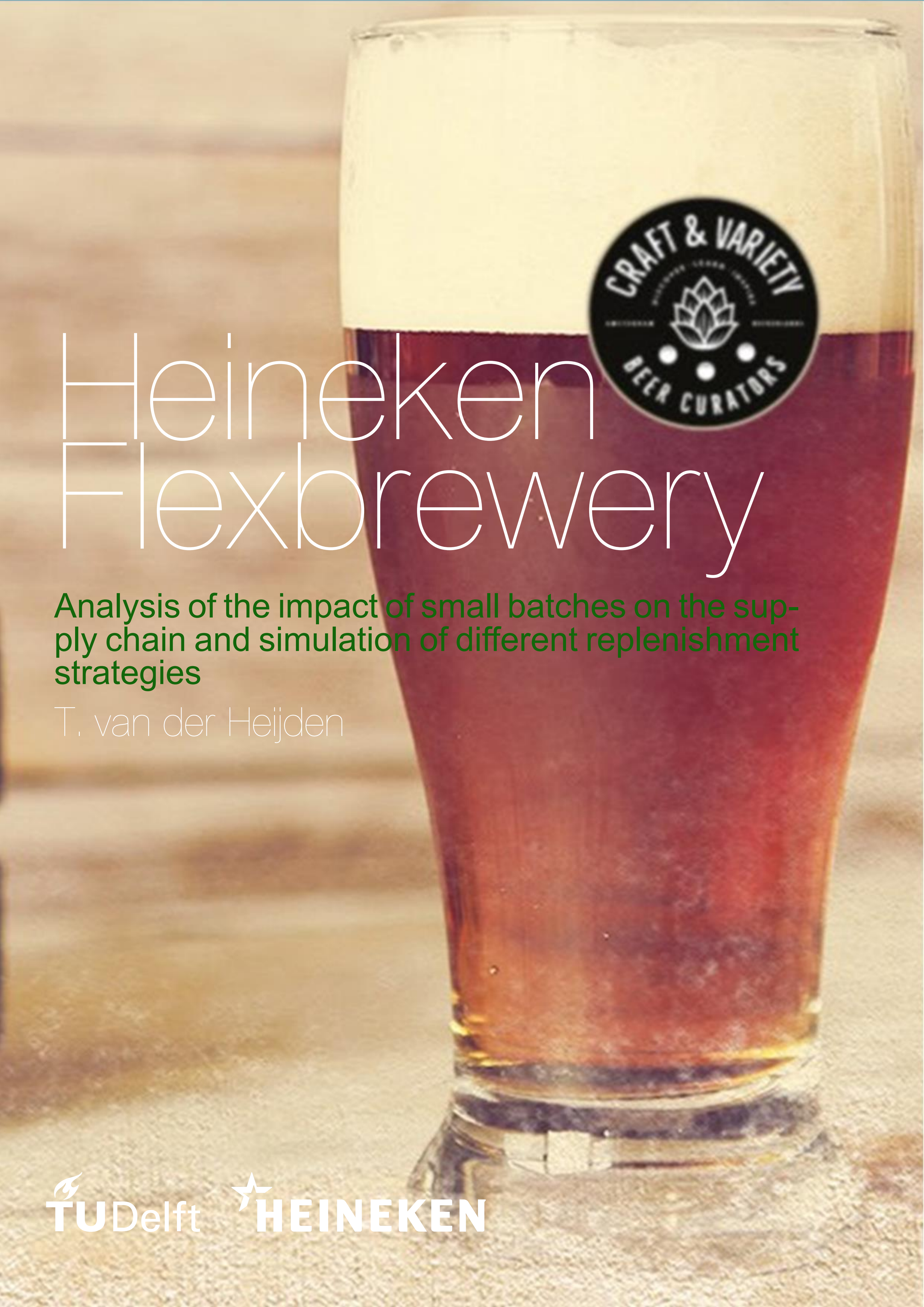

Heineken Flexbrewery

Analysis of the impact of small batches on the supply chain and simulation of different replenishment strategies

T. van der Heijden

TU Delft HEINEKEN

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by

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to obtain the degree of Master of Science
at the Delft University of Technology,
to be defended publicly on Monday October 22, 2018 at 02:00 PM.

Student number:	4011945	
Report number:	2018.TIL.8279	
Project duration:	December 4, 2017 - October 22, 2018	
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Preface

Dear reader,

The report that lays before you is the last piece of the puzzle that completes my master Transport, Infrastructure & Logistics at Delft University of Technology to obtain the degree of Master of Science.

This last piece of the puzzle was created during a internship at Heineken. A year ago, Arjen van Diepen brought me into contact with Rob Tummers. Rob and I agreed that we could help each other and defined a project with Rob as my company supervisor. To make this project into a master thesis project I got help from my university supervisors Jaap Vleugel, Wouter Beelaerts van Blokland and Rudy Negenborn.

I have experienced this project as fun and informative. At Heineken I got the chance to find my own way in a big organisation with the right guidance when I needed it. From my university supervisors I received the right tools to make this project a success.

Therefore I want to thank all my supervisors, I am truly grateful for all the support. Thank you Rob, Jaap, Wouter and Rudy. Next to my supervisors I also want to thank my friends and family for all the support they gave me. You where always helpful and kind to me during my thesis and the other years spend at the University. Without you it wouldn't be the same. Thanks! Finally I want to say special thanks to my girlfriend who was there for me every day.

Thomas van der Heijden
Utrecht, October 2018

Summary

DEFINE

Heineken is one of the biggest brewers in the world, in order to remain this position they have to follow market trends closely. The last few years craft beer is getting more and more popular. In 2017 craft had a market share of 10% in the Netherlands and was after non-alcohol the category with the biggest growth. Heineken already had several craft beers in their portfolio, but what was missing were local brands. Since Heineken customers wants to offer the full portfolio and Heineken could not offer it themselves they allowed free riders. To make this no longer necessary, Heineken want to offer their customers their own local brands.

Local brands, means smaller demand what leads to smaller batches. The existing Heineken breweries in the Netherlands are not capable of brewing such small batches, so a new brewery has to be implemented. This brewery is called the flexbrewery because it has to be able to brew a brought variety of beers. The batch size and variety of beers has an impact on the supply chain and this research wanted to get a grip on this impact by answering the following research questions:

What is the best decoupling point and according replenishment strategy for the supply chain of the HEINEKEN flexbrewery?

This question can be split up in five sub-questions.

- *What is a flexbrewery?*
- *What is a decoupling point?*
- *Where in the supply chain should the decoupling point be ?*
- *What is replenishment?*
- *Which replenishment strategy fits the supply chain best?*

The paper follows the DMADE method. The choice for this method is based on the proven value of the DMAIC method and its adaptation to the design aspect. The sub-questions will be answered in different phases and together form the answer to the main research question. The DEFINE phase already started at the introduction and will answer the first sub-question be explaining the flexbrewery in more depth. The next phase is the MEASURE phase. Here is defined what measures are taken into account analysing the system and what supply chain KPIs there are. The ANNALYSE phase starts with theory on supply chain design answering the second sub-question whereafter it will be applied on the flexbrewery and will answer the third sub-question. The DEFINE phase starts with theory on inventory management answering sub-question four whereafter different alternatives are determined. These alternatives are modelled using Discrete Event Simulation. The final phase of this research is the EVALUATE phase. Here the results of the different models are compared answering the last sub-question whereafter the main research question is answered in the conclusion.

The flexbrewery will be operated by Heineken Netherlands Supply (HNS) and will brew local recipes for customers of Heineken Netherlands (HNL). There are two types of customers. Customers that order beers with a recipe developed by HNL and customers that order beers with an own recipe.

MEASURE

Now it is clear what a flexbrewery is, it should be possible to quantify its impact. The impact will be caused by the differences between the flexbrewery and the existing processes. The main difference is a smaller demand which asks for smaller batches. Next to a volume demand also exist of a time factor and this is determined by the lead time. So the impact of the flexbrewery will be measured using demand, batch size and lead time.

ANALYSE

The analyse phase starts with theory on supply chain design. Supply chain design exists of three parts. A start, a strategy and a structure. At the start the product type is characterised as functional or innovative. There is no perfect match with one of the product types and local brands, but it is clear that there is a better match with innovative products.

The strategy is related to the decoupling point, which is the point to where customer demand reaches and the supply chain switches from a push to a pull strategy. For the supply chain of the flexbrewery a make to stock (MTS) strategy should be adopted in order to answer the desired customer lead time.

Following the MTS strategy the decoupling point will be at the distributor between producer and customer. This way the scope of the research is determined to be from producer downstream to customer.

DESIGN

The choice for MTS, causes the next classic supply chain dilemma: just in time or just in case? Just in time sounds efficient (minimise inventory), but has the risk of stock-outs. Just in case sounds safe (minimise stock-outs), but comes with high holding cost. There has been a lot of research into inventory optimization, where the reorder point plays a central role. Inventory reduces over time by multiple orders (demand), if the inventory level is lower than the ROP a new batch will be produced and delivered after LT. The ROP is determined by the product of demand and LT where the situation without SS is based on average demand and LT and the situation with SS is based on the maximum demand and LT. To determine what ROP is best for the local brands three alternatives will be compared.

Alternative I: Just in case

To make sure a service level of 100% will be achieved, all products will have a safety stock. Which leads to inventory, obsolescence and the according costs.

Alternative II: Just in time

Is the counterpart of the first alternative where all products have a safety stock of zero. This way a decreased service level should be accepted, but average inventory level and number of obsoletes should also be lower.

Alternative III: ABC

Is a combination of the other two alternatives based on the idea that different products should be treated differently. Since the other alternatives provide two different approaches, two groups where made using the ABC-method. The first group consist of fast moving products which will have a safety stock and the second group consist of slow moving products without safety stock.

The alternatives are modelled and compared using a simulation. The simulation model of the Flexbrewery was built using SIMIO. SIMIO is a general purpose simulation package that allows building, verifying and analysing simulation models. The discrete-event simulation software SIMIO is often used in academics due to the complete documentation that follows with the software, its easy to use interface and its extensive possibilities.

EVALUATE

Alternative I: Just in Case distinguishes itself with a safety stock for all products. The SS should prevent out of stock situations resulting in lost sales. Alternative I meets this requirement. The service level of 100% means that all orders are fulfilled. The inventory level and obsoletes can not be evaluated on itself, it should be compared too other alternatives. Also the cost do not stand alone, since the cost are not complete (e.g. handling is excluded) and not a business case complete with costs and benefits is made.

Alternative II: Just in Time does not have a safety stock which means that the IL should be lower, but when demand exceeds the forecast lost sales can occur. The lower IL leads to less obsoletes. The results show a SL of 90%, a decrease of 10% compared to Alternative I. Opposite there is indeed a lower inventory and number of obsoletes. Cost of inventory are €31,785 lower than at Alternative 1 and the cost of obsoletes are reduced with €23,873. Together Alternative II reduces cost with €55,658 which is equal to €5,566 per lost percentage point.

Alternative III: ABC is a combination of the other two alternatives. A high SL (and according inventory and obsoletes) for fast movers, just like Alternative I and a lower SL (and according inventory and obsoletes) for slow movers, just like Alternative II. The results of Alternative III show that this results in an overall reduction in SL of 2% compared with Alternative I. Inventory cost are with €22,295 in between Alternative I and Alternative II and cost of obsoletes is equal to Alternative II. In total are the cost of Alternative III €47,273 lower than with Alternative I, which is equal to €23,637 per lost percentage point.

This paper can be concluded by answering the research question. For the supply chain of the flexbrewery a make to stock (MTS) strategy should be adopted in order to answer the desired customer lead time. An advantage of the MTS strategy is that the new products can join the existing logistics. The decoupling point is located at the distributor between producer and customer. The best way to implement this strategy depends on what the minimum service level is and on how a decrease is SL is valued. When an SL of 100% is required, Alternative I: Just in Case should be implemented. If a SL of 90% is acceptable and minimum cost are required, Alternative II: Just in Time should be implemented. When a relative maximum cost reduction is required, Alternative III: ABC should be implemented. When lost sales are added as direct cost Alternative II turns out to be inferior to the other alternatives, but this relation is not substantiated enough. Delisting of products can undo this shift or at least strengthen the original cost differences.

The first thing that stands out when you read the main research question and its answer is that the question is about a complete supply chain design and the answer is focussed on the supply chain strategy and its implementation. In the report is explained that the strategy is a part of the supply chain design. This focus is the result of scoping down to the later explained inventory management resulting from the choice for a MTS strategy.

Secondly the choice for MTS can feel strange reading the report. First most characteristics are matched with MTO and then MTS is chosen. This has to do with the fact that characteristics like demand and life cycle are high or low relative to what they are compared to and more important, that some characteristics are leading in a choice like that for the flexbrewery the desired customer lead time was.

A model is only as good as its input. The demand was created by a sales forecast and limited sales data, therefore the results should be used with care. Even though the sensitivity analysis showed that the model was relatively robust for changes in demand.

A final limitation of the model is the fact that delisted products are not included. It is found that this way the model underestimates the number of obsoletes and that Alternative I is most sensitive to this effect, then Alternative III en then Alternative II. It is not clear how often this occurs, so the real effect could not be quantified.

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Glossary

ATO Assemble to order.

BBT Bright beer tank.

BPH Bottles per hour.

CODP Customer order decoupling point.

DC Distribution centre.

DES Discrete event simulation.

DMADE Define measure analyse design evaluate.

DMAIC Define measure analyse improve control.

ETO Engineer to order.

HL Hectolitre (100L).

HNL Heineken Netherlands.

HNS Heineken Netherlands Supply.

IL Inventory level.

KPI Key performance indicator.

LS Lost sales.

LT Lead time.

MTO Make to order.

MTS Make to stock.

ROP Reorder point.

SC Supply chain.

SCD Supply chain design.

SCOR Supply chain operations reference model.

SKU Stock-keeping unit.

SL Service level.

SPC Swimlane process chart.

SS Safety stock.

DEFINE

1 Introduction

HEINEKEN is the number one brewer in Europe and the number two brewer in the world. They have operations in over 70 markets globally, which makes them the world's most international brewer. (Heineken, b) To keep up with their competitors Heineken follows trends closely.

Globally, craftbeer makes up 14% of the premium beer segment, and is the fastest growing category of the segment (BCG, 2016). This makes craft & variety an important category within Heineken. In order to grow their presence with this category Heineken has developed different strategies. Their portfolio includes craft line extensions, local craft brands, and iconic international growth of craft & variety (Heineken, a).

This research is focussed on local craft since this category was missing in the Heineken portfolio. The combination of growing demand and an incomplete portfolio creates an opportunity for "free-riders". Non concern beers will be offered at places where Heineken invested a lot to be present. According to Heineken data, 15% of the Heineken taps offers a non concern brand (Disselkoen, 2017). As long as Heineken can not offer an alternative, they can not refuse free-riders (without loosing market share). So Heineken wants to be able to offer their own local brands and gain market share.

One way to develop local craft brands is by implementing a flexbrewery. A flexbrewery is a small scale brewery that brews for local demand. It answers the demand of local bars and events for an (exclusive) local craft beer. This way flexbrewing is a win win situation where Heineken can offer a full portfolio to the customer and the customer receives a unique selling point.

Except the fact that in both places beer is brewed, a flexbrewery is really different from the traditional Heineken breweries. Both scale (batch size) and flexibility (variety of products) has a big impact on the supply chain. A new supply chain has to be designed, were all the processes from the suppliers' supplier until the customers' customer has to be streamlined. This will be done by answering the following research question and according sub-questions:

"What is the best Decoupling Point and according Replenishment Strategy for the Supply Chain of the HEINEKEN Flexbrewery?"

- *What is a flexbrewery?*
- *What is a decoupling point?*
- *Where in the supply chain should the decoupling point be ?*
- *What is replenishment?*
- *Which replenishment strategy fits the supply chain best?*

This report will first DEFINE the craft trend and the Heineken flexbrewery in more detail by answering the first sub-question in the next chapter. Chapter 3 concludes the first phase of this research with the approach on how to answer the main research question. The MEASURE phase describes important variables and key performance indicators and can be found in Chapter 4. Followed by the ANALYSE phase where in Chapter 5 literature about supply chain design is reviewed and the answer to the second sub-question can be found. In Chapter 6 this theory is applied on the supply chain of the flexbrewery concluding the ANALYSE phase with the answer on the third sub-question. The DESIGN phase starts in Chapter 7 with theory on replenishment answering the fourth sub-question followed by a description of three possible implementations of this strategy. These three alternatives are compared to each other using simulation which is explained in Chapter 8. The last phase, the EVALUATION phase starts in Chapter 9 by answering the last sub-question with the results and evaluation of the simulated alternatives. The overall conclusion and answer to the main research question can be found in Chapter 10 followed by discussion on the interpretation of this answer, recommendations to further research and finally a reflection on the complete process of this research.

2 Context

The introduction already explained in short what a flexbrewery is and were it comes from. This chapter will explain the concept in more depth, but first elaborates more on the trend of craft- beer and breweries to put the flexbrewery in the right perspective.

2.1. Craft trend

Craft brewers have transformed global beer markets over the past two decades. After a century of consolidation, resulting in the domination of a few global multinationals and the homogenization of beer a counter-revolution with a dramatic increase in the number of craft brewers has taken place (Garavaglia and Swinnen, 2018).

Figure 2.1 shows the number of breweries in the Netherlands from the 19th century until 2015. The 20th century is characterised by consolidation of the number of breweries. Technological improvements made economies of scale possible and only a few brewers survived resulting in a ”Pilsener Desert”, characterized by the fact that by 1980 brewers almost exclusively produced pilsner beer. Products were so homogeneous that even connoisseurs and professional tasters could not distinguish between them in blind taste tests. From then the whole picture changed. Starting as a counter-movement small breweries started to brew different beer styles based on the Belgian speciality beers and overseas Ale’s. This turned out to be a success and the craft beer revolution has began. (van Dijk et al., 2018). This same trend is also found in the USA and different European countries (Carroll and Swaminathan, 2000).

There are different terms like, “craft brewery,” “artisanal brewery,” microbrewery,” “independent brewery,” specialty brewery,” and “local brewery” used to identify breweries which “recently” started on a “small” scale to brew different” types of beer, which distinguishes them from the mass-produced beer from larger lager breweries. So there is not a generally accepted definition. Criteria that are present at almost al definitions are ownership, production process, scale, age and tradition and form in a way a definition on itself. The differences in definition reflect differences in perspectives and local circumstances and also difficulties in defining craft beer. Everyone can recognise a craft beer, but it is hard to agree on whether some beers are craft or not and thus how to define what a craft brewery or a craft beer is. (Garavaglia and Swinnen, 2018).

Contract brewery

A special form of craft brewing that has played a role in the emergence of craft beers in many countries is contract brewing. Contract brewing occurs when brewers do not own their own equipment and premises for producing beer: they contract other breweries to brew for them. These brewers have been referred to in sometimes exotic ways, including “gypsy brewers,” “phantom breweries,” and “cuckoo breweries” (Dann, 2015; Weiner, 2014).

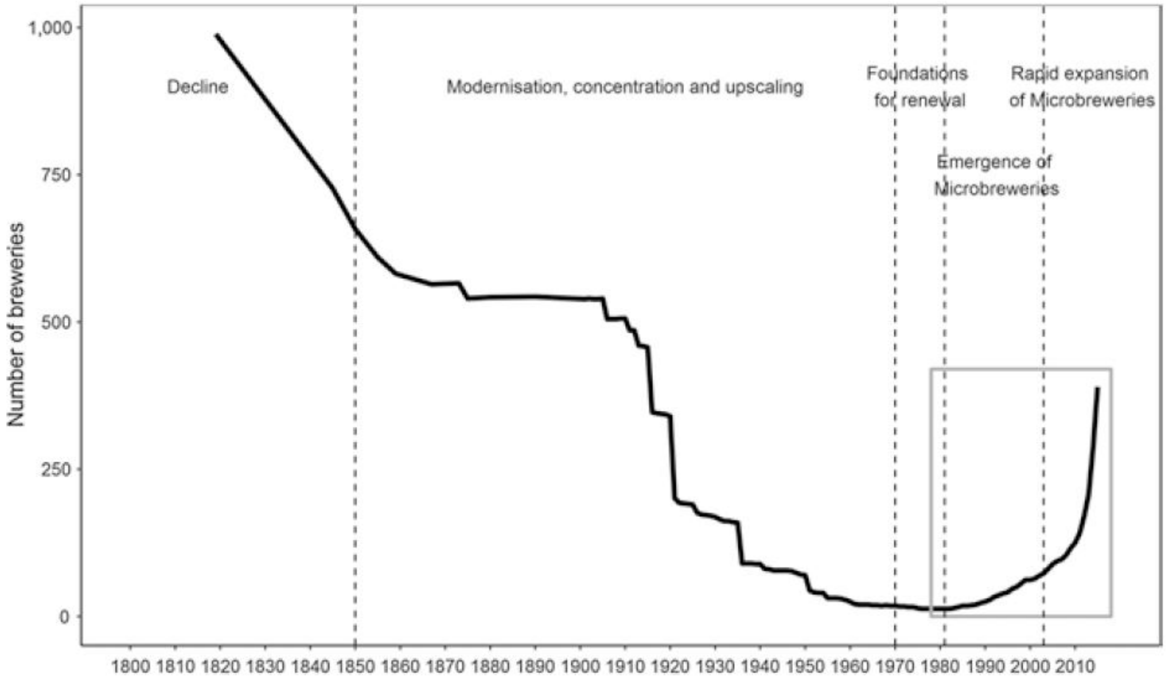


Figure 2.1: Historical evolution of Dutch beer brewing population (Unger, 2001)

2.2. Flexbrewery

Figure 2.2 shows the Dutch beer market in 2017. The market had a total volume of 12 million hectolitre (HL) of which 10% was craft. Between 2016 and 2017 the market grew with 177 kHL, 48% of this growth consisted of craft (Nederlandse-Brouwers, 2017).

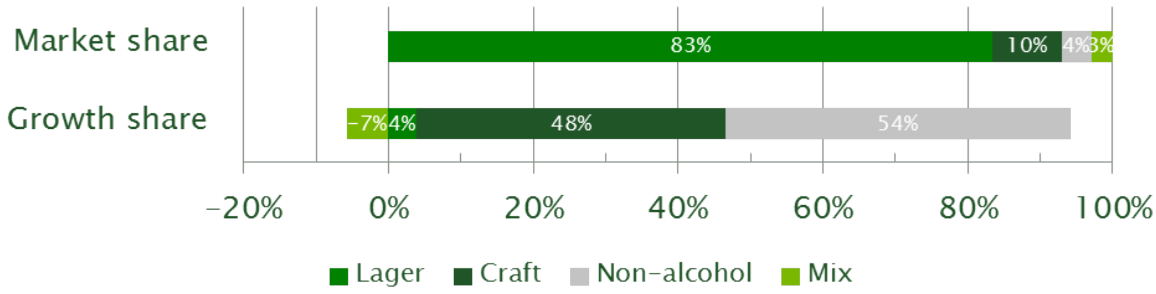


Figure 2.2: Beer consumption numbers the Netherlands 2016 (Nederlandse-Brouwers, 2017)

Heineken can't ignore this craft trend, so they developed their own craft definition and strategy. According to Heineken craft is a premium beer with a compelling origin and brand story, not available everywhere and special, demonstrating brewing craftsmanship. In their Craft & Variety strategy Heineken focusses on different pillars. One of them is Local Craft and this is where the flexbrewery comes in (Mataheroe, 2018).

