MASTER

Improving retail product freshness of perishable goods with strategic distribution flow management
a design for Hollander Barendrecht

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Improving retail product freshness of perishable goods with strategic distribution flow management: 
A design for Hollander Barendrecht

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Abstract

This report describes the design, input and results of a model that explores what type of distribution flow type increases the retail product freshness in a perishable goods supply chain. The model evaluates different flow types in a perishable goods supply chain with one supplier and a central warehouse that supplies multiple stores. The model is based on several types of distribution flow elements which include information sharing and inventory allocation policies in the supply chain, under service level restrictions in the stores. Moreover, a business case at Hollander Barendrecht provides insights on how the distribution flow types perform, and for which type of products and stores the design is most beneficial. Furthermore the business case shows which adjustments are necessary in an existing supply chain in order to achieve the benefits of the suggested design.
Management Summary

The first chapter of this report serves as an introduction for my master thesis project that has been performed at Hollander Barendrecht BV (in sequence HB), a subsidiary of the Greenery which is a large company based in Barendrecht with a main focus on fruits and vegetables. HB is a logistics service provider that supplies perishable goods to over 270 stores of PLUS retail in the Netherlands. The daily operations of HB consist of the inbound logistics, inventory management, order picking and shipment of perishable goods to PLUS stores.

Problem statement
The supply chain in which HB operates is one of a kind in the Netherlands. HB acts as a central distribution centre (DC) for perishable goods that supplies 272 stores at the time of writing. Unlike many other perishable goods DC’s in the country the DC is not owned by the super-market chain itself. For PLUS stores, there is no central automated store order system that is used to replenish stores yet, leading to a varying demand pattern. This challenge can partially be overcome by keeping stock in the DC. However, the products at HB are perishable which means that the products become obsolete and cannot be used after a certain period of time (Prastacos, 1981). HB however has the ambition to become a more sustainable organisation and reducing waste is one of the challenges.

Besides availability, freshness of perishable products is also an important attribute. Since consumers wish to buy the product with a shelf life as long as possible, unnecessary loss of this shelf life in the supply chain will reduce the perceived product value of the customer (Tsiros & Heilman, 2005). It is therefore important that the perishable goods HB supplies to stores have maximum retail product freshness, which is defined as the freshness of the product at the moment of purchase in the store. Increasing retail product freshness can be achieved by either: 1) Increasing the product lifetime, by means of packaging methods or other adjustments in the processing of the product, or 2) decreasing the time the product spends in the supply chain before it gets to the store. The focus should go toward solving the second problem. Multiple stock points within the supply chain exist in the current situation and in order to reduce the time spent in the supply chain, eliminating or reducing stock could be a solution. The main focus should be on how HB can influence the performance of the supply chain by managing the flow of the perishable goods. The contribution of this model based research project is therefore to find the potential freshness gains by redesigning the distribution flow of the perishable goods, under a store service level constraint.

The most important question raised by the company therefore is:

“How should the flow of perishable goods be managed by the central DC, to improve retail product freshness?”

Research directions
Given the problem statement, the research directions for resolving the problem were determined. Combining existing supply chain structures and supply chain cooperation possibilities led to a few scenarios that were explored in the research.

The most basic distribution flow is the one shown in Figure 1. In this supply chain the stores place orders at HB and HB replenishes the stores from their stock. HB orders their goods at the DC suppliers who make the goods to stock. The system can be described as a classic pull driven system were each upstream actor waits with replenishment until the preceding actor orders. For the store, DC and supplier it holds that whenever stock is insufficient to fulfil demand, no backorders are in place. No specific information sharing structures are used.

The next supply chain structure is similar to the previous one but here information sharing is in
place. The stores use the EWA replenishment policy (Broekmeulen & van Donselaar, 2009) to order goods at the DC. This policy corrects the store inventory position for estimated outdating to determine the order size. Furthermore the stores share their information with the DC. This way in case of stock outs, the DC can use an allocation rule to determine how many goods the store will receive. The supplier also receives information of the forecast from the DC and makes the products to stock (MTS) for HB based on this forecast. Furthermore the supply can be synchronised with the production schedules of the supplier to ensure a maximum product freshness. This distribution flow is shown in Figure 2. Again, all demand is lost after stock outs occur.

A further possibility in scenarios is the make to order (MTO) policy for the supplier. Here the supplier does not keep stock and produces the exact amount of products that HB orders. This means that the start of production is synchronised with the order placement. This leads to maximum availability and freshness. The data between retail outlets and DC are shared and this is the basis for the forecast that is made for the supplier order. Again, the stores order using the EWA-replenishment policy. In this flow the lost sales environment in case of stock outs also holds. This last research direction is shown in Figure 3. The allocation rule, production and replenishment synchronisation and the production strategy (MTS/MTO) are seen as the distribution flow elements that together make the supply chain scenarios.

Analyses and modeling
In order to construct a model to simulate the events for the different distribution flow elements, the current methods were analysed and a sample set of products was selected from HB’s assortment that are delivered in bulk by the supplier and are kept in stock at the DC. The products were selected based on their shelf life, case packs size and the amount of time they have been in the assortment of HB. The products within the final sample set of 7 products were dairy or deli meat products. Furthermore the customer demand for these 7 products was approximated with use of the store demand data at the DC. The selection of stores that had the full sample set of products in their assortment led to a store sample of 56 stores. The stores were modelled using the EWA-replenishment policy (Broekmeulen & van Donselaar, 2009) as replenishment strategy with a standard lead time equal to 1 day and for the DC using a \((R,s,nQ)\) replenishment policy with a lead time equal to 1 day. The allocation rule that was used in case of out of stock situations in the DC was either sequential (based on the sequence of ordering) or based on runout
times. The runout time is determined by taking the inventory level of the store and dividing it by the average customer demand per day and gives the expected amount of time the store can last with their current inventory. Fastest runout will receive allocation first by the DC, and all available DC inventory will be allocated this way in case of shortages. The production at the supplier is modelled different for two policies. The MTS policy is realised by sharing the forecast generated by the DC with the supplier. Furthermore synchronisation between the DC and the supplier depends on the review period in the DC ($R_{DC}$) and the production interval of the supplier $R_P$. When $R_{DC} = R_P$ the order and supply is synchronised, leading to maximum freshness. When products are produced on a MTO basis, the supplier receives the order from Hb just before production and will produce the exact amount and ship this to the DC. The simulation is programmed in the Visual Basic for Applications programming language and a Microsoft Access database is used to run the simulation and generate the results.

