Managing the impact of a complex product portfolio on outbound logistics operations

A case study at HEINEKEN

L.M. Pigeaud

Delft University of Technology

Managing the impact of a complex product portfolio on outbound logistics operations

A case study at HEINEKEN

By

Lennard Maarten Pigeaud

in partial fulfilment of the requirements for the degree of

Master of Science
in Transport, Infrastructure and Logistics

at the Delft University of Technology,
to be defended publicly on Friday August 14, 2015 at 12:00 pm.

Non-confidential version

Student Number:	1516736	
Thesis Committee:	Prof. Dr. Ir. A. Verbraeck	TU Delft
	Dr. B. Wiegmans	TU Delft
	Dr. J.L.M. Vrancken	TU Delft
External Supervisors:	S. Reimers	HEINEKEN
	J. Schrijvers	HEINEKEN

PREFACE

This report describes my thesis project, the final work of my Masters in Transport, Infrastructure and Logistics at Delft University of Technology. The research is carried out at HEINEKEN Netherlands Supply, within the Customer Service & Logistics department at Zoeterwoude. Research focus is to analyse the impact of an expanding product portfolio on outbound logistics operations.

First off I would like to thank HEINEKEN for giving me the opportunity to carry out my thesis project within their organization. After my previous internship at HEINEKEN, this project provided me with additional knowledge of and enthusiasm for the organization's supply chain. During the past six months I have seen all relevant parts of the production facilities in the Netherlands, which has given me great insight in the different complexities that are experienced. The research truly made me aware of the technical and organizational challenges that arise when a supply chain in Fast Moving Consumer Goods is tailored towards product diversity.

I owe special thanks to my daily supervisor Sebastiaan Reimers, who has been a very strong support during all steps of my research. I have been working with him as an intern since September 2014 and I learned a lot during this period. I would also like to thank all other colleagues in the Market Demand Management department for their support and interest in my project.

For providing me with strong academic guidance and advice, I would like to thank my assessment committee, Alexander Verbraeck, Bart Wiegmans and Jos Vrancken. I owe special thanks to Bart Wiegmans for his flexible support, detailed advice and good conversations.

Finally, I would like to thank my family and friends for their continuous support during my years as a student but especially during the past months.

Delft, July 2015

Lennard Pigeaud

SUMMARY

The past few years have shown a significant increase in demand for diversity in the global beer market. HEINEKEN, the third largest beer brewer in the world, has therefore embraced a global strategy with a diverse product portfolio in beer and packaging types. This strategy towards diversity is directly affecting the supply chain of global supplier HEINEKEN Netherlands Supply (HNS). The organization has to cope with increasing demand and diversity for over 160 countries as their direct customers. The result of increased diversity is clearly seen in the number of produced Stock Keeping Units (SKU's) at the Zoeterwoude brewery, which almost doubled from 2012 to 2014. The three main processes within the HNS supply chain are brewing, packaging and outbound logistics. The current supply chain planning is mainly focused on packaging, as this is the most expensive process. However, the growing volume and SKU diversity have resulted in additional challenges within outbound logistics operations. These challenges are perceived as complexity by HNS without identifying clear factors and drivers for this perception. In this research is therefore analysed how diversity influences the perceived complexity at the outbound logistics organization of HNS. The main research question is:

What is the impact of an expanding product portfolio on perceived complexity in outbound logistics operations and how can the main drivers for this perception be managed in the future?

Complexity in this research is defined as the uncertainty in processes as a result of increased diversity. Based on the commercial HEINEKEN strategy, the diversity in the portfolio for HNS is expected to increase in the future. The research goal is therefore not to challenge product diversity but to determine the key factors that drive uncertainty at HNS based on the diversity. Through extensive literature research and expert interviews at HNS, different types of perceived complexity in a supply chain have been defined. These types are structured in the framework for perceived complexity, illustrated in Figure 1. Market and customer variety form the input of perceived complexity, factors that cannot be influenced by a production organization like HNS.

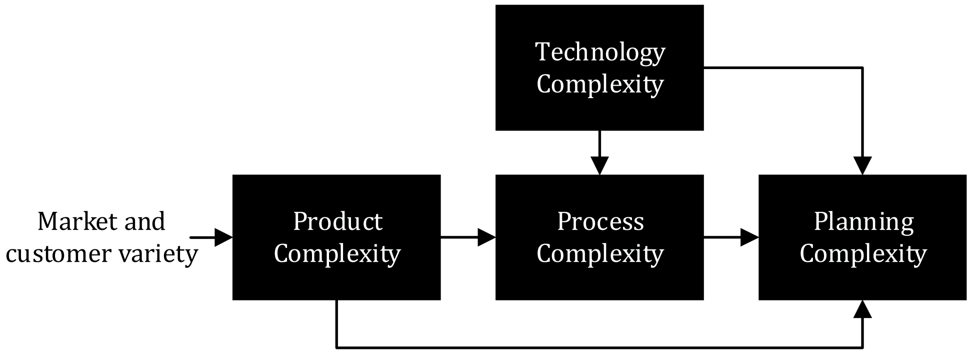


FIGURE 1: THE FRAMEWORK FOR PERCEIVED COMPLEXITY IN A SUPPLY CHAIN (AUTHOR'S OWN DRAWING)

A qualitative analysis based on the framework has revealed the main drivers for each type of perceived complexity. A quantitative case study analysis at HNS has strengthened the framework by analysing trends for the key factors that drive perceived complexity at the breweries in Den Bosch and Zoeterwoude. The results of both the qualitative and quantitative analysis are summarized below.

Product complexity - Uncertainty related to the product portfolio. This is driven by the number of SKU's that are produced by an organization and the volume related to these SKU's. At HNS specifically, uncertainty is driven by the diversity in loading types requested by the market. The expanding portfolio has reduced insight in the logistical impact per SKU, increasing uncertainty of the expected volume flows in the warehouses at Zoeterwoude and Den Bosch.

Technology complexity – Uncertainty related to available technology, both physical and information related. Physical technology is related to capacities of equipment and warehouse layout. As this information is clearly reported at HNS, no specific uncertainty is related to physical technology in this research. At HNS, uncertainty is mainly driven by missing information in the variety of IT systems, perceived as information technology complexity. A very important driver for perceived complexity is the absence of logistics parameters per SKU that determine the impact of a packaging plan on outbound logistics operations.

Process complexity - Uncertainty in the logistics processes resulting from a mismatch between products and technology. HNS is faced with a simultaneous increase of SKU diversity and volume, leading to full warehouses and inefficient use of space. Reactive solutions are currently in place to cope with the high storage volume as no clear outlook of expected volumes is provided.

Planning complexity - Uncertainty in logistics planning, driven by the absence of the most important logistics parameters per SKU. The current IT and planning structure at HNS limit the possibility to plan the expected stock and load volumes in the long term.

From the case study analysis is concluded that information availability is the most important driver for perceived complexity at HNS. The Zoeterwoude and Den Bosch brewery both face an increase in storage volume of finished SKU's, while the logistics parameters that determine storage demand are not measured. This limits the translation of the long-term packaging plan towards storage and load planning, thereby increasing uncertainty in expected volumes. It is also concluded that HNS can reduce the uncertainty driven by this missing information, as the logistics parameters are all covering internal processes that are controlled by HNS. The planning organization therefore has a large influence on the perceived complexity; measuring the logistics parameters correctly enables HNS to create more clarity in the long term by planning the expected demand for storage and loading. Managing perceived complexity at HNS is therefore focused on designing a long-term logistics planning model that is based on the packaging plan. A functional model is designed for the Zoeterwoude brewery that determines the impact of the main volume flows on outbound logistics processes. The identified flows are the packaging flow at the brewery and co-fill, re-pack and inter-brewery flows that come into the warehouse from other facilities. The main parameters that determine the logistical impact in the model are the following:

- **Loading type;** determines the type of warehouse handlings and demand for storage
- **Cross-dock percentage**; determines how much of the volume can be loaded directly
- **Storage time:** determines how long a certain SKU has to be stored in the warehouse

By coupling the 78-week packaging planning with the logistical parameters per SKU, the logistical impact can be calculated for the same time horizon. The model output is a clear overview of expected stock levels and load volumes per loading type in pallets. During model validation can be concluded that the model can predict the expected storage and load volumes with a bias of ±20%.

Conclusions based on the model output can be made when using the packaging plan from May 2015 until December 2016 as input. Based on this plan is foreseen that mainly storage demand for Export will often exceed the storage capacity, thereby indicating the need for external storage. This is mainly caused by the large Conventional Truck volume that cannot be loaded directly with the cross-dock lanes. It is already known within the organization of HNS that stock volume for this specific loading type is a bottleneck but this has never been quantified and presented next to the demanded stock volume for other loading types. The logistics model now provides a long-term outlook of the expected volume on stock, which clearly shows the impact that Conventional Truck loading has on the total Export stock volume. Proactive solutions can now be found for the expected capacity shortage. Different packaging scenarios can be run to evaluate the impact on outbound logistics. Several successful experiments have already been completed with the model, illustrating the added value of the model for HNS. A clear implementation plan is also part of the research, ensuring the sustainability of the model for future use.

Based on the research, model design and outputs several recommendations can be made to manage and reduce the perceived complexity at HEINEKEN Netherlands Supply. This research has pointed out that the perception of complexity in outbound logistics is mainly driven by a lack of information and planning. It is therefore highly recommended to place logistics planning next to packaging planning in the organization. The developed model provides a good starting point for strategic planning, proven by its application at Zoeterwoude. First experiments have already been completed to tailor the model to Den Bosch and it is recommended to continue this. Besides implementing the model, it is the author's strong belief that the lack of interchange ability between the different IT systems limits the possibility to plan ahead, mainly in the outbound logistics processes. It is therefore recommended to set up a project that clearly defines what information different stakeholders need to successfully plan and manage their operations. Besides that, it is very important to secure the right information in a more centralized planning system. This will significantly increase alignment and visibility of information across the HNS supply chain.

A final remark can be made to the complexity framework. From this research can be concluded that the framework successfully supports the analysis of perceived complexity in an organization, proven by its applicability to HNS. However, given the time constraints attached to this research, it is not assumed that the framework is complete. Further research should point out if the relationships sketched in the framework are also found at other companies, increasing the robustness of the complexity framework.

LIST OF FIGURES

LIST OF TABLES

GLOSSARY

Co-fill	-	Outsourced production / packaging volume
Conventional Truck Loading	-	Truck loading for Export markets
Cross-dock	-	Direct loading of pallets without storage
Domestic Loading	-	Truck loading for the Domestic market
FMCG	-	Fast Moving Consumer Goods
HL	-	Hectolitre
HNS	-	HEINEKEN Netherlands Supply
IB	-	Inter-brewery volume
IT	-	Information Technology, providing planning data
Manual Loading	-	Manual container loading without pallet
Mechanical Loading	-	Forklift container loading without pallet
MTO	-	Make To Order
MTS	-	Make To Stock
NPI	-	New Product Introduction
OS	-	Operations Scheduling
Re-pack	-	Outsourced reforming of finished product
Schep Loading	-	Forklift container loading with pallet
SKU	-	Stock Keeping Unit (one pallet carrying one SPC)
SPC	-	Specific Product Code; one unit of production
SSCP	-	Strategic Supply Chain Planning
TSCP	-	Tactical Supply Chain Planning
VMI	-	Vendor Managed Inventory

TABLE OF CONTENTS

1. INTRODUCTION

This chapter starts with a short overview of the HEINEKEN Company and its products and customers in paragraph 1.1. The trend towards a more complex product portfolio is explained, resulting in the problem definition and research objective in paragraph 1.2. Paragraph 1.3 states the research questions and the chapter is ended with a visual overview of the report structure in paragraph 1.4.

1.1. INTRODUCING THE HEINEKEN COMPANY

1.1.1. The HEINEKEN Company

HEINEKEN is the third largest beer brewer in the world and the largest in Europe. The company owns local organizations in over 70 countries with approximately 165 breweries. The company´s global strategy is to promote local brands but also introduce global brands around the world. Amongst other beers, they brew Heineken, which is the world’s leading premium beer. In 2014, the company had a revenue of 19,3 billion euros and produced 181 million hectolitres of beer globally. The company is continuously increasing its market share in developing countries in Africa and Asia while maintaining its strong position in developed markets (HEINEKEN NV, 2014). This global strategy is in line with the worldwide beer consumption development with volume growth in Africa, Asia and Latin America and stagnating volume in North America and Europe (Canadean, 2011).

HEINEKEN was founded in 1864 when Gerard Adriaan Heineken acquired the brewery ‘De Hooiberg’ in Amsterdam. Over the years the Heineken family took over more breweries and in 1968 ‘de Amstel Brouwerij’ was acquired. In 1975 a new large brewery was opened in Zoeterwoude, where also HEINEKEN Netherlands is headquartered. Currently there are three breweries in the Netherlands: Zoeterwoude, Den Bosch and a small brewery in Wijlre (HEINEKEN CS&L, 2015). The three breweries each have their own characteristics, producing specific beer types that lead to different portfolios per brewery. Zoeterwoude mainly produces the large volume beers such as Heineken and Amstel. Den Bosch is often referred to as the specialty brewery because more than 40 different types of beer are produced there.

1.1.2. HEINEKEN Netherlands Supply: global supplier in the Netherlands

Within the global HEINEKEN supply chain network, the three breweries in The Netherlands function as a key source for other company-owned organizations worldwide. The supply chain of the three breweries together is managed by the organization HEINEKEN Netherlands Supply, further to be addressed as HNS. 75% of the produced volume at the breweries is Export volume and the organization serves approximately 160 countries as their direct customers. Most of these customers are other HEINEKEN operating companies that source products from HNS. Through this global network, HNS delivers a large variety of Stock Keeping Units (SKU’s) to its markets. With their global customer network, the vision of HNS is to become ´the world´s best supply chain by being business and innovation partner with markets, supporting customers to win´. This should be reached by offering the best service at high and constant quality. The focus is on innovative products, supplying a large variety of products against the lowest possible price per hectolitre (HEINEKEN CS&L, 2015).

With the above stated vision and goals in mind, HNS aims at moving forward with a very diverse product portfolio that can be delivered worldwide, resulting in an increasing amount of SKU’s. The Customer Service & Logistics department at the Zoeterwoude brewery is responsible for managing the increased complexity in the supply chain that this encompasses.

1.2. THESIS MOTIVATION: INCREASED PERCEPTION OF COMPLEXITY IN THE SUPPLY CHAIN

For a Fast Moving Consumer Goods (FMCG) organization like HEINEKEN, the ability to win in the market every day is the key for success. Given the global and competitive market that HNS supplies, this is not an easy task as each country has its own desires, market developments, laws, regulations and language. To enable global market reach, production organizations must therefore be able to produce a high diversity of finished products or so-called Stock Keeping Units (SKU's) (Ward, 2010). Effectively managing the supply chain when the product portfolio is growing is a challenging task to be fulfilled. With a significant growth of product types, packages and customers, companies lose sight on the impact of an increasing portfolio on the supply chain. No clear vision exists of which products or product groups have the largest impact on operational bottlenecks and/or costs, resulting in additional uncertainty. This uncertainty is perceived as additional complexity; introducing more diversity in the portfolio reduces the insight on SKU level. The problem related to this perceived complexity is that no clear factors or drivers are identified that affect uncertainty, thus the perception of complexity. The goal of this research is therefore to find the drivers for perceived complexity, both through theoretical and practical research. In short, the perception for complexity arises from three angles, all explained in detail below (Chou, 2013):

1) Customer demand: increased diversity and volume
2) Large amount of Export and Domestic customers
3) Current brewery configuration limits diversity

Customer demand: increased diversity and volume

In line with the previous section, the beer industry also sees an increased demand for diversity in beer products. The trend in developed markets has shown stagnation in volumes for regular products and packages, whereas the demand for special beer types and packages has been increasing. This trend is expected to continue, leading to more product introductions and increased diversity in beer types, brands and packaging materials. Developing markets show an increase in regular beer types but are also expected to move towards a more diverse portfolio (HEINEKEN CS&L, 2015). The trend to diversity in all markets results in an overall growth of demand for diversity in beer types, packages and deliveries. Diversity has a direct impact on capacity and combining this with an increasing volume in general provides additional challenges within the supply chain. The figure below provides a clear overview of the diversity in SKU's that grows within the internal supply chain of HNS.

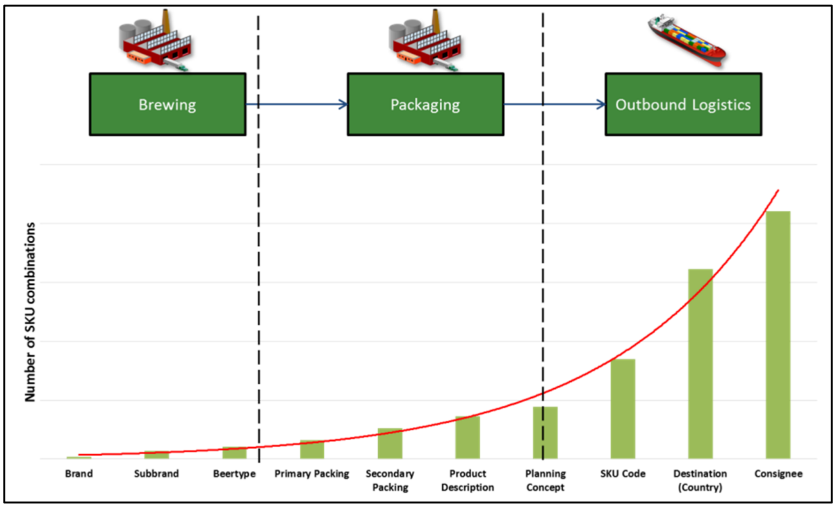


FIGURE 2: DIVERSITY WITHIN THE SUPPLY CHAIN OF HNS (AUTHOR'S OWN DRAWING)

Large amount of Export and Domestic customers

The fact that one production plant supplies customers all over the world is a large contributor to the variety of SKU's that the organization produces. HNS produces products for approximately 160 countries as its direct customers. Besides these, Dutch retailers form a large part of the Domestic customers served by HNS. This diversity in customers has an impact on the complexity of the supply chain. Every country has its own laws and regulations, which results in different labels and packaging materials. Besides that, every country has its own logistics requirements, which results in a high diversity of loading and transportation configurations. In this way, products that appear to be similar on first sight have different destinations and have to be designed, produced, planned and handled differently. The combination of customer specific requirements with the increased demand for diversity from each customer results in additional SKU's in the portfolio, perceived as additional complexity within the current supply chain operations.

Current brewery configuration limits diversity

More diversity in SKU's puts increased pressure on the capacity and resources of a production facility (Ward, 2010). This is very much applicable in this study, as the breweries at Den Bosch and Zoeterwoude are reaching their maximum capacity. The brewery at Den Bosch is specialized in diversity of beer and packaging types, whereas the Zoeterwoude brewery is specialized in large volumes of regular beer types. As the demand for specialties increases, more diversity is introduced at Den Bosch resulting in less capacity available for regular beer types such as Heineken and Amstel. The production of these regular beer types is therefore transferred from Den Bosch to the brewery in Zoeterwoude. However, the Zoeterwoude brewery has been designed in 1975 as a bulk brewery for mainly the Dutch and US market. The brewing process, packaging lines and logistics operations here are all designed for large volume batches that only allow a limited diversity in SKU's. The movement of production to Zoeterwoude results in a significant growth of SKU's at the Zoeterwoude brewery. The brewery in Zoeterwoude is not designed for this trend, which results in additional challenges related to complexity within brewing, packaging and logistics operations.

In a portfolio management study carried out at Hewlett-Packard, the challenge was not only to manage the perceived complexity resulting from diversity in products, but more fundamentally finding the true drivers and effects accompanied with increased perceived complexity (Ward, 2010). The same challenge is arising for HNS; measuring the true impact of diversity on supply chain processes and planning is often difficult as the impact per SKU is not captured. In this way, making decisions on new product introductions in a market are often granted without a direct vision on the related effects that it might have at different stages in the supply chain. Only in aggregate, HNS experiences production capacity constraints and warehouse space shortages but it is not translated back to individual case studies or an overall planning.

1.3. RESEARCH QUESTIONS

Related to the previous section, the research goal of this study is to identify, analyse and quantify perceived complexity in the supply chain. This should be done by addressing the key factors or drivers for perceived complexity in different forms. The focus area will be outbound logistics, as large bottlenecks are arising within this process at HNS due to an increase in volume and portfolio diversity. In order to investigate the true impact of an expanding portfolio and volume on perceived complexity in outbound logistics operations, the following main research question is proposed.

What is the impact of an expanding product portfolio on perceived complexity in outbound logistics operations and how can the main drivers for this perception be managed in the future?

To answer the research question in a structured way, the following sub questions are proposed in corresponding order:

1. What are the main drivers for product portfolio complexity?
2. What are the main drivers for perceived complexity in outbound logistics operations?
3. How are the drivers for complexity in product portfolio and logistics operations related?
4. What can be done to manage the perceived complexity in logistics operations?

Based on the above, the research is not aimed at reducing product complexity resulting from a growing portfolio. The focus is however on finding the factors that drive perceived complexity in a supply chain and ultimately providing solutions to manage these factors more closely.

1.4. OVERVIEW OF REPORT STRUCTURE

The following picture provides a clear overview of research steps with corresponding chapters in this report. Chapter 2 will describe the current beer supply chain of HNS. Subsequently, a literature research on complexity is carried out in chapter 3. From literature and interviews at HNS a framework for perceived complexity is designed. This framework qualitatively addresses the drivers and types of perceived complexity in outbound logistics operations, thereby answering the first three sub research questions. The framework is subsequently used for quantitative case study analysis at HNS in chapter 4. This will result in a list of main drivers for perceived complexity and bottlenecks at HNS. To propose a solution to manage this perceived complexity, chapter 5 provides a model that improves the planning of expected flows in outbound logistics. With this model, sub research question four is answered. Chapter 6 will conclude the report with scientific conclusions, conclusions for HNS and recommendations.

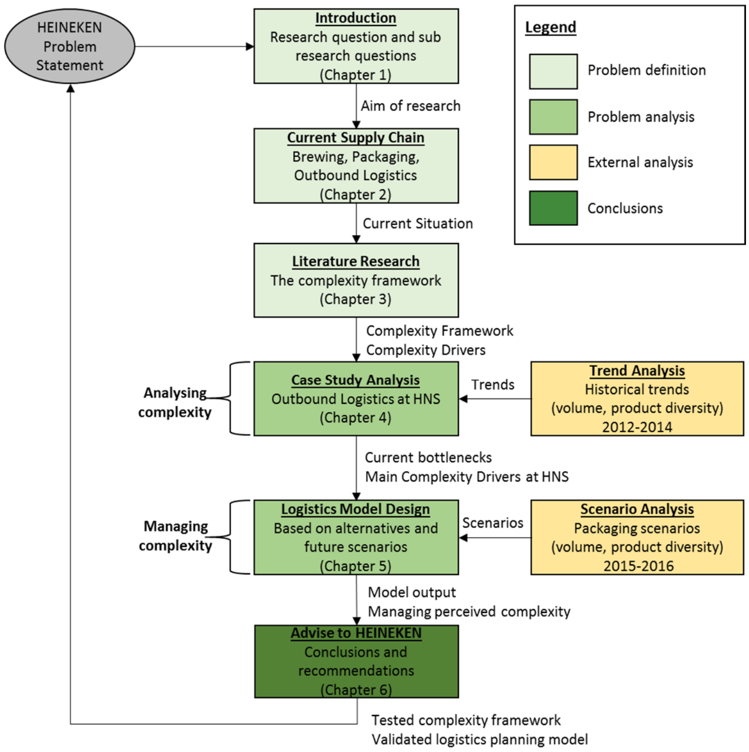


FIGURE 3: OVERVIEW OF REPORT STRUCTURE

2. THE BEER SUPPLY CHAIN: AN OVERVIEW

This chapter explains the supply chain considered in this research. Different definitions and views of supply chains have been established in literature. A supply chain includes all processes and facilities concerned with procurement of raw materials, transform them into intermediate goods and final products, and finally deliver the products to customers (Hillier & Lieberman, 2001). Most companies and researchers employ a company-centric view where the supply chain of the researched organization is a central entity, with upstream suppliers and downstream customers (Lambert & Cooper, 2000). The physical locations determine the supply chain network. Within the network, technology plays an important role to enable the processes in a supply chain. Two types of technology can be identified; physical and information technology (IT). Physical technology represents the equipment available for production and distribution, such as production lines and warehouses. Information technology (IT) in this research represents the availability of information through the technology that enables information management (IT systems). The focus of IT is not on the systems themselves but on the distribution, accessibility and availability of information across the supply chain.

The combination of physical and information technology enables a company to execute supply chain processes, which are the activities that are undertaken with the technology to source, produce and deliver the supply chain's products (Ludema, 2013). To adequately manage a supply chain's processes, accurate supply chain planning is required (Rushton, et al., 2014). Supply Chain Management (SCM) includes this planning flow, thereby co-ordinating and controlling material, parts and finished goods from supplier to customer (Stevens, 1989) (Van Der Niet, 2014).

Concluding from above, a supply chain delivers products with the use of technology, through a set of processes, while these processes are managed through a planning flow at each step in the supply chain. With these definitions in place, a supply chain can be visualized on a high level (see Figure 4). Each supply chain process has its own Source, Make and Deliver function, the key steps in making a product based on the Supply Chain Operations Reference (SCOR) Model developed by the Supply Chain Council (Ludema, 2013). The SCOR model is a useful tool in visualizing and analysing a company supply chain, making a clear distinction between the key steps within each process. This model is therefore used as a framework to describe the current supply chain at HNS.

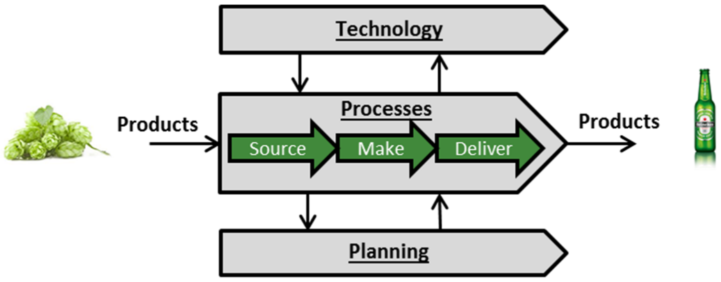


FIGURE 4: SUPPLY CHAIN STRUCTURE, ADAPTED FROM (LUDEMA, 2013)

Figure 5 shows a geographical overview of the three HNS breweries with their production capacities and employees. The Zoeterwoude and Den Bosch breweries serve both the Domestic and Export customers, where Brand in Wijlre is a local brewery for the Domestic market only. The research focus is on Zoeterwoude and Den Bosch as these plants are the key sources for the organization's Domestic and Export customers. On high level, supply chain planning for Den Bosch and Zoeterwoude is carried out at the same department, as some of the products produced at these plants can be interchanged.

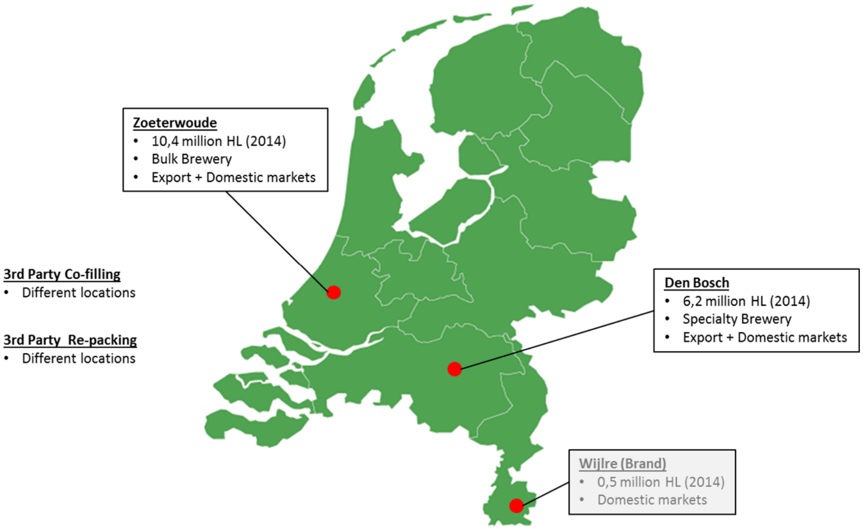


FIGURE 5: GEOGRAPHICAL OVERVIEW OF HNS, ADAPTED FROM (HEINEKEN CS&L, 2014)

The three supply chain processes assessed in this research are brewing, packaging and outbound logistics operations. Within each supply chain process, the Source, Make and Deliver flow can be found. Each supply chain process also has individual technology in place, both physical and information related. The supply chain planning is divided in three functions, with supply chain planning covering brewing and packaging and with logistics planning covering outbound logistics. Order management is a specific flow that follows the actual customer orders visible in the system. Combining all these flows in the basic supply chain structure from Figure 4, the following figure provides a representation of the considered supply chain.

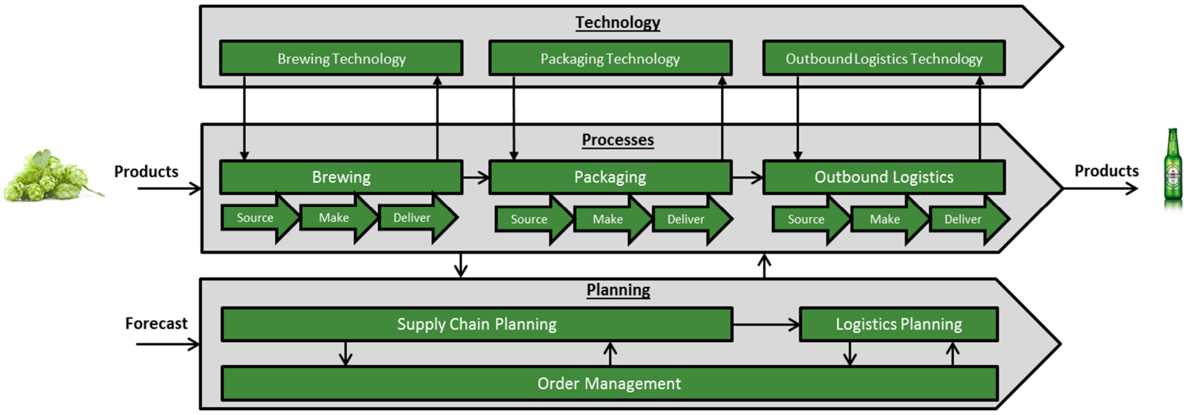


FIGURE 6: SUPPLY CHAIN STRUCTURE OF HEINEKEN NETHERLANDS SUPPLY (AUTHOR'S OWN DRAWING)

In the following paragraphs, the supply chain in this research will be further described using Figure 6. For each supply chain process the technology, products and planning are described. Paragraph 2.1 will describe the supply chain products, where after paragraph 2.2 will provide a high level overview of the supply chain technology within the three processes at HNS. Afterwards, paragraph 2.3 describes the planning aspects in the supply chain. Paragraph 2.4 will conclude this chapter with a clear scope for further research.

2.1. SUPPLY CHAIN PRODUCTS: BREWING, PACKAGING, OUTBOUND LOGISTICS

This paragraph describes the variety of products that is produced within brewing, packaging and outbound logistics. The products within each supply chain process are described for both Zoeterwoude and Den Bosch.

2.1.1. Products within brewing: beer types

The products produced by the brewing process are bright beer types, stored in bright beer tanks. With the current trend in demand towards more sweetened, flavoured beer types the diversity in types has increased in the past years as can be seen in "Appendix 2: trends in beer types". The available physical technology at a plant has a large impact on the beer types that can be produced. The physical technology at the Den Bosch brewery has many options for small batches and many beer types; this brewery is therefore used to produce the increased bright beer diversity. Zoeterwoude does not see a significant increase in beer types as the available technology at this facility does not allow much diversity in the brewing process.

2.1.2. Products within packaging: primary, secondary and tertiary packaging

After brewing, the different beer types are packaged at the packaging lines. Each specific product is built up by filling the different beer types in different packages and palletizing these packages. The following picture shows the different steps in producing a product at HNS.

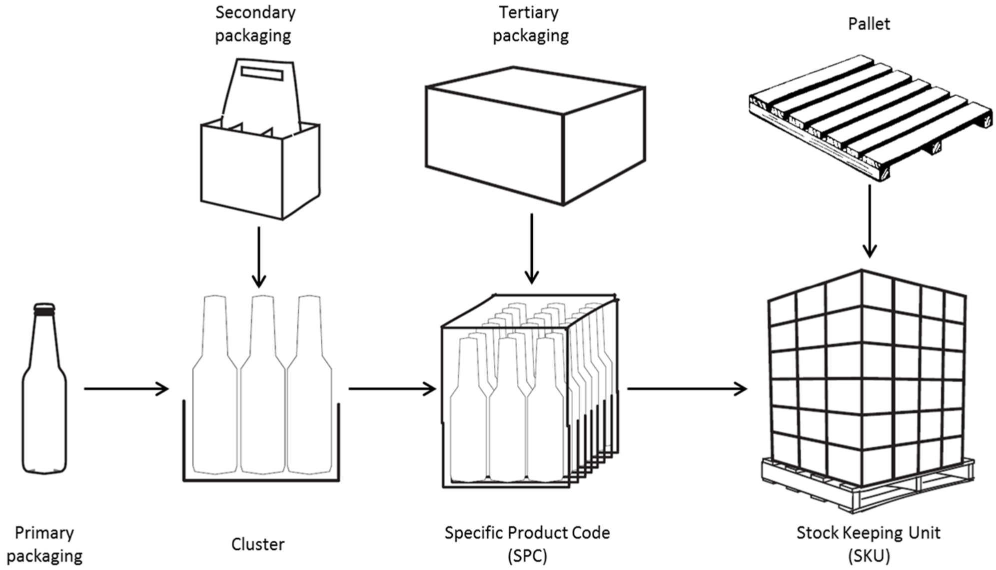


FIGURE 7: BUILD UP OF PRODUCTS WITHIN PACKAGING, BASED ON (VAN DER MEER, 2015)

A distinction is made between primary, secondary and tertiary packaging, corresponding to the sequence in which the process is executed on the packaging line. At first, a primary packaging type is filled, for example a one-way bottle, a returnable bottle, a can or a keg. The primary packaging can be combined with a secondary packaging, for example a 6-pack, 4- pack or 24-pack. This results in a cluster. The cluster can be combined with a tertiary packaging, for example a crate, tray or carton box. The result of this combination is the finished Specific Product Code (SPC), which is the end product of the packaging line. Except for keg SPC's, almost all tertiary packaging types hold 24 units of product as this is easy to produce on the packaging lines. From the packaging line, the SPC is transported to the palletizer where every SPC is palletized for efficient warehousing. The palletized SPC is considered an SKU (Stock Keeping Unit). An SKU is therefore defined as a unique pallet carrying one specific SPC. Each SPC has its own pallet load and also different pallets are used, based on market requirements or type of loading. Each SKU only holds one specific SPC and is given the same code. The number of unique SPC's produced is therefore equal to the number of unique SKU's produced and shipped.

All the different combinations of primary, secondary and tertiary packaging types lead to a large amount of different SPC's and SKU's. This diversity intensifies when delivering international markets, as many countries have their own requirements and/or restrictions. This leads to diversity in label prints and designs, resulting in a high variety of SKU's produced at the three HNS breweries.

2.1.3. Products within outbound logistics: SKU's and loaded transports

Products within outbound logistics are all SKU's that come into the warehouse through the palletizers at the end of the packaging lines. When an SKU needs to be stored in the warehouse it will get an individual storage location. As will be explained in the next paragraph, SKU's are handled in different areas based on their customer (Export and Domestic) and based on the loading type. A loaded transport of SKU's from the warehouse is considered the end product of the outbound logistics process.

Besides SKU's that are produced and shipped at the same brewery, three other flows exist that need to be handled and stored in the warehouse:

- Inter-Brewery flows: Finished SKU's that are interchanged between Den Bosch and Zoeterwoude with truck transport.
- Co-fill flows: Production of SKU's that is outsourced to a third party due to capacity issues or demanded primary package sizes that are not produced by HNS. The SKU's produced by these parties are transported to the brewery and stored. Shipments to the customer are loaded from the brewery warehouse.
- Re-pack flows: SKU's that are packaged at the brewery and then transported to a third party that repacks the products to a different configuration or specific promotional package. The re-packed SKU's are transported back to the brewery and stored. Shipments to the customer are loaded from the brewery warehouse.

2.2. SUPPLY CHAIN PROCESSES AND TECHNOLOGY: BREWING, PACKAGING AND OUTBOUND LOGISTICS

This paragraph describes the three identified supply chain processes in more detail, together with the technology that is used within the processes.

2.2.1. Brewing process and technology

The production of beer starts with the brewing process. Brewing consists of several stages, where each beer type has different characteristics, time requirements and specific processes. The general process will be described here using Source, Make and Deliver. The ´Source´ step in the brewing process is essentially sourcing the raw materials for the specific beer type. These materials include malt (barley), water, yeast, hop and sometimes additional flavours for sweetened beers. The ´Make´ step consists of many individual steps that are different for each beer type. In general, the first step is brewing wort. Wort is brewed in brew tanks where the malt is mixed with water. This mix is warmed up, filtered and in the end hop is added which gives beer its typical bitter taste and flavour. The composition of the raw materials and the duration of brewing is different for each wort type. The finished wort is mixed with yeast, which will start the fermentation process in the designated fermentation tanks. The yeast type and fermentation time is again different for each beer type, determining the flavour and aromas of the product. The last step of fermentation is aging in the lager tanks, which is used to stabilize and clear the beer. After this process the aged beer can be filtered, although unfiltered beers also exist. At the filter, remaining turbidity is removed and the aged beer can be transformed into many different beer types based on the applied filter and any added flavours. With more sweetened beer types in the portfolio, an increasing amount of flavours are added at the filter to create new beer types. The filtered beer is called bright beer and can be stored in bright beer tanks. This step is considered the ´Deliver´ step of the brewing process.

