	72,1	72,1	72	72
	Schweppes Tonic	CIP	CIP	144	144	CIP	CIP	CIP	CIPL	CIPL	CIP	CIP
	kinley Tonic	CIP	CIP	144	144	CIP	CIP	CIP	CIPL	CIPL	CIP	CIP
FANTA	Fanta Orange	144	CIP	144	144	72	72	72	72,1	72,1	72	72
	Schweppes Bitter Len	144	CIP	144	144	72	72	72	72,1	72,1	72	72
	Kinley Bitter Lemon	144	CIP	144	144	72	72	72	72,1	72,1	72	72
NON Pres	Coca-Cola light	144	CIP	144	144	72	72	72	72,1	72,1	72	72
	Coca-Cola Zero	144	CIP	144	144	72	72	72	72,1	72,1	72	72
	Nestea Lemon	144	CIP	144	144	72	72	72	72,1	72,1	72	72
SPRITE	Sprite	144	CIP	144	144	72	72	72	72,1	72,1	72	72

Figure 10: CIP-matrix line 3

Line 1 & 2

The changeovers done on line 1 and 2 are only marginal and therefore no data has been gathered for these two production lines. Normally only a flavor change is done and sometimes the size of the BIBs require some small alterations, but considering the BIB-lines are so straight forward this is done within minutes and no great deviations in changeover time are therefore to be expected.

Line 3

Once again the only major change that has to be done here are flavor changes, however since in this case this means that the entire filler has to be rinsed this is a bit more complex. As explained before, the changeover time depends on the type of rinsing that has to take place, which in turn depends on the previous and to be produced flavor. This gives the following changeover performance table, as shown in Table 5.

In this table, the first column gives the type of changeover that is done, in the case of line 3 there are only changeovers that require rinsing. The second column gives the average time this type of changeover required, based on the analysis of all known changeovers in 2013. The third column gives the target time that is set for this particular changeover, every possible changeover has a target time within the changeover should be completed in normal circumstances.

It is possible that very experienced personnel manages to do the changeover faster, but inexperienced personnel will most likely fail to perform the changeover within the set target time. The final column states the average LU that is achieved in the first hour following the changeover, based on all values of all known changeovers of 2013.

As can be seen in Table 5, the actual time of the changeovers is for both types of rinsing less than the target time. However, a regular CIP requires on average almost ten minutes more than the target time causing a delay in production as well as a greater costs than expected since the costs of stoppage are time dependent.

Table 5: Changeover performance line 3

Type of changeover	Average actual time of changeover [min]	Target time of change over [min]	Average LU in first hour [%]
Rinsing	48,73	55	69,15
Rinsing Light product	51,00	55	74,92
CIP	94,67	85	71,86
CIP Light product	96,25	95	69,63

Line 4

Considering line 4 is dedicated to making only Coca-Cola products, the amount of changeover is reasonably low. Furthermore, the amount of different changeovers is low since all these products are very similar as they have the same type of bottles and packing. Because the bottles all have the same shape and size, the blower and filler of line 4 do not require any rebuilds, saving a great deal of time and reducing the variety in possible changeovers.

All of the possible changeovers for line 4, the average actual time the changeover required, the target time of the changeovers and the average LU in the first hour following the changeover are stated in Table 6. All but the label or foil change are within reasonable margin with the set target times, as can be seen the average time for a label or foil change is more than double the target time. Therefore, the target time set for this changeover might be too short.

Table 6: Changeover performance line 4

Type of changeover	Average actual time of changeover [min]	Target time of change over [min]	Average LU in first hour [%]
Rebuild Traypacker	23,17	25	61,33
Rebuild foilpacker	22,65	20	63,77
1x rinsing ex rebuild filler	37,88	40	69,13
Blow&Go ex rebuild filler	26,62	25	65,52
2x rinsing ex rebuild filler	56,00	60	96,00
Label or foil change	11,50	5	82,25

Line 5

This is one of the production lines that not only has to deal with a lot of changeovers but also a great variety of different types of changeovers since line 5 produces a large variety of flavors and product sizes. If a change in size is required, for example from a 1,5 liter bottle to a 1 liter bottle, a rebuilt of the blowers is required. Also, in some cases even though the size of the bottle stays the same, the blowers have to be rebuilt since a different bottle shape is required. Every time the desired flavor belongs to a different flavor group as the current flavor the blowers have to be rebuilt. There are seven different bottles shapes per bottle size that all correspond to a certain flavor group. These flavor groups are: Coca-Cola, Fanta, Schweppes, Fernandes, Sprite, Nestea and Dr. Pepper.

If the size of the bottles is changed, the filler needs to be adjusted as well. Due to safety restriction this is impossible to do during cleaning so this has to be done once the cleaning is done and this thus requires additional time for the changeover. Therefore a distinction between rinsing excluding and including a rebuild of the filler has been made. All of the possible changeovers for line 5, with the average actual time the changeover required, the target time of the changeovers and the average LU in the first hour following the changeover are stated in Table 7.

Table 7: Changeover performance line 5

Type of changeover	Average actual time of changeover [min]	Target time of change over [min]	Average LU in first hour [%]
Rebuild Traypacker	31,92	25	62,96
Rebuild foilpacker	23,015	20	63,31
1x rinsing ex rebuild filler	43,61	40	63,70
Blow & Go ex rebuild filler	28,34	25	64,02
1x rinsing inc rebuild filler	57,55	55	49,79
2x rinsing inc rebuild filler	76,00	75	54,68
CIP exc rebuild filler	123,57	105	44,86
2x rinsing ex rebuild filler	60,41	60	55,21
Rebuild traypacker after 6*4	73,00	55	33,00
CIP increbuild filler	119,76	120	54,96
Rebuild Blower	67,14	40	44,07
Label or foil change	9,31	5	63,16

In contradiction to line 3 and 4, line 5 has several changeovers that require a substantial amount of extra time in comparison to the set target times. The changeovers that cause the most problems are the rebuild of the traypacker, CIP excluding a rebuild of the filler, rebuild traypacker after 6 X 4 and the rebuild of the blower. Once again, it can be seen that the target time for a label or foil change is too short.

The rebuild of the blower takes over 67 minutes, which is 27 minutes longer than the target time meaning half an hour of production is lost every time the blower needs to be rebuilt, due to dissatisfying changeover results. Furthermore, every time a CIP excluding a rebuild of the filler or the traypacker has to be rebuild after a 6 X 4 packaging, another additional 18 minutes per changeover are lost due to ill performance.

Line 6

As for line 5, line 6 requires a substantial amount of changeovers due to the large variety in products that is produced on this production line. Table 8 gives the target times and the average actual time of the changeover that took place on line 6 in 2013.

The high similarity between line 5 and line 6 gives an ideal opportunity to compare performance. The main problem for line 5 were the rebuild of the traypacker, CIP excluding a rebuild of the filler, rebuild traypacker after 6 X 4 and the rebuild of the blower. The main problems for line 6 are rebuild of the foilpacker, Blow & Go including as well as excluding a filler rebuild, a blower rebuild and a label or foil change. Therefore the only two problems that exist both for line 5 as for line 6 are the blower rebuild and the label or foil change. This strongly suggests that the responsible team leader plays an important role in the changeover performance.

Table 8: Changeover performance line 6

Type of changeover	Average actual time of changeover [min]	Target time of change over [min]	Average LU in first hour [%]
Rebuild Traypacker	23,60	25	76,00
Rebuild foilpacker	41,32	20	49,82
Blow & Go incl rebuild filler	54,50	40	67,50
1x rinsing ex rebuild filler	44,98	40	65,06
1x rinsing incl. rebuild filler	55,93	55	53,51
2x rinsing incl. rebuild filler	71,84	75	48,05
Cip ex rebuild filler	108,07	105	60,71
2x rinsing ex rebuild filler	63,50	60	60,79
Rebuild traypack after 6*4	58,58	55	56,8
CIP inc rebuild filler	114,00	120	61,62
Rebuild Blower	61,4	40	63,58
Label or foil change	18,64	5	59,27
Blow & Go ex rebuild filler	34,45	25	62,98

Line 8

The can line produces a significant amount of flavors, but since all cans are the same size, the variety in changeovers is limited. In Table 9, which gives the actual and target times of the changeovers done on line 8, two things arise that could be seen as remarkable. The first is that once again the actual changeover time for a label or foil change is double that of the target time, clearly indicating that either the personnel is not well trained in this changeover or that the target time is simply not realistic. The second remarkable fact is that the actual time of the CIP excluding a filler rebuild requires a half hour extra than the target time causing major delays in the production plan.

Table 9: Changeover performance line 8

Type of changeover	Average actual time of changeover [min]	Target time of change over [min]	Average LU in first hour [%]
Rebuild Traypacker	24,33	25	79,25
Rebuild foilpacker	19,00	20	78,00
1x rinsing ex rebuild filler	41,35	40	75,16
Cip ex rebuild filler	134,62	105	53,46
2x rinsing ex rebuild filler	42,94	60	84,31
Rebuild traypack after 6*4	42,50	55	69,00
Label or foil change	10,00	5	74,33
Rinsing	30,00	30	86,00

In summary, the idle time due to a changeover is caused by the time the acting team requires to perform said changeover. By investigating all changeovers of 2013, the average time per type of changeover per line has been calculated and can be used for the model. The cost of the changeover consists of the personnel and electricity costs during the changeover time.

3.1.2. *Run-up costs*

The cost of run-up and run-down losses can be expressed in a similar way as the cost of the idle time due to changeovers, since run-up and run-down losses result in a reduced line utilization. The time lost due to the reduced LU in minutes times the costs per minute give a representation of the costs.

$$Loss_{Run-up} = 60 * (1 - LU_{1st\ hour}) * (n * p + e)$$

$$LU_{1st\ hour} = Line\ Utilization\ in\ the\ first\ hour\ after\ changeover$$

$$n = amount\ of\ workers$$

$$p = costs\ per\ person\ per\ hour$$

$$e = electricity\ cost\ per\ hour\ during\ downtime$$

The losses due to run-up can therefore be found by using the values from the tables in paragraph 6.1.1. Translated into actual cost with the help of the formula above the costs of run-up have been calculated. In order to get an understanding of the amount of time lost on the run-up the author spoke with several employees that work on or around the production line to get an understanding of their experience with run-up. During these talks it became clear that all though the run-up varied from time to time, it usually staid between the 10 and 20 minutes, which in turn translates in a LU in the first hour of around 70%. In order to verify this assumption and to create insight in the differences per line and per changeover an extensive research has been done.

Line 3

Firstly the run-up costs of line 3 were calculated by using the average LU in the first hour over 2013. During this year four different types of changeover took place and it can be seen that the variance between the average LU is reasonably low which is due to the fact that the changeover are all very similar and none of them require major alterations on the line. The average LU and actual cost of the changeovers of line 3 can be found in Table 10.

Table 10: Run-up costs line 3

Changeover	Average LU in first hour [%]	Actual costs [€]
Rinsing	69,15	€ 95,73
Rinsing light	74,92	€ 77,82
CIP	71,86	€ 87,33
CIP light	69,63	€ 94,26

Line 4

The average LU and the actual costs of the changeovers done on line 4 are given in Table 11. Taking a closer look at the run-up effects of line 4 a greater variance can be seen in comparison to the LU of line 3. Especially the 2x rinsing without the rebuild of the filler and the label or foil change show far better LU than the rest of the changeovers. For the label or foil change this is most likely due to the fact that only a very small alteration is done on the line with very little chance of mistakes and thus failures. The fact that the 2x rinsing performs so will is however a little more remarkable. If however it is taken into account that the time to perform a double rinsing is quite substantial and this therefore gives the personnel some extra time to perform other alterations on the line with far less time pressure this peak could be explained.

Table 11: Run-up costs line 4

Changeover	Average LU in first hour [%]	Actual costs [€]
Rebuild traypacker	61,33	€ 108,38
Rebuild foilpacker	63,77	€ 101,55
1x rinsing ex rebuild filler	69,13	€ 86,53
Blow & Go ex rebuild filler	65,52	€ 96,65
2x rinsing ex rebuild filler	96,00	€ 11,21
Label or foil change	82,25	€ 49,75

Line 5

As mentioned before, a large amount of changeovers is performed on line 5. The average LU of 2013 of all of these changeovers has been analyzed and the actual costs of the run-up have been calculated, both of these values are given in Table 12. The analysis of the results gives some interesting results, especially if a comparison is made between line 4 and line 5. All values of the average LU and actual costs are given in Table 12.

The average LU of line 5 tends to be a bit lower for most of the changeovers involved, even though the same events took place. A possible explanation for this is that although the same type of changeover took place, because a truly different product is used, this creates a bigger risk of failure. For example, the bottle shape never changes on line 4, whereas it does on line 5 creating a bigger risk of failure and thus a longer run-up time.

Furthermore, the average LU after the CIP ex rebuild is very low, which is remarkable since the CIP time should give more than enough time for the personnel to do the possible other required rebuilds on the line. This should therefore be an area of interest to the line managers. The LU after a rebuild of the blower is also very low, this is however explainable due to the fact that a shape or size change of the bottle has a great impact on the entire process and there are therefore many risks involved. Since the time to do a blower rebuild is rather short, this puts a great deal of stress on the personnel to get everything set up on time, increasing the chances of mistakes and thus failures during the run-up time.

The final remarkable average LU is that after the rebuild required after a 6 X 4 packaging. This is a well-known problem, during the talks the author had with the line personnel an unanimous answer was given on the question what changeover caused the most problems, they all said a changeover from or to the 6 X 4 packaging which causes quite some friction with the employees. The 6 X 4 packing requires major alterations to the packing line, which greatly increases the risk of failures which is clearly shown in the poor LU following this changeover.

Table 12: Run-up costs line 5

Changeover	Average LU in first hour [%]	Actual cost [€]
Rebuild traypacker	62,96	€ 92,71
Rebuild foilpacker	63,31	€ 91,84
1x rinsing ex rebuild filler	63,70	€ 90,86
Blow & Go ex rebuild filler	64,02	€ 90,06
1x rinsing incl rebuild filler	49,79	€ 125,67
2x rinsing incl rebuild filler	54,68	€ 113,43
CIP ex rebuild filler	44,86	€ 138,03
2x rinsing ex rebuild filler	55,21	€ 112,12
Rebuild after 6 x 4	33,00	€ 167,70
CIP incl rebuild filler	54,96	€ 112,74
Rebuild blower	44,07	€ 140,00
Label or foil change	63,15	€ 92,23

Line 6

As for line 5, line 6 requires a large amount of changeovers and a great variety in the type of changeovers required. The results of the analysis of the average LU in 2013 of line 6 after changeovers is given in Table 8. A closer look at the values of the average LU of line 6 in comparison to that of line 5 shows that line 6 performs significantly better than line 5 which is, considering their great similarities, rather odd. Especially the performance of line 6 after a rebuild of the blower or after the 6 X 4 packaging is far better. This strongly suggests that there is a strong connection between the LU after a changeover and the personnel responsible for this changeover.

Table 13: Run-up costs line 6

Changeover	Average LU in first hour [%]	Actual cost [€]
Rebuild traypacker	76,00	€ 60,07
Rebuild foilpacker	49,83	€ 125,59
Blow & Go inc rebuild filler	67,50	€ 81,35
1x rinsing ex rebuild filler	65,07	€ 87,44
1x rinsing incl rebuild filler	53,51	€ 116,36
2x rinsing incl rebuild filler	48,05	€ 130,03
CIP ex rebuild filler	60,71	€ 98,33
2x rinsing ex rebuild filler	60,79	€ 98,13
Rebuild after 6 x 4	56,85	€ 108,01
CIP incl rebuild filler	61,63	€ 96,05
Rebuild blower	63,58	€ 91,16
Label or foil change	59,27	€ 101,94
Blow & Go ex rebuild filler	62,98	€ 92,67

Line 8

The final production line that has been analyzed is the can-line, or simply line 8. Since this is the newest production line the performance is far better than that of the other production lines. This can be seen in the average LU over 2013 shown in Table 14, which shows reasonably high results for most changeovers. The only changeover that truly shows disappointing results is the CIP ex rebuild of the filler, with only 53,46%

Table 14: Run-up costs line 8

Change over	Average LU in first hour [%]	Actual costs [€]
Rebuild traypacker	79,25	€ 39,49
Rebuild foilpacker	78,00	€ 41,87
1x rinsing ex rebuild filler	75,16	€ 47,28
CIP ex rebuild filler	53,46	€ 88,57
2x rinsing ex rebuild filler	84,31	€ 29,85
Rebuild after 6 x 4	69,00	€ 58,99
Label or foil change	74,33	€ 48,84
Rinsing	86,00	€ 26,64

The run-up time has a negative effect on the LU of the first hour after the changeover, therefore the average LU after each changeover in 2013 have been studied. The total time lost due to a changeover, so both the changeover time as the run-up time is seen as waiting, the costs of which are the personnel and electricity cost during this time.

3.2 *Cost of Defects*

The cost of defects can be seen in several processes at CCE Dongen: Start- and stop losses and yield results.

3.2.1. *Start- and stop losses*

The cost of the start and stop losses are dependent on which line is being evaluated, which syrup is being used and which syrup was used last. In essence, the cost is as simple as the amount of unused syrup that is left in the piping times the actual price of the syrup.

Unfortunately it was impossible to measure the exact amount of syrup loss due to the absence of accurate flow meters at the mixers. In order to still be able to give a realistic view of the start & stop losses of each of the lines three different methods were used. First, the filler operators of all lines as well as the syrup room operators were asked if they were able to give an estimate of the total volume of the piping and the amount that stayed behind during a change in flavor. Second, the lengths of all pipelines have been measured with the help of the building plan of the factory the actual volume of the piping was calculated. Finally, the start & stop losses have been calculated by subtracting all other costs from the total loss of production.

A comparison has been made between the three to check their validity, which was necessary considering the great amount of uncertainties involved. In order to get an understanding of the volumes and to create an upper boundary the total volume of the piping per line has been calculated. In addition to the volume of the piping from the syrup-matrix to the fillers, the average volume from the tanks to the matrix has been used to get the total volume from tank to filler. The total volume per line can be seen in Table 15.

Table 15: Measurements of piping

line	1	2	3	4	5	6	8
Length of pipeline [m]	204	204	208	38,5	53,5	65,5	132,5
Internal diameter [m]	0,07	0,07	0,07	0,07	0,07	0,07	0,07
Volume [m3]	0,785	0,785	0,800	0,148	0,206	0,252	0,510
Volume tank to filler [L]	843,88	843,88	859,28	206,97	264,69	310,87	568,72

When interviewing the operators, it quickly became clear that their estimates might be slightly enthusiastic with values ranging between 50 and 100 liters lost at lines 4, 5 and 6. The values from the calculated losses give, even though they are greatly fluctuating, a far more realistic view with losses of around 30 to 40 liters at lines 4, 5 and 6. There is another drawback to the calculated losses, since this does not take into account the differences in mixing ratio nor the different prices of the base syrup. This could be one of the reasons for the fluctuating losses. The data of the calculated losses can be found in Appendix E: Calculated losses of syrup.

As a final check, a simple hand calculation has been done in order to get a grip of the amounts that are being lost. If one assumes that a small film with an average of around 0,5 mm will stay behind in the piping, the volume can be calculated. According to the authors calculation, around 3% of the total volume will stay behind. This is slightly lower than the values of the calculated losses but in order to be on the safe side, the author has chosen to go for the minimum values of the losses.

The used method resulted in the following results, which can be seen in Table 16. The costs per liter syrup are as said before dependent on the type of syrup, which is why there are currently differences between the values in the table. The big differences between the total loss per run of line 1,2 and 3 versus the rest of the lines is due to the simple fact that these lines are situated at a far greater distance from the syrup room.