**Results**
The outcomes of the supply chain simulations for the different scenarios provided an overview of the effectiveness of the distribution flow elements. The results were compared to a baseline scenario were no inventory allocation was in place, production was done on a MTS basis and the production and replenishment was not synchronised. The results for inventory allocation based on runout times indicated that the stores were able to realise the 95% service level restriction that was set for the experiment whilst lowering the reorder level at the DC. For all but one SKU this resulted in a relative increase in freshness (absolute increase was very low), but the system waste (stores, DC and supplier combined) decreased for all products as well as the average inventory in the DC. For the production and replenishment synchronisation the effects on the retail product freshness were very limited (at maximum 1.4%). Average DC inventory increased due to taking in the inventory for multiple days at once, and waste remained about the same for most SKUs. A make to order strategy showed the best results for single element performance. The MTO provided freshness increases of up to 9.5%
The combination of the distribution flow elements however, showed to be the most beneficial for the retail product freshness. The scenario that provided the greatest increase in retail product freshness was the same for all products. In this scenario the DC uses runout based allocation, products are made to order, supply is synchronised and DC service level is lowered. For this scenario the following results were achieved by the suggested design:

- The average amount of order lines for the DC decreased or remained the same (0% to -50%)
- Average DC inventory went down (-10% to -81%)
- The relative waste of the system was reduced for all SKUs (87% to 99%)
- Retail product freshness was increased for all SKUs (1% to 14%)

**Recommendations**
The most important recommendations for HB is to involve all supply chain actors in the realisation of the suggested scenario. Since the retail product freshness can be improved by means of collaboration and synchronisation of the events in the supply chain it is suggested that HB persuades all involved stakeholders to accept and embrace the new design, since all stakeholders will benefit from the suggested scenarios when the focus is shifted from optimising local performance to supply chain wide performance.
Preface

This report is the result of my master thesis project, which is the final requirement for my master’s degree in Operations Management and Logistics at the Eindhoven University of Technology. It thereby also marks the end of my time as a student. A time in which I have gotten to know lots of new people, have lived in three new cities and attended a lot of memorable events. It was also the time in which I have been able to develop myself on an academic, professional but also on a personal level. The accumulation of these learnings over the years made it possible for me to successfully perform the thesis project from March until October 2016 at Hollander Barendrecht B.V.

Before I present the findings of my research project I would like to thank everyone who made this project possible. First of all my thanks to Peter van de Voorde, my supervisor at HB for all the time and effort and especially the enthusiasm with which he supervised the project. His feedback and ideas throughout the project have been very helpful and it was of great support to see that the outcomes of the research were well received. Additionally I would like to thank all the other employees who provided new insights during a meeting or who took the time to help me gain a better understanding of the organisation.

Furthermore I would like to thank my first supervisor, Rob Broekmeulen who has provided excellent guidance throughout the project. His knowledge about, and enthusiasm for the retail sector has helped me in many ways. Whether it were some new insights regarding the research project, or just one of our numerous conversations about the retail industry and its development. He was always able to send me off with a renewed sense of excitement for the project.

I would also like to thank my second supervisor, Marco Slikker for his valuable feedback on my research proposal and the concept version of my report. My thanks also go out to Rik Eshuis, for getting on board with the project on a short notice in the final phase.

Lastly I would like to thank my family, girlfriend, friends and fraternity for their support and most of all for the good times I have had with them over the course of my student life.

Maurice Wijshoff

Barendrecht, October 2016
List of Abbreviations

ASO  Automated Store Ordering
BIS  Business Information System
CPFR  Collaborative Planning, Forecasting and Replishment
CU  Consumer Units
DC  Distribution Centre
FCFS  First Come First Serve
FEFO  First Expired First Out
G&A  Goods and Assortment
HB  Hollander Barendrecht
IT  Information Technology
KPI  Key Performance Indicator
MTO  Make To Order
MTS  Make To Stock
OOS  Out of Stock
PSL  Shelf Life just after Production
PTZ  Pick to Zero
RFID  Radio Frequency Identification
RPF  Retail Product Freshness
SKU  Stock Keeping Unit
SLA  Service Level Agreement
SSL  Store Shelf Life
VMI  Vendor Managed Inventory
WMS  Warehouse Management System
XD  Cross dock
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1. Introduction

The first chapter of this report serves as an introduction for my master thesis project. It will provide some information regarding the history of the company, the research context and the motivation for this study. The problem statement will be introduced and the further outline of the report will be provided.

1.1 Company description

Located in Freshport Rijnmond, one of the biggest fruit and vegetable business areas of the Netherlands, is Hollander Barendrecht B.V. (HB). A company founded by Siem den Hollander as a fruit and vegetable vendor in Rotterdam that has grown out to supply more than 270 stores in the Netherlands with fresh produce every day.

After starting as a fruit and vegetable vendor, the company noticed the strong growth of the sales share of fruits and vegetables in supermarkets during the 1970’s and decided to tap into this developing market segment. They started to supply stores and during that period of time continued expanding their client base. Over time however, their main client became Plusmarkt supermarkets. The further growth of sales and the upcoming importance for supplying supermarkets led to a new phase for HB and in 1993 Hollander moved its operations to a new site in Barendrecht. While HB continued its operations from the site in Barendrecht, in 1996 a group of Dutch auctioneers of fresh agricultural products together with the Dutch Central Bureau of Horticulture-auctioneers decided to merge and form The Greenery BV (The Greenery, 2016). Within a year’s time HB became a subsidiary of this newly formed marketing and sales organisation that was also located in Barendrecht. In the years that followed after the formation of the Greenery, Hollander's most important customer Plusmarkt also continued growing. In the year 2001 the supermarket chain transformed into the cooperation of entrepreneurs that was called PLUS supermarkets from that point on. With PLUS as their biggest client, HB decided to completely dedicate their operations to the retailer in the year 2003 as a service provider for (semi-) fresh products.

The pinnacle of the cooperation between the three firms was the decision to build a brand new distribution centre for fresh and semi-fresh goods at Freshport Rijnmond. This modern distribution centre now supplies about 270 PLUS stores in the Netherlands with perishable goods. An additional element that gained importance within the operations of HB became the logistics of perishable goods. Since they were now a logistics service provider that delivered directly to the stores, HB started using their own fleet of vehicles. For current operations shipment to the stores is done partially with its own vehicle fleet, and partially contracted (Hollander Barendrecht, 2016). On an annual basis HB handles about 59.1 million case packs of fresh produce (Deloitte Accountants, 2016).

The company currently employs about 170 permanent employees in office, logistics and warehouse. An additional workforce of near 150 employees work on flex basis to provide some means of flexibility for order-picking.

Over time Hollander has thus been able to keep up with market transformations and has aimed to play an important role in their supply chain, whether this was as a fruit and vegetables vendor, wholesaler or logistics service provider of perishable goods. Their vision for the near future is to be the most sustainable perishable goods service provider in the country by the year 2020.
1.2 Research context and motivation

Over the past years HB has developed a vision for the future in which they want to achieve a number one position in the field of logistic service providers for the perishable goods market. The goal is to be the leading player in the market when it comes to sustainability. Combined with their mission to provide the best service in an innovative way, exploring new possibilities to do their business is an ongoing process. Combining the need for sustainability and innovativeness with the success of previous projects performed at the company (Kock (2015); Gerkbecks (2014)), the company was interested in performing another research project. The research was intended to build further upon the results of the previous projects and to fit within the strategic direction the company set out to follow. The idea to find a structure to improve the freshness of products they deliver to their customers, which would lead to a waste reduction in the supply chain as a whole seemed to fit within these boundaries, as well as within the personal belief of the researcher that the industry should move towards a lower level of food waste.

1.3 Problem statement

As stated in the brief introduction above, HB supplies about 270 supermarkets of PLUS. They deliver goods to the stores and since HB dedicated itself to PLUS, they do not supply goods to any other clients. HB has a wide range of suppliers, which are selected beforehand by PLUS retail. Even though PLUS is HB’s sole client, this does not mean that Hollander is the only supplier of (semi-) fresh goods to the stores. Since the entrepreneurs that own the shops have the freedom to source locally, this offers a small degree of competition for HB. The simplified supply chain of HB is displayed in Figure 4.