Concluding on a high level, the required physical technology for brewing consists of brew tanks, fermentation tanks, lager tanks, filters and bright beer tanks. Mainly the filters determine which beer types can be brewed with the available technology. In the table below the different assets per brewery are shown. It can be concluded that Den Bosch is a specialty brewery with smaller brew tanks and many filters, thereby being able to produce small batches and many beer types. Zoeterwoude is a bulk brewery with large tanks and limited options at the filter. A graphical overview of the physical brewing technology of both breweries is given in “Appendix 1: available technology at Den Bosch and Zoeterwoude”. The information technology related to planning and monitoring brewing activities is left out of scope for this research, as the focus is on outbound logistics operations.

2.2.2. Packaging process and technology

The beer in the bright beer tanks can be stored for a maximum of 72 hours before it has to be packaged at the packaging lines. The stored bright beer can be packaged in a high variety of packaging types. Depending on the primary packaging type and size, different packaging lines are in place. After sourcing the beer from the bright beer tanks, the ‘Make’ process at the packaging line is divided in three key steps: filling the primary packaging, bundling the primary packaging in a secondary packaging and bundling the secondary in a tertiary packaging. The flexibility of the lines is determined by the variety in sizes of primary packaging they can handle and the different configurations in secondary packaging they can produce. The output of the packaging process is a finished SPC, thus a combination of primary, secondary and tertiary packaging. The ‘Deliver’ process at the end of the packaging line consists of palletizing the SPC’s and putting a shrink wrap over the pallet. The finished pallet is called an SKU and always carries one specific SPC. It is delivered to the warehouse, where it can be stored in stock or directly transported to customers all over the world. Zoeterwoude and Den Bosch both have a large amount of packaging lines to produce the demanded diversity. A clear graphical overview of the packaging lines can be found in “Appendix 1: available technology at Den Bosch and Zoeterwoude”.

Information technology for packaging is similar for both Den Bosch and Zoeterwoude. Different planning tools are used for each planning horizon, being strategic planning (78 weeks ahead), tactical planning (13 weeks ahead) and operational planning (7-10 days ahead. The basis for supply chain planning is the forecast per SKU per customer which is loaded into the planning systems. These systems bundle the different forecasts to a total packaging plan per SKU and matches the demand with the available capacity. Customer related information per SKU is no longer available after this stage. Information outputs of the planning tools are the planned volumes per SKU per packaging line, combined with packaging master data such as packaging types, beer type, brand and market (Domestic or Export). In general, one centralized planning database is used to couple and store all packaging related information per SKU. Historical data on realized packaging can be found in reporting tools or Microsoft Excel (based on data from the planning database).

2.2.3. Outbound logistics process and technology

The finished SKU from packaging ends up in the brewery warehouse, where each SKU is handled separately. Within the warehouse, several routes from palletizer to loading are possible and also several loading types and transport modalities are used. The ‘Source’ process consists of the inbound flow of pallets from packaging. The ‘Make’ flow is the handling of pallets within the warehouse. The ‘Deliver’ flow is the loading of pallets. How and where the pallets are handled and/or stored depends on the customer assigned to the SKU. A distinction is made between Export and Domestic customers. The following sections will describe the differences for Export and Domestic SKU’s in both Den Bosch and Zoeterwoude.

Warehouse at Zoeterwoude: Export and Domestic SKU’s separated in the same warehouse

At Zoeterwoude, one large warehouse is used to store and transport pallets, but a clear distinction is made between Export and Domestic products. SKU’s for the Domestic market are mostly produced on dedicated Domestic packaging lines that end up in the Domestic warehouse area. Production is planned with the Make to Stock principle which requires a significant storage space to build up stock. Because the warehouse environment and SKU’s are relatively standard, Automated Guided Vehicles (AGV’s) are used to stock the finished SKU’s at dedicated warehouse locations. The AGV’s are also used to arrange a constant flow of empty returned bottles and kegs towards the packaging lines. When the stocked pallets in the warehouse are ordered by a Dutch customer (for example a retailer), the pallets are loaded with one-pallet wide forklifts from the warehouse to the trucks at the loading docks. This is mostly done by placing the pallets on a chain conveyor that loads the truck, so-called ‘Domestic loading’. Export SKU’s at Zoeterwoude are produced based on the Make to Order or Vendor Management Inventory (VMI) principle, which means that no planned stock of these SKU’s is stored at the brewery. Designed for bulk loading in containers, a streamlined logistics process is in place with cross-dock lanes. These conveyor belts can source the pallets directly from the palletizer and transport them through the warehouse towards the loading docks. Not all Export palletizers are directly connected to a cross-dock lane and therefore three-pallet wide forklifts are used to source the products from these palletizers. At the loading docks a dedicated truck with container is loaded directly. However, not all Export SKU’s are loaded in containers and not all containers are available in time. A buffer storage in the brewery warehouse is therefore still necessary where pallets are stored that cannot be loaded directly. Compared to the total produced volume the storage space is however limited and therefore sometimes additional storage space is rented.

The ‘Deliver’ process in both the Domestic and Export warehouse consists of loading the transport at the loading docks. The following loading types exist at HNS:

1. **Domestic loading**: Domestic truck loading from the Domestic warehouse
2. **Schep loading:** Container pallet loading with standard forklift truck (Export)
3. **Mechanical loading**: Container loading without pallet with special forklift truck (Export)
4. **Manual loading:** Container manual loading by workers (Export)
5. **Conventional Truck loading:** Truck loading with standard forklift truck (Export)

Pallet loading is mainly done by a standard forklift truck. Loading the container without pallets is also done but requires extra handlings to remove the pallet. On rare occasions, the container is loaded manually by workers in the warehouse. Mostly a specific forklift and pallet is used for loading without pallets. This process is called Mechanical loading and is shown in Figure 8 below. It enables the skilled forklift driver to remove the special pallet with the special forklift. Only the individual production units (SPC’s) with beer are then placed inside the container.

FIGURE 8: 'MECHANICAL' LOADING PROCESS: REMOVING THE PALLET (AUTHOR'S OWN PICTURE)

After loading, the truck transports the container to the inland container terminal Alpherium, which is 14 km from the brewery. A safety stock of containers from several shipping companies is held at this terminal to ensure container availability at the brewery so that a large amount of products can be directly loaded using the cross-dock lanes.

Warehouse at Den Bosch: Export and Domestic SKU's separated in different warehouse

At Den Bosch the outbound logistics are arranged differently from Zoeterwoude. Again, a distinction is made between Export and Domestic SKU's but here all products end up in the same warehouse with cross-dock lanes connected to each palletizer. The Domestic Make-to-Stock SKU's at Den Bosch are directly cross-docked into trucks that bring the products to the warehouse of a third party logistics provider next door. This warehouse is used as buffer for the Domestic market, both for finished SKU's and returnable materials (bottles, crates and kegs). Export SKU's at Den Bosch are cross-docked towards the loading docks and directly loaded in trucks or containers. If the container or truck is not available, products are stored in the brewery warehouse. Similar to Zoeterwoude, the Export brewery warehouse is relatively small related to the total produced volume as the focus is on direct loading with the cross-dock lanes.

Information technology in outbound logistics

As with packaging, information technology for outbound logistics is similar for both Den Bosch and Zoeterwoude. However, different systems than for packaging are used in outbound logistics with the result that different information is available here. For outbound logistics it is important to know the loading type per SKU as this determines different requirements for storage and loading. The loading type is determined by the customer and can therefore be linked to an SKU based on customer orders. Actual orders are only visible three to four weeks before loading and therefore logistics planning is carried out on a three to four week horizon. In general, the same centralized planning databases used for packaging are used for outbound logistics to couple and store all logistics related information per SKU such as orders and loading type.

2.3. SUPPLY CHAIN PLANNING: BREWING, PACKAGING AND OUTBOUND LOGISTICS

After a clear description of the products, processes and technology this paragraph explains how the supply chain processes are planned, thereby providing the necessary planning information at each step in the supply chain. Planning brewing and packaging is done by the department Supply Chain Planning. Order management and logistics planning are related to outbound logistics, both carried out on operational level (looking three to four weeks ahead).

2.3.1. Supply Chain Planning for brewing and packaging

To adequately manage a supply chain, accurate supply chain planning is required (Rushton, et al., 2014). In many cases, supply chain planning is executed in a hierarchical structure based on timelines. Strategic planning is aimed at choosing optimal production timing, location and investments over a long time horizon. Operational planning is much more detailed and mostly covers the exact sequencing of manufacturing tasks in a short timeframe. Tactical planning takes place on a level between strategic and operational scheduling and is aimed at key resource limitations (Van Der Niet, 2014). HNS follows the hierarchical supply chain planning structure, thereby planning the brewing and packaging process. The department Strategic Supply Chain Planning (SSCP) at HNS focuses on the medium and long term planning, thereby matching demand from Domestic and Export markets. On a monthly basis this department carries out Sales & Operations Planning (S&OP) which has the goal to balance supply and market demand as effectively as possible within an 18 months horizon. The basis is a strategic 18 months sales forecast provided by the department Market Demand Management. Different packaging scenarios are calculated, where SSCP focuses on matching demand with packaging capacities (Van Der Niet, 2014). Within the 18 months horizon, Tactical Supply Chain Planning (TSCP) makes a weekly packaging planning for the Den Bosch and Zoeterwoude breweries for up to 13 weeks ahead. For each beer type it is determined how much beer needs to be produced and where and which SKU's are packaged on which packaging line in which week. Besides this, the department also manages all the deliveries of packaging materials and stock sizes of those materials. The operational supply chain planning at HNS is done by Operational Scheduling (OS), which is split up per brewery. OS translates the weekly planning from TSCP to the hourly operations within the brewery with a horizon of three to four weeks. It generates the hourly filtration schedule, packaging schedule and calls off new raw and packaging materials for production.

2.3.2. Order management and logistics planning

Organizing outbound logistics is considered as two separate flows; the first flow is order management, which explains how orders are placed and handled at HNS using different strategies. The other flow is logistics planning, which combines the operational packaging planning and the placed orders into a physical storage and load planning.

Order Management

Regarding order management at HNS, three different strategies of order management are organized, depending on the served markets. The first strategy is called make-to-order (MTO), which HNS uses for a large part of its Export customers. This strategy suits operations where there is sufficient confidence in the nature, volume and timing of demand to reserve most of the raw materials and capacity it requires to satisfy its customers (Slack, et al., 2010). With the MTO concept at HNS, production of a specific SKU is only planned and started when an MTO customer has placed an order. Because HNS does not have insight in stock levels or in-market sales data of the MTO customers, a proper forecast is very important to plan operations at HNS efficiently. In 2014, HNS delivered approximately 20% of the volume with the MTO concept to

80% of the customers. The second order management flow is called Replenishment, which follows the Vendor-Managed Inventory (VMI) concept. This method is used to align information along the supply chain by allowing the supplier to manage the stock levels at the downstream customer (Slack, et al., 2010). In the case of HNS this means that employees at Zoeterwoude manage the stock levels held at the customer, providing the brewery insight in the volume and nature of demand from these so-called Replenishment customers. This method is executed mainly for large volume customers and customers that do not have the resources to plan themselves. Approximately 50% of the volume is delivered with the VMI concept to approximately 15% of the customers. The final 30% of volume is delivered through the Make-To-Stock principle, which is only used for the Domestic market at HNS. This means that HNS is responsible for maintaining a sufficient stock level for the market at the brewery warehouses. This concept is chosen to ensure product availability for the Dutch customers of HNS, thereby maintaining the required service level.

Logistics Planning

Logistics planning is focused on storage and load planning in the brewery warehouses. This is only carried out on operational level by Operations Scheduling (OS). The planning is made by using the customer orders in the system and the planned packaging time of the order. Based on the hourly planning for packaging, OS makes a logistics planning for when which SKU is loaded or stored. The actual customer orders are only placed three to four weeks ahead of the expected delivery and therefore logistics planning is currently only done on an operational time horizon. Based on the operational packaging plan a storage, load and resource planning is made by OS.

2.4. SCOPE: PRODUCTS, PROCESSES, TECHNOLOGY & PLANNING IN OUTBOUND LOGISTICS

Concluding from the paragraphs above, the key supply chain processes are brewing, packaging and outbound logistics. A distinction is made between supply chain technology, products, processes and planning. Chapter 1 has shown that complexity is perceived in all supply chain processes and in different forms. It would be interesting to analyse the impact of growing diversity within the whole supply chain, yet specific areas of research need to be defined considering the required depth for a master thesis. As the diversity grows going from beer type to SKU to customer, outbound logistics is the activity that needs to cope with the increased demand for diversity. Each new SPC that is palletized at the end of the packaging line results in a separate SKU that needs to be handled in the warehouse. The research will therefore focus on how the outbound logistics technology and planning can cope with diversity in SKU's, combined with the diversity in loading types. Researching outbound logistics at HEINEKEN specifically is interesting as the company currently faces challenges in warehousing due to increased diversity and capacity shortages. Based on this conclusion, outbound logistics will be the focus area in this research.

The following figure summarizes the key findings of this chapter with the identified supply chain components: technology, processes, products and planning with the focus on outbound logistics.

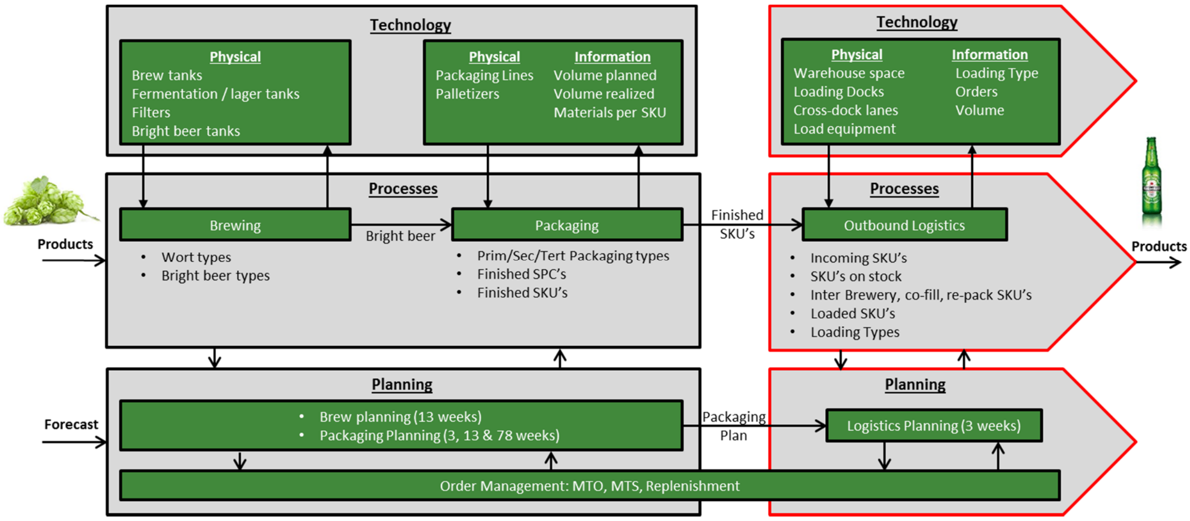


FIGURE 9: SCOPE: OUTBOUND LOGISTICS TECHNOLOGY, PROCESSES, PRODUCTS AND TECHNOLOGY

3. LITERATURE RESEARCH FOR PERCEIVED COMPLEXITY IN OUTBOUND LOGISTICS

After a detailed identification of the supply chain products, processes, technology and planning, the focus will now be on where and why complexity is perceived in the supply chain and how this affects outbound logistics. In chapter 1 is explained that complexity is perceived as a result of uncertainty. The goal is therefore to identify those factors that influence uncertainty in outbound logistics. The following funnel approach is used to provide structure in the research towards the key factors that drive uncertainty in outbound logistics, specifically at HNS. These factors are considered the drivers for perceived complexity.

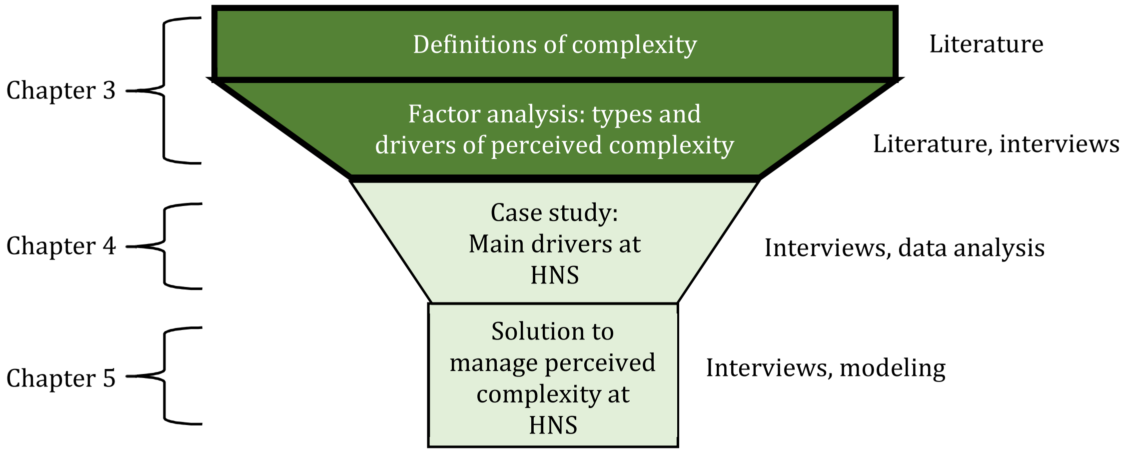


FIGURE 10: FUNNEL APPROACH TO DEFINE PERCEIVED COMPLEXITY AND DRIVERS

In this chapter, the first two layers of the funnel above are described by defining perceived complexity and its drivers. At first, a general definition of complexity is found in literature in paragraph 3.1. Paragraph 3.2 will discuss different approaches to identify types of perceived complexity within the supply chain, using the supply chain structure from Figure 6. Paragraph 3.3 summarizes the different approaches and relates the different types of perceived complexity in a conceptual framework. Subsequently, paragraph 3.4 will provide a qualitative factor analysis that derives the key factors related to uncertainty. These are the measurable drivers for perceived complexity, found through literature and interviews with experts at HNS. The final result of this chapter is a complexity framework presented in paragraph 3.5 that contains a long list of drivers for perceived complexity. The chapter is concluded by providing key hypotheses based on the complexity framework. These hypotheses are tested in chapter 4, where two specific case studies for perceived complexity at HNS are analysed in detail based on available data and expert interviews.

3.1. DEFINITION AND UNDERSTANDING OF COMPLEXITY

A clear definition of complexity is necessary to generate a common understanding of the word and apply this definition further in a supply chain and logistics context. In general, complexity is being recognized as a multifaceted concept. The adjective form of ‘complex’ is defined in the Oxford Dictionary as ´compound, complicated´, where another definition of the adjective complex is ´composed of many interconnected parts; compound; composite’. Diving further into this last definition, the adjective form of compound is defined as ‘consisting of two or more substances´ (Oxford Dictionaries, 2010). A research executed at Procter & Gamble identified complexity (Webster, 1964) as “1a: the quality or state of being composed of two or more separate or analysable items, parts, constituents, or symbols 2a: having many varied parts, patterns or elements, and consequently hard to understand fully 2b: marked by an involvement of many parts, aspects, details, notions, and necessitating earnest study or examination to understand or cope with'' (Den Hartog, 2012).

Previous studies in other disciplines have revealed a large range of perspectives on complexity. The definitions range from complexity in biology or physics ((Mazzocchi, 2008), information technology (Meyer & Curley, 1991) and operations research (Eglese, et al., 2005). However most articles are found where complexity is defined in an organizational perspective, finding complexity in different units of an organization. For example organizational design complexity (Den Hartog, 2012) but also complexity of products and product design (Kaski & J., 2002). Complexity in a supply chain context is also defined, by reviewing how complexity in supply chains affects operational performance (Bozarth, et al., 2009) (Serdar-Asan, 2011). In the context of product portfolio complexity, authors relate this form of complexity to the drive of differentiation and globalization of products (Closs, et al., 2008). Next to ´internal´ complexity in an organization, other authors focus on ´external´ complexity, resulting from the ever-changing business environments that (global) firms operate in (Vasconcelos & Ramirez, 2011).

Addressing all the different fields where complexity is found, the word has many definitions in itself. One common understanding is that complexity is experienced when there is a large diversity in aspects; diversity in products, processes, steps, locations, components etcetera. However, the definitions apply on specific areas of knowledge, thereby focusing on a single perspective. This approach is limited; as pointed out by (Den Hartog, 2012) and (Wang & von Tunzelmann, 2000), complexity should be approached as a multifaceted concept with possible relationships between complexity types. This view is embraced in the context of this study, as the result of more diversity in products has a direct impact on the processes within the supply chain. The focus should therefore be on how the diversity in products impacts the perceived complexity within a supply chain's processes. Besides this, complexity should be approached from an objective point of view as complexity is perceived by an organization; what is complex for one company might not be complex for another company.

At HEINEKEN, complexity is perceived as having more SKU's to produce with the same planning organization, technology and processes. By adding SKU's to the portfolio, the impact and information per SKU becomes less visible and therefore uncertainty increases. Complexity in this research is therefore defined as the uncertainty resulting from increased diversity. The goal is to identify those factors that contribute to uncertainty of processes in outbound logistics. If these factors can be identified and monitored, the perceived complexity is addressed and can be managed with a clear focus. The next section will go into detail on this approach, revealing the source and types of perceived complexity in a supply chain and its impact on outbound logistics.

3.2. PERCEIVED COMPLEXITY IN OUTBOUND LOGISTICS: DIFFERENT VIEWS

A first view on supply chain complexity is found in the work done by (Perumal, 2009). In the book 'Waging War on Complexity Costs', this author lies out the complexity types presented in Figure 11, which are interwoven and interconnected.

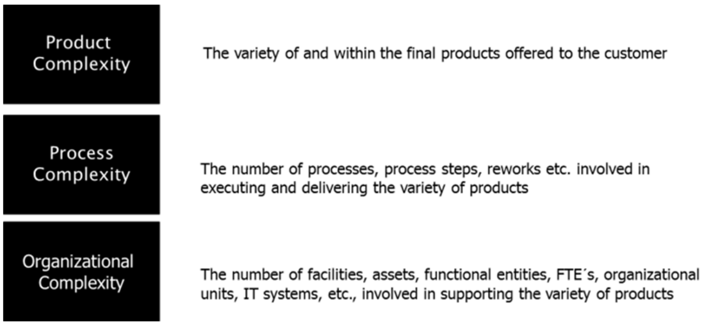


FIGURE 11: THREE TYPES OF COMPLEXITY DEFINED BY (PERUMAL, 2009)

A first remark should be defined on how Perumal describes product complexity; focus in this research will not be on the variety *within* the final products to the customer, as this focuses on product development and engineering. As outbound logistics operations only deals with finished SKU's, only the variety *of* final products is considered in this research, where products and SKU's are considered the same. The work by Perumal assesses three complexity areas, thereby providing a good starting point. Complexity in the supply chain, specifically outbound logistics, can be further revealed by combining the definition of complexity with the earlier stated supply chain definition and components. In four areas complexity can be found, corresponding to the structure described in paragraph 2.4: Products, Technology, Processes and Planning. It is necessary to strengthen these aspects with literature and relate the areas of perceived complexity with each other. To motivate all four areas, the following sections will provide extensive literature research within each individual complexity area.

3.2.1. Product complexity: diversity in SKU's

According to (Pasche, 2009), the source of perceived supply chain complexity is *market and customer variety*, meaning the diversity in customers and products related to these customers. Product complexity is explicitly described by a variety of authors. Relevant definitions are found in the work done by (Wang & von Tunzelmann, 2000), defining complexity within the product but also in the markets that are delivered with the products:

- Complexity within the product (product design and technology); Complexity related to the number of components, design decisions and functions of a (new) product architecture (innovation).
- Complexity in delivering markets**;** market delivery complexity is concerned with customer diversity and market dynamics. Customers may differ in terms of their geographic, demographic, and other social characteristics, whereas market dynamics include factors as the stages of market evolution and competition, all influencing decision how to best deliver to the market. This influences the operations at the production plant, as different markets may require different ways of loading or transporting the SKU's.

As mentioned above, outbound logistics is the area where finished SKU's need to be handled. Complexity *within* the product (product design and technology) is therefore left out of scope as it focuses on product development. It is assumed that a single product in itself is not perceived as complex for outbound logistics, but that the complete portfolio of different SKU's does have an impact on logistics operations. To identify the sources of SKU diversity, the thesis work performed by (Den Hartog, 2012) is used, defining where diversity in SKU's originates from:

- Business complexity; complexity caused by the ever-changing nature of the business environment. This can be caused by for example changing regulations, market trends, changes in volume, changing consumer needs, etc. Even though the true reason of change may be (far) outside the organizations scope, its ramifications will influence the organizations complexity as the organization tries to adapt its products and/or processes to best fit the business environment. In practice this might result in market specific SKU's in the portfolio to meet the customer demands and requirements.

- <u>Product portfolio complexity</u>; complexity related to the inherent characteristics of a complete product portfolio, related to the fact that all SKU's need to be produced and handled individually.

Combining the views of Wang & Von Tunzelmann , Den Hartog and Pasche, product complexity in outbound logistics is uncertainty that is caused by the product portfolio. This uncertainty is driven by the large number of SKU's in the portfolio, originating from customer diversity and market regulations. Besides that, also more SKU's are created by adding new products (innovations) to the portfolio in general. The source of product complexity therefore lies at the customer, where the demand for diversity is created. A similar approach is described by (Bozarth, et al., 2009) as 'downstream complexity', related to the number of customers served and the heterogeneity in customer needs. Serving global customers results in a large number of products (SKU's) that need to be produced and handled differently. The result is additional SKU's in the portfolio, thereby driving perceived *product complexity* within outbound logistics.

The next section will go into detail on supply chain technology, combining the available technology with production and distribution of the large diversity in the product portfolio.

3.2.2. Technology complexity: physical and information related

Technology in the supply chain entails all physical structures available for production and distribution. Besides that, according to (Gunasekaran & Ngai, 2004), the role of information technology (IT) in the supply chain is becoming increasingly important with the trend towards more complexity and diversity. IT systems can enable integration of information flows between supply chain stakeholders, both with external suppliers and customers but also within the internal company supply chain. To take the IT development into account, technology in the supply chain encompasses two types of technology: the available physical technology/equipment for producing and delivering products on the one hand and the information technology (IT) to provide information at each step in the supply chain on the other hand.

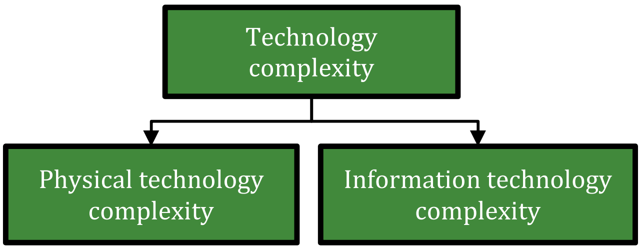


FIGURE 12: TWO TYPES OF TECHNOLOGY COMPLEXITY (AUTHOR'S OWN DRAWING)

Regarding physical technology in outbound logistics, warehousing assets and equipment are the most common types of technology. Its capacities and connections determine what can be handled and are therefore important aspects to take into account. In the past years, technology within logistics has become increasingly complex by automation; to enable this automation a certain form of standardization in processes is necessary. Clear examples of automation within logistics are used in the container terminal industry, with automated systems that operate in a standardized environment (Kohler, et al., 2013). At production plants, also at HNS, efficient standardized solutions are always explored to increase operational performance through automation. Examples are the AGV's at the warehouse in Zoeterwoude and the cross-dock lanes at both breweries. While these systems often add operational performance, they are built for standardized routes and purposes and therefore have limited flexibility. However, with an increasing diversity of products to be produced, flexibility in physical operations becomes more important. Physical technology complexity entails the limitations that standardized technology brings to outbound logistics. Perceived complexity in physical technology is therefore related to uncertainty when the standard procedure is changed or not followed.

Information technology (IT) is important when looking at information flows within outbound logistics. As mentioned in chapter 2, IT is not focused on the systems themselves but on data availability and interchange ability between different systems, creating a broader scope of supply chain and logistics planning. When a more diverse product portfolio is created, all relevant information per SKU needs to be processed well to make the information accessible across the supply chain. If the information technology does not allow this, at some places within the supply chain information will be missing. Complexity in information technology is perceived when important information is not available, thereby causing uncertainty in supply chain planning.

Concluding, perceived technology complexity is the uncertainty created when product diversity exceeds the boundaries of the technology in place, both physical and information related. The following paragraph will go into detail on process complexity, which results from a mismatch between product and technology complexity.

3.2.3. Process complexity: warehousing operations

Process complexity can be directly linked to the combination of technology and product complexity. As mentioned in Figure 11, Perumal et al. (2009) describe process complexity as "the number of processes, process steps, reworks etc. involved in executing and delivering the variety of products". The authors indicate that process complexity is impacted by product complexity; when the diversity (thus product complexity) in SKU's increases, uncertainty related to the product portfolio increases as well. As the processes need to produce and deliver all SKU's, uncertainty in processes will also increase due to a lacking overview on SKU level. An interview with (Horsman, 2015) at HNS resulted in another definition of process complexity. He described process complexity in the supply chain as "doing things that you are not used to do", linking process complexity directly with uncertainty in technology: when you change the volume and amount of SKU's without aligning the physical and information technology, process complexity is the result. Drivers for process complexity are therefore found by connecting the SKU diversity with the available physical and information technology. Process complexity linked to IT is mainly experienced as a result of incomplete information flows. Often, different processes in the supply chain use different IT systems. The different IT systems often only capture the relevant information for the specific purpose where the system is used. This can result in incomplete information and thus uncertainty in other parts of the organization. In outbound logistics operations at HNS often a misalignment between the production plan and the logistics plan is experienced, resulting in uncertainty of expected stock levels or peak moments for loading.

Concluding, process complexity is a result of combining product complexity with technology complexity. When misalignment exists between products and available technology, the uncertainty thus process complexity will increase. This will have an impact on the planning part in the supply chain, as will be explained in the following section.

3.2.4. Planning complexity

As with the other types of complexity, the perceived complexity in planning is very much related to uncertainty in the future. Without accurate and long-term planning the future becomes unpredictable, thereby increasing uncertainty in an organization (Slack, et al., 2010). Uncertainty is also created when having more SKU's to plan while the information per SKU is not well captured (Bozarth, et al., 2009). Another driver for planning complexity is outsourcing. When outsourcing activities to third parties, for example re-packing, co-filling or external storage at HNS, additional work has to be done to manage these flows and follow the progress of third party activities. When the processes of third parties are not completely integrated within the own organization, additional uncertainty (thus planning complexity) is experienced in the planning of these third parties.

3.3. THE FRAMEWORK FOR PERCEIVED COMPLEXITY

In the previous sections, several views are proposed for defining the different types of perceived complexity within outbound logistics. A combination of these different views can provide a clear definition of complexity types, what these entail and how the different types are related. Combining and relating the different views results in a framework that is used as further reference in this research. In the following is described how the framework in Figure 13 is built up with the previous assessed definitions of complexity.

According to (Pasche, 2009), the source of perceived complexity is *market and customer variety*. In the proposed framework, underlying aspects of market and customer variety are complexity in delivering markets from (Wang & von Tunzelmann, 2000), environmental complexity from (Den Hartog, 2012) and downstream complexity from (Bozarth, et al., 2009). Resulting from this diversity in customers, products need to be tailored to specific countries/customers, resulting in more product portfolio complexity (Den Hartog, 2012). The result is more SKU's in the portfolio that can result in uncertainty on individual SKU level. This uncertainty forms the perception of *product complexity* within outbound logistics.

Having more SKU's to produce and deliver, the physical and information technology in the supply chain need adaptations to enable the planning and production of all SKU's. The perceived *technology complexity* is the uncertainty created when product diversity exceeds the boundaries of the technology in place, both physical and information related. The mismatch between product diversity and available technology leads to increased uncertainty or unpredictability in the supply chain processes, as additional production steps or changeovers might be necessary. In the specific case of HNS, additional SKU's form a problem as the bulk brewery in Zoeterwoude is not built for diversity. By adding SKU's, the impact on individual SKU level becomes less visible. This uncertainty is perceived as additional *process complexity,* where the production process setup becomes less suitable for the desired mix in volume and SKU's.

Besides impact on physical and IT related processes, additional product complexity also influences the logistics planning. Every SKU has to be planned and ordered individually, creating more perceived complexity in the logistics planning and order management processes. Any additional production step and/or location also needs to be planned, driving perceived complexity in planning. Therefore, both experienced product and process complexity influence the perceived *planning complexity.*

Figure 13 shows the finished framework, resulting from the sketched relations above. From the figure it can be concluded that a high degree of product complexity, in combination with technology complexity, leads to additional process complexity. Besides that, product, process and information technology complexity together lead to additional planning complexity. This theoretical framework will be used in chapter 4 to analyse perceived complexity at HNS. Referring to chapter 1, market diversity and product complexity are expected to increase for HNS in the future. Therefore, it is assumed that additional product complexity is expected and cannot be influenced by HNS. This research will focus on how additional product diversity influences uncertainty in processes and planning given the current technology in place.

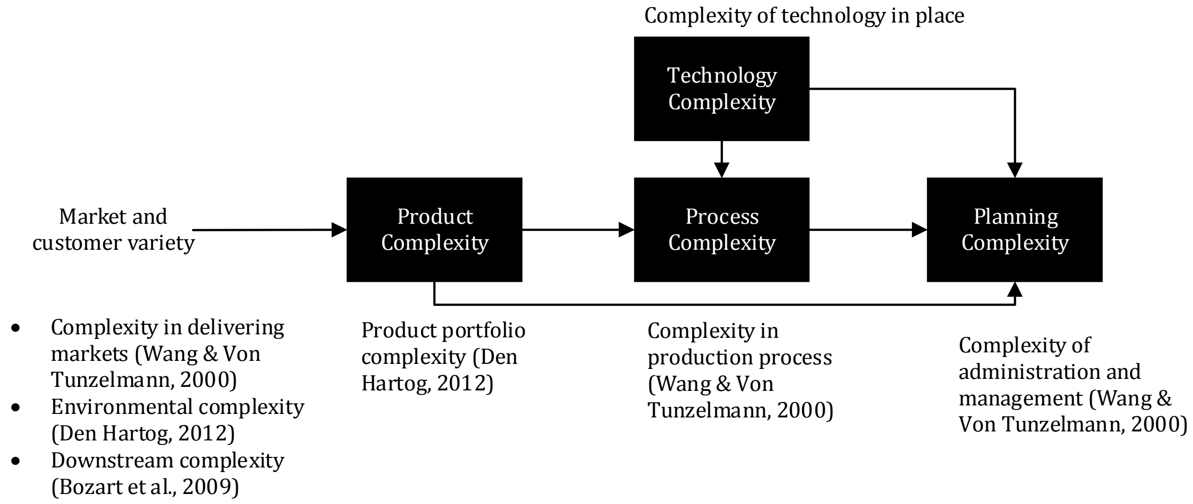


FIGURE 13: PROPOSED FRAMEWORK FOR PERCEIVED COMPLEXITY (AUTHOR'S OWN DRAWING)

3.4. DRIVERS FOR PERCEIVED COMPLEXITY: CONTROLLABILITY AND PREDICTABILITY

With a clear definition of perceived complexity, the framework will now be linked to the supply chain structure in Figure 9 with the focus on outbound logistics. This will derive measurable factors that drive the perception of complexity. These so-called complexity drivers are defined for each complexity type by determining the factors that influence the uncertainty in products, technology, processes and planning. The complexity drivers will be assessed on how well the outbound logistics organization is able to control and predict them.

3.4.1. Drivers for perceived product complexity

Perceived product complexity is uncertainty related to the size of the product portfolio. As previously defined, products in outbound logistics are finished SKU's (thus palletized SPC's) that come from the palletizers of the packaging lines. These SKU's use the physical technology and corresponding processes to go from the palletizer towards final loading. This is summarized in the picture below, which is a section of Figure 9.

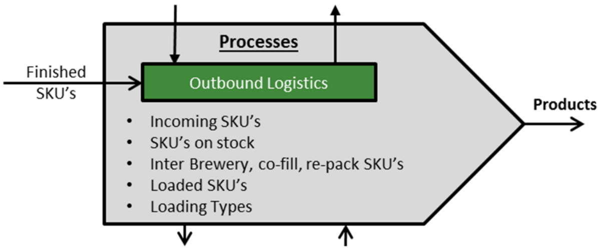


FIGURE 14: PRODUCT FLOW IN OUTBOUND LOGISTICS (AUTHOR'S OWN DRAWING)

The number of finished SKU's to be handled in the warehouse (incoming, on stock and loaded SKU's) is a driver for product complexity, because an overview of the impact per SKU decreases as the portfolio expands. Often the SKU diversity and volume are not controlled by the production organization as commercial benefits related to the diverse portfolio are considered more important than the operational issues it might create. In the case of HEINEKEN the focus is on diverse portfolios in all markets, making SKU diversity an essential part of the strategy. For global supplier HNS, especially for the logistics operations within HNS, SKU diversity is therefore considered a given. There are however good plans in place for product introductions, making the expected diversity fairly predictable. Next to SKU diversity, volume is also a driver for complexity. Relating to business complexity from (Den Hartog, 2012), the market trend for HNS sees an increase in volume in general which results in operations reaching maximum capacity. The total volume in pallets to be handled is therefore a driver for perceived complexity; it is fairly unpredictable as it is dependent on accuracy of customer forecasts and orders (Reimers, 2015). The volume cannot directly be controlled by the outbound logistics organization, as the production plan determines the volume per plant based on market demand. Besides the number of SKU's and volume, also the complexity in delivering markets is found at HNS with different loading types for Export that take more time than others. The diversity is found in Schep, Mechanical and Conventional Truck loading. Uncertainty arises in outbound logistics when the loading type of a specific SKU is not known (Schreuder, 2015). This uncertainty is strongly dependent on IT, as information per SKU is captured in the IT systems. The diversity in loading types, resulting from delivery requirements from several markets, is therefore also a driver for complexity. Table 1 summarizes the drivers measuring perceived product complexity.