Table 16: Start/Stop losses

line	1	2	3	4	5	6	8
Loss [%]	3,00%	3,00%	3,00%	3,00%	3,00%	3,00%	3,00%
Syrup per L[€]	€ 4,15	€ 4,15	€ 2,12	€ 2,50	€ 1,84	€ 2,27	€ 0,61
Start loss [€]	€ 105,14	€ 105,14	€ 54,61	€ 15,49	€ 14,60	€ 21,20	€ 10,36
Stop loss [€]	€ 105,14	€ 105,14	€ 54,61	€ 15,49	€ 14,60	€ 21,20	€ 10,36
Loss per run[€]	€ 210,27	€ 210,27	€ 109,21	€ 30,99	€ 29,19	€ 42,39	€ 20,72

3.2.2. *Yield loss*

The loss due to yield has been calculated by analyzing data from all production runs between 01-01-2014 and 01-05-2014. This has been done for every production line in order to get an understanding in the difference of the yield per line. Each line gives different results since there are differences in the age of the equipment and the products made on every line and the production speed. In order for the reader to understand the differences per line, each line will be assessed individually.

Line 1 & 2

These lines are a bit of an exception, since the syrup is not mixed but put directly in boxes. It is therefore impossible to win or lose any yield on the mixing ratio. The only way to get a positive yield is to gain an advantage in the syrup room. This however is outside of the scope of this research.

Line 3

This is the 200 ml RGB line and the oldest production line at CCE Dongen. Since the accuracy of the filler of line 3 is slightly lower than that of the other, newer production lines it has quite a bit of overfill and therefore the achievable syrup yield is a lot lower. The average overfill of line 3 is around 1,5 ml per bottle, which is around 0,8% leading to a significant reduction in yield. Considering the line has a maximum capacity of 40.000 bottles per hour, demand is rather high since the entire Dutch catering industry is supplied with this line and the variety in products is minimal, the runs tend to be considerably longer than those of the other lines.

Figure 11 gives the values of the average yield achieved based on the run length. Considering the fluctuating values of the achieved yield, the figure gives the average value of the yield within the specific time frame as well as the standard deviation in order to create an understanding of the range the yield will most likely be in. The average number of weekly changeovers for line 3 is around 4 changeovers per week, this however always concerns a flavor change since there are no other sizes or types of packing involved.

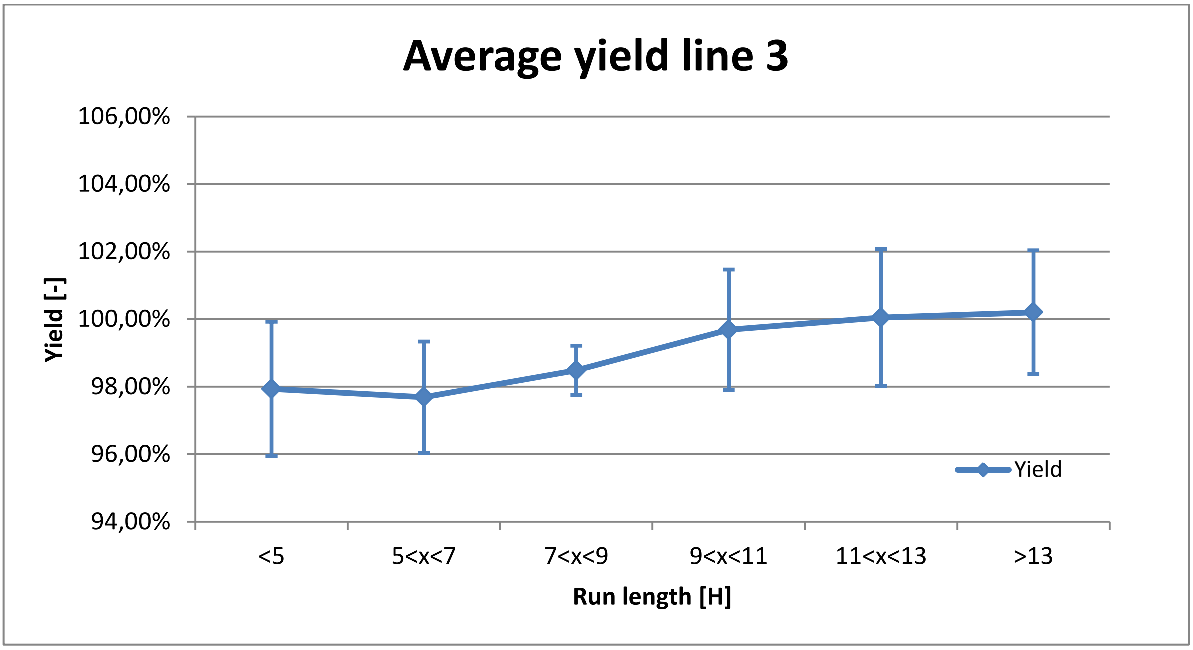

Figure 11: Average yield line 3

Line 4

This is the line dedicated to Coca-Cola products (Coca-Cola Regular, Coca-Cola Light, Coca-Cola Light caffeine free and Coca-Cola Zero). In general only these three products are made on line 4 and only 1,5 liter bottles either packed on pallets or in Dollies. Since the Coke flavors are the most selling ones this line tends to have the longest run lengths. Furthermore, since only minor changes are done during a changeover on line 4 the yield shows very good results as can be seen in Figure 12. Furthermore, since line 5 only produces 1,5 L bottles the average overfill is minimal with 0,6 ml or 0,04%. The average amount of changeovers per week of line 4 is around 4 changeovers per week. The peak at three hours is most likely caused by the simultaneous production of dollies during a regular production run, since line 4 is capable of producing for the packer and dolly stacker at the same time. However, these runs have different production numbers and thus other yield results in according to the data.

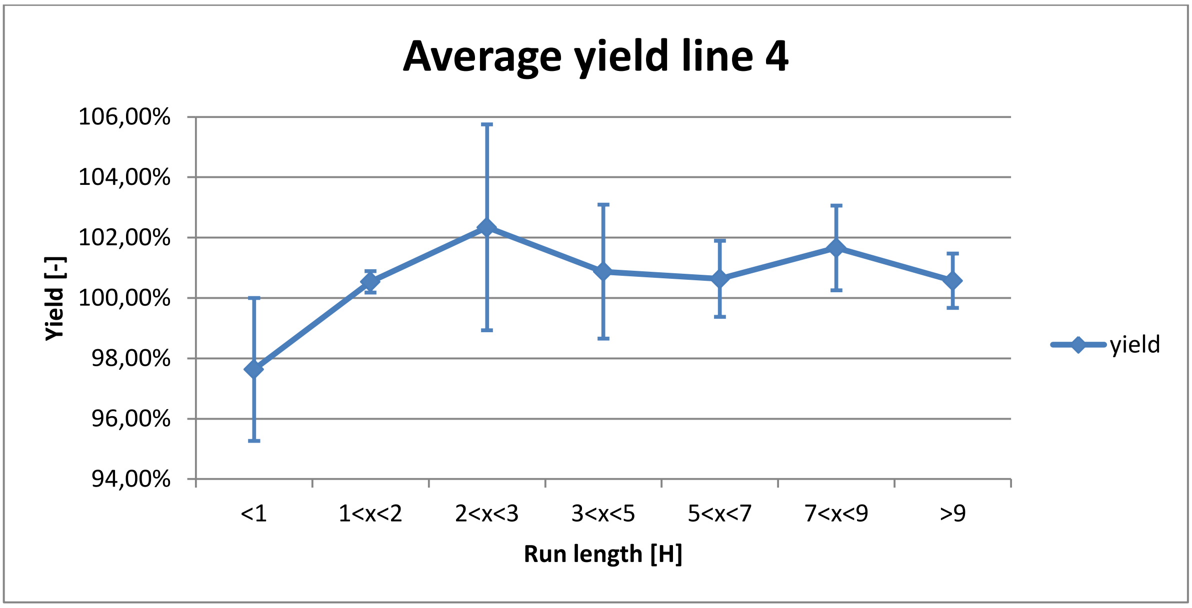

Figure 12: Average yield line 4

Line 5

This line is dedicated to the large pet bottles, and is capable of producing 1; 1,5 and 2 liter bottles off all possible flavors. This means that the number of changeovers on this line is quite high since the diversity of potential products is substantial. The average amount of changeovers per week of line 5 is considerably higher with around 12 changeovers per week. Due to the high variety of products several spot checks were done to see if a change in flavor or size would have effect on the expected yield but all checked values remained well within the margins of error and therefore no distinction is made between SKUs on the same line. The average overfill of line 5 is around 0,7 ml which translates into a 0,06% overfill. Figure 13, which gives the expected yield of line 5, gives an almost perfect representation of the author's expected yield curvature and the deviations that go alongside with it.

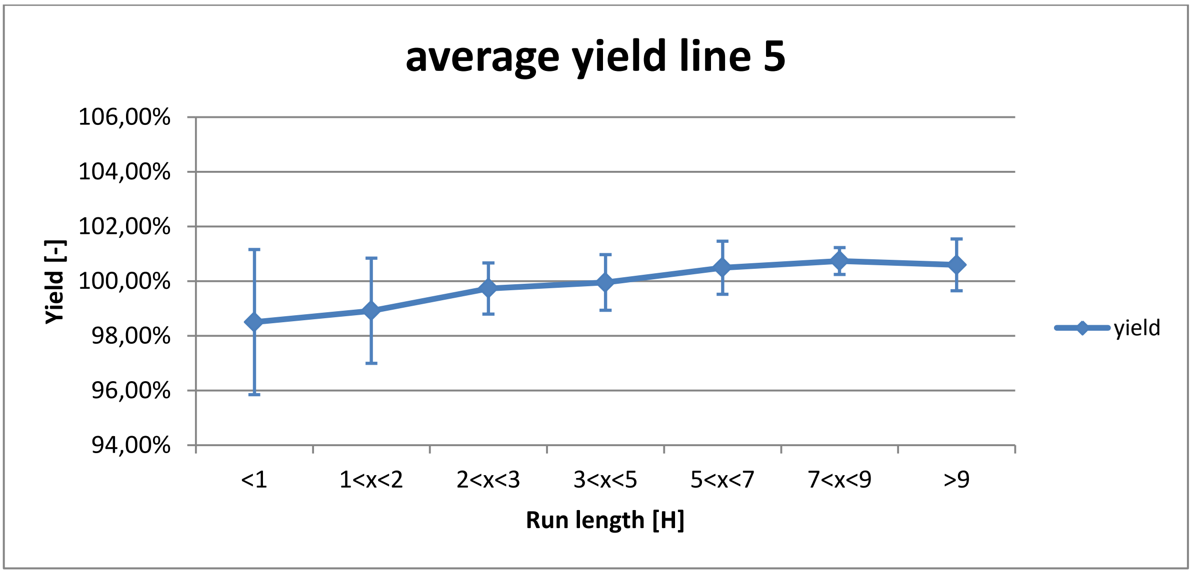

Figure 13: Average yield line 5

Line 6

The small PET line focuses mainly on producing 0,5 liter bottles in a wide variety of flavors all though it is also capable of producing 1 liter bottles if necessary. Considering the large variety of flavors the amount of changeovers is reasonably high in comparison to the other lines all though is with an average of 9 changeovers per week slightly lower than line 5. The expected yield for line 6 is represented in Figure 14. The average overfill of a 0,5 liter bottle is around 0,4 ml, which is around 0,08% of the volume.

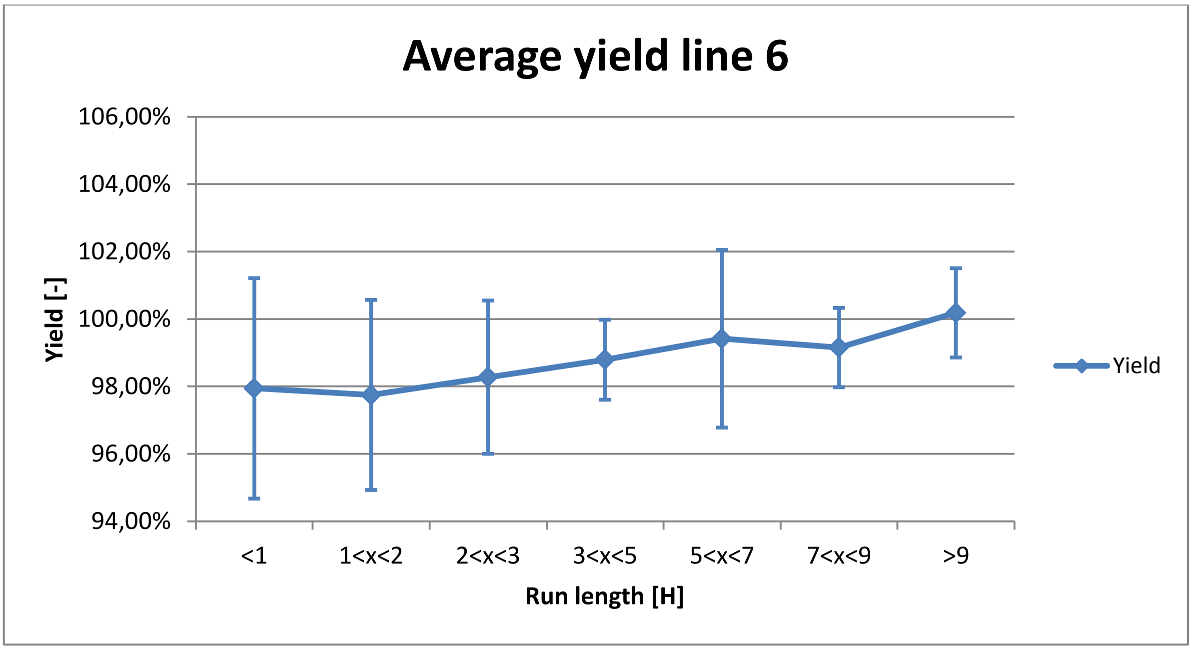

Figure 14: Average yield line 6

Line 8

The last line, which is also the newest, is the can line which produces the well-known 330 ml cans in a wide variety of flavors and packaging. At maximum capacity, when it uses two legs to feed the filler, it is capable of producing 120.000 cans per hour but in general only one leg is used and the production capacity in that case reaches 90.000 cans per hour. The reason that it is preferred to use one leg at a time is because this makes it possible to set up the other leg for the following product reducing changeover times. With the improved technology in comparison to the other production lines the average overfill is only 0,4 ml but since the to be filled volume is much lower as for the other lines this translates into a loss of 0,13%. The yield curve of line 8 is shown in Figure 15

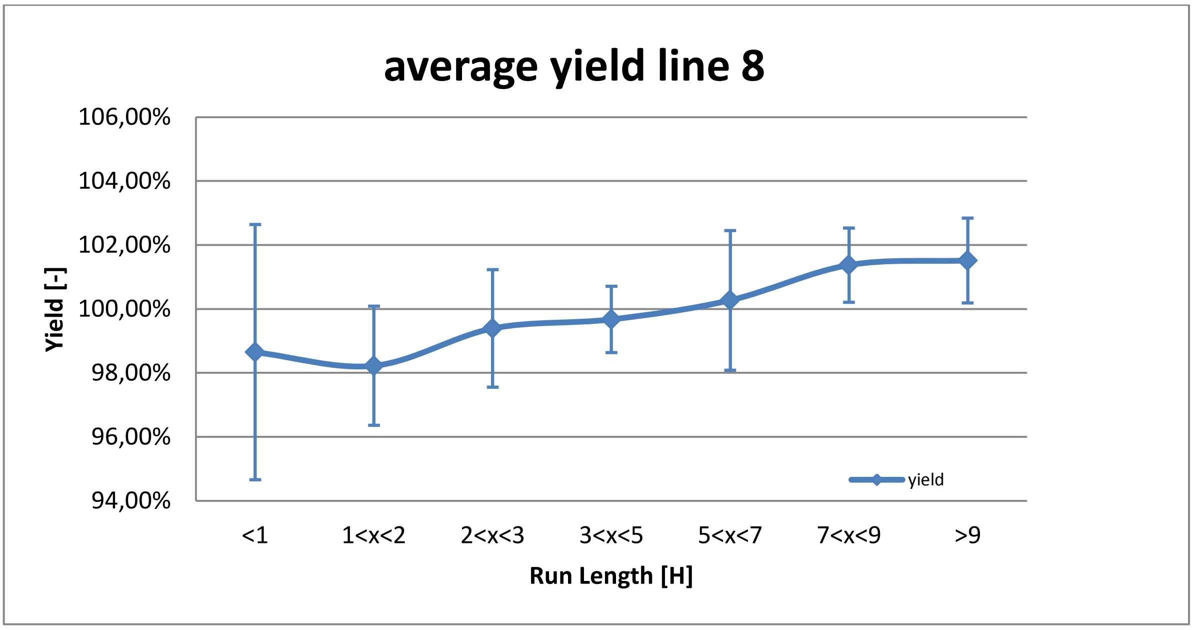

Figure 15: Average yield line 8

In conclusion, the yield results show a similar pattern resembling a logarithmic function for each line, although in some cases deviations do occur due to differences in the lines. However, the results do clearly show that it is safe to assume that an estimate of the yield results can be given before the production run. In order to be able to predict the outcome of the yield results of a production run beforehand the logarithmic function that is nearest to the gathered data is required, especially since this rule out the deviations.

3.3 *Cost of Overproduction*

Since CCE Dongen produces perishable products, overproduction is a serious threat. In the best case scenario, products can be sold at far lower prices when they go over one third of the expiry date but otherwise they will have to be destroyed. Therefore, the cost of overproduction is much higher as any other cost considered in this research. This made the cost of overproduction an upper limit for the batch sizes. The expiry dates of all the products that CCE Dongen produces can be found in Appendix C: Shelf live.

3.4 *Cost of Inventories*

The inventory holding costs consists of the cost of renting storage space, since the average storage time in general is around two weeks the depreciation of the goods can be neglected. The storage costs are calculated per pallet per week. Logically, the amount of products per pallet deviates, and thus the inventory holding costs per product. In order to calculate the inventory holding cost per product a conversion table was used, which can be found in Appendix D: CCE case ratios.

The total storage costs per pallet are € 3,10 per week, which is the sum of the rent block storage, the rent of a Dusseldorf pallet and the rack space. The amounts are given in Table 17. The formula used to calculate the inventory holding cost is the following:

$$Cost_{inventory} = \frac{S * N_{pallets} * Cost_{pallet}}{2}$$

$$S = Weeks\ of\ stock$$

$$N_{pallets} = Produced\ number\ of\ pallets$$

$$Cost_{pallet} = Cost\ per\ pallet\ per\ week$$

Table 17: Pallet storage costs

Rent	
Cell	Price per pallet/week
Rent Block storage	**0,9900 €**
Rent DusselDorf pallets	**0,7700 €**
Rent Rack storage	**0,9000 €**
Rent Sleeved pallets storage	**2,0000 €**
Dolly in pal equivalent (5D = 1 pal)	**2,5000 €**
Rent block storage in rack	**1,350 €**

The weeks of stock in this formula is calculated by dividing the to-be-produced batch size by the average expected weekly demand. This clearly demonstrates the dependency of the inventory cost on the batch sizes of a production run.

In conclusion, the analysis of the cost of waste shows that the cost of waiting is influenced by the time of changeovers and the cost of defects, overproduction and inventories are all influenced by the batch size. In order to be able to transform all costs into a model, it will be necessary to predict the yield results of a production run beforehand.

4. Modeling production performance optimization from a waste reduction perspective

During the analysis of the costs of waste occurring during production it came to light that the cost of defects, overproduction and inventories are all dependent on the batch size whilst the cost of waiting is dependent on the changeover performance. Based on this knowledge it is possible to create a model with which the cost of a production run can be calculated.

However, before all of this is possible, a method for estimating the yield curve needs to be derived which is done with the help of the least square method. Next, the proposed model will be shortly discussed and the optimized production costs based on the demand of 2013 will be compared for the calculated production costs of the actual batch sizes of 2013. Furthermore, the benefits of improving the changeover performance will be highlighted.

4.1 *Predictive modeling of the yield curve*

For yield management to become a success, it is key to get a proper understanding of the behavior of the syrup yield curve. In order to be able to predict the yield results of a production run, the empirical gathered data has to be transformed into a formula. By categorizing the yield results based on their respective run length, an insight is created in the expected yield pattern of a production run. As mentioned before, it is the authors strong believe that the actual yield based on the run length should follow a logarithmic function, the yield curve. With the help of the formula a representation of the yield curve is given, allowing the research to make a prediction of the expected yield result of a production run.