The existing Heineken breweries in the Netherlands are not capable to answer demand for local craft brands. The smallest batch Heineken breweries can brew in the Netherlands is around 700HL. Local craft asks for batches not bigger than 50HL. The flexbrewery should fill this gap and the concept has the following specifications.

Specifications

The flexbrewery will be operated by Heineken Netherlands Supply (HNS) and will brew local recipes for customers of Heineken Netherlands (HNL). There are two types of customers. Customers that order beers with a recipe developed by HNL (local) and customers that order beers with an own recipe (tailor made). So the flexbrewery will always brew commissioned by HNL and can operate both as a traditional and a contract brewery.

Assuming five work days per week and 52 brew weeks this results in 260 brew days. HNL expects more then 260 batches per year, so it should be possible to brew more then one batch per day.

The biggest physical flows will be water and malt. Assuming the brewery will be at an existing production site, water will be present. The supply of the other ingredients has to be determined. Per 15HL circa 250kg malt is needed, resulting in about the same amount of spent grain.

The brewhouse should exist of a mashtun, lautertun and a combined kettle/whirlpool. After cooling the wort needs to ferment and lager for circa two weeks. Because of this duration there are eight fermentation vessels of 20HL and/or 35HL needed. The yeast will be removed by a separator and there is no need for filtration and stabilisation. Pasteurisation is still in consideration. There will be three bright beer tanks (BBTs).

The finished beer will be packed in kegs, so a simple keg filling line will be installed. There will also be a bottle line (Ca. 1000 bottles per hour (BPH)) and it will be possible to fill directly into a mobile tank or truck. (Nieuwland, 2018). The specification is done, so that the flexbrewery can fulfil market demand as predicted by HNL. This forecast can be found in Appendix E and Chapter 4 explains how batch size and demand are related.

3

Research Approach

3.1. Research Structure

The research will have the DMADE structure as can be seen in Figure 3.1. The structure is based upon the DMAIC method from the theories around Lean and SixSigma for Process Design and Performance by Beelaerts van Blokland (2017) and adapted to this research. The choice for this method is based on the proven value of the DMAIC method and adaptation to the design aspect.

This chapter is the last part of the *DEFINE* phase. The introduction explained the reason of this research, after which the flexbrewery concept was explained in more depth. The next phase is the *MEASURE* phase. Here will be defined what measures will be taken into account analysing the system and what supply chain KPIs there are. The *ANNALYSE* phase starts with theory on supply chain design whereafter it will be applied on the flexbrewery. After analysing the flexbrewery process different alternatives will be determined in the *DEFINE* phase. These alternatives will then be modelled using Discrete Event Simulation. The final phase of this research is the *EVALUATE* phase. Here the results of the different models will be compared whereafter conclusions and recommendations will be made.

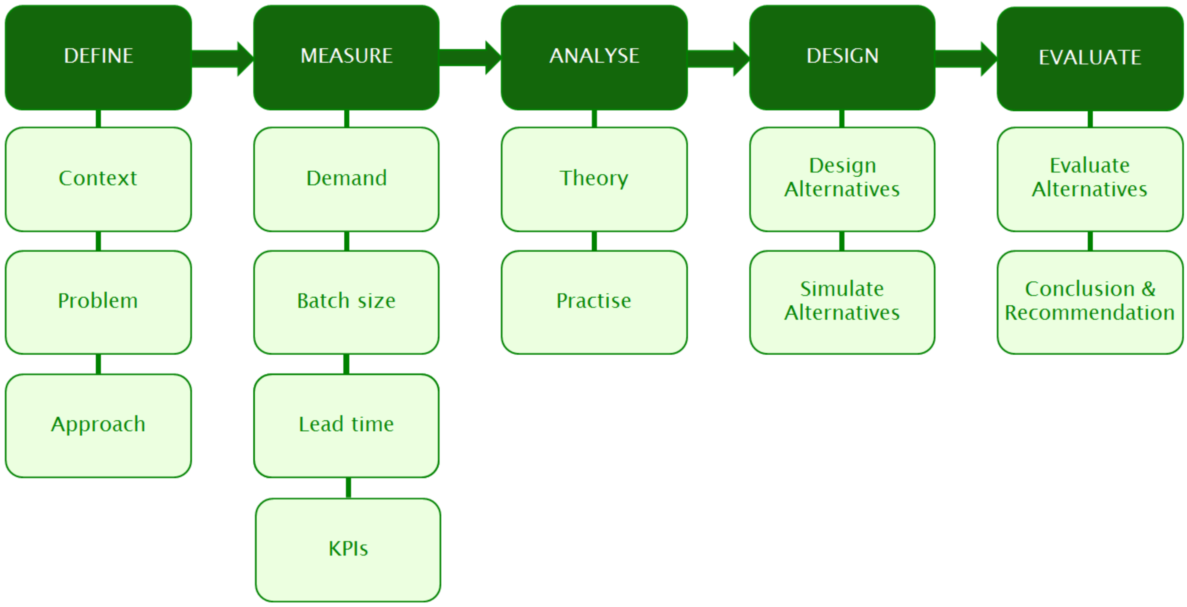


Figure 3.1: Structure of the proposed research based on the research design matrix of Beelaerts van Blokland (2017)

3.2. Research Methodology

After defining the concept of Flexbrewing and Supply Chain Design the processes will be analysed in more detail. There has been many different methodologies developed to depict business processes. One of the most widely used forms is the flowchart. It visualises the business process as well as the patterns of decision-making. An extension of the flowchart is the Swimlane Process Chart (SPC), it consists of several ”lanes” that represent different stakeholders. The phases of the process are shown on top of the diagram. This is suitable for depicting more complex processes which are difficult to be handled only with the classical flowchart. The SPC is also known as swim lane, swim lane diagram or Cross-Functional Flowchart (Shibayama et al., 2017).

When the processes are clear, the Supply Chain will be described using the Supply Chain Operations Reference (SCOR) model. The SCOR model is a product of APICS resulting from the merger between Supply Chain Council and APICS in 2014. The SCOR model was first published in 1996 and updated regularly to adapt to changes in supply chain business practices. SCOR is a powerful tool for evaluating and comparing supply chain business practices. ”It provides a unique framework that links business process, metrics, best practices and technology into a unified structure to support communication among supply chain partners and to improve the effectiveness of supply chain management and related supply chain improvement activities” (APICS, 2017b). This section will explain the SCOR model itself and how it is linked to the different phases of this research according to the description of APICS (2017b).

SCOR Framework

The SCOR framework exists of six major processes. SCOR processes are unique processes a supply chain requires to execute in order to support its primary objective to fulfil customer orders. The SCOR model contains multiple tabbed sections around these six processes from the suppliers' supplier to the customers' customer as can be seen in Figure 3.2. The definition of the six major processes can be seen in Table 3.1

The six major processes are the level-1 processes. These define the scope, content and performance targets of the supply chain. For each level-1 process there are at least three differentiating level-2 process categories, which define the operations strategy from where process capabilities are set. All level-2 process categories have different level-3 process elements. Process elements define the configuration of individual processes, set the ability to execute and focusses on processes, inputs/outputs, skills, performance, best practices and capabilities. A complete overview of all processes at every level can be found in Appendix D.

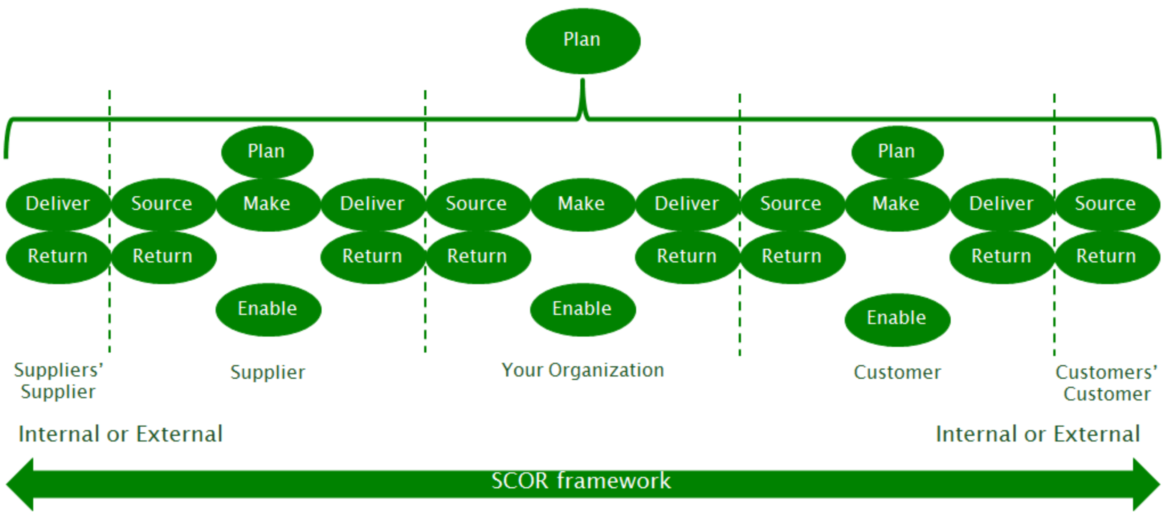


Figure 3.2: SCOR Framework (APICS, 2017b)

Table 3.1: Definitions of the six major (Level-1) processes (APICS, 2017b)

Process	Definition
Plan	A Plan process describes the activities associated with developing plans to operate the supply chain. The Plan processes include the gathering of requirements, gathering of information on available resources, balancing requirements and resources to determine planned capabilities and gaps in demand or resources and identify actions to correct these gaps.
Source	A Source process describes the ordering (or scheduling of deliveries) and receipt of goods and services. The Source process embodies the issuance of purchase orders or scheduling deliveries, receiving, validation and storage of goods and accepting the invoice from the supplier.
Make	A Make process describes the activities associated with the conversion of materials or creation of the content for services. Conversion of materials is used rather than 'production' or 'manufacturing' as Make represents all types of material conversions: Assembly, Chemical processing, Maintenance, Repair, Overhaul, Recycling, Refurbishment, Remanufacturing and other common names for material conversion processes. As a general guideline: These processes are recognized by the fact that one or more item numbers go in and one or more different item numbers come out of this process.
Deliver	A Deliver process describes the activities associated with the creation, maintenance and fulfilment of customer orders. The Deliver process embodies the receipt, validation and creation of customer orders, scheduling order delivery, pick, pack and shipment and invoicing the customer. The sD4 Deliver Retail process provides a simplified view of Source and Deliver processes operated in a Make-to-Stock retail operation.
Return	A Return process describes the activities associated with the reverse flow of goods. The Return process embodies the identification of the need to return, the disposition decision making, the scheduling of the return and the shipment and receipt of the returned goods.
Enable	A Enable process describes the activities associated with the management of the supply chain. Enable processes include management of business rules, performance management, data management, resource management, facilities management, contract management, supply chain network management, managing regulatory compliance, risk management, and supply chain procurement.

Simulation

SCOR is a static tool that does not include any possibility to do dynamic analysis (Persson et al., 2012). In order to overcome shortcomings of the traditional analytical methods in modelling and analysing the supply chain, simulation, especially discrete-event simulation (DES), has been widely applied as a decision-making tool for supply chain optimization (Long, 2014).

The simulation model of the Flexbrewery will be build using SIMIO. SIMIO is a general-purpose simulation package that allows building, verifying and analysing simulation models. The discrete-event simulation software SIMIO is often used in academics due to the complete documentation that follows with the software, its easy to use interface and its extensive possibilities.

Simulation is a key technique for the study of the dynamics of supply chain systems. There are a number of simulation systems that are based on the SCOR model. Albores et al. (2006) found in their comparison that SCOR-based simulators present advantages over general purpose and business process simulators, although some limitations can be found with all systems. The main advantages are the speed of model building and the comprehensiveness of metrics available.

In order to use these advantages the Flexbrewery model utilises the symbols and terminology of the SCOR model as an add on to the simulation software SIMIO. This way the best of both worlds are combined. The standardised framework of SCOR with the dynamics of SIMIO.

MEASURE

4
Measure

Now it is clear what a flexbrewery is, it should be possible to quantify its impact. The impact will be caused by the differences between the flexbrewery and the existing processes. The main difference is a smaller demand which asks for smaller batches. Next to a volume demand also exist of a time factor and this is determined by the lead time. So the impact of the flexbrewery will be measured using demand, batch size and lead time.

4.1. Demand

The ”craft” beers that will be brewed at the flexbrewery differ from existing Heineken products by targeting a specific smaller market then before. This is characterised by the main measure demand. Demand tells you how many markets there are and how big those markets are. The demand can be divided into two categories. Beers brewed for a specific location (local) and beers brewed for a specific occasion (tailor-made). The main difference is that for local, strong brands will be build to complete the Heineken portfolio and tailor-made beers are brewed specially for the customer. The marketing department of Heineken Netherlands have made a forecast for both types until 2022 which can be found in Appendix E. The forecast was made bottom-up because of the lack of historic data since this is a new market for Heineken. The forecast is based on the number of selling points, the number of tabs per selling point and the volume concern and non concern craft beer.

4.2. Batch size

The lower demand in combination with a limited shelf live means a lower batch size. The batch size will be determined by the volume that can be brewed in one brew cycle. The brewing process exist of multiple steps, where the first few steps take a couple of hours and the lagering takes a few weeks. Consecutive batches of the same recipe can be fermented together in bigger lager tanks or different batches can be put in different tanks. The batch size will be determined by the process with the smallest volume before fermenting.

Combining the demand from Appendix E with a shelf life of 26 weeks results in a maximum batch size of 340HL for the product with the highest demand and a maximum batch size of 12HL for the product with the lowest demand (4.1) Figure 4.1 shows a histogram with the frequency of batch sizes per year. Two conclusions can be drawn. Firstly a smaller batch size is needed since even the product with the highest demand (fast mover) will need a smaller batch size then currently possible (340HL < 700HL). Secondly 20HL is the most frequent batch size considering a shelf life of 26 weeks.

From 2020 the slow mover would also be possible with a batch size of 20HL and a shelf life of 26 weeks to be sold out before getting out of date. The bigger batches can be split into smaller batches (e.g. a 40HL can be split into two 20HL batches). This way all the products can be brewed in a brewery with a fixed batch size (The batch size is fixed in a way that it has a maximum and a small range under the maximum). Table 4.2 shows how many brews per day are needed assuming different batch sizes over the years. It can be concluded that it should be possible to brew at least two batches per day.

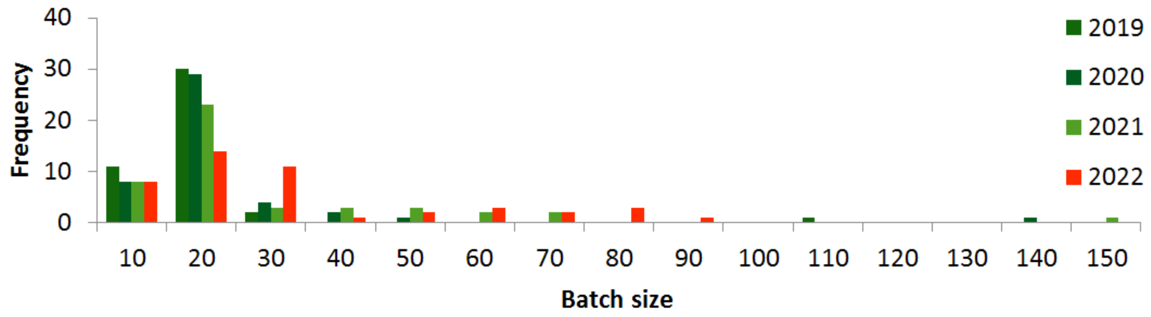


Figure 4.1: Histogram of batch size [HL] frequency per year

Table 4.1: Maximum batch size [HL] in relation to a shelf live of 26 weeks

Product	2019	2020	2021	2022
Fast mover	220	300	340	260
Slow mover	12	20	20	20

Table 4.2: Number of brews per day for quarter with highest demand of the year

Batch size	2019	2020	2021	2022
10	2	3	4	4
15	2	2	3	3
20	2	2	2	2
25	1	2	2	2
30	1	2	2	2

4.3. Lead time

In a logistics context lead time (LT) is the time between recognition of the need for an order and the receipt of goods. For make-to-order products, it is the length of time between the release of an order to the production process and shipment to the final customer. For make-to-stock products, it is the length of time between the release of an order to the production process and receipt into inventory (Pittman and Atwater, 2016).

Every link in the supply chain has its own LT and also a desired LT of the previous link. The final customer only has a desired LT. All LTs together form the total LT.

4.4. KPIs

The above mentioned measures can describe the flexbrewery in numbers, but can't describe the performance. Therefore key performance indicators (KPIs) are needed. The SCOR model has a comprehensive approach for understanding, evaluating and diagnosing supply chain performance. that consists of three elements that describe different aspects of performance. The three elements are: Performance Attributes, Metrics and Process/Practice Maturity.

Performance Attributes

A performance attribute describes strategic characteristics of supply chain performance and is used to prioritize and align the supply chain's performance with the business strategy. The SCOR model recognizes five performances attributes which are defined in Table 4.3

Metrics

Metrics are discrete performance measures that measure the ability to achieve the strategic directions of the performance attributes. They comprise themselves of levels of connected hierarchy. SCOR recognizes three levels of pre-defined metrics. Level-1 metrics are diagnostics for the overall health of the supply chain. Lower level metrics serve as diagnostics for higher level metrics. The diagnostic relationship helps to identify the root cause or causes of a performance gap of a higher level metric. Figure D.1 of Appendix D gives an complete overview of all performance attributes and metrics.

Process/Practice Maturity

Also know as ”best practices” is an objective reference tool to evaluate how well supply chain processes and practices incorporate and execute accepted best-practice process models and leading practices.

Table 4.3: Definitions of SCOR Performance Attributes (APICS, 2017b)

Performance Attribute	Definition
Reliability	The ability to perform tasks as expected. Reliability focuses on the predictability of the outcome of a process. Typical metrics for the reliability attribute include: On-time, the right quantity, the right quality.
Responsiveness	The speed at which tasks are performed. The speed at which a supply chain provides products to the customer. Examples include cycle-time metrics.
Agility	The ability to respond to external influences, the ability to respond to marketplace changes to gain or maintain competitive advantage. SCOR Agility metrics include Adaptability and Overall Value at Risk.
Costs	The cost of operating the supply chain processes. This includes labour costs, material costs, and management and transportation costs. A typical cost metric is Cost of Goods Sold.
Assets	The ability to efficiently utilize assets. Asset management strategies in a supply chain include inventory reduction and in-sourcing vs. outsourcing. Metrics include: Inventory days of supply and capacity utilization.

ANALYSE

5

Theory: Supply Chain Design

According to Christopher (2005) a supply chain (SC) is a network of organizations that are involved, through upstream (towards supplier) and downstream (towards consumer) linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer.

In essence three primary flows can be identified in every supply chain. An information flow, a physical flow and a financial flow. The information flow flows upstream from the customer to the supplier, resulting in a downstream physical flow and finally an upstream financial flow. The flows start at the customer and this makes supply chains customer-driven (Hines, 2004). Figure 5.1 shows an example of a supply chain indicating the three different flows.

In order to answer the needs of the customer the different flows should be synchronised (Taylor, 2004). This can be done by designing the supply chain, better known as supply chain design (SCD). There has been done a lot of research in this field and there are three clear phases of SCD identified (Christopher, 2005; Fawcett et al., 2007; Sharifi et al., 2006; Taylor, 2004).

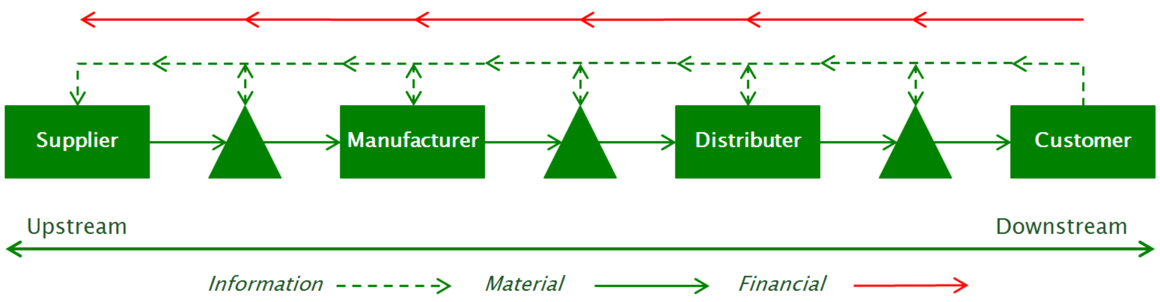


Figure 5.1: Example of a supply chain

5.1. Supply Chain Start

As mentioned above the need of the customer activates the flows. So in order to respond to the need, the need should be understood. Who is the customer and what do they need? This can be a product or a service. In this research the focus is on products. Products have different characteristics like: demand, variety, life cycle and lead-time. Despite a broad variety of products they can be categorised in two types of products and each type has its own impact on SCD (Fisher, 1997). The two types of products are functional products and innovative products. Table 5.1 shows the basic differences between them and the next section explains their impact on the SC.

Table 5.1: Basic differences between functional and innovative products (Nel and Badenhorst-Weiss, 2010)

	Functional products	Innovative products
Demand	Stable	Variable
Life cycle	Long	Short
Profitability	Low	High
Forecast error	Low	High
Stock-out rates	Low	High
Markdown	Low	(Potentially) high
Obsolescence	Low	High
Volume	High	Low
Lead time	Long	Short
Inventory cost	Low	High
Product variety	Low	High
Demand uncertainty	Low	High

5.2. Supply Chain Strategy

When the needs of the end customer are clear a supply chain strategy can be developed. A supply chain strategy is required to manage the integration of all the supply chain activities in order to achieve a competitive advantage for the supply chain (Hines, 2004). As the needs are market driven and they have an impact on the strategy, the strategy is also market driven (Lee, 2002). At the same time are supply chain strategies as varied as the disciplines from which they originate (Boone et al., 2007). So with two product types there are also two types of supply chains. Christopher (2005) describes them as an efficient or 'lean' supply chain and a effective or 'agile' supply chain.

Lean supply chains are focussed on cost efficiency. Wastes or non-value-added activities should be eliminated and economies of scale should be pursued. This strategy fits functional products with high and stable demand where forecasts are leading (Lee, 2002).

Agile supply chains are focussed on responsiveness and flexibility. Supply chain agility is the ability of the supply chain as a whole to rapidly align and respond to dynamic demand. Agile supply chains fit innovative products in this way (Swafford et al., 2005). Table 5.2 shows some characteristics of lean and agile supply chains.