TABLE 1: DRIVERS FOR PRODUCT COMPLEXITY, BASED ON (DEN HARTOG, 2012), (SCHREUDER, 2015)

Driver	Unit of measurement	Controllability	Predictability
SKU Diversity	Number of unique SKU's	Low	High
Volume	Total volume in pallets	Low	Low
Loading type diversity	Loading type per SKU	High	Depends on IT

3.4.2. Drivers for perceived technology complexity

Technology complexity is defined as the uncertainty created when product diversity exceeds the boundaries of the technology in place, both physical and information related. Physical technology in outbound logistics is related to the warehouse layout, equipment such as forklifts, cross-dock lanes and the number and types of loading docks. Information technology is related to information availability for the different stakeholders in the supply chain. This is summarized in the figure below, following from Figure 9.

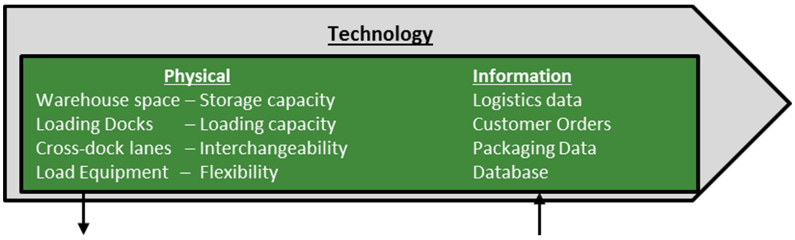


FIGURE 15: TECHNOLOGY IN OUTBOUND LOGISTICS (AUTHOR'S OWN DRAWING)

Physical technology complexity can be measured by the capacities of the individual components, thereby determining what volume and degree of product complexity can be handled. Important drivers are overall storage capacity and the size of individual storage locations (in pallets). Storage capacities are known by the organization and therefore predictable. The capacities are also controllable as investments can be made when capacity is lacking. At HNS, another driver for physical technology complexity is the loading capacity. As with storage capacity, the loading capacity is controllable by the organization but it is not predictable; the loading capacity largely depends on the volume ratio per loading type that needs to be loaded in a specific period of time (Hoondert, 2015). At HNS, this can vary significantly and is therefore unpredictable. Besides capacities, flexibility in the physical warehouse is specifically important at HNS with different warehouse locations for Domestic and Export products. The interchange ability between these locations is an important driver that measures the flexibility of the warehouse and its equipment. The warehouse layout is managed and designed by HNS, thereby making the rate of interchange ability controllable and predictable for the organization (Van Kooten, 2015). The table below summarizes the drivers for physical technology complexity.

TABLE 2: DRIVERS FOR PHYSICAL TECHNOLOGY COMPLEXITY, BASED ON (HOONDERT, 2015)

Driver	Unit of measurement	Controllability	Predictability
Storage capacity	Volume in Pallets	High	High
Size of storage locations	Size in Pallets	High	High
Loading capacity	Pallets / hour	High	Low
Equipment flexibility	% of SKU's that can be transported with the equipment	High	High
Interchange ability between storage areas	-	High	High

Besides physical technology, perceived complexity in information technology is very important to address, as information accessibility drives the efficiency of supply chain planning (Slack, et al., 2010). Because IT should enable data interchange ability and accessibility, the perceived complexity within IT can be approached by determining how often data is updated. Complexity in IT is also perceived when certain information is missing. For outbound logistics at HNS specifically, insight is needed in the parameters that determine the volume on stock: the loading type of an SKU, the cross-dock % per SKU that is directly loaded and the storage time per SKU when it is stocked in the warehouse (Plooij, 2015) (Reimers, 2015). The organization can control these parameters, however if they are not measured properly they will not be predictable. The last factor to take into account is the diversity in IT systems, indicating how well data is accessible for all stakeholders in the supply chain. The table below summarizes the drivers for information technology complexity.

TABLE 3: DRIVERS FOR INFORMATION TECHNOLOGY COMPLEXITY, BASED ON (REIMERS, 2015)

Driver	Unit of measurement	Controllability	Predictability
Inventory visibility in IT systems	Update frequency	High	Low
Absence of logistics parameters per SKU	Loading type per SKU, storage time per SKU, cross-dock % per SKU	High	Low
IT system diversity	Number of planning systems	High	High

3.4.3. Drivers for perceived process complexity

As indicated in the complexity framework, process complexity is a direct result of combining product and technology complexity. Process complexity has been defined as the number of processes or process steps involved within outbound logistics (Perumal, 2009). With this in mind, uncertainty in processes increases when the mismatch between products and technology increases.

Looking at the mismatch between product diversity and physical technology, it is important to compare the capacities and warehouse layout with production batch sizes and SKU diversity. With the increased product complexity (more SKU's) at HNS, it is uncertain which SKU's need to be stored, how long and with what volume (Schreuder, 2015). The result is uncertainty in outbound logistics processes and reactive process steps when the volume and/or number of SKU's are not aligned with the initial plan or capacity. Examples are unpredictable mismatches between storage demand and capacity or mismatches between production batch size and storage location size. Results of insufficient storage capacity at the brewery can also be more external storage, adding process steps and costs (Hoondert, 2015). Whereas the demand for storage is fairly unpredictable at HNS, the physical capacities are known and can be controlled by the organization. The mismatch between demand and capacity is therefore controllable (storage capacity can be controlled) but unpredictable (storage demand is hard to plan ahead).

The mismatch between product diversity and information technology is focused on correctly measuring the logistics parameters per SKU. With more SKU's, data becomes more important in order to capture all relevant data that make an SKU unique. If data per SKU is unavailable or incomplete, more processes steps are the result due to incomplete information (rework) or trying to estimate data by making assumptions (Reimers, 2015). Absence of the earlier identified logistics parameters at different parts of the supply chain is therefore also an important driver for process complexity.

The table below summarizes the drivers for perceived process complexity, resulting from mismatches between product and technology complexity.

TABLE 4: DRIVERS FOR PROCESS COMPLEXITY, BASED ON (SCHREUDER, 2015), (REIMERS, 2015)

Drivers	Unit of measurement	Controllability	Predictability
Mismatch between storage capacity and demand	Difference in pallets	High	Low
Mismatch between batch size and storage location size	% of utilized locations vs. % of utilized space	High	Low
Storage at third parties	Pallets per year	High	Low
Absence of logistics parameters per SKU	Loading type per SKU, storage time per SKU, cross-dock % per SKU	High	Low

3.4.4. Drivers for perceived planning complexity

Planning complexity is the result of process and product complexity. It is focused on time and human resources that are involved in logistics planning and order management, as shown below and in Figure 9.

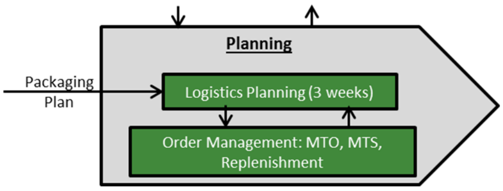


FIGURE 16: PLANNING IN OUTBOUND LOGISTICS (AUTHOR'S OWN DRAWING)

An important driver for perceived complexity in a planning organization is the horizon that is used for planning. A very short planning horizon increases uncertainty as no expectations are available for the future. The horizon used for planning can be controlled and predicted by the organization by providing the right data and tools for long-term planning. As stated before, more process complexity, thus more process steps, require more effort in logistics planning. Examples are a packaging plan with more co-fill and/or re-pack SKU's, which are produced by third parties. Managing the logistics planning around more process steps means that additional time and people are needed for efficient planning. Drivers for planning complexity are thus experienced as the hours per week spent on logistics planning, order management and (if applicable) third parties. The required resources for weekly planning are assumed to be similar from week to week. Therefore, the resource allocation for planning is assumed to be controllable by and predictable for the organization.

TABLE 5: DRIVERS FOR PLANNING COMPLEXITY

Drivers	Unit of measurement	Controllability	Predictability
Logistics planning horizon	Weeks	High	High
Time spent on logistics planning	Hours per week	High	High
Time spent on order management	Hours per week	High	High
Time spent on managing third parties	Hours per week	High	High

3.5. INTERMEDIATE CONCLUSIONS: LONG LIST OF COMPLEXITY DRIVERS AND HYPOTHESES

This paragraph concludes the chapter with a clear overview of the drivers for complexity by combining the complexity framework and drivers that were derived in the factor analysis of paragraph 3.4. Figure 17 shows this combination and with this the framework is finished.

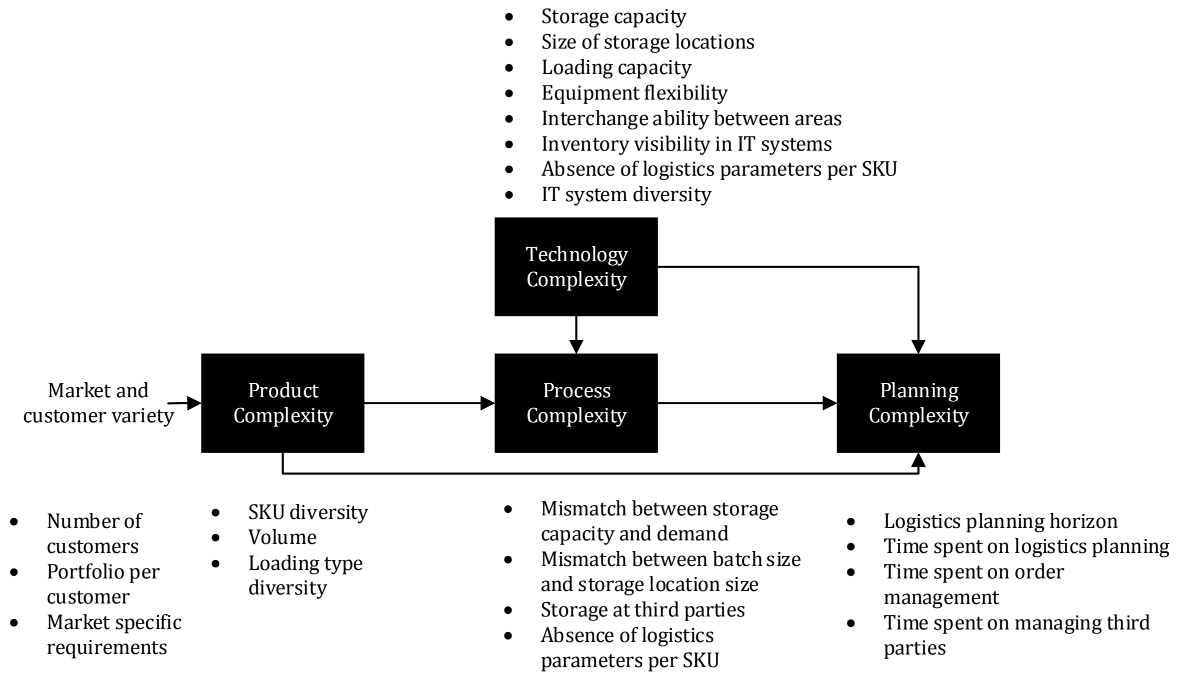


FIGURE 17: THE FRAMEWORK FOR PERCEIVED COMPLEXITY WITH ITS DRIVERS (AUTHOR'S OWN DRAWING)

With the framework and drivers in place, the context of perceived complexity has been qualitatively analysed with literature and industry experts. It can be concluded that complexity is perceived by an organization in different forms with all types resulting from increased market demand for diversity. The complexity framework clearly shows how market diversity impacts product complexity and what the main drivers for perceived complexity are. The framework therefore gives a qualitative answer to the first three sub research questions of this thesis, providing a clear understanding of perceived complexity in outbound logistics operations. To strengthen the positioning of the complexity framework in research, it can be tested by applying it to a supply chain that faces increased perceptions of complexity. Based on the framework in Figure 17 hypotheses can be identified which are deduced from the relations between the different types of complexity.

Hypothesis 1: Market variety leads to additional product complexity
With an increase of customers and portfolio size of customers, the perceived product complexity at an organization increases. This can be measured with the volume, number of SKU's and diversity in loading types in outbound logistics.

Hypothesis 2: Product and physical technology complexity lead to process complexity
The layout in outbound logistics does not change with the change in SKU's. This has impact on the match between storage demand and capacity, thereby influencing efficiency of warehousing operations.

Hypothesis 3: Product and IT complexity lead to process and planning complexity:
The information systems and accessibility of information does not follow the change in SKU's. This results in a lack of information throughout the complete supply chain, limiting accurate planning and creating uncertainty in logistics processes.

The hypotheses sketched above need to be validated and linked with specific case studies. Chapter 4 will therefore use case studies at HNS to test the usefulness of the complexity framework and its hypotheses. Through extensive qualitative and quantitative analysis at HNS is concluded if and how the complexity drivers are present at HNS. The long list of complexity drivers can be converted into a short list for HNS, ending up with the most important drivers for perceived complexity in this study. This will strengthen the answers given to the first three research questions. Subsequently can be researched how the short list of drivers for perceived complexity can be managed more closely in the future. This will be done in chapter 5, where a solution is proposed to manage the most critical factors for perceived complexity at HNS.

4. CASE STUDY ANALYSIS: PERCEIVED COMPLEXITY AT HEINEKEN NETHERLANDS SUPPLY

The developed complexity framework from chapter 3 can be applied to any supply chain that faces an increased perception of complexity. To illustrate this, the following sections will elaborate on layer three in the funnel as described below: filtering the main drivers for perceived complexity at HNS from the long list of drivers. The hypotheses and drivers per complexity type from chapter 3 are used in the following sections to develop an understanding of the perceived complexity at HNS.

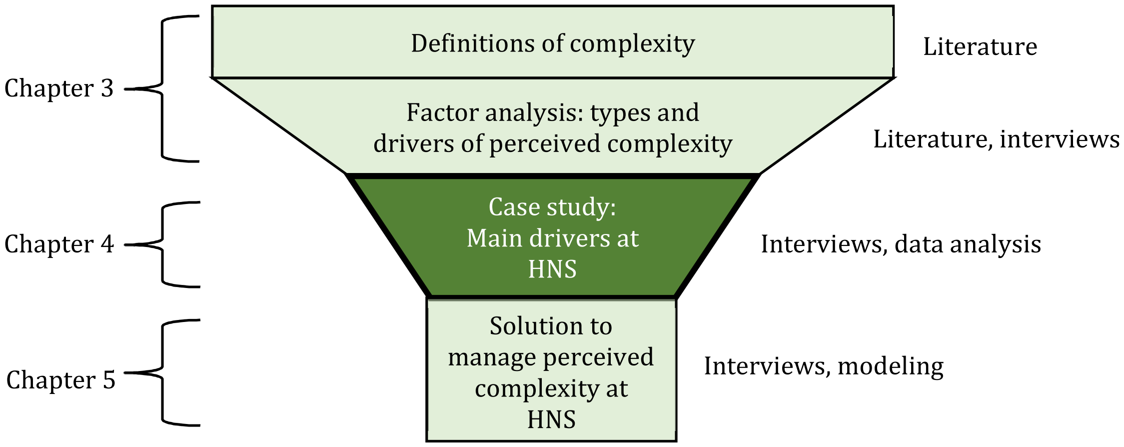


FIGURE 18: FUNNEL APPROACH TO DEFINE THE MAIN DRIVERS FOR PERCEIVED COMPLEXITY AT HNS

The following paragraph will describe the methodology used during the analysis at HNS. Afterwards, paragraph 4.2 and 4.3 will provide extensive data analysis for Zoeterwoude and Den Bosch respectively, thereby actively researching the identified drivers for product, physical technology and process complexity. Paragraph 4.4 will elaborate on perceived IT and planning complexity at both breweries as both are managed with the same systems and planning structure. Paragraph 4.5 concludes the chapter with a short list of main drivers for perceived complexity at HNS and the largest bottlenecks related to these drivers. The short list of complexity drivers thereby provides an answer for the first three sub research questions.

4.1. METHODOLOGY: QUANTITATIVE AND QUALITATIVE ANALYSIS

To test the usefulness of the complexity framework, the different types and drivers for perceived complexity from the previous chapter are placed into the organization of HNS. Through expert interviews, quantitative and qualitative analysis at HNS is tested if the complexity framework can be used to address the main drivers for perceived complexity in an organization. The outcome of the analysis should be a short list of drivers that have the largest impact on perceived complexity. HNS possesses a large amount of historical data within outbound logistics, providing a good base for data analysis. With the use of the complexity framework, analysis on the specified drivers of perceived complexity will provide knowledge and focus for HNS, while simultaneously testing the complexity framework on its academic and practical relevance. Some of the identified complexity drivers, mainly those related to technology, are however not quantifiable. In this case, the drivers are qualitatively analysed by the available information such as maps of the physical layout and information flows within the IT environment. The following paragraphs will describe individual case studies where paragraph 4.2 will focus on Zoeterwoude and paragraph 4.3 will focus on Den Bosch. For both breweries is analysed how product and technology complexity result in additional process complexity. The impact on planning complexity in terms of resources or hours per week is left out of scope in these case studies as this is largely dependent on the efficiency and educational level of people involved. Reorganizations at HNS have changed the average educational level of employees, thereby not making it a reliable base for analysis. The perceived planning complexity will be taken into account by focusing on the planning horizon and information flows involved in logistics planning at HNS.

For each complexity type is analysed which drivers are applicable to HNS and which are not. This is done through quantitative analysis, qualitative analysis and interviews within the organization. The result of this chapter will be a clear overview of the main drivers that have the largest influence on perceived complexity at HNS. For these drivers, a link can be made to a solution that can manage the drivers more closely. Providing solutions forms the last layer of the funnel in Figure 18.

4.2. ANALYSIS OF PERCEIVED COMPLEXITY AT ZOETERWOUDE

The brewery in Zoeterwoude is built for bulk production of regular beer types without too much diversity. The brewery has a theoretical capacity of 15 million hectolitre (HL) per year and was essentially laid out to produce large volumes for mainly the USA and The Netherlands. The outbound logistics warehouse is built in line with this initial demand, with a large Domestic warehouse and a relatively small Export warehouse as most of the Export products are cross-docked and directly loaded. With the current growth of diversity in beer types, more of the traditional Heineken and Amstel SKU’s are transferred from Den Bosch to Zoeterwoude. The result is more diversity that is not in line with the current layout. The following sections will explain the impact that this has, using the complexity framework structure.

4.2.1. Product complexity: large volume and SKU diversity

Corresponding to the complexity framework, product complexity at Zoeterwoude can be perceived in three different forms:

1. Number of unique SKU’s
2. Volume to be handled in the warehouse
3. Loading type diversity

For outbound logistics at HNS, product complexity mainly results from the choices that are made in the brewing and/or packaging process as those steps define where which SKU’s are produced, in which sequence and what volume. It is therefore not controlled by the outbound logistics organization. In “Appendix 3: trends in number of SKU´s” is analysed how the number of SKU’s has grown in the past years, with acceleration in 2014 because of the rise in volume. The trend is expected to continue as illustrated by the masterplan data in Appendix 5. One clear consequence of producing more SKU’s is that the average produced volume per SKU has decreased at Zoeterwoude. Figure 19 shows this based on the actual production volumes known to HNS. With more SKU’s in smaller volumes to produce, more production changeovers are necessary and therefore the efficiency and capacity on the packaging lines is at stake. For outbound logistics at Zoeterwoude, more SKU’s in smaller volumes results in a change in demand for storage; more unique SKU’s in smaller batches of pallets need to be stored individually.

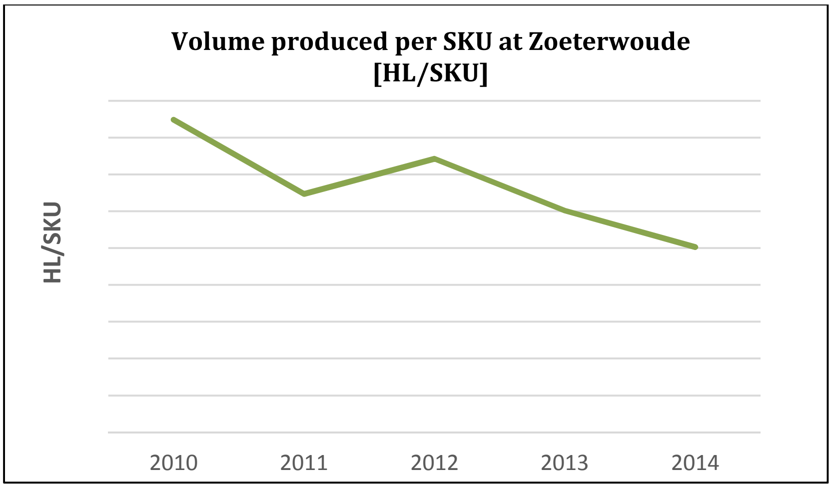


FIGURE 19: TREND TOWARDS LESS VOLUME PER SKU AT ZOETERWOUDE (AUTHOR'S OWN ANALYSIS)

An interview with the logistics coordinator at HNS has pointed out that the rise in SKU's provides additional uncertainty in warehousing operations. For outbound logistics it is important to know the loading type per production batch of an SKU, as this determines the cross-dock % and demand for storage. However, on individual SKU level the impact on the demand for storage and loading is unknown as one SKU can have more than one loading type (Hoondert, 2015). Other flows that add to this uncertainty are flows that come in from third parties, being the co-fill, re-pack and inter-brewery transports. The volume expected from these flows is not planned, influencing the uncertainty and unpredictability of volume and number of SKU's in the warehouse. Co-filling leads to additional finished SKU's that come in from third parties while re-packing leads to additional finished SKU's that need to be stored, loaded and stored again after the re-pack products are returned to the brewery warehouse. Inter-brewery transports results in additional SKU's coming from other HNS breweries.

Table 6 shows the trend in number of unique SKU's on stock at Zoeterwoude. A clear trend towards more SKU's can be seen for both Export and Domestic markets.

TABLE 6: GROWTH IN NUMBER OF SKU'S ON STOCK AT ZOETERWOUDE (AUTHOR'S OWN ANALYSIS)

Growth in number of SKU's on stock Zoeterwoude	2012-2013	2013-2014
% Growth in number of Export SKU's	24%	19%
% Growth in number of Domestic SKU's	1%	18%

Besides the number of SKU's in the warehouse, loading is also changing at Zoeterwoude, as is illustrated in Figure 20.

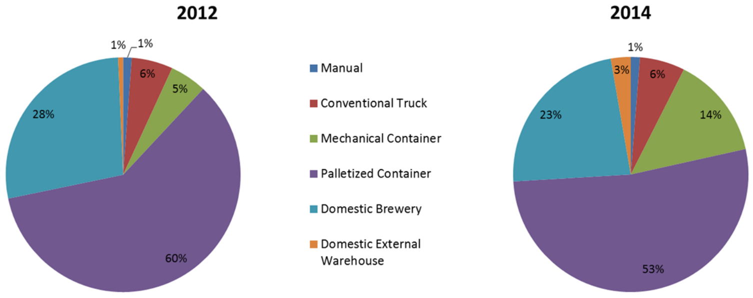


FIGURE 20: VOLUME RATIO OF LOADING TYPES AT ZOETERWOUDE (AUTHOR'S OWN ANALYSIS)

At Zoeterwoude an increase in volume of the un-palletized Mechanical loading and Conventional Truck loading is seen. The increase in Mechanical loading is resulting from volume that is transferred from Den Bosch to Zoeterwoude. Mechanical loading is a complex process that requires skilled workers and dedicated pallets, forklift trucks and loading stations to remove the pallet. The increase in Mechanical loading creates a bottleneck as not enough skilled personnel and Mechanical loading stations are available. Besides the trend in Mechanical loading, Conventional Truck loading remains constant at 6% of the total volume from 2012 to 2014. With the increase in total volume, the Conventional Truck volume is also rising as can be seen below. This trend is continuing with a steeper curve in 2015. As pallets for Conventional Truck loading cannot be cross-docked directly, more pallets need to be stored in the warehouse. How much pallets need to be stored exactly is however not known, as an SKU can have more than one loading type. Without an overview of volume per loading type, the uncertainty of the expected demand for storage increases. Conventional Truck transport is becoming an increasing bottleneck as a result of more volume shipped to France and logistics forwarders that are supplied by truck. The forwarders are supplied based on the MTO management concept and therefore have a drumbeat with two weeks of production. This means that large product orders for these parties can remain in the warehouse for two weeks, covering the time between packaging and loading.

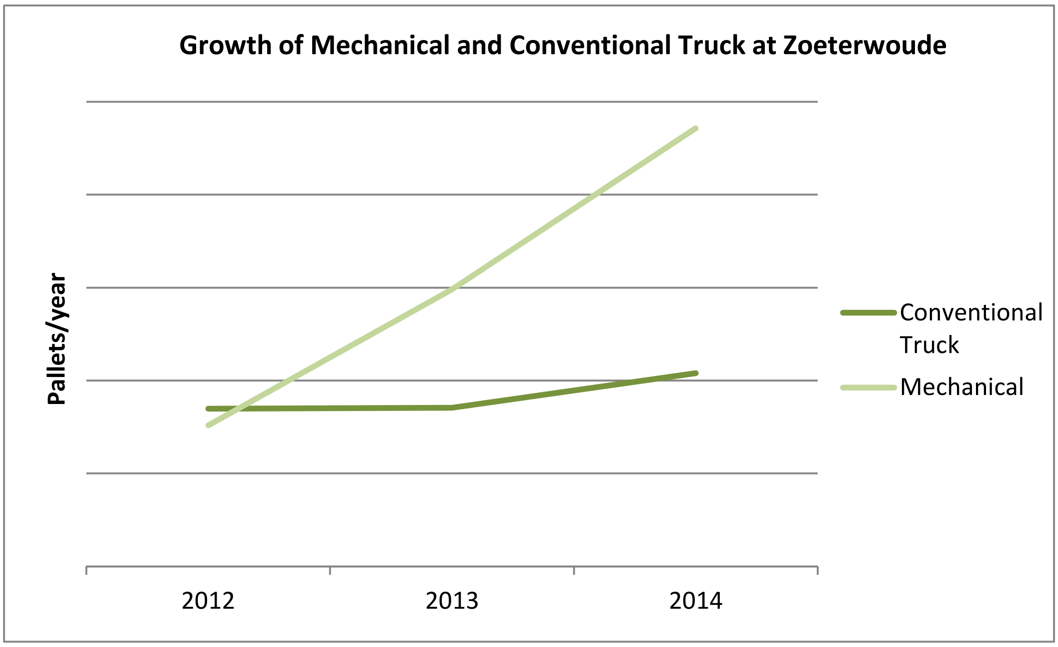


FIGURE 21: GROWTH OF 'COMPLEX' LOADING TYPES AT ZOETERWOUDE (AUTHOR'S OWN ANALYSIS)

Concluding, all three drivers for product complexity from the complexity framework are important at Zoeterwoude:

1) **SKU diversity:** more individual SKU's are handled, adding to uncertainty in demand for storage.
2) **Volume:** the total volume is rising and is expected to rise at least until 2020, leading to additional challenges in overall warehouse capacity.
3) **Loading type diversity:** a specific increase of Mechanical and Conventional Truck loading is found. Mainly Conventional Truck volume is a very unpredictable flow that has a large impact on perceived complexity. It is not planned in advance and has a large impact on stock levels in the warehouse.

4.2.2. Physical technology complexity: inflexible layout

Technology complexity at Zoeterwoude is to be found in information and physical technology. However, as the same IT environment covers both Den Bosch and Zoeterwoude, this will be described later for both locations. Only physical technology complexity for Zoeterwoude is analysed here. Referring to chapter 3, the limited storage and loading capacities are the main drivers for this type of perceived complexity. The current warehouse at Zoeterwoude is split in three dedicated areas:

- Domestic warehouse, where SKU's for the Domestic customers are held on stock (mainly Amstel and Heineken crates).
- Export warehouse, with cross-dock lanes in place and a relative small warehouse for SKU's that are not cross-docked and need to be stored.
- Inbound warehouse, which lies in between the Domestic and Export warehouse. Here packaging materials (crown corks, cartons etcetera) are stored which are delivered to the individual packaging lines by forklift trucks.

A schematic overview of the warehouse and its areas is provided in "Appendix 1: available technology at Den Bosch and Zoeterwoude". The specific split in warehouse areas at Zoeterwoude has been built because Export and Domestic SKU's are produced on dedicated packaging lines that end up in the specific warehouse areas. However, with the current move towards diversity, it is expected that the strong separation between Domestic and Export packaging lines will fade. The result is that Export products end up in the Domestic area and vice versa and therefore the warehouse should accommodate interchange ability. With the current inbound warehouse lying in between the Export and Domestic warehouse interchange ability is however not easy to realize. Interchange ability is also limited by the cross-dock lanes; these are mostly directly connected to the Export packaging lines but not to the Domestic lines. Besides the specific warehouse areas, another issue is rising with the current size of storage locations in the Zoeterwoude Export warehouse. Most of these locations are large three-pallet wide locations. With a trend to more SKU's in smaller batches, these locations are not used efficiently. Result is inefficient use of storage space, external warehousing and more SKU's that are placed in front of each other in one storage location.

The above mentioned bottlenecks indicate that the current warehouse is not aligned with the increased diversity and that increased flexibility in layout is needed. Several interviews with logistics experts at HNS have however clarified that first a long-term overview of expected flows in the warehouse should be created before changes are made in warehouse layout (Hoondert, 2015) (Schrijvers, 2015). This is motivated by the fact that physical changes are expensive and have a permanent impact on the operations. Also, capacities of physical technology are known and controllable by the organization whereas the actual volume flows to be handled with the technology are currently uncertain. The physical technology is therefore not perceived as complex within HNS; complexity is mainly perceived based on uncertainty in expected flows and mismatches between these flows and the physical layout. This mismatch has been defined as process complexity, which is analysed for Zoeterwoude in the next paragraph.

4.2.3. Process complexity: unpredictable stock levels

Process complexity within outbound logistics is resulting from mismatches between product complexity and physical technology. The general volume growth leads to additional storage volume at Zoeterwoude, while the growth in SKU's simultaneously increases the uncertainty and diversity in storage volume. The trend is shown in Figure 22; on average more pallets are stored, but the volume per SKU is decreasing. At the same time, the warehouse is almost always used to its full capacity (Schreuder, 2015). Main issue arising here is that the expected storage volume is hard to plan because the packaging plan does not translate the volumes into a long-term logistics plan (Schrijvers, 2015). The translation from packaging to logistics cannot be made because the logistics parameters per SKU are not measured in the planning systems. As this is related to IT, it will be discussed in section 4.4. It is stressed out that the absence of correct measurements for these logistics parameters make it very hard to predict and control the expected demand for storage, while current stock levels are reaching or even exceeding maximum capacity.

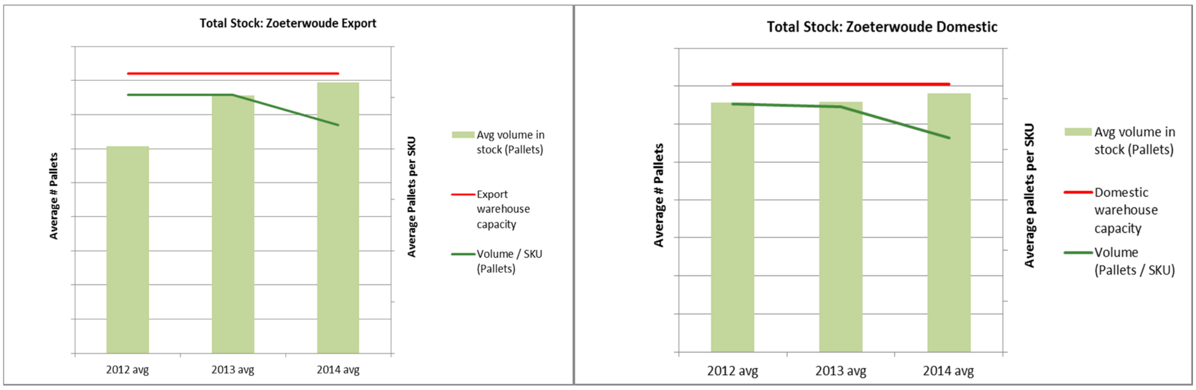


FIGURE 22: MISMATCH BETWEEN STORAGE DEMAND AND CAPACITY (AUTHOR'S OWN ANALYSIS)

Besides unpredictability of storage demand, the trends in Figure 22 lead to less efficient use of the warehouse. The current warehouse is split up in a Domestic and Export area, each divided in different zones that each contain multiple storage locations. Currently, the zones in the Export area have large storage locations that are often not fully utilized. Figure 23 shows the efficiency for a specific zone in 2014. The following formulas for warehouse efficiency are used:

$$Average\ Location\ Occupation = \frac{Number\ of\ storage\ locations\ used}{Total\ number\ of\ storage\ locations} * 100\%$$

$$Average\ Space\ Utilization = \frac{Number\ of\ pallets\ stored}{Total\ storage\ capacity\ in\ pallets} * 100\%$$

The high Average Location Occupation in the warehouse at Zoeterwoude indicates that most of the storage locations in the zone are often occupied. However, the Average Space Utilization is much lower, indicating that an occupied location is not stocked to its full capacity. The result is unusable warehouse space as SKU's cannot be placed in the same storage location.

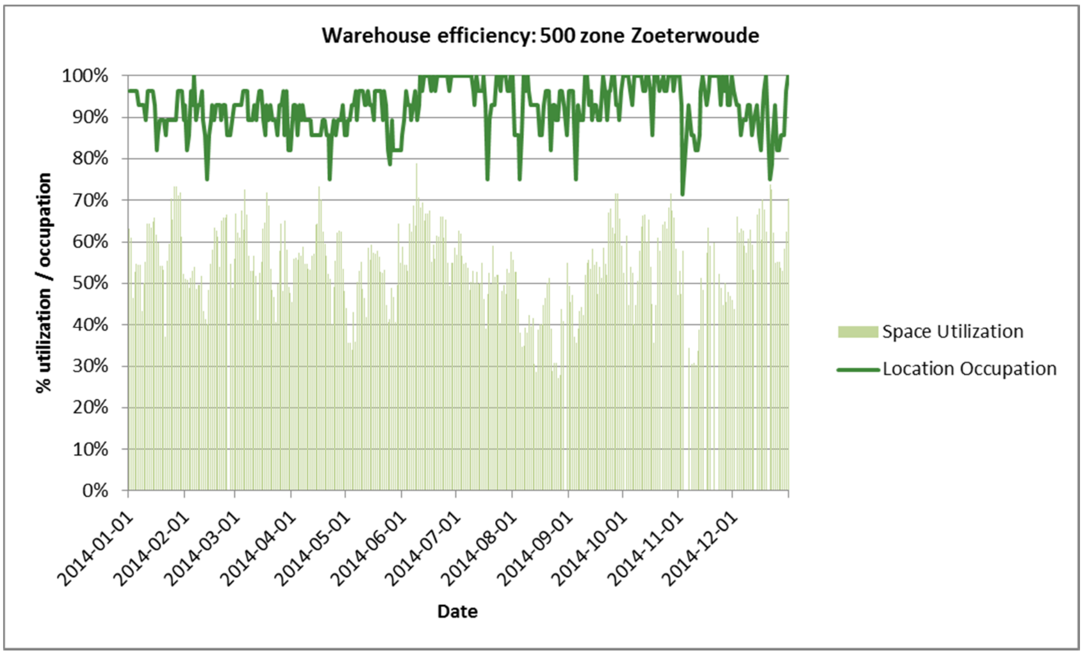


FIGURE 23: WAREHOUSE EFFICIENCY FOR THE 500 ZONE AT ZOETERWOUDE (AUTHOR'S OWN ANALYSIS)

On a higher level, the space utilization for each warehouse zone in 2014 is measured in Figure 24. For each zone is measured what percentage of time the zone was less than 33% utilized, between 33% and 66% utilized and more than 66% utilized. It can be concluded that zones 200 and 100 are performing best as these zones are mostly utilized above 66%. This makes sense as these are dedicated Make to Stock locations for the Dutch market (Heineken and Amstel crates) and are therefore always used for storing these SKU's. Overall however it can be concluded that all storage locations are often not used to their full capacity as the utilization rate is very low, mainly for the Export storage locations. The empty space can however not be used for other SKU's as not more than one SKU can be placed in the same location. Result is that the warehouse is considered to be full while there is still unused space available.