With the help of excel, the closest approximation of the yield data with a logarithmic function in the form of: $y = a\ln(x) + b$ was found with the help of the ordinary least square method. This method sums the square values of the deviation of the actual data and the proposed formula and searches for the formula which has the lowest sum. By calculating the coefficient of determination an estimate of the goodness of fit can be given, as was explained in paragraph 2.3.2. The logarithmic function is essential in realizing a model which is capable of predicting accurate and realistic yield results as the formula will give a smooth function. Since each production line showed different yield results, a formula for each of the lines had to be derived.

Formula Line 3

$$y = Min((0{,}025\ln(x) + 0{,}9340)\,;1{,}01)$$

$$y = Yield\ in\ percentage$$

$$x = run\ length\ in\ hours$$

When this formula is compared with the actual gathered data, as has been done in Figure 16, the result is a smooth line that gives a very close estimate of the found values. Considering the actual yield has a clear upper limit which is lower than that of the function, a fixed upper limit of the formula is chosen for further calculations. In order to do so the formula chooses the minimum of the logarithmic estimate or the 101%. The coefficient of determination of the logarithmic estimate is 0,8532, which proves that the function is a good representation of the data.

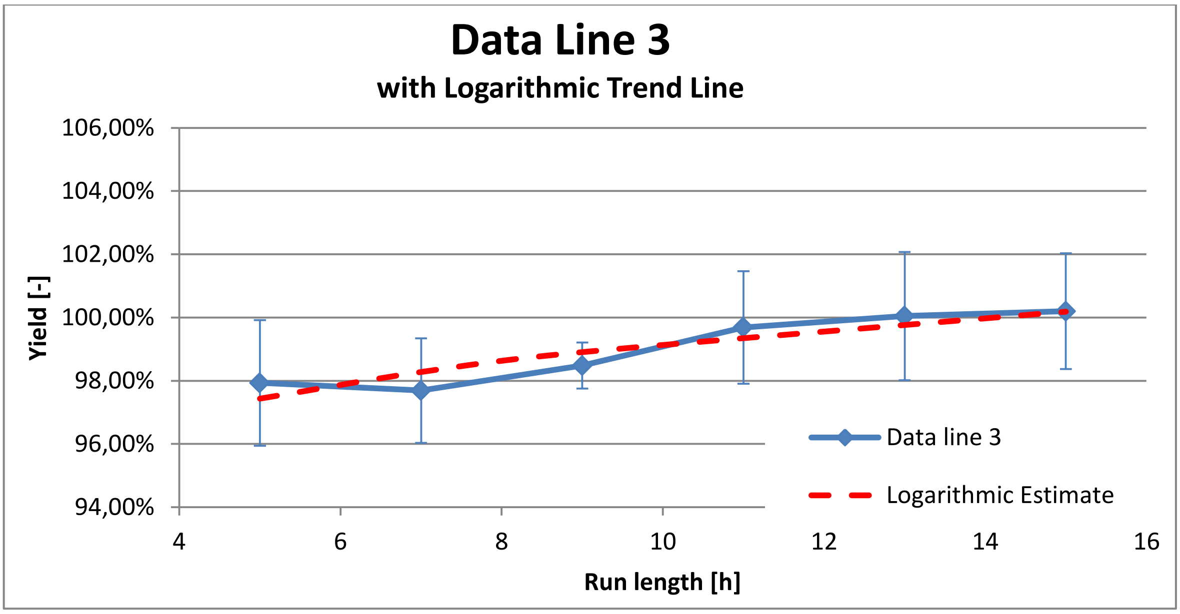

Figure 16: Logarithmic estimate line 3

Formula line 4

$$y = Min((0{,}0101\ln(x) + 0{,}9917)\,;1{,}02)$$

$$y = Yield\ in\ percentage$$

$$x = run\ length\ in\ hours$$

The logarithmic estimate of the data of line 4 is calculated and shown in Figure 17. This is done in order to create a smooth line that gives a close estimate of the found values. Considering the actual yield has a clear upper limit which is lower than that of the function, a fixed upper limit of the formula is chosen for further calculations. In order to do so the formula chooses the minimum of either the logarithmic estimate or 102%. The coefficient of determination of the logarithmic estimate is 0,3536; which means there is a loose correlation between the logarithmic estimate and the data.

The low coefficient of determination is mostly due to the fact that there is an enormous deviation at runs between two and three hours as can be seen in Figure 17 and the reduction in yield for runs longer than 9 hours. The peak between two and three hours is due to the fact that line 4 produces dollies at the same time they produce normal packages, as explained in the previous chapter. The dip at nine hours is most likely due to changes done by members of the new shift as this reduction is seen on most production lines. Since line 4 is essentially the same as line 5 and line 6 and these lines do give the expected pattern it is the authors' expectation that the chosen formula does give a decent approximation even though the coefficient of determination is much lower as for the other lines.

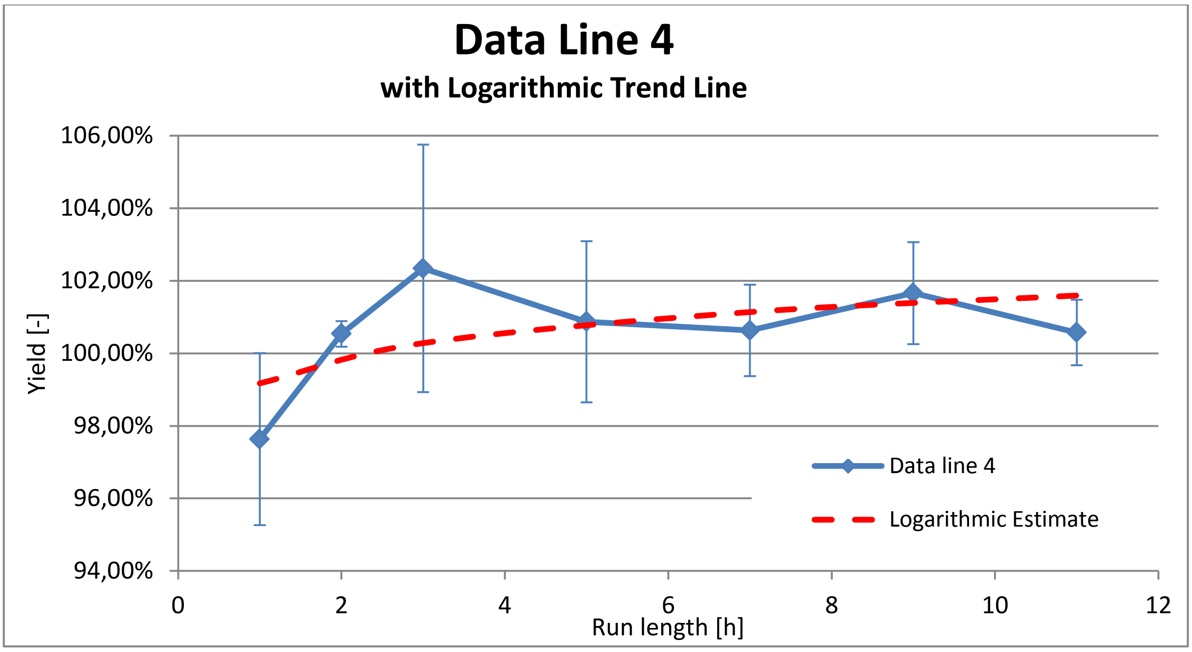

Figure 17: Logarithmic estimate line 4

Formula line 5

$$y = Min((0{,}0097\ln(x) + 0{,}9846)\,;1{,}02)$$
$$y = Yield\ in\ percentage$$
$$x = run\ length\ in\ hours$$

Once again an upper limit has been implemented in the formula in order to keep a realistic estimate of the yield results. For line 5 the upper limit of the yield lays at 102%, as can be seen in the formula. The actual data and the logarithmic estimate are shown in Figure 18. The logarithmic estimate of line 5 gives an almost perfect estimation of the actual data and the coefficient of determination is therefore very high with 0,9611 meaning that there is a very strong resemblance between the actual data and the estimated function.

It can be noticed that the deviation of the data reduces with longer run lengths, which was the author's expectation since small deviations caused by human errors have a much smaller effect on longer runs. These deviations arise due to employees that forget to activate an order, or start an order to soon causing a mismatch in the data. Furthermore, once again a small reduction in yield can be noticed at runs longer than 9 hours. Another indication that it is likely that a shift change has a negative effect on the yield result of a production run, especially when the run goes on for several hours in the next shift.

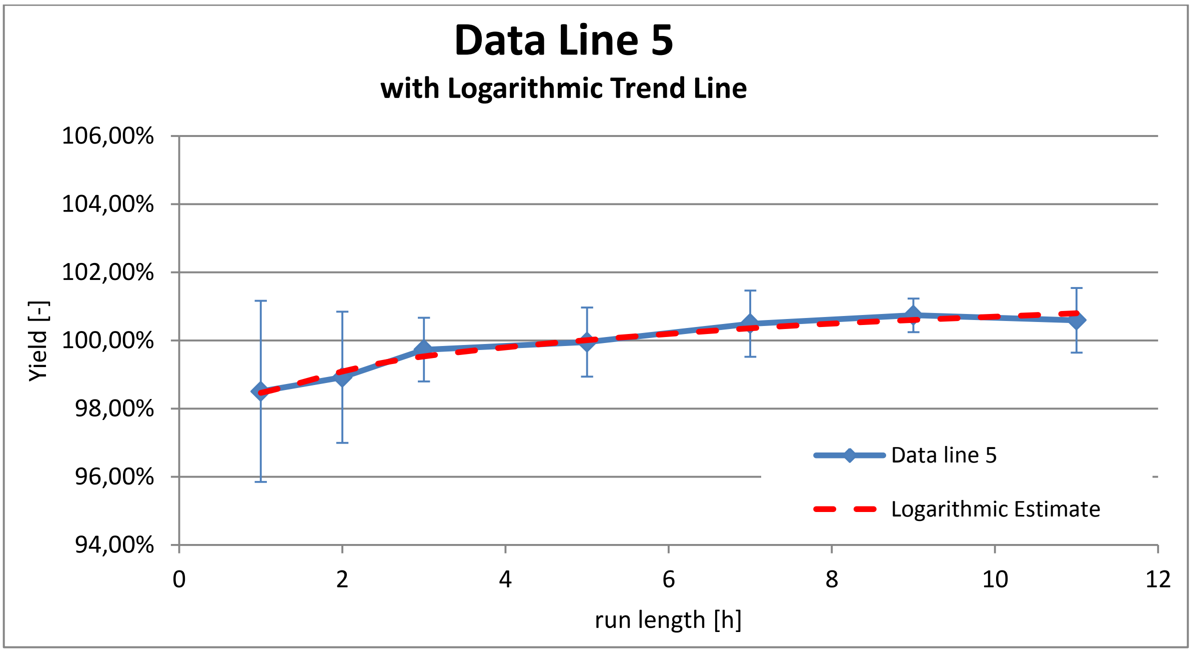

Figure 18: Logarithmic estimate of line 5

Formula line 6

$$y = Min((0{,}0091\ln(x) + 0{,}9750)\,;1{,}01)$$
$$y = Yield\ in\ percentage$$
$$x = run\ length\ in\ hours$$

Once again an upper limit has been implemented in the formula in order to keep a realistic estimate of the yield results. For line 6 the upper limit of the yield lays at 101%, the upper limit for line 6 is lower as for line 4 and line 5 due to the fact that even though it is similar to these lines the loss due to overfill is slightly higher since the to be filled volume is much smaller reducing the maximum achievable yield of the line. The actual data and the logarithmic estimate are shown in Figure 19. The logarithmic estimate of line 6 gives a very accurate estimation of the actual data and the coefficient of determination is therefore high with 0,8199 meaning that there is a strong resemblance between the actual data and the estimated function.

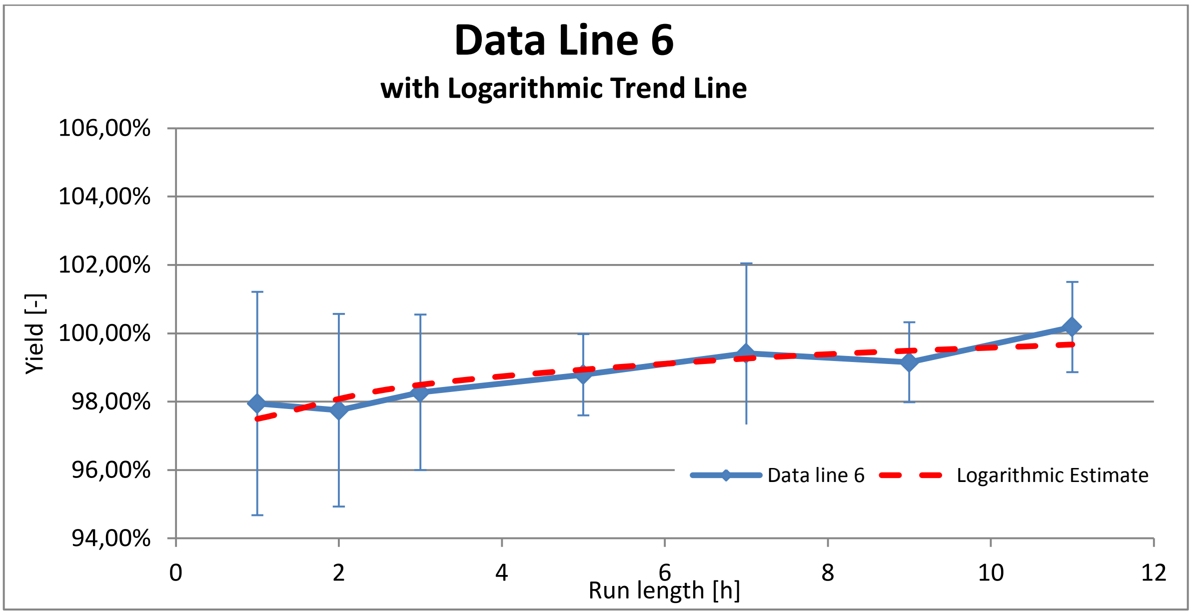

Figure 19: Logarithmic estimate line 6

Formula line 8

$$y = Min((0{,}0134\ln(x) + 0{,}9797)\,;1{,}02)$$
$$y = Yield\ in\ percentage$$
$$x = run\ length\ in\ hours$$

Once again an upper limit has been implemented in the formula in order to keep a realistic estimate of the yield results. For line 8 the upper limit of the yield lays at 102%, the upper limit for line 8 is equal to that of line 4 and line 5 even though the percentage of overfill is rather high. This is due to the fact that the improved technology offers better control on the system and thus better results can be obtained and a higher achievable yield is possible. The actual data and the logarithmic estimate are shown in Figure 20.

The logarithmic estimate of line 8 gives a very accurate estimation of the actual data and the coefficient of determination is therefore high with 0,8403 meaning that there is a strong resemblance between the actual data and the estimated function. The small stagnation in the growth of the graph at the values between 3 and 5 hours is due to the fact that this usually is the break-point where the choice of using either one or two legs is taken. Producing the same volume on two legs will result in a slightly lower yield since the time to adjust the machinery is smaller. Since the data does not show whether one or two legs where used, all calculations have been made with the assumption that one leg was used.

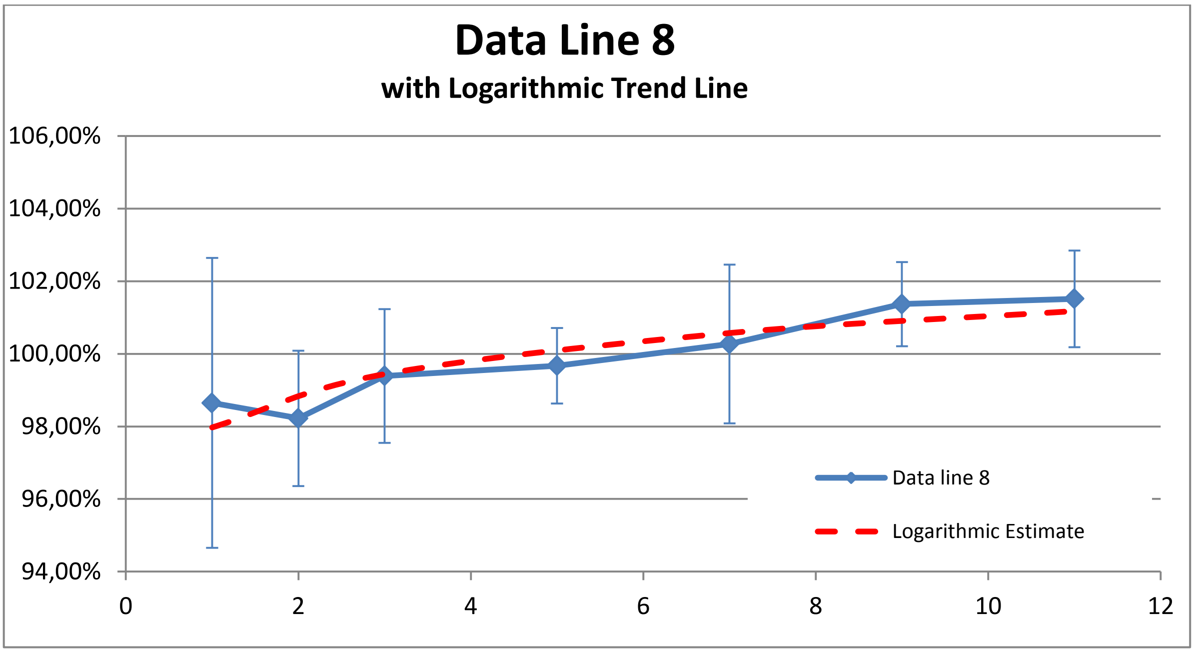

Figure 20: Logarithmic estimate of line 8

With the help of the derived formulas, which give a fair estimate of the expected yield results depending on the run length, and all other costs of waste a model can be built to optimize the production performance based on said costs. This model allows CCE to create a quick insight into the cost of a production run and find the optimal batch size based on a minimization of the total cost of waste.

4.2 *Proposed model for production planning*

Based on all information gathered during the research, a preliminary model has been built in excel with which CCE is capable of quickly calculating the cost of a production run. With the help of solver software in excel, a minimization of the total sum of the cost of waste for a specific run expressed in the cost per pallet can be made within minutes by altering the batch size (desired units).

The model is capable of calculating the expected cost of production of a run by entering the required data. The required data is: the last produced product and packaging, the to-be-produced product and packaging, the run size and the demand. Since the demand of CCE's products is subject to frequent changes, a dynamic model is necessary in order to be able to keep up. Figure 21 shows the lay-out of the model for line 4. Since each production line has different characteristics, each one has its own calculator.

As can be seen in Figure 21, the model checks if the given combination of flavor and packaging exists before the calculation is done.

By means of the model, it is possible to find the optimized batch sizes for CCE's products based on their demand and identify potential waste reducing solutions.

lijn 4	
Crewsize inc. Lineriders	9
New	Coca-Cola
Last	Coca-Cola light
Size New [L]	1,5
Size Last [L]	1,5
Packaging New	4P
Packaging Last	4P
Check if exists	No Problem
Capacity p/h	30000
Desired units	280000
CIP matrix value	CC
CIP time [min]	37,8844
Blower rebuild?	no
Rebuild time [min]	37,8844
LU first hour [%]	69,13043478
Total [min]	56,40613913
Cost of stopage	€ 310,52
Start/Stop cost	€ 26,31
Expected yield	102,00%
Yield loss/profit	€ 2.780,32
Expected run length [H]	11,78451178
Number of CCE Cases	23333,331
Number of Liters	420000
Number Pallets	584
Loss/Profit per Piece	€ 0,009
Loss/Profit per CCE Case	€ 0,105
Loss/Profit per Liter	€ 0,006
Loss/Profit per Pallet	€ 4,184
Average weekly demand	472.542
Shelflife [months]	5
Pallet storage costs per week	€ 3,11
Total costs per pallet	3,26266784

Figure 21: Representation of the model

4.3 *Optimizing batch sizes: reducing costs of Defects, Overproduction and Inventories*

By strategically enlarging or downgrading some stock levels and thus batch sizes, the necessity for some changes might become less urgent and stock keeping costs can be prevented. This however requires great care, since the chance of going out of stock will increase with reduced stock levels. With the help of the model, it is possible to find the batch size that has to lowest total sum of waste. It is important to note that some waste will always be inevitable in the process.