![Figure 4: Simplified overview of the perishable goods supply chain at HB.](image)

The supply chain in which HB operates is one of a kind in the Netherlands. HB is completely dedicated to PLUS supermarkets and since they supply stores from one location, they therefore act as their central distribution centre (DC) for perishable goods. Unlike many other perishable goods DC’s in the country, the DC is not owned by the supermarket chain itself. It remains a separate company that provides service to the cooperation of PLUS entrepreneurs who own the stores. Another special feature in the supply chain is that since these supermarkets are being managed locally, the replenishment decision for perishable goods is also made locally. There is no central automated store order system (ASO) that is used to replenish stores yet. This generates an additional challenge for HB because they have to deal with orders that are made manually and are adjusted by the store clerks. This means that the orders received are based on subjective judgement, instead of an order amount that would have been generated automatically.

This challenge is partially covered by the DC through keeping more products in stock. However, the products at HB are perishable, which means that the products become obsolete and
cannot be used after a certain period of time (Prastacos, 1981). Being an actor in a perishable goods supply chain therefore includes the risk of generating wasted products. For HB waste is considered to be those products that do not have the minimal remaining lifetime that the downstream supply chain actor (PLUS supermarkets) can accept. As mentioned before it is the ambition to become a more sustainable organisation and reducing waste is one of the challenges. The amount of waste in the DC is at a relative low level at the time of writing, but nevertheless can be improved. Especially in periods that include holidays the waste is higher than average. An overview of fluctuation in the waste level during 2015 is shown in Figure 5.

Since HB is a logistics service provider for PLUS, their desire is to be of added value in the supply chain of their customer. Keeping inventory at the DC in order to be able to replenish stores is one of the services that HB currently provides for PLUS, even if it is at the cost of creating waste. The relation between waste and service level has been researched extensively and eliminating waste completely whilst maintaining the same service level is not manageable. Besides availability, freshness of perishable products is also an important attribute. Since consumers wish to buy the product with a shelf life as long as possible and unnecessary loss of this shelf life in the supply chain will reduce the perceived product value of the customer (Tsiros & Heilman, 2005). It is therefore important that the perishable goods HB supplies to stores are as fresh as possible, or put in other words: have maximum retail product freshness. Increasing retail product freshness can be achieved by either:
1) Increasing the product lifetime, by means of packaging methods or other adjustments in the processing of the product, or 2) decreasing the time the product spends in the supply chain before it gets to the store. Since HB does not process the products or adjusts the way the products are packed, the focus should be shifted toward solving the second problem. Multiple stock points within the supply chain exist in the current situation, being the one at the supplier, the stock at DC and the stock on the store shelves. In order to reduce the time spent in the supply chain, eliminating or reducing stock points could be a solution for HB in order to achieve improved retail product freshness, and thereby also possibly reduce the amount of waste. Considering the fact that HB wants to be an essential link between supplier and the stores, the main focus should therefore be on how they can influence the performance of this supply chain by managing the flow of the perishable goods. The contribution of this model based research project is therefore to find the potential freshness gains by redesigning the distribution flow of the perishable goods, under a store service level constraint. Moreover, the company strives to reduce waste and improve the performance of the supply chain as a whole.
The most important question raised by the company therefore is:

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“How should the flow of perishable goods be managed by the central DC, to improve retail product freshness?”
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1.4 Report structure

In this first chapter the company and its background have been described, as well as the motivation for this study. Furthermore, the problem statement was introduced. The second chapter will provide an overview of the perishable goods that HB handles and the supply chain in which this takes place. Chapter three will provide a literature overview in which a theoretical background is given on relevant themes. The chapter also contains the research question and the related subquestions and together with the research methodology it will provide a clear view on the research assignment as whole. Chapter four contains the analysis of the current situation and the description of the product and store selection. The fifth chapter gives an overview of the simulation model and the underlying concepts that are used for the simulation. The next chapter provide the numerical results for the tested scenarios and is followed by a chapter with implementation suggestions. The final chapter contains the conclusions and discussion of the research project.
2. The perishable goods supply chain of HB

This chapter contains an overview of the perishable goods supply chain of HB. It will provide an overview of the core activities of HB and the way products are handled and prepared for shipment to the store. The difference between the products in the assortment will be explained as well.

2.1 Perishable goods at HB

The goods that HB supplies to PLUS stores are all fresh products, which means they become obsolete after a certain specified period of time or unacceptable for consumption when the lifetime of the product is reached. They therefore have to be stored under certain ambient conditions in the DC, in order to prevent rapid deterioration. A classification of perishable products based on their lifetime is given by van Donselaar et al. (2006). They classify perishables with a lifetime shorter than 10 days after production as days fresh products, and products with a lifetime between 10 and 30 days after production as weeks fresh products. Both categories are included in this research assignment. Since lifetime is limited after production, the products that are delivered to the DC and subsequently to the stores have restriction on the remaining lifetime that is accepted by the supply chain actor further downstream in the chain. Products that arrive at the DC need to have a certain remaining lifetime, which is specified for each product. The product then has to be shipped to the stores with a second specified remaining lifetime, and the time between the two is the maximum amount of time the product can spend in storage at the DC. In July 2016 the amount of products that HB had in their assortment was 2822. The assortment at HB consist of fresh fruits and vegetables, dairy products, cheese, fresh meat or meat substitutes, fresh fish, fresh deli meats, processed (cut) fruits and vegetables, fresh yellow fats, fresh salads and fresh prepared meals.

2.2 Perishable supply chain network

The perishable products that are available to consumers in PLUS supermarkets are made by a wide range of companies. Whether they produce, process or consolidate products as their main activity, all of these companies fulfil the role of supplier to HB. Altogether, these 295 suppliers have to deliver their goods to the DC in Barentrecht. The way these goods are handled at the DC is different for several types of products. The assortment of perishable products at HB can therefore be categorised based on the way the product is handled in the DC. The flow of goods in the perishable supply chain for HB is shown in Figure 6.

![Figure 6: Supply chain network of perishable products at HB.](image-url)
Figure 7 shows the categorisation of the assortment of HB. Category 1A contains the products that are kept in stock at the DC and are delivered in bulk by the supplier. These bulk products arrive on pallets\(^1\) and are placed in a designated storage location in the warehouse, and these products are allowed to be kept in stock for more than one delivery cycle (in which all store orders are picked for that day). Category 1B contains the goods that are delivered in bulk but are not intended to be kept in inventory for more than a cycle and hence inventory should be depleted after order picking for that cycle. This is called the pick to zero (PTZ) category. For the supplier this means that they assemble an order for the aggregate store demand and load it onto pallets. These pallets are then sent to HB where they are put in a fixed location in the warehouse and the order pickers take the separate store orders from these pallets. Since this concept assumes that the supplier delivers the exact amount of products for all stores combined, the inventory of these products will be zero after order picking at HB, hence the term PTZ. The aforementioned categories are both sub-categories of bulk goods (category 1).

Category 2 of HB’s assortment contains all cross dock products. The term ‘cross dock’ (XD) as used by HB can best be described as stated by Shakeri et al. (2010): “Cross docking is a strategy that involves receiving product from a supplier or manufacturer for several end destinations and occasionally consolidating it with other products for common final delivery destinations.” For HB these goods are picked on store level by the supplier and put on a roll-container or dolly. When the store order is too small to sufficiently load a container, several small orders are consolidated and loaded onto one container. These are shipped to Hollander where they are unloaded in the expedition area: store specific containers are moved directly to the matching expedition location and the consolidated category is first split to store level and then (together with any other small amounts of XD products for that store) put on another load carrier and moved to the matching expedition location. From here on the goods are shipped to all of the 272 stores throughout the country by truck.