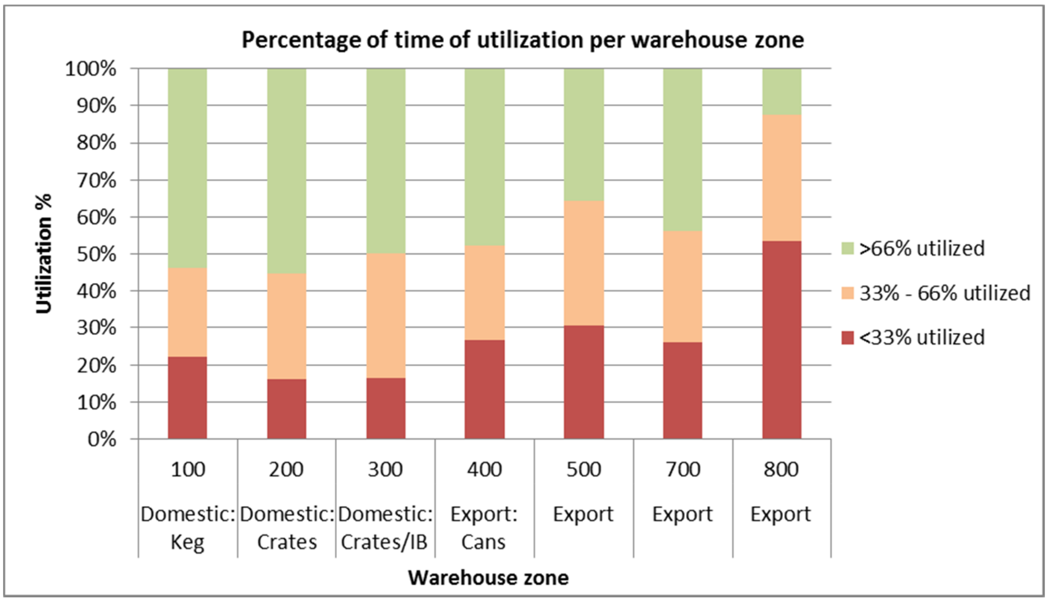


FIGURE 24: TIME PERCENTAGE OF UTILIZATION PER WAREHOUSE ZONE AT ZOETERWOUDE (AUTHOR'S OWN ANALYSIS)

The inefficient use of warehouse space indicated above has two consequences; the first is that often multiple SKU's are placed in one location because there are too many SKU's compared to the number of storage locations. This phenomenon results in additional handlings when products are stored in front of other products. The second consequence is that the full warehouses increase the need for external storage. Combining the inefficient use of storage space with the increasing stock levels in general results in more pallets that are stored at external parties. Naturally, this results in extra handlings and costs. Figure 25 shows the trend in stock levels in the Jonker Loods, an external warehouse where HNS rents additional storage space. Each bar in the figure shows the stock levels for one week. It can be concluded that from 2012 to 2014 more often warehouse space was rented at the Jonker loods and that the average storage volume at the Jonker loods increased as well. This results in increasing costs for external warehousing, being 16% of the total costs for outbound logistics at Zoeterwoude in 2014 (see Figure 26).

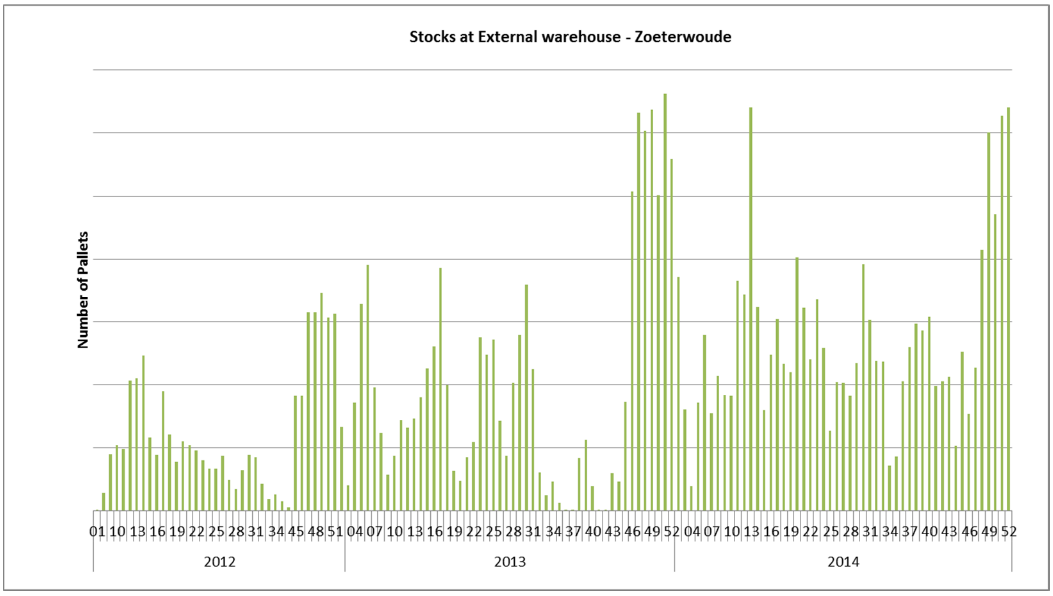


FIGURE 25: TRENDS IN EXTERNAL WAREHOUSING FOR ZOETERWOUDE (AUTHOR'S OWN ANALYSIS)

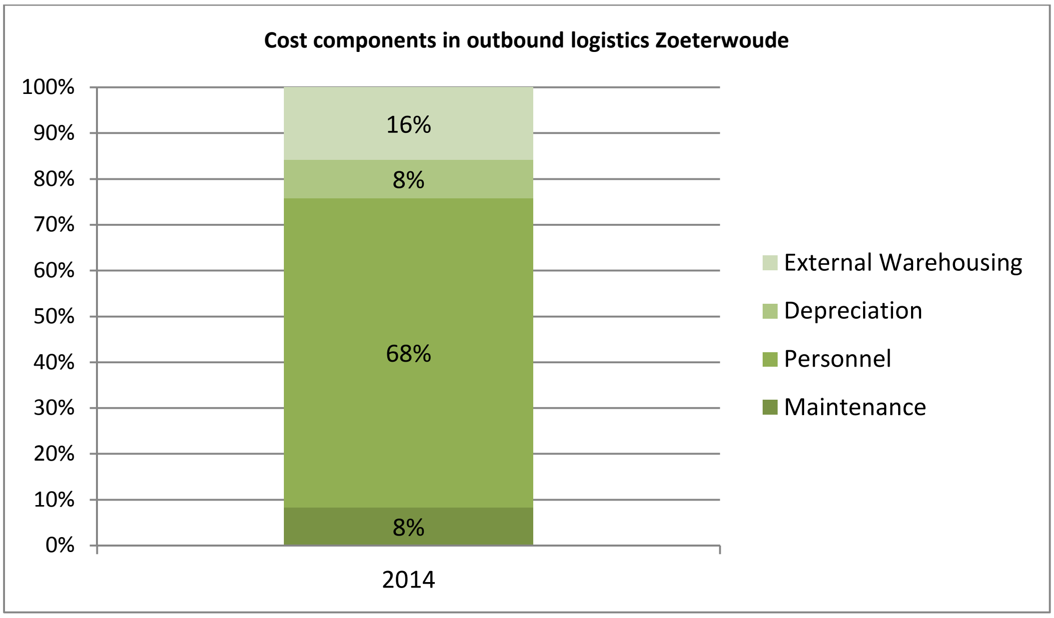


FIGURE 26: COST COMPONENTS FOR OUTBOUND LOGISTICS AT ZOETERWOUDE (BLANKHORST, 2015)

Concluding from the analysis, all four drivers for process complexity are found at Zoeterwoude:

1) **Mismatch between storage capacity and demand**: storage demand is higher than capacity, while the expected storage volume is hard to predict and control by the outbound logistics organization.
2) **Mismatch between batch size and storage location size:** low warehouse efficiency as a result of more SKU's that need to be stored simultaneously.
3) **Storage at third parties**: has increased significantly from 2012 to 2014 due uncertainty in storage volume and lack of storage capacity.
4) **Absence of logistics parameters per SKU:** The planning systems at HNS do not provide logistics parameters per SKU, thereby reducing the predictability of storage demand based on the packaging plan.

Process complexity at Zoeterwoude is mainly perceived as a result of unpredictable storage volumes. The absence of measurements for logistics parameters per SKU is therefore considered as the most important driver for perceived complexity, as no long-term logistics plan can be made in the current situation. The low warehouse efficiency at Zoeterwoude is also an important issue to address, but the uncertainty in storage volume has a significant higher impact on perceived complexity and uncertainty in outbound logistics (Schrijvers, 2015) (Bakker, 2015).

4.3. ANALYSIS OF PERCEIVED COMPLEXITY AT DEN BOSCH

At Den Bosch, similar trends as for Zoeterwoude are found. However, the trend in number of SKU's is not changing as significant as at Zoeterwoude because the Den Bosch brewery has already been producing a large portfolio for a longer period. At Den Bosch issues mainly arise with current shortages on warehouse capacity in general, as will be explained below.

4.3.1. Product complexity: large volume and new product introductions

A similar analysis as at Zoeterwoude is performed on product complexity at Den Bosch. Product complexity can therefore be found in three different forms:

1. Number of unique SKU's
2. Volume to be handled in the warehouse
3. Loading type diversity

In "Appendix 3: trends in number of SKU´s" is shown how the number of SKU's at HNS has grown in the past years, with acceleration in 2014 because of the rise in volume. Similar to Zoeterwoude, Den Bosch also sees an increase in SKU's on stock as can be seen in the table below.

TABLE 7: GROWTH IN NUMBER OF SKU'S ON STOCK AT DEN BOSCH (AUTHOR'S OWN ANALYSIS)

SKU's on stock Den Bosch	2012-2013	2013-2014
% Growth in number of Export SKU's	2%	5%
% Growth in number of Domestic SKU's	1%	17%

The increase in SKU's at Den Bosch is not as significant as at Zoeterwoude. Because Den Bosch has already been a specialty brewery for a longer period, the number of SKU's produced here has always been significantly higher than at Zoeterwoude. The layout of the warehouse at Den Bosch is better suited for SKU diversity with small storage locations in place that can accommodate many SKU's in small batches. However, the growth of SKU's for the Domestic market does have an influence on the demand for storage capacity at Den Bosch. The Domestic market sees an increase in demand for new, special beer types. HNS has successfully incorporated the need for diversity in the Domestic sales strategy, but this does have an effect on the logistics operations. While the number of SKU's does not grow significantly, the number of new SKU's replacing old SKU's is increasing. HNS has a separate policy for new SKU's that requires a safety stock of twice the volume for existing SKU's to account for uncertainty in forecasted sales of new products (Berghout, 2015). As a direct result of this more storage capacity is needed. As mentioned in chapter 2, all Domestic products at Den Bosch are stored at a third party logistics provider next door. With the large amount of new product introductions, the demand for storage at this logistics partner is rising.

Besides the increase in stock related to Domestic product introductions, additional storage capacity is also needed for the Export products. This is related to the growth of Conventional Truck volume, as is illustrated below.

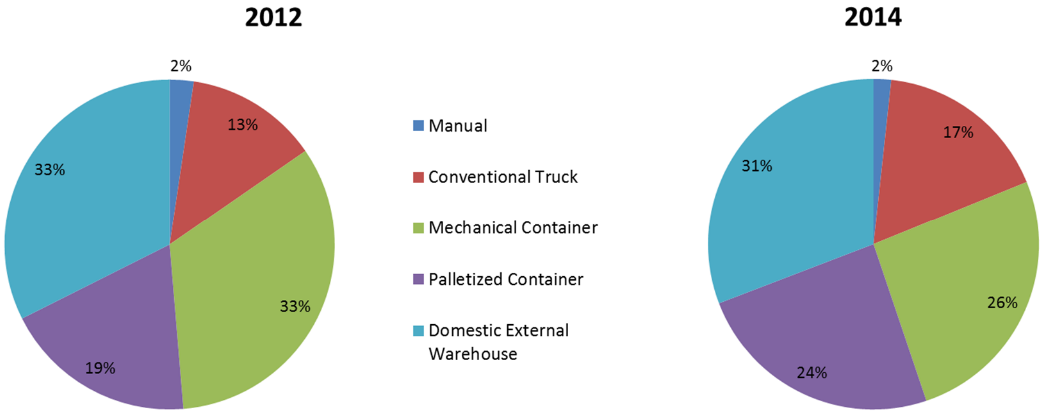


FIGURE 27: VOLUME RATIO OF LOADING TYPES AT DEN BOSCH (2012 AND 2014)

From Figure 27 can be concluded that the volume of Mechanical containers is decreasing at Den Bosch. This is a logical result of the transfer of Mechanical SKU's from Den Bosch to Zoeterwoude, as mentioned earlier. Another trend can be seen at Den Bosch towards more Conventional Truck loading, from 13% in 2012 to 17% in 2014. With a growth in volume in general, the Conventional Truck volume has increased significantly as can be seen below. At Den Bosch, a large part of the additional Conventional Truck volume is caused by an increasing volume for the German market that is supplied with trucks. Similar to Zoeterwoude, SKU's can have more than one loading type and Conventional Truck volume can never be cross-docked. The result is that also at Den Bosch a high uncertainty is experienced in the expected volume on stock related to the unpredictability of Conventional Truck volume.

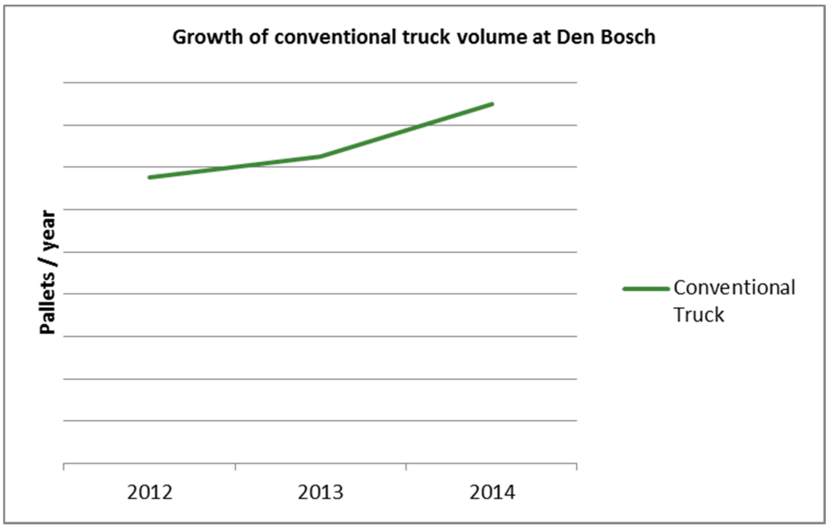


FIGURE 28: TRENDS IN CONVENTIONAL TRUCK VOLUME LOADED AT DEN BOSCH (AUTHOR'S OWN ANALYSIS)

Concluding from the above, all three drivers for product complexity from the complexity framework are found at Den Bosch:

1) **SKU diversity:** more individual SKU's are handled, mainly due to new product introductions. This adds to uncertainty in demand for storage and diversity
2) **Volume:** the total volume is rising and is expected to rise at least until 2020, leading to additional challenges in warehouse capacity.
3) **Loading type diversity:** a specific increase of Conventional Truck loading is found. Mainly Conventional Truck volume is a very unpredictable flow that has a large impact on perceived complexity. It is not planned in advance and has a large impact on stock levels in the warehouse.

4.3.2. Physical technology complexity: warehouse capacity

Physical technology complexity is perceived as limited storage capacity and loading capacities. When looking at Den Bosch, the brewery warehouse is relatively small compared to the total volume that is produced. Similar to Zoeterwoude, this is not directly a bottleneck as a large part of the volume is directly cross-docked in a container. Because the brewery warehouse is relatively small, all SKU's for the Domestic market (thus with the Make to Stock principle) are stocked at the external logistics centre called Logistics Centre Den Bosch (LCDB). Besides this volume, the LCDB also holds stock of co-fill, re-pack SKU's and inter-brewery SKU's as the brewery warehouse does not have space for these activities.

The brewery warehouse at Den Bosch is thus mainly used for Export products. A schematic overview of the warehouse and its areas is provided in "Appendix 1: available technology at Den Bosch and Zoeterwoude". Compared to Zoeterwoude, the warehouse is more flexible with cross-dock lanes in the middle from which all docks can be loaded. Besides that, the storage locations are already smaller leading to a higher warehouse efficiency. No real issues on this aspect are therefore experienced at Den Bosch (Bakker, 2015). The only issue that is experienced is related to a lack of overall storage capacity. However, as with Zoeterwoude, capacities of physical technology at Den Bosch are known and controllable. The physical technology is therefore not perceived as complexity within HNS; complexity is mainly perceived based on uncertainty in expected flows and mismatches between these flows and the physical layout. This mismatch has been defined as process complexity, which is analysed for Den Bosch in the next paragraph.

4.3.3. Process complexity: unpredictable stock levels

Following from previous section, the outbound logistics layout at Den Bosch is already suitable for diversity. However, complexity is perceived with the increasing stock levels. More Domestic SKU’s are introduced due to the new strategy towards diversity and product innovations. This trend has put an increased pressure on the rented LCDB warehouse, related to the high safety stock policy for new products. Both the volume and the number of SKU’s for the Domestic market have increased significantly as can be seen in Figure 29. It shows the average stock levels for the first 22 weeks in the years 2013 to 2015.

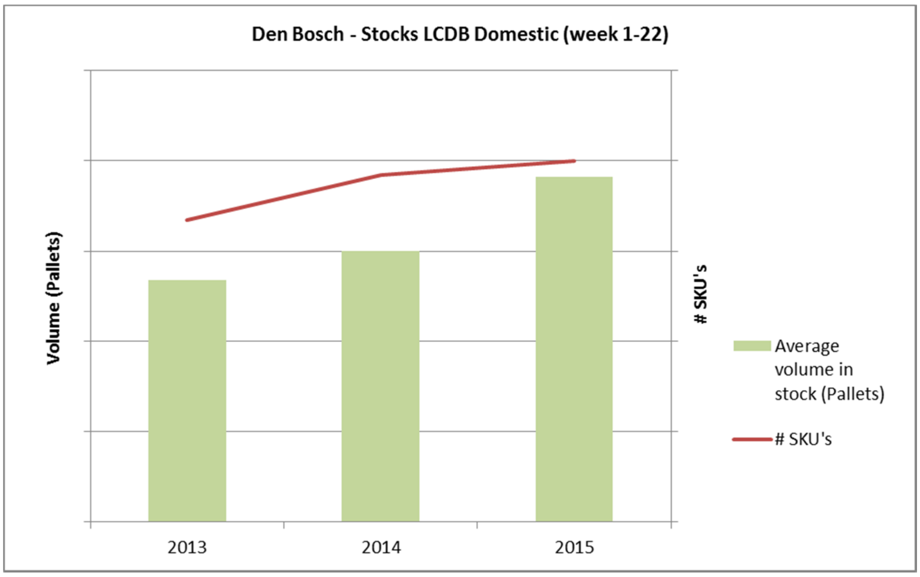


FIGURE 29: STOCK LEVELS FOR DOMESTIC SKU'S AT DEN BOSCH (AUTHOR'S OWN ANALYSIS)

Besides increase in Domestic stock levels, also a trend can be seen towards more Export SKU’s being stored in the LCDB warehouse. As mentioned before, this is a direct result of more Conventional Truck transport to Germany and logistics forwarders. The volume has become larger than the capacity of the brewery warehouse and therefore additional storage is rented at the LCDB. Results are increased costs for HEINEKEN.

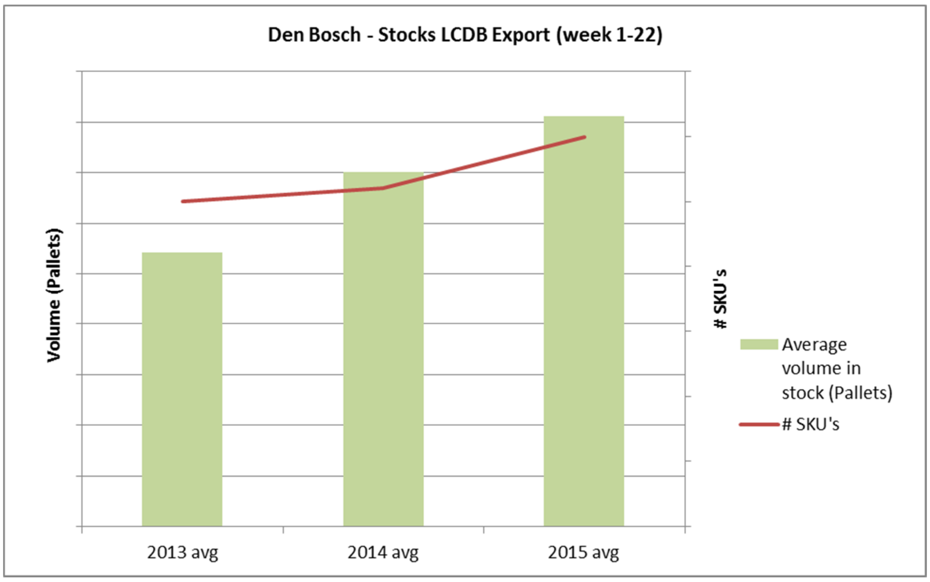


FIGURE 30: STOCK LEVELS FOR EXPORT SKU'S AT DEN BOSCH (AUTHOR'S OWN DRAWING)

As with Zoeterwoude, the main issue with the increased stock levels is that the expected storage volume is hard to plan. The translation from the packaging plan to outbound logistics cannot be made because the logistics parameters per SKU are not available in the planning systems for packaging planning. Concluding from the analysis, the following drivers for process complexity are found at Den Bosch:

1) **Mismatch between storage capacity and demand**: storage demand is higher than capacity, while the expected storage volume is hard to predict and control by the outbound logistics organization at HNS.
2) **Storage at third parties**: has increased significantly from 2013 to 2015, mainly due to the increase in Conventional Truck loading for Export markets and new product introductions for the Domestic market.
3) **Absence of logistics parameters per SKU:** The planning systems at HNS do not provide logistics parameters per SKU, thereby reducing the predictability of storage demand based on the packaging plan.

There is no significant mismatch between batch size and storage location size at Den Bosch as the warehouse layout here is much more focused on diversity. It should be mentioned that process complexity in both Den Bosch and Zoeterwoude is mainly perceived as a result of unpredictability of storage demand. The absence of the logistics parameters per SKU is therefore considered as the most important driver for perceived complexity, as no long-term logistics plan can be made in the current situation (Schrijvers, 2015). The following paragraph will focus on this rising issue of missing information for accurate logistics planning.

4.4. ANALYSIS OF PERCEIVED TECHNOLOGY AND PLANNING COMPLEXITY

Paragraphs 4.2 and 4.3 have analysed the trends in perceived complexity at both the Zoeterwoude and Den Bosch brewery. Both paragraphs have focused on how product complexity, combined with the current physical technology, lead to additional process complexity. From both case studies is concluded that uncertainty, thus perceived complexity, is mainly related to missing information in logistics planning. This section will therefore focus on the information flows present at HNS. As explained earlier, the structure in Figure 31 is in place for planning.

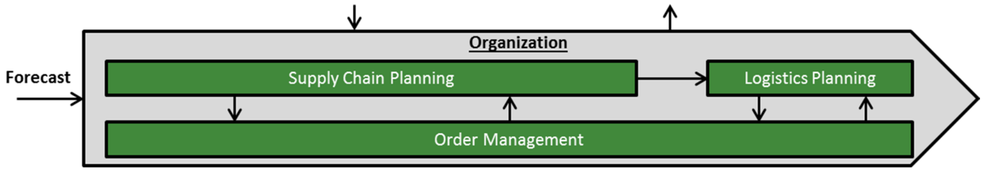


FIGURE 31: HIGH LEVEL PLANNING AT HEINEKEN NETHERLANDS SUPPLY (AUTHOR'S OWN DRAWING)

Different IT systems are used to support the three planning processes in Figure 31. In paragraph 2.3 was also explained that supply chain planning is organized on strategic level (78 weeks ahead), tactical level (13 weeks ahead) and operational level (3 to 4 weeks ahead). With the trend towards more SKU's to be produced, the impact of the packaging plan on outbound logistics activities has become unclear. Combining this with the limited warehouse capacity, the impact of long-term logistics planning is not to be underestimated as it can provide insight in expected volumes in the warehouse. The following paragraphs go into detail about the current issues that are faced based on the limited data availability for outbound logistics.

4.4.1. Information technology complexity: unmeasured logistics parameters

Information exchange between packaging and logistics is very important as it enables the translation of the packaging plan into a logistics plan. As mentioned, the logistics parameters that determine the required storage and loading capacity should therefore be measured accurately. For HNS these parameters are the loading type per SKU, the cross-dock percentage per SKU and the average storage time of an SKU in the warehouse (Plooij, 2015) (Reimers, 2015). Currently these parameters are not measured in the packaging plan, disabling the implementation of long- term logistics planning and creating uncertainty in operations. Stock levels, warehouse utilization and available capacity are only measured on an operational level and are not forecasted on a tactical and strategic level. The root cause of the unmeasured parameters is the current IT set up at HNS. It is illustrated in Figure 32.

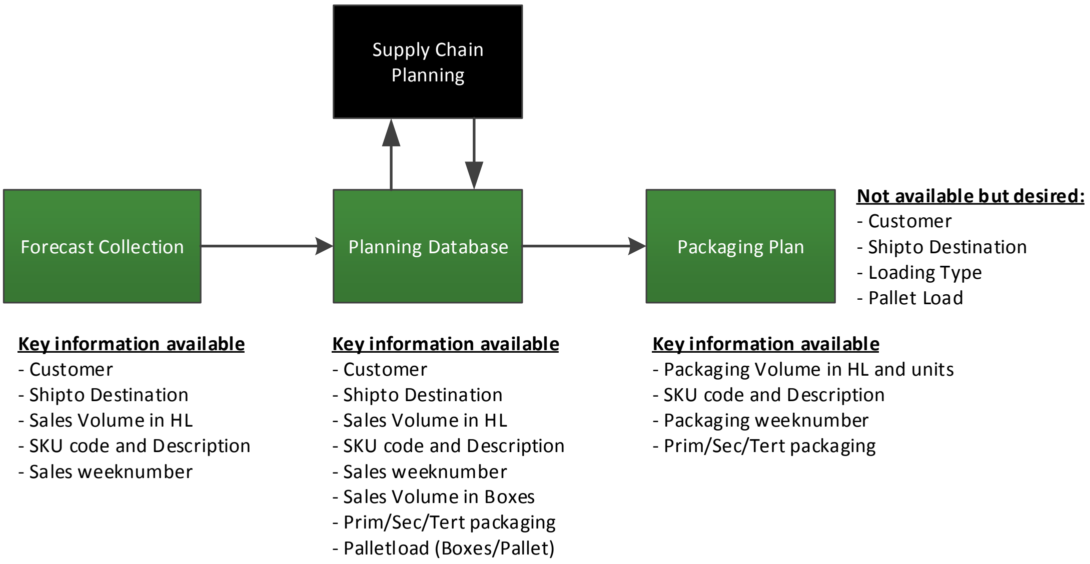


FIGURE 32: SKU RELATED INFORMATION FLOWS IN PLANNING, BASED ON (VAN DELZEN, 2015)

Following from the figure, at forecast collection all customer related data is available. This information is important to determine the loading type and thus the impact on outbound logistics activities. All this information is stored in the planning database, where more data is added to the forecast in an updateable overview. The information issue arises when the forecast in the planning database is used for supply chain planning. At this point, all customer data is lost due to the bundling of SKU's in one or more production batches. As one SKU can be shipped to several customers with different loading types, the impact of the packaging plan on outbound logistics cannot easily be identified based on the SKU code. This is the main reason why logistics planning on tactical and strategic level is not yet in place, next to the fact that logistics was not a large bottleneck in the past. But with the growing SKU portfolio, volume and sketched bottlenecks in outbound logistics, information alignment has become very important and with that a longer planning horizon for outbound logistics.

As concluded here and in previous sections, the main driver for perceived complexity at HNS is the absence of logistics parameters per SKU. With no clear measurements for logistics parameters such as loading type and cross-dock percentage, the organization is not capable of developing a long-term logistics plan. However, as all of these factors are related to internal processes, they should be controllable and predictable by the HNS planning organization. Improvements should therefore be found in developing measurements for the key logistics parameters to give better insight in the expected volumes for outbound logistics operations. This will reduce uncertainty, thus perceived complexity.

4.4.2. Planning complexity: limited planning horizon

Logistics planning is very much related to information technology, as planning is done based on the available information in the different IT systems. The following figure zooms in on Figure 31 to illustrate the different planning processes at the different horizons. The two red boxes indicate that tactical and strategic logistics planning are currently non-existing at HNS.

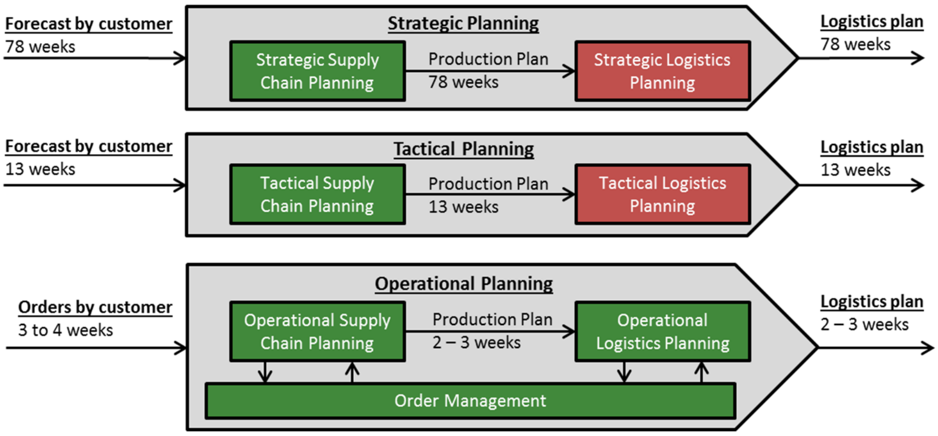


FIGURE 33: DIFFERENT PLANNING HORIZONS FOR SUPPLY CHAIN AND LOGISTICS PLANNING (AUTHOR'S OWN DRAWING)

From the figure above can be concluded that strategic and tactical supply chain planning are organized based on sales forecasts. Operational supply chain planning is organized based on actual customer orders. Currently, logistics planning is only done at operational level as the logistics parameters per SKU are only known based on actual orders. On tactical and strategic level, logistics planning becomes very complicated as the information structure in Figure 32 does not provide the right parameters for long-term logistics planning. With the current trends in product diversity and volume, the warehouses are full and reactive solutions are found to make sure that the warehouse does not become a bottleneck for packaging. The importance of a long-term proactive planning for outbound logistics has therefore become more important and with that the importance of having a clear view on what the impact of the 78-week packaging plan is on outbound logistics operations.

Connecting the above with the complexity framework, planning complexity at HNS is driven by the logistics planning horizon. Currently, HNS has a limited horizon for logistics planning, resulting in uncertainty in expected stock and load volumes.

4.5. INTERMEDIATE CONCLUSIONS: COMPLEXITY AT HNS AND NEED FOR PROACTIVE LOGISTICS PLANNING

The previous paragraphs have provided an in-depth analysis of the perceived complexity at the breweries in Zoeterwoude and Den Bosch. The following paragraph concludes the chapter by summarizing the analysis, transforming the long list of complexity drivers from chapter 3 to a short list of drivers that have the largest impact on perceived complexity at HNS. Main conclusion is that the complexity perception is driven by inaccessible logistics information, which creates uncertainty and limits long-term logistics planning at HNS. This aspect is worked out in section 4.5.2, indicating the need for logistics planning to manage the perceived complexity.

4.5.1. Short list of complexity drivers for HNS

This section summarizes which of the drivers from the complexity framework are found at HNS and which of these drivers are the most important to manage closely in the future. For each complexity type is summarized which drivers are found at each of the analysed breweries. The found drivers for product complexity answer sub research question one. The drivers for the other complexity types answer sub research question two whereas the link between the different types of perceived complexity answers sub research question three.

Product complexity

For both Den Bosch and Zoeterwoude, all three drivers from the complexity framework have been found during the analysis phase. An increase in volume and SKU diversity can be seen, as well as an increase in loading type diversity. It is assumed that these trends are not controlled by HNS, as the commercial benefits coming from increased diversity are valued more by HEINEKEN than the operational consequences. Next to this, at both breweries the volume for Conventional Truck loading is increasing, which is a very unpredictable flow that has a large impact on stock levels at both breweries.

Relevant drivers for HNS: SKU Diversity, Volume, Loading type diversity

Technology complexity

It can be concluded that physical technology complexity is not experienced at Den Bosch and Zoeterwoude. The physical capacities and capabilities of the warehouse equipment are all controllable by the organization and fairly predictable; complexity is mainly perceived based on uncertainty in expected logistical flows and mismatches between storage volumes and the physical layout. The uncertainty in volumes is largely driven by the unavailability of information, as main logistics parameters are not measured or inaccessible for logistics planning. The absence of important logistics parameters per SKU that determine the demand for storage is therefore a very relevant driver for perceived technology complexity at HNS.

Relevant driver for HNS: Absence of logistics parameters per SKU

Process complexity

Process complexity is experienced at both Den Bosch and Zoeterwoude in terms of storage demand that exceeds capacity. At both breweries this leads to more external storage. The large diversity in SKU's has resulted in inefficient warehousing operations at Zoeterwoude as the warehouse layout there is not suitable for diversity. An issue at both breweries is that the rising storage demand is hard to predict and control by the outbound logistics organization. The unpredictability of storage volume is directly related to technology complexity, as the logistics parameters per SKU are not well measured. This unpredictability is the root cause of perceived process complexity; reactive solutions are in place for increased storage but no proactive plan is in place that determines the storage plan for a longer period. The two most important drivers are therefore related to the expected storage demand and the absence of logistics parameters that determine this demand.

Relevant driver for HNS: Mismatch between storage capacity and demand, absence of logistics parameters per SKU

Planning complexity

Complexity in logistics planning is perceived by HNS when looking at the planning horizon. Insight in expected stock and load volumes is only gained on operational level, creating uncertainty in future requirements. As with process complexity, the planning uncertainty is related to the absence of logistics parameters per SKU that can translate the packaging plan to a logistics plan.

Relevant driver for HNS: Absence of logistics parameters per SKU

4.5.2. Managing perceived complexity: from reactive to proactive planning

Following from the previous section, the hypotheses and drivers from the complexity framework are tested with the analysis at both breweries. Results are shown below.

TABLE 8: HYPOTHESES AND MAIN DRIVERS FOR PERCEIVED COMPLEXITY AT HNS

	Hypothesis	Main drivers Zoeterwoude	Main drivers Den Bosch	Hypothesis conclusion
1	Market variety leads to additional product complexity	SKU diversity Volume Loading type diversity	SKU diversity Volume Loading type diversity	Relation found
2	Product and physical technology complexity lead to process complexity	Physical technology complexity is not perceived as priority at HNS	Physical technology complexity is not perceived as priority at HNS	Relation not found
3	Product and IT complexity lead to process and planning complexity	Mismatch between storage capacity and demand Absence of logistics parameters per SKU	Mismatch between storage capacity and demand Absence of logistics parameters per SKU	Relation found

Hypothesis 1: Market variety has led to additional product complexity with more SKU's to be handled in both Zoeterwoude and Den Bosch, with a higher volume and with more diversity in loading types. The sketched relation by hypothesis 1 is thus found at HNS. As the chosen strategy by HEINEKEN towards more diversity has proven to be successful, solutions should point out how HNS can manage the increased uncertainty that this strategy encompasses.

Hypothesis 2: It can be concluded that the relation between products and physical technology is not the source of perceived process complexity in outbound logistics. Uncertainty in processes is not driven by the physical equipment but by the uncertainty of the flows that need to be handled with the equipment. The relation sketched by hypothesis two is therefore not found at HNS; the uncertainty in expected flows is related to hypothesis 3.

Hypothesis 3: From the analysis can be concluded that the relation sketched by this hypothesis is very important. At HNS, complexity is mainly perceived because logistics information is not well reported or unavailable. Storage capacity is limited at both breweries but the logistics parameters that determine the storage demand are not measured. Only on the short term a logistics planning is made, resulting in reactive instead of proactive actions and uncertainty in the expected flows within the warehouses.

Having identified the main drivers for perceived complexity at HNS, the last step is to provide solutions to manage the perception of complexity in the future. From the analysis is concluded that information availability is the key driver for perceived complexity at HNS, mainly related to logistics parameters that are not taken into account in the current planning processes. It is also stated that the uncertainty coming from this missing information can be reduced, as the logistics parameters are all covering internal processes that are controlled by HNS. The organization therefore has a large influence on the perceived complexity; measuring the logistics parameters correctly will enable HNS to create a long-term outlook of expected demand for storage and loading. In this way, the main source for perceived complexity at HNS will be more measurable and manageable. It is therefore decided to focus mainly on solving issues related to hypothesis 3. The following chapter will describe the design of a functional and predictive model for long-term logistics planning. The expected outcomes should be a reliable planning of expected flows, volumes and loading type diversity in the warehouse. The model should provide better insight in future logistics requirements, thereby reducing uncertainty and thus the perceived complexity.

5. MANAGING PERCEIVED COMPLEXITY THROUGH PROACTIVE LOGISTICS PLANNING

This chapter will describe the last layer of the funnel structure introduced in chapter 3. It is focused on finding solutions to better manage the perceived complexity at HNS, thereby answering sub research question four. The solution is found through the design of a long-term logistics planning model based on the strategic packaging plan. This model creates insight in the expected flows for outbound logistics, enabling HNS to find issues related to storage capacity early in advance. This should be achieved by identifying and measuring the key logistics parameters that are currently not available per produced SKU. Paragraph 5.1 will briefly motivate the methodology for logistics planning. Thereafter, paragraph 5.2 until 5.4 will describe the model design and verification/validation steps. Paragraph 5.5 and 5.6 illustrate how the model can be used for proactive logistics planning in the current HNS organization. Paragraph 5.7 concludes the chapter with model conclusions and describes how the model supports in managing uncertainty and perceived complexity at HNS.