On the other hand, larger batches will enable higher yield results but the inventory holding costs will rise when stock levels are increased. Logically, the increase of the inventory holding costs may never be larger than the costs inflicted by changes in the production planning when looking for a reduction of the production costs. There is another limit to the maximum stock size, which is the result of the perishable nature of the products. Since products are not allowed to be sold when they go over one-third of their respective expiry date the days of sale of the stock level may never be equal or bigger than this number of days.

4.3.1. *Product groups*

With the help of the model, the total production costs with the inventory holding costs included can be calculated. Since the demand forecasts and the actual production data of 2013 was at the authors disposal, it was possible to recalculate the production cost per CCE case.Since, given the limited timespan of the project, it was impossible to investigate every single one of the over 180 SKUs the author has decided to divide the SKUs into different groups per production line.

For each line three different groups have been created based on their demand. The first group is a genuine bulk product, which in most cases is the type of Coca-Cola regular that is produced on that specific line. The second group of products is one that can be considered as an average selling product and the last group is the range of products with the lowest selling volume.

Table 18: Product groups per line

Product groups per line			
	Bulk Group	Average group	Minor group
Line 3	Coca-Cola 0,2L RGB	Fanta 0,2L RGB	Bitter Lemon 0,2L RGB
Line 4	Coca-Cola 1,5L 4P	Coca-Cola Zero 1,5L 4P	-
Line 5	Fanta 1,5L X6	Fanta Zero 1,5L X6	Fanta Cassis Zero 1,5L X6
Line 6	Coca-Cola 0,5L X24	Coca-Cola Zero 0,5L X12	Sprite 0,5L X6
Line 8	Coca-Cola 0,33L X24	Fanta 0,33L X24	Fernandes Green Punch 0,33L X12

In this way, an estimated guess of the entire product range can be made without having to investigate every single one of the products extensively. In the table below, Table 18, the chosen product to represent each product group per production line can be seen. Line 4 does not have a minor group, since this line is dedicated to only produce 1,5L Coke products which are always produced in bulk volumes.

4.3.2. *Comparison Actual and Optimized Batch Sizes*

The optimal batch size can be determined via a standard Economic Order Quantity model, in which the setup cost of switching from making one product to making another are traded off against the costs of holding the larger inventories of finished goods that go with longer runs and less frequent changeovers. In the case of the used model in this research, an extra dimension was added in the form of the production yield formula.

In determining the optimal batch size, knowing the demand is essential since this greatly influences the storage time of a batch. As was learned in the prerequisite research, giving an accurate demand forecast proves to be far from easy for most of the products CCE sells.

With the knowledge of the actual sales volumes of 2013, the two-weeks in advance forecast of sales of 2013 and the actual produced quantities per week in 2013 it is possible to make a comparison between the actual produced batch sizes and the optimal batch sizes for the given demand.

With the help of solver software for excel, the authors has been able to find the optimal batch sizes depending on the monthly demand for each line and product. The solver software is a relatively simple linear solver that can find an optimum for a set of given constraints and variables. In this case, the optimum is finding the minimal production costs, with inventory holding costs included, per case for the production run, which must be achieved by varying the batch size of the production run.

the constraint is that the batch size may never be more than one third of the expire time times the demand since that would mean that part of the produced items will have to be thrown away, which of course would only lead to higher cost. The expiry time, or shelf live as it is called at CCE, of all products can be found in Appendix C: Shelf live.The results of the solver where compared with the actual produced batch sizes to compare the production costs of the actual batch sizes that took place in 2013 and the optimal batch sizes. This has been done in order to see if a substantial financial benefit could be achieved by changing the batch sizes of certain products. Furthermore, by changing batch sizes of certain products in the right way one might be able to achieve more flexibility in the production planning and thus reducing stress in production.

The comparison of the bulk group of line 3, Coca-Cola 0,2L RGB can be seen in Table 19 in order for the reader to get an understanding of the work done. For the further results, a summary of the data is given. The full data of the comparison between the actual produced quantities and the optimal batch sizes of all the chosen products can be found in Appendix F: Comparison optimal and actual batch sizes.

Table 19 shows the monthly demand, the average batch size that has been produced and the ideal batch size in CCE cases. As can be seen in the table, the deviation is shown per pallet, this has been done since the storage costs are calculated per pallet and not per case. The number of CCE cases per pallet deviates per product and these ratios can be found in Appendix D: CCE case ratios. The total number of pallets produced is given and is multiplied with the difference in deviation of the actual and ideal situation. Finally, the number of weeks of stock is given to get an understanding of the total amount of times a product needs to be on the production planning each month.

Table 19: Actual and Optimized batch size comparison of Coca-Cola 0,2L bottles

	Demand CCE cases	Average batch size	Optimal batch size	Cost per pallet actual	Cost per pallet ideal	Nr of pallets	Potential saving	Weeks of stock
Jan	117.846	66.250	27.351	-€ 2,70	-€ 1,40	3.786	€ 4.918,53	0,93
Feb	161.136	47.218	30.098	-€ 1,55	-€ 1,00	1.348	€ 743,36	0,75
Mar	331.919	76.400	43.470	-€ 0,84	-€ 0,30	5.457	€ 2.954,61	0,52
Apr	164.744	67.667	30.362	-€ 1,29	-€ 0,98	2.900	€ 903,01	0,74
May	196.105	55.210	33.249	-€ 1,07	-€ 0,79	3.155	€ 885,42	0,68
June	513.357	79.389	53.478	-€ 0,24	€ 0,01	5.671	€ 1.451,65	0,42
July	115.360	52.000	27.854	-€ 1,68	-€ 1,44	2.229	€ 548,74	0,97
Aug	232.916	68.507	35.978	-€ 1,03	-€ 0,61	3.914	€ 1.611,91	0,62
Sept	222.480	52.568	34.926	-€ 1,05	-€ 0,66	3.755	€ 1.487,91	0,63
Oct	164.151	36.637	30.515	-€ 1,02	-€ 0,98	2.094	€ 89,42	0,74
Nov	229.163	55.567	35.972	-€ 0,82	-€ 0,63	3.175	€ 610,92	0,63
Dec	253.600	55.696	37.646	-€ 0,68	-€ 0,53	3.183	€ 460,52	0,59
Total yearly saving:							€ 16.666,01	

Line 3

A summary of the results per line has been made to give the reader a quick overview of the results. Table 20 gives this summary for line 3, what can be seen is that the current actual used batch sizes for the bulk group is far bigger as the optimum whereas the batch sizes of both the average as well as the minor group are smaller as the ideal scenario. The reason of this difference most likely lays in the fact that CCE is very afraid of having its products exceed the expiry date. Since this is very unlikely to happen with the bulk products they are willing to boost up these production runs as there is very little chance of these products not selling. Another reason for the bulk group's large volume is to up the total production yield by using the bulk's run high yield levels to compensate the low yield of the smaller runs.

Table 20: Overview batch size comparison line 3

Line 3: 0,2L RGB			
	Bulk Group	Average group	Minor group
Product	Coca-Cola	Fanta	Bitter Lemon
Average actual batch size	59.426	19.070	7.985
Average Optimized batch size	35.057	25.945	10.401
Average weeks of stock	0,68	2,67	4,27
Potential saving	€ 16.666,80	€ 2.378,91	€ 987,45

Line 4

As said before, line 4 only produces high volume Coke products so there does not exist a minor group on this line. As can be seen in Table 21, once again the bulk group's actual batch size far exceeds that of the optimized batch size. The average weeks of stock is only half a week in the ideal scenario, which might seem odd but by being able to greatly reduce the number of pallets in storage this way the total costs will be still lower than producing in a single run. Furthermore, this also improves flexibility as adjusting run size based on demand can be done more often and on shorter notice. The average group batch size is rather close to the ideal situation, so there won't be much to gain here. The reduction in the batch sizes for the bulk group and thus its inventory levels creates the required room for enlarging other production runs.

Table 21: Overview batch size comparison line 4

Line 4: 1,5L PET-bottles			
	Bulk Group	Average group	Minor group
Product	Coca-Cola 4P	Coca-Cola Zero 4P	-
Average actual batch size	35.044	20.837	-
Average optimized batch size	20.766	19.613	-
Average weeks of stock	0,52	1,51	-
Potential saving	€ 15.160,88	€ 2.449,27	-

Line 5

The main SKUs being produced at line 5 are 1,5L PET-bottles from every flavor except Coca-Cola therefore the bulk group of this line is not a Coke product but Fanta. As can be seen in Table 22 the actual batch size is larger than the ideal batch size for the bulk group which is in contradiction to the previous lines. One of the reasons for the larger batch size is that in order to achieve a positive yield result the line needs to run for a longer period given the fact that more drastic rebuilds are required in comparison to line 4.

Table 22: Overview batch size comparison line 5

Line 5: 1,5L PET-bottles			
	Bulk Group	Average group	Minor group
Product	Fanta X6	Fanta Zero X6	Fanta Cassis Zero X6
Average actual batch size	20.884	10.034	1.556
Average optimized batch size	43.535	16.460	4.687
Average weeks of stock	2,68	3,08	6,29
Potential saving	€ 22.311,37	€ 3.876,48	€ 5.454,86

A very important factor in the optimal batch size of the minor group is that it is essential to produce at the beginning of the month. This is beneficial since the expiry date is determined on the first of the month of the following month. Meaning that if one produces on the first week of the month, instead of the last, a whole month extra shelf time is acquired. Since the average weeks of stock of the minor group is very close to one third of the total expiry time, this trick will result in having far less chance of products going over CCE's expiry date.

Line 6

The focus of line 6 lays on the smaller PET-bottles and in particular on the 0,5L ones and the overview of this line is given in Table 23. In this case, both for bulk as for the average group the actual batch sizes are far smaller than the ideal situations. As for the minor group, since the demand for Sprite is so low, the optimized batch size based on the production costs would mean having over 8 weeks of stock. This is however impossible as this would result in having to throw away product as the product would be expired. Therefore the actual batch size is maintained since increasing it would lead to higher costs as would a decrease in batch size. Only if demand rises the batch size of the minor group can be increased.

Table 23: Overview batch size comparison line 6

Line 6: 0,5L PET-bottles			
	Bulk Group	Average group	Minor group
Product	Coca-Cola X24	Coca-Cola Zero X12	Sprite X6
Average actual batch size	22.842	9.130	1.281
Average optimized batch size	41.927	33.952	1.281
Average weeks of stock	2,09	3,8	6,66
Potential saving	€ 14.966,08	€ 4.677,59	0

Line 8

The can line only produces 0,33L cans in a wide variety of flavors. Once more, the optimal batch size for the bulk group is far larger than the actual batch size as can be seen in Table 24. The same goes for the optimal batch size of the average group, but what is truly interesting in this case is the fact that for the first time the optimal batch size for the minor group is smaller than the actual batch size.

There is however a very logical explanation for this when one looks at the cost price per syrup which can be found in Appendix F: Cost of syrup. As the costs price for most syrup is between two and three euros per liter, the cost price for Fernandes Green Punch is only 61 cents which is only around a quarter of the price of most of the other syrups. This means that the yield losses for Fernandes are far less drastic and that the storage costs play a more important role, thus reducing the ideal batch size.

Table 24: Overview batch size comparison line 8

Line 8: 0,33L cans			
	Bulk Group	Average group	Minor group
Product	Coca-Cola X24	Fanta X24	Fernandes GP X12
Average actual batch size	51.781	18.969	9.745
Average optimized batch size	97.796	50.415	8.009
Average weeks of stock	2,16	3,03	2,56
Potential saving	€ 25.679,62	€ 15.160,88	€ 514,60

4.3.3. *Conclusion of the batch size comparison*

When the optimal batch sizes are studied, some interesting facts come to light and rather different results per line can be seen. A short recap of the ratio between the current batch sizes and the optimal batch sizes are given in Table 25. First off, logically the most money can be saved by adjusting the batch sizes of the bulk group as they present the largest volume. However, a far larger number of SKUs falls in the average group and the actual saving per CCE case is much bigger in this group. This effect is the strongest on lines 6 and 8, where the optimized batch sizes are triple and double of the actual batch sizes.

Table 25: Recap of optimal batch size compared to current batch size

	Bulk group	Average group	Minor Group
Line 3	Half	Equal	Equal
Line 4	Half	Equal	-
Line 5	Double	Double	Triple
Line 6	Double	Triple	Equal
line 8	Double	Triple	Equal

Since all lines have multiple SKUs which fall in the different categories, the potential saving will run in the tens or even hundreds of thousands euros even with only an approximation of the optimal batch sizes. The exact number of the products per demand group for each of the production lines is given in Table 26. Moreover, since the batch sizes will be increased the stock levels tend to be higher thus reducing the risks of having to produce last minute due to a potential out of stock. The same more or less goes for the bulk group of these two lines, when larger batch sizes are being implemented a substantial amount of money can be saved.

Table 26: Number of products in demand group per line

	Line 3	Line 4	Line 5	Line 6	Line 8
Bulk Demand	1	2	3	2	2
Average Demand	3	12	8	4	4
Minor Demand	6	-	50	33	19

If the amounts calculated for the potential cost savings are multiplied with the number of products in Table 26, a rough estimate of the total potential saving can be made. This shows that a total sum of € 630.552,86 can be saved. This is however a very rough estimate, but it does clearly show the enormous improvement possible, if CCE were to optimize batch sizes via yield management.

For the Coca-Cola 24-pack a potential cost saving per CCE case of 1,09 eurocents is possible and for the Fanta 24 pack a cost saving of 1,75 eurocents is possible in the ideal situation. All though lean manufacturing suggest a constant strive for the lowest amount of stock should be the goal, this might not go for this case. A more realistic view would be to aim at a Minimum Reasonable Inventory (MRI) where any further attempts to decrease stocks would not be worthwhile (Grünwald, 1992)

As for line 3 and 4, the bulk group's optimal batch sizes should be reduced which will most likely lead to some friction from the operators who still firmly believe in "bigger is better" when it comes to run sizes. However since demand of these products is extremely high even when produced twice per week a positive yield is realized.

Therefore, it would be more financially beneficial if the run sizes would be reduced since this will result in lower storage cost and controlling stock levels is easier when there are two production moments per week since if sales are behind the second run can be decreased and if sales are far better than expected the second run can be increased. When done with care, it might even be possible to strive for a JIT delivery system and thus reducing storage costs to a minimum.

As for the minor group, enlarging the batch size of products on line 5 would mean a significant cost saving and a major potential reduction of the cost price per CCE case of 14 eurocents. The products of the minor group of line 3 also have a small financial benefit from being produced in larger volumes, but will most likely profit more from the reduced chances of planning changes due to the risk of going out of stock. For the other lines having larger batch sizes is simply not that beneficial due to the risks of expiry.

The comparison of the current and optimal batch sizes showed that the batch sizes of the bulk products may be reduced, but the batch sizes of average and minor selling products ought to be higher as in the current situation. By doing so, CCE is capable of saving hundreds of thousands of euros.

4.4 *Improving changeover performance: reducing cost of waiting*

During the analysis of the changeover times, it came to the authors attention that in many cases the set target times were not met. Furthermore, large deviation between the performance of the different teams have been found. Therefore, with the intent of minimizing production cost, a research in the potential cost saving of improving changeover performance has been done.

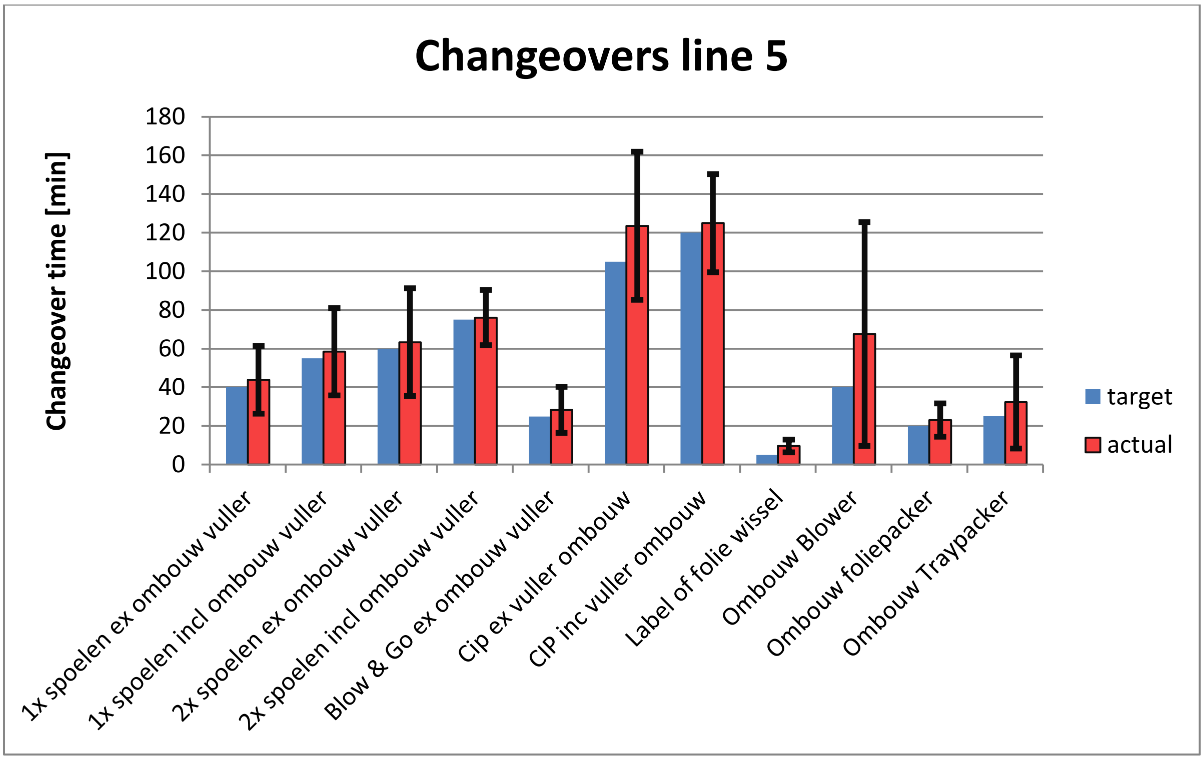

Figure 22: Comparison of calculated data and target times of line 5

The difference between the target times and the actual average changeover times is clearly shown in Figure 22 and Figure 23, where the changeover times have been presented in graphs. Furthermore, the standard deviation of the calculated data has been shown to give the reader an idea of the differences that occur in the changeover times. As can be seen, the target times are seldom made, causing production to be behind the production planning. If this delay becomes too big, this might result in the necessity to alter the production plan which leads to sub-optimalisations and additional costs.