2.3 Logistic network operations

In this section the logistic operations and main activities of the supply chain actors within the network of HB will be described in order to gain a better understanding of how the physical flow of products from supplier to consumer takes place.

Order arrivals

The PLUS stores are replenished by Hollander in two time frames, a morning delivery and an afternoon delivery. Each store is replenished at least once a day, but may be replenished during both time frames. Note here that stores can only receive a certain assortment group once per day. This means that stores that receive two deliveries per day have products of some assortment groups in their first shipment and receive the products of other assortment groups

\(^1\)For an example of the different types of load carriers used at HB, see Appendix A.
during their second shipment. All assortment groups combined make up the entire assortment of HB, and each of the assortment groups can be placed within one of the categories mentioned in Figure 7. An example of a delivery schedule for an anonymous store is given in Figure 8. As can be seen in the figure the stores have a certain order time. This is the time by which they have to send their product orders to the distribution centre. Stores that receive goods in the morning delivery have order deadlines ranging from 12:30 to 16:00 the day prior and for the afternoon delivery this is between 16:00 and 22:00 the day prior. Some stores however can even order products the same day between 8:00 - 10:00. This extra order time frame has been introduced to offer some form of compensation to the entrepreneurs because they are willing to receive goods in the later time frame, so that load for HB is spread. All of these order deadlines are for the product category of bulk goods that are kept in stock at the DC. For the other two categories the order flow is different. XD orders are directly sent to the supplier by the store and HB is informed about the amount of case packs that is ordered so that they can adjust their logistics planning accordingly. Store orders for PTZ products of a delivery moment are consolidated by Hollander before they are sent to the supplier twice a day, this is done automatically at 01:00 and 13:00.

**Inventory management**

The management of inventory at HB is the responsibility of the ‘purchasing department’ at HB. Because of the background of the company as a wholesaler this department is internally referred to as the ‘purchasing department’, whilst their day-to-day work could best be classified as inventory management. They aim at keeping enough inventory to reach a high service level towards the stores whilst keeping waste at a minimum. Note that this is only applicable for the bulk goods that are allowed to be in stock for more than one delivery cycle. In order to achieve the desired service level, the inventory managers at HB use a forecast tool to forecast demand and they order the produce from their suppliers such that their stock levels are sufficient to fulfil store demands. Furthermore an ordering tool provides an order suggestion for the inventory managers. The delivery schedules of the suppliers to HB are of importance here. The suggested order calculation includes current on-hand inventory, goods in transit, required safety stock and the forecasted store orders for the time between the current order moment and the next delivery by the supplier. If the inventory position for a delivery time frame is expected to be negative, the inventory manager can overrule the store-order amount and choose to lower the amount of goods delivered to these stores. This procedure is basically a form of inventory allocation. The used methods differ to some extent and are based on the experience of the inventory manager. The main rule is one in which each store receives a certain percentage e.g. 70 % of their original order amount, such that total amount of available DC inventory is sent to stores. Another possible response is that all stores in one delivery block (morning or afternoon delivery) receive

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Figure 8: Delivery schedule for store X, marking the assortment groups per delivery².

² All assortment groups that contain XD are cross docked, PTZ, PTZE and PTZU are pick to zero products and all the remaining assortment groups are bulk products kept in stock.
their orders and the stores in the other block do not. A final possibility is an absolute maximum, in which all stores regardless of order size receive a maximum of $n$ case packs. These rules are determined by the inventory managers and are based solely on the inventory position at the DC and do not take the inventory position and (expected) sales in the stores into account. Making the right choice between the allocation methods is therefore a challenge that HB currently faces. Inventory allocation in case of DC shortages can therefore be identified as a possible factor for improvement in the current situation.

Besides these tasks, the inventory managers further monitor the inventory levels for the products in their portfolio and if necessary, they will call their suppliers to order more products or request an emergency shipment. In case of a surplus of inventory that is expected to become obsolete, the inventory manager can try to sell this inventory to any entrepreneurs that are willing to take the product at a discount. This way the waste of the DC is limited and since the product has not expired yet, it can still be sold in stores.

**Goods Arrival**

As mentioned before, the goods arrival happens in three different ways. The XD products are brought in at the expedition area, whereas all bulk products are received at another place in the DC. The trucks that bring in goods from the supplier are unloaded at the arrival area and the goods are then checked for quality, temperature, quantity and other anomalies. Once the product is approved, the goods are checked in and the pallets are moved to their locations, where they are loaded on a first expired first out (FEFO) basis. The DC consists of two floors, and if the products need to be placed on a different level the products are placed in the elevator and from there on moved to their location.

**Order picking**

When the store orders for a store are finalised they are sent to the warehouse management system (WMS) which is called MLS. These orders are transformed into order pick lists for the employees in the warehouse. The order pick system is voice activated and ensures that the order picker is sent towards the correct picking location and that he or she picks the right amount of product. They load the products onto roll containers that are available throughout the DC. The roll containers move along a giant chain conveyer that runs all over the first floor and spirals up the second floor before coming down again. This ensures that an empty container is always available within reach. The order picker either uses a cart which can have three containers, or they use a single one which they move by hand. When the container is picked from the conveyer the order picker scans the code so that the container is from there on linked to the order they are picking. Once the container is full, the picker transfers the container back to the conveyer and it moves towards the expedition area.

**Consolidation and loading**

The conveyer carrying all containers runs along the expedition area, which is divided into several areas that each contain multiple loading docks at which a truck can dock. The containers are equipped with Radio Frequency Identification tags (RFID) and this ensures that the container will automatically be guided of the conveyer once it reaches the correct area. From here on the containers are moved into the dock areas (which are numbered) and the containers for the same store are put in the same area. To ensure a high degree of utilisation for the trucks, multiple stores can be loaded into one truck. When space in the truck in insufficient, it might be necessary to consolidate several containers to make sure that the entire shipment fits in the truck. This will be done before the truck is loaded, and when the loading is complete the truck is ready to head to the store.
Distribution
After the trucks are loaded with the goods for the stores on their route, the trucks head out to supply the 272 stores of PLUS with their orders. As mentioned before part of the vehicle fleet that supplies the stores is HB's own fleet and the remaining part of the fleet are trucks from third party logistic service providers. When trucks arrive at the store, they unload the goods for each store and possibly load any return goods that are stored at the supermarket. From here on the trucks either head to any remaining PLUS stores within their route, a supplier or back to the DC.

Returns
In order for the DC to be able to keep shipping goods to the stores, the load carriers and crates in which products are shipped to the stores need to be returned to the DC. The truck drivers together with store clerks will load these returns in the truck which are taken back to the DC. Besides the logistics material that needs to be returned to the DC, HB offers a return policy on fruits and vegetables that do not meet the required quality standards. The products that are insufficient in quality or deteriorate in such way during the three days after delivery can be sent back to the DC. This stream of goods is then processed at the DC and the stores are refunded for the product. When the trucks arrive in Barendrecht they unload all containers and crates in which the product was shipped at the return centre, where the crates are counted cleaned and processed to be put to use once more. The empty containers are later transported back to the DC where they can be used for new deliveries.