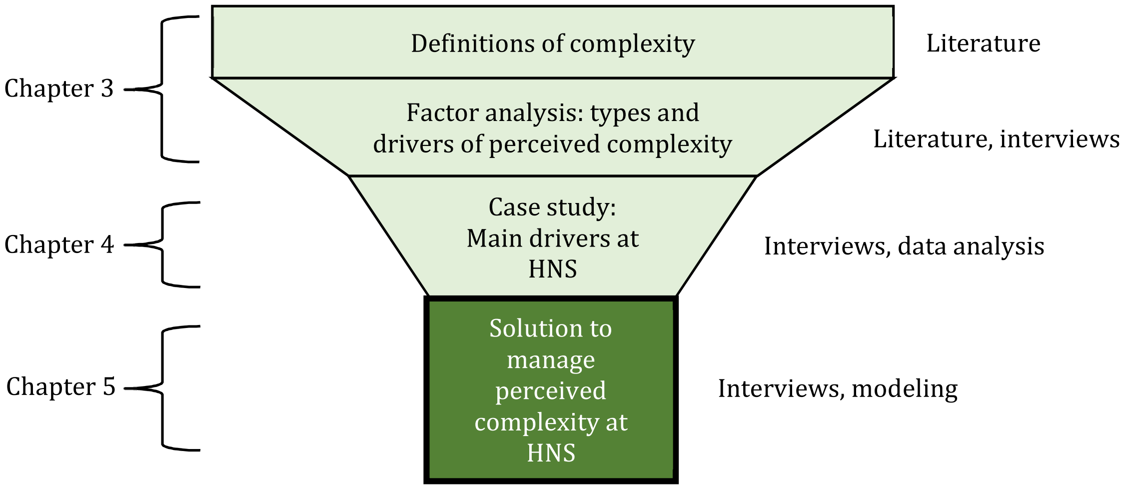


FIGURE 34: FUNNEL STEP 4: PROVIDE A SOLUTION FOR PERCEIVED COMPLEXITY AT HNS

5.1. METHODOLOGY: BASIC PLANNING DESIGN FROM LITERATURE

Many other studies have been performed in the past to determine the impact of production on warehousing and logistics. Already in 1999 the changes towards complexity are addressed by (Van Den Berg & Zijm, 1999), describing that "low volumes have to be delivered more frequently with shorter response times from a significantly wider variety of stock keeping units (SKU's)". To measure the expected flows in a warehouse, (Gu, et al., 2007) distinguish the following flows in a production warehouse: 1) Receiving pallets from production, 2) storage of pallets in the warehouse for a certain amount of time, 3) order picking and 4) shipping to the customer.

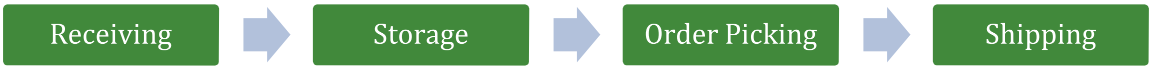


FIGURE 35: WAREHOUSE OPERATIONS, BASED ON (GU, ET AL., 2007)

For HNS, the flows are slightly different as most of the Export volume is directly cross-docked into containers. Besides that, additional flows are received, being the co-fill, re-pack and inter-brewery flows that are not produced at the same plant. All these flows have to be analysed individually as they have different characteristics. To account for this, the basic structure for supply chain analysis is used, identified by (Ganeshan, et al., 2001). This basic methodology gives a clear presentation of the main components within supply chain simulation or analysis, either for a large scale supply chain or a smaller part of it like outbound logistics at HNS.

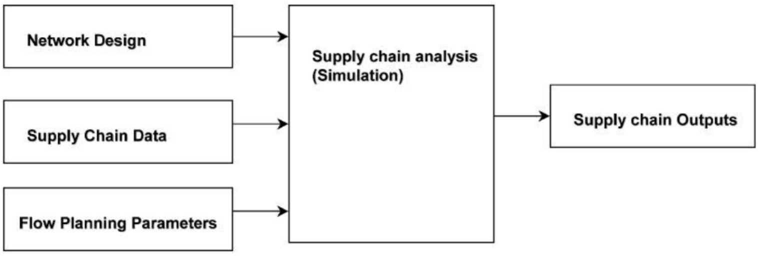


FIGURE 36: BASIC STRUCTURE FOR SUPPLY CHAIN ANALYSIS ((GANESHAN, ET AL., 2001)

Network design in the figure above is considered a synonym for physical technology, determining the warehouse capacities in terms of storage and loading. The supply chain data is considered the incoming volume, which will be identified for each flow in the following paragraph. Flow planning parameters are very important for HNS, being the logistics parameters that determine the stock and loading volumes in the warehouse. These are currently not measured and this drives a large part of the perceived complexity at HNS. The designed model must therefore measure these parameters to provide an accurate logistics planning. With the data, flows and network in place, a supply chain analysis model, in this case a logistics planning model, will be built that can provide the organization with reliable supply chain outputs. In order to design a logistics plan based on the packaging plan it is required to couple data points from different IT systems. As the research is carried out at Zoeterwoude, data for this brewery is better accessible and therefore the model will primarily be designed with parameters and values for Zoeterwoude. However, the model is built in such a way that it can also be used at Den Bosch by only changing input values. The model is built in Microsoft Excel using Visual Basic for Applications (VBA) as this program provides an easy link between the different systems at HNS that need to be coupled. Outputs should clearly indicate volume expectations for outbound logistics such as expected demand for storage and loading volume per loading type. The next paragraph will provide the functional structure of the model, based on the four steps indicated by Figure 35.

5.2. FUNCTIONAL MODEL DESIGN: STRATEGIC LOGISTICS PLANNING

The base of the outbound logistics model is the packaging plan. Each month, the 78-week packaging plan is updated by the department Strategic Supply Chain Planning (SSCP), thereby planning on a weekly basis what volume of which SKU's is produced on which packaging line. The volume is planned in units of production (one SPC) and in hectolitre. Based on the packaging plan, four main logistics flows are taken into account in the logistics model: 1) the packaging volume at the brewery, 2) the co-fill volume that comes in from external parties, 3) the re-pack volume and 4) the inter-brewery volume. For each of the flows a separate functional model is designed to calculate the inflow, stock and outflow in pallets. The most important logistics requirements for each flow are identified on a weekly basis, based on Figure 35:

1) **Receiving:** Expected inflow volume [pallets]
2) **Cross-dock:** Expected cross-dock volume (for packaging at the brewery) [pallets]
3) **Storage:** Expected volume on stock per loading type [pallets]
4) **Picking / Shipping:** Expected volume loaded per loading type [pallets]

Each of the main logistics flows is now explained in detail using a functional model that elaborates on the key logistics parameters. This functional model has been designed using different interviews and sessions with internal stakeholders at HNS to ensure that all relevant parameters are taken into account. For an overview of assumptions and model variables is referred to “Appendix 6: input variables and assumptions within the logistics model”.

5.2.1. Packaging volume: inflow, stock and outflow

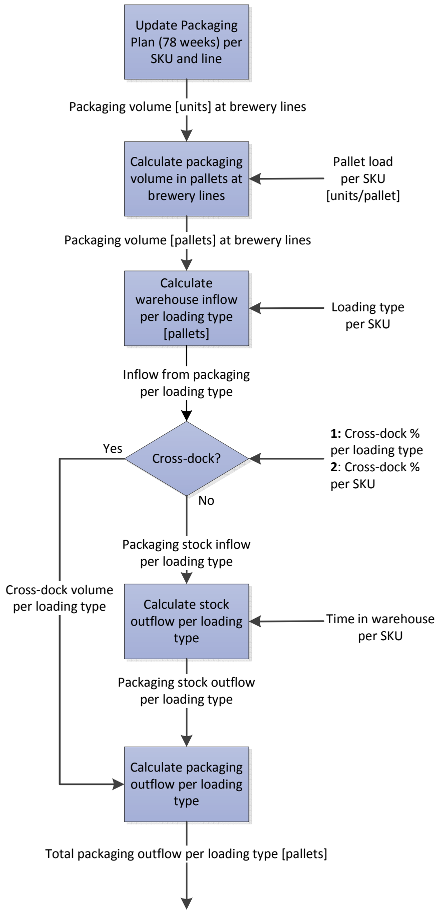


FIGURE 37: MODELING THE PACKAGING FLOW

The largest flow is the packaging volume that is produced at the brewery lines. To determine the impact of the packaging plan on outbound logistics, the steps as shown in Figure 37 are followed. The first step is to convert the packaging volume in units of one SPC into pallets of one SPC, thus translating the SPC volume to SKU volume. This will determine the impact in the warehouse. The conversion is done with the pallet load per SKU, which is found in the planning database. Afterwards, the loading type per SKU is defined with one option for Domestic SKU’s (Domestic loading) and four options for Export SKU’s (Schep, Mechanical, Conventional Truck or Manual loading). The loading type for Export SKU’s is found by looking at historical shipments per SKU, 78 weeks back. Two alternatives for determining the loading type are defined during a working session (Reimers & Meesters, 2015);

1) **General load**: One loading type per SKU, choosing the loading type for the SKU with the largest historical volume %.
2) **Detailed load**: More than one loading type per SKU, based on the historical volume % of the SKU shipped per loading type.

The first alternative is simple but might not give accurate insights and therefore both options will be considered until validation. Having defined the loading type, the next step is to determine the cross-dock percentage per SKU. This is an important variable as it determines how much volume will be stored in the warehouse. To give an accurate representation, again two options are defined (Reimers & Meesters, 2015);

1) **General cross-dock**: percentage per loading type. Based on historical data for 2014 the following cross-dock percentages are assumed: Manual Loading 0%, Conventional Truck Loading 0%, Mechanical Loading 90%, Schep Loading 90%. Domestic SKU’s are never cross-docked as a result of the Make-To-Stock concept, therefore receiving 0% as value.
2) **Detailed cross-dock**: percentage per SKU found in historical data. If no percentage for an SKU is found the percentage is set at 100%, assuming that all volume is cross-docked.

Again the first alternative is high level and the second is more detailed. Both alternatives are used until validation. In total, four alternatives of loading type and cross-dock percentage determination are taken into account in the model, as shown in Table 9. These calculation alternatives will all be worked out until validation, where the optimal alternative is chosen for the final model.

TABLE 9: ALTERNATIVES TO DETERMINE LOADING TYPE AND CROSS-DOCK PERCENTAGE PER SKU

Calculation alternatives	Cross-dock % per loading type	Cross-dock % per SKU
1 loading type per SKU	General load, General cross-dock	General load, Detailed cross-dock
>= 1 loading type per SKU	Detailed load, General cross-dock	Detailed load, Detailed cross-dock

Following from Figure 37, the cross-docked volume is directly loaded and therefore partly determines the warehouse outflow per week. The volume that is not cross-docked will go into stock and for these SKU's an average storage time need to be found. At HNS this parameter is not measured on SKU level and therefore the value is estimated. For this purpose, the variable 'time in warehouse' in weeks is calculated, determining the difference between stock inflow and outflow to the customer in weeks. This difference is calculated based on storage data per SKU in 2014, counting the number of days/weeks that an SKU was subsequently stored in the warehouse at the same location. If an Export SKU is not found in this analysis, it was not held on stock in 2014 thus it is assumed that it was always cross-docked. It will therefore get a time in warehouse of zero weeks. If a Domestic SKU is not found in the analysis it will receive the overall average storage time of two weeks, as these SKU's are never cross-docked as a result of the Make-To-Stock principle. These assumptions have been validated internally at HNS and can be changed as input variables in the model when needed. Looking at Figure 37, now all parameters are found to determine the warehouse outflow. The weekly warehouse outflow of packaging volume can be calculated as the sum of the cross-docked volume and the volume loaded from stock.

5.2.2. Co-fill volume: inflow, stock and outflow

Determining the impact of co-filling on outbound logistics follows a similar procedure as the packaging at the brewery. At first, the 78-week plan is translated from production units to pallets using the pallet load. The next step is determining the actual warehouse inflow per week, which requires more input variables for co-fill. As the SKU's are packaged at an external co-fill party, a lead-time per co-fill party decouples the packaging week from the inflow week into the HNS warehouse. Besides that, a volume allocation needs to be defined to determine which percentage of volume produced at the co-fill party goes to which brewery warehouse (Den Bosch or Zoeterwoude). This allocation key is a decision variable in the model. The co-fill parameters that determine the volume arrival per brewery are summarized in the following table, based on data received from Tactical Supply Chain Planning at HNS.

TABLE 10: CO-FILL PARAMETERS FOR THE LOGISTICS MODEL, BASED ON (VAN OOST, 2015)

Co-fill party	Volume allocation Zoeterwoude	Volume allocation Den Bosch	Lead-time (weeks)
Co-fill 1	25%	75%	1
Co-fill 2	30%	70%	0
Co-fill 3	17%	73%	2
Co-fill 4	18%	82%	1

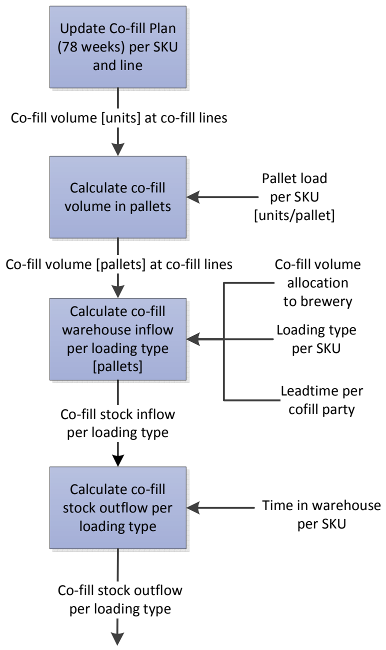


FIGURE 38: MODELING THE CO-FILL FLOW

Having identified the total volume, the loading type per SKU for co-fill is determined using the same two alternatives used for regular packaging volume. With this in place, a co-fill stock inflow per loading type is calculated. The storage time in warehouse for co-fill SKU's is set at two weeks, based on historical data analysis of 2014 and interviews at HNS (Hoondert, 2015).

5.2.3. Re-pack volume: inflow, stock and outflow

The re-pack volume is the most complex flow within HNS and is mainly used for promotions and other pack types that cannot be produced on the packaging lines. A base SKU for re-pack is at first produced at the brewery packaging line which is then held on stock and transported to the re-pack party. After the re-pack process the pallets with the new re-pack SKU are returned to the brewery warehouse. The production, warehousing and loading of the base SKU is already planned based on the regular packaging plan and therefore only the return flow from the re-pack party needs to be addressed in the model. This is done using the visualized structure in Figure 39.

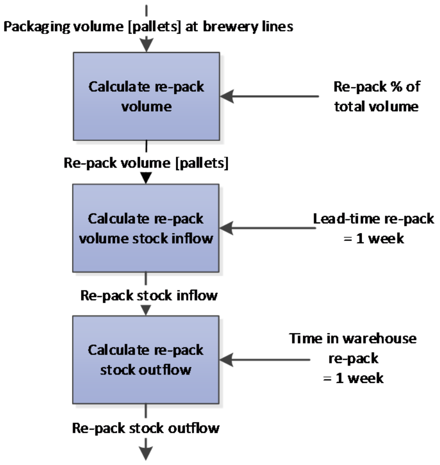


FIGURE 39: MODELING THE RE-PACK FLOW

The re-pack volume is not planned 78 weeks ahead as most of the re-pack actions are short term. Therefore, assumptions are made using re-pack experts at HNS to make reliable estimations (Berghout, 2015). The estimation is done based on the total packaged volume at the brewery lines. From historical data, a specific percentage of the total volume is assumed to be re-packed with a split between Export (1% for Zoeterwoude) and Domestic volume (1,5% for Zoeterwoude). The volume based on this percentage is expected to return to the brewery warehouse as re-pack stock inflow, one week after packaging. The time in warehouse of re-pack SKU's is assumed to be one week before they are loaded from stock to the customer (Berghout, 2015). All Export SKU's are assumed to be loaded with the Schep (palletized container) method and all Domestic SKU's with the Domestic loading method (Reimers & Meesters, 2015).

5.2.4. Inter-brewery volume: inflow, stock and outflow

The final flow to take into account is inter-brewery (IB) volume. This flow covers stock reallocation of finished SKU's from one HNS brewery to the other. Volume for inter-brewery transport that is produced at the same plant is already covered with the regular packaging plan. Therefore, only incoming inter-brewery volume needs to be addressed. This is done using the visualized conceptual model. As with re-pack, this flow is not planned ahead. Therefore, assumptions are made for this flow using historical data. In shipment files of 2014 is found that 90% of the inter-brewery volume was stock reallocation of Domestic SKU's and that on average 2% of the total Domestic volume per week was received from inter-brewery flows. The expected volume is based on these assumptions to calculate the stock inflow into the warehouse. Based on the same shipment file is concluded that inter-brewery volume remains in the warehouse for two weeks on average before it is loaded. As all inter-brewery transport is assumed to be Domestic volume, all outflowing volume receives the Domestic loading type.

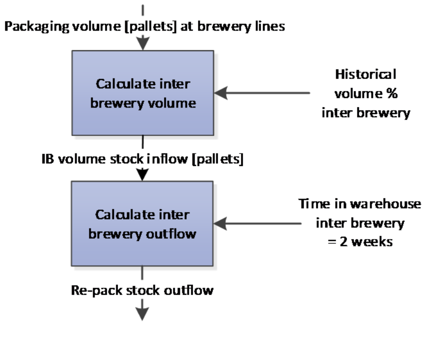


FIGURE 40: MODELING THE INTER- BREWERY FLOW

5.3. DETAILED MODEL DESIGN: INSIGHT IN EXPECTED STOCK LEVELS AND LOAD VOLUMES

The previous paragraph has defined a clear functional structure for the logistics model that has been validated by various internal stakeholders at HNS. Based on the functional structure, this paragraph describes the design of model outputs. By using the strategic packaging plan as input the logistics model will calculate the different volumes expected in the Zoeterwoude warehouse for the packaging, co-fill, re-pack and inter-brewery flows. Through different interviews at HNS has been identified what the key output parameters of the model should be. The aim is to make a long-term planning of expected volumes in outbound logistics. A split between loading types is important, comparing storage and loading capacities with expected weekly volumes (Werkman, 2015) (Hoondert, 2015). The logistics plan should have the same planning horizon as the packaging plan, thus looking 78 weeks ahead. Main goal is to identify bottlenecks at peak periods in the long term by providing the right data for logistics planning, thereby reducing perceived complexity (Werkman, 2015) (Reimers, 2015). The following sections will go into detail on the two main model outputs; stock levels in section 5.3.1 and load volumes in 5.3.2.

5.3.1. Planning the expected stock volumes

As HNS currently experiences high demand for storage, the model should plan the expected stock levels per loading type on a weekly basis. This should support the organization in making proactive decisions towards expected peaks. With functional design of the individual flows in the previous section, the expected stock levels can be calculated by using the following figure.

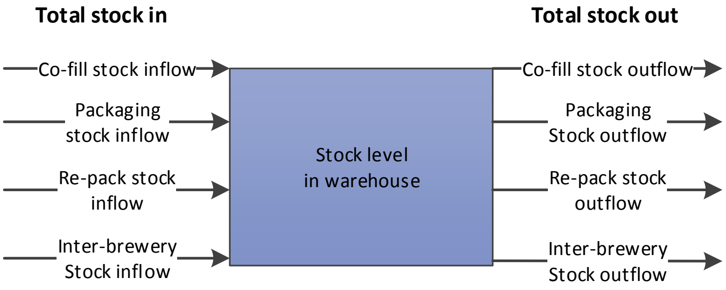


FIGURE 41: INFLOW, STOCK AND OUTFLOW IN THE WAREHOUSE (AUTHOR'S OWN DRAWING)

The largest inflow volume is packaging stock inflow. To calculate this, an important parameter is the cross-dock percentage. This variable determines how much of the packaging volume of a specific SKU is loaded directly and will thus not be stored in the warehouse. For packaging, the four calculation alternatives (General/Detailed Loading, General/Detailed Cross-dock) are all used to calculate the packaging stock inflow per week. As an example, the stock inflow for all ‘Schep’ packaging volume in week n is calculated with the following formula, where the cross-dock percentage is either calculated per loading type (General Cross-dock) or per SKU (Detailed Cross-dock):

$$Stock\ inflow_{Schep,packaging,n} = (1 - crossdock\ \%) * packaging\ volume_{Schep,n}$$

For stock inflow of co-fill, re-pack and inter-brewery no cross-dock percentage is available as these flows come in from external parties. These flows are only split in loading type (using both the General and Detailed Loading alternative) to determine the volume per loading type. With this in place, the following formulas can be used to calculate the stock inflow, stock level and stock outflow in week n. The following formulas use ‘Schep’ as example loading type. The volumes for the other loading types are calculated in the same manner.

$$\begin{aligned} Stock\ inflow_{Schep,n} &= Stock\ inflow_{Schep,packaging,n} + Stock\ inflow_{Schep,co-fill,n} \\ &+ Stock\ inflow_{Schep,re-pack,n} + Stock\ inflow_{Schep,interbrewery,n} \end{aligned}$$

$$\begin{aligned} Stock\ outflow_{Schep,n} &= Stock\ outflow_{Schep,packaging,n} + Stock\ outflow_{Schep,co-fill,n} \\ &+ Stock\ outlow_{Schep,re-pack,n} + Stock\ outflow_{Schep,interbrewery,n} \end{aligned}$$

$$Stock\ level_{Schep,n} = Stock\ level_{Schep,n-1} + Stock\ in_{Schep,n} - Stock\ out_{Schep,n}$$

To determine the stock level in week *n*, the stock level from week *n-1* is used as base. For the first week of the model horizon, values for week *n-1* are found in the historical stock data. With these formulas in place, the overall stock inflow, level and outflow can be calculated using similar formulas, taking the sum of all loading types:

$$\begin{aligned} Total\ stock\ inflow_{n} &= stock\ inflow_{Schep,n} + stock\ inflow_{Mechanical,n} + stock\ inflow_{Manual,n} \\ &+ stock\ inflow_{Conventional\ Truck,n} + stock\ inflow_{Domestic\ Loading,n} \end{aligned}$$

$$\begin{aligned} Total\ stock\ outflow_{n} &= stock\ outflow_{Schep,n} + stock\ outflow_{Mechanical,n} + stock\ outflow_{Manual,n} \\ &+ stock\ outflow_{Conventional\ Truck,n} + stock\ outflow_{Domestic\ Loading,n} \end{aligned}$$

$$Total\ Stock\ level_{n} = Total\ stock\ level_{n-1} + Total\ stock\ inflow_{n} - Total\ stock\ outflow_{n}$$

The total stock level can be mapped against the available capacity, thereby indicating if the storage demand will fit in the warehouse. In this way, a detailed outlook of storage demand versus capacity can be given.

5.3.2. Planning the expected load volumes

Besides stock volumes, insight in weekly load volume per loading type is also important to estimate the workload and see if the loading dock capacity is sufficient. As with stock levels, for each calculation alternative (General/Detailed Loading, General/Detailed Cross-dock) the loaded volumes are planned for each loading type. This can be done with the formula below, taking into account both cross-dock and non-cross-dock volume that needs to be loaded in week *n*. Again the example for 'Schep' loading is used. The volumes for the other loading types are calculated in the same manner.

$$Total\ loading_{Schep,n} = Total\ load\ from\ stock_{Schep,n} + Total\ crossdock_{Schep,n}$$

$$\begin{aligned} Total\ load\ from\ stock_{Schep,n} &= Stock\ outflow_{Schep,packaging,n} + Stock\ outflow_{Schep,co-fill,n} \\ &+ Stock\ outlow_{Schep,re-pack,n} + Stock\ outflow_{Schep,interbrewery,n} \end{aligned}$$

$$Total\ crossdock_{Schep,n} = crossdock\ \% * packaging\ volume_{Schep,n}$$

The load volume from stock in the first week of the planning horizon is calculated separately, as the stock outflow in that week is actually based on stock that was present before the planning horizon started. To estimate the volume loaded from stock in the first week of planning, the measured stock volume from the week before is used together with the average time in warehouse per loading type. The following table illustrates this; for Domestic loading it means that 55% of the volume on stock at planning start will be loaded in the first week, 20% in the second week and so on. For all Export loading types, the average time in warehouse found is one week, thus all stock from the week before planning started will be loaded from stock in the first week of the planning horizon.

TABLE 11: AVERAGE TIME IN WAREHOUSE PER LOADING TYPE, BASED ON 2014 DATA

	Volume % - Average time in warehouse			
Loading type	1 week	2 weeks	3 weeks	4 weeks
Domestic Loading	55%	20%	15%	10%
Mechanical Loading	100%			
Manual Loading	100%			
Conventional Truck Loading	100%			
Schep Loading	100%			

Having determined the load plan per loading type, the total load plan in week n can be calculated as follows:

$$\begin{aligned} Total\ loading_n = {} & Total\ loading_{Schep,n} + Total\ loading_{Mechanical,n} + Total\ loading_{Manual,n} \\ & + Total\ loading_{Conventional\ Truck,n} + Total\ loading_{Domestic,n} \end{aligned}$$

The total loading in week *n*, either by loading type or as a sum, can be mapped against the available capacity to indicate if it is possible to load the expected volume. With this in place, the model components and outputs have been designed. Different packaging plans can be loaded into the model to generate output for the requested period. The next paragraph will describe how the model output is generated by loading the packaging plan of different months, thereby verifying and validating the model output.

5.4. VERIFICATION AND VALIDATION OF MODEL OUTPUT

This paragraph will elaborate on verification and validation of the logistics model. To verify the model outputs, the packaging plan for May 2015 is loaded as input data. The model outputs as defined in the previous paragraph are subsequently analysed with several basic tests to see if the model gives expected outputs when changing the input variables. After verification, the actual production data of 2014 are loaded in the model. By doing this, the accuracy of the model outputs based on actual production for 2014 can be compared with the actual stock and loaded volumes measured in 2014.

5.4.1. Verification steps with planning data of May 2015

For verification the packaging plan of May 2015 is loaded in the logistics model, covering the horizon from week 19 2015 until week 52 2016. Through a series of tests as suggested by (Kelton, et al., 2010) and (Van Der Niet, 2014) is determined if the model is built in the right way and that the output behaves as expected.

Face validity by internal stakeholders

The first check that is performed is showing the model output based on the packaging plan of May 2015 to stakeholders within HNS. With the manager Supply Chain Planning is checked on high level if the expected load and stock volumes are representative and of expected size. On high level, the stock levels are in line with historical data and no strange outliers are found in the model output. On a more detailed level, the output per loading type is checked with the Logistics Coordinator at Zoeterwoude. Also now is concluded that the data shows volumes that are in line with actual volumes per loading type being handled in the warehouse.

Pallets in = pallets out

This test is performed to see if all pallets that are stocked in the warehouse are removed again at a later point in time. To check this, Table 18 in "Appendix 7: logistics model verification" shows the warehouse inflow and outflow when the 'Time in warehouse' variable is set at zero weeks for all SKU's. From the table can be seen that all pallets that flow in are also being loaded in the same week. No pallets are 'lost' in the warehouse, thus can be concluded that the model calculates the pallet in- and outflow correctly.

Extreme values

To further check the model behaviour, extreme values for several input parameters are tested. When the cross-dock percentage of all Export loading types is set at 100%, the calculation alternatives with 'General cross-dock' show that all packaging stock is removed from the warehouse. When the cross-dock percentage is set at 0%, Export stock levels rise significantly. The same holds when varying the cross-dock percentage per SKU; then the alternatives with 'Detailed cross-dock' show a significant increase in stock when all SKU's get a cross-dock percentage of 0%. No stock is seen when all SKU's receive a cross-dock percentage of 100%. Another input variable that is changed is time in warehouse per SKU. If set very high (five weeks) for each SKU, stock levels rise significantly as the volume remains the warehouse for a longer period. If set very low (all one week), stock levels decrease significantly for Domestic SKU's. This makes sense as 45% of the Domestic volume has an average time in warehouse of two weeks or more (according to Table 11). Changing the time in warehouse for Export SKU's to one week shows a small decrease for Export stock, which is also in line with expectations as Export SKU's already have a time in warehouse of one week on average (according to Table 11).

Sensitivity

A sensitivity analysis is conducted to check which variables have the most influence on the model output. At first, an increase of volume of 10% of the external flows (co-fill, re-pack and inter-brewery) is tested. This hardly influences the stock or load volume as expected because the flows are small compared to the packaging volume. When changing the total packaging volume (+10% or -10%), a linear change of stock and load volume is seen in the model.

During the sensitivity analysis, the model proved to be very sensitive for the cross-dock percentage. Besides that, the model is also very sensitive for the 'Time in warehouse' variable of all SKU's. As mentioned in chapter 3 and 4, both parameters are also considered to be very important in reality to determine the demand for storage. The sensitivity of the model on these parameters therefore represents the actual situation at HNS.

5.4.2. Validation steps with actual data of 2014

Model validation is used to check if the model output is similar to the actual system, thus indicating that the model is right (Kelton, et al., 2010). For this purpose, the actual weekly produced volumes from January 2014 until May 2015 are loaded in the model. The output parameters from the model can then be checked with the actual measured logistics output within this horizon. The tested parameters for validation are volume on stock and volume loaded per loading type. All four calculation alternatives for determining loading and cross-dock percentage from Table 9 are tested on these parameters, comparing them one to one in order to choose the preferable alternative. For each alternative the bias between model output and actuals is measured by the following formula.

$$bias = \frac{model\ output - actual\ output}{actual\ output} * 100\%$$

Regarding the long planning horizon and purpose of the model, the bias for each of the calculation alternatives is measured on a four weekly basis, representing monthly bias. Weekly bias for such a long horizon is hard to achieve and also not required for the purpose of the model. Main aim is to identify bottlenecks at peak periods in the long term, thus bias in four week buckets is acceptable (Reimers, 2015). For detailed data related to model validation is referred to Appendix 8: logistics model validation using data of 2014”.

<u>Face validity by internal stakeholders</u>

The first validation step that is performed is showing the model output based on the actual data of 2014 to stakeholders within HNS. These are the Market Demand Analyst and Strategic Supply Chain Specialist which are both closely involved in the development of the model. These persons have different roles within the organization and both are confident with the model structure and the model outputs.

<u>Stock volume per loading type</u>

The forecasted stock volume for 2014 by the model is checked against the actual measured stock levels per loading type in 2014. The monthly bias between plan and actuals is calculated for each of the four alternatives in the model (General/Detailed Loading, General/Detailed Cross-dock). Monthly stock volumes are represented by taking the average of four weeks of stock. Stock levels for Manual loading are left out of scope as the small volume for this loading type is considered irrelevant. This assumption has been validated by the Market Demand Analyst and Supply Chain Specialist at HNS. For the other loading types, the bias between model output and historical stock data is calculated in “Appendix 8: logistics model validation using data of 2014” for all four calculation alternatives. For the total stock levels (thus of all loading types together), the figure below provides the bias on a monthly basis. It can be concluded that all four calculation alternatives estimate the stock levels with a maximum bias of 25%.

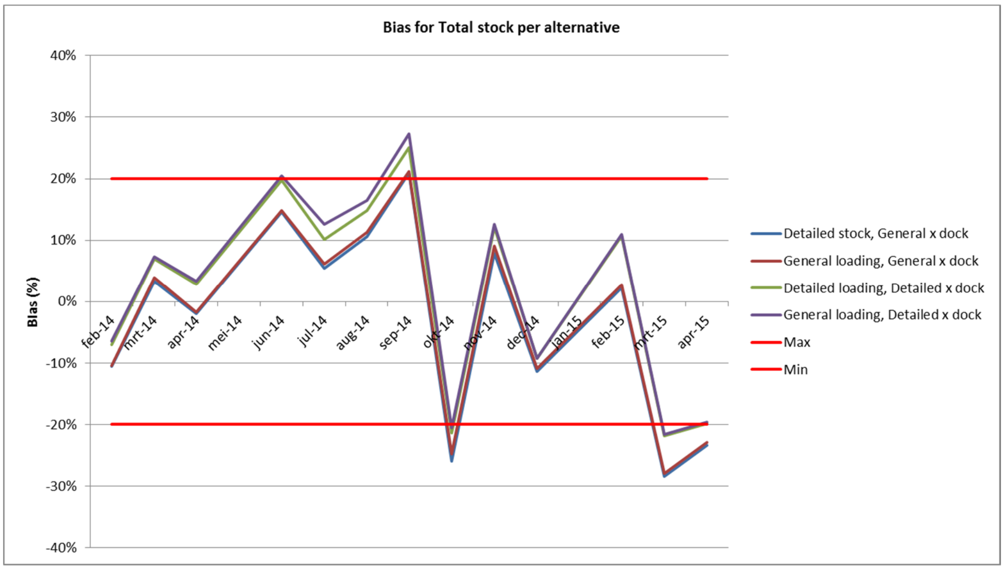


FIGURE 42: BIAS BETWEEN MODEL OUTPUT FOR STOCK LEVELS AND ACTUAL STOCK LEVELS

The model output shows biases above equally above and below 0%, thereby indicating that the planned volumes are in line with actuals measurements. Peaks in bias can be seen in September 2014, October 2014 and March 2015. These peaks can be explained by the fact that actual stock levels measured in 2014 are already the result of human interventions to solve operational issues. Especially with current high stock levels at Zoeterwoude, the large amount of last minute solutions to deal with the high storage volume has caused large fluctuations in the actual stock levels (Hoondert, 2015). The model output cannot forecast these interventions, resulting in bias between model output and actual measurements. Besides this, it will be impossible to achieve 0% bias for stock as the primary function of a warehouse is to form a buffer for the uncertainty between supply and demand. The warehouse decouples supplied volume from demanded volume and there will always be uncertainty in both volume flows (Hoondert, 2015). This uncertainty can especially be seen for stock of Conventional Truck loading; the spread of truck arrival times is quite high, therefore making it hard to predict when a truck will arrive at the brewery. The detailed analysis of stock bias per loading type can be found in "Appendix 8: logistics model validation using data of 2014". From this analysis can be concluded that the 'Detailed loading, General cross-dock' calculation alternative approaches reality best with accurate results for Schep and Mechanical stock volumes. Larger biases can be found for Conventional Truck stock, related to the uncertainty of truck arrival. Overall can be concluded that the model provides the most accurate results with the 'Detailed loading, General cross-dock' alternative to estimate future stock levels, with a bias of approximately 20% above or below the actual measured volume.

Load volume per loading type

A similar validation analysis as with stock volume has been performed for load volume. The monthly volume loaded is represented by the sum of four weeks. Again for each loading type a bias is calculated for all four calculation alternatives in "Appendix 8: logistics model validation using data of 2014". For the total load volumes (thus of all loading types together), the figure below provides the bias on a monthly basis. It can be concluded that all alternatives, except the "Detailed loading, Detailed cross-dock" alternative, estimate the loaded volume with a fairly high accuracy.

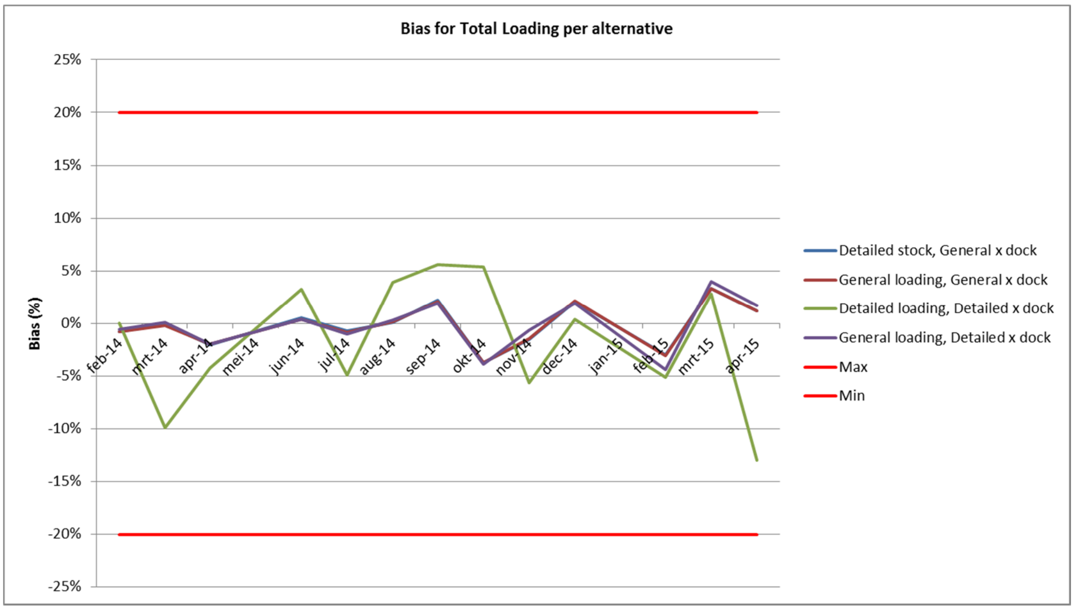


FIGURE 43: BIAS BETWEEN MODEL OUTPUT FOR LOAD VOLUME AND ACTUAL LOADED VOLUME

From the detailed analysis in "Appendix 8: logistics model validation using data of 2014" can be concluded that alternatives with 'General cross-dock' calculation give the best results compared to actual measured load volumes. Very accurate results are found for Mechanical and Schep loading volumes. This is a direct result of the high cross-dock percentage for these loading types, making the load volume more predictable. Larger biases can be found for Conventional Truck and Domestic volumes. The Conventional Truck volume is again influenced by the uncertainty in truck arrivals within a week whereas Domestic volume is influenced by the short-term variety in customer demand.

From the combined validation of stock and load volume can be concluded that the 'Detailed loading, General cross-dock' alternative gives the most accurate results. This calculation alternative is therefore chosen in the final model. It can also be concluded that stock levels are harder to plan than load planning. Load planning is fairly predictable based on the high cross-dock volume that is directly loaded. It is recognized by HNS that stock volume is much harder to plan due to the variety in reasons why stock is held of Export SKU's. These are mostly short-term reasons such as production faults, container unavailability or other operational issues. However, with the strategic horizon of the logistics model these factors cannot be taken into account. It is assumed that this will not be an issue on a strategic level, as long as the overall demand for stock and load volume is in line with reality. The validation has shown that with a bias of 20%, the logistics model can provide acceptable forecasts for the expected stock and load volumes.