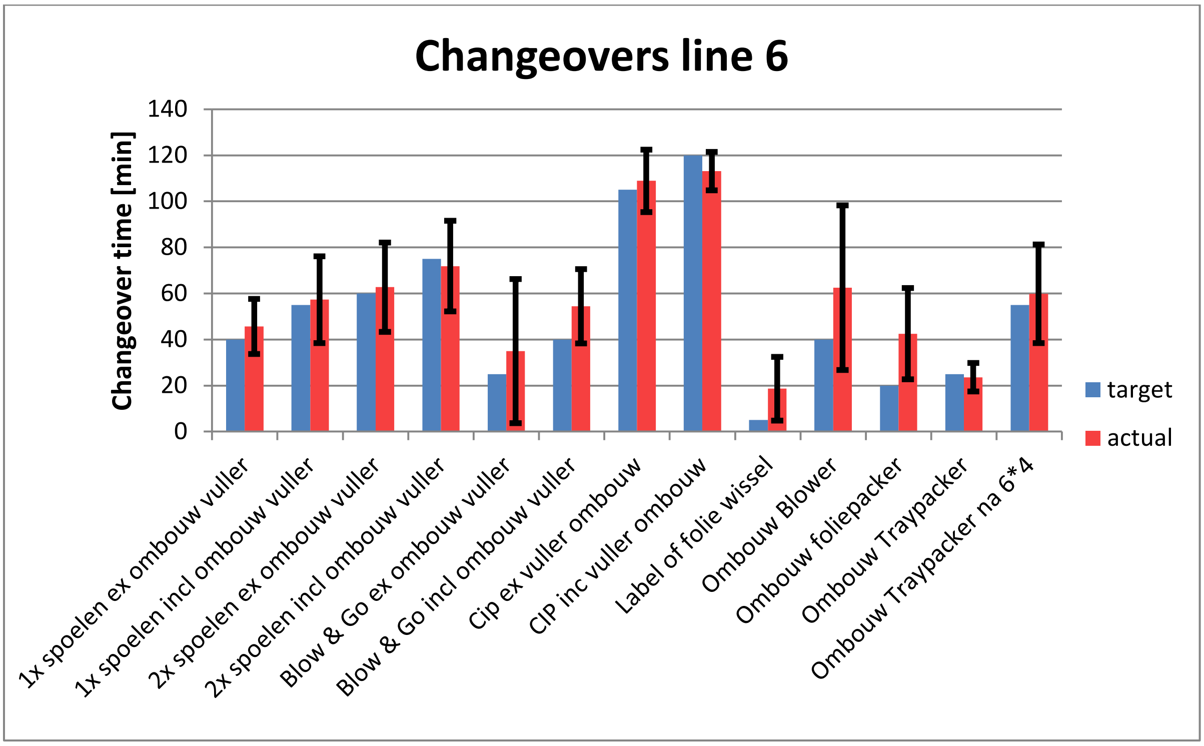

Figure 23: Comparison of calculated data and target times of line 6

Improving changeover performance is more than just increasing the speed of the changeover, the quality of the changeover is also taken into account. The speed of the changeover is expressed in the actual time in minutes that was required for performing the changeover whereas the quality of a changeover can be expressed by the LU of the first hour after a changeover. This is applicable since the higher the quality of the changeover, the higher the LU in the first hour. The total time of a changeover, the sum of the time the changeover took and the lost time due to a reduced LU is seen as the changeover performance and is expressed as the total idle time.

In order to see what the effect of improving the changeover performance has on the total cost, the analysis of the changeover data of 2013 will be used. Since the data can be sorted on which team leader was responsible for the changeover a distinction can be made of the on average best performing and least performing team leader per line per changeover and compare the results to get a realistic understanding of the potential savings.

4.4.1. *Current situation*

At first the current situation is analyzed, once again this has been done for all lines except 1 and 2 since they do not require any changeovers. The total time of all changeovers is calculated, including the time loss due to a reduction in LU in the first hour after the changeover. The total idle time caused by the reduction of the LU in the first hour following the changeover and the changeover time can be expressed in minutes with the help of the following formula:

$$T_{idle} = T_{co} + (100 - LU) * 60$$
$$T_{idle} = Idle\ time\ in\ minutes$$
$$T_{co} = Time\ of\ changeover\ in\ minutes$$
$$LU = Line\ Utilization$$

The total costs of the idle time is the number of idle hours times the size of the crew and the hourly pay per crewmember which has been set at € 30,- per hour. The results can be found in Table 27. In Figure 24 a graphical representation of the costs of idle time have been given, where it is easy to see that line 5 and line 6 are the biggest contributors to the total costs.

Table 27: Changeover performance current situation

	crew size	minutes	hours	costs of idle time
Line 3	10	8.087	134,79	€ 41.825,65
Line 4	9	9.097	151,62	€ 42.499,67
line 5	8	39.679	661,32	€ 165.536,25
line 6	8	32.042	534,04	€ 133.676,40
line 8	6	7.199	119,98	€ 22.834,03
total	31	88.018	1.466,96	€ 406.372,00

Around 74% of the total cost for idle time during changeovers is causes at lines 5 and line 6, which is due to the high number of changeovers not extremely remarkable but it does make it clear that the focus for improvements should lie on these two production lines.

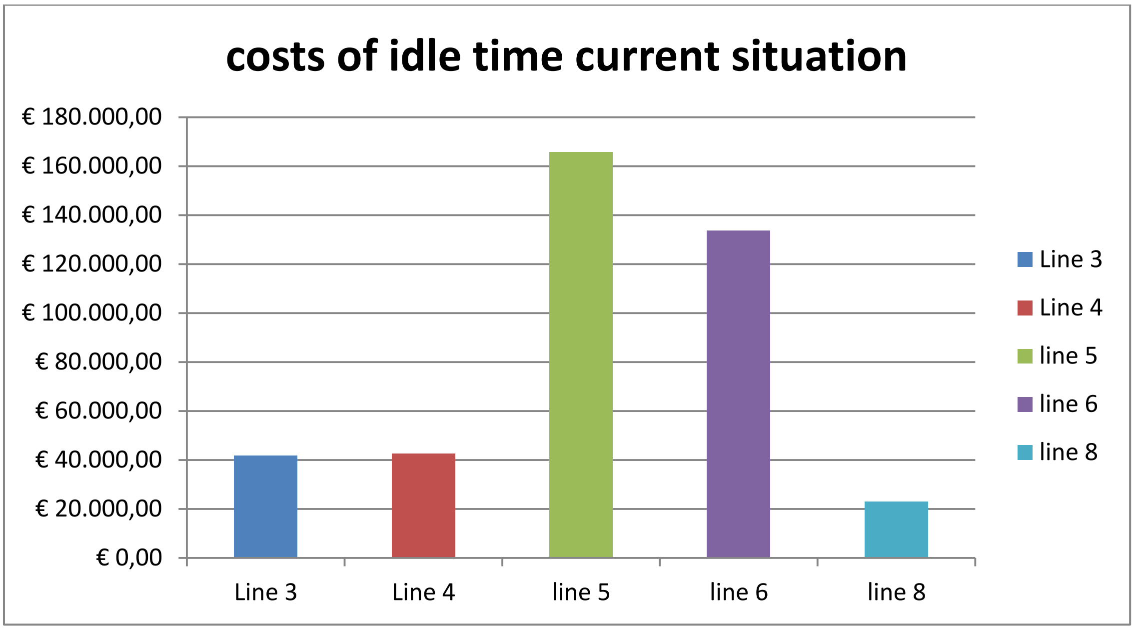

Figure 24: Cost of idle time current situation

4.4.2. *Worst case scenario*

In order to show the importance of training and experience and clearly mark the differences between the performances of different team leaders in changeovers a worst case scenario has been made in which only the worst scoring results are shown. Here, the same formula to calculate the costs of idle time during changeover as for the current situation has been used with the sole exception that the average result of the entire group of team leaders has been replaced by the average time the worst performing team leader. This thus gives an insight in the costs that would have been made if the level of expertise were equal to the worst performing team leader and gives information which changeovers at which lines suffer most from inexperienced personnel.

Table 28: Changeover performance worst case scenario

	Crew size	min	hours	Costs of idle time
Line 3	10	8.799	146,65	€ 45.508,07
Line 4	9	11.038	183,97	€ 51.567,84
line 5	8	48.782	813,05	€ 203.514,40
line 6	8	41.440	690,67	€ 172.882,44
line 8	6	9.410	156,85	€ 29.849,17
total	31	110.672	1.844,54	€ 503.321,93

Once more, first an overview of the calculated values is given in Table 28 and a graphical representation of the costs of idle time can be seen in Figure 25. As can be seen around 75% of the entire costs for idle time is causes by line 5 and line 6, which is logical as these represent by far the highest amount of changeovers.

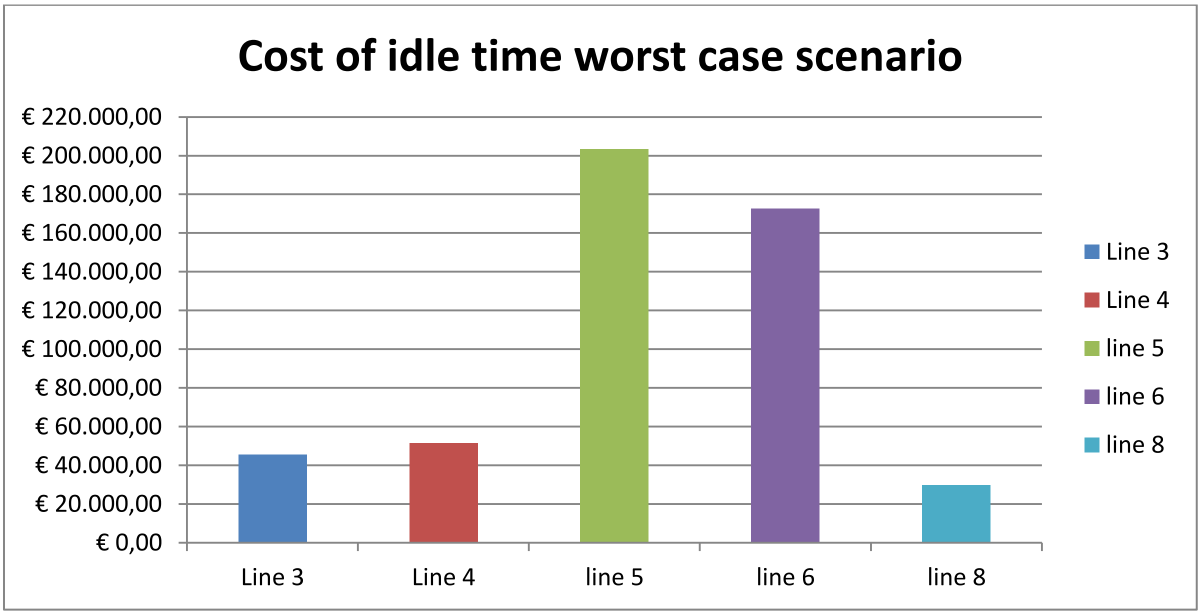

Figure 25: Cost of idle time in worst case scenario

4.4.3. *Best case scenario*

Just as for the worst case scenario, it is possible to calculate what would have been the total time required for all changeovers if the best performing team leader would have done all of the changeovers. This has been done in order to create an understanding of the idle time created by changeovers if properly trained and experienced personnel would have been involved in the changeovers instead of inexperienced personnel or a temporary employee. Furthermore, it gives insight in which types of changeovers on which line require additional training and of which ones this is most beneficial to do so.

Table 29: Changeover performance in best case scenario

	Crew size	min	hours	Costs of idle time
Line 3	10	7.714	128,58	€ 39.898,92
Line 4	9	7.226	120,44	€ 33.760,77
line 5	8	31.567	526,12	€ 131.693,95
line 6	8	23.581	393,03	€ 98.379,23
line 8	6	6.160	102,68	€ 19.540,98
total	31	68.536	1.142,27	€ 323.273,85

An overview of the idle time has been given in Table 29, in which it can be seen that once more line 5 and line 6 are the biggest contributors to the total cost of idle time. However, their contribution to the total is slightly less with 71% of the total as that it was for the current and worst case scenario meaning that not only the most profit can be achieved since the amount of changeover is higher the room for improvement at these lines is also bigger. A graphical representation of the costs of idle time in the best case scenario is given in Figure 26.

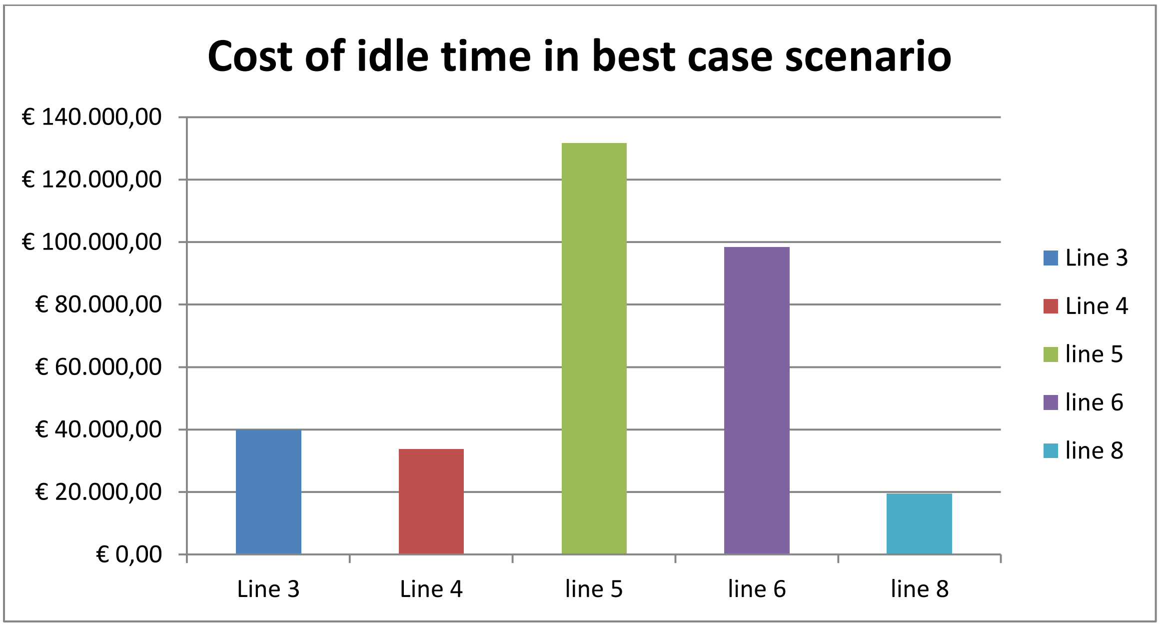

Figure 26: Costs of idle time in best case scenario

4.4.4. *Conclusion of changeover performance analysis*

When all data of the current situation, the best case scenario and the worst case scenarios are compared some very interesting results come to light. In Figure 27 the costs of the idle time caused by changeovers of all three scenarios are shown next to each other and a significant difference between them can be noted.

This difference is only caused by the changeovers that were filled in by the team leaders, if all changeovers of 2013 were to be taken into account this difference would be approximately be 1,5 times larger than the values that are being presented currently. As it is impossible to check the exact amount of changeovers that has been done in 2013 this will be left out of the research. However, in addition the possible costs saving per line divided by the amount of changeovers calculated is shown to give an impression in the amount that can be saved per changeover and the effect that a potential increase in changeovers will have.

The total costs of all changeovers of 2013 if they would have been done by the worst performing team leaders, so in the worst case scenario, would excess half a million euro. The costs in the current situation are only slightly over four hundred thousand euro. The total amount of idle time expressed in hours, which can be seen in Table 30, for the worst case scenario is 1844 hours per year whereas in the current situation only 1467 hours is lost meaning an additional 377 hours in total, so an average of around 75 hours per production line, of potential production time is lost. This effect is off course bigger on the production lines that cope with a lot of changeovers and smaller with the ones that have only a little amount of changeovers.

Table 30: Overview of the changeover performance results

	Minutes	Hours	Cost of idle time
Current situation	88.018	1.467	€ 406.372,00
Worst case	110.672	1.845	€ 503.321,93
Best case	68.536	1.142	€ 323.273,85

Moreover, when all changeovers would have been done by the best performing team leader, as has been calculated in the best case scenario, a reduction of just over € 80.000,- can be achieved which is an decrease of 20% in the costs of idle time. Furthermore, in the current situation, a total of 1467 hours of idle time is causes by changeovers. However, when the best case scenario is realized only 1142 hours of idle time can be noted. Thus, not only is there the financial benefit of € 80.000,- but there is also the potential to gain an additional 325 hours of production time on a yearly base.

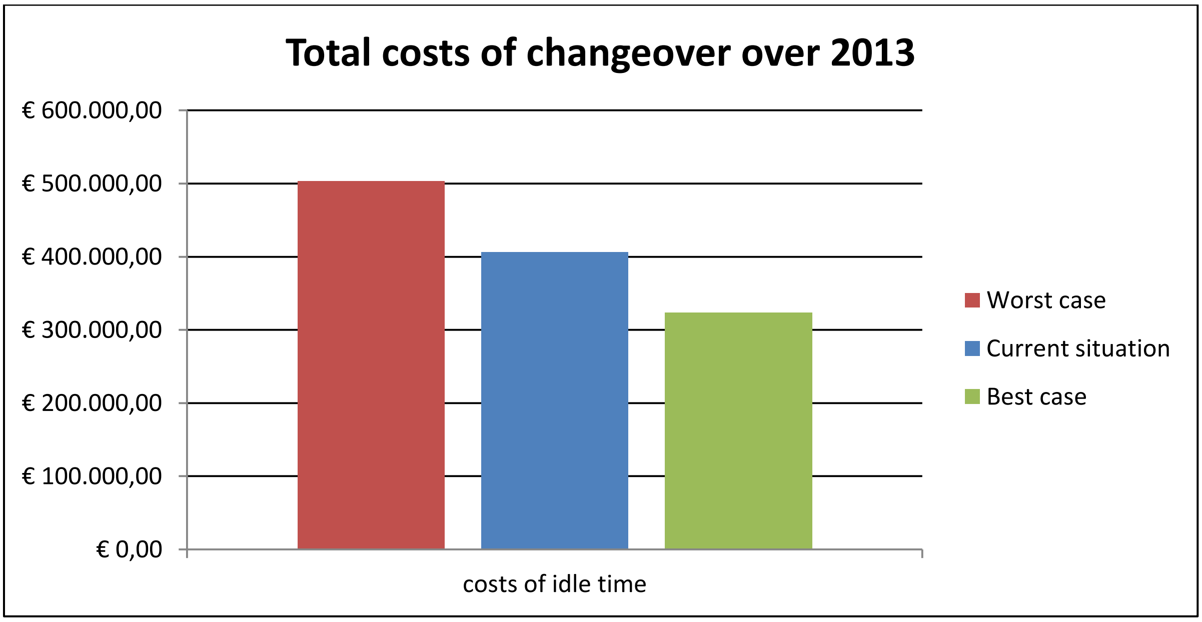

Figure 27: Total costs of changeovers in 2013

In order to see which of the changeovers had the biggest impact on the costs of idle time and therefore required the most attention all changeovers per line have been investigated. A list of the biggest potential cost savers to the idle time can be found in Table 31. The table gives the amount of minutes, hours and thus the potential saving that can be saved between the current situation and the best case scenario. The potential saving is solely calculated based on the reduction of idle time, if the additional benefit of gaining extra production time also would be taken into account the savings would even be bigger. This however is very hard to express in numbers and falls outside of the scope of this research.

Table 31: Points of interest changeover performance improvements

	min	Hours	Potential saving
Line 4			
1 x rinsing ex rebuild	733	12,22	€ 3.424,45
Rebuild foliepacker	950	15,83	€ 4.438,24
line 5			
1 x rinsing ex rebuild	2.536	42,27	€ 10.579,77
Blower rebuild	1.425	23,75	€ 5.944,86
Line 6			
1 x rinsing ex rebuild	1.444	24,07	€ 6.024,13
blow & go	2.011	33,52	€ 8.389,56
Rebuild foliepacker	1.570	26,17	€ 6.549,78
Rebuild traypacker 4 x 6	1.446	24,10	€ 6.032,47
line 8			
1 x rinsing ex rebuild	786	13,10	€ 2.493,06

In order to get an understanding of the reduction in cost per changeover, the total number of changeovers that have been taken into account per line is given alongside the average cost per changeover in the current situation and the potential saving per changeover in Table 32. In this table it is clear to see that the changeovers with the most effect are those of line 4, line 5 and especially that of line 6. As the number of changeovers will most likely rise in the future, it would be very wise if CCE decided to focus much attention on reducing the changeover times and thus costs as this proves to be a substantial cost saver.

Table 32: Potential saving per changeover

	Number of Changeovers	Average cost per changeover	Potential saving per changeover
Line 3	109	€ 383,72	€ 17,68
Line 4	179	€ 237,43	€ 48,82
Line 5	578	€ 286,39	€ 58,55
Line 6	426	€ 313,79	€ 82,86
Line 8	116	€ 196,85	€ 28,39

To sum up, by improving changeover performance the costs of waiting can be greatly reduced. A study on the performance of all team leaders showed large deviations in performance, resulting in higher costs. By giving proper training to get every team leader on the required level of expertise, around € 80.000 a year can be saved.