Backhauling
Because of a desire to use the capacity of their vehicle fleet as efficiently as possible, HB has been using the concept of backhauling in their logistics operations as well. This is one of the concepts that helped them receive the lean and green award (for sustainable mobility) and is in line with the vision of the company to become more sustainable. For the operational part in the supply chain this means that after trucks have delivered goods to stores, their journey back to HB could include driving to a supplier to pick up HB’s goods for DC replenishment. By doing this the DC maximises the utility of their own trucks as and thereby not only reduces logistic costs but also harmful emission into the environment.
3. Research assignment

After the introduction of the perishable supply chain and the initial problem statement at HB, this chapter will go deeper into the research material. The chapter will provide an academic background and solution directions found in literature. Furthermore this chapter includes the research directions that will be explored and the research questions and related subquestions.

3.1 Literature review

To support the proposed research project in finding feasible and academically relevant solutions, a literature study has been conducted. This section includes a theoretical background in the concepts of distribution flows for perishable supply chains, supply chain cooperation and inventory allocation methods.

3.1.1 Supply chain structures

Supply chain management research has provided multiple ways to classify the supply chain structure and distribution flows of a certain supply network. One distinction often made is the distinction between push or pull driven supply chains. To understand the difference between the two strategies, Pyke and Cohen (1990) have given a definition that is applicable for the perishable goods supply chain of HB. The main dichotomy for push versus pull classification in their research is whether decisions are made upstream or downstream in the supply chain. In supply chains that are pull driven, the downstream locations are identified to have the decision making power and they therefore trigger a replenishment. The replenishment decisions of the downstream supply chain actor is generally based on local information. This local information is the information that is known to the downstream supply chain actor at that moment of time. A retail outlet for instance can order its goods at the DC basing their decision on their own inventory level, demand variability, delivery lead-time and their relevant costs. This means that there is a locally optimised ordering strategy for this specific supply chain actor. The same goes for the other supply chain actors in the chain, making it a supply chain full of locally optimised subsets, without chain wide optimisation. The inefficiency between the supply chain actors can be seen in examples where ordering a specific amount of goods might be optimal for inventory replenishment of the downstream actor, but very inefficient for the production of the specific product. Since a supply chain with perishable goods is limited in the amount of time products are usable, short lead times are often necessary. In order to be responsive to downstream demand fluctuations combined with the need for short lead times, a lot of actors in a pull driven supply chain maintain an inventory. They supply downstream nodes from their own inventory and replenish that inventory by pulling goods from their suppliers. A related advantage for downstream supply chain actors in a pull driven supply chain therefore is that this minimises their inventory risk. This is because the supplying actor bears the inventory risk because they hold inventory while the downstream actor replenishes as needed (Cachon, 2005). Reasons mentioned for implementing such strategies are the ability to respond faster to variation in demand and lower overall inventory because exact orders are pulled through the system. On the other hand, Pyke and Cohen (1990) mention the increased variability that a pull driven supply chain generates for upstream nodes as a disadvantage. For non-perishables the effects of pull driven distribution have been described by van Donselaar et al. (2010); Angerer (2006). The automated store order systems (ASO) described in the work of van Donselaar et al. (2010) however are not readily applicable to perishable goods supply chains since additional information on the age of the inventory is necessary.
As van der Vlist (2007) suggest, there might be an argument against the existence of fully pull-driven supply chains, since they assume unlimited capacity from upstream nodes. Once upstream capacity is restricted in some form and goods cannot be delivered due to stock-outs, an upstream node will have to make a decision on how to allocate goods to downstream nodes, hence introducing a push element.

Push driven supply chains are the opposite of the pull driven supply chain with regards to the decision making power. The decision making nodes are the upstream actors and they base their decision on a more global view. This global view includes more detailed information from the supply chain as a whole instead of locally available information. As for instance van der Vlist (2007) describes, push systems highly depend on proper downstream visibility. This is because the upstream node takes inventory information or expected demand at downstream nodes into account for their own replenishment decisions. The strategy also has different beneficial elements as compared to a pull strategy. The supply risk of a push driven systems is shifted and spread over the supply chain actors. Instead of the preceding actors having the inventory, the risk is now shifted partially towards downstream actors because the goods are pushed to the next node in the supply chain. Furthermore, the success of the push replenishment system depends on the accuracy of the forecast that is made for a specific time period. Having difficulties downstream the chain in determining the forecast can arise from inaccurate store sales data. Adding to this complexity, Broekmeulen and van Donselaar (2009) suggest that because of outdated cost for perishables their service levels are lower, hence resulting in a larger percentage of demand that is not registered due to stock outs. This reduces the accuracy of sales data, and hence increases the complexity of implementing the push system in a perishable goods supply chain. On the other hand the literature reviewed by Wijshoff (2016) suggests that from the moment of production, in a push driven chain methods such as cross docking at the distribution centre level might be implemented in order to shorten lead time, minimise inventory in the pipeline and shorten the time spent in the supply chain.

van der Vlist (2007) suggests another form of distribution flow that could be applicable to this study. The hybrid distribution flow contains elements of both the push driven supply as well as the pull driven supply chain. Within the hybrid structure a decoupling point exists as seen in Figure 9, where as Chung (2008) describes it ‘the boundary between activities that are forecast driven and the activities that are order driven’ is placed. The hybrid scenario presents elements that reflect the reality of the supply chain as it is in place for HB, as well as some elements that might be used in future designs.

3.1.2 Supply chain cooperation

In any type of supply chain, whether it is a pull driven, push driven or hybrid form, cooperation between the supply chain actors is a key component in decision making and a good flow of products throughout the chain. Several authors have reviewed the effects and importance of information sharing throughout the supply chain. They provide clear indication that proper information sharing will increase performance throughout the supply chain. Eksoz et al. (2014) for example have combined aspects of previous literature and specifically looked at information
required to improve performance of forecasts. From a retailer perspective, providing suppliers with information about pricing, promotional types and the assortment types was able to reduce the amount of time needed for them to make a decent forecast and even increase the accuracy of the forecast. For suppliers, sharing information on delivery schedules and production plans with their customers as well as sharing their information about the shelf-life of products in supplier stock increases transparency and can help reduce forecasting errors for the retailer as well. These examples mentioned above are all elements that the supply chain of HB could benefit from. Aligning incentives for information sharing should be a first step amongst actors, so some form of collaboration should be stimulated.

One of the methods that have been developed over the years to enhance information flow between supply chain actors and achieve supply chain collaboration is the collaborative planning forecasting and replenishment (CPFR) approach. For the current supply chain, CPFR should range from the retail outlet to the supplier and all information available can be used when shared properly. Retail outlet information should for instance be accessible by the retail DC. This includes information on expected customer demand, demand variability, inventory levels, estimated outdating and any promotional activities. In order to forecast on a collaborative basis with their supplier, the DC needs this information from the retailer. The collaborative forecasting element can greatly increase performance in the supply chain and within the CPFR framework it is very important. There are however some challenges in realising the potential benefits of CPFR and Panahifar et al. (2015) categorise them as:

- Challenges related to human interactions and biases;
- Challenges due to traditional behaviours; and
- Challenges in communication and defining accountability.