Table 5.2: Some characteristics of lean and agile supply chains (Nel and Badenhorst-Weiss, 2010)

	Lean Supply Chain Strategy	Agile Supply Chain Strategy
Project features	Standard	High variety
Product life cycle	Long	Short
Marketplace demand	Predictable	Volatile
Product variety	Low	High
Order winners	Cost	Time, availability
Supply chain emphasis	Efficiency: economies of scale	Responsiveness, flexibility

Thus far, two product types leading to two strategies have been discussed. As the world is almost never as simple as black and white, it is neither in this case. Lean and agile represent conflicting interests, but can also complement each other. This way a third 'hybrid' strategy is possible. Hybrid supply chains are a combination from lean and agile approaches and are also called leagile supply chains (Mason-Jones et al., 2000).

Leagile supply chains combine lean and agile approaches, but not at the same time. Leagile supply chains will have a point where the lean approach switches to the agile approach. This point is called the Customer Order Decoupling Point (CODP) or in short decoupling point (Simchi-Levi et al., 2003). The decoupling point is also the point until where the customer demand penetrates the supply chain upstream and switches to forecasts or in other words where push meets pull. The position of the decoupling point is dependant on the right balance between lean and agile. (Christopher, 2005).

So the customer demand reaches until the decoupling point. The customer pulls the products downstream from the decoupling point. Therefore the processes on the customer side of the SC should be agile to answer this unpredictability. Upstream of the decoupling point the demand is more stable and processes should be lean. Processes are aligned and optimized for cost savings and forecasts pushes products into the SC (Mason-Jones et al., 2000).

The different positions of the CODP characterise the overall supply chain strategy. Sharman (1984) already distinguished four different strategies. Make to stock (MTS), assemble to order (ATO), make to order (MTO) and engineer to order (ETO). The different strategies according the CODP are visualized in Figure 5.2.

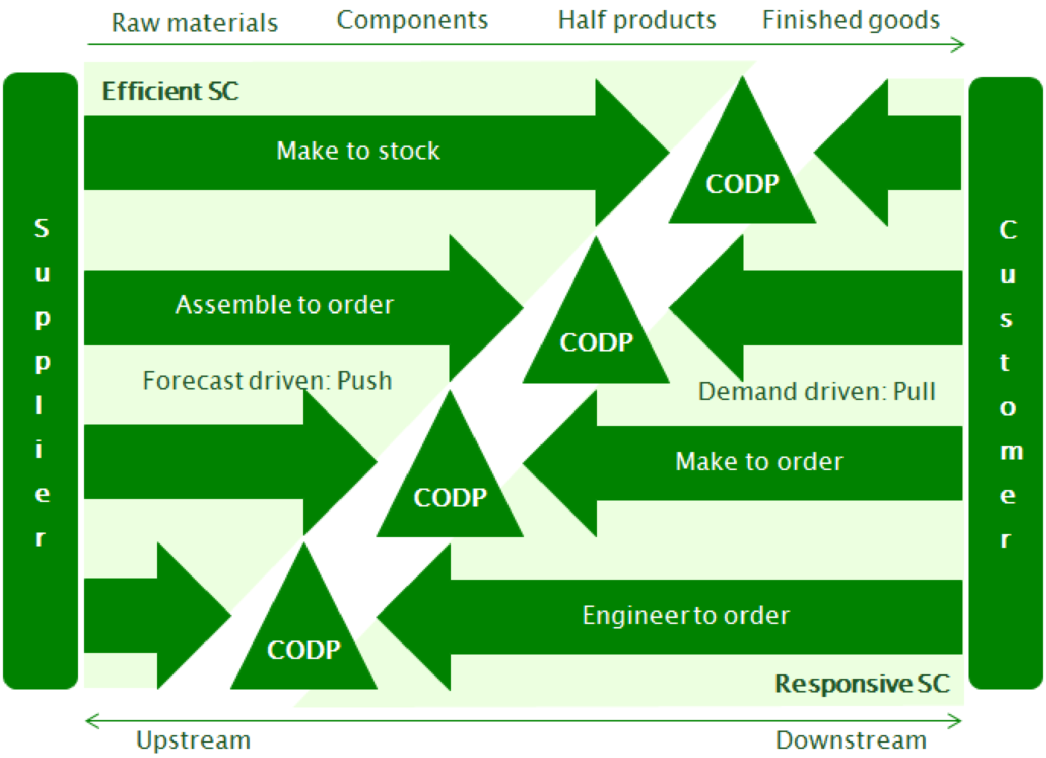


Figure 5.2: Position of the CODP and according strategy based on Nel and Badenhorst-Weiss (2010); Olhager (2012)

5.3. Supply Chain Structure

Once the strategy is determined a supporting supply chain structure should be found (Taylor, 2004) The supply chain structure refers to the sequential links among supply chain activities (Appelqvist et al., 2004). The supply chain structure thus implies the integration of the links between supply chain members (Defee and Stank, 2005).

Trough integration supply chain members become supply chain partners. Before selecting partners the type of partnership and the role in this partnership should be defined. Not all members have to be integrated. Trust between partners is essential. Collaboration thus comprises closely integrated, mutually beneficial relationships that enhance supply chain performance (Lambert et al., 1996).

Supply chain performance is determined by supply chain drivers. Six supply chain drivers, namely facilities, inventory, transportation, information, sourcing and pricing, are identified. These drivers interact with each other (Chopra and Meindl, 2007).

The supply chain performance, determined by drivers can be measured by Key Performance Indicators (KPIs). Wisner et al. (2009) state that in order to align performance between supply chain partners specific measures should be adopted. These measures should be able to construe the supply chain strategy.

6

Practice: Flexbrewery

Nel and Badenhorst-Weiss (2010) made a conceptual framework from the theory described in Chapter 5 and can be found in Appendix B. This chapter will describe the supply chain decisions for the flexbrewery using this framework. The first section describes the customer and characteristics of the product the customer wants. Section 6.2 determines the supply chain strategy using a swimlane process chart and finally Section 6.3 describes the supply chain structure using SCOR.

6.1. Supply Chain Start

Section 5.1 compared innovative and functional products on multiple characteristics. In Table 6.1 the products the flexbrewery will produce are described according the same characteristics.
There is no perfect match with one of the product types, but it is clear that there is a better match with innovative products.

Table 6.1: Characteristics of the flexbrewery

Demand	Variable
Life cycle	Short
Profitability	High
Forecast error	High
Stock-out rates	Low
Markdown	Low
Obsolescence	High
Volume	Low
Lead time	Long
Inventory cost	High
Product variety	High
Demand uncertainty	High

6.2. Supply Chain Strategy

To determine the strategy the process will be analysed using a swimlane process chart (SPC). Figure 6.1 shows the SPC of the flexbrewery. The process consists of five phases. It starts with the order intake, followed by planning, procurement, production and finally distribution.
The order intake is first setted up for a MTS strategy. Here is the order received by the distributor who checks if the product is on stock or not. When the product is on stock it will be delivered. When the product is not on stock marketing has to decide if the product will be produced. For a MTO strategy the distributor will be skipped during the first phase, so the order goes directly to marketing.
The planning stage consists of two steps. Reserving capacity in the brewery and planning the production. For a MTS strategy the input for the planning are the stock-level, sales data and activation data. For MTO it is just the activation data from marketing that determines what products are produced.
When production is planned procurement can ensure all supplies are on hand when production starts. The phases of planning production and purchasing supplies together take four to eight weeks.
Then brewing starts which will take two to five weeks in total. After production the beer is transported to the distributor from where it will be delivered to the customer. When a MTO strategy is followed again the distributor is skipped and the beers are directly delivered to the customer.

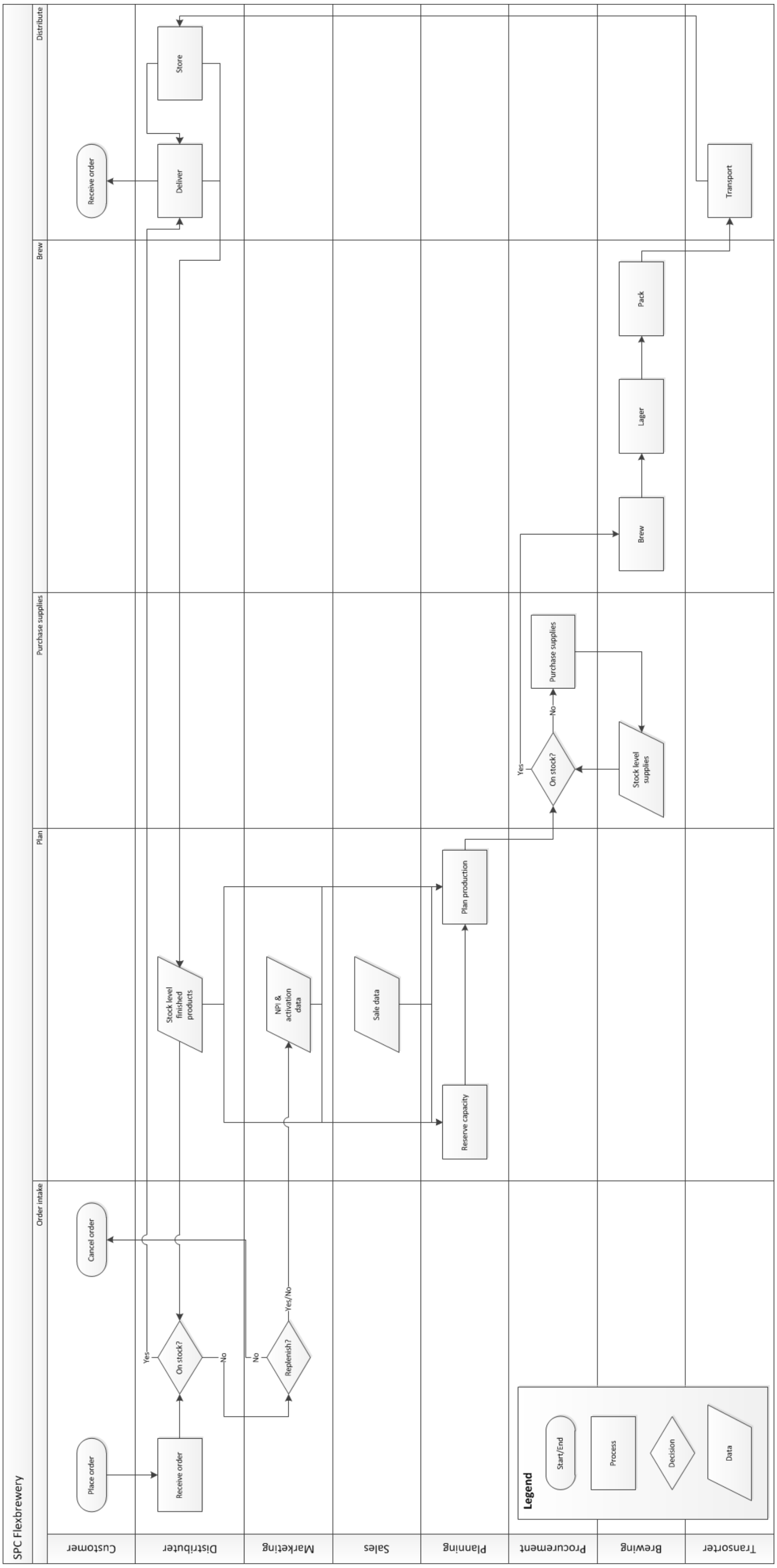


Figure 6.1: SPC of the flexbrewery

Looking at the conceptual framework the products suit a MTO strategy, however the customer asks for smaller lead times and smaller batches (individual customer level) then the flexbrewery can process. Since there are several competitive products in the market, Heineken does not have the power to force the customer to accept higher lead times and bigger order quantities. This leads to a MTS strategy which also has advantages. This way the flexbrewery can join existing Heineken systems of sales and distribution. Since customers already order Heineken products, the flexbrewery products can be added to the same system. The same way the products can join the distribution from DC to customer in stead of dedicated transport of flexbrewery products only. The final synergy possibility is that of transport from brewery to DC.

6.3. Supply Chain Structure

Figure 6.2 gives a high level overview of the supply chain. The flexbrewery will be supplied by one or more suppliers. The produced beer will be transported by Heineken to a distribution centre (DC) of Sligro and Sligro will bring it to the customer. The physical-, information and financial flows within this chain are indicated. The red box indicates the scope of this research. Since the MTS strategy will be used the focus is on the relation between manufacturer and distributor. Downstream relations will remain unchanged and upstream relations will be taken into account in other research within Heineken.

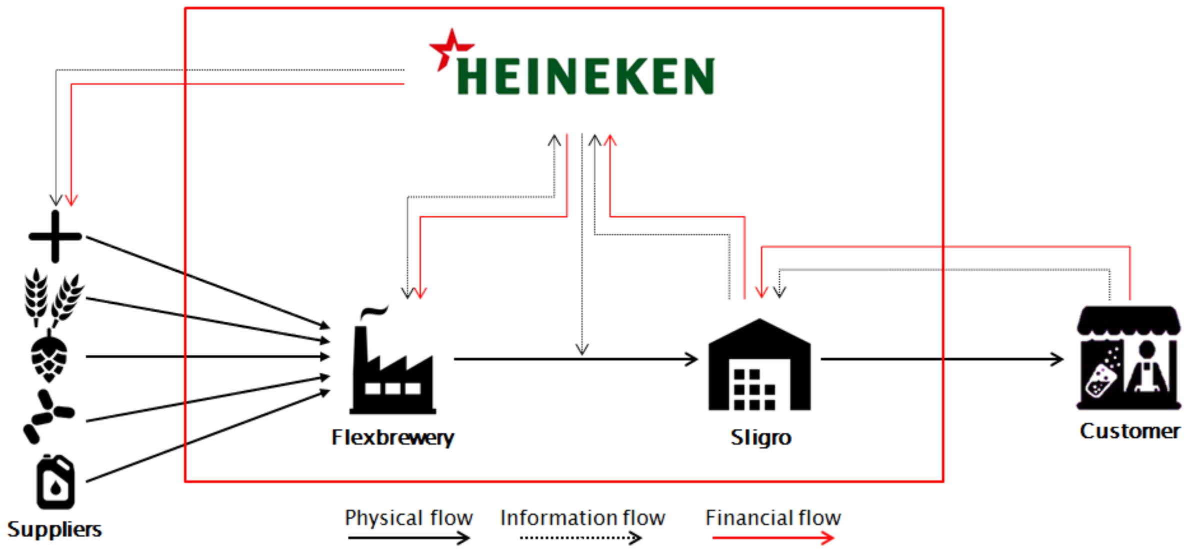


Figure 6.2: Position of the Flexbrewery in the supply chain

Figure 6.3 shows the supply chain of the flexbrewery following the SCOR framework introduced in Section 3.2 assuming a MTS strategy.

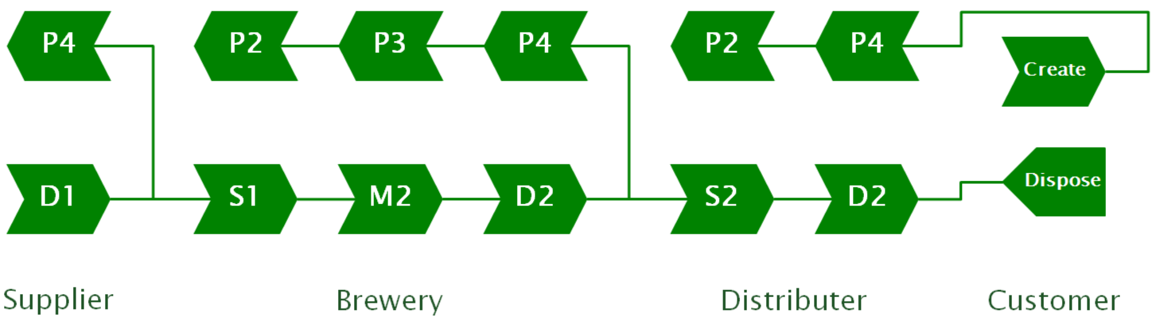


Figure 6.3: Flexbrewery supply chain based on SCOR template of Persson and Araldi (2009)

DESIGN

7

Inventory Management

7.1. Theory: Inventory Optimization

The choice for MTS, causes the next classic supply chain dilemma: just in time or just in case? Just in time sounds efficient (minimise inventory), but has the risk of stock-outs. Just in case sounds safe (minimise stock-outs), but comes with high holding cost. There has been a lot of research into inventory optimization, where the reorder point plays a central role. Figure 7.1 visualises this principle.

There are multiple policies of inventory optimization. They are all variants on the base policy of a simple reorder point (s). The base model can be replenished up to a fixed level ((s,S) policy) or with a fixed amount ((s,Q) policy). This can be done continuous or periodic ((R,s,Q) policy). For the flexbrewery the last policy is assumed. In general, the (R,s,Q) model can be stated as: "review the inventory level every R units of time, if the inventory is less than or equal to s you must-order Q.

In classic inventory models it is common to assume that excess demand is back ordered (Axsäter, 2000; Silver et al., 1998; Zipkin, 2000). An extensive study by Gruen et al. (2002) reveals that only 15% of the customers who observe a stock out will wait for the item to be on the shelves again, whereas the remaining 85% will either buy a different product (45%), visit another store (31%) or do not buy any product at all (9%). Similar percentages are found by Verhoef and Sloot (2006), who conclude that 23% of the customers will delay the purchase in case of excess demand. These results show that most of the original demand can be considered to be lost in many retail settings. However, these results are about retail there are similarities to this research. The local bars have multiple alternatives and as mentioned the in previous chapter, the customer does not want to wait a couple of weeks.

Inventory systems with a backorder assumption have received by far the greatest attention in inventory literature. This is mainly because (R,s,S) policies are proven to be optimal replenishment policies for such systems (Karlin and Scarf, 1958). When excess demand is lost instead of back ordered, much less is known about the optimal replenishment policy. Bijvank and Vis (2012) have made a optimal replenishment model for lost sales. They compared a (R,s,S) with a (R,S) policy. So this research differs from (Bijvank and Vis, 2012) that it is not in retail and has a fixed order quantity.

Reorder point

D_{avg}:	Avarage demand	[HL/t]
D_{max}:	Maximum demand	[HL/t]
LT_{avg}:	Average lead time	[t]
LT_{max}:	Maximum lead time	[t]
ROP:	Reorder point	[HL]
SS:	Safety stock	[HL]

SS $= D_{max} * LT_{max} - D_{avg} * LT_{avg}$

ROP $= D_{avg} * LT_{avg} + SS$
$= D_{avg} * LT_{avg} + D_{max} * LT_{max} - D_{avg} * LT_{avg}$
$= D_{max} * LT_{max}$

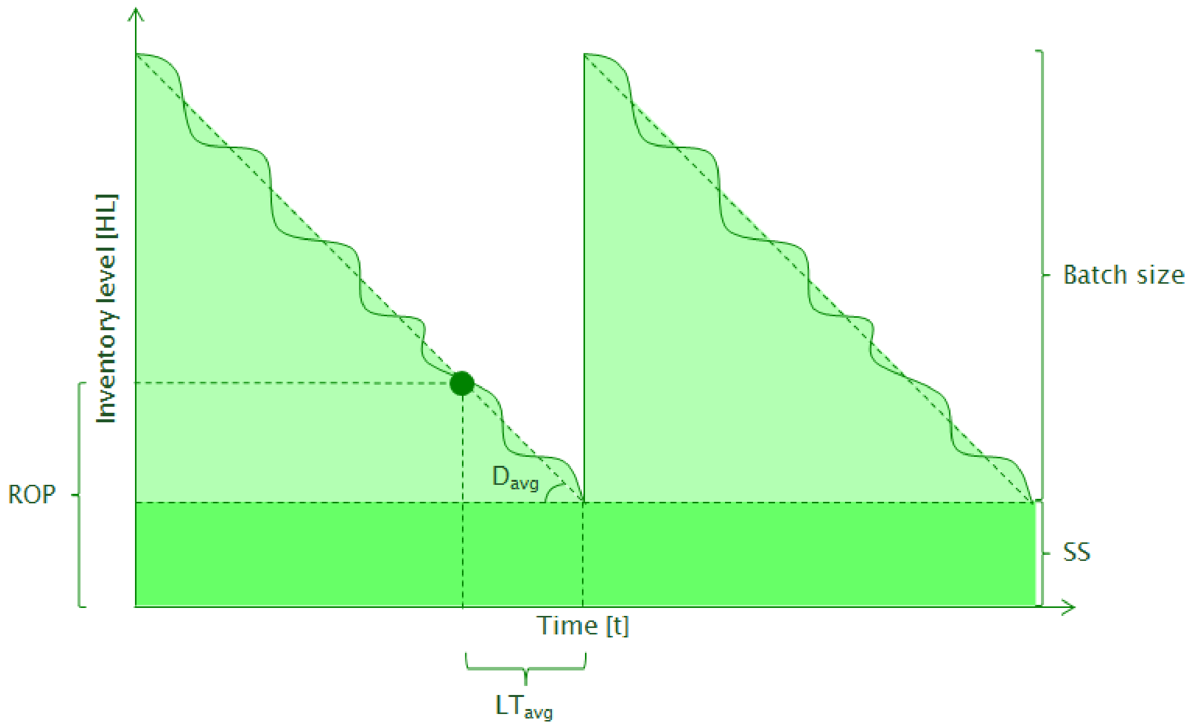


Figure 7.1: Reorder point with safety stock (R,s,Q) policy

7.2. Alternatives

To determine what inventory policy suits the flexbrewery best, three alternatives have been defined. The first two alternatives are extreme policies following from and named after the theory in the previous section and the third alternative is a mix of both extremes. Alternative one is called: "just in case" and is characterised by a safety stock for all products. This alternative is based on the philosophy of the marketing department to never sell no. Alternative two is called: "just in time" and is characterised by a reorder point without safety stock. This alternative is defined as a counterpart of Alternative one, to challenge the idea that service level is more important than cost. Alternative three is called: ABC because the policy is based on the ABC inventory classification system which treats different (groups of) products in a different way.

ABC inventory classification systems are widely used to streamline the organisation and management of inventories consisting of very large numbers of stock-keeping units (SKUs). Therefore the main reason to apply ABC classification is that in most cases the number of SKUs is to large to implement SKU-specific inventory control methods (Teunter et al., 2010). According to the definition of Pittman and Atwater (2016) ABC classification is the classification of a group of items in decreasing order of annual dollar volume (price multiplied by projected volume) or other criteria. This array is then split into three classes, called A, B, and C. The ABC principle states that effort and money can be saved through applying looser controls to the low-dollar-volume class items than will be applied to high-dollar-volume class items. ABC classification is also known as ABC analysis and is based on Pareto's Principle (also known as the 80/20 rule).

Figure 7.2 shows the ABC analysis of the flexbrewery demand and is based on Table F.1. Since the prices of the different SKUs will be roughly the same and are still unknown, only the annual volume is used (y-ax). The x-as shows the number of SKUs, both axes are in percentages. The bullets show the boundaries of the different classes. The first group exists of 22% of the SKUs that represent 53% of the annual volume. The second group exists of 54% of the SKUs that represent 40% of the volume and the third groups exists of the final 24% of the SKUs that represent 7% of the annual volume.