5.5. MODEL RESULTS FOR 2015 AND 2016: EXPECTED STOCK LEVELS AND LOAD VOLUMES

With the model verified and validated in the previous section, this paragraph describes the results derived from the model when the packaging scenario of May 2015 is loaded. Based on this plan a stock projection and load volume projection for 2015 and 2016 is provided by the model output. The model shows the expected stock and load volumes for all four volume flows combined, being packaging, co-fill, re-pack and inter-brewery. In the following is illustrated how HNS can use the model to stimulate proactive instead of reactive logistics planning, thereby recognizing issues related to storage earlier in advance. With a long-term plan for stock and loading in place, uncertainty is reduced and perceived complexity can be managed within outbound logistics operations at HNS. Detailed figures of the model output can be found in "Appendix 9: detailed overview of model results". The most important output of the model is shown here, being the expected stock and load volumes for Export SKU's. Insight in Export volumes is mainly interesting for HNS as these are the MTO and Replenishment markets of which no safety stock is planned at the brewery. Therefore no long-term plan of expected stock is currently in place. Besides that, Export volume has different loading types and insight in the differences per loading type can be found with the model.

Export stock planning for Zoeterwoude

Figure 44 below shows the result of the model for Export stock planning per loading type, together with the available theoretical capacity and actual capacity. The difference between theoretical and actual storage capacity is the efficiency rate. As mentioned in chapter 4, the efficiency of the Zoeterwoude warehouse is quite low as a result of the introduced SKU diversity. The actual warehouse efficiency is approximated at 65% for Export and 80% for Domestic, validated internally at HNS (Hoondert, 2015).

From the model output in Figure 44 several conclusions can be made:

1) Stock demand often exceeds the stock capacity.
2) Stock demand is mainly driven by Conventional Truck volume.
3) Based on the outlook for stock demand, the bottlenecks can be identified earlier and proactive decisions can be made towards these bottlenecks.

The first two conclusions are recognized in reality as large volumes are stored externally at the Jonker loods and HNS has been facing issues related to the high stock of Conventional Truck volume. The impact of co-fill, re-pack and inter-brewery flows on overall stock levels is minimal, related to the small volumes of these flows compared to the packaging volume. However, the flows do add volume in the warehouse and are therefore taken into account in the overall picture. Based on the outlook shown in Figure 44, the contribution of the model to logistics planning can be clearly illustrated. Large peaks in stock in the beginning of 2016 are expected, related to a significant increase of production for Conventional Truck loading. The driver behind this expected volume increase can now be found with the model. Doing so reveals that specific SKU's for France cause the increase in stock for the beginning of 2016. It is already known within the organization of HNS that stock for these specific SKU's form a bottleneck. However, the bottleneck has never been quantified and presented next to the demanded stock capacity for other loading types and SKU's. The logistics model now provides a long-term outlook of the expected stock per loading type, which clearly shows the impact that Conventional Truck loading has on the total Export stock volume. With this overview in place, uncertainty in stock planning is partly solved by providing the right information for expected volumes early in advance.

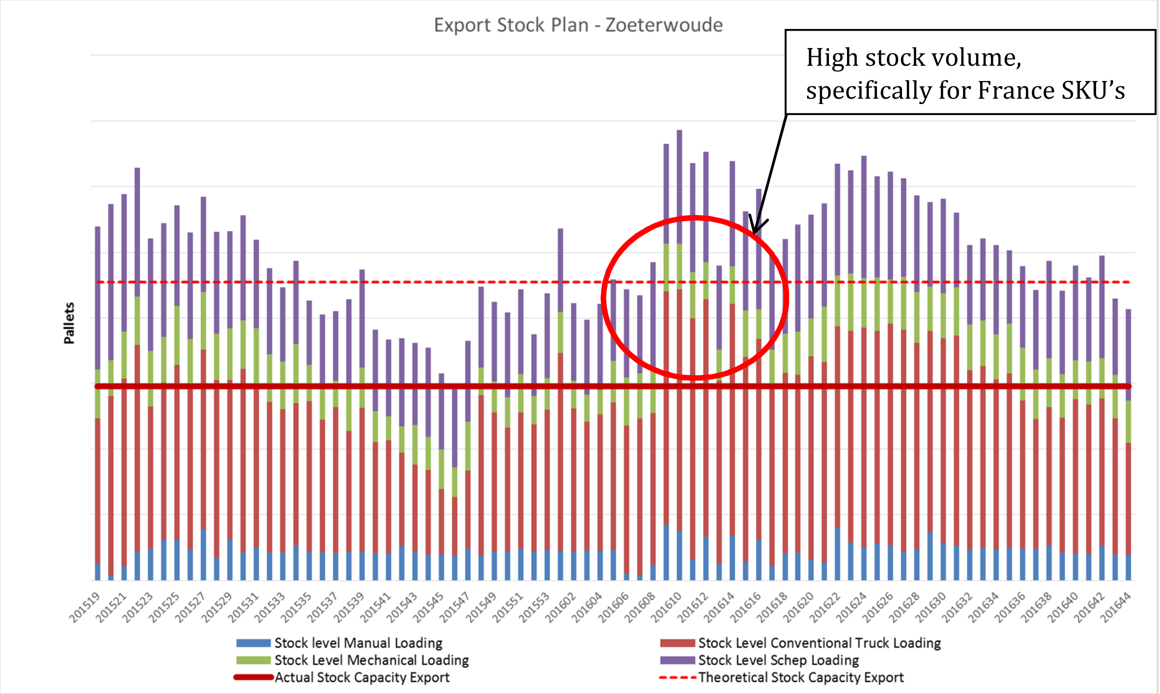


FIGURE 44: MODEL RESULTS FOR 78-WEEK STOCK PLANNING

With the outlook displayed above, proactive solutions can be found for the expected capacity shortage. A practical scenario that can be tested with the model is a potential improvement project on reducing the stock volume for France SKU's. This specific example is chosen as France is an important customer that is highly dependent on specific SKU's produced at Zoeterwoude. The peak identified in Figure 44 is resulting from pre-stock volume that is produced for the summer months in France. This volume is always loaded in a truck and therefore a large volume is held on stock at the brewery. For the peaks in early 2016, an option might be to load the volumes for France directly, either in a container or in a trailer that is directly available after production at the brewery site. The produced volume for France can then directly be cross-docked; hence it will not be present as Conventional Truck stock in the warehouse. The logistics model can be used to determine what impact this has on the stock position in the future. Figure 45 shows the model output if all volume for the specific products for France is cross-docked; a significant amount of stock volume for Conventional Truck loading is no longer present, with significant lower peaks in the first half of 2016. This example clearly shows the purpose of the logistics planning model; it can provide information on how large the reduction in stock will be, thus the reduced need for external storage. These savings can then be compared with the costs of keeping containers or trailers available for direct loading, thereby analysing if the business case for this solution is viable or not. In this way, foreseen bottlenecks in the (near) future can be addressed beforehand, reducing the uncertainty for outbound logistics in the 78-week planning horizon.

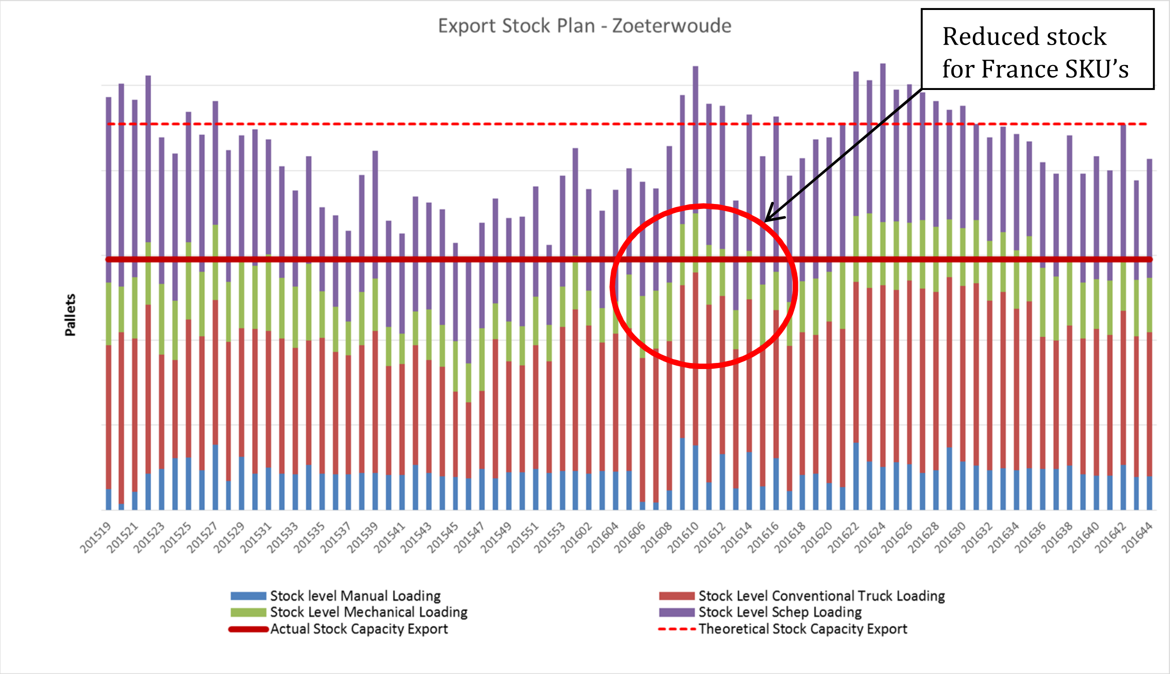


FIGURE 45: EXAMPLE STOCK PLANNING SCENARIO WITH REDUCED STOCK FOR FRANCE

The example for France has illustrated how the model can be used to identify, analyse and solve issues related to storage capacity. Besides this example other experiments can be done with the model. Different packaging scenarios can be run to evaluate the impact on outbound logistics. Also the impact of projects related to shortening time in warehouse or increasing cross-dock percentage for specific SKU's or loading types can be tested with the model. The stock plan clearly shows areas for improvement to either reduce the demanded stock volume or to accept it and find alternative solutions. With the outlook in place, perceived complexity at HNS in terms of uncertainty can be better managed as bottlenecks are identified earlier in advance. In this way also external warehousing partners can be contacted at an earlier stage, as the model output shows the need for external warehousing in the future. Contract managers at HNS can now provide these partners with a clear plan of expected storage needs.

<u>Export load planning for Zoeterwoude</u>

For the load plan a similar output as for stock volume is generated by the model, shown in Figure 46. The figure provides a clear volume distinction between the loading types. The first conclusion here is that, given the theoretical capacity, loading should never be an issue at Zoeterwoude. The brewery has enough loading docks in place to load the expected volume. The actual capacity for loading is hard to determine, as it varies significantly based on the load volume per loading type in a specific time period. In practice however no major issues in loading capacity are experienced at HNS, indicating that the actual loading capacity is sufficient (Hoondert, 2015). The model output for loading contributes to logistics planning by providing an outlook for expected loading and unloading of co-fill, re-pack and inter-brewery flows. The loading volumes are presented in the figure below, showing that the volumes are very small compared to the loading of packaging volume. A detailed planning for unloading of co-fill, re-pack and inter-brewery flows can be found in “Appendix 9: detailed overview of model results”. Until now it was very uncertain for outbound logistics operations when these incoming flows would arrive. The model now provides an estimation of the incoming volume that can be used in the combined unload and load planning.

Interesting conclusions are found when comparing the load volumes in Figure 46 with the stock volumes. Stock for Conventional Truck transport forms a large part of the total expected stock volume whereas the load volume for Conventional Truck is only a small part of the total expected load volume. This is very much related to the cross-dock percentage and time in warehouse of Conventional Truck SKU’s, again emphasizing the impact of this loading type on the demand for storage.

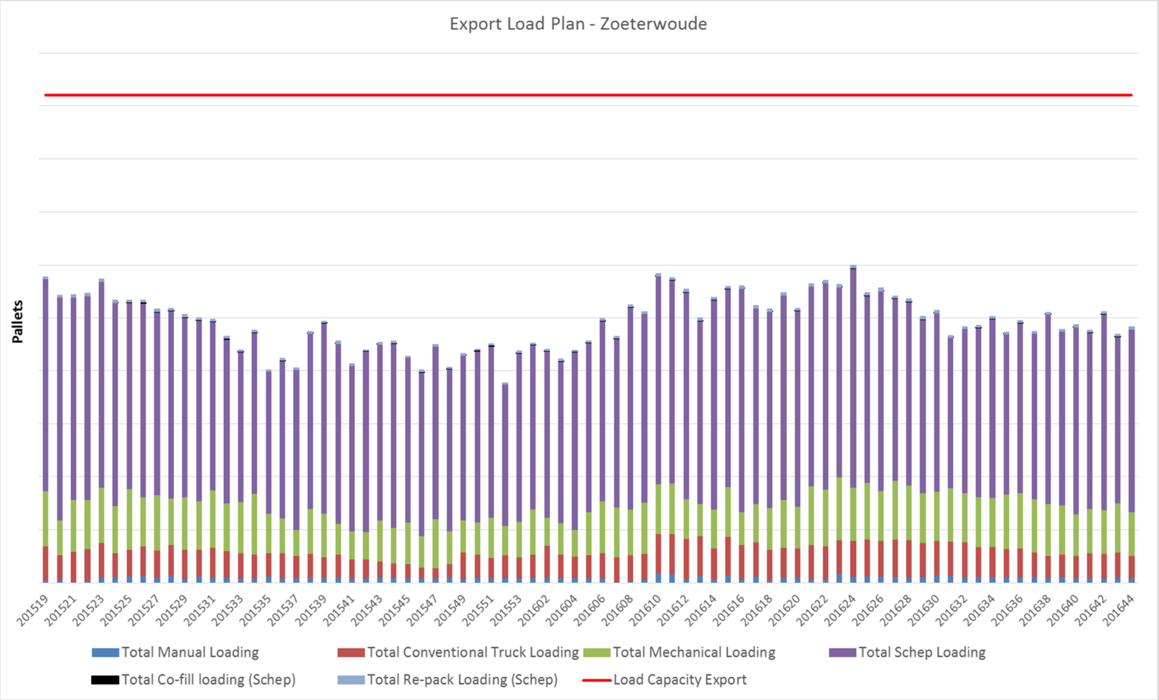


FIGURE 46: MODEL RESULTS FOR 78-WEEK LOAD PLANNING

5.6. IMPLEMENTATION OF THE LOGISTICS PLANNING MODEL AT HEINEKEN

The previous paragraph has clearly illustrated how the model and model output can be used in planning the expected stock levels and load volumes. To strengthen the usability of the model at HNS, this paragraph will describe how the logistics planning model can be implemented within the current planning organization. The practical use of the model has been validated by the HNS organization with the use of a flow chart and RACI-matrix. This technique clearly defines the Responsible, Accountable, Consulted and Informed stakeholders for logistics planning at HNS:

- **Responsible:** Stakeholder who is responsible for the actual fulfilling of the task.
- **Accountable:** Stakeholder who is ultimately accountable for the task begin fulfilled. This is the manager of the person responsible for the task.
- **Consulted:** Stakeholder who is not directly involved in carrying out a task, but should be consulted in certain cases.

- **Informed:** Stakeholder who receives output from the process or task, or who have a need to stay informed.

The flow chart in Figure 47 and matrix in Figure 48 are built together with stakeholders at HNS, thereby ensuring that the logistics model can be used in the monthly planning cycle. A clear division is made in planning input, planning analysis and actions based on the model output. A description of the processes and actions displayed in Figure 47 and Figure 48 is now given.

Planning input

The monthly planning cycle currently starts in the first or second week of the month with an update of the 78-week Demand Plan for all markets. This update is provided by the Market Demand Analyst. Based on these volumes, the Strategic Planning Coordinator develops several packaging scenarios. This person has a large role in the planning process and is therefore also chosen as the responsible person for the logistics planning. To extend the packaging plan to outbound logistics, the Strategic Planning Coordinator should update the loading type per SKU, which is determined by an automated file based on historical shipments. Simultaneously, he or she should receive updated logistics parameters from the Logistics IT Manager, being the cross-dock percentage, storage time per SKU and the warehouse efficiency. With all this information, the Strategic Planning Coordinator will be able to update the logistics plan that results in updated model output.

Planning analysis

The model output as presented in paragraph 5.5 can be used to address bottlenecks in storage capacity for the upcoming 78 weeks. Peak moments for stock demand can be addressed in the model, as shown with the specific example of SKU's for France. The Strategic Planning Coordinator is responsible for addressing these peaks and sending the model output with a short list of comments to the Logistics Coordinator. The Logistics Coordinator is responsible for day to day operations in the warehouse and therefore has good knowledge of realistic capacities and available resources. This person is responsible for reviewing the logistics plan that is provided. If he/she encounters bottlenecks, the Logistics Coordinator should prepare these for the Supply Review Meeting. This meeting is led by the Strategic Planning Coordinator and is attended by all supply chain managers. New will be the attendance of the Logistics Coordinator and/or Logistics Manager, who were previously not attending this meeting. In the meeting the packaging planning will be discussed and, additional to that, the logistics plan. For outbound logistics, the outcome of the meeting should be a clear overview of potential bottlenecks for which solutions need to be found. The identified bottlenecks are communicated to all stakeholders by the Strategic Planning Coordinator.

Actions based on model output

For the identified logistics bottlenecks during the Supply Review, two alternatives are suggested to solve them. If it concerns a market/customer specific bottleneck like the found issues for France, solutions should be created by the Strategic Planning Coordinator and the consulted Market Demand Manager. The Market Demand Managers are in direct contact with all HNS customers and can therefore help in solving specific bottlenecks, for example the direct loading of volume for France. If a bottleneck is not customer specific or if no solution can be found with the customer, the issue should be solved at the brewery. In this case, the Logistics Coordinator will look for other options. The logistics team leaders are thereby consulted for their operational knowledge. When it is foreseen that storage volume will exceeds capacity during a specific period, logistics contract managers can provide third parties with an updated planning of expected volumes. This has two expected benefits for external communication: firstly, the relationship and communication with third party logistics providers is improved. Secondly, HNS can be confident that the required capacity is available at third parties when it is needed, as they can provide these logistics partners with a more accurate long-term plan.

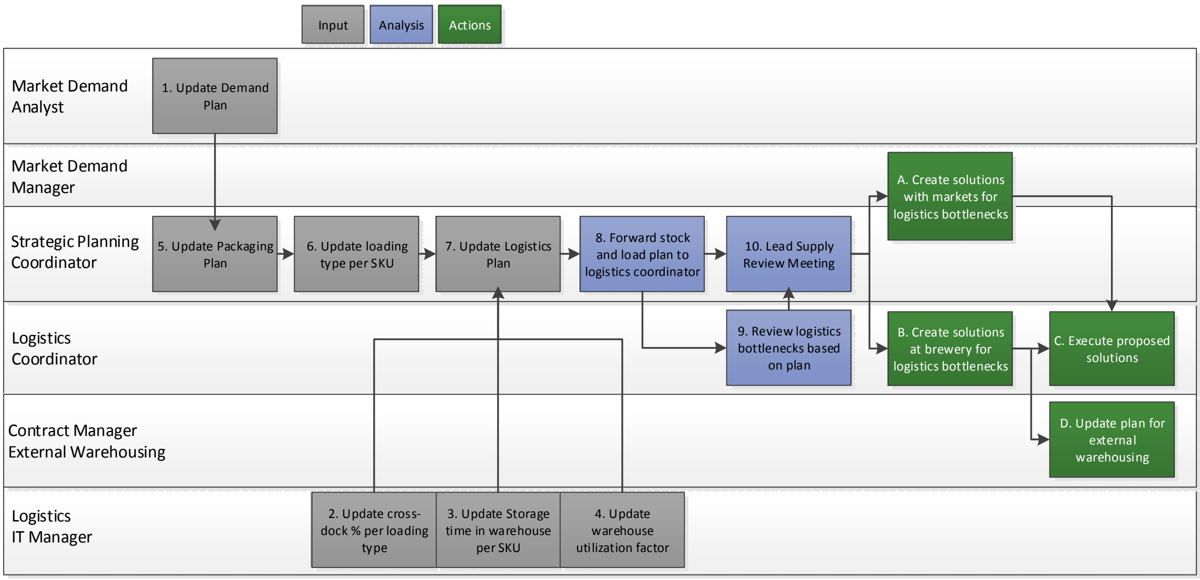


FIGURE 47: IMPLEMENTATION FLOWCHART FOR LOGISTICS PLANNING AT HNS

R = RESPONSIBLE = Stakeholder executes action
A = ACCOUNTABLE = Stakeholder is responsible that action is executed
C = CONSULTING = Stakeholders needs to be involved for advice
I = INFORMING = Stakeholder needs to be informed

		When to take action	Manager Logistics	Manager Customer Service	Manager Supply Chain Planning	Market Demand Analyst	Strategic Planning Coordinator	Logistics Coordinator	Logistics IT Manager	Market Demand Manager	Team Leaders Logistics	Contract Manager External Warehousing
Market Demand Analyst												
1	Update Demand Plan	First/second week of month		A		R	I					
Operational Logistics IT Manager												
2	Update Cross-dock % per loading type	First week of month						A	R			
3	Update Storage Time in Warehouse per SKU	First week of month						A	R			
4	Update Warehouse Efficiency factor	First week of month						A	R			
Strategic Planning Coordinator												
5	Update Packaging Plan	Second week of month			A		R					
6	Update loading type per SKU	Second week of month			A		R					
7	Update Logistics Plan	Second week of month			A		R					
8	Forward stock and load plan to logistics coordinators	Second week of month			A		R	I				
10	Lead Supply Review meeting. Make agreements: - Stock plan - Load plan - Potential bottlenecks in horizon	Third week of month	I	I	A	I	R	I				I
A	Create solutions with markets for logistics bottlenecks	Fourth week of the month		A			R			C		
Logistics Coordinator												
9	Review logistics bottlenecks based on logistics plan	Before Supply Review meeting	A					R				
B.	Create solutions at brewery for logistics bottlenecks	Third week of month	A					R			C	
C.	Execute proposed solution(s)	Start of next month	A					R			C	
Contract Manager External Warehousing												
D.	Update plan for external warehousing	Start of next month	A				I					R

FIGURE 48: IMPLEMENTATION MATRIX FOR LOGISTICS PLANNING AT HNS

5.7. MODEL CONCLUSIONS: MANAGING THE PERCEIVED COMPLEXITY

The logistics planning model has been designed, verified and validated in such a way that the builder and client are confident with the output generated by the model. With a clear representation of the results and positioning of the model in the current organization, this paragraph reflects on how the model contributes to managing the perceived complexity at HNS. In this way sub research question four is answered. Referring to chapter 4, the main drivers for uncertainty in outbound logistics at HNS are the high storage demand and the absence of logistics parameters to determine the storage demand in the long term. The designed model in this chapter can be used to manage both drivers for complexity, as illustrated below.

1. The logistics model provides the missing information between packaging and logistics planning by measuring the logistics parameters per SKU. These main logistics parameters are the loading type per SKU, the cross-dock percentage and the storage time in warehouse per SKU.
2. The logistics model provides a long-term outlook for stock and load planning with a bias of approximately 20% based on validation with actual data. With the outlook in place, HNS can foresee mismatches between storage demand and capacity at an earlier stage in the planning process.

Because the model provides measurements for the key logistics parameters per SKU, the expected volumes and product diversity becomes more visible for outbound logistics operations. This has a direct impact on perceived process and planning complexity; part of the uncertainty is removed by planning the impact that a certain packaging plan has on the warehouse. With this information specific mismatches between storage demand and capacity can be addressed proactively. It also enables HNS to improve the communication with partners in warehousing. From the verification phase can be concluded that the cross-dock percentage and storage time in warehouse are very important parameters and these should therefore be measured closely. At validation has been seen that mainly the Conventional Truck volume is hard to plan accurately while it is the main source of stock in the Export warehouse. The model can now be used to address bottlenecks in the long term and plan solutions accordingly.

As illustrated, the model can be used to experiment with alternative scenarios for outbound logistics, either by analysing different packaging scenarios or by finding alternative ways for loading specific SKU's. An important remark here is that the packaging plan should not be dependent on the logistics plan as packaging will always remain the most dominant part of the HNS supply chain. However, for each packaging scenario the model can provide a stock and load planning which makes it easier to compare the logistics impact of different scenarios. This comparison can help in making decisions for specific business cases like the example given for France. Regarding technology complexity, the logistics model provides a link between different IT systems in place at HNS to determine the logistics parameters per SKU. The most important contribution of the model is increased information alignment between packaging and outbound logistics, providing increased visibility of the impact that a certain packaging plan has on the brewery warehouse.

The author is convinced that the logistics model can be directly implemented as an extension of the current strategic planning process. The implementation steps for the model are designed together with the responsible people within HNS planning, thereby clearly positioning the model in the current monthly planning cycle. This ensures sustainable use of the model in the future. Successful experiments with the model have already been executed by HNS, strengthening its effectiveness for long-term logistics planning.

6. CONCLUSIONS AND RECOMMENDATIONS

This final chapter will focus on the conclusions and recommendations for the analysed complexity in outbound logistics at HNS. Paragraph 6.1 will focus on answering the research question, indicating the key drivers for perceived complexity and showing how the logistics model can help in managing these drivers more closely. Paragraph 6.2 will focus on the academic relevance of the complexity framework and the applicability of the designed logistics planning model. The chapter ends with paragraph 6.3, providing recommendations for further research.

6.1. CONCLUSIONS FOR HEINEKEN: THE ROLE OF INFORMATION AND PLANNING

This research focuses on analysing perceived complexity at HNS and it is attempted to find the main drivers for this perception. The corresponding main research question is the following:

What is the impact of an expanding product portfolio on perceived complexity in outbound logistics operations and how can the main drivers for this perception be managed in the future?

Complexity in this research is defined as the uncertainty in processes as a result of increased diversity. Therefore, the research goal is to determine the key factors that drive uncertainty and provide recommendations for HNS on how to manage these factors more closely. The complexity framework has identified the main drivers for uncertainty, thus perceived complexity, within four complexity types that are described below.

Product complexity: SKU diversity, volume, loading type diversity

Product complexity is perceived as uncertainty in the product portfolio. In literature and at HNS has been found that market diversity is the source of product portfolio complexity. Combining the needs of global customers creates a large product portfolio. For a global production organization like HNS, perceived complexity related to this large portfolio is driven by the number of SKU's that need to be produced and the volume related to these SKU's. At HNS, volume and SKU diversity are growing simultaneously and therefore the organization copes with capacity issues. The SKU diversity and volume cannot be controlled by the production organization, as commercial benefits related to the diverse portfolio are considered more important than the operational issues that diversity creates. At HNS specifically, additional product complexity is driven by the diversity in loading types requested by the market. The expanding portfolio has reduced insight in the loading type per SKU, thereby increasing uncertainty of expected volume flows in the outbound logistics warehouse.

Technology, process and planning complexity

Next to portfolio complexity, three other complexity types are distinguished that drive perceived complexity in outbound logistics operations; technology complexity, process complexity and planning complexity.

- **Technology complexity** is perceived as uncertainty when product diversity exceeds the boundaries of the technology in place, both physical and information related. Physical technology focus on the capacities and capabilities of equipment and warehouse layout. As the equipment specifications are well known at HNS, no specific uncertainty is related to physical technology. However, uncertainty is rising when connecting the physical layout with the volumes and SKU diversity to be handled in the warehouse. The increase in SKU's results in the fact that HNS does not know the impact of a certain packaging plan on logistics operations, thereby increasing uncertainty. This uncertainty is mainly driven by missing information on SKU level, perceived as information technology complexity. A very important driver for perceived complexity is the absence of important logistics parameters per SKU that determine the impact on outbound logistics.

- **Process complexity** is uncertainty in the actual logistics processes resulting from a mismatch between products and technology. HNS is faced with a simultaneous increase of SKU diversity and volume, leading to full and inefficient warehouses and limited capacity for storage. At both breweries the absence of logistics parameters on SKU level disable a long-term outlook of expected storage demand. The expected volumes in the warehouse are therefore hard to predict and control. The result is uncertainty in outbound logistics processes and reactive process steps when the volume and/or number of SKU's are not aligned with the initial plan or capacity. The mismatch between storage demand and capacity on the one hand and unavailability of logistics parameters per SKU on the other hand drive the perceived process complexity.
- **Planning complexity** is uncertainty in logistics planning, also driven by the absence of the most important logistics parameters per SKU. The current IT and planning structure at HNS limit the possibility to plan the expected stock and load volumes in the long term.

From the analysis is concluded that information availability is the most important driver for perceived complexity at HNS, mainly because logistics parameters are not taken into account in the current planning processes. This limits the translation of a certain packaging plan towards outbound logistics. It is also concluded that HNS can reduce the uncertainty driven by this missing information, as the logistics parameters are all covering internal processes that are controlled by HNS. The organization therefore has a large influence on the perceived complexity; measuring the logistics parameters correctly enables HNS to create more certainty in the long term by planning the expected demand for storage and loading.

Managing the drivers for perceived complexity: the role of information and logistics planning

From this research can be concluded that the role of logistics planning is very important to manage perceived complexity. Uncertainty at HNS can be reduced by providing an outlook for expected storage and load volumes, thereby proactively addressing expected bottlenecks for storage in advance. To provide this outlook at HNS a logistics planning model is designed. During model design has been concluded how essential it is to have the right information available for planning. Three key logistics parameters are identified to translate the packaging plan to a logistics plan:

- **Loading type per SKU;** determines warehouse handlings and demand for storage
- **Cross-dock percentage**; determines how much of the volume can be loaded directly
- **Storage time:** determines how long a certain SKU is stored in the warehouse

The logistics planning model translates the packaging plan at HNS to a logistics plan by assigning the three logistics parameters to each individual SKU. From analysis of the model output, several main conclusions can be drawn;

1) Stock demand often exceeds the stock capacity.
2) Stock demand is mainly driven by Conventional Truck volume.
3) Based on the outlook for storage demand, bottlenecks can be identified earlier and proactive decisions can be made towards these bottlenecks.

Based on the above conclusions, the model can be used to experiment with alternative scenarios for outbound logistics, either by analysing different packaging scenarios or by finding alternative ways for loading specific SKU's or product groups. The practical use of the model at HNS has been validated by addressing specific peaks in storage demand based on packaging plans for 2015 and 2016. The most important contribution of the model is the increased information alignment between packaging and outbound logistics, providing better visibility of the impact that a certain packaging plan has on the brewery warehouse. First experiments with the model have already been completed at HNS, clearly foreseeing issues for the storage of specific SKU's for the French market. By identifying these issues early in advance, the logistics model contributes in reducing uncertainty for outbound logistics operations at HNS. The suggested implementation steps provided for the model have been validated at HNS, supporting the author's belief that the model can be directly implemented as an extension of the current monthly planning cycle.

6.2. SCIENTIFIC CONCLUSIONS

This paragraph concludes on the relevance and applicability of the developed framework for perceived complexity, as well as applicability of the logistics planning model.

Relevance and applicability of the complexity framework

It can be concluded that the developed complexity framework has supported in defining perceived complexity within the HNS supply chain, providing the key drivers for uncertainty in outbound logistics operations. With its structured layout, the framework was also used as a communicative tool when addressing complexity to the problem owners at HNS. The relations between the different complexity types and drivers are obtained during practical interviews, thereby strengthening the practical relevance of the framework. For the researcher, the framework has provided structure during data analysis, pointing out the key drivers for uncertainty within the organization. Based on the analysis, the framework pointed out the need for long-term logistics planning as a result of missing planning information. Here, the role of the complexity framework was to define complexity at a high level, structure the analysis and define the most important drivers that need to be managed closely. One case study is however not enough to conclude that the framework is finalized and applicable to any supply chain. Considering the limited time and resources available it can be concluded that the framework has proved itself as an effective tool to address perceived complexity in this research. The author is confident that the framework will also work at other companies as the four interrelated complexity types provide a structured approach when researching complexity. Thee individual drivers of complexity might differ for other supply chains but it is assumed that the basic structure of the complexity framework will help in defining the right drivers for complexity at other companies.

Applicability of the logistics model

The applicability of the logistics model has been clearly identified and validated at Zoeterwoude. It is expected that the model can also be easily applied to Den Bosch, as outbound logistics processes there are planned with the same logistics parameters. First experiments at Den Bosch have already been completed. During these experiments is concluded that only small adaptations are needed, such as updating plant specific capacities and values of logistics parameters. The application of the logistics model in other organizations will be more difficult, related to the specific planning systems used at HNS. The relevance of the model for other organizations is focused on measuring the right logistics parameters. At HNS has been discovered how important it is to correctly measure the loading type per SKU, the cross-dock % and the storage time in warehouse. Some if not all of these parameters are relevant for any warehouse that has similar characteristics to those at Zoeterwoude and Den Bosch.

6.3. RECOMMENDATIONS AND IDEAS FOR OTHER CASE STUDIES AT HEINEKEN

Based on the research and conclusions, several recommendations can be made towards the management of HNS. These are described below.

Provide the right information for each stakeholder

This research has pointed out that the perception of complexity in outbound logistics is mainly driven by a lack of information and planning. The logistics model in this research has therefore connected data points from different systems to determine the logistics parameters per SKU, thereby reducing uncertainty in outbound logistics. The calculation of these parameters had to be done manually because the packaging plan loses all customer relevant information per order or forecast on SKU level. In this way, HNS is not able to see which customer orders or forecasts are behind a certain production batch. This does not lead to problems during packaging planning as here information on SKU level is enough. However, for a more end to end overview in the supply chain it is also essential to know which information is important for other stakeholders. It is therefore recommended to set up a project that clearly defines what information the different stakeholders need to successfully plan and manage their operations. Encountered during the research is that HNS possesses an extensive database. However, with this extensive amount of data it remains important to 1) measure and report the right parameters, 2) measure the parameters consistently across the supply chain organization and 3) make the information visible and accessible to the relevant stakeholders.

One of the main drivers for the lack of information is the diversity in IT systems used at HNS. Separate systems are used in different entities of the supply chain which limits data exchange. It is the author’s strong belief that the lack of interchange ability between these systems limits the possibility to plan ahead, mainly in the outbound logistics processes. HNS is already investing in improvement projects for more centralized IT. It is highly advised to start determining which stakeholders need what information and then continue to secure the right information in a more centralized system. This will significantly increase alignment and visibility of information across the HNS supply chain.

Projects for warehouse layout at Zoeterwoude

Besides the lack of certain information, another driver for perceived complexity at HNS is the rising demand for storage. The management of HNS has recognized this issue and is already busy with projects to manage the increase in storage demand. A project that can help with this at Zoeterwoude is related to the warehouse efficiency. In this research, an analysis has been done on the warehouse utilization and flexibility at Zoeterwoude. It showed that smaller production batches and more SKU’s result in a fairly low warehouse efficiency. This indicates that a significant change in portfolio requests a change in physical warehouse layout as well. To improve the warehouse efficiency it is recommended to extend the analysis on this topic, thereby analysing the average batch size per SKU (in pallets) for inflow, stock and outflow. It is advised to research if the warehouse efficiency can be improved by comparing the batch size and number of SKU’s with alternative warehouse layouts. Case studies related to this might be solved with Discrete Event Simulation as this technique enables a quick comparison of different scenarios. A benchmark study with Den Bosch might also be part of this research as the warehouse there is already much more tailored to SKU diversity.

Embedding logistics planning in the organization

The last recommendation given to HEINEKEN is related to the organization itself. According to all employees that are interviewed, logistics should never be the bottleneck because packaging operations are far more expensive. However, logistics has become a bottleneck and it is therefore recommended to place logistics planning next to packaging planning in the organization. The developed logistics planning model provides a good starting point for strategic planning. First attempts have already been completed to tailor the model to Den Bosch and it is recommended to continue this. The model can even be tailored to tactical level, thereby creating an accurate 13-week outlook on stock and load planning. This can be done with the same functional structure and parameters. Furthermore, to embed logistics planning in the organization it is advised to make one person responsible for warehouse planning on strategic and tactical level. In this way an owner of the warehousing and logistics planning is created.

ACADEMIC REFLECTION

The main goal of this research was to identify, analyse and quantify the perception of complexity within a supply chain organization. For this purpose extensive literature research was done to address the key types of complexity and relate these with each other. The work provided on complexity analysis by (Pasche, 2009) and (Perumal, 2009) proved to be a good theoretical starting point for this research. In addition to their work, a variety of authors have been consulted that provided different insights in complexity, both from a theoretical and business point of view. From these analyses was concluded that the perception of complexity is driven by uncertainty. By combining these views in different complexity types, a framework is created that relates uncertainty to product, process, technology and planning components. The framework is extended with specific drivers for each complexity type, increasing the potential to measure the perception of complexity within an organization.

The theoretical complexity framework is applied in a case study at HNS to tests its usefulness when addressing perceived complexity in an organization. For both Den Bosch and Zoeterwoude the framework has provided structure in quantitative and qualitative analysis. The most important research conclusion is that absence of certain information is the biggest driver for uncertainty, thus perceived complexity. From this research can be concluded that the complexity framework successfully supports the analysis of experienced complexity in an organization, proven by its applicability to HNS. However, given the time constraints attached to this research, it cannot be concluded that the framework is complete. The identified complexity drivers might vary across companies which face different challenges and have different supply chains. On a higher level though, the author strongly beliefs that the four related complexity types within the complexity framework can support a structured analysis within a variety of organizations. Further research should point out if this is indeed the case, increasing the robustness of the designed framework.