In order to overcome these challenges input and alignment from all supply chain actors involved is needed. Traditional behaviours and human interaction are hard to change, but information technology (IT) systems and increased communication can help in overcoming these issues. The IT systems make new behaviour more easily implementable and make the results of new behaviour more visible because they can provide performance overviews quickly. On the other hand, the ability of IT systems to manage collaboration has also been identified as a restricting factor. When systems are not able to share information adequately they decrease the effects of CPFR. This is a very important requirement in the current research, since it could be a key component in the effectiveness of information sharing. When it comes to forecasting, aligning the time component is mentioned by Eksoz et al. (2014) to be of importance, since deviating forecasting frequencies can have a negative effect on forecast performance. Research also shows that the information input in collaborative forecasting can increase forecast accuracy, reduce bullwhip effects and improve the quality of information that is exchanged. Accountability in the supply chain should be clearly defined in advance and should be involved in creating incentive alignment for all involved actors as was found in the literature review by Wijshoff (2016). The research of Panahifar et al. (2015) provide a clear conclusion on the superior performance of CPFR over other methods such as vendor managed inventory (VMI). When implemented properly CPFR has the potential to provide substantial benefits for all supply chain partners that are involved.

### 3.1.3 Inventory management

The most downstream actor of the perishable goods supply chain of HB that keeps inventory is the retail outlet. Whether or not they reach their target customer service level and the amount of waste that is generated by the retail outlet depends on the store replenishment policy. For perishable goods a service level between 90% and 98% is generally a reasonable target according
Achieving such service levels requires a good replenishment policy, and multiple studies have been performed on the performance of such inventory replenishment policies. To determine how many products should be ordered at which time, the use of these replenishment policies in the retail environment is very common. The basic inventory replenishment method that is relevant for the current supply chain is the \((R, s, nQ)\) policy (following the notation of Silver et al. (1998)), since this type of system is encountered very often in practice (van Donselaar & Broekmeulen, 2014). In this replenishment policy, the review period \(R\) is the time between successive inventory evaluations at which the inventory position is checked. If the inventory position is below a predetermined reorder level \(s\), a replenishment order will be made. The order quantity is a multiple \(n\) of the fixed base replenishment quantity \(Q\), where \(Q\) equals the amount of consumer units in a case pack. This reorder policy works well for non-perishable goods, but because this reorder policy does not include the age of the products that are in inventory, thus is unable to predict when inventory will be lowered due to outdating of perishable goods. The research of Duan and Liao (2013) concludes that age based replenishment policies are therefore superior to the replenishment policies that do not consider the age of the inventory in stock at the retail outlet. Their work is an extension of the research performed by Broekmeulen and van Donselaar (2009), who introduced a new age based policy called the EWA policy. The Estimated Withdrawal and Ageing policy is similar to a regular \((R, s, nQ)\) policy, but an outdating component is introduced.

The model sets the reorder level \(s\) by taking the safety stock plus the expected demand during the lead time plus the review period \((L+R\) days). When a review moment takes place, the model will not only take into consideration the inventory position at that moment, but it deducts the estimated amount of outdating over \((L+R-1)\) days from the inventory position. Note here that “the outdating on the \((L+R)\)th day does not affect the ability to meet demand during that day, since outdating takes place at the end of the day after demand has taken place” (Broekmeulen & van Donselaar, 2009). If the inventory position that is corrected for the estimated outdating is lower than the reorder point, an order will be placed.

Managing the amount of outdated products and improving the store service level by implementing the EWA policy should be considered when a store is looking to evaluate their current replenishment strategy. Implementing the policy in a perishable goods chain like the one at PLUS is considered manageable. The fact that the policy provides an estimate on outdating also prevents sudden out of stock situations in stores. These happen due to outdating of a certain batch on the shelf, and the system helps to ensure that restocking is possible in time because an order is generated based on estimated outdating. Additional benefits of the replenishment policy is that there are data on the (estimated) age of products in the store as well as expected demands. These data could be very useful when shared with other actors within the supply chain as the previous section has brought forward. The distribution centre in a divergent network where all stores use the EWA policy could make a better forecast for the amount of products needed in the stores and could therefore forecast the necessary amount to be kept in stock at the DC more accurate. Since stock levels in the DC are based on a better forecast, this strategy could reduce the necessary safety stock. If the reasoning of Thron et al. (2007) also hold for lowering safety levels, a lower inventory will reduce the average age of the product at the moment of sale (based on a first delivered first sold policy).

In the identification of supply chain structures and the collaborative approaches to managing an efficient supply chain, it is established that inefficiencies will still occur. This also holds for inventory management, which can result in either stock outs or waste. In the case of stock outs at the distribution centre, decisions have to be made about how to distribute the remaining inventory at the DC to the stores. Determining which store receives which quantity of remaining inventory can be based on a variety of allocation rules. In literature some of the allocation rules

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that have been used in (perishable) supply chains have been reviewed. Howard and Marklund (2011) review a First Come First Serve (FCFS) allocation in which the sequence of store orders coming in determines the allocation of goods. They conclude that it might be interesting to use this rule, however they do not include the costs of wasted produce which makes the use of this rule undesirable for a perishable goods supply chain. Cohen and Pierskalla (1981) introduce a set of allocation rules that provide each of the stores that require replenishment from the DC with a certain amount of product. They firstly propose the random fraction allocation rule that allocates the remaining DC inventory such that all stores receive an equal percentage of their total orders. This percentage is determined at the moment all orders have been received by the DC, and then the percentage is set (e.g. all stores receive 70% of their original order quantity). Their second allocation rule is the fixed fraction allocation rule which allocates the remaining DC inventory to stores on a predetermined fixed fraction per store. This means that every time the DC experiences a shortage, the stores receive the same fraction of the total remaining DC inventory. Although these allocation rules are more complex than the FCFS rule, they have some disadvantages as well. The random fraction allocation rules can be influenced by retailers that increase their original order quantity because they know they will receive a higher volume in total. The second rule does not allow this influence, but the fixed fraction allocation rule does not consider the actual store inventory levels when replenishing. Introducing the outdating cost component into the inventory allocation problem is done by Prastacos (1981). His research provides an allocation mechanism that aims to minimise expected waste and expected shortage costs in a divergent system with a central warehouse. The myopically optimal rule he developed is based on equalising the shortage probabilities in the stores. It states that the store with the highest probability of shortage should be allocated a product first, and the store with the highest remaining shortage probability thereafter should be allocated products second etc. until there is no more central stock to allocate.

The difference between the rule introduced by Prastacos (1981) and the implementation of such rule in the supply chain for groceries is that there is a handling component in the DC. As Mertens (2016) also suggests, it is possible that one store is allocated multiple products of different ages. However, picking products of multiple ages for a certain store is not efficient and should therefore be avoided. Adding a segregation rule which ensures that after allocating the total number of products, the different ages of the inventory in the DC are assigned to stores in FIFO order will make the allocation rule useable. The allocation is such that the products for a certain store are picked in FIFO order in the DC. Note here that the stores that are allocated a product first, should now receive the oldest product from the DC (FIFO). This allocation procedure works for products with a case pack size of one consumer unit (CU) but for bigger case packs there will need to be some form of batching, since only complete case packs can be picked in the DC.