The characteristics of the three alternatives described above are summarised on the following page. Followed by the next section where the KPIs will be identified and explained.

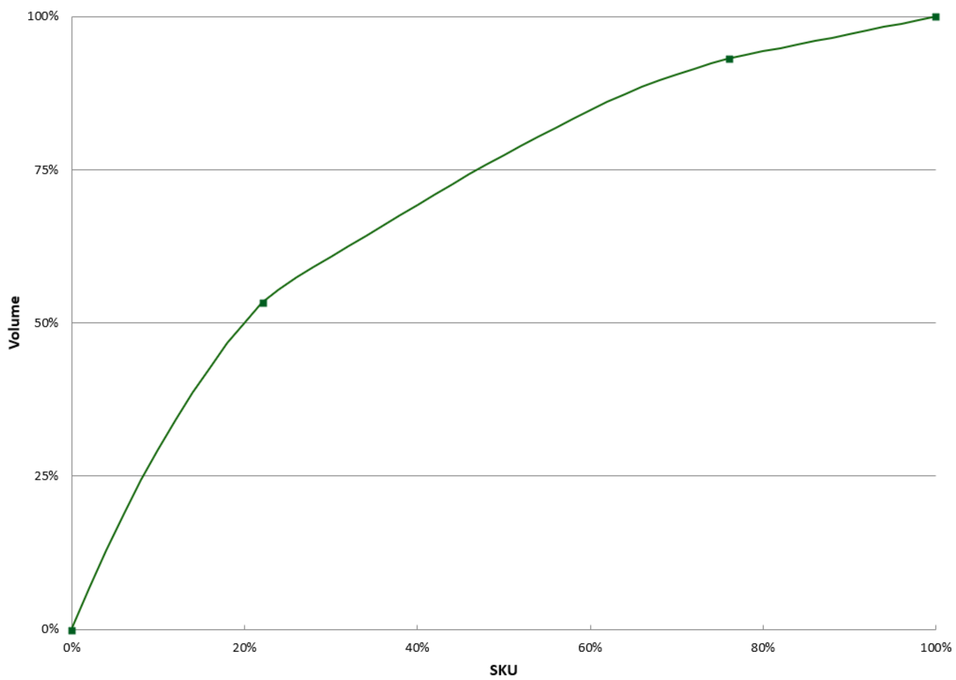


Figure 7.2: ABC analysis demand forecast local brands

Alternative I: Just in case

To make sure a service level of 100% will be achieved, all products will have a safety stock. Which leads to inventory, obsolescence and the according costs.

SS = D_{max} * LT_{max} - D_{avg} * LT_{avg}
ROP = D_{avg} * LT_{avg} + SS
= D_{avg} * LT_{avg} + D_{max} * LT_{max} - D_{avg} * LT_{avg}
= D_{max} * LT_{max}

Alternative II: Just in time

Is the counterpart of the first alternative where all products have a safety stock of zero. This way a decreased service level should be accepted, but average inventory level and number of obsoletes should also be lower.

SS = 0
ROP = D_{avg} * LT_{avg}

Alternative III: ABC

Is a combination of the other two alternatives based on the idea that different products should be treated differently. Since the other alternatives provide two different approaches, two groups where made using the ABC-method. The first group consist of fast moving products which will have a safety stock and the second group consist of slow moving products without safety stock.

Fast mover:
D_{avg} > 180 HL/year
ROP = D_{max} * LT_{max}

Slow mover:
D_{avg} < 180 HL/year
ROP = D_{avg} * LT_{avg}

7.3. KPIs

Section 4.4 introduced possible KPIs to measure supply chain performance. Together with the theory on inventory management three KPIs can be identified to compare the alternatives. Inventory level, service level and obsolete inventory.

Inventory Level

Inventory level (IL) is the inventory that is on hand that varies over time. Inventory is expressed in [HL]. IL belongs to the performance attribute asset management efficiency, metric AM.1.1 - Cash-to-Cash Cycle Time and process AM.3.45 -Inventory Days of Supply (Finished Goods)

Service Level

Service level (SL) is a measure of satisfying demand through inventory in time to satisfy the customers' delivery dates and quantities (Pittman and Atwater, 2016). Service level is expressed as the percentage [%] of demand picked complete from stock. SL belongs to the performance attribute reliability, metric RL.1.1-Perfect Order Fulfilment and process AM.2.1-Days Sales Outstanding

Obsolete Inventory

According to Pittman and Atwater (2016), obsolete inventory are inventory items that have met the obsolescence criteria established by the organisation. For the purpose of freshness Heineken has set a maximum of six months at the DC. After six months the beers cannot be sold and loose their value. The value that is lost is the cost of the beer itself plus the cost of the container (keg or bottle). The cost of the container can be neglected when a returnable container is used. Obsolete inventory belongs to the performance attribute asset management efficiency, metric AM.1.1 - Cash-to-Cash Cycle Time and process AM.3.28 - Percentage Excess Inventory.

8 Simulation

8.1. Conceptualisation

Before the simulation model itself is build, a conceptualisation is made. The conceptualisation helps to understand what decisions have to be made by the model and what information is needed to make these decisions. The conceptualisation is visualized using a flowchart. It shows the order process flow and can be found in Figure 8.1.

The flow starts when an order comes in. The first decision that has to be made is whether there is enough inventory to fulfil the order. If there is not sufficient inventory the order is cancelled completely, transferring to lost sales (LS). The number of LS together with the number of orders determines the service Level (SL)). When then the inventory level (IL) is sufficient to fulfil the order, the IL has to be adapted.

When the IL changes it will be compared to the reorder point (ROP). The ROP is determined by the safety stock (SS), lead time (LT) and demand. Demand is determined by average of all incoming orders. When the IL is smaller than the ROP, a new batch has to be brewed and when the batch arrives at the DC, the IL has to be adapted. When the IL is bigger than the ROP, the process stops and waits for the next order to start over.

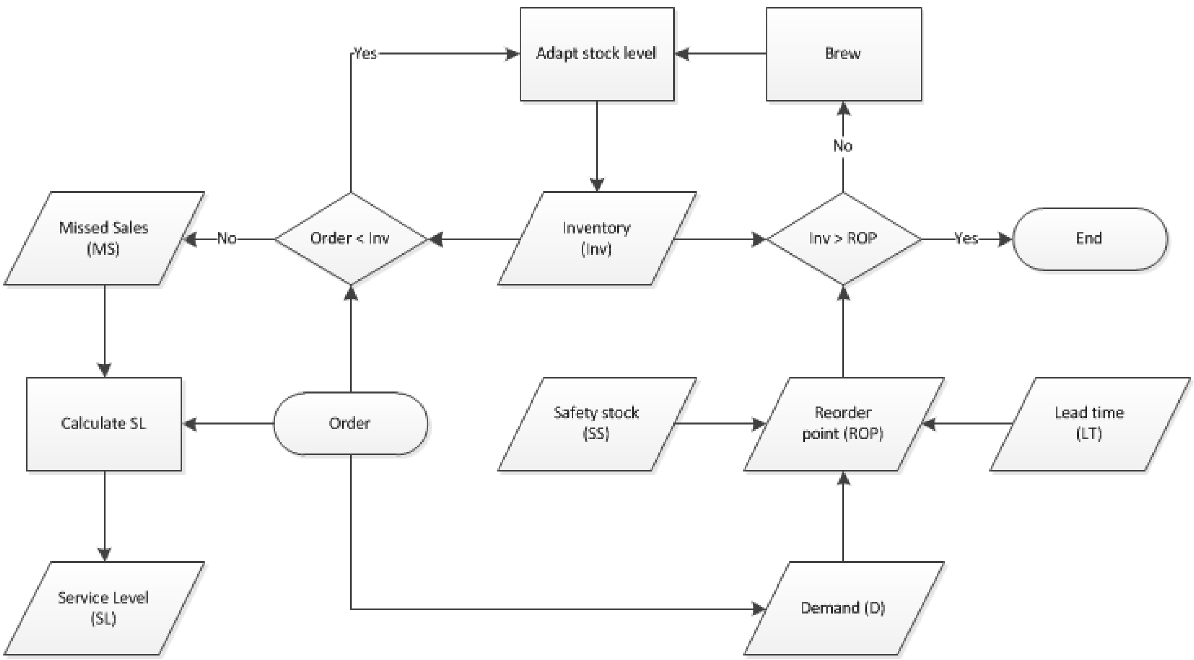


Figure 8.1: Order process flow

8.2. Specification

Figure 8.2 shows a screenshot of the model. The simulation model exists of seven objects and three paths. There are four different types of objects. A source (Order), a combiner (DC), a workstation (Brew_start) and four sinks (Lost_Sales, Sales, Obsoletes and Brew_End). The first three objects form the basis of the model and will be discussed one by one. The four sinks are used to delete entities and collect statistics.

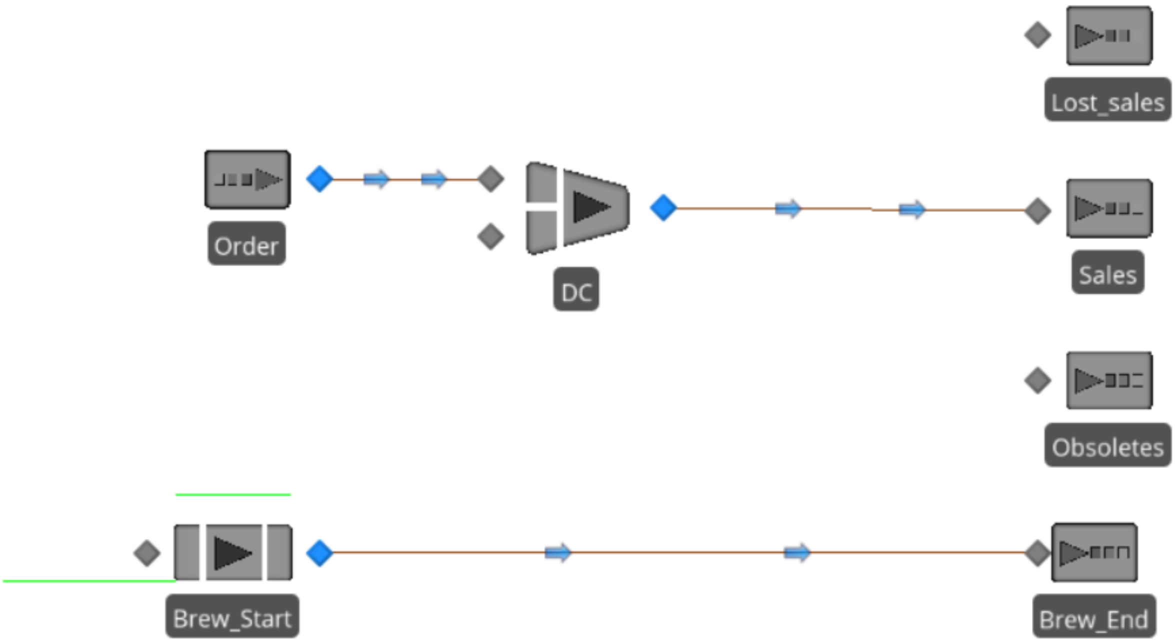
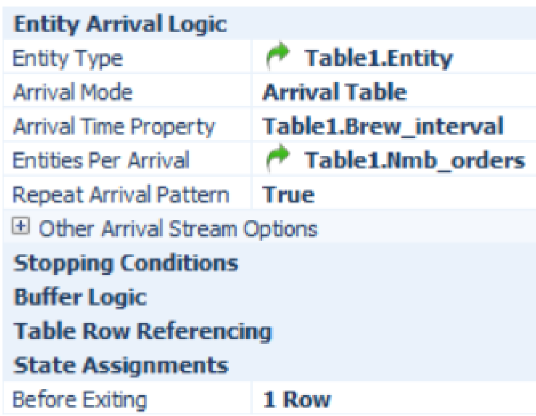


Figure 8.2: Screenshot of the Simio model

Order

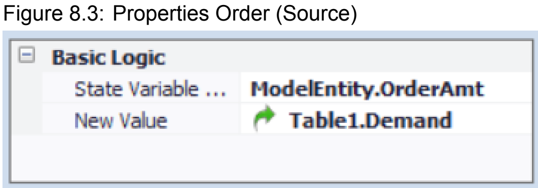
The generation of orders is done by a source object. A source object may be used to generate entities of a specified type (Simio LLC, 2006). The Properties of the source are shown in Figure 8.3. All the inputs are linked to "Table1" in Simio. The same table can be found in Appendix G.2.

The entity arrival logic first determines the entity type, then the moment of arrival followed by how many entities per arrival and finally it is stated that the arrival pattern repeats itself. Then there is also a state assignment (Figure 8.4) which determined the OrderAmt per entity also from the data table. The order amount varies according a Gamma distribution with shape factor 2.759 and a scale factor that is 1/2.759th of the average demand. This way the average order amount will be equal to the average demand. The shape factor is statistically determined using actual sales data. The distribution fitting is explained in Appendix H. Translated to the project this means that every week 45 product orders are created with a variable order amount.



Entity Arrival Logic	
Entity Type	Table1.Entity
Arrival Mode	Arrival Table
Arrival Time Property	Table1.Brew_interval
Entities Per Arrival	Table1.Nmb_orders
Repeat Arrival Pattern	True
⊞ Other Arrival Stream Options	
Stopping Conditions	
Buffer Logic	
Table Row Referencing	
State Assignments	
Before Exiting	1 Row

Figure 8.3: Properties Order (Source)



⊟ Basic Logic	
State Variable ...	ModelEntity.OrderAmt
New Value	Table1.Demand

Figure 8.4: Properties Order - State Assignment

DC

The distribution of products is modelled with a combiner. A combiner object may be used to model a process that matches multiple entities, forms those entities into a batch, and then attaches the batched members to a parent entity (Simio LLC, 2006). Figure 8.5 shows the properties of the object: DC. The inventory of the DC is formed by the members that will be batched according the order amount (ModelEntity.OrderAmt). The incoming orders are the parent entities that will be matched with the batched members from the same entity (ModelEntity.priority). The combiner checks if there is enough inventory to meet the order amount. If there is not enough inventory the order is sent to the Sink: Lost_sales (Figure 8.6). If the inventory level of the specific SKU is sufficient, the order and inventory are matched and leave the system via the Sink: Sales. The final activity of the combiner is checking how long members are waiting (how long SKUs are on hand) If this is longer than 26 weeks a reneging (back out of) decision is made and the member entity leaves the system via the Sink: Obsoletes (Figure 8.7).

Batching Logic	
Batch Quantity	**ModelEntity.OrderAmt**
⊟ Matching Rule	**Match Members And Parent**
Member Match Expression	**ModelEntity.Priority**
Parent Match Expression	**ModelEntity.Priority**
Parent Ranking Rule	First In First Out
Member Ranking Rule	First In First Out
Process Logic	
Capacity Type	Fixed
Initial Capacity	1
⊟ Parent Transfer-In Time	**1**
Units	**Seconds**
⊟ Member Transfer-In Time	**1**
Units	**Seconds**
Process Type	Specific Time
⊞ Processing Time	0.0
Off Shift Rule	Suspend Processing
Buffer Logic	
⊟ Parent Input Buffer	
Capacity	Infinity
⊟ Balking & Reneging Options	
Balk Decision Type	None
Renege Triggers	**1 Row**
⊟ Member Input Buffer	
Capacity	Infinity
⊟ Balking & Reneging Options	
Balk Decision Type	None
Renege Triggers	**1 Row**
⊟ Output Buffer	
Capacity	Infinity

Figure 8.5: Properties DC (Combiner)

⊟ **Renege Trigger**	
Trigger Type	Time Based
⊞ Wait Duration	0.0
Renege Decisi...	Always
Renege Node ...	**Input@Lost_sales**
⊞ **Advanced Options**	

Figure 8.6: Properties DC - Renege Trigger Parent Input Buffer

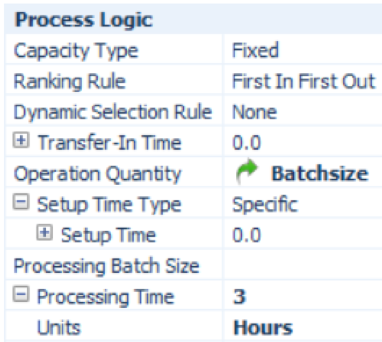
⊟ **Renege Trigger**	
Trigger Type	Time Based
⊟ Wait Duration	**26**
Units	**Weeks**
Renege Decisi...	Always
Renege Node ...	**Input@Obsoletes**
⊞ **Advanced Options**	

Figure 8.7: Properties DC - Renege Trigger Member Input Buffer

Brew

The Brew part is modelled using a Workstation (Brew_Start and a TimePath (Lagering). The workstation is activated by a ”process” in Simio and represents the mashing, lautering en cooking phases of brewing and the timepath the fermenting and lager phases plus the transport to the DC.

The process that activates the brew part can be simplified to the decision: should we brew? There should be brewed when the inventory (OnHand) plus ordered products (OnOrder) are smaller than the ROP, so the decision is dependent on the inventory level and the ROP. OnHand is updated every time a product enters or leaves the object DC and OnOrder when a product enters Brew_Start or Brew_End. After every change a re-order decision is made. To determine the ROP, the average and maximum demand is needed. The average demand is the average order amount of the review period. There is chosen for a moving average to keep variation in the average over time. When the average is calculated over all previous orders it will approach a constant which is not in line with reality. The process logic of both the replanishment and the average demand can be found in Appendix G.1.



Process Logic	
Capacity Type	Fixed
Ranking Rule	First In First Out
Dynamic Selection Rule	None
⊞ Transfer-In Time	0.0
Operation Quantity	**Batchsize**
⊟ Setup Time Type	Specific
⊞ Setup Time	0.0
Processing Batch Size	
⊟ Processing Time	**3**
Units	**Hours**

Figure 8.8: Properties Brew_Start (Workstation)

So when the decision the brew is made the brewing is moddelled with a workstation and a timepath. A Workstation object may be used to model a single capacity processing location and a TimePath object may be used to define a pathway between to node locations where the traveltime is user-specified (Simio LLC, 2006). The processing time of the workstation is set to three hours with a batch size of 100 kegs (20 HL) and a capacity of one batch at a time. The timepath has a processing time (Leadtime) of three weeks. When the batches arrive at the Brew_end they are transferred to the member input of the combiner (DC).

Experiments

The last part of the specification in Simio, is the specification of experiments. Experiments are used to make production runs that compare one or more variations in the system. Experiments have a set of control variables and output responses.

Controls

The control variables are the values assigned to the properties of the associated model. The control variables have a initial value (Table 8.1) that is used to compare the three alternatives. The controls can also be varied, creating multiple scenario’s. This was done during the sensitivity analysis (8.3).

Table 8.1: Controls Simio experiments

Controls	Initial value
Batch size [keg]	100
Lead time [week]	3
Review period [week]	3
Demand Multiplier	1

Responses

The output responses correspond to the KPIs of Section 7.3 and are used to compare the alternatives and to determine the impact of the control variables. The experiment environment in Simio was used to calculate the volumes which will be translated into cost using Microsoft Excel in the last section.

$$SL[\%] : \frac{Sta\_Orders.LastRecordedValue - Sta\_Lost\_Sales.LastRecordedValue}{Sta\_Orders.LastRecordedValue}$$

$$IL[HL] : DC.MemberInputBuffer.Contents.AverageNumberWaiting * 20/100$$

$$Obs[HL] : DC.MemberInputBuffer.NumberReneged * 20/100$$

$$LS[HL] : Sta\_Lost\_Sales.LastRecordedValue * 20/100$$

Cost

The volumes calculated in the Simio model can be translated into cost. This is done in Microsoft Excel using the specifications of Table 8.2.

Inventory

Inventory leads to cost. The cost of inventory is calculated per pallet. Within Heineken a price per pallet per week of €XXX is used. The volumes are round up to get an integer number of pallets and the total is multiplied by 52 weeks to get the cost of one year.

$$IL[€] = (ROUNDUP(((0.4 * IL[HL] * 100)/400, 0) + ROUNDUP(((0.6 * IL[HL] * 100)/428)) * XXX * 52$$

Obsoletes

Table 8.2 shows the cost per HL for the kegs and bottles used in the simulation. The cost come from a contracted partner and since returnable kegs will be used, the cost of the container are excluded for kegs.

$$Obs[€] = 0.6 * Obs[HL] * XXX + 0.4 * Obs[HL] * XXX$$

Lost Sales

bla bla

$$LS[€] = (0.6 * LS[HL] * XXX + 0.4LS[HL] * XXX) * profit\ margin$$

Table 8.2: Specifications of keg and bottle.

	Cost [€/HL]	Volume [L]	Pallet load [#/pallet]	Pallet load [L/pallet]	Ratio
Keg	XXX	20	20	400	40%
Bottle	XXX	0.33	1,296	428	60%

8.3. Verification & Validation

Before going to the results the model has to be checked on model errors and reality. By verification the question: "is the model right?" will be answered. Validation answers the question: "is it the right model?".

Verification

The green line in Figure 8.9 shows the inventory level of Prd19 over a year, Pdr19 is the product with the highest demand (fast mover). This figure gives a lot of information on how the model behaves. The inventory starts empty and after three weeks replenishment arrives, with a batch size of 20HL. One week later the first sales are made and the second replenishment arrives, this is correct since the ROP of Prd19 is bigger than 20HL. From there a pattern starts of repeating orders with variable sizes and periodic replenishment with a fixed batch size of 20HL.