For HEINEKEN Netherlands Supply, the complexity framework has pointed out the need for long-term logistics planning. The model that was built for this purpose strongly supports HEINEKEN’s goal to create long-term visibility in outbound logistics requirements and volumes. Although the author strived to reach the highest model accuracy as possible, an enormous number of operational factors play a role in the planning and actual volume development at HNS. The model provides the link between production and logistics, but it should be noted that a warehouse actually functions as a buffer between production and customer demand. Therefore, the most ideal situation would be to couple supply and demand in one model to create a more accurate planning of warehouse inflow, stock and outflow. However, the current information structure available at HNS makes it hard if not impossible to relate supply and demand directly. The different processes within the supply chain function as separate entities instead of as a whole which makes alignment and data interchange ability harder. Given these restrictions on resources and time available, it is the author’s strong belief that the model does provide all key variables to determine logistics requirements in the long term.

BIBLIOGRAPHY

Asselman, R., 2015. *Order Management at HEINEKEN Netherlands Supply* [Interview] (24 March 2015).

Bakker, E., 2015. *Team leader logistics Den Bosch* [Interview] (9 March 2015).

Berghout, M., 2015. *Market Demand Manager Netherlands at HNS* [Interview] (12 May 2015).

Blankhorst, A., 2015. *Cost components CS&L Zoeterwoude,* Zoeterwoude: HEINEKEN Finance.

Bozarth, C., Warsing, D., Flynn, E. & Flynn, B., 2009. The impact of supply chain complexity on manufacturing performance. *Journal of Operations Management,* pp. 78-93.

Canadean, 2011. *Global Beer Trends Report 2011,* Toronto: Canadean.

Chou, J., 2013. *Efficient product rationalization within a single product portfolio,* Boston: Northeastern University.

Closs, D., Jacobs, M., Swink, M. & Webbs, G., 2008. Toward a theory of competencies for the management of product complexity: six case studies.. *Journal of Operations Management,* 26(5), pp. 590-610.

Den Hartog, E., 2012. *Reducing complexity at Procter & Gamble,* Enschede: University of Twente.

Eglese, R., Mercer, A. & Sohrabi, B., 2005. The grocery superstore vehicle scheduling problem. *The Journal of the Operational Research Society,* pp. 902-911.

Ganeshan, R., Boone, T. & Stenger, A., 2001. The impact of inventory and flow planning parameters on supply chain performance: An exploratory study. *International Journal of Production Economics,* Volume 71, pp. 111-118.

Gu, J., Goetschalckx, M. & McGinnis, L., 2007. Research on warehouse operation: A comprehensive review. *European Journal of Operational Research,* Volume 177, pp. 1-21.

Gunasekaran, A. & Ngai, E., 2004. Information systems in supply chain integration and management. *European Journal of Operational Research,* Volume 159, pp. 269-295.

HEINEKEN CS&L, 2014. *Layout CS&L Verpakken 2014,* Zoeterwoude: HEINEKEN Netherlands Supply.

HEINEKEN CS&L, 2015. *Masterplan 2020,* Zoeterwoude: HNS.

HEINEKEN NV, 2014. *Annual Report 2014,* Amsterdam: HEINEKEN.

Hillier, F. S. & Lieberman, G. J., 2001. *Introduction to Operations Research - Seventh Edition.* s.l.:McGraw-Hill Higher Education.

Hoondert, P., 2015. *Logistics Coordinator Zoeterwoude* [Interview] (12 June 2015).

Horsman, K., 2015. *'Complexity in the Supply Chain'* [Interview] (5 March 2015).

Kaski, T. & J., &. H., 2002. Measuring product structures to improve demand/supply. *International Journal of Technology Management,* pp. 578-598.

Kelton, W., Sadowski, R. & Swets, N., 2010. *Simulation with Arena.* 5th ed. New York: Mc Graw Hill.

Kohler, S., L., P., Schilthuis, M. & De Wit, E., 2013. *AGV with RFID: An exploratorive study in the possibilities of RFID usage in guiding AGV's in a container terminal,* Delft: s.n.

Lambert, D. & Cooper, M., 2000. Issues in supply chain management. *Industrial Marketing Management,* Volume 29, pp. 65-83.

Ludema, M., 2013. *Supply Chain Mapping with SCOR,* Delft: Ludema, M..

Mazzocchi, F., 2008. Complexity in biology: Exceeding the limits of reductionism and determinism using complexity theory. *EMBO reports,* pp. 10-14.

Meyer, M. & Curley, K., 1991. An applied framework for classifying the complexity of knowledge-based systems. *MIS Quarterly,* pp. 454-472.

Oxford Dictionaries, 2010. *Oxford Dictionary of English.* 2nd ed. Oxford: Oxford University Press.

Pasche, M., 2009. *Product Complexity Reduction - Not Only a Strategy Issue,* Gothenburg: Chalmer University of Technology.

Perumal, A., 2009. *Waging war on Complexity Costs: Reshape Your Cost Structure, Free Up Cash Flows and Boost Productivity by Attacking Process, Product and Organizational Complexity,* New York: McGraw-Hill.

Plooij, O. D., 2015. *Introducing Product Diversity into a Supply Chain Designed for Bulk,* Delft: Delft University of Technology.

Rajeev, K., 2011. *Supply Chain infrastructure - prospects and challenges in recession hit economy,* s.l.: s.n.

Reimers, S., 2015. *Market Demand Analyst at HNS* [Interview] (16 June 2015).

Reimers, S. & Meesters, J., 2015. *Logistics parameters* [Interview] (1 June 2015).

Rushton, A., Croucher, P. & Baker, P., 2014. *The Handbook of Logistics and Distribution Management: Understanding the Supply Chain.* London: Kogan Page.

Schreuder, J., 2015. *Team leader logistics at HNS* [Interview] (4 March 2015).

Schrijvers, J., 2015. *Manager Customer Service at HNS* [Interview] (4 March 2015).

Serdar-Asan, S., 2011. *A REVIEW OF SUPPLY CHAIN COMPLEXITY DRIVERS.* Istanbul, Istanbul Technical University.

Shah, N., 2005. Process industry supply chains: Advances and challenges. *Computers and Chemical Engineering,* Volume 29, pp. 1225-1235.

Slack, N., Chambers, S. & Johnston, R., 2010. *Operations Management.* 6th Edition ed. Essex: Prentice Hall.

Stevens, G., 1989. Integrating the Supply Chain. *International Journal of Physical Distribution & Logistics Management,* pp. 3-8.

Van Delzen, A., 2015. *Supply Chain Specialist at HNS* [Interview] (10 March 2015).

Van Den Berg, J. & Zijm, W., 1999. Models for warehouse management: Classification and examples. *International Journal of Production Economics,* Volume 59, pp. 519-528.

Van der Meer, A., 2015. *Achieving packaging manufacturing flexibility through the interplay of design and production process characteristics,* Enschede: University of Twente.

Van der Meer, A., 2015. *HNS Packaging Overview,* Twente: Alexandra van der Meer.

Van Der Niet, F., 2014. *Supply Chain Planning and Simulation at HEINEKEN,* Delft: Van Der Niet, F..

Van Kooten, P., 2015. *Project Manager Logistics at HNS* [Interview] (20 May 2015).

Van Oost, R., 2015. *Teammanager Tactical Supply Chain Planning* [Interview] (19 May 2015).

Vasconcelos, F. & Ramirez, R., 2011. Complexity in business environments. *Journal of Business Research,* Issue 64, pp. 236-241.

Wang, Q. & von Tunzelmann, N., 2000. Complexity and the functions of the firm: breadth and depth. *Research Policy,* 29(8), pp. 805-818.

Ward, J. e. a., 2010. *HP Transforms Product Portfolio Management with Operations Research,* Palo Alto: HP Laboratories.

Webster, 1964. *Webster's Third new International Dictionary of English Language.* Springfield: MA: G.&C. Merriam.

Werkman, H., 2015. *Manager Export Logistics at HNS* [Interview] (9 June 2015).

APPENDIX

APPENDIX 1: AVAILABLE TECHNOLOGY AT DEN BOSCH AND ZOETERWOUDE

This section is not available in the public version of this thesis.

APPENDIX 2: TRENDS IN BEER TYPES

This appendix shows the trend in beer types per brewery in the past years. An increase in beer types can be seen at Den Bosch, while the number of beer types at Zoeterwoude remains constant due to limitations in filtering for sweetened beers at this bulk brewery.

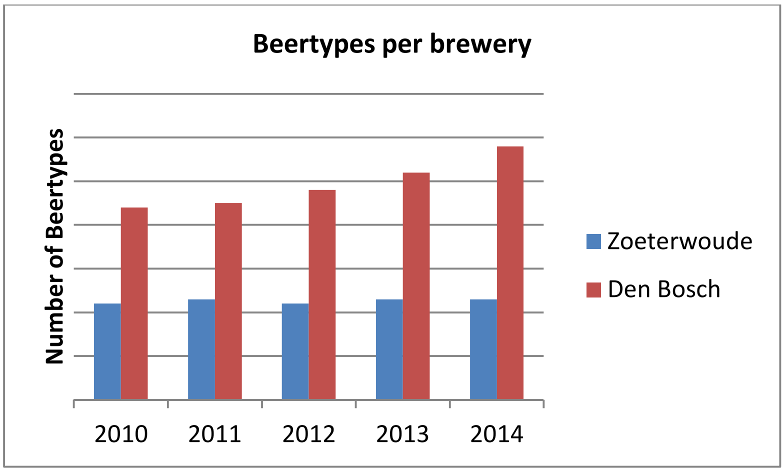


FIGURE 49: TRENDS IN NUMBER OF BEERTYPES

APPENDIX 3: TRENDS IN NUMBER OF SKU´S

This appendix shows the trend in number of SKU´s produced per brewery in the past years. Where Den Bosch shows an increase in number of beer types, the number of SKU´s grows significantly at Zoeterwoude. This is a result of transferring SKU´s from Den Bosch to Zoeterwoude, thereby creating capacity for the new beer types and SKU´s at Den Bosch. The trend in SKU's is accelerated in 2014, a year that saw growth in both volume and diversity.

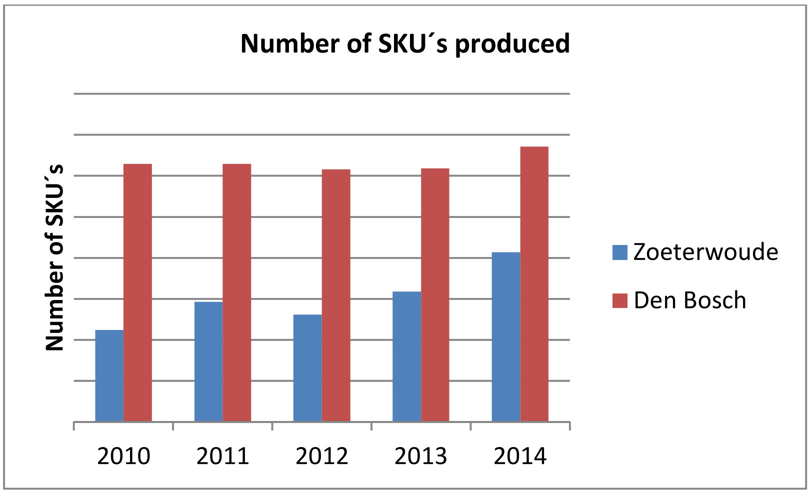


FIGURE 50: TRENDS IN NUMBER OF SKU'S PRODUCED PER PLANT

The following graph depicts how many SKU's were shipped per plant. This is always more than the amount of SKU's produced at a plant, as inter-brewery, re-pack and co-fill flows result in additional SKU's that are handled and shipped within the warehouse. An increase in the number of SKU's shipped can be seen at both breweries but the increase at Zoeterwoude is more significant.

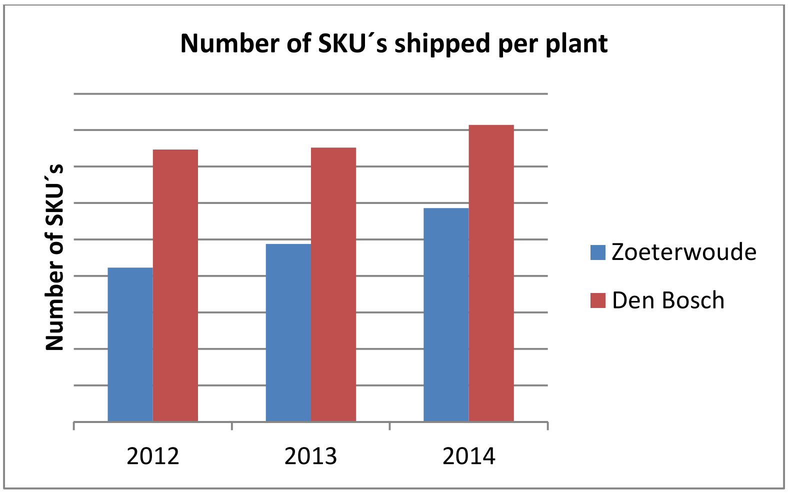
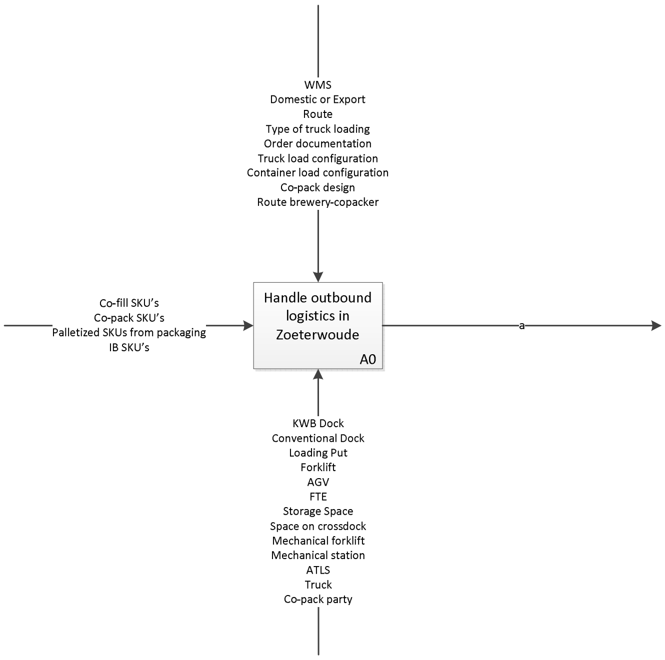


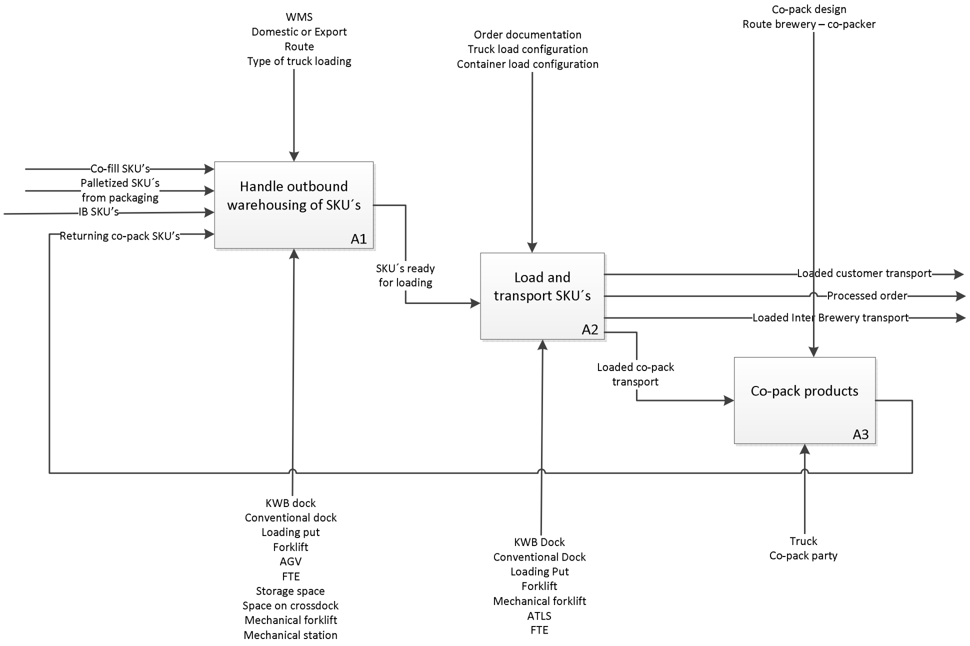
FIGURE 51: TRENDS IN NUMBER OF SKU'S SHIPPED PER PLANT

APPENDIX 4: PROCESS DIAGRAMS OF OUTBOUND LOGISTICS OPERATIONS

The following diagrams provide detailed information regarding the outbound logistics processes at Zoeterwoude. The IDEF-0 methodology is used here to determine all flows in the outbound processes with its input, output, resources and controls.



A0: Handle Outbound Logistics in Zoeterwoude



Decomposition of A0: Handle outbound logistics at Zoeterwoude

FIGURE 52: IDEF-0 DIAGRAMS FOR OUTBOUND LOGISTICS AT ZOETERWOUDE: A0 AND A1

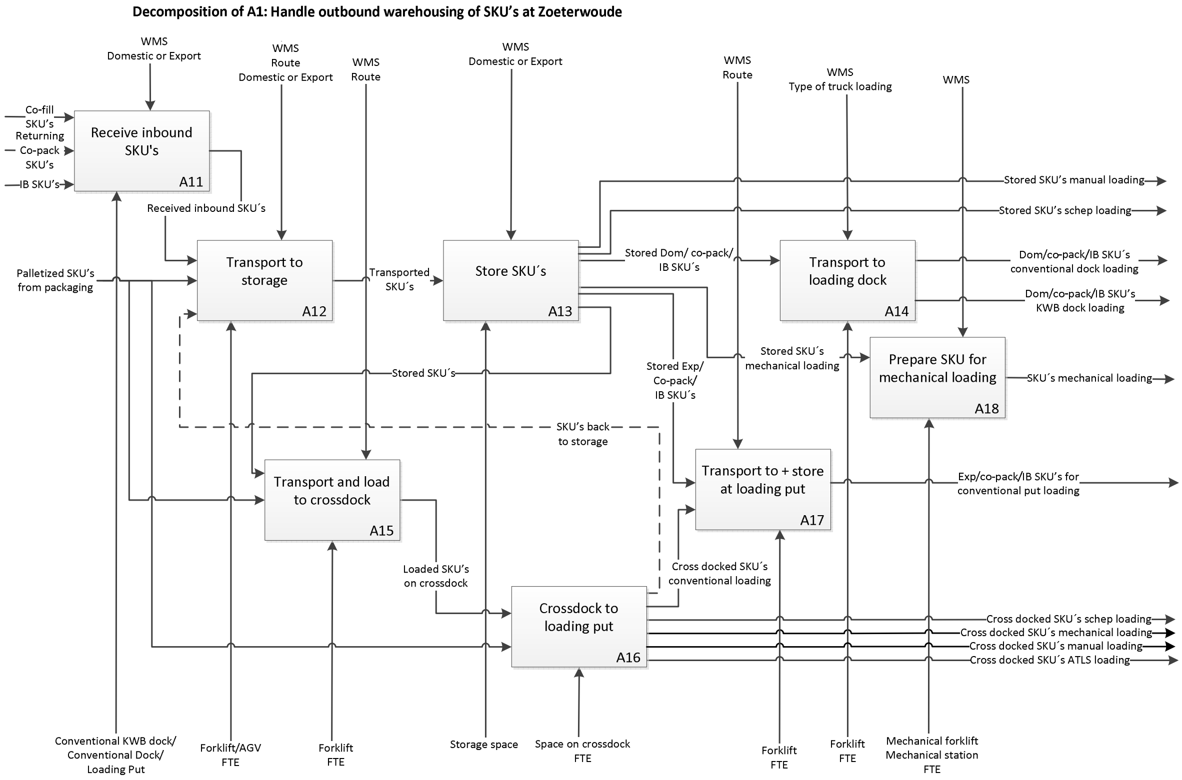


FIGURE 53: IDEF-0 DIAGRAM OF WAREHOUSE HANDLING PROCESSES AT ZOETERWOUDE

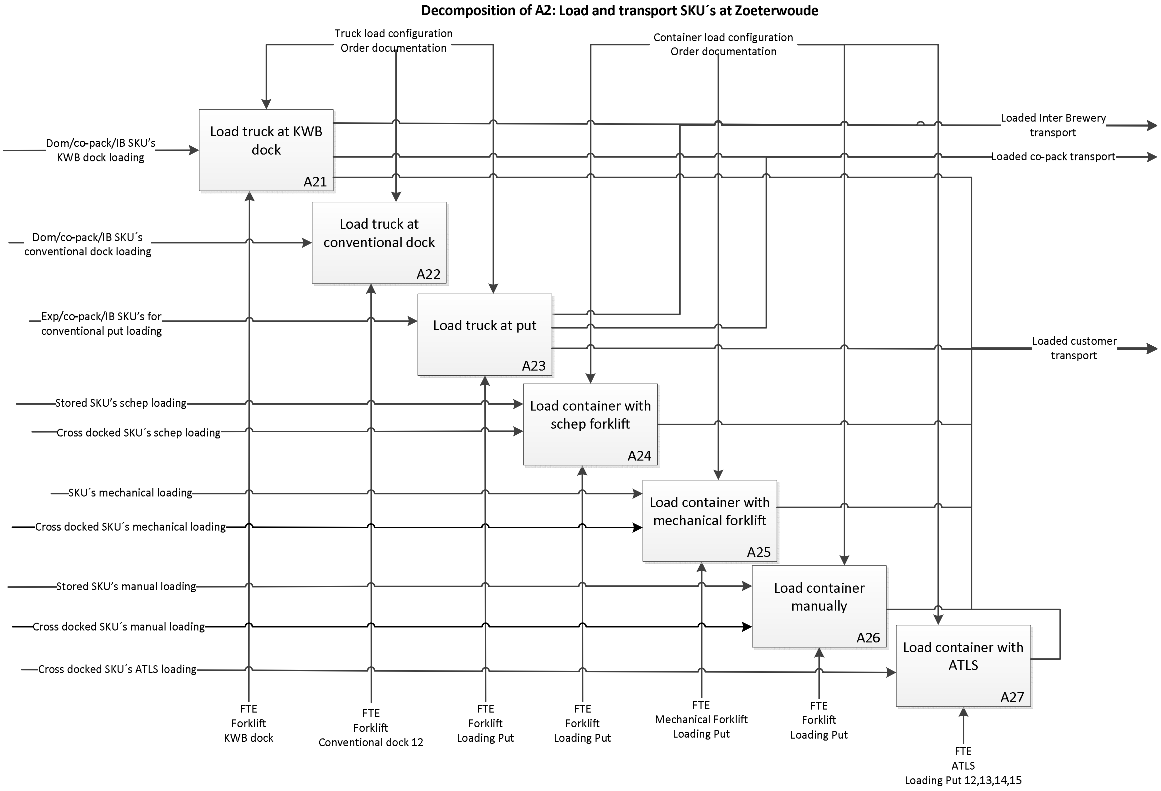


FIGURE 54: IDEF-0 DIAGRAM OF LOADING PROCESSES AT ZOETERWOUDE

APPENDIX 5: FORECASTED VOLUMES BASED ON MASTERPLAN HNS 2015-2020

The figure below shows the expected demand and SKU diversity for HEINEKEN Netherlands Supply for 2015 until 2020, based on trends from 2010 to 2014. The trend lines show that both the number of SKU's and the volume will increase.

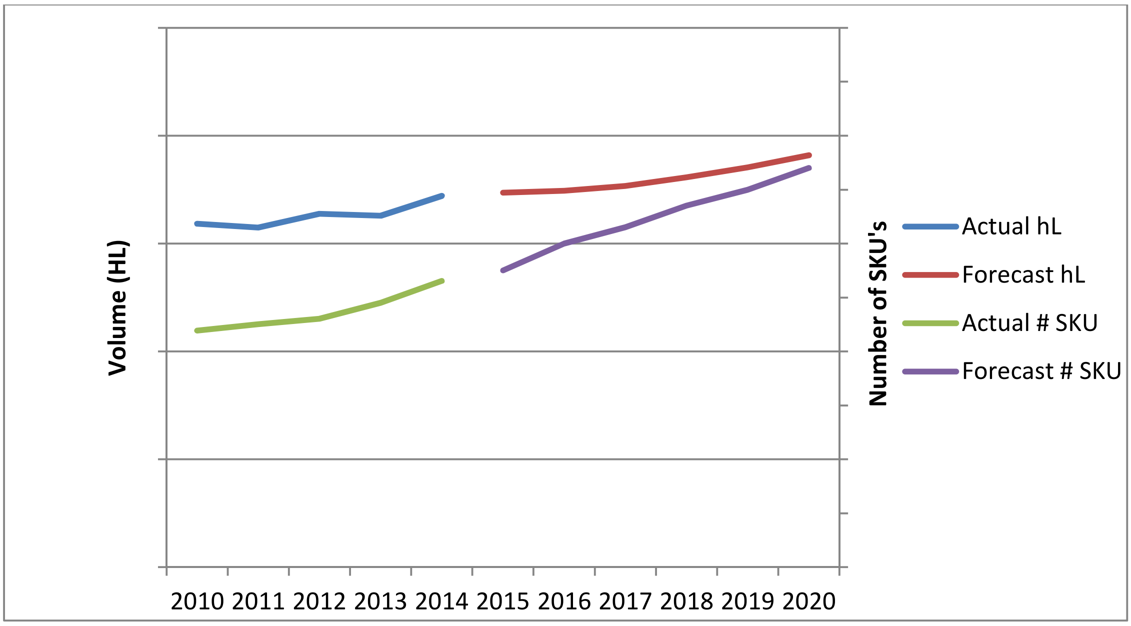


FIGURE 55: EXPECTED TREND IN VOLUME AND SKU'S FOR HNS, BASED ON (HEINEKEN CS&L, 2015)

APPENDIX 6: INPUT VARIABLES AND ASSUMPTIONS WITHIN THE LOGISTICS MODEL

For the logistics model designed in this research, four main flows are distinguished: 1) packaging, 2) co-fill, 3) co-pack and 4) inter-brewery transport. To determine the logistics impact on the warehouse per loading type for each of these flows, functional models are described in chapter 5. This appendix describes the variables and assumptions used in the model.

Pallet load per SPC

The pallet load defines the number of SPC production units per pallet, found in the HNS planning database. This number is used to translate all planned production quantities to the number of pallets (thus SKU's of one SPC):

$$Packaging\ Quantity\ [pallets] = \frac{Production\ quantity\ [units]}{Pallet\ Load\ [units\ /\ pallet]}$$

If Pallet Load = 0 or unknown, the input parameter for pallet load is used (standard set at 70 units per pallet). Pallet quantities are rounded up to the nearest number.

Loading type per SKU: two calculation alternatives

The loading type for each produced SKU is determined using historical shipment data. Per SKU is analysed how it was loaded in the past 78 weeks. This historical analysis will be updated during each monthly update of the model. As indicated in chapter 5, two options are defined to determine the loading type per SKU. These are described below.

TABLE 12: TWO ALTERNATIVES FOR DETERMINING THE LOADING TYPE PER SKU

Alternative	Description	Input variable
General	1 loading type per SKU	Largest volume % loaded per SKU
Detailed	>=1 loading type per SKU	% volume split per loading type per SKU

If an SKU is for the Dutch market, Domestic loading is always applied. If an Export SKU is not found in historical data, the 'General' alternative will use Schep loading as standard as this is the largest volume. It is however a variable in the model. The 'Detailed' alternative will use the average volume split per loading type when an SKU is not found in the historical data.

Cross-dock percentage: two calculation alternatives

The cross-dock percentage determines how much of the produced volume is directly cross-docked and loaded and therefore will not be stored in the warehouse. Two options are defined for the cross-dock percentage, described below.

TABLE 13: TWO ALTERNATIVES FOR DETERMINING THE CROSS-DOCK PERCENTAGE PER SKU

Alternative	Description
General	Cross-dock % per loading type
Detailed	Cross-dock % per SKU (historical data)

For the general cross-dock percentage calculation per loading type the following parameters are used based on 2014 data. The parameters are variables in the model that can be varied. As each SKU has already received a loading type, each SKU will also receive a cross-dock percentage based on this alternative.

TABLE 14: ASSUMPTIONS FOR GENERAL CROSS-DOCK PERCENTAGE

Loading type	Cross-dock %
Manual	0%
Conventional Truck	0%
Mechanical	90%
Schep	90%
Domestic Loading	0%

For determining the detailed cross-dock percentage per SKU historical data is used. If the cross-dock percentage of an individual SKU is not found, the cross-dock percentage is taken as a variable that is standard set at 100%, thus assuming that all volume is cross-docked.

Time in warehouse per SKU

When a packaged SKU at the brewery is not cross-docked it is stored in the warehouse for a certain period. The variable 'Time in warehouse per SKU' determines for each SKU how long it remains in the warehouse. This is based on historical data for 2014. For co-fill, co-pack and inter-brewery flows fixed parameters are assumed, as these SKU's normally remain in the warehouse for a relatively fixed period.

TABLE 15: TIME IN WAREHOUSE OF CO-FILL, RE-PACK AND INTER-BREWERY FLOWS

Flow	Time in Warehouse	Motivation
Co-fill	3 weeks	Based on historical data (2014)
Re-pack	2 week	Based on expert interview ((Berghout, 2015)
Inter-brewery	2 weeks	Based on historical data (2014)

Not for all SKU's a time in warehouse is found from historical data. Therefore, an input variable is set for these unfound SKU's on 0 weeks for Export, assuming that all non-found SKU's are cross-docked 100% and thus do not receive a time in warehouse. Unfound Domestic SKU's will receive an average time in warehouse of 2 weeks.

Co-fill: Allocation per brewery and lead-time

Currently, HNS uses four different packaging lines at third parties for co-filling. After co-filling, the packaged products are transported to either the Den Bosch or the Zoeterwoude brewery. Different lead-times per co-fill party are determined between production at the co-fill party and inflow in the brewery warehouse. Besides that, a volume allocation is made per co-fill party to each brewery. The lead-time and allocation are variables in the model and are defined in the following table, based on 2014 data.

TABLE 16: ALLOCATION OF CO-FILL VOLUME PER BREWERY

Co-fill party	Volume allocation Zoeterwoude	Volume allocation Den Bosch	Lead-time (weeks)
Co-fill 1	25%	75%	1
Co-fill 2	30%	70%	0
Co-fill 3	17%	73%	2
Co-fill 4	18%	82%	1

Re-pack volume %

The re-pack flow is not planned 78 weeks ahead. To estimate the impact of the re-pack flow in the warehouse, a volume % of the total packaging volume per brewery and market is found in historical data (2012 to 2014). These parameters are input variables in the model. The following table gives the information that is used as standard input.

TABLE 17: ASSUMPTIONS FOR RE-PACK VOLUME

Market	Zoeterwoude % of total packaging volume	Den Bosch % of total packaging volume
Re-pack Domestic	1%	1%
Re-pack Export	1,5%	5%

Inter-brewery volume %

As with re-pack, inter-brewery is not planned 78 weeks ahead so again an assumption for this volume is made. As inter-brewery is 98% Domestic volume, the volume is calculated as a fixed percentage of the Domestic volume, determined at 2% of the total volume per week based on historical data.

Warehouse efficiency

The warehouse efficiency rate determines how much of the theoretical storage capacity can be used in reality. This depends on how well the batch size of an SKU to be stored is matched with the storage location size. This efficiency is analysed in paragraph 4.2.3. The following assumptions are validated at HNS for the warehouse efficiency rates: 65% for the Export warehouse and 80% for the Domestic warehouse.

APPENDIX 7: LOGISTICS MODEL VERIFICATION USING DATA OF MAY 2015

This appendix supports the model verification in chapter 5, based on the packaging plan of May 2015. Several tests are performed to see if the logistics planning model works in the right way.

Warehouse in = warehouse out

To see if all stock that flows into the warehouse also disappears at some point in time, the total warehouse inflow is compared with the total warehouse outflow. For this test, all volume is considered to be cross-docked directly and time in warehouse of all SKU's in considered 0 weeks. The results are shown below for the first weeks of the planning horizon; it is concluded that all stock that comes in also is loaded from the warehouse.

TABLE 18: VERIFICATION OF PALLET IN- AND OUTFLOW IN THE WAREHOUSE

Week	Total In	Total Out
201523	38.728	38.728
201524	38.333	38.333
201525	38.629	38.629
201526	36.707	36.707
201527	36.397	36.397
201528	40.530	40.530
201529	35.803	35.803
201530	34.963	34.963
201531	33.441	33.441
201532	33.006	33.006
201533	31.264	31.264
201534	34.214	34.214
201535	28.479	28.479
201536	29.855	29.855
201537	27.383	27.383

APPENDIX 8: LOGISTICS MODEL VALIDATION USING DATA OF 2014

This appendix supports the model validation in chapter 5. Both stock and loading bias are calculated for this purpose, comparing the model output with the actual measurements from January 2014 until May 2015. During the bias measurements, the months January and May in a year are not considered as representative months because a large number of public holidays in these months affect the historical data.

Stock level validation

For stock levels, the bias per calculation alternative is measured by the following formula on a monthly basis, represented by a four weeks average.

$$stock\ bias\ (month) = \frac{planned\ stock\ (month) - actual\ stock\ (\ month)}{actual\ stock\ (month)} * 100\%$$

For each loading type, the four calculation alternatives (General/Detailed loading, General/Detailed Crossdock) are assessed on their stock bias. This is visualized in the figures below. A spread of 20% is allowed, either above or below the actual measured stock level. Manual loading is not taken into account as this is a very small volume, making the bias measurements irrelevant and inaccurate.

Conventional Truck Loading – Stock bias

Conclusion: Bias is quite large, but this is related to the actual stock volumes that vary significantly. The bias is therefore accepted as the Conventional Truck stock itself is unpredictable due to the uncertainty of truck arrival.

Best alternative: Detailed loading, general cross-dock

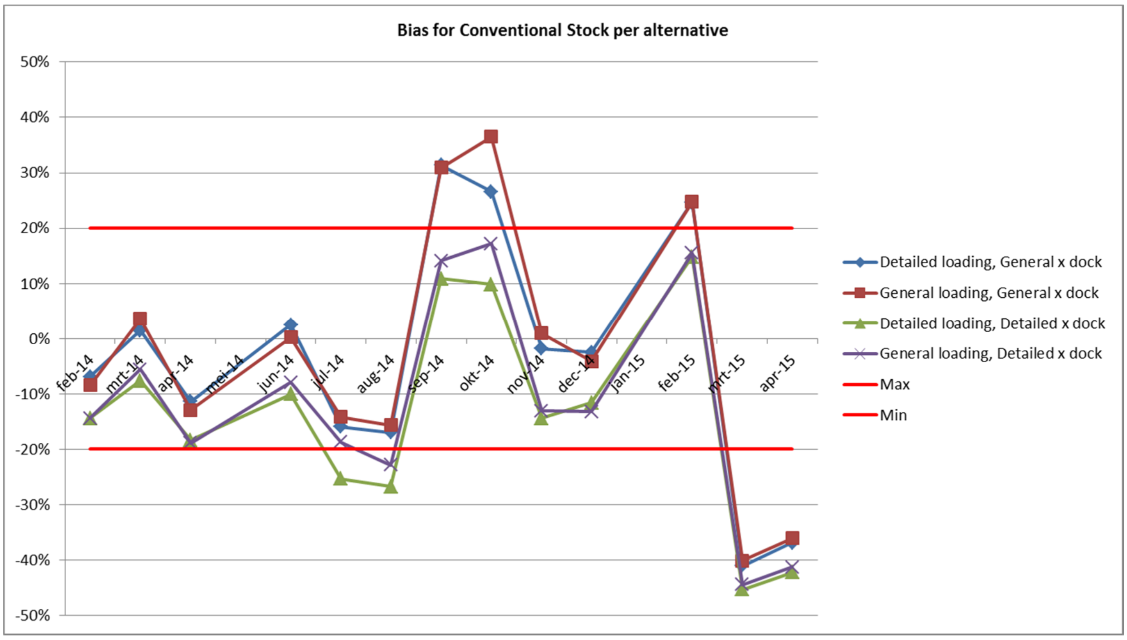


FIGURE 56: MODEL BIAS FOR CONVENTIONAL TRUCK STOCK

Mechanical Loading – Stock bias

Conclusion: Bias is quite large, but around the right size of actual measured stock volume.

Best alternative: Detailed loading, general cross-dock

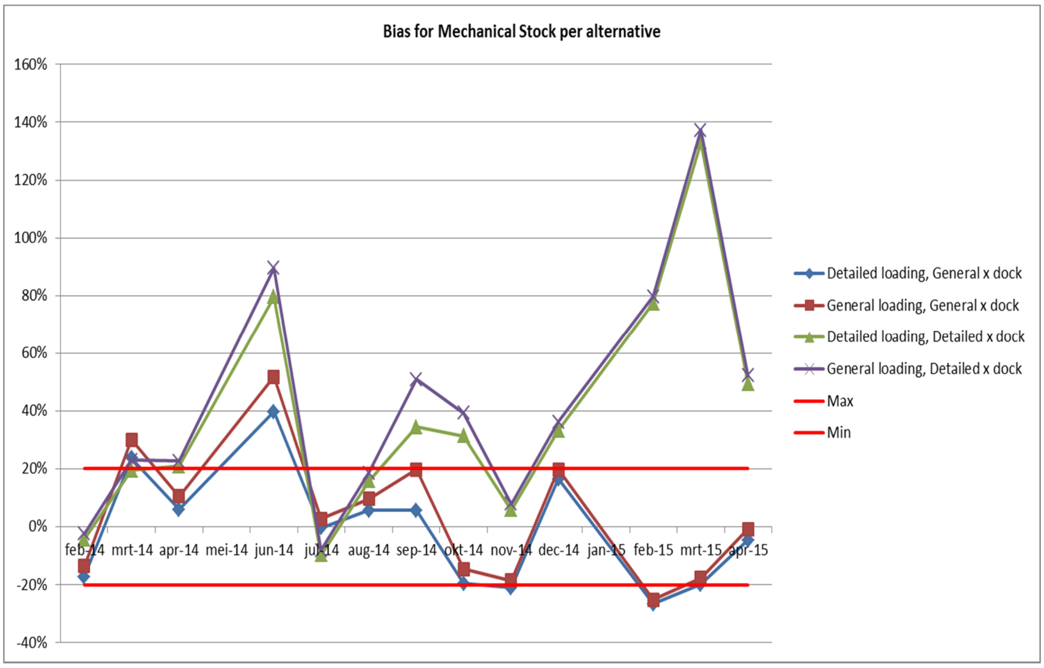


FIGURE 57: MODEL BIAS FOR MECHANICAL STOCK

Schep Loading – Stock bias

Conclusion: Bias for general cross-dock alternatives is acceptable. The detailed cross-dock alternatives predict a stock volume that is significantly too high, indicating that the cross-dock percentage per SKU does not provide an accurate planning.