5. Implementation

Based on the insights acquired during the course of the research, a future strategy for the production planning has been developed. The way that CCE Dongen should plan their production according to the author will be a combination of the alteration of batch sizes, changeover performance and some other findings done during the course of this research. If done correctly, this will result in significant lower production costs and less downtime. Furthermore it will create a vision for CCE on the improvement points that they ought to focus on in the upcoming years if they want to maintain their advantage over their competitors.

5.1 *Making use of the model*

First off, it must be said that the CCE plant in Dongen is already performing well above average and processes are monitored and controlled very neatly with the help of MES programs. Especially considering the fluctuating demand in combination with the large amount of SKUs CCE Dongen has to cope with. None the less, it may be expected that the improvements will resort in major cost savings which are essential since CCE Dongen struggles with fierce competition.

With the help of the model, the production planning department at CCE is capable of determining the optimal batch sizes of the to-be-produced products for the upcoming week. Furthermore, whenever a change in the production planning arises, they are capable of calculating the additional costs as well as the effect it has on other batches. Since insight in the demand is essential for the model to work properly, close contact with the demand planners is essential.

The current production planning tool in SAP requires an update in order to stay effective, the most important update that is required is the mismatch in target times of changeovers and the actual time required. Since the difference between target times and actual changeover times can be substantial, this leads to large deviations between the production plan and actual production, causing all sorts of sub-optimizations and in some cases even results in having to cancel production runs.

If possible, the planning model should also take the run-up time for the production lines into account. Currently a factor of the theoretical capacity is being used for the expected capacity per hour, this factor is dependent on the run length. When a small run is produced this factor is lower as when a large run is being produced thereby accounting for the run-up effect. This however gives an unjustified planning at the start of the run, since production will be behind plan which might result in unnecessary stress and potential failures

In the future CCE Dongen should focus on optimizing of batch sizes in order to reduce production costs and on the improvement of the changeover performance. This will lead to a more stable production planning, as less deviation occurs and the critical products tend to have larger batch sizes. Furthermore, clear boundaries for minimal batch sizes can be set and the costs for last-minute changes in the production planning can be calculated giving CCE an important weapon in choosing whether or not it should accept these changes.

For the new strategy to succeed, CCE will need to get their personnel behind it as well which is of course the hardest part. Although making mistakes is only human and can be made because of a lack of training or experience, it is the authors believe that a lot of the mistakes that are being made are caused by a lack of interest and discipline. This is partially caused by the fact that many employees having been doing more or less the same work for years and sometimes even decades, which caused a loss of interest due to a lack of challenges.

As can be learned from the changeover performance analysis, getting everybody on board and especially giving proper trainings as to make sure everyone has the required level of expertise to fulfill their job requirements will be essential in improving productivity. As was found in the literature, reducing set-up time and costs will lead to a reduction in the production costs and thus it enables CCE Dongen to reduce batch sizes without losing profit (Allahverdi & Soroush, 2008).

5.2 *Peak demand*

Peak demands are, as was learned from the analysis of the demand, a frequently occurring issue at CCE. However, it is the authors believe that by handling these peak demands with care and in the right way, the stress on production can be maintained to a minimum. This does require doing some minor changes in the production planning process.

This starts with the way CCE looks at their stocks, as currently they maintain a method of days of sales that is based on the average demand of the upcoming two weeks. This however means that even if in the first week nothing is sold but the demand of the next week is very high production has to take place as soon as possible resulting in unnecessary stock during the first week. This method has proven to be rather inefficient especially for the products with very little demand of which demand fluctuations are very high. Especially since the past has shown us that predicted demand tends to have a substantial deviation from the actual sales, but logically the closer to the actual selling dates the more accurate the predictions get.

A very important factor that does have to be taken into account here is the risk of running out of stock if production is postponed, since this would mean that other runs need to be shortened and extra unfavorable changeovers have to be done in order to make sure that all clients can be supplied.

5.2.1. *Peak demand for bulk demand group*

For the peak demand of the SKUs that have high demand, like Coca-Cola and some Fanta products, a large potential costs saving can be achieved by adjusting the current production planning since the optimized batch size tends to have an upper limit. This upper limit is caused by the fact that these runs are easily long enough to gain favorable yield results. Only if demand is much lower than the average yearly demand a significant reduction in the optimal batch size can be noticed, this however is very rare for these bulk products.

In addition, the chances of these products expiring due to sales being behind are close to zero. Therefore, with peak demands for bulk products it is best to keep as close to the optimized batch size and when required schedule an extra production run. Since the forecast accuracy of the bulk products tends to be reasonably accurate, this will most likely not be necessary.

5.2.2. *Peak demand for average demand group*

Products that fall into the average demand group will be produced on a less regular basis if the optimal batch sizes will be followed. Depending on the product once every two or three weeks, in the case of peak demand this might mean that the period between two batches will be reduced if the chance of going out of stock becomes too large. The demand uncertainty of the average demand products is higher, creating the need to have larger stock levels in order to be able to maintain the high customer service level. The larger stock levels are created by enlarging batch sizes, giving an even more positive effect.

5.2.3. *Peak demand for minor demand group*

For the products with very little demand, peak demands can be around four times the average demand. Although the forecast accuracy of this group is rather poor, the true peaks are always due to a sales promotion known to CCE. In general, a peak will mostly mean that the time between two batches will be reduced with two weeks, since the higher stock levels should be able to cope with the demand. If according to the demand forecast production is required, a run with the calculated opimized batch size should be scheduled to enable complete customer service.

5.3 *Reducing batch sizes*

In the current situation, reducing batch sizes of most of CCE's products would be unwise, it can however be wise to look into ways to reduce batch sizes without an increase in production cost for the future. This can be beneficial in handling peak demands and the major fluctuations in demand in a cost efficient way.

Literature suggest that in order to do so CCE will have to reduce setup times and increase changeover performance in order to be able to produce smaller batch sizes in an economically feasible way (Kilpatrick, 2003) However, due to the high prices of the syrup, the most important factor in reducing batch sizes in a cost efficient way at CCE Dongen is by improving the production yield results for short production runs. Enabling high syrup yield results for small production runs will have a major impact on the feasibility of a production run. For example, for line 6 which deals with many changeovers and small runs, an improvement in the yield results of 1% can lead to a batch size reduction of over 10%.

Furthermore, there are enormous differences in the prices of syrup which has a big impact on the optimized batch sizes of the products. This can be clearly seen when Schweppes Tonic and Fernandes Red Grape are being compared. Although the products have an almost identical demand, the cost price of the syrup for Fernandes is only € 0,61 per liter and that of Schweppes is € 2,75 per liter. Their actual batch sizes in 2013 were next to identical, whilst the optimized batch size of Schweppes is 174 thousand cans and the optimized batch size of Fernandes is only 110 thousand cans.

In short, the preliminary model gives CCE the opportunity to quickly adapt to changes in demand and gives guidelines for minimal batch sizes. However, several changes in the current way CCE Dongen plans its production should be made in order to make optimal use of the proposed model and to reduce the chances of unnecessary delays.

6. Conclusion

CCE Dongen currently solely focuses on achieving the highest production efficiency by measuring the syrup yield, leaving several costs out of scope. By means of this research and within the limitations and assumptions of the project, an insight in the waste that occurs during production of carbonated sodas at CCE Dongen has been created. By analyzing the cost of waste and transforming this into a preliminary model based on a variation of yield management a more complete image of the production efficiency has been created. This has been done in order to answer the main research question:

How to optimize batch sizes at CCE Dongen from a production yield perspective facing fluctuating demand conditions?

With the help of lean thinking, the production planning process and the way changeovers are being dealt with have been analyzed, creating a clear image of their costs. The cost of waiting, defects, overproduction and inventory have been taken into account. With the help of a variation of yield management, a model was built based on the acquired data. By means of this model, the production costs for each batch size can be calculated, thus giving the user the possibility to calculate the optimal batch size for the expected demand based on the minimal production costs.

The production cost of the actual batch sizes of 2013 have been calculated with the help of the model and were compared to the optimized batch sizes for the given demands. A distinction between three product groups per line based on their demand has been made: a bulk group, an average group and a minor group. The changes in size of the batches that have to be made in order to go from the actual batch sizes of 2013 towards the optimal batch sizes are given in Table 33.

Table 33: Change from actual 2013 batch size to Optimal batch size

	Bulk group	Average group	Minor Group
Line 3	Half	Equal	Equal
Line 4	Half	Equal	-
Line 5	Double	Double	Triple
Line 6	Double	Triple	Equal
line 8	Double	Triple	Equal

If CCE focuses on staying as close as possible to the optimized batch sizes for its products calculated with the help of the developed model, a reduction in the production cost of around € 600.000 can be achieved. This especially goes for the products that require a far larger batch size to make full use of the production efficiency. Furthermore, as the batch sizes will grow, the number of changeovers will reduce resulting in higher line utilization.

During the analysis of the idle time due to changeovers, the author found significant differences in the performance per team leader. By comparing the performances of the different team leaders a distinction between a worst case, the current and the best case scenario were made to show the effect of proper training and experience. By means of employing the right personnel, a cost saving of over € 80.000 can be realized. Furthermore, the reduction in idle time creates an additional 325 hours of production time that can be won. In addition, the improvement of the changeover performance will reduce the chances of production staying behind of plan and thus an even larger potential cost saving may be assumed.

Currently, only the true bulk products such as Coca-Cola have the potential to give a financial benefit when the batch sizes are reduced. For almost all other products, especially for the group of products with an average demand, reducing batch sizes will only lead to an increase in production cost as this will reduce the yield results. In order to make a significant reduction of batch sizes economically feasible for CCE Dongen, the yield results for short production runs will have to increase drastically.

In order to take full advantage of the renewed production cost optimization, an increase of the batch sizes is required. This is contrary to the common perception found in literature that a reduction of the batch sizes leads to a reduction in costs. The larger batches are required due to the major impact the syrup yield results, which are very dependent on the run length, have on the feasibility of a batch. This strongly suggests that the point of minimum reasonable inventory has been surpassed. This shows the advantage of using yield management for batch size production companies, as this takes the advantage of larger batch sizes into account. Furthermore, the fast, fairly accurate and cheap method of modeling seen in yield management is ideal for a dynamic company facing products with fluctuating demands such as CCE.

In conclusion, by transforming the cost of waste into a model, much alike the ones used for yield management, the optimal batch sizes for each product can be calculated based on the expected demand. Since the model is dynamic, it is capable of adjusting the outcomes to the fluctuating demand conditions seen at CCE. Producing the optimal batch sizes enables a cost saving of over half a million euros, showing the potential of yield management models for production industries.

6.1 *Recommendations*

In order for CCE to further improve their production in the future there are several interesting options to take a look at.

Collaboration between branch plants

There is still quite a lot of competition between the different branch plants. Even though from time to time the different branch plants take over some production of the other plants, this only happens in exceptional cases such as strikes, extreme demand or supply shortages. Since these are always last-minute decisions, branch plants only accept these types of orders if they are favorable because this improves their production results or they get a financial gain.

Reevaluate core business goals

Coca-Cola Enterprises set out very ambitious goals for its supply chain and thus for its production plants. However, most of these goals have been set out from a sales perspective and it is very common that personnel focuses more on achieving their targets as to making logical choices. This is especially true at the end of each period, which can be seen from planners that purposely wait an extra week with ordering, as to reduce the DOS for products so they make their targets.

Get everyone on the required level of expertise

Although more and more processes at CCE are being automated, the production personnel is still an essential part of the process. As became clear from this research, getting this personnel at an acceptable level of expertise is crucial if the target times set for the changeovers must be achieved. Furthermore, it came to the author's attention that many unnecessary and costly mistakes were made in the production process that were most likely the result of either a lack of experience or disinterest.

Work with same system

Although the performance of CCE Dongen is measured in CCE Cases and sales tends to stick to this measurement as well, most of the personnel in Dongen uses amounts in actual cases. This is the cause for many misunderstandings in volume sizes since there are substantial deviations between the CCE cases and actual cases especially for the BIBs. Even though the idea of a fixed value is logical, the ratios are far from it, which can easily lead to misjudgments in operational management.

Differences syrup cost

Not only the mismatch in the case ratios gives a wrong image to the operation results, so does the fact that the prices for the different syrup strongly deviate. Since the syrup cost play a very important role in the economic feasibility of a batch size, it would be logical if this would be taken into consideration. However, run sizes are currently mostly judged on line utilization and yield results therefore favoring larger batch sizes. This is in great deal taken care of by using the model since the optimized batch sizes of the cheapest syrups are far lower than that of the expensive syrups. This is logical since the inventory holding cost become far more important. However, some of the syrups require far more effort to make as others, making this an interesting field for further research.

Choose your battles wisely

Since the amount of variables is enormous, it is very important that the focus for improvement processes is on the right projects. Furthermore, the goal of the project must stay clear. Reducing changeover time will have a positive effect on the economic feasibility of reduced batch sizes, but gaining better control of the yield results will be far more beneficial.

6.2 *Discussion*

All though the author strived to give an as realistic image of reality as possible, the enormous amount of variables that play a role in the choices being made at CCE makes this near to impossible, especially given the amount of time of the project. Therefore it should be noted that the research done is not, and most likely never will be, fully complete. However, it is the author's strong believe that the most important variables have been identified and been taken into account and that the research therefore does fulfill the requirements.

Since the model is merely a preliminary model, several potential improvement points a highlighted.

Yield results

In the current calculations the achievable syrup yield results are based on the line on which production takes place, however it might be arguable that the type of syrup plays a role as well. Even though in a small spot check no proof was found, this is not excluded. Furthermore, the filler operators will most likely play an important role in the achieved yield results as well.

Start/Stop losses

Although the assumptions made in the calculation of the amounts of syrup staying behind in the piping are fair, it still remains but an estimate. In order to get the true amounts mass flow meters need to be installed in the filler, so CCE is capable of accurately measuring the amount of syrup that stays behind in the piping.

Syrup room

Currently, the mixing of the syrup has been left out of the scope of the project. As for the production lines, the syrup room suffers from efficiency losses when smaller batches are being produced.

Especially considering the labor cost of making a small tank of syrup is next to equal as that of making a large tank of syrup. Furthermore, the proportional loss of syrup staying behind in tanks is smaller for large batches.

Yield management

The way of thinking introduced by yield management shows real potential for production companies such as CCE, facing fluctuating demands which have to make crucial choices on very short notice. However, further research is required in order to create a base model suitable for a wider variety of companies.

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Appendix A: Scientific Research Paper

How to optimize batch sizes at CCE Dongen from a production yield perspective facing fluctuating demand conditions?

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Abstract

Coca-Cola Enterprises faces a reduction in sales volume and large fluctuations in demand, resulting in smaller batch sizes that caused higher production costs. By means of lean thinking, insight in the contributors to the production costs is realised and with the help of a variation of the yield management model specialized for production companies the optimal batch sized based on minimal production costs have been calculated. The yield management model shows real potential for production companies facing large demand fluctuations that benefit from larger batch sizes.

I. Introduction

The past few years characterize a significant decrease in the sales volume of carbonated sodas in the Dutch market. This decrease is clearly visible at Coca-Cola Enterprises (CCE), the biggest bottler and distributor of the product portfolio of Coca-Cola Company in Europe. The Dutch market is primarily supplied by the Dutch CCE branch plant located in Dongen.

The premium brand status of Coca-Cola products forces CCE to have high customer service levels and does not allow for demand control via dynamic pricing. In addition, a competitive environment exists between different branch plants of CCE forcing the research to focus solely on CCE Dongen.

The annual sales volume of CCE Dongen in 2010 was around 50 million CCE cases, approximately 400 million liters of soda. The expected sales volume to retailers for 2014 is around 42 million CCE cases, a decrease in sales of approximately 15%. Next to the decrease in volume, retailers have become reticent in their communication around sales promotions, causing large fluctuations in the declining demand. The typical demand fluctuation of Fanta Orange cans is given in .

CCE Dongen produces over 180 Stock Keeping Units (SKUs), differentiated by a wide variety of flavors (Coca-Cola, Fanta, Sprite etc.) and different types of packaging (glass bottles, PET-bottles and cans). In order to cope with the market demands, changeovers on the production lines take place regularly.

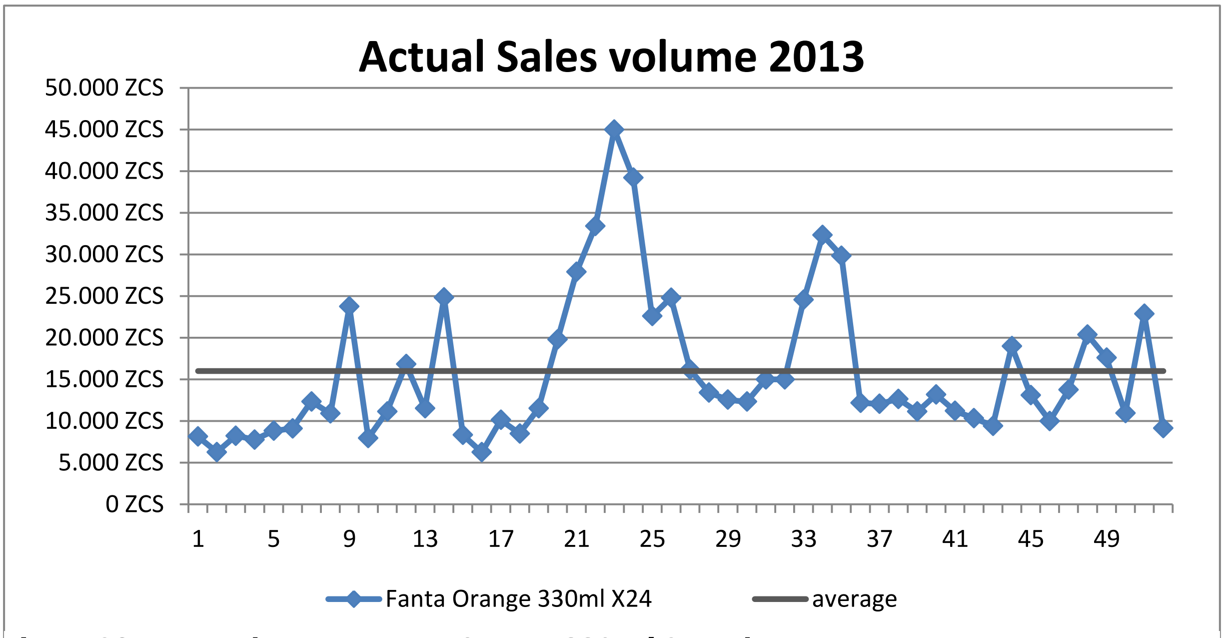

Figure 28: Demand pattern Fanta Orange 330 ml 24pack

The reduced sales and the demand fluctuations, in combination with an increase in the number of SKUs and a preferred reduction in lead-time has caused CCE Dongen to rethink the way they manage their production processes in order to stay competitive.

Currently, CCE primarily focuses on the syrup yield of a production run, which is the ratio between the amount of finished products and the theoretically possible amount of finished product based on the syrup intake. Several other costs of production are left out of the equation, creating a distorted view of the costs.

II. Method

To limit the increase of the cost per CCE case, an improvement of efficiency and effectiveness of production will be essential. In this case, efficiency is producing sodas with a minimum amount of waste and effectiveness is producing the sodas that the customers desire at that exact time. The question the author aims to answer with this research is the following:

How to optimize batch sizes at CCE Dongen from a production yield perspective facing fluctuating demand conditions?

By answering this question the author aims to realize a cost minimization and profit maximization without losing any flexibility and gaining control of production. Flexibility can be seen as the ease to alter the production planning and control as the influence CCE Dongen has on the batch sizes and order of the products that are to be produced.

In order to answer the research question, several sub-questions will need to be answered:

- Which forms of waste can be identified in the production process at CCE Dongen?
- Which forms of waste are relevant to this research?
- How was production performance improved in other industries?
- What are the costs of the relevant forms of waste?
- How can these costs be predicted via a model?