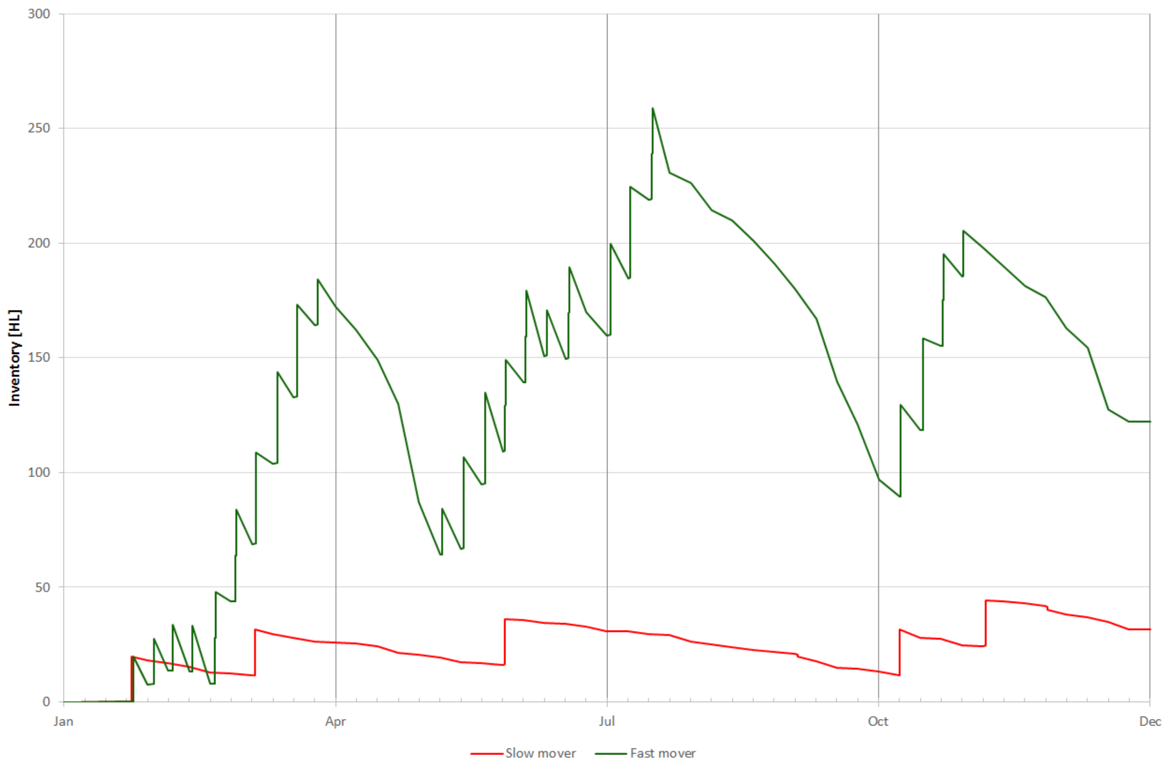


Figure 8.9: Inventory Level of Prd14 and Prd19 over a year for Alternative 1

The red line in Figure 8.9 shows a comparable behaviour but than of Prd14, the product with the smallest demand (slow mover). The figure starts the same and then it becomes clear that the order sizes are indeed smaller, resulting in also a lower ROP. Now it is clear that the orders, the distribution and the brew parts work as they were specified for Alternative 1.

Appendix G.3 shows the same figures for Alternative 2 and Alternative 3. The behaviour is the same, but for Alternative 2 the ROP of both products is lower resulting in lower inventory levels. For Alternative 3 only the slow mover has a lower ROP than at Alternative 1. So also Alternative 2 and Alternative 3 correspond to the predetermined behaviour.

Sensitivity

To check whether the model performs in the right way under different circumstances a sensitivity analysis is performed. For the sensitivity analysis the controls lead time, batch size and demand are varied 10% up and down, whereafter the effect on the number of obsoletes, the service level and the inventory level is checked. The first thing that pops up is that there are no effects on the SL. The small changes in input does not create lost sales. Secondly the direction of the effects is checked and all effects are in the expected direction. The third check is on the IL where all effects look linear (same change up and down) and within reasonable boundaries. The number of obsoletes is most effected by changes in input and the changes are different for growth and shrinkage. These differences are caused by the fact that it is an indirect effect (e.g. LT↑ → ROP↑ → IL↑ → Obs↑). This makes it harder to predict the effect, but it is clear that the effect should be taken into account, especially changes in LT.

Table 8.3: Sensitivity analysis

Input	Δ Input	Δ Obs	Δ SL	Δ Inv
Leadtime	+10%	93%	0%	9%
	-10%	-32%	0%	-9%
Batchsize	+10%	30%	0%	3%
	-10%	-21%	0%	-3%
Demand	+10%	-5%	0%	7%
	-10%	28%	0%	-7%

Validation

Now the model is verified the next step is to check whether the model can represent the real world situation accurately enough. Only when this is the case the model can be used for supporting real world decisions. Perfect validation of the model is impossible because the only perfect model is the real system itself. The goal of the validation therefore is to demonstrate that the model is valid enough for project purposes. There are several techniques to show this is the case. One common validation technique is to start with a model of the existing system. Compare the results of the simulation model against the performance of the real system. As the results of the simulation model are compared to the real word, this is called results validation (Smith and Sturrock, 2014). Since the flexbrewery is not implemented yet, there are no results to compare. There are not enough numbers available from the contract brewer and the numbers of competitors are not public. Therefore another validation technique is needed. A validation technique which can be used in this situation is to use the experience of the stakeholders. The people involved know the system well and are able to watch an animation and provide some measure of confidence. If the results and global structure of the model are consistent with how they perceive the system should operate, then the simulation model is said to have face validity. Two experts within Heineken are consulted. Experts on both the project and on inventory management. By viewing the model step by step and looking at the model inputs it was concluded that, taking the model assumptions into account the model is good enough in order to predict differences between the alternatives. Beside this two effects should be taken into consideration when interpreting the results. The model does not simulate product introductions or product delistings.

Product Introduction

When a product is produced for the first time, there is no inventory. When the ROP is bigger than the batch size it takes a few batches and therefore time to built enough inventory to balance supply and demand. During this time lost sales can occur. The model does not take product introductions into account so the number of lost sales is underestimated. Since the model compares three alternatives between themselves, the question is if the effect is the same for all alternatives. In order to quantify the introduction effect the simulation is done with and without warm-up period. During the warm-up period all 45 SKUs are introduced. Table 8.4 shows the change in LS per alternative. First it can be concluded that with all alternatives there are more lost sales without a warm-up time than with a warm-up time, just as expected. More important is the conclusion that there are no significant differences between the alternatives. All alternatives seem to react the same way and with the same order size. This means that although the model does not simulate product introductions it is still valid to determine the difference between the alternatives.

Table 8.4: Change in Lost Sales per alternative caused by product introductions

	Total difference [HL]	Difference per SKU [HL]
A1	821	18
A2	953	21
A3	861	19

Product Delisting

The opposite of an introduction is a product delisting. Products will be delisted when demand approaches zero for a longer period. In the model is assumed that a new product replaces the delisted product. What it does not take into account is a situation where demand suddenly disappears and the complete inventory transforms into obsolete inventory. If this occurs the obsolete inventory is underestimated by the model. Same as with the products introduction, the question is if there is a difference between the three modelled alternatives. Figure 8.10 shows the inventory levels of all 45 products together for the three alternatives. It is clear that the average inventory levels of the different alternatives are not equal. This means that the number of obsoletes after a delisting are also not equal. So when the results in the next chapter will be evaluated, the effect of delisting products should be considered.

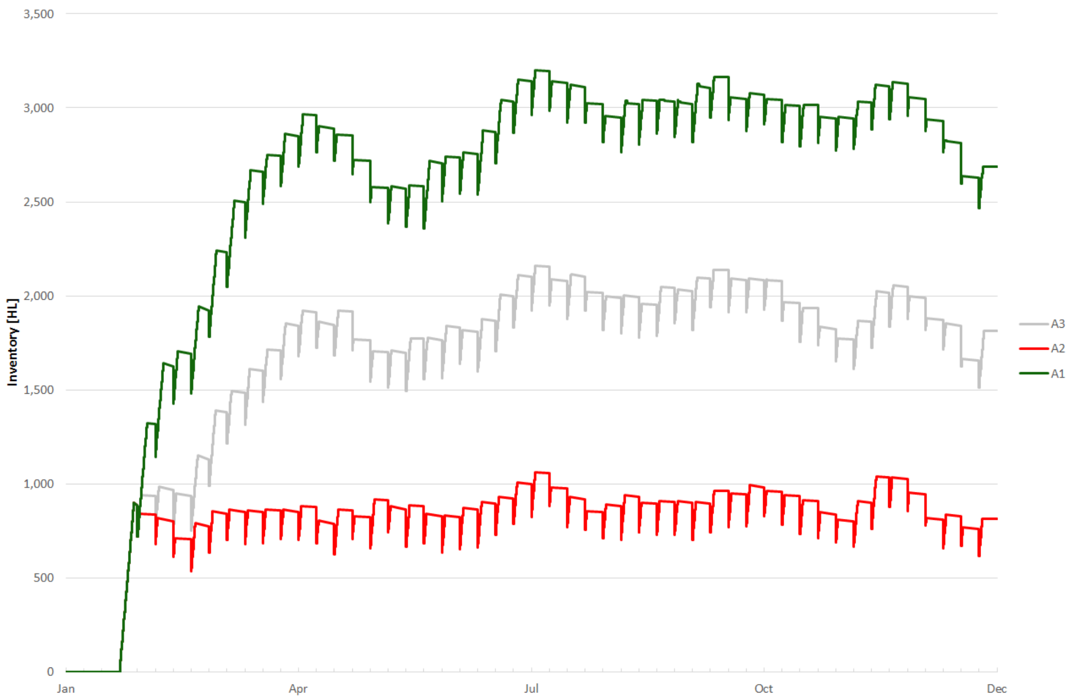


Figure 8.10: Inventory Level of all products together for all three alternatives

EVALUATE

9
Results

Table 9.1 shows the results of the experiments specified in Section 8.2. The experiment ran for 52 weeks with a warm-up time of 13 weeks. A warm-up period is the time period after the beginning of a run at which statistics are to be cleared. Warm-up periods are useful for removing the effects of atypical system conditions from the statistics collection (Simio LLC, 2006). The alternatives in Table 9.1 correspond to the alternatives introduced in Section 7.2. SL is calculated by dividing the volume of all outgoing sales by the volume of all incoming orders of the combiner (DC). IL is the average quantity of products over the year and Obs is the total volume that is reneged from the inventory. For IL and Obs the cost are calculated using the specifications from Section 7.3.

The subtotal is the sum of the cost of inventory and the cost of obsolescence. This way the difference between the alternatives can be quantified. Service level is not part of the subtotal because the effects of a change in service level could not be quantified. In order to make the comparison between service level and cost more complete, the cause of a change in service level is quantified. This cause is lost sales and is calculated by the product of the volume of lost sales and the profit margin of a sale. Since it is classified what this margin is, only the totals are presented. The last column shows the total cost that is the sum of inventory, obsolescence and lost sales. Since there are also indirect effects on top of the lost sales, service level is also not fully covered by this total. It already gives more information, but there is still a trade-off to make.

Table 9.1: Results of the three alternatives of a simulation of 52 weeks with a warm-up time of 13 weeks

Alternative	SL [%]	IL [HL]	IL [€]	Obs [HL]	Obs [€]	Subtotal [€]	LS [€]	Total [€]
1	100	XXX	45,695	XXX	24,011	**69,706**	579	**70,285**
2	90	XXX	13,910	XXX	138	**14,048**	61,690	**75,738**
3	98	XXX	30,420	XXX	450	**30,870**	14,758	**45,628**

Pareto frontier

This trade-off can be seen in Figure 9.1 and 9.2 showing the Pareto front of the different alternatives with and without the cost of lost sales. A pareto optimal solution can then be seen as an optimal trade-off between the objectives. By definition, Pareto solutions are considered optimal because there are no other designs that are superior in all objectives. In this case the cost reduction compared to A1 on the horizontal axes and SL on the vertical axes. The set of all Pareto optimal solutions is called the Pareto front (Pareto, 1964). Since the objective is to maximize SL and cost reduction all possible combinations under the Pareto front are inferior and all possible combinations above the Pareto front are superior and should be added to the front.

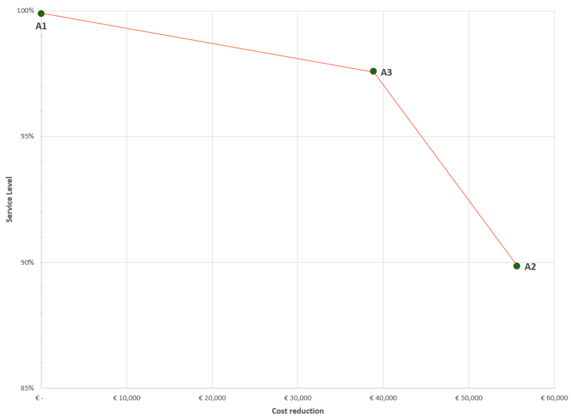


Figure 9.1: Service level vs. cost reduction of A2 & A3 compared to A1 with pareto frontier (lost sales excluded)

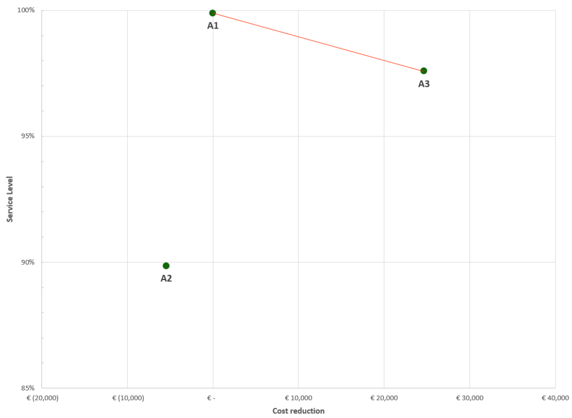


Figure 9.2: Service level vs. cost reduction of A2 & A3 compared to A1 with pareto frontier (Lost sales included)

In Figure 9.1 the cost reduction is based on the subtotal of Table 9.1, so without the cost of lost sales. Alternative one has the highest SL and (by definition) no cost reduction. Alternative two has the highest cost reduction and the lowest SL and alternative three is in between them on both objectives. The three alternatives together form the Pareto front.

Figure 9.2 shows the cost reduction including lost sales, SL remains the same for all alternatives. There are two changes compared to Figure 9.1. The first change is that the cost reduction of alternative three relative to alternative one is smaller. The second and biggest change is that alternative two shifted from the alternative with the highest relative cost reduction to the alternative with the highest cost. So next to a reduction in SL there is a cost increase. In this case alternative two is inferior to the other two alternatives and no longer part of the Pareto front.

From validation could be concluded that the delisting of products should be taken into consideration because all alternatives underestimates obsolescence cost when products get delisted. Figure 8.10 Showed that alternative three has the highest average inventory and underestimates the obsolescence cost the most, then alternative three and alternative two the least of the three. Combining this knowledge with Figure 9.1 makes it clear that the Pareto front remains the same, only the differences in cost between the alternatives will grow. The Pareto front including lost sales from Figure 9.2 on the other hand can change. The cost reduction from alternative three compared to alternative one will grow and the cost reduction of alternative two will grow even more making it possible to be part of the Pareto front again. Therefore the cost reduction of alternative two has to be bigger than the cost reduction of alternative one and alternative three.

This situation occurs when the difference in obsolescence cost between alternative two and alternative three is bigger than the difference in cost reduction in Table 9.1. The number of product delistings needed for this difference is determined as follows:

Delists per year [SKU] = Δ Cost reduction / Obsolescence cost / Δ Average inventory
= XXX
= 3 (7% of the SKUs per year)

9.1. Alternative I: Just in Case

Alternative one distinguishes itself with a safety stock for all products. The SS should prevent out of stock situations resulting in lost sales. Looking at the results in Table 9.1 alternative one meets this requirement. The service level of 100% means that all orders are fulfilled. The inventory level and obsoletes can not be evaluated on itself, it should be compared to other alternatives. Also the cost do not stand alone, since the cost are not complete (e.g. handling is excluded) and not a business case complete with costs and benefits are made.

9.2. Alternative II: Just in Time

Alternative two does not have a safety stock which means that the IL should be lower, but when demand exceeds the forecast lost sales can occur. The lower IL leads to less obsoletes. The results show a SL of 90%, a decrease of 10% compared to alternative one. Opposite there is indeed a lower inventory and number of obsoletes. Cost of inventory are €31,785 lower than at alternative one and the cost of obsoletes are reduced with €23,873. Together alternative two reduces cost with €55,658 which is equal to €5,566 per lost percentage point. When lost sales are quantified using the profit margin the total cost exceed the total cost of the other alternatives making alternative two a inferior alternative, but when more than 7% of the SKUs get delisted per year alternative two re-enters the Pareto front.

9.3. Alternative III: ABC

Alternative three is a combination of the other two alternatives. A high SL (and according inventory and obsoletes) for fast movers, just like alternative one and a lower SL (and according inventory and obsoletes) for slow movers, just like alternative two. The results of alternative three show that this results in an overall reduction in SL of 2% compared with alternative one. Inventory cost are with €22,295 in between alternative one and alternative two and cost of obsoletes is equal to alternative two. Without lost sales the cost of alternative three are €47,273 lower than with alternative one, which is equal to €23,637 per lost percentage point. Including lost sales in the total cost reduces the cost difference with alternative one where product delistings increase this difference. Calculating lost sales as a direct cost makes alternative three cost wise the best choice and remains this position when there are no more than 3 SKUs delisted per year.

10 Conclusion

10.1. Research Questions

In response to the growing demand for local beers as part of the broader craft beer trend, Heineken Netherlands wants to reduce their minimum batch size to answer this demand and complete their portfolio. This research focussed on the impact on the supply chain of this reduction and how this could be implemented by answering the main research question on the basis of five sub-questions:

"What is the best decoupling point and according replenishment strategy for the supply chain of the HEINEKEN flexbrewery?"

What is a flexbrewery? The flexbrewery as described in this project is a brewery that brews beers for local demand. The flexbrewery distinguish itself from the existing Heineken breweries by a smaller batch size and a higher product variety

What is a decoupling point? A decoupling point is the position in the supply chain to where customer demand reaches. It is the point where the supply chain switches from a push to a pull strategy and where the main inventory is placed.

Where in the supply chain should the decoupling point be? For the supply chain of the flexbrewery a make to stock (MTS) strategy should be adopted in order to answer the desired customer lead time. An advantage of the MTS strategy is that the new products can join the existing logistics. The decoupling point is located at the distributor between producer and customer.

What is replenishment? Replenishment is making sure there is enough inventory by determining the moment that a new batch should be produced. There are different strategies in determining this moment and determining what is enough.

Which replenishment strategy fits the supply chain best? The best way to implement this strategy depends on what the minimum service level is and on how a decrease is SL is valued. When a SL of 100% is required, Alternative I: Just in Case should be implemented. If a SL of 90% is acceptable and minimum cost are required, Alternative II: Just in Time should be implemented. When a relative maximum cost reduction is required, Alternative III: ABC should be implemented.

This way the main research question can be answered as follows. The decoupling point of the supply chain of the Heineken flexbrewery should be located at the distributor between producer and customer following a make to stock supply chain design with a stock level that suits the requirements of the customer. When lost sales are added as direct cost alternative II turns out to be inferior to the other alternatives, but this relation is not substantiated enough. Delisting of products can undo this shift or at least strengthen the original cost differences.

10.2. Discussion

The first thing that stands out when you read the main research question and its answer is that the question is about a complete supply chain design and the answer is focussed on the supply chain strategy and its implementation. In the report is explained that the strategy is a part of the supply chain design. This focus is the result of scoping down to the later explained inventory management resulting from the choice for a MTS strategy.

Secondly the choice for MTS can feel strange reading the report. First most characteristics are matched with MTO and then MTS is chosen. This has to do with the fact that characteristics like demand and life cycle are high or low relative to what they are compared to. More important is that some characteristics are leading in a choice. For the flexbrewery the desired customer lead time turned out to be the determining factor. Although it is possible to respect the desired lead time with an other strategy than MTS. In this project it felt out of scope because one of the requirements was that the beer should be brewed the ”traditional” way, but when taking flavour dosing or an other form of downstream diversification into account a assemble to order (ATO) strategy could be a solution.

A model is only as good as its input. The demand was created by a sales forecast and limited sales data, therefore the results should be used with care. Even though the sensitivity analysis showed that the model was relatively robust for changes in demand.

Batch size is an important variable since the whole flexbrewery is based on the need for smaller batches. But how small? The batch size is influenced by different factors. First there is the (local) demand in combination with the freshness of the product that determines a maximum batch size. Secondly there are economies of scale that make bigger batches more effective in terms of cost and third there is the effect that smaller batches lead to lower inventory and obsoletes. The last two effects are opposites, so a balance should be found. In this project the balance was found at 20HL because this was the maximum in terms of freshness and the minimum when multiple batches per day were taken into account. The fact that the batch size was on the ”limit” of the freshness (of the slow mover) caused the big difference in obsoletes between the alternatives with and without safety stock.

A final limitation of the model is the fact that delisted products are not included. It is found that this way the model underestimates the number of obsoletes and that alternative one is most sensitive to this effect, then alternative three and then alternative two. It is not clear how often this occurs, so the real effect could not be quantified.

10.3. Recommendations

Since research is never finished a few recommendations can be made. The recommendations are split up, first some recommendations for further research and then some practical recommendations regarding the project at Heineken.

Literature

This research started with a trend of growing demand for local beers. It is likely that this trend is broader than the beer market only. It could be interesting to compare the impact of this trend of multiple different supply chains. Other products that experience this trend could be for example: vegetables, bread and meat. This research focusses on the downstream side of the supply chain. Smaller batches also influence suppliers, so more research into upstream effects could be interesting.

Heineken

The last recommendation for further research also applies for Heineken. They have a solution for the supply of the flexbrewery for now, but when this trend perseveres other options should be taken into account. Since the model was most sensitive to lead times, lead times should be checked during the project. When changes occur the conclusions should be reconsidered. ATO was out of scope for this project, but the local brands seem to fit this strategy. Letting go of the ”traditional” way of brewing opens up more possibilities for example downstream diversification. The final recommendation is to look into the number of delisted products that could be expected. This way can be determined if alternative two is a valid option or not.

10.4. Reflection

The final section of this report will reflect on the conducted master thesis project. First the process will be evaluated, then the interface with the literature will be reviewed and finally a personal reflection on the project will be given.

Process

This master thesis project is conducted during an internship at Heineken. Ten months ago the project started without a clear scope or problem, but with confidence from me and my company supervisor that the developments of Heineken on local craft beers offered enough challenges for a master thesis. The first few months were needed to get a good feeling of the developments and finding the right scope. This first phase took longer then initially planned, also seeing a scope change.

The next phase started off in the wrong way. My university supervisors pointed out to me that I was trying to fit the problem in a method instead of finding the right method to solve the problem. After taking a few steps back the project really started to develop.

The modelling phase was a iterative process where inputs from the company and the university complemented each other leading to a complete working model.

The last phase made me take a few steps back again. Why did I do what I did and do I have what I expected? The followed DMADE method gave the right support to get trough the different phases by making sure that all steps were taken and were in the right order.

Literature

This research relates to a few brought fields in literature. Batch size determination, supply chain design and inventory management are all fields that have a long and rich history in literature. The first challenge is to find those articles that relate closest to your research. The second challenge is to find the research gap. A lag of information that is not only applicable to one specific situation.

This research found a gap in batch size literature. There is a world full of research on batch size determination, but not on the effect of that batch size on the supply chain. Together with the practical implications on inventory management this research filled a piece of unknown territory.

Personal

Finally I want to give a personal reflection on this master thesis project. I think it was an informative period with ups and downs which I will take with me the rest of my life. First of all the opportunity to have the freedom to line out your own project. It took some extra time, but by doing so I really got to know the project. Secondly working in a big corporate organisation together with people who really like and know what they are doing was both motivational and helpful. Being present and involved when decisions are made and next also seeing the result of these decisions was a great experience. At the same time I also think that I could have used the present knowledge and skills more often. I have experienced that I want to solve my own problems and sometimes waited too long before asking for help. This applies also to the feedback from my university supervisors. The combination of multiple supervisors with different backgrounds is a real advantage compared to the regular supervision. It took me some time to realise that they were there to help me with this knowledge not only to judge.