Another form of inventory allocation is based on the runout times of the stores. The allocation rule evaluates the stores that are in need of replenishment and provides each store with a runout time. The runout time is determined by taking the inventory level of the store and dividing it by the average customer demand per day and gives the expected amount of time the store can last with their current inventory. The allocation procedure then allocates case packs starting with the smallest runout time up until the largest until central inventory is depleted. As Mertens (2016) has found, an allocation rule can be of great importance when OOS is more frequent or the amount of available product for shipment to the stores is lower (reduced fill rate of the DC). In his research the service level was restricted to be at least 80%, so it might be worthwhile for this assignment to explore the possibilities of lowering the service level in the DC combined with an allocation rule and explore at which fill rate the systems still performs adequate.
3.2 Research directions

Given the problem statement and the constructs found in literature, the research directions were determined and from there on the research question and subquestions were derived. The distribution flow of perishable goods in the supply chain of HB ranges from the supplier through HB to the stores of PLUS. Combining the supply chain structures and supply chain cooperation possibilities leads to a few scenarios that will be explored in the research.

The most basic distribution flow is the one shown in Figure 10. In this supply chain the stores place orders at HB and HB replenishes the stores from their stock. HB orders their goods at the DC suppliers who make the goods to stock. The system can be described as a classic pull driven system were each upstream actor waits with replenishment until the preceding actor orders. For the store, DC and supplier it holds that whenever stock is insufficient to fulfil demand, no backorders are in place. Information on inventory positions and expected demands is only local and not shared between the supply chain actors.

Figure 10: Basic distribution flow with three stock points

The next supply chain structure is similar to the previous one but here information sharing is in place. The stores use the EWA replenishment policy (Broekmeulen & van Donselaar, 2009) to place orders at the DC and share their information with the DC. This way in case of stock outs the DC can use an allocation rule to determine how many goods a store will receive. The supplier also receives information of the forecast from the DC and makes the products to stock (MTS) for HB based on this forecast. Furthermore the supply can be synchronised with the production schedules of the supplier to ensure a maximum product freshness. This distribution flow is shown in Figure 11. Again, all demand is lost after stock outs occur.

Figure 11: Synchronised distribution flow with make to stock production

Another possibility is the make to order (MTO) policy for the supplier. Here the supplier does not keep stock and produces the exact amount of products that HB orders. This means that the start of production is synchronised with the order placement. This leads to maximum availability and freshness. The data between retail outlets (again using the EWA replenishment policy) and DC are shared and this is the basis for the forecast that is made for the supplier order. In this flow the lost sales environment in case of stock outs also holds. This last research direction is shown in Figure 12. The allocation rule, production and replenishment synchronisation and the production strategy (MTS/MTO) are seen as the distribution flow elements that together make the supply chain scenarios.

Figure 12: Synchronised distribution flow with make to order production
3.3 Scope

For this project, a few steps in the scoping process needed to be taken in order to include the relevant aspects of the supply chain, as well as keeping the research assignment within manageable bounds. Some of these boundaries have been set by the researcher and a few parts of the scope have been marked by practical boundaries discussed with the company. As has been brought forward in the introduction, HB faces a challenge in providing the stores with products that are as fresh as possible. Improving on this subject could provide a means for them to keep a competitive advantage and maintain an important role in the supply chain of PLUS supermarkets. The leading role of the DC in achieving retail product freshness improvement should be the main focus. Literature suggests using all echelons in the supply chain. For this thesis only the stores, HB and their suppliers will be considered. All suppliers of raw materials or those who provide other goods or services in any way to HB’s suppliers are out of scope, since this is out of the control span for HB. The involvement of PLUS supermarkets in the supply chain will be from a strategic viewpoint. The replenishment methods described for the supermarkets are assumed to be realistic on a longer horizon. In the company introduction it is mentioned that PLUS does not currently have an ASO system in place. Since they are however working on implementing SAP (an ASO), any suggestions made for PLUS can be implemented on a longer term within SAP.

As the relationship between HB and a supplier originates from the need for a certain product that the supplier can provide, narrowing down HB’s assortment is key for the scoping process. As discussed in Section 2.1 there are three main product categories for Hollander. Of these three, the PTZ and XD categories are not intended to be kept in stock at the DC for more than one delivery cycle. Even though some inefficiencies occasionally exist within the PTZ category, these are considered negligible. In order to fully harvest the effect of potential savings by increasing freshness (and thereby reducing average product age, thus possibly reducing waste (Thron et al., 2007)), the products of the two categories mentioned above will be out of the research scope. This decision is justified by the reasoning that products that are shipped to stores in the same cycle as they are delivered to Hollander do not accumulate any product age that can be reduced by this project. The product category that will be used for the master thesis will therefore be the bulk goods that are kept in stock at the DC. A further selection within the product category will be described in Chapter 4.

Within a supply chain costs often play a big role in the way day to day operations are carried out. Since managing costs are also often a means of performance for the different stakeholders in the supply chain, a certain set of cost related factors will have to be taken into account as well. For HB the relevant costs related factors for this research are keeping inventory, logistics handling in the DC for incoming goods and the generated waste.

3.4 Research question

Given the possibilities described in literature and the available research directions it is not yet evident which distribution flow would be most suitable for different products. Therefore the research aims to elaborate on the issue and the main research question of the model-based research is formulates as follows:

“How should the flow of perishable goods be managed by the central DC, to improve retail product freshness?”
The subquestions related to the main research questions are:

1. **How is the current distribution flow designed at Hollander Barendrecht?**
2. **How can the alignment of information throughout the supply chain improve the supply chain performance?**
3. **What is the effect of using an allocation rule for out of stock situations in the DC on the service level and waste in the stores?**
4. **What availability level should be achieved by the DC in order to realise an aggregate service level of 95 per cent in the stores?**
5. **What is the effect of a different design for the stakeholders in the supply chain?**

The first subquestion is raised to establish the current situation of HB, so that a valid and verified model can be made for the simulation. This question also gives room for the analysis phase of the research assignment. This includes the structures of the supply chain and the methods used for replenishment of the stores and the central distribution centre.

The second question investigates the relation between information sharing and performance of the supply chain. Since the research directions pointed out different scenarios the model will investigate the effect of increased information sharing and synchronisation of production and DC replenishment.

The next question aims at finding the possibilities for a better allocation of goods in case of stock outs at the DC. As mentioned before, the use of an allocation rule has been identified as a possible improvement for the performance on service level and waste reduction in the retail outlets. The extent to which using an allocation rule will actually influence the performance will have to be tested. Furthermore this will provide information on what type of product and store will be influenced most by allocation.

Sub question four relates to question three, as the frequency of stock outs will increase in a situation where lower service is provided. The aim of this question is to find what DC service level would be sufficient, given that the stores have a 95% service level to their customers. Lowering the service level would imply having lower inventory and therefore possibly increasing retail product freshness. It should be clear here however, that the restriction on the service level should be met for all stores, only then will the service level in the DC be considered adequate.

The last subquestion has a future goal. When the new distribution flows design would be in place, how would this affect the stakeholders in the supply chain. What factors would have to be overcome in order for them to accept and be cooperative in the new design?

### 3.5 Research methodology

Since the research is based on evaluating the performance of different distribution flow elements, it can be classified as quantitative research. Furthermore, the method of simulation has been identified as an adequate alternative for real life testing and a framework for research within such an environment has been provided in literature. Mitroff et al. (1974) have identified 4 research stages for quantitative model-based research. The stages and the links (or actions) between the stages are shown in Figure 13 and will be the guideline for the research project.
The stages of this framework help to safeguard all the necessary steps for proper research. Using this framework as a guide for the research project will make sure that all necessary research steps are taken. The stages in the framework and the way that the linking actions are undertaken in this research assignment is given in the remainder of this section.