III. Theory

Lean thinking

By means of lean thinking all forms of waste that occur during the production processes have been identified (Womack & Jones, 2003`).

The types of waste and their respective costs that occur in the production process of CCE are:

- *Waiting:* Waiting consist of the idle time during changeovers and the run-up loss, both of which are expressed in the cost of personnel and electricity.
- *Defects:* The cost of defects is seen in the loss caused by syrup that stays behind in the piping during a changeover in flavor (i.e. from Coca-Cola to Fanta). As well as in the syrup yield since achieving the perfect mixing ratio requires some time, during which the target volume of finished product per liter syrup will not be achieved. The costs of syrup and syrup yield losses are the amount of extra used syrup multiplied by the price per liter.
- *Overproduction:* Since CCE Dongen produces perishable products, batch sizes may never be bigger than the demand before the expiry date.
- *Inventory:* When producing to stock, the inventory holding costs need to be taken into account. This is a fixed price per pallet per week.

Yield Management

Since the waste occurring at CCE is dependent on the batch sizes, regular production performance management philosophies, such as Just-In-Time are less suitable, as they do not take the beneficial effect that larger batches have on production losses into account. Therefore, a deviation of yield management has been used. Since yield management, commonly used in the aviation industry, focuses on gaining the maximum profit by modeling the outcome.

In order for yield management to work for CCE the focus will still lay on maximum profit per CCE case, but this will be realized by minimalizing the production costs per CCE case instead of maximizing the sales. Normally, the question yield management aims to answer is "how much should one sell at what price?" (Kimes, 1994). In the case of CCE the question yield management should answer would be "How large should the batch size of a specific product be based on the given demand?". To be able to answer this question and to minimize the production cost, all factors that contribute to the production cost need to be identified. Furthermore, in order for yield management to work an estimate of the expected production cost is required and the ability to predict the production cost via a model is essential.

One of the key characteristics of the yield management problem is that it has to be solved repeatedly, preferably every time new information is known. Because of this, any solution method must be fast, fairly accurate and not too expensive. Optimality is desired, but may not be as important as solving the problem quickly with a fair degree of accuracy (Kimes, 1989). The same goes for CCE, every time a new order comes in, they must be able to quickly get an understanding of the approximate batch size, with the lowest production costs. Thus stressing the need for knowledge of the contributors to the production costs and being able to model their behavior.

IV. Analysis

The idle time due to a changeover is caused by the time the acting team requires to perform said changeover. By investigating all changeovers of 2013, the average time per type of changeover per line has been calculated and can be used for the model. The cost of the changeover is based on the amount of hours (H), the number of people working simultaneously on the line (n), the hourly wages of the personnel (p) and the electricity costs per hour during downtime (e).

$$Cost_{stoppage} = H(n * p + e)$$

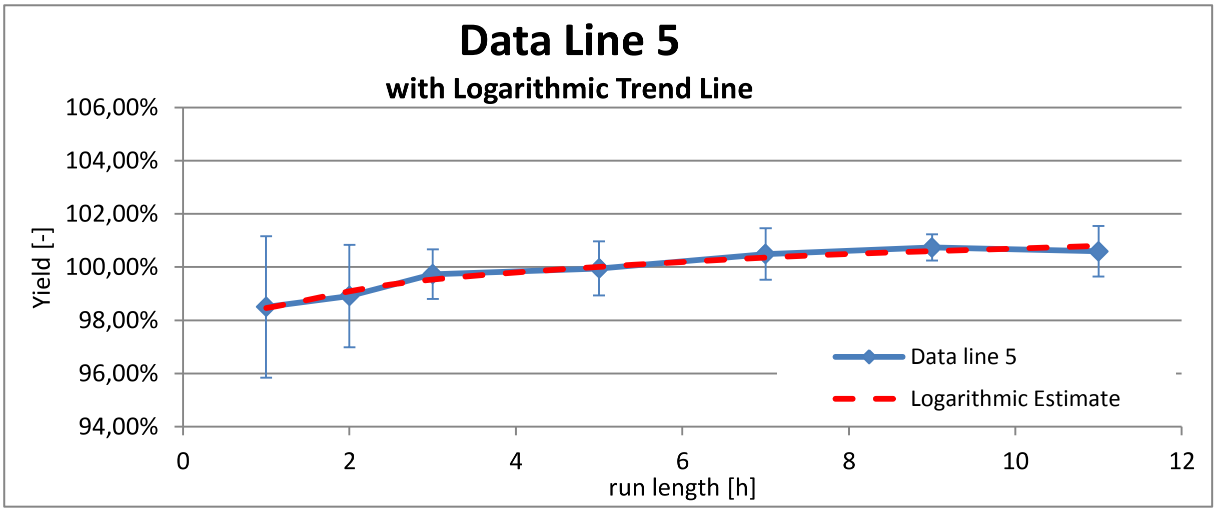

Figure 29: Representation of the yield results of production line 5

The run-up time has a negative effect on the LU of the first hour after the changeover, therefore the average LU after each changeover in 2013 have been studied. The total time lost due to a changeover, so both the changeover time as the run-up time is seen as waiting. The costs of the run-up times are dependent on the personnel and electricity

as well as the line utilization of the first hour following a changeover ($LU_{1st\ hour}$).

$$Loss_{Run-up} = 60 * (1 - LU_{1st\ hour}) * (n * p + e)$$

The start/stop losses are greatly dependent on the distance from the syrup tanks to the production line and the price of the syrup being used. This is caused by the fact that the difference between the most expensive syrup is over four times the price of the cheapest and that the largest distance between the tanks and filler is over five times that of the shortest distance.

The yield results show a pattern resembling a logarithmic function for each line, as can be seen in Figure 29. Although in some cases deviations do occur due to differences in the lines, such as overfill and production speed. Even though the deviations exist, the results do clearly show that it is safe to assume that an estimate of the yield results can be given before the production run. In order to be able to predict the outcome of the yield results of a production run beforehand the logarithmic function that is nearest to the gathered data is required, especially since this rule out the deviations.

V. Modelling

Predictive modeling of the yield curve

In order to successfully model the production cost, an estimate of the expected yield results is required. Therefore, predictive modeling is used. With the help of excel, the closest approximation of the yield data with a logarithmic function in the form of: $y = a\ln(x) + b$ was found with the help of the ordinary least square method. This method sums the square values of the deviation of the actual data and the proposed formula and searches for the formula which has the lowest sum. The yield curve of production line 5, alongside with the predictive modeled estimate is shown in Figure 29.

The model

All costs that are caused by these forms of waste have been calculated or measured and have been transformed into a preliminary model. With the help of the production data of 2013, the renewed, optimal production costs have been calculated for several characteristic products.

The products have been divided into three groups per line based on their demand: Bulk demand, Average demand and Minor demand.

Table 34: Changes in batch size from current to optimal

	Bulk group	Average group	Minor Group
Line 3	Half	Equal	Equal
Line 4	Half	Equal	-
Line 5	Double	Double	Triple
Line 6	Double	Triple	Equal
line 8	Double	Triple	Equal

With the help of the model, and based on the demand of 2013, the optimal size of a batch based on the renewed production costs have been calculated. The change in batch size to achieve the minimal sum of waste is shown in Table 34.

By choosing strategic batch sizes for specific product groups an enormous reduction in cost, potentially exceeding half a million euros, can be achieved. The increase in batch sizes for most product groups will cause higher inventory costs, but this is covered by higher yield performances. In addition, this will result in a reduction in the total amount of changeovers, reducing cost of waiting.

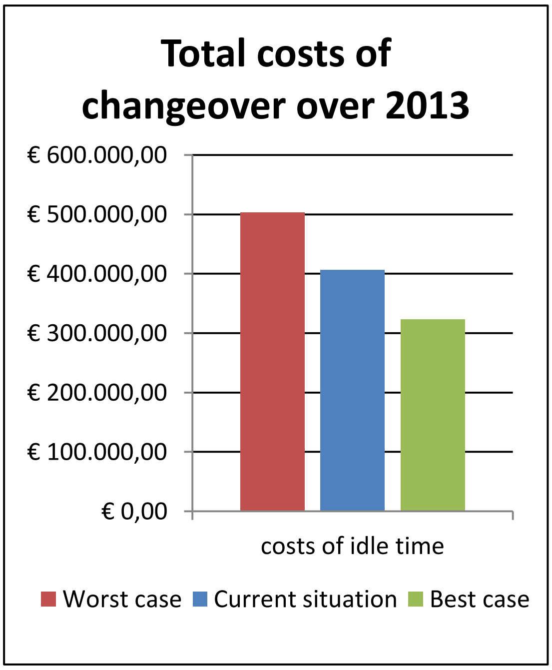

Figure 30: Total cost of changeover performance 2013

During the analysis of the changeover times, a comparison between the performances of the different team leaders has been made. In the worst case scenario, all changeovers were done by the poorest performing team leader and in the best case scenario all changeovers would have been done by the best performing team leader. By means of employing the right personnel that has been given adequate training, a cost saving of over € 80.000 per year can be realized. In addition, the reduction in idle time creates an additional 325 hours of production time per year and a more stable production planning is realized since fewer fluctuations in the changeover time occur.

VI. Conclusion

In order to take full advantage of the renewed production cost optimization, an increase of the batch sizes is required. This is contrary to the common perception of Just-In-Time that a reduction of the batch sizes leads to a reduction in costs due to lower inventory holding costs. The larger batches are required due to the major impact the syrup yield results have on the feasibility of a batch, since they are very dependent on the run length. This strongly suggests that the point of minimum reasonable inventory has been surpassed. This shows the advantage of using yield management for batch size production companies, since this takes the advantage of larger batch sizes into account. Furthermore, the fast, fairly accurate and cheap method of modeling seen in yield management is ideal for a dynamic company facing products with fluctuating demands such as CCE.

VII. Discussion

The enormous amount of variables that play a role in the choices being made at CCE makes this near to impossible to take into account every cost, especially given the amount of time of the project. Therefore it should be noted that the research done is not, and most likely never will be, fully complete. Further research into the syrup yield results, the start/stop losses and the mixing of the syrup will be required in order to get a full understanding of the production costs.

Furthermore, additional research in the workings of the yield management model for similar companies is required to properly show the workings of the model in production industries.

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Appendix B: Production process at CCE Dongen

Syrup Production

The first step of production is the preparation of syrup, which is done in the syrup room. Here the raw materials are converted into syrup and stored in tanks. Outside of the factory, right next to the syrup room two silos are situated that are dedicated for storing sugar that is used for the making of the base syrup.

The first step of making syrup is blending the sugar with water, the water is slightly heated up so that the sugar dissolves more easily. After this step a thick, substance with a very high sugar percentage is created called sugar-syrup. Logically, when making light or zero products instead of adding sugar, sweeteners such as stevia and aspartame are added.

The following step is to add concentrate, which contains the famous secret ingredient. The recipe of the concentrate is unknown to the workers at CCE and it is bought from the Coca-Cola Company factories in France, England or Ireland. Usually the concentrate consists of two or three different substances coming from different boxes. These boxes need to be carefully mixed in exactly the right quantities. Therefore, the sizes of these boxes demands minimum batch sizes and forces CCE to maintain specific batch sizes.

Finally some minor ingredients as citric acid and preservatives are added to create the base-syrup which is still a quite thick substance that contains high amounts of sugar. The base-syrup is stored in tanks, ranging between 15.000 and 63.000 liters. Due to the syrup-matrix, a mazelike system of pipes, it is possible for the each tank to supply each line and to supply multiple lines simultaneously from a single tank.

Mixing & Filling

When a line is ready for production, the operator gives a call to the syrup room to start pumping base-syrup to the mixer. In the mixer, water is added to create the actual soda. Depending on which product is being made, the mixing ratio of base-syrup and water is between 3 and 5,4. The right mixing ratio is checked by measuring the BRIX value. BRIX stand for the breaking index, which is an indication of the weight percentage of the sucrose in a water based fluid. In order for the sodas to pass the strict norms the BRIX has to be between two strict targets.

The performance of the filling is expressed as the yield of the line. The yield of the line is the amount of liters of approved product divided by the target volume. The target volume is based on the used volume of syrup times the mixing ratio. However, as the mixing ratio has a certain bandwidth, it is possible to achieve a yield of over 100%. This requires extremely accurate steering of the process and is therefore only possible with longer production runs.

The soda is pumped towards the filler and with the help of the venture effect CO_2 is added. The filler is a large rotating drum which allows for the line to continue to move and still have a decent amount of time to fill the bottles. If the filling time would be reduced, the products would start to foam and a lot of product would get lost and many bottles would be under-filled and thus rejected. Once filled the bottles or cans are sealed by either a cap or a lid.

Bottle blowing

In the case of the PET-lines, PET bottles are shaped to the correct shape and size in the blower hall; this is done by the bottle blowers. Each line has its own bottle blower capable of producing the required shapes and sizes for the line. Each size and shape has its own blowing mold. The plastic bottles come in the blowers as prefabs, which look a lot like test tubes. The main reason that the bottles are blown on location is because to transport costs would otherwise be far higher since the actual bottles are far bigger than the prefabs. The prefabs are simply heated up with the help of UV-lamps and are blown into shape with air pressure. Once the bottles are the right size and shape, they are being transported to the filler by air transport.

Packing & Stacking

Whilst the glass bottles will be simply put in a crate after filling, the PET-bottles and cans will have to be packed. There are several possible packages for both PET as for cans, examples are 4-packs and 6-packs of 1,5 liter bottles and a 24 tray of cans. At the entrance of the packer, the bottles will first be spread over the required amount of rails, which should be equal to the width of the pack. The next step is to separate the bottles for the packs length. This is done by so called "takers", they take the right amount of bottles by pressing them gently together and running alongside the line, if a tray is required this will now be put underneath the bottles. The final step of packing is putting shrinking foil around the bottles.

When required there is the possibility to add a handle to the packing so it is easier to carry. When this is not required the handle-machine simply functions as a passing station towards the palletloader.
In the palletloader, the packs are arranged in the right way as to fill the full width of the pallet. This goes on until the length of the pallet is reached to create a full layer of the pallet. This layer is then pushed upon the pallet and the pallet is lowered as to be able to receive the following layer. Each layer is separated with a sheet of cardboard. Once the pallet reaches its required height it is transported to the foil wrapping station and the pallet will be completely wrapped in foil to make sure

nothing falls of the pallet. The pallet now gets a label, is tagged and scanned and will be transported towards the warehouse for further handling.

Appendix C: Shelf live

Table 35: Shelf live of CCE Dongen products

Shelflive in months	0,33	0,5	1	1,5	2	0,20
Coca-Cola	12	4	5	5	5	18
Vanilla Coke	12					
Cherry Coke	12	4	5			
Coca-Cola Zero	6	4	5	5	5	6
Coca-Cola light Caffeine Free	6			5		
Coca-Cola light	6	4	5	5	5	6
Coca-Cola light lem.	6		5			
Dr. Pepper	11	8		8		
Fanta cassis	12	4		5		12
Fanta Lemon	12	4		5		
Fanta orange	12	4	5	5	5	12
Fanta Raspberry & Passion Fruit	12					
Fanta Lemon zero				5		
Fanta Orange zero	6	4	5	5		
Fanta pomelo				5		
Fanta cassis zero	6			5		6
Fanta Zero				5		
Fernandes Cherry Bouquet	18		6			
Fernandes Cream ginger			6			
Fernandes Green punch	18		6			
Fernandes super pineapple	18		6			
Fernandes Red Grape	18					
Fernandes Ch. Bouquet ligth	6		5			
Fernandes Gr. Punch light	6		5			
kinley Bitter Lemon						12
Kinley tonic						12
Nestea		12				12
Nestea lemon sparkling stevia	12		5			12
Schweppes Bitter lemon	11	8	8	8		11
Schweppes Bitter lemon light				5		
Schweppes Citrus Fusion		8		8		
Schweppes lemon fusion				8		
Schweppes American Ginger Ale	11		8	8		11

Schweppes Tonic Water (pungent)	11	8	8	8		11
Schweppes				8		
Schweppes	11			8		
Sprite	12	4		5	5	12
Sprite Stevia						12
Sprite zero	6			5		

Appendix D: CCE case ratios

Table 36: CCE case ratios

DESCRIPTION	CCE Cases per Piece	Pieces per Pallet	Liters Per Piece
5 L	1,321	92	5
10 L	2,642	64	10
19 L	5,019	40	19
20 L	5,284	40	20
250 L	66,05	1	250
0,2 L	0,041666667	1680	0,2
1,5 4P	0,083333325	480,000048	1,5
1,5 6P	0,083333333	660	1,5
1,5 X6	0,083333333	660	2,5
1,5 6P FR	0,083333333	528	1,5
1,5 96	0,083333	384,001536	1,5
1,5 12P	0,0833333	660	1,5
1,5 X12	0,0833333	660	1,5
2 X6	0,125	432	2
2 6P	0,125	480	2
2 X4	0,125	480	2
1 4P	0,083333333	672	1
1 6P	0,083333333	840	1
1 X6	0,083333333	840	1
1 X12	0,083333333	1008	1
0,5 X24	0,041666667	2016	0,5
0,5 X12	0,041666667	2016	0,5
0,5 4 x 6	0,041666667	1728	0,5
0,5 4 x 6P	0,041666667	1728	0,5
0,5 6 x 4	0,041666667	2016	0,5
0,33 24	0,041666667	2880	0,33
0,33 6 x 4	0,041666667	2880	0,33
0,33 4 x 6	0,041666667	2880	0,33
0,33 2 x 9	0,041666667	2688	0,33
0,33 21+3	0,041666667	2880	0,33
0,33 12	0,041666667	2904	0,33
0,33 3 x 8	0,041666667	2640	0,33
0,33 2 x 12	0,041666667	2880	0,33

Appendix E: Calculated losses of syrup

Table 37: Calculated start/stop loss line 3

Week	Average fill	loss	overfill	reject	Yield	start/ stop	Run s	loss per run
1	201,9	1995	1218	209	0	567	3	189
2	201,498	4041	1479	1099	-200	1663	7	238
3	201,8257	-490	1536	399	-3000	576	2	288
4	202,2	1447	1742	327	-1000	378	4	94
5	201,667	-280	1266	1366	-3500	588	3	196
6	201,4439	1741	1094	484	-500	663	6	110
7	201,8478	1607	852	275	0	480	2	240
8	201,5128	4371	1388	1284	200	1499	5	300
9	201,9577	2258	2136	595	-1000	527	2	264

Appendix F: Comparison optimal and actual batch sizes

Table 38: Comparison optimal and actual batch size

Coca-Cola 0,33L X24	Actually produced	optimal batch size	Differ-ence	Nr of pallets	total difference	Weeks of stock
January	127.022	72.960	-€ 1,39	1.059	€ 1.474,03	2,78
February	182.001	102.485	-€ 1,32	1.517	€ 1.998,17	2,61
March	245.520	103.576	-€ 2,10	2.046	€ 4.296,73	1,41
April	193.000	102.608	-€ 1,12	1.608	€ 1.809,15	2,64
May	185.001	102.958	-€ 1,72	1.542	€ 2.646,20	2,10
June	420.500	103.936	-€ 0,01	3.504	€ 36,41	0,73
July	148.915	84.579	-€ 0,58	1.241	€ 718,67	2,77
Augustus	282.000	103.333	-€ 0,63	2.350	€ 1.474,18	2,05
September	178.000	103.334	-€ 2,96	1.483	€ 4.385,01	1,78
October	150.000	87.724	-€ 1,38	1.250	€ 1.720,13	2,74
November	193.001	102.965	-€ 0,56	1.608	€ 905,26	2,50
December	189.074	103.092	-€ 2,68	1.576	€ 4.215,70	1,81
Total					€ 25.679,62	