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APPENDIX

A

Research Paper

Analysis of the Impact of Small Batches on the Supply Chain and Simulation of Different Replenishment Strategies

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Keywords: Supply chain strategy, Inventory management, local demand

ABSTRACT. The last years craft beer is becoming more and more popular. Heineken responses to this trend in different ways. The last gap in this strategy is offering local brands to the market. In order to do so they have to reduce their batch size. This research looked into the impact of smaller batches on the supply chain. The first conclusion is that local brands also need to follow a make to stock strategy to fulfil customer demand. Then three alternatives in inventory management were simulated to make a trade off between service level and cost. The final conclusion is that a it seems best to keep safety stock for fast movers and no safety stock for slow movers, but it depends on how service level is valued.

DEFINE

Heineken is one of the biggest brewers in the world, in order to remain this position they have to follow market trends closely. The last few years craft beer is getting more and more popular. In 2017 craft had a market share of 10% in the Netherlands and was after non-alcohol the category with the biggest growth (Nederlandse-Brouwers, 2017). Heineken already had several craft beers in their portfolio, but what was missing were local brands. Since Heineken customers wants to offer the full portfolio and Heineken could not offer it themselves they allowed free riders. To make this no longer necessary, Heineken want to offer their customers their own local brands.

Local brands, means smaller demand what leads to smaller batches. The existing Heineken breweries in the Netherlands are not capable of brewing such small batches, so a new brewery has to be implemented. This brewery is called the flexbrewery because it has to be able to brew a brought variety of beers. The batch size and variety of beers has an impact on the supply chain and this research wanted to get a grip on this impact by answering the following research questions:

What is the best Decoupling Point and according Replenishment Strategy for the Supply Chain of the HEINEKEN Flexbrewery?

This question can be split up in five sub-questions.

- *What is a flexbrewery?*
- *What is a decoupling point?*
- *Where in the supply chain should the decoupling point be ?*
- *What is replenishment?*
- *Which replenishment strategy fits the supply chain best?*

The paper follows the DMADE structure as can be seen in Figure A.1. The structure is based upon the DMAIC method from the theories around Lean and SixSigma for Process Design and Performance by Beelaerts van Blokland (2017) and adapted to this research. The choice for this method is based on the proven value of the DMAIC method and adaptation to the design aspect. The sub-questions will be answered in different phases and together form the answer to the main research question. This first phase is the DEFINE phase. It started with an introduction and after the methodology it will answer the first sub-question be explaining the flexbrewery in more depth. The next phase is the MEASURE phase. Here will be defined what measures will be taken into account analysing the system and what supply chain KPIs there are. The ANNALYSE phase starts with theory on supply chain design whereafter it will be applied on the flexbrewery, this will answer the second sub-question. After analysing the flexbrewery process different alternatives will be determined in the DEFINE phase. These alternatives will then be modelled using Discrete Event Simulation. The final phase of this research is the EVALUATE phase. Here the results of the different models will be compared whereafter conclusions and recommendations will be made by answering the main research question.

The flexbrewery will be operated by Heineken Netherlands Supply (HNS) and will brew local recipes for customers of Heineken Netherlands (HNL). There are two types of customers. Customers that order beers with a recipe developed by HNL (local) and customers that order beers with an own recipe (tailor made). So the flexbrewery will always brew commissioned by HNL and can operate both as a traditional and a contract brewery. The brewhouse should exist of a mashtun, lautertun and a combined kettle/whirlpool. After cooling the wort needs to ferment and lager for circa two weeks. Because of this duration there are multiple fermentation vessels of different volume needed. The yeast will be removed by a separator and there is no need for filtration and stabilisation. There will also be multiple bright beer tanks (BBT). The bright beer will be packed in kegs or bottles and it will be possible to fill a mobile tank/truck directly.

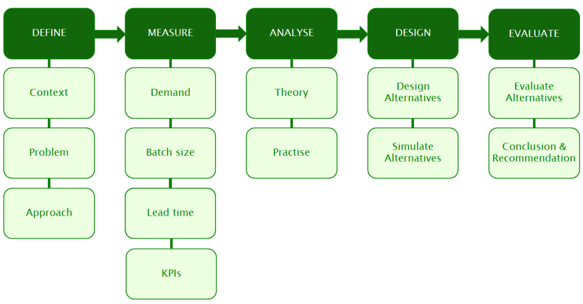

Figure A.1: Structure of the proposed research based on the research design matrix of Beelaerts van Blokland Beelaerts van Blokland (2017)

MEASURE

Now it is clear what a flexbrewery is, it should be possible to quantify its impact. The impact will be caused by the differences between the flexbrewery and the existing processes. The main difference is a smaller demand which asks for smaller batches. Next to a volume demand also exist of a time factor and this is determined by the lead time. So the impact of the flexbrewery will be measured using demand, batch size and lead time.

The craft beers that will be brewed at the flexbrewery differ from existing Heineken products by targeting a specific smaller market then before. This is characterised by the main measure demand. Demand tells you how many markets there are and how big those markets are.

The lower demand in combination with a limited shelf live means a lower batch size. The batch size will be determined by the volume that can be brewed in one brew cycle. The brewing process exist of multiple steps, where the first few steps take a couple of hours and the lagering takes a few weeks. Consecutive batches of the same recipe can be fermented together in bigger lager tanks or different batches can be put in different tanks. The batch size will be determined by the process with the smallest volume before fermenting.

In a logistics context lead time (LT) is the time between recognition of the need for an order and the receipt of goods. For make-to-order products, it is the length of time between the release of an order to the production process and shipment to the final customer. For make to stock products, it is the length of time between the release of an order to the production process and receipt into inventory (Pittman and Atwater, 2016). Every link in the supply chain has its own LT and also a desired LT of the previous link. The final customer only has a desired LT. All LTs together form the total LT.

ANALYSE

According to Christopher Christopher (2005) a supply chain (SC) is a network of organizations that are involved, through upstream (towards supplier) and downstream (towards consumer) linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer. In order to answer the needs of the customer the different flows in the SC should be synchronised (Taylor, 2004). This can be done by designing the supply chain, better known as supply chain design (SCD). There has been done a lot of research in this field and there are three clear phases of SCD identified (Christopher, 2005; Fawcett et al., 2007; Sharifi et al., 2006; Taylor, 2004).

Supply Chain Start

The first phase of SCD focusses on the product type. Despite a broad variety of products they can be categorised in two types of products and each type has its own impact on SCD (Fisher, 1997). The two types of products are functional products and innovative products both with their own characteristics. There is no perfect match with one of the product types and local brands, but it is clear that there is a better match with innovative products.

Supply Chain Strategy

The next phase determines the supply chain strategy. With two product types there are also two types of supply chains. Christopher Christopher (2005) describes them as an efficient or 'lean' supply chain and an effective or 'agile' supply chain. So two product types leading to two strategies? As the world is almost never as simple as black and white, it is neither in this case. Lean and agile represent conflicting interests, but can also complement each other. This way a third 'hybrid' strategy is possible. Hybrid supply chains are a combination from lean and agile approaches and are also called leagile supply chains (Mason-Jones et al., 2000). Leagile supply chains combine lean and agile approaches, but not at the same time. Leagile supply chains will have a point where the lean approach switches to the agile approach. This point is called the Customer Order Decoupling Point (CODP) or in short decoupling point ((Simchi-Levi et al., 2003)). According the product type a SC with a more upstream CODP then the existing MTS SC should be possible for the local brands. After analysing the processes and visualising them in a flowchart it turned out that the difference in producer LT and customer LT makes this impossible and a MTS strategy should be adapted which answers the second subquestion.

Supply Chain Structure

Once the strategy is determined a supporting supply chain structure should be found in the last phase of the SCD (Taylor, 2004). The supply chain structure refers to the sequential links among supply chain activities (Appelqvist et al., 2004). The supply chain structure thus implies the integration of the links between supply chain members (Defee and Stank, 2005). Figure A.2 shows the SC of the Flexbrewery. Since a MTS strategy will be followed, the scope will be on the flow from brewery to distributor. The downstream flow from distributor to customer can remain the same as the existing processes making use of synergy advantages. Upstream flows from supplier to manufacturer will be subject to other research.

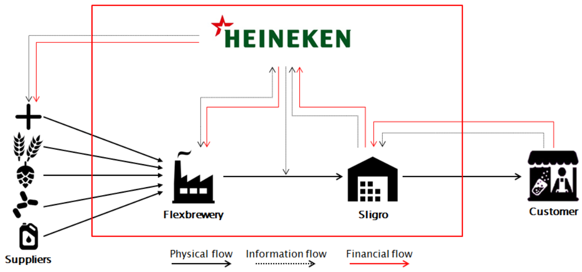

Figure A.2: Position of the Flexbrewery in the supply chain and scope of this research

DESIGN

The choice for MTS, causes the next classic supply chain dilemma: just in time or just in case? Just in time sounds efficient (minimise inventory), but has the risk of stock-outs. Just in case sounds safe (minimise stock-outs), but comes with high holding cost. There has been a lot of research into inventory optimization, where the reorder point plays a central role. Figure A.3 visualises this principle with the according information:

Reorder point

D_{avg}:	Avarage demand	[HL/t]
D_{max}:	Maximum demand	[HL/t]
LT_{avg}:	Average lead time	[t]
LT_{max}:	Maximum lead time	[t]
ROP:	Reorder point	[HL]
SS:	Safety stock	[HL]

$$SS = D_{max} * LT_{max} - D_{avg} * LT_{avg}$$

$$\begin{aligned} ROP &= D_{avg} * LT_{avg} + SS \\ &= D_{avg} * LT_{avg} + D_{max} * LT_{max} - D_{avg} * LT_{avg} \\ &= D_{max} * LT_{max} \end{aligned}$$

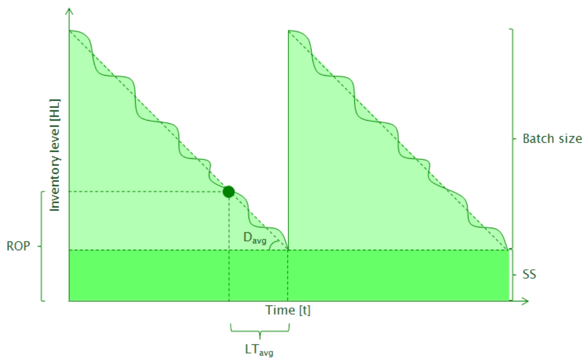

Figure A.3: Reorder point with safety stock (R,s,Q) policy

So inventory reduces over time by multiple orders (demand), if the inventory level is lower than the ROP a new batch will be produced and delivered after LT. The ROP is determined by the product of demand and LT where the situation without SS is based on average demand and LT and the situation with SS is based on the maximum demand and LT. To determine what ROP is best for the local brands three alternatives will be compared.

Alternative I: Just in case

To make sure a service level of 100% will be achieved, all products will have a safety stock. Which leads to inventory, obsolescence and the according costs.

SS $= D_{max} * LT_{max} - D_{avg} * LT_{avg}$
ROP $= D_{avg} * LT_{avg}$ + SS
$= D_{avg} * LT_{avg} + D_{max} * LT_{max} - D_{avg} * LT_{avg}$
$= D_{max} * LT_{max}$

Alternative II: Just in time

Is the counterpart of the first alternative where all products have a safety stock of zero. This way a decreased service level should be accepted, but average inventory level and number of obsoletes should also be lower.

SS = 0
ROP $= D_{avg} * LT_{avg}$

Alternative III: ABC

Is a combination of the other two alternatives based on the idea that different products should be treated differently. Since the other alternatives provide two different approaches, two groups where made using the ABC-method. The first group consist of fast moving products which will have a safety stock and the second group consist of slow moving products without safety stock.

Fast mover:
D_{avg} > 180 HL/year
ROP $= D_{max} * LT_{max}$

Slow mover:
D_{avg} < 180 HL/year
ROP $= D_{avg} * LT_{avg}$

Simulation

The alternatives will be modelled and compared using a simulation. The simulation model of the Flexbrewery was built using SIMIO. SIMIO is a general purpose simulation package that allows building, verifying and analysing simulation models. The discrete-event simulation software SIMIO is often used in academics due to the complete documentation that follows with the software, its easy to use interface and its extensive possibilities.

EVALUATE

Alternative I: Just in Case distinguishes itself with a safety stock for all products. The SS should prevent out of stock situations resulting in lost sales. Looking at the results in Figure A.4 Alternative I meets this requirement. The service level of 100% means that all orders are fulfilled. The inventory level and obsoletes can not be evaluated on itself, it should be compared too other alternatives. Also the cost do not stand alone, since the cost are not complete (e.g. handling is excluded) and not a business case complete with costs and benefits is made.

Alternative II: Just in Time does not have a safety stock which means that the IL should be lower, but when demand exceeds the forecast lost sales can occur. The lower IL leads to less obsoletes. The results show a SL of 90%, a decrease of 10% compared to Alternative I. Opposite there is indeed a lower inventory and number of obsoletes. Cost of inventory are €31,785 lower than at Alternative 1 and the cost of obsoletes are reduced with €23,873. Together Alternative II reduces cost with €55,658 which is equal to €5,566 per lost percentage point.

Alternative III: ABC is a combination of the other two alternatives. A high SL (and according inventory and obsoletes) for fast movers, just like Alternative I and a lower SL (and according inventory and obsoletes) for slow movers, just like Alternative II. The results of Alternative III show that this results in an overall reduction in SL of 2% compared with Alternative I. Inventory cost are with €22,295 in between Alternative I and Alternative II and cost of obsoletes is equal to Alternative II. In total are the cost of Alternative III €47,273 lower than with Alternative I, which is equal to €23,637 per lost percentage point.

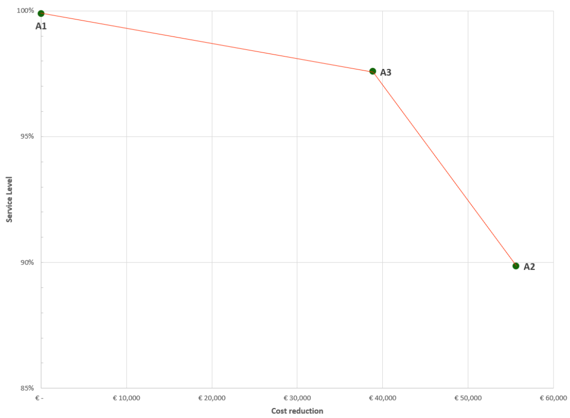

Figure A.4: Service level vs. cost reduction of A2 & A3 compared to A1 with Pareto frontier (lost sales excluded)

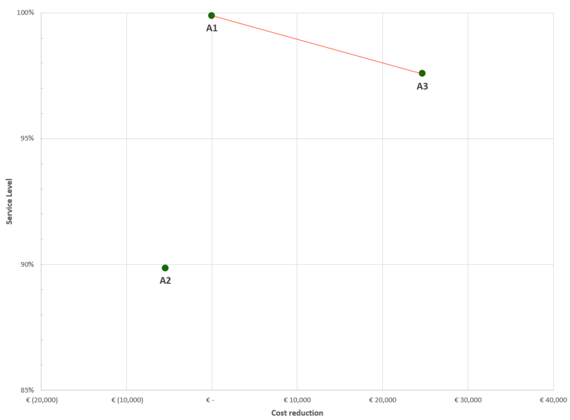

Figure A.5: Service level vs. cost reduction of A2 & A3 compared to A1 with Pareto frontier (Lost sales included)

Conclusion

This paper can be concluded by answering the research question. For the supply chain of the flexbrewery a make to stock (MTS) strategy should be adopted in order to answer the desired customer lead time. An advantage of the MTS strategy is that the new products can join the existing logistics. The decoupling point is located at the distributor between producer and customer. The best way to implement this strategy depends on what the minimum service level is and on how a decrease is SL is valued. When an SL of 100% is required, Alternative I: Just in Case should be implemented. If a SL of 90% is acceptable and minimum cost are required, Alternative II: Just in Time should be implemented. When a relative maximum cost reduction is required, Alternative III: ABC should be implemented. When last sales are added as direct cost Alternative II turns out to be inferior to the other alternatives, but this relation is not substantiated enough. Delisting of products can undo this shift or at least strengthen the original cost differences.

Discussion

The first thing that stands out when you read the main research question and its answer is that the question is about a complete supply chain design and the answer is focussed on the supply chain strategy and its implementation. In the report is explained that the strategy is a part of the supply chain design. This focus is the result of scoping down to the later explained inventory management resulting from the choice for a MTS strategy.

Secondly the choice for MTS can feel strange reading the report. First most characteristics are matched with MTO and then MTS is chosen. This has to do with the fact that characteristics like demand and life cycle are high or low relative to what they are compared to and more important, that some characteristics are leading in a choice like that for the flexbrewery the desired customer lead time was.

Looking at the third sub-question, it should be stated that a model is only as good as its input. The demand was created by a sales forecast and limited sales data, therefore the results should be used with care. Even though the sensitivity analysis showed that the model was relatively robust for changes in demand.

A final limitation of the model is the fact that delisted products are not included. It is found that this way the model underestimates the number of obsoletes and that Alternative I is most sensitive to this effect, then Alternative III en then Alternative II. It is not clear how often this occurs, so the real effect could not be quantified.

Recommendation

Since research is never finished a few recommendations can be made. Both theoretical and practical.

Theoretical:

- Explore other markets where demand for local products is growing and look for general learnings (e.g. vegetables, bread or meat).
- Look at the impact of smaller batches on the relation between producer and supplier.

Practical:

- Analyse upstream supply chain impact (impact on suppliers)
- Since the model was very sensitive to lead time, internal and external lead times should be clear and reliable.
- Look at the possibility of ATO by downstream diversification.
- Determine the number of delisted products to get a better estimate of the obsolescence cost.

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B

Conceptual Framework

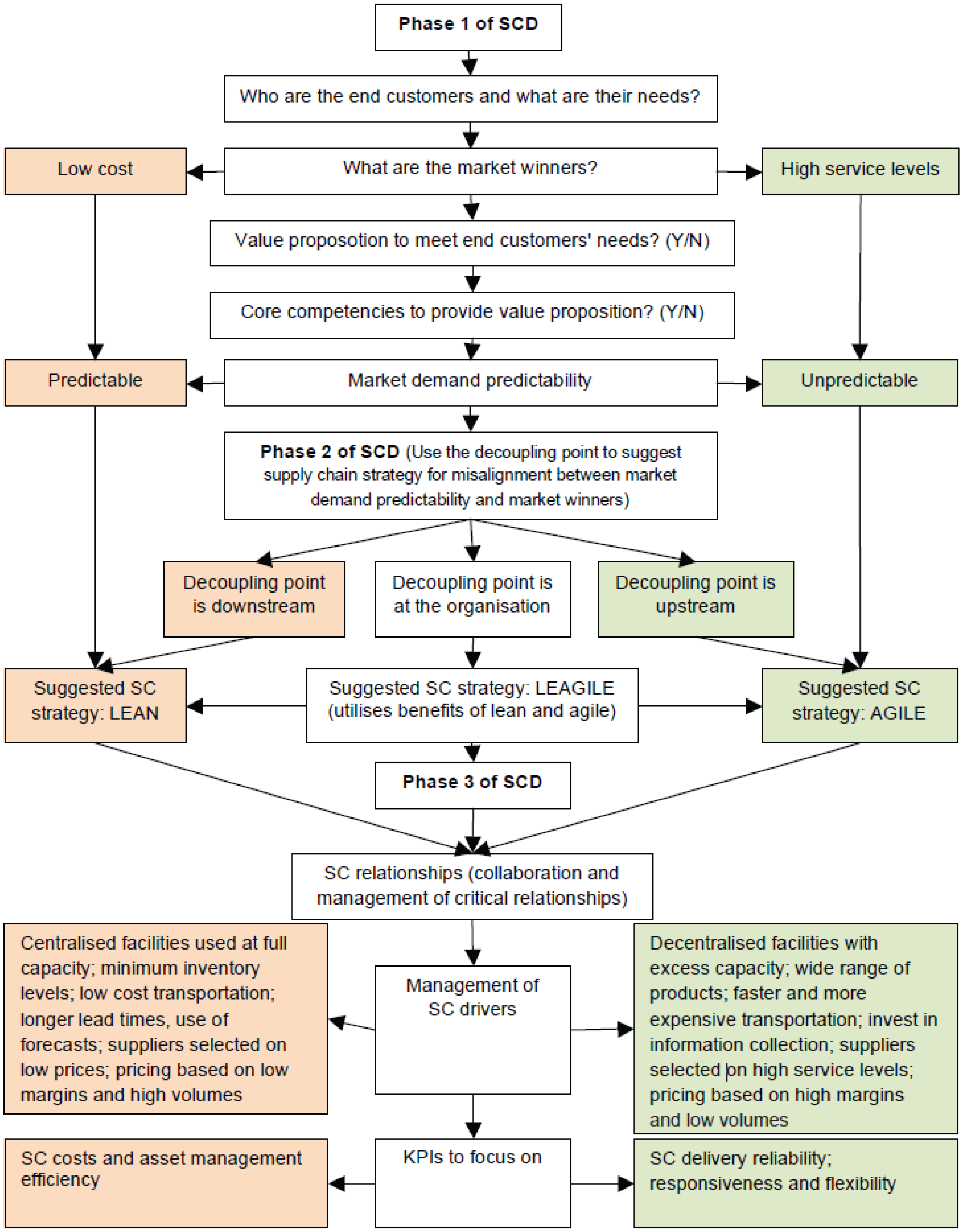

Figure B.1: Conceptual framework to analyse SCD practices (Nel and Badenhorst-Weiss, 2010)

C SPC

In Section 6.2 the Swimlane process chart (SPC) was introduced and explained. This appendix shows the different diagrams in more detail. The SPC's are constructed according information from the different involved actors using the Cross-Functional Flowchart template of Microsoft Visio 2010.