Best alternative: Detailed loading, general cross-dock

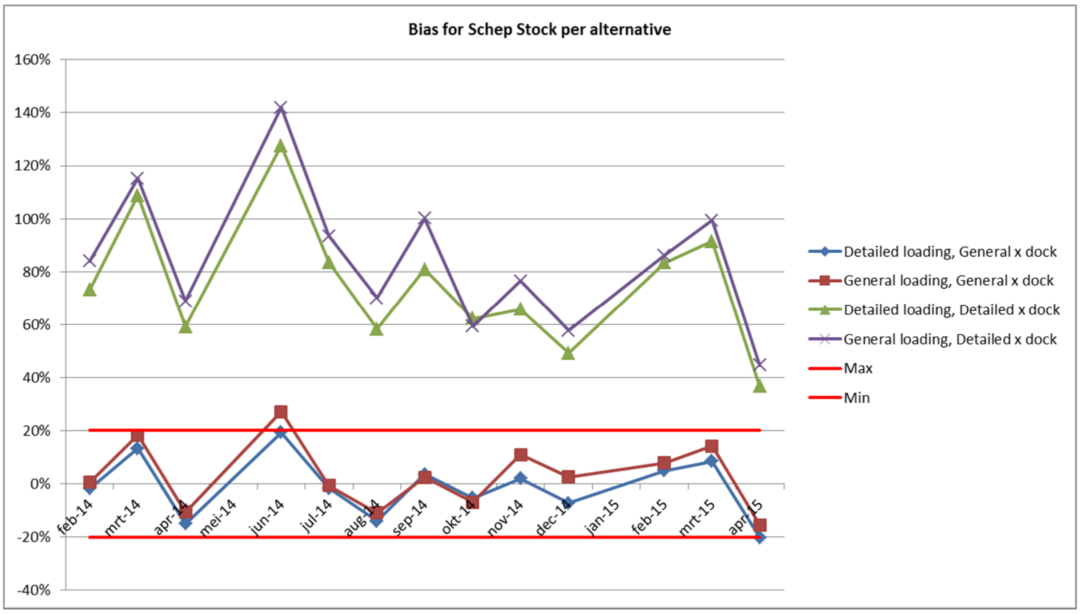


FIGURE 58: MODEL BIAS FOR SCHEP STOCK

Domestic Loading – Stock bias

Conclusion: Bias is equal and acceptable for all calculation alternatives as they all estimate the Domestic stock in the same way. Peaks in the bias result from short-term uncertainties in demand that cannot be measured with the model.

Best alternative: no difference between alternatives.

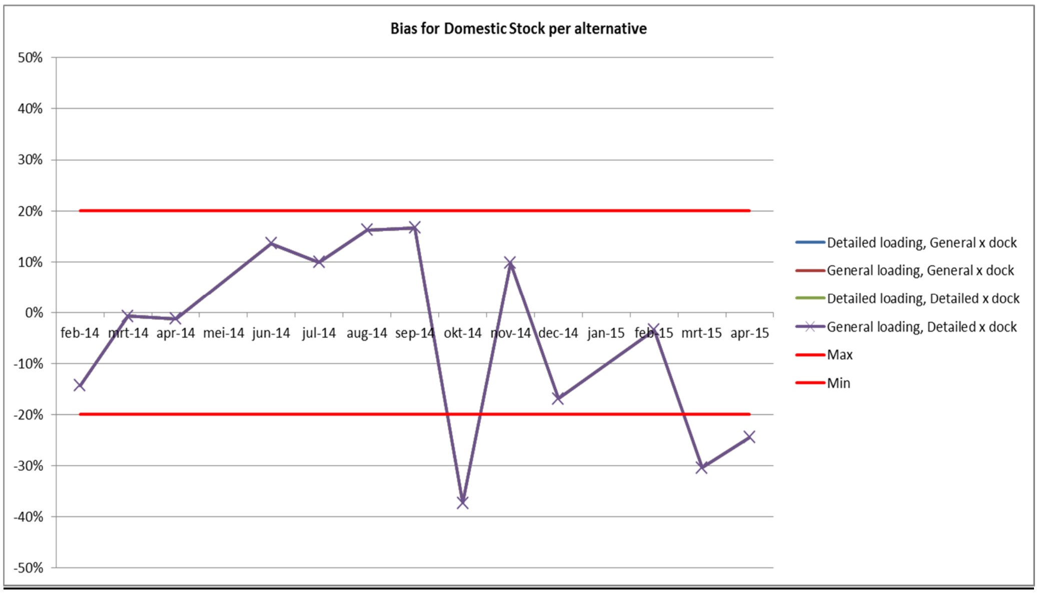


FIGURE 59: MODEL BIAS FOR DOMESTIC STOCK

Total Export – Stock bias

Conclusion: For total Export, the bias for the alternatives with 'General cross-dock' is acceptable. Large peaks are caused by deviations in the actual measured stock for Conventional Truck as this flow is hard to plan in reality.

Best alternative: Detailed loading, general cross-dock

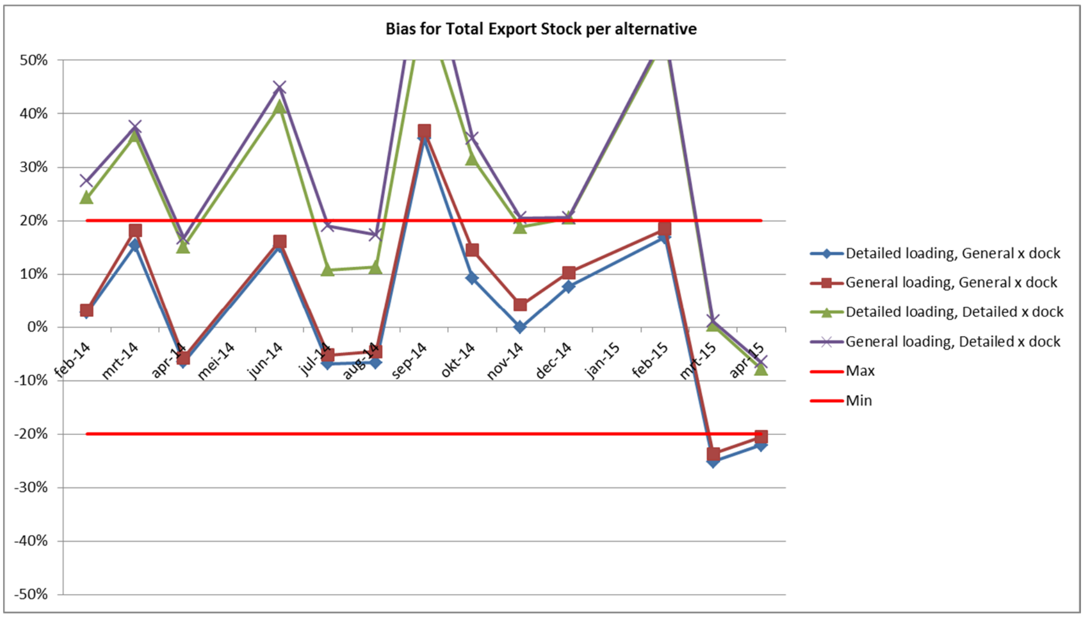


FIGURE 60: MODEL BIAS FOR TOTAL EXPORT STOCK

Load volume validation

The bias of loaded volume for each loading type is calculated similarly to the stock volume bias with the following formula.

$$load\ bias\ (month) = \frac{planned\ loading\ (month) - actual\ loading\ (\ month)}{actual\ loading\ (month)} * 100\%$$

For each loading type, the four calculation alternatives (General/Detailed loading, General/Detailed Crossdock) are assessed on their load bias. This is shown in the figures below. A spread of 20% is allowed, either above or below the actual measured load volume. Manual loading is not taken into account as this is a very small volume, making the bias measurements irrelevant and inaccurate.

Conventional Truck Loading – Load volume bias

Conclusion: Similar to stock, the bias for loading is quite large, which is related to the actual load volumes that can vary significantly. The bias is therefore accepted as the Conventional Truck stock itself is unpredictable due to the uncertainty of truck arrival within the planned week.

Best alternative: no significant best alternative measurable.

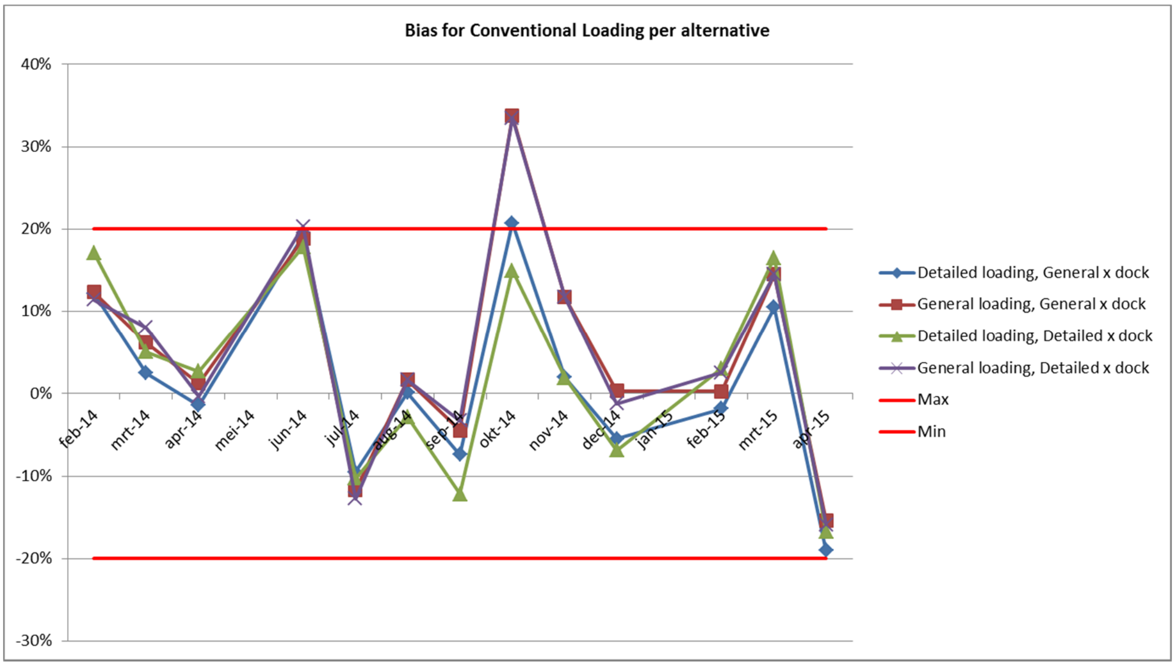


FIGURE 61: MODEL BIAS FOR CONVENTIONAL TRUCK LOADING

Mechanical Loading – Load volume bias

Conclusion: Except for "Detailed loading, Detailed cross-dock", all alternatives show a very low bias, indicating that the model provides an accurate volume planning.

Best alternative: no significant best alternative measurable.

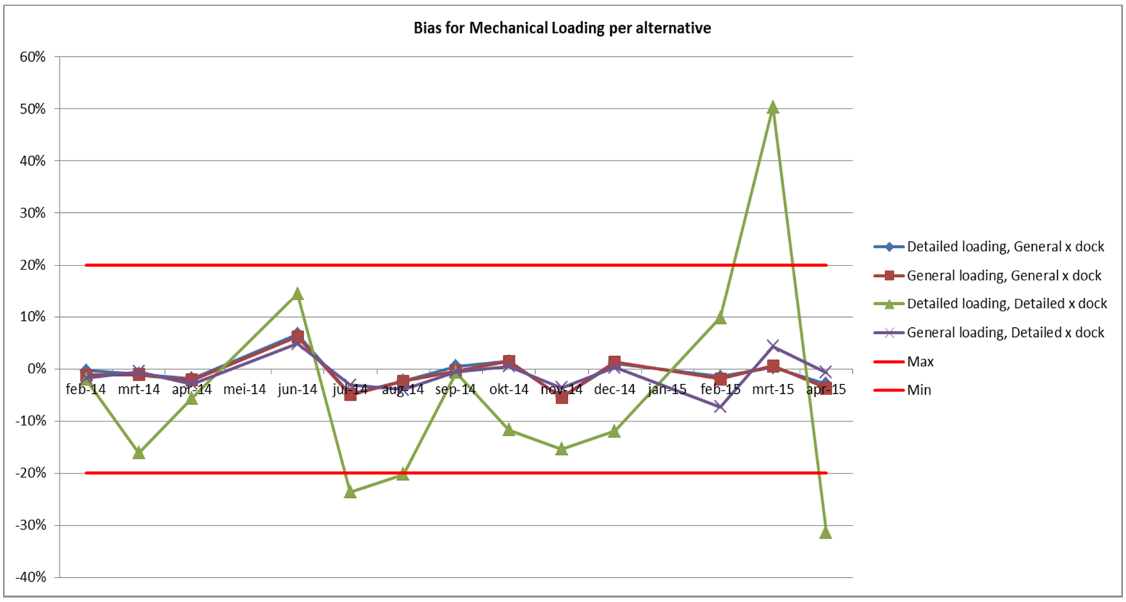


FIGURE 62: MODEL BIAS FOR MECHANICAL LOADING

Schep Loading – Load volume bias

Conclusion: Except for "Detailed loading, Detailed cross-dock", all alternatives show a very low bias, indicating that the model provides an accurate volume planning.

Best alternative: no significant best alternative measurable.

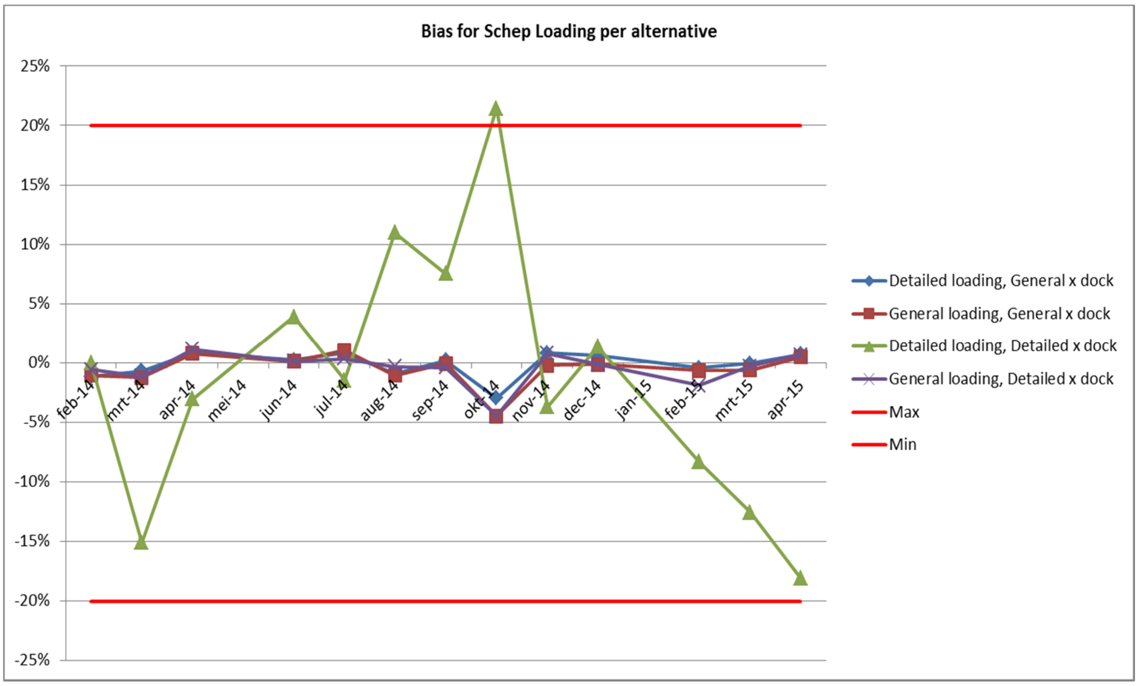


FIGURE 63: MODEL BIAS FOR SCHEP LOADING

Domestic Loading – Load volume bias

Conclusion: Bias is equal and acceptable for all alternatives as all alternatives calculate the volume for the Domestic market in the same way. Peaks result from difference in demand that cannot be measured with the model, as the model output is based on packaging data.

Best alternative: no difference between alternatives.

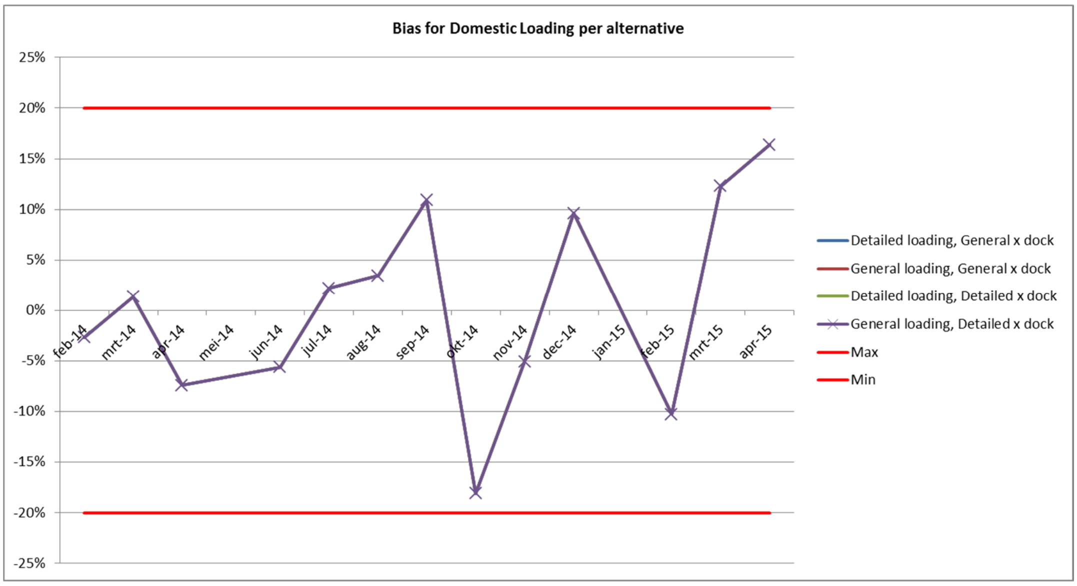


FIGURE 64: MODEL BIAS FOR DOMESTIC LOADING

Total Export – Stock bias

Conclusion: The bias for the general cross-dock alternatives is acceptable. Large peaks are caused by actual measured Conventional Truck volumes which are hard to plan in reality.

Best alternative: Detailed loading, general cross-dock

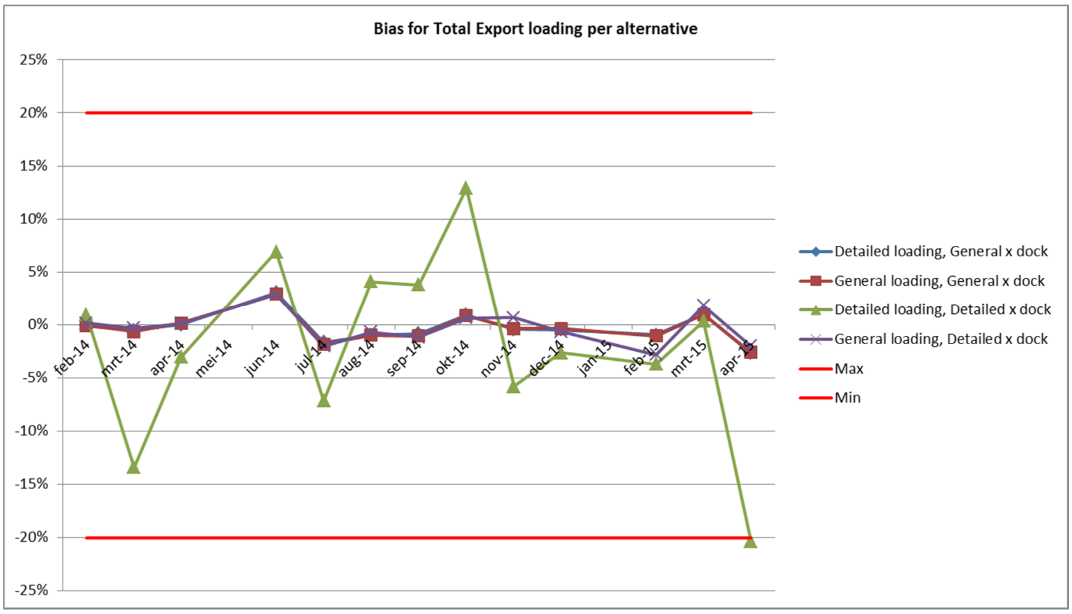


FIGURE 65: MODEL BIAS FOR TOTAL EXPORT LOADING

APPENDIX 9: DETAILED OVERVIEW OF MODEL RESULTS

This appendix shows the most important model results, supporting paragraph 5.5. A division is made between stock planning and load planning.

Stock planning

The model provides a total stock planning, thus providing the total stock demand for each loading type. This is shown below with two separate theoretical stock capacities, as in practice the Export and Domestic SKU's are stored in separate areas. As mentioned in 5.5, a division can be made in the theoretical stock capacity and the actual stock capacity, where the actual capacity accounts for warehouse efficiency. For clear reporting purposes, in the figure below only the actual capacity is shown. The warehouse efficiency rates are 65% for Export and 80% for Domestic, based on "Appendix 6: input variables and assumptions within the logistics model". From the figure below can be concluded that the total stock volume is often exceeding capacity, thereby showing the need for external warehousing. The stock volume for Domestic SKU's is the highest, resulting from the Make To Stock principle. The Domestic stock also follows a strong seasonality pattern with high peaks in the Dutch summer. Stock for Export is mainly resulting from Conventional Truck volume, with also high peaks in the summer.

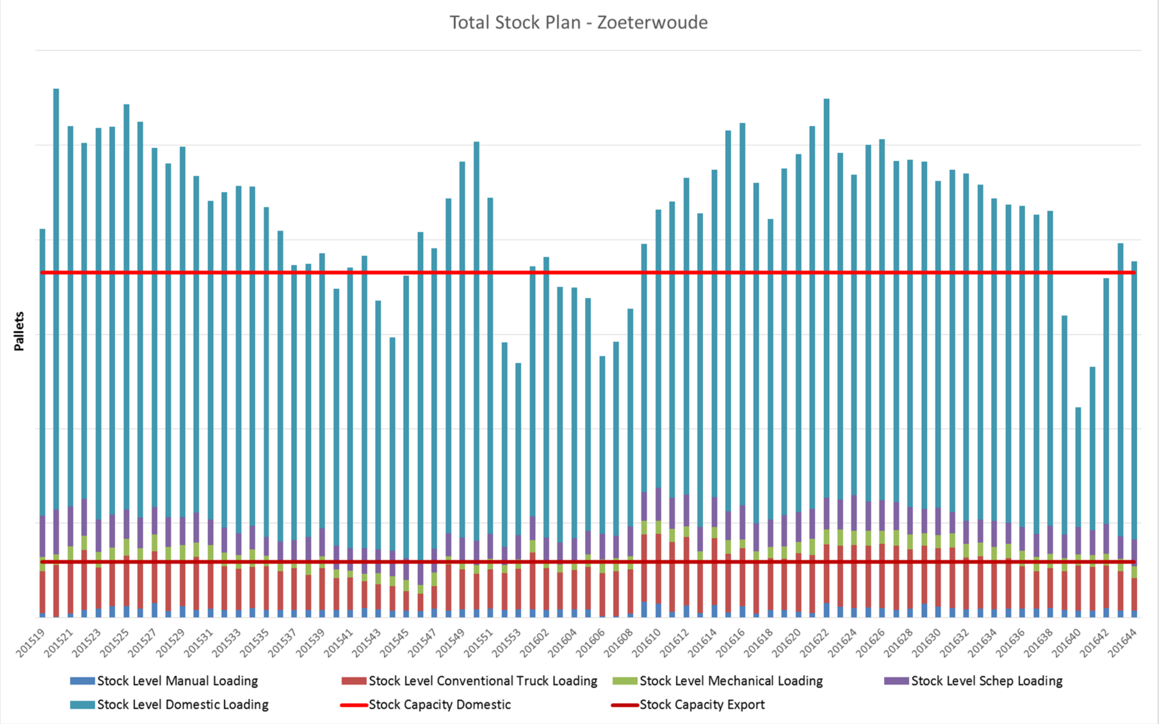


FIGURE 66: MODEL OUTPUT: TOTAL STOCK PLANNING FOR ZOETERWOUDE

Because the warehouse at Zoeterwoude is currently split up in a Domestic and Export area, the following graphs show a detailed stock planning for both areas. From Figure 67 can be concluded that stock for the Domestic market has a strong seasonality pattern, with high peaks in the summer and during the Christmas period. During these periods, stock levels can even reach volumes above the theoretical capacity. External warehousing will therefore be needed.

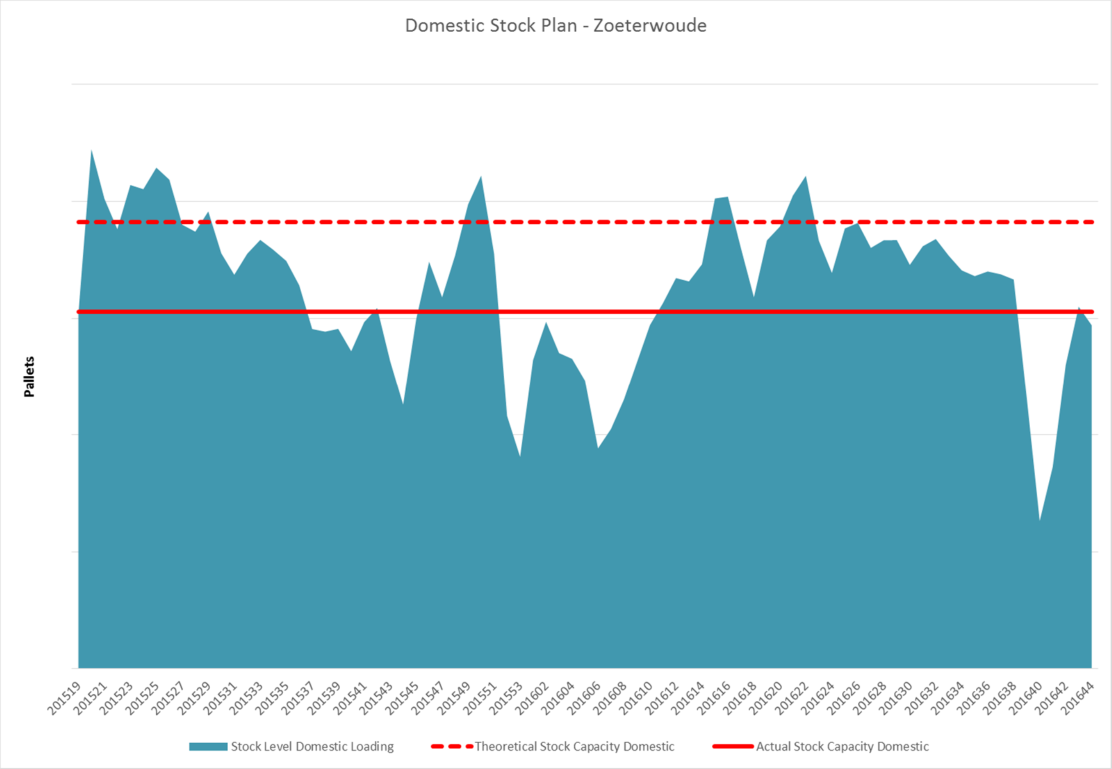


FIGURE 67: MODEL OUTPUT: STOCK PLANNING FOR DOMESTIC SKU'S

The graph representing Export stock levels by loading type is shown in paragraph 5.5. The graph below shows the total Export stock planning together with the cross-dock percentage. It can be concluded that the expected stock in the warehouse is inversely proportional with the cross-dock percentage; a week with a low cross-dock percentage results in higher stock levels.

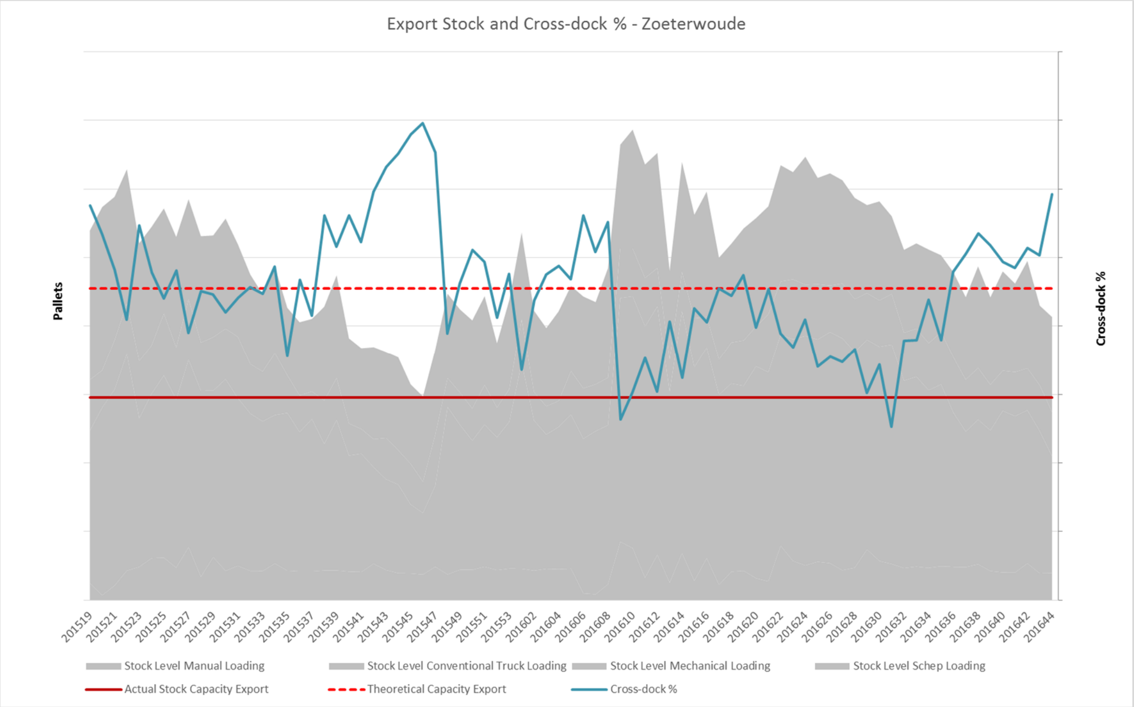


FIGURE 68: MODEL OUTPUT: EXPORT STOCK PLANNING AND CROSS-DOCK PERCENTAGE

Load planning

The model output for Domestic loading is shown in Figure 69. The load planning by loading type for Export is shown in paragraph 5.5. A strong seasonality pattern can be seen in the figure below, resulting from increased Domestic demand in the summer.

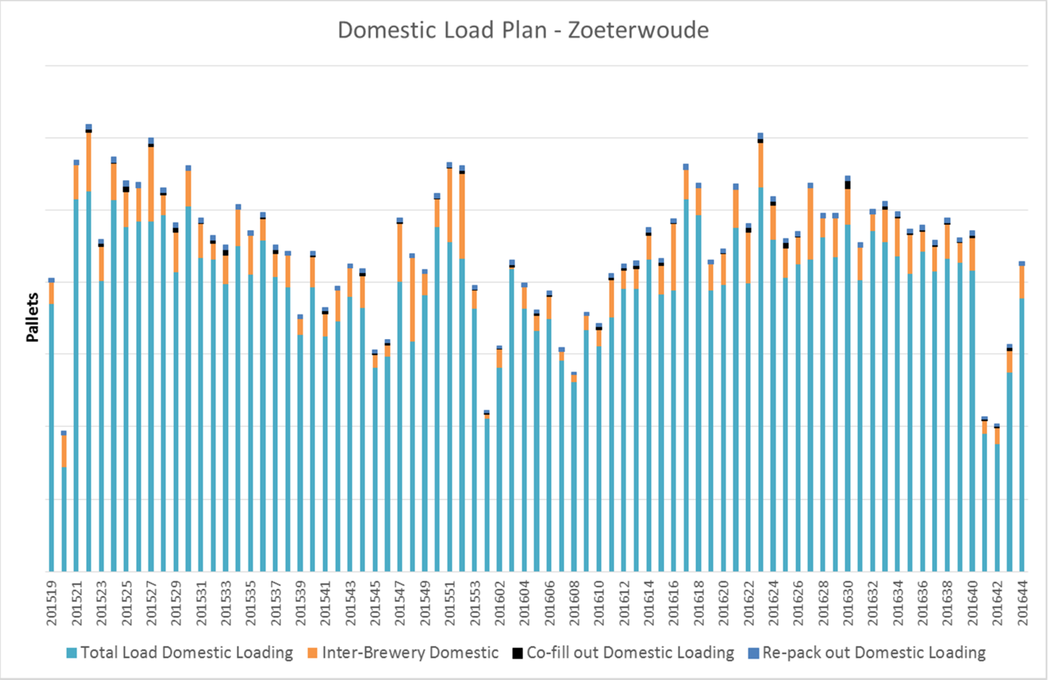


FIGURE 69: MODEL OUTPUT: LOAD PLANNING FOR DOMESTIC SKU'S

Figure 70 shows the planned incoming volume from third parties that will be unloaded from trucks into the warehouse (co-fill, re-pack and inter-brewery). Inter-brewery for Domestic SKU's is the largest volume, also showing a seasonality pattern.

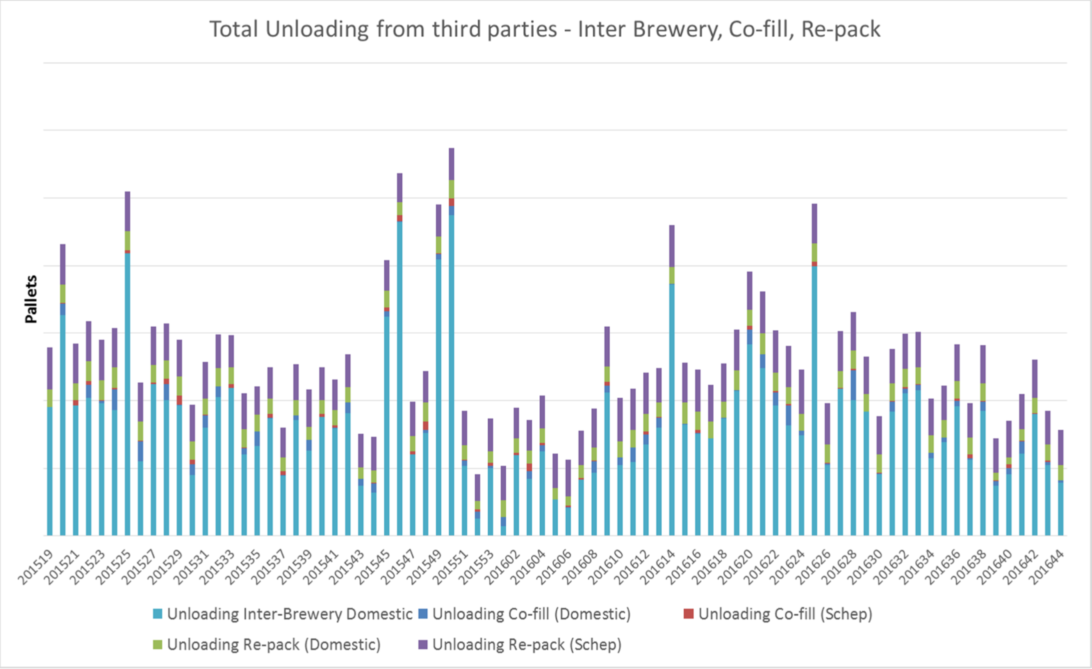


FIGURE 70: MODEL OUTPUT: PLAN FOR UNLOADING FROM THIRD PARTIES

APPENDIX 10: MODEL VARIABLES TO CHANGE FOR DEN BOSCH

This paragraph will describe the variables in the model that need an update when the model is implemented for the brewery at Den Bosch. Most of the variables in "Appendix 6: input variables and assumptions within the logistics model" will need an update as is shown in the table below.

TABLE 19: MODEL VARIABLES TO CHANGE FOR APPLICATION AT DEN BOSCH

Input Parameter	Description	Source
Packaging Plan	The 78-week packaging plan for all Den Bosch packaging lines	HNS Planning database
Loading type per SKU	The different loading types available per SKU	Shipment history for Den Bosch (78 weeks)
Cross-dock % per loading type	The different cross-dock % available per loading type	Logistics database Den Bosch
Time in warehouse per SKU	The average time in weeks that an SKU remains in the warehouse	Logistics database Den Bosch
Warehouse capacity	Storage capacity in pallets	Logistics database Den Bosch
Loading capacity	Loading capacity in pallets per hour	Den Bosch Logistics department
Re-pack %	Assumption for the re-pack volume, as a percentage of the total packaging volume at Den Bosch	Shipment history for Den Bosch (78 weeks)
Inter-brewery %	Assumption for inter-brewery, as a percentage of the total packaging volume at Den Bosch	Shipment history for Den Bosch (78 weeks)