Coca Cola 200ml	Actually produced	optimal batch size	Difference	Nr of pallets	total difference	Weeks of stock
Jan	264.996	27.351	-€ 1,30	3.786	€ 4.918,53	0,93
Feb	94.436	30.098	-€ 0,55	1.349	€ 744,15	0,75
Mar	382.000	43.470	-€ 0,54	5.457	€ 2.954,61	0,52
Apr	203.000	30.362	-€ 0,31	2.900	€ 903,01	0,74
May	220.838	33.249	-€ 0,28	3.155	€ 885,42	0,68
June	396.943	53.478	-€ 0,26	5.671	€ 1.451,65	0,42
July	156.000	27.854	-€ 0,25	2.229	€ 548,74	0,97
Aug	274.008	35.978	-€ 0,41	3.914	€ 1.611,91	0,62
Sept	262.839	34.926	-€ 0,40	3.755	€ 1.487,91	0,63
Oct	146.549	30.515	-€ 0,04	2.094	€ 89,42	0,74
Nov	222.269	35.972	-€ 0,19	3.175	€ 610,92	0,63
Dec	222.784	37.646	-€ 0,14	3.183	€ 460,52	0,59
Total				-€ 16.666,80		

Fanta 200ml	Actually produced CCE cases	Optimal batch size	Difference	Nr of pallets	total difference	Weeks of stock
Jan	13.397	15.914	-€ 0,10	191	€ 19,11	3,47
Feb	53.588	25.857	-€ 0,10	766	€ 79,35	2,92
Mar	46.889	40.739	-€ 0,59	670	€ 394,74	2,12
Apr	36.839	25.720	-€ 0,03	526	€ 13,37	2,93
May	33.491	25.725	-€ 0,43	478	€ 207,82	2,72
June	73.685	26.153	-€ 0,13	1.053	€ 141,99	1,39
July	30.142	21.639	-€ 0,36	431	€ 156,51	3,15
Aug	36.793	25.898	-€ 0,44	526	€ 229,55	2,68
Sept	30.143	25.935	-€ 1,21	431	€ 519,27	2,29
Oct	36.840	25.866	-€ 0,33	526	€ 171,18	2,91
Nov	36.843	25.938	-€ 0,33	526	€ 174,78	2,90
Dec	60.285	25.953	-€ 0,31	861	€ 271,22	2,54
					€ 2.378,91	

Bitter Lemon 200ml	Actually produced	Optimal batch size	Difference	Nr of pallets	total difference	Weeks of stock
Jan	6.583	7.352	-€ 0,08	94	€ 7,59	5,01
Feb	9.802	9.250	-€ 0,05	140	€ 7,11	4,86
Mar	8.168	12.952	-€ 0,77	117	€ 90,28	4,01
Apr	13.068	10.725	-€ 1,24	187	€ 230,78	3,98
May	6.534	11.623	-€ 1,39	93	€ 129,93	4,08
June	16.336	12.399	-€ 0,80	233	€ 186,98	3,79
July	8.168	11.063	-€ 0,47	117	€ 54,36	4,05
Aug	13.069	11.701	-€ 0,08	187	€ 14,94	4,05
Sept	6.534	11.377	-€ 1,28	93	€ 119,28	4,15
Oct	13.117	8.900	-€ 0,63	187	€ 117,12	4,34
Nov	6.583	8.278	-€ 0,30	94	€ 28,10	4,66
Dec	18.241	9.188	€ 0,00	261	€ 0,98	4,30
Total					-€ 987,45	

Appendix F: Cost of syrup

Table 39: Syrup prices

price/L [€]	Name:	Brand:	Flavour:
2,08	SYRUP CC CH/CL-1.10	COKE	CHERRY
2,25	SYRUP CV CL/VA-0003.00/001	COKE	VANILLE
2,09	SYRUP CHERRY COKE CL/CH-3001.000	COKE	CHERRY
2,11	SYRUP SP/D-74.641	SPRITE	ZERO
2,42	SYRUP COKE LIGHT LEMON 7095.887	COKE	LIGHT LEMON
2,20	SYRUP CF COKE LIGHT DK/S-80.397	COKE	FREE LIGHT
1,89	SYRUP FORZ OR/D-1127.501	FANTA	ZERO ORANGE
1,71	SYRUP FOR OR-1127.001	FANTA	ORANGE
1,72	SYRUP FLE LE-482.001	FANTA	LEMON
1,60	SYRUP FLEZ LE/D-482.501	FANTA	ZERO LEMON
1,66	SYRUP FLE LE-442.101	FANTA	LEMON
1,67	SYRUP FOR OR-1084.101	FANTA	ORANGE
1,68	SYRUP KBL BT/LE-84.101	KINLEY	BITTER LEMON
2,18	SYRUP CR CC/DS HR	COKE	REGULAR
3,09	SYRUP CZ DJ-4451.6913 HR	COKE	ZERO
4,10	SYRUP NPE TE/PE-34.001	NESTEA	PEACH
2,20	SYRUP CL DK-4086.3913	COKE	LIGHT
3,10	SYRUP CL DK-4086.3913 HR	COKE	LIGHT
2,20	SYRUP CL DK-95.397	COKE	LIGHT
1,85	SYRUP SP SP-127.001	SPRITE	LEMON
2,00	SYRUP SP SP-127.002 HR	SPRITE	LEMON
2,16	SYRUP FOR OR-1084.102 HR	FANTA	ORANGE
1,64	SYRUP FOR OR-1084.001	FANTA	ORANGE
1,51	SYRUP DRP 86005717/0001	DR PEPPER	MIDCAL
1,95	SYRUP FRF BE-129.001	FANTA	RED FRUIT
2,61	SYRUP SWTF 86005844/0001	SCHWEPPES	TROPICAL FUSION
2,65	SYRUP SWCF 86005545/0002	SCHWEPPES	CITRUS FUSION
2,75	SYRUP SWTO 86002830/0007	SCHWEPPES	TONIC
1,93	SYRUP SBLL 86005865/0001	SCHWEPPES	BITTER LEMON LIGHT
2,30	SYRUP SWGA 86005483/0004	SCHWEPPES	GINGER ALE
2,27	SYRUP SWBL 86005841/0001	SCHWEPPES	BITTER LEMON
1,53	SYRUP FPOZ GF/D-291.501	FANTA	ZERO POMELO
2,12	SYRUP FTR FP/B-433.10	FANTA	STILL TROPICAL
0,54	SYRUP FSP FGS 002	FERNANDES	SUPER PINEAPPLE
0,58	SYRUP FCG FGS 001	FERNANDES	CREAM GINGER

0,61	SYRUP FRG FGS 003	FERNANDES	RED GRAPE
0,21	SYRUP FGPL FGS 009	FERNANDES	GREEN PUNCH LIGHT
0,61	SYRUP FGP FGS 008	FERNANDES	GREEN PUNCH
0,76	SYRUP FCB FGS 005.03	FERNANDES	CHERRY BOUQUET
0,37	SYRUP FCBL FGS 007.03	FERNANDES	CHERRY BOUQUET LIGHT
2,08	SYRUP SP SP-74.1011 HR	SPRITE	LEMON
1,68	SYRUP FOR OR-1127.101	FANTA	ORANGE
2,17	SYRUP FOR OR-1127.102 HR	FANTA	ORANGE
2,78	SYRUP SWLF 86005803/0003	SCHWEPPES	LEMON FUSION
2,62	SYRUP FCA BC-67.001/.002	FANTA	CASSIS
2,41	SYRUP FCAZ BC/D-68.501/.502	FANTA	CASSIS ZERO
3,44	SYRUP NLSP TE/LE-100.005	NESTEA	LEMON SPARKLING
2,20	SYRUP CZ DJ-4451.6913	COKE	ZERO
2,71	SYRUP SWAL 86006522/0001	SCHWEPPES	APPLE LIME FUSION
2,03	SYRUP SP/B-0135.003 HR	SPRITE	LEMON
1,85	SYRUP SP/B-0135.002	SPRITE	LEMON
4,09	SYRUP NPE TE/PE/B-34.201	NESTEA	PEACH
2,61	SYRUP NLSP TE/LE/B-161.001	NESTEA	LEMON SPARKLING
3,46	SYRUP NLSP TE/LE/B-161.002	NESTEA	LEMON SPARKLING
3,54	SYRUP NLSP TE/LE-160.002	NESTEA	LEMON SPARKLING
4,21	SYRUP NPE TE/PE/B-34.601	NESTEA	PEACH
2,62	SYRUP NLSP TE/LE-160.001	NESTEA	LEMON SPARKLING
2,20	SYRUP CL DT-71.727	COKE	LIGHT
3,52	SYRUP NLSP TE/LE/B-161.102	NESTEA	LEMON SPARKLING
1,90	SYRUP SP/B-142.000	SPRITE	LEMON
2,08	SYRUP SP B-142.002 HR	SPRITE	LEMON
1,90	SYRUP SP B-142.003	SPRITE	LEMON
2,04	SYRUP FSTR FP/B-650.001	FANTA	STILL TROPICAL
2,11	SYRUP SPZ SP/D-74.645	SPRITE	ZERO
2,12	SYRUP FRP RA/PA/B-0009.10-B01	FANTA	RASPBERRY PASSIONFRUIT
0,63	SYRUP FPM FGS 010.03	FERNANDES	PINK MELON
2,06	SYRUP COCA-COLA	COKE	REGULAR
1,93	SYRUP SPRITE SP-74.105	SPRITE	LEMON
2,20	SYRUP COCA-COLA ZERO DJ-4251.697	COKE	ZERO
1,90	SYRUP KIN TONIC WATER TW-40.097	KINLEY	TONIC

Appendix G: Changeover time evaluation

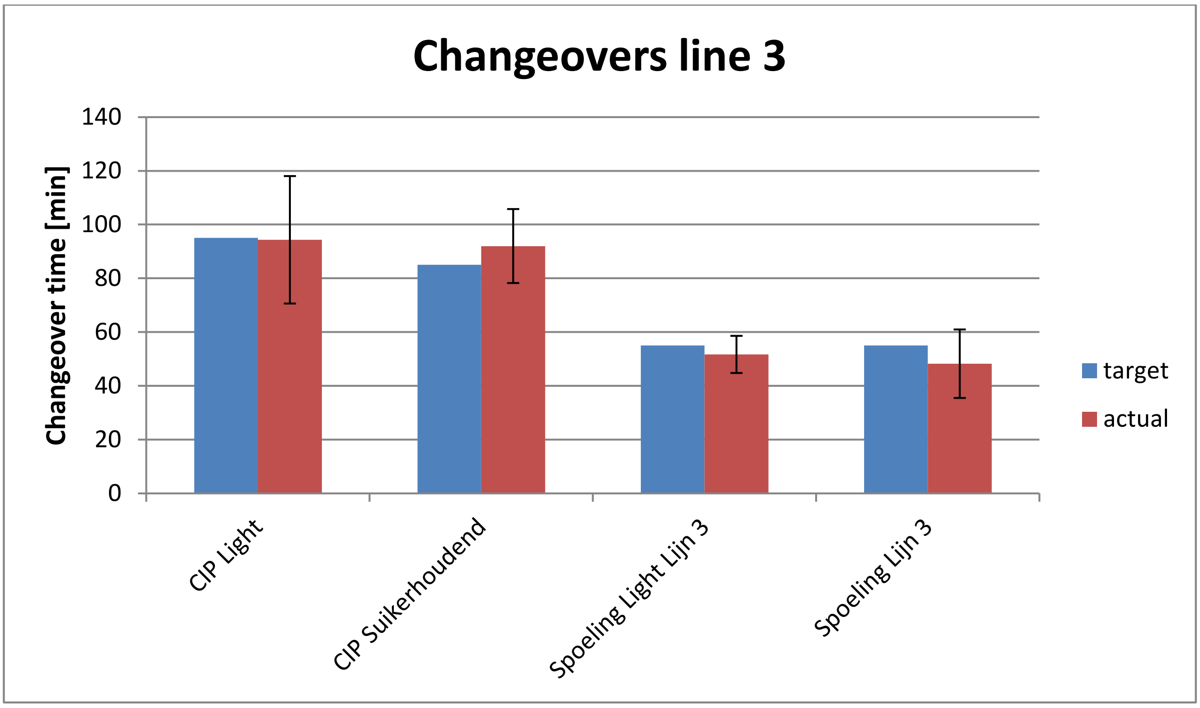

Figure 31: Comparison calculated data with target times line 3

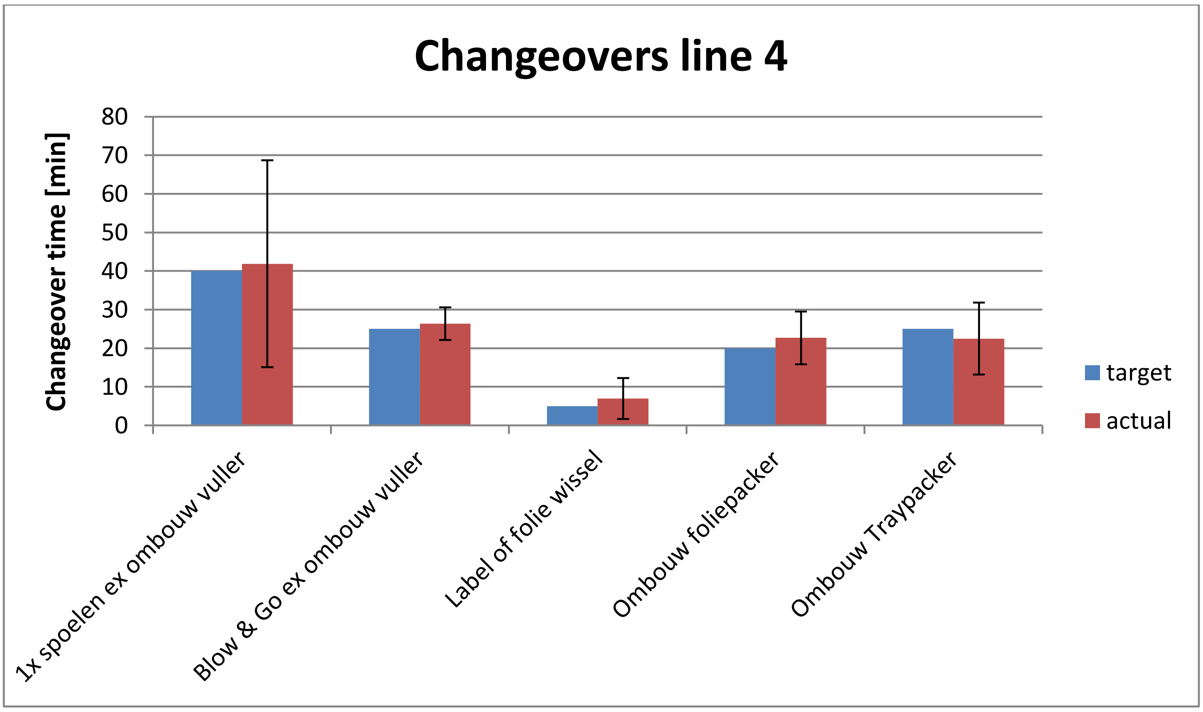

Figure 32: Comparison calculated data with target times line 4

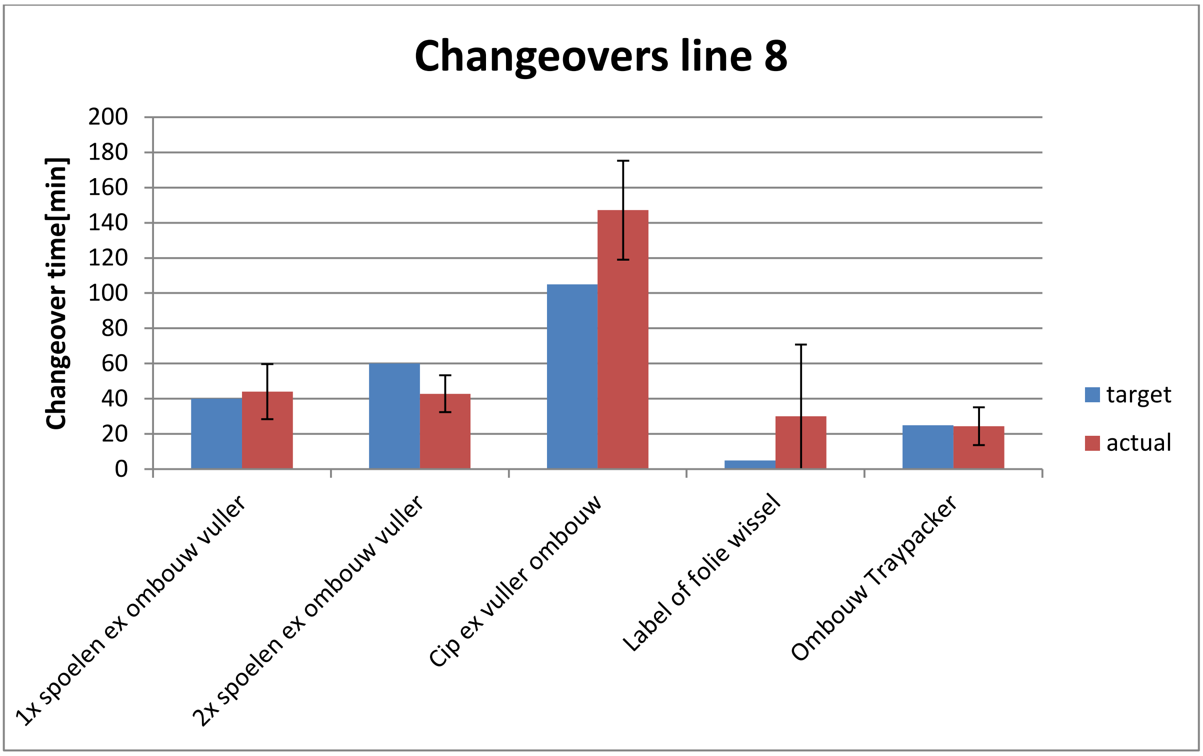

Figure 33: Comparison calculated data with target times line 8

Appendix H: Line capacity

Table 40: Production speed per line

			Line Running Speed 2014 Budget
DO1	BIB 250L	BIB 250L	25
DO2	BIB 05L	BIB 05L	600
	BIB 10L	BIB 10L	500
	BIB 20L / BIB 19L	BIB 20L / BIB 19L	400
DO3	Glass 0,2L contour	Coca-Cola	40.000
	Glass 0,2L contour lt/zro	Coca-Cola Light	36.000
		Coca-Cola Zero	36.000
	Glass 0,2L Ginger/Tonic	Kinley Tonic	30.000
		Nestea Lemon	30.000
		Ginger Ale	30.000
		Schweppes Tonic	30.000
	Glass 0,2L FTA/SW/Kinley	Kinley Bitter Lemon	38.000
		Fanta Orange	38.000
		Schweppes Bitter Lemon	38.000
DO4	PET 1.5 L 4P CF CCLT	PET 1.5 L 4P CF CCLT	24.000
	PET 1.5 L 4P	4P	30.000
	PET 1.5 L 6P FR	6P FR	26.000
	PET 1.5 L 6P	6P	30.000
	PET 1.5 L DOLLY 24x4P	PET 1.5 L DOLLY 24x4P	30.000
	PET 1.5 L DOLLY x96	96	30.000
DO5	PET 1.0 L	1	30.000
	PET 1.5 L 4P	4P	24.000
	PET 1.5 L 6P	6P	30.000
	PET 1.5 L 12P	12P	30.000
	PET 2.0 L	2	24.000
DO6	PET 0.5 L	0,5	32.000
	PET 1.5 L 4P	4P	24.000
	PET 1.5 L 6P	6P	30.000
	PET 1.0 L	1	30.000
DO8	CAN 0.33 L x24	CAN 0.33 L x24	120.000
	CAN 0.33 L 12P	CAN 0.33 L 12P	120.000
	CAN 0.33 L 4P	CAN 0.33 L 4P	120.000
	CAN 0.33 L 2x9 7+2	CAN 0.33 L 2x9 7+2	120.000
	CAN 0.33 L 12P	CAN 0.33 L 12P	120.000

CAN 0.33 L x24	CAN 0.33 L x24	90.000
CAN 0.33 L 12P	CAN 0.33 L 12P	45.000
CAN 0.33 L 4P	CAN 0.33 L 4P	90.000
CAN 0.33 L 2x9 7+2	CAN 0.33 L 2x9 7+2	60.000
CAN 0.33 L 12P	CAN 0.33 L 12P	90.000