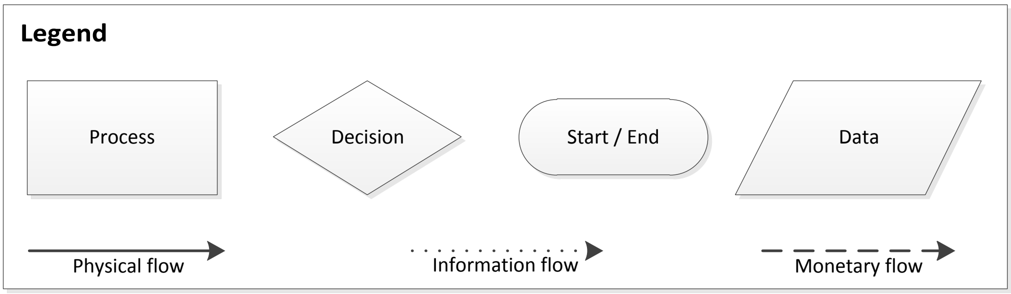

Figure C.1: Legend of the SPC

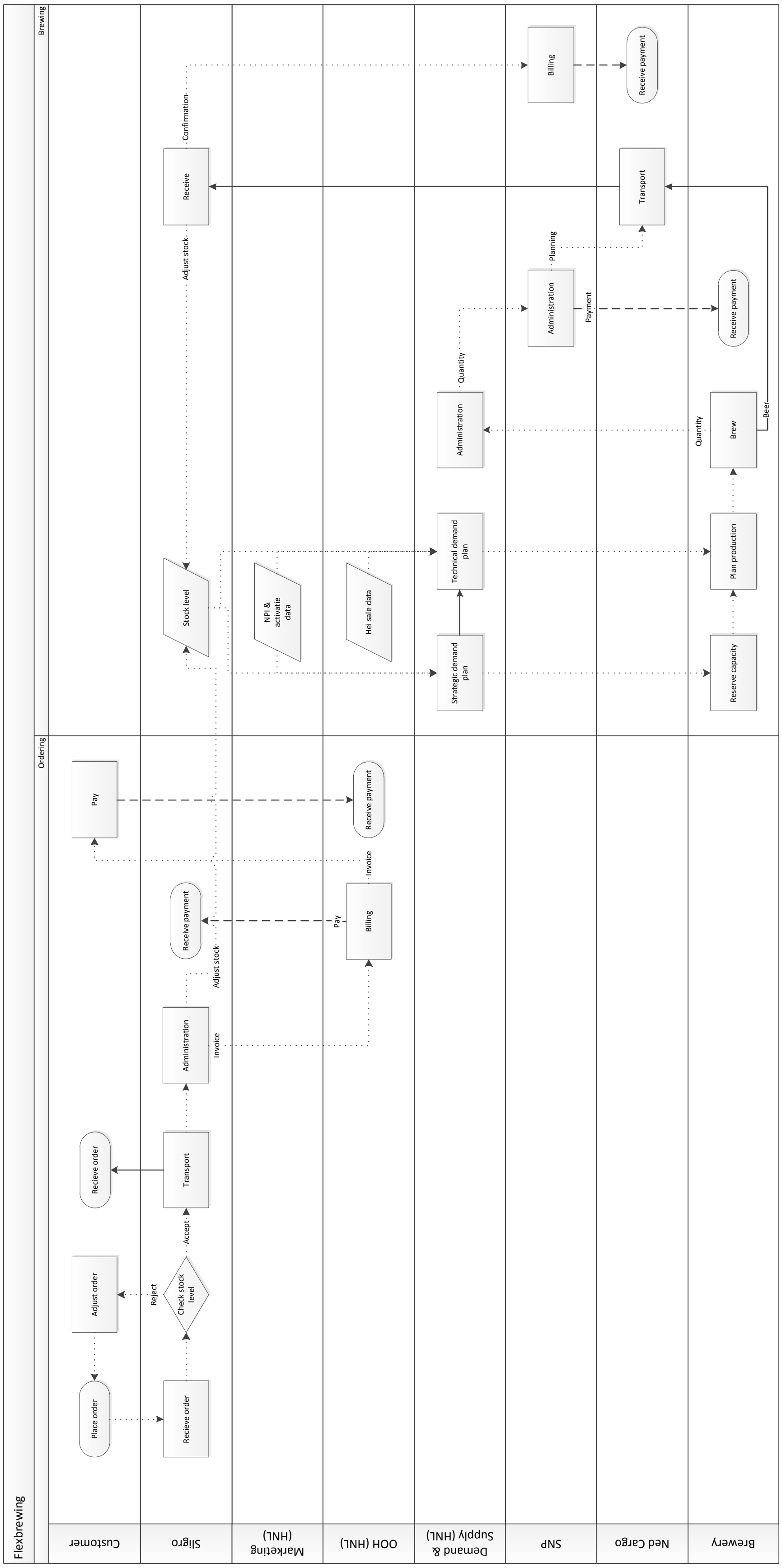

Figure C.2: Total SPC of the flexbrewery

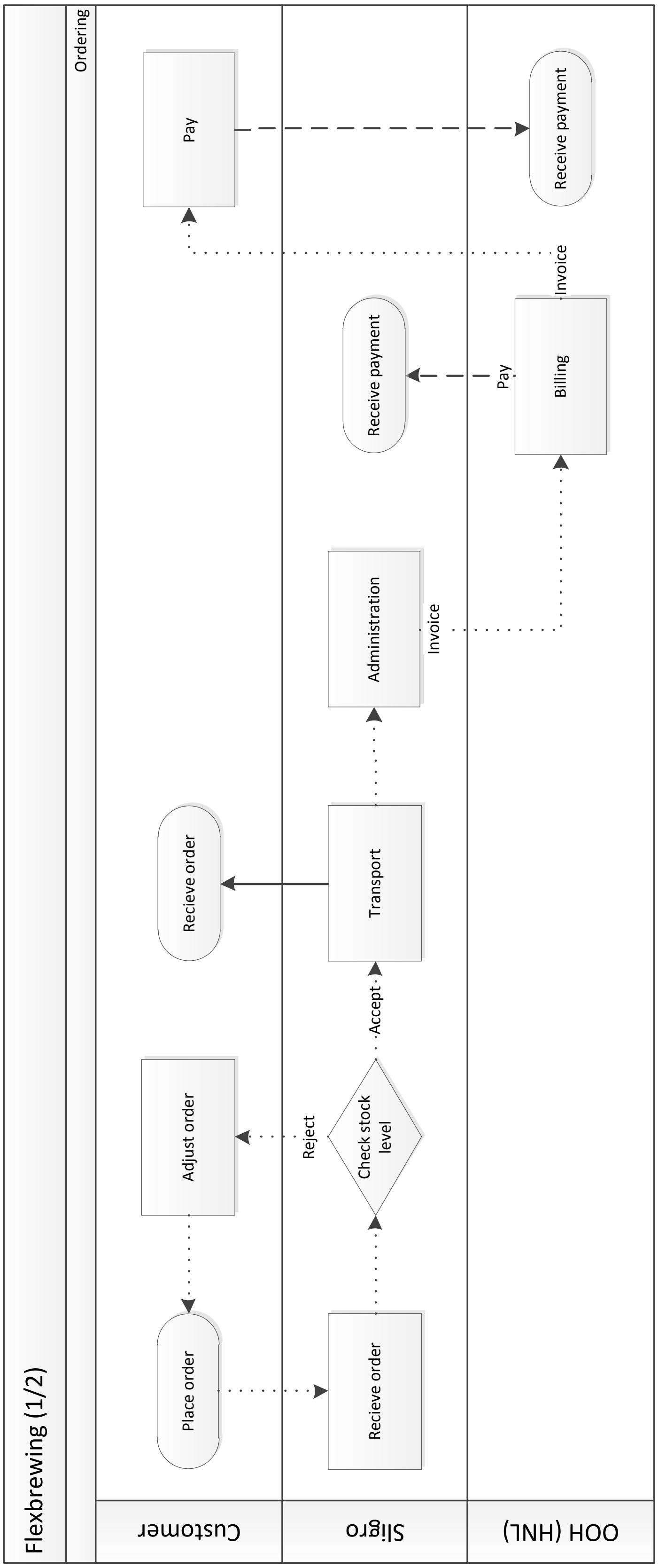

Figure C.3: Ordering phase of the SPC of the flexbrewery

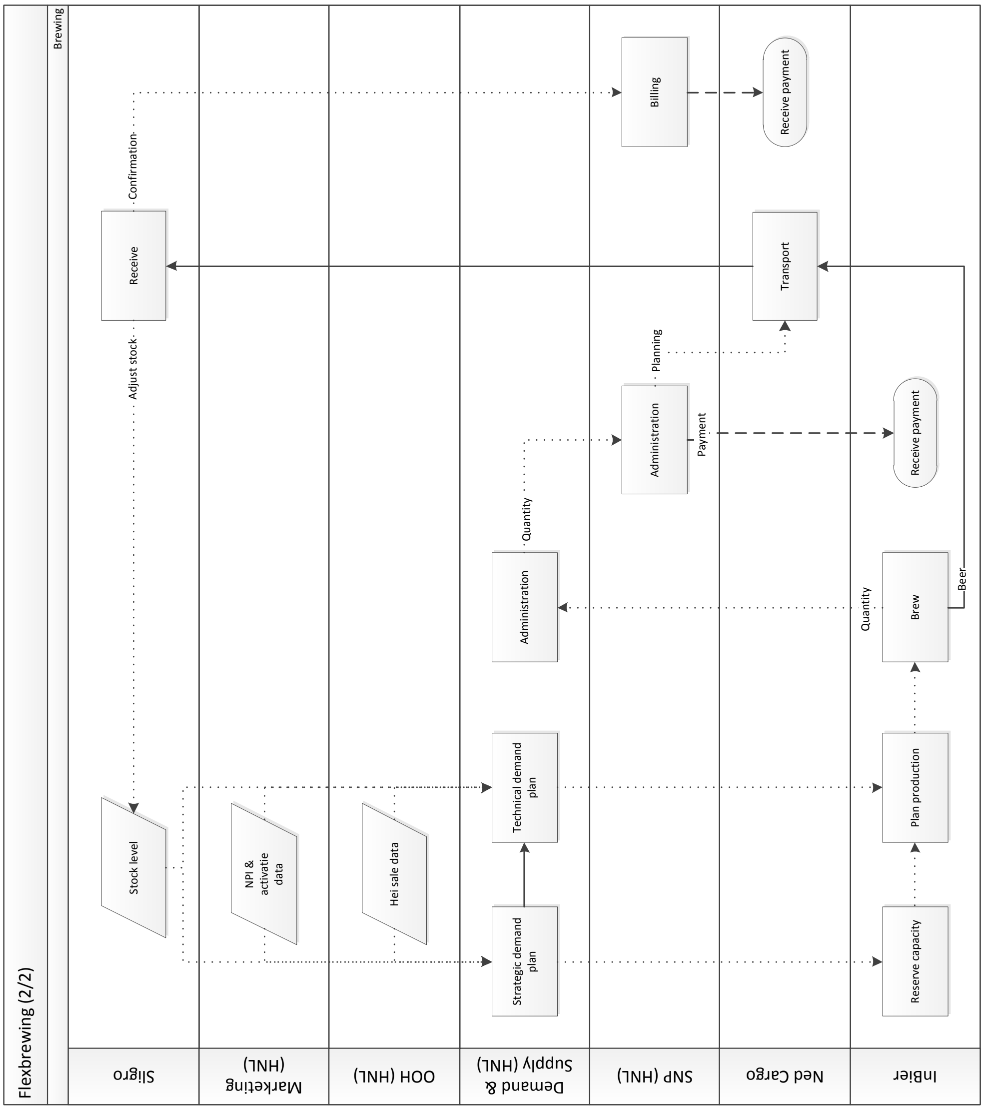

Figure C.4: Brewing phase of the SPC of the flexbrewery

D

SCOR model

Figure D.1: Complete overview of SCOR Performance Attributes and Metrics (APICS, 2017a)

E

Demand Forecast

E.1. Tailor Made

Table E.1: Demand Forecast Tailor Made [HL]

	2019				2020				2021				2022			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	0	25	0	25	0	25	0	25	0	0	25	25	0	50	0	25
2	25	0	25	0	25	0	25	0	0	25	0	25	0	0	50	0
3	25	0	25	0	25	0	25	0	25	0	25	0	25	0	25	0
4	50	0	50	0	25	25	25	25	25	25	25	25	25	25	25	25
5	25	25	25	50	100	125	0	50	75	50	75	50	75	50	75	50
6	25	75	0	100	75	125	75	175	75	175	75	175	75	175	75	175
7	50	100	0	100	25	75	125	125	125	125	125	125	125	125	125	125
8	50	0	100	0	100	50	75	100	75	100	150	100	75	100	75	100
9	0	25	75	0	75	25	50	50	50	50	50	50	50	50	50	50
10	0	0	50	0	50	0	25	50	25	50	25	50	25	50	25	25
11	0	0	0	50	0	50	50	0	50	0	50	0	50	0	50	0
12	0	0	0	25	0	25	25	0	0	0	0	25	25	25	25	0
13	0	0	25	0	25	0	25	0	0	0	0	25	25	25	25	0
14	0	0	0	0	0	0	25	0	25	0	0	0	0	0	25	0
15	0	25	0	25	0	0	0	0	0	0	25	0	0	0	0	0
Total	**250**	**275**	**375**	**375**	**525**	**525**	**550**	**600**	**550**	**600**	**650**	**675**	**575**	**675**	**650**	**575**

E.2. Local Brands

Table E.2: Demand Forecast Local Brands [HL]

	2019				2020				2021				2022			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1																
1	15	25	25	18	20	50	50	30	30	70	70	35	50	80	80	50
2	15	17	17	17	30	60	60	30	50	70	70	50	50	80	80	50
3	15	15	15	15	15	20	20	20	20	20	20	20	20	20	30	35
4	10	0	10	10	10	0	20	20	20	0	20	20	20	0	15	15
5	0	20	20	10	0	20	20	10	0	20	20	10	20	20	0	10
2																
1	10	15	15	15	15	20	30	30	30	30	30	30	30	60	60	70
2	10	15	15	15	15	25	25	20	20	60	60	20	30	130	130	30
3	10	15	15	15	15	15	20	20	20	20	40	40	20	50	50	60
4	10	0	10	10	10	0	10	10	10	0	10	10	10	0	10	10
5	0	20	20	10	0	20	20	10	0	20	20	10	20	20	20	0
3																
1	10	15	15	15	15	20	20	20	20	60	60	50	30	20	20	40
2	10	15	15	15	15	27	35	20	20	60	60	60	50	90	90	60
3	10	15	15	15	15	15	20	20	70	70	70	70	80	80	80	80
4	0	0	10	10	10	0	10	10	10	0	10	10	10	0	10	10
5	0	20	20	10	0	20	20	10	0	20	20	10	20	20	20	0
4																
1	0	110	110	100	110	150	150	120	120	170	170	130	50	50	50	20
2	0	0	30	30	30	20	20	20	20	20	15	15	15	15	20	20
3	0	0	0	20	20	0	40	40	40	0	40	40	40	0	0	0
5																
1	15	10	15	15	15	15	20	20	40	80	80	60	60	120	120	60
2	10	10	15	15	15	15	15	20	20	40	40	20	40	80	80	40
3	10	10	15	15	15	15	15	20	20	20	20	20	20	20	20	20
4	10	10	0	10	10	10	0	10	10	10	0	10	10	10	0	10
5	0	0	20	20	10	0	20	20	10	0	20	20	10	20	20	20
6																
1	15	10	15	15	15	15	20	20	20	50	50	20	20	30	20	20
2	10	10	15	15	15	15	15	20	20	60	60	30	30	80	80	20
3	10	10	15	15	15	15	15	20	20	20	20	20	20	20	20	20
4	10	10	0	10	10	10	0	10	10	10	0	10	10	10	0	10
5	0	0	20	20	10	0	20	20	10	0	20	20	10	20	20	20
7																
1	9	15	10	15	15	15	15	20	20	20	20	20	20	20	30	20
2	15	10	10	15	15	15	15	15	20	20	20	20	20	20	30	20
3	6	10	10	15	15	15	15	15	20	20	20	20	20	20	20	20
4	0	10	10	0	10	10	10	0	10	10	10	0	10	10	10	0
8																
1	9	15	10	15	15	15	15	20	20	20	20	20	20	20	30	20
2	15	10	10	15	15	15	15	15	20	20	20	20	20	20	30	20
3	6	10	10	15	15	15	15	15	20	20	20	20	20	20	20	20
4	0	10	10	0	10	10	10	0	10	10	10	0	10	10	10	0
5	0	0	0	0	0	0	20	20	10	0	20	20	10	0	20	20
9																
1	8	15	15	10	15	15	15	15	20	20	20	20	20	20	20	30
2	12	10	10	10	15	15	15	15	15	20	20	20	20	20	20	30
3	8	10	10	10	15	15	15	15	15	20	20	20	20	20	20	20
4	0	0	0	10	10	10	10	10	0	10	10	10	0	10	10	10
10																
1	8	15	15	10	15	15	15	15	20	20	20	20	20	20	20	30
2	12	10	10	10	15	15	15	15	15	20	20	20	20	20	20	30
3	8	10	10	10	15	15	15	15	15	20	20	20	20	20	20	20
4	0	0	0	10	10	10	10	10	0	10	10	10	0	10	10	10
Total	**331**	**557**	**657**	**670**	**695**	**812**	**970**	**870**	**930**	**1280**	**1415**	**1140**	**1065**	**1425**	**1485**	**1120**

F
ABC Analysis

Table F.1 shows the ABC analysis of the flexbrewery demand. The ABC analysis is used to determine the different categories for Alternative III in Section 7.2. The total demand of year 2022 per SKU (Table E.2) is used as an input, since this is also the input for the simulation. The demand is sorted in decreasing order and the percentage of the volume and the number of SKUs is determined. The lines in bold indicate the transition between two categories. The indication of these lines was done visually using Figure 7.2.

Table F.1: ABC analysis demand forecast local brands

D [HL]	D [#Kegs]	D [%]	D cum [%]	SKU cum [%]
360	35	7%	7%	2%
320	31	6%	13%	4%
320	31	6%	19%	6%
290	28	5%	24%	8%
260	25	5%	29%	10%
260	25	5%	34%	12%
240	23	5%	39%	14%
220	21	4%	43%	16%
210	20	4%	47%	18%
180	17	3%	50%	20%
170	**16**	**3%**	**53%**	**22%**
110	11	2%	55%	24%
105	10	2%	57%	26%
90	9	2%	59%	28%
90	9	2%	61%	30%
90	9	2%	62%	32%
90	9	2%	64%	34%
90	9	2%	66%	36%
90	9	2%	68%	38%
90	9	2%	69%	40%
90	9	2%	71%	42%
90	9	2%	73%	44%
90	9	2%	74%	46%
80	8	2%	76%	48%
80	8	2%	77%	50%
80	8	2%	79%	52%
80	8	2%	80%	54%
80	8	2%	82%	56%
80	8	2%	83%	58%
70	7	1%	85%	60%
70	7	1%	86%	62%
70	7	1%	87%	64%
60	6	1%	89%	66%
60	6	1%	90%	68%
50	5	1%	91%	70%
50	5	1%	92%	72%
50	5	1%	92%	74%
40	**4**	**1%**	**93%**	**76%**
30	3	1%	94%	78%
30	3	1%	94%	80%
30	3	1%	95%	82%
30	3	1%	95%	84%
30	3	1%	96%	86%
30	3	1%	97%	88%
30	3	1%	97%	90%
30	3	1%	98%	92%
30	3	1%	98%	94%
30	3	1%	99%	96%
30	3	1%	99%	98%
30	3	1%	100%	100%

G
Simio Model

G.1. Processes

Average Demand

The average demand is the average of the order amount of the last few weeks. The number of weeks (ReviewPeriod) is variable, but in default is three weeks. This process determines this average. The process is started when an order is exited from the source. The first step is to copy the associated entity. Then the order amount is also copied. This entity is then stored in the according storage. The search step sums the order amounts of the stored entities after that the assign step saves this sum in the order table. To make sure that the maximum number of entities stored is equal to the ReviewPeriod a decision is made and when there are more entities the first entity is removed and destroyed.

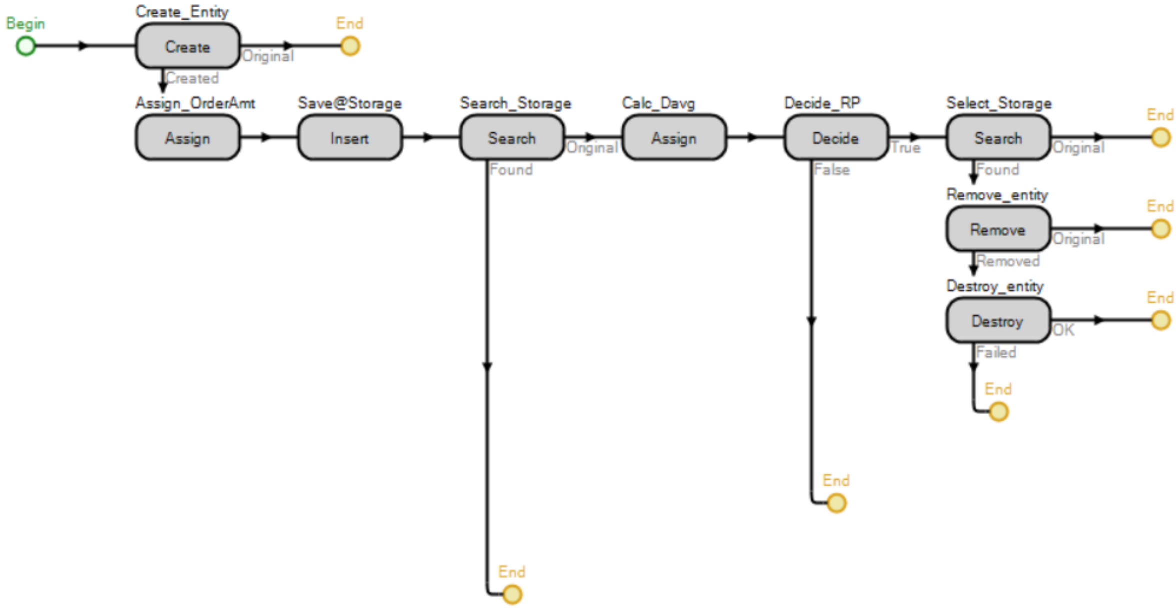

Figure G.1: Average demand process

Replenishment

The replenishment process start with the decision whether the number of products OnHand plus OnOrder together are smaller than the ROP. If this is true the model checks which SKU it is. An entity of the same SKU is created and sent to the Workstation: "Brew_Start". Finally the SKU is added to OnOrder. If OnHand plus OnOrder is bigger than the ROP there is no replenishment needed, except when obsoletes will occur. This is checked with the decision if OnOrder=0. If this is false the process ends, if this is true a last decision have to be made. This decision is made after the right SKU is searched in the right queue. Then there is decided if the product is in the queue for more than 22 weeks, so will be obsolete before it can be replenished. If this is true, replenishment is activated and if this is not true the process is ended.

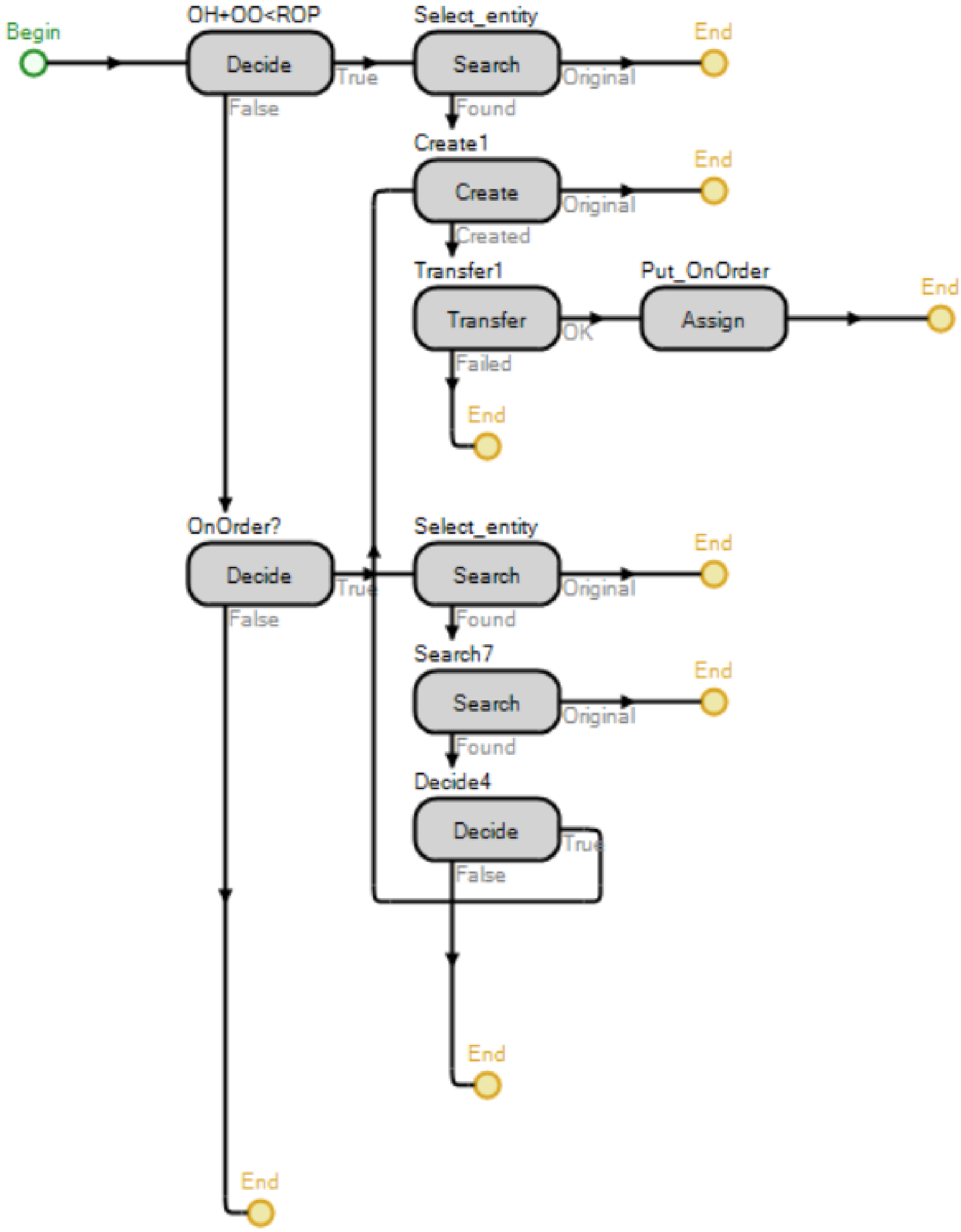

Figure G.2: Replenishment process

G.2. Data

Table G.1 shows the first eight columns of the data table used by the Simio model, Table G.2 shows the last five columns. The first column identifies the different SKUs and the second column defines the number of orders per cycles. Column three and four are places where to store data. Column five identifies the arrival time of the orders and the last row identifies at what time to repeat (after one week) the cycles. The sixth column defines demand per SKU.

Table G.2 starts with the same column to identify the SKUs. The second third and forth column link to a place where information is stored and the last column identifies what SKUs have a safety stock and what not in Alternative three.

Table G.1: Order Table of the Simio Model (part A)

Product		StaOnHand	StaOnOrder		Demand	Davg	OrderAmt
Prd1	1	OnHand1	OnOrder1	0	Random.Gamma(8,3.125)	Davg1	OrdAmt1
Prd2	1	OnHand2	OnOrder2	0	Random.Gamma(8,3.125)	Davg2	OrdAmt2
Prd3	1	OnHand3	OnOrder3	0	Random.Gamma(8,1.262)	Davg3	OrdAmt3
Prd4	1	OnHand4	OnOrder4	0	Random.Gamma(8,0.601)	Davg4	OrdAmt4
Prd5	1	OnHand5	OnOrder5	0	Random.Gamma(8,0.601)	Davg5	OrdAmt5
Prd6	1	OnHand6	OnOrder6	0	Random.Gamma(8,2.644)	Davg6	OrdAmt6
Prd7	1	OnHand7	OnOrder7	0	Random.Gamma(8,3.846)	Davg7	OrdAmt7
Prd8	1	OnHand8	OnOrder8	0	Random.Gamma(8,2.163)	Davg8	OrdAmt8
Prd9	1	OnHand9	OnOrder9	0	Random.Gamma(8,0.361)	Davg9	OrdAmt9
Prd10	1	OnHand10	OnOrder10	0	Random.Gamma(8,0.721)	Davg10	OrdAmt10
Prd11	1	OnHand11	OnOrder11	0	Random.Gamma(8,1.322)	Davg11	OrdAmt11
Prd12	1	OnHand12	OnOrder12	0	Random.Gamma(8,3.486)	Davg12	OrdAmt12
Prd13	1	OnHand13	OnOrder13	0	Random.Gamma(8,3.846)	Davg13	OrdAmt13
Prd14	1	OnHand14	OnOrder14	0	Random.Gamma(8,0.361)	Davg14	OrdAmt14
Prd15	1	OnHand15	OnOrder15	0	Random.Gamma(8,0.721)	Davg15	OrdAmt15
Prd16	1	OnHand16	OnOrder16	0	Random.Gamma(8,2.043)	Davg16	OrdAmt16
Prd17	1	OnHand17	OnOrder17	0	Random.Gamma(8,0.841)	Davg17	OrdAmt17
Prd18	1	OnHand18	OnOrder18	0	Random.Gamma(8,0.481)	Davg18	OrdAmt18
Prd19	1	OnHand19	OnOrder19	0	Random.Gamma(8,4.327)	Davg19	OrdAmt19
Prd20	1	OnHand20	OnOrder20	0	Random.Gamma(8,2.885)	Davg20	OrdAmt20
Prd21	1	OnHand21	OnOrder21	0	Random.Gamma(8,0.962)	Davg21	OrdAmt21
Prd22	1	OnHand22	OnOrder22	0	Random.Gamma(8,0.361)	Davg22	OrdAmt22
Prd23	1	OnHand23	OnOrder23	0	Random.Gamma(8,0.841)	Davg23	OrdAmt23
Prd24	1	OnHand24	OnOrder24	0	Random.Gamma(8,1.082)	Davg24	OrdAmt24
Prd25	1	OnHand25	OnOrder25	0	Random.Gamma(8,2.524)	Davg25	OrdAmt25
Prd26	1	OnHand26	OnOrder26	0	Random.Gamma(8,0.962)	Davg26	OrdAmt26
Prd27	1	OnHand27	OnOrder27	0	Random.Gamma(8,0.361)	Davg27	OrdAmt27
Prd28	1	OnHand28	OnOrder28	0	Random.Gamma(8,0.841)	Davg28	OrdAmt28
Prd29	1	OnHand29	OnOrder29	0	Random.Gamma(8,1.082)	Davg29	OrdAmt29
Prd30	1	OnHand30	OnOrder30	0	Random.Gamma(8,1.082)	Davg30	OrdAmt30
Prd31	1	OnHand31	OnOrder31	0	Random.Gamma(8,0.962)	Davg31	OrdAmt31
Prd32	1	OnHand32	OnOrder32	0	Random.Gamma(8,0.361)	Davg32	OrdAmt32
Prd33	1	OnHand33	OnOrder33	0	Random.Gamma(8,1.082)	Davg33	OrdAmt33
Prd34	1	OnHand34	OnOrder34	0	Random.Gamma(8,1.082)	Davg34	OrdAmt34
Prd35	1	OnHand35	OnOrder35	0	Random.Gamma(8,0.962)	Davg35	OrdAmt35
Prd36	1	OnHand36	OnOrder36	0	Random.Gamma(8,0.361)	Davg36	OrdAmt36
Prd37	1	OnHand37	OnOrder37	0	Random.Gamma(8,0.601)	Davg37	OrdAmt37
Prd38	1	OnHand38	OnOrder38	0	Random.Gamma(8,1.082)	Davg38	OrdAmt38
Prd39	1	OnHand39	OnOrder39	0	Random.Gamma(8,1.082)	Davg39	OrdAmt39
Prd40	1	OnHand40	OnOrder40	0	Random.Gamma(8,0.962)	Davg40	OrdAmt40
Prd41	1	OnHand41	OnOrder41	0	Random.Gamma(8,0.361)	Davg41	OrdAmt41
Prd42	1	OnHand42	OnOrder42	0	Random.Gamma(8,1.082)	Davg42	OrdAmt42
Prd43	1	OnHand43	OnOrder43	0	Random.Gamma(8,1.082)	Davg43	OrdAmt43
Prd44	1	OnHand44	OnOrder44	0	Random.Gamma(8,0.962)	Davg44	OrdAmt44
Prd45	1	OnHand45	OnOrder45	0	Random.Gamma(8,0.361)	Davg45	OrdAmt45
Prd	0	OnHand1	OnOrder1	1	0	Davg1	OrdAmt1

Table G.2: Order Table of the Simio Model (Part B)

Product	Storage	NmbWaiting	Index	SS
Prd1	Storage1.Queue	Storage1.Queue.NumberWaiting	Index1	2.9
Prd2	Storage2.Queue	Storage2.Queue.NumberWaiting	Index2	2.9
Prd3	Storage3.Queue	Storage3.Queue.NumberWaiting	Index3	1
Prd4	Storage4.Queue	Storage4.Queue.NumberWaiting	Index4	1
Prd5	Storage5.Queue	Storage5.Queue.NumberWaiting	Index5	1
Prd6	Storage6.Queue	Storage6.Queue.NumberWaiting	Index6	2.9
Prd7	Storage7.Queue	Storage7.Queue.NumberWaiting	Index7	2.9
Prd8	Storage8.Queue	Storage8.Queue.NumberWaiting	Index8	2.9
Prd9	Storage9.Queue	Storage9.Queue.NumberWaiting	Index9	1
Prd10	Storage10.Queue	Storage10.Queue.NumberWaiting	Index10	1
Prd11	Storage11.Queue	Storage11.Queue.NumberWaiting	Index11	1
Prd12	Storage12.Queue	Storage12.Queue.NumberWaiting	Index12	2.9
Prd13	Storage13.Queue	Storage13.Queue.NumberWaiting	Index13	2.9
Prd14	Storage14.Queue	Storage14.Queue.NumberWaiting	Index14	1
Prd15	Storage15.Queue	Storage15.Queue.NumberWaiting	Index15	1
Prd16	Storage16.Queue	Storage16.Queue.NumberWaiting	Index16	2.9
Prd17	Storage17.Queue	Storage17.Queue.NumberWaiting	Index17	1
Prd18	Storage18.Queue	Storage18.Queue.NumberWaiting	Index18	1
Prd19	Storage19.Queue	Storage19.Queue.NumberWaiting	Index19	2.9
Prd20	Storage20.Queue	Storage20.Queue.NumberWaiting	Index20	2.9
Prd21	Storage21.Queue	Storage21.Queue.NumberWaiting	Index21	1
Prd22	Storage22.Queue	Storage22.Queue.NumberWaiting	Index22	1
Prd23	Storage23.Queue	Storage23.Queue.NumberWaiting	Index23	1
Prd24	Storage24.Queue	Storage24.Queue.NumberWaiting	Index24	1
Prd25	Storage25.Queue	Storage25.Queue.NumberWaiting	Index25	2.9
Prd26	Storage26.Queue	Storage26.Queue.NumberWaiting	Index26	1
Prd27	Storage27.Queue	Storage27.Queue.NumberWaiting	Index27	1
Prd28	Storage28.Queue	Storage28.Queue.NumberWaiting	Index28	1
Prd29	Storage29.Queue	Storage29.Queue.NumberWaiting	Index29	1
Prd30	Storage30.Queue	Storage30.Queue.NumberWaiting	Index30	1
Prd31	Storage31.Queue	Storage31.Queue.NumberWaiting	Index31	1
Prd32	Storage32.Queue	Storage32.Queue.NumberWaiting	Index32	1
Prd33	Storage33.Queue	Storage33.Queue.NumberWaiting	Index33	1
Prd34	Storage34.Queue	Storage34.Queue.NumberWaiting	Index34	1
Prd35	Storage35.Queue	Storage35.Queue.NumberWaiting	Index35	1
Prd36	Storage36.Queue	Storage36.Queue.NumberWaiting	Index36	1
Prd37	Storage37.Queue	Storage37.Queue.NumberWaiting	Index37	1
Prd38	Storage38.Queue	Storage38.Queue.NumberWaiting	Index38	1
Prd39	Storage39.Queue	Storage39.Queue.NumberWaiting	Index39	1
Prd40	Storage40.Queue	Storage40.Queue.NumberWaiting	Index40	1
Prd41	Storage41.Queue	Storage41.Queue.NumberWaiting	Index41	1
Prd42	Storage42.Queue	Storage42.Queue.NumberWaiting	Index42	1
Prd43	Storage43.Queue	Storage43.Queue.NumberWaiting	Index43	1
Prd44	Storage44.Queue	Storage44.Queue.NumberWaiting	Index44	1
Prd45	Storage45.Queue	Storage45.Queue.NumberWaiting	Index45	1
Prd	Storage1.Queue	0	Index1	1

G.3. Inventory

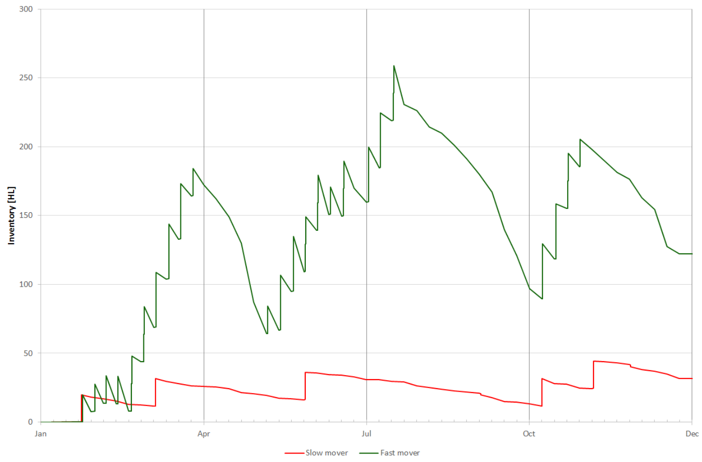

Figure G.3: Inventory Level of Prd14 and Prd19 over a year for Alternative 1

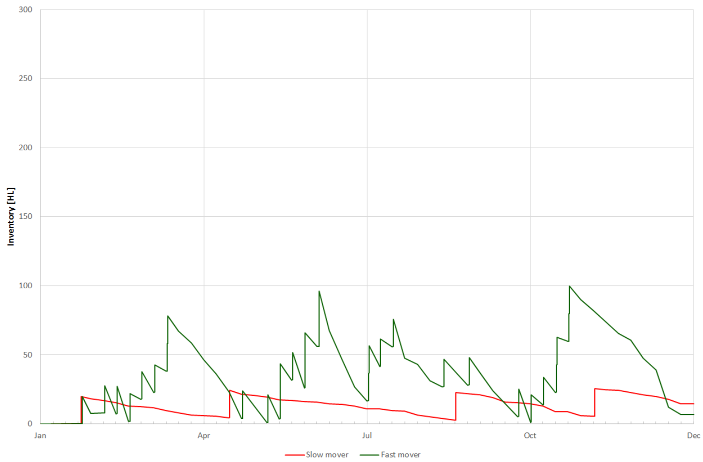

Figure G.4: Inventory Level of Prd14 and Prd19 over a year for Alternative 2

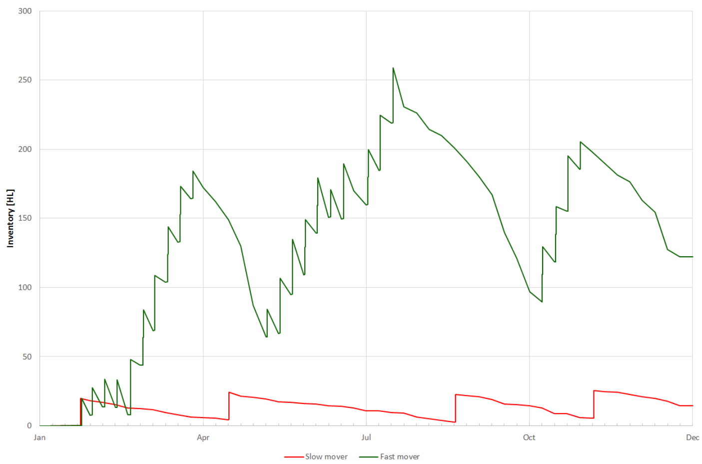

Figure G.5: Inventory Level of Prd14 and Prd19 over a year for Alternative 3

H

Distribution Fitting

The given forecast provides an average demand over time. In order to determine the distribution of the demand, a sample of the sales data of one of the products was taken. Table H.1 shows the descriptive statistics of the sample. Since it was not allowed to publish the sales data, the product information and units of measurement are left out.

Table H.1: Descriptive statistics of the sample of sales data

	N	Min	Max	Mean	Std. Dev
VAR 00001	28	0.10	2.30	0.925	0.557

Figure H.1 shows the histogram of the sample of the sales data (green). The sample seems to be right-skewed and has a natural lower limit of zero. This characteristics correspond to the Gamma distribution. In order to test if the sample indeed corresponds with the Gamma distribution, the parameters are determined and the goodness of fit was tested.

To determine the initial shape (α) and rate (β) of the Gamma distribution, the method of moments was used then a Q-Q Plot was made using SPSS. The Q-Q Plot is a plot of the percentiles of the gamma distribution against the corresponding percentiles of the sample. Since the plot follows roughly a straight line with a positive slope it is concluded that the sample follows the gamma distribution. Finally 1000 random samples where drawn from the Gamma distribution with the found parameters and included in the histogram of Figure H.1.

Method of moments:

$$\alpha = \left(\frac{\bar{x}}{s}\right)^2 = 2.759$$

$$\beta = \left(\frac{\bar{x}}{s^2}\right) = 2.982$$

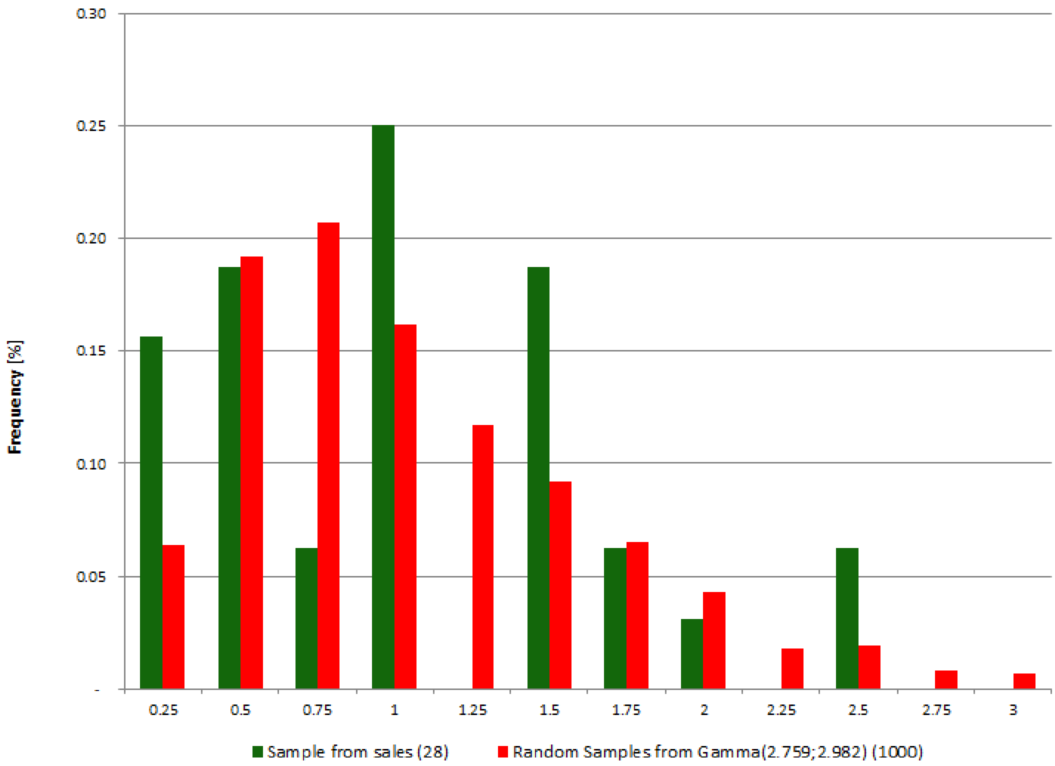

Figure H.1: Histogram of the sample of sales and Gamma distribution

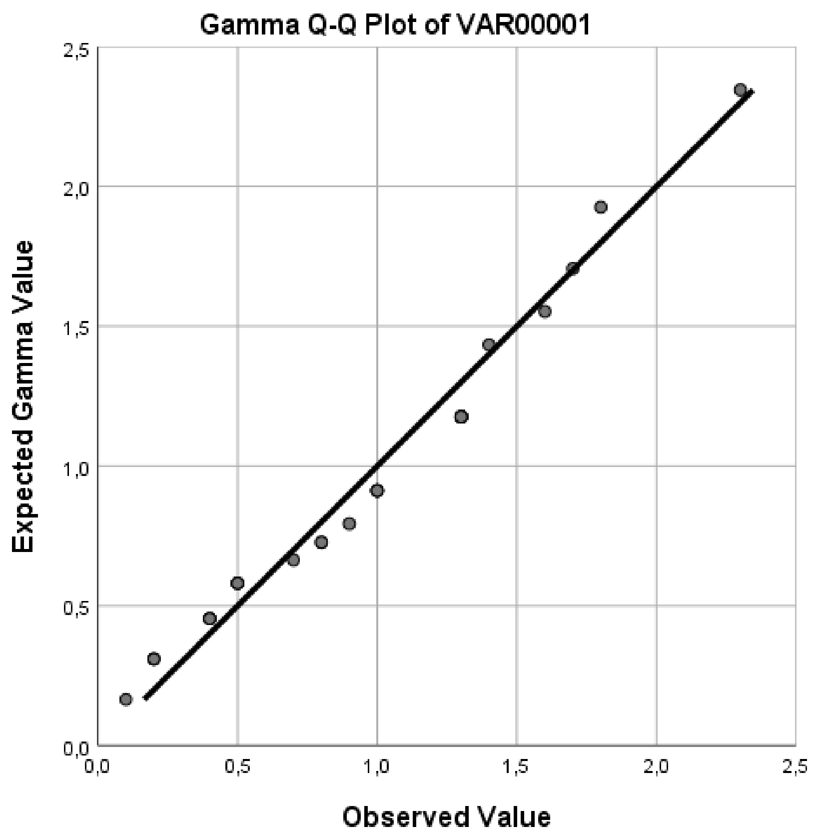

Figure H.2: Gamma Q-Q Plot of the sample of sales data