The reality, or problem situation is the first stage in the process. In this thesis the reality is given by the company introduction together with the problem statement, since these have shown the current situation and the problems that are faced by the company. To transform the current reality to a conceptual model, Mitroff et al. (1974) designed the conceptualisation action. The conceptual model should, in broad terms, define the particular problem to be solved and it then specifies the field variables that will be used to define the nature of the problem and the level at which the variables will be treated. The conceptualisation action has been completed in the first parts of this chapter, where the scope was defined and relevant concepts found in literature were presented and the research question and sub questions were introduced. Furthermore, since this chapter also includes the first solution directions it can be seen as the first feedback loop in the model.

In order to make a scientific model of the conceptual model that has been derived in the previous stage, the modelling action will have to take place. In this action the design parameters and the functional requirements of the model have to be specified and together they will provide the quantitative simulation model. When the scientific model has been made, the validation action will take place based on the comparison between the current situation and the proposed model. Most of the input for the scientific model will come forward in chapter 4 and the model is presented in chapter 5.

The model solving step will include testing different scenarios of the supply chain design. With this set of scenarios (also shown in chapter 5) the performance of the modelled supply chain will be tested. Since this is a strategic study, some aspects that result in the solution will be based on assumptions made for steps in the modelling stages. A sensitivity analysis will provide an insight in the way that relaxing these assumptions will influence the performance of the modelled supply chain. The results of this stage will then be used for the feedback action on the conceptual model.

The comparison of outcomes for the different scenarios in chapter 6 will provide the solution stage of the research methodology by Mitroff et al. (1974). In the implementation action, the solutions will have to be used to design some transformation steps in order to reach a new and improved reality. This is done in chapter 7 and will complete the methodology steps.
4. Analysis

In this chapter the analysis of the current situation of HB will be given. First the current distribution flow management will be described followed by a description of the methods used in the operational processes. Furthermore the chapter includes a more detailed analysis of the data that was used to construct the quantitative simulation model.

4.1 Current distribution flow management

In the introduction of this report the flow of goods and the supply chain structure of HB has been provided. Together these form the basis for the analysis of the current distribution flow and its management. The scoped supply chain consists of \( N \) suppliers, one central distribution centre (HB) and \( J \) PLUS stores. At each of the three nodes in the supply chain the actors keep an inventory of the product. The stores and HB order the products from their preceding supply chain actor when they are in need of replenishment, thus triggering the supply from downstream. Having compared this with the supply chains in the research directions given in Chapter 3.2, the conclusion was that the supply chain could be categorised as pull driven. The management of the goods flow throughout the supply chain will be described starting at the most downstream supply chain node, the PLUS stores.

**PLUS stores**

PLUS stores get an order advice generated by their Goods & Assortment System (G&A) on a daily basis. The store clerks decide whether or not they agree with the order advice and adjust the order when they consider this necessary. This inventory management system has some resemblance with an \((R,s,nQ)\) strategy, since the store clerk reviews the shelf periodically and decides on how many case packs to order. The reorder level \( s \) however depends on the store clerk, since they judge if, and how much to order. In accordance with that, Kock (2015) found that “supermarkets change a lot in the initial settings of the store ordering system” and that “the quality of the ordering process is dependent on the store clerk with this task”. This results in a situation with a lot of variation in the orders, which makes it hard to predict what the actual amount of orders will be for upstream actors in the supply chain. This is an indication that the current system of making orders is not an optimal one, and that no information is shared with the DC. When the store clerks enter the amount of product to order, these are forwarded to HB at the time of the store specific order deadline. The deadline depends on the order and delivery schedule that is used to replenish the stores.

**Hollander Barendrecht**

In order to fulfil the store demand, the inventory management department at HB is responsible for sufficient inventory at the DC. The team consists of 7 inventory managers and 1 supervisor inventory manager. As mentioned before, the term used in the company for the department is the ‘purchasing department’. This originated from the tasks that this department once performed, but important aspects of purchasing like sourcing and price negotiation have been long removed from the responsibilities of this department. In order to provide an accurate view of their responsibilities within the supply chain they will be denoted as inventory managers for the remainder of the thesis. The communication with the suppliers is divided between the inventory managers and each of them has a certain amount of suppliers in their portfolio. In case of the absence of an inventory manager each supplier is also assigned to a second inventory manager as means of backup.

For the actual order process HB uses three distinct computer tools to forecast the demand at DC, order the goods at the supplier and monitor the inventory at the DC.
The forecasting tool uses the historical data of the store orders to make a forecast per SKU in case packs per day for the upcoming three weeks. In order to make sure that the tool does not contain data that would influence the forecasting accuracy for regular demand, the tool can be adjusted such that specific forecasts are not displayed automatically and are left out. These gaps then have to be filled manually by the inventory manager. Examples of these exclusions are holidays, promotional activities and forecasts that are out of the bounds that have been determined in the initialisation of the tool. A further specification of these terms and an example of the parameter setting screen is shown in Appendix B. The forecasted amounts that are generated by the system which are displayed in the forecasting tool can still be adjusted by the inventory managers. Reasons mentioned for making adjustments in the forecasted amounts were for instance the influence of the weather on products whose demand is sensitive to fluctuations in temperature (which is not incorporated in the tool). Especially during warmer periods the inventory managers would order more of the product than the tool suggested.

Next to the forecasted orders for the coming three weeks, the forecasting tools also provides the actual store orders of the past week as well as the historical forecast error for the product. This gives an insight in how much the tool deviated from the actual store orders. The forecast error is also mentioned in the user guide of the software as a good indicator for use in the calculation of safety stock. When the forecasts are completed, either manually or automatically, the numbers have to be approved so that the order system can import the forecast.

When the amounts in the forecasting tool have been approved, the order tool can import the forecasts and the inventory managers can start making the replenishment orders. Ordering is done on a predetermined schedule agreed upon with the supplier. This means that for HB there is a predetermined review period for the ordering of goods. The order tool imports data from the forecasting tool mentioned in the previous section and furthermore imports settings that the inventory manager can adjust in the business information system (BIS) that HB uses, which is called RPO. In this system the inventory manager sets a minimal inventory coverage percentage, i.e. they determine which days of forecasted demand the current order will have to cover. This is the forecasted amount for the following day up to and including the day of the next arrival. In terms of inventory management theory this would be the expected demand during the review period and the lead time.

Furthermore the inventory manager provides the necessary safety stock in RPO, this is a percentage of the forecasted amount of the day following the last day included in the minimal inventory coverage. The percentage is set by the inventory manager, but the historical forecast error percentage provided in the forecasting tool is mentioned as a guideline. Furthermore a maximum order coverage percentage has to be entered into RPO. This is the maximum amount of days the product can be at the DC before it can no longer be sent to the store and will be considered as waste. This measure is built into the tool to prevent ordering excess amounts of product that are expected to expire at the DC before they can be shipped to the store. When these parameter values have been set, the order tool will determine an order advice for the inventory manager. The order advice is given in two steps, first a minimum and maximum order advice are given, and next a final order advice is given by the system. The minimal order advice is generated as given in Equation 4.1. Because the store forecast is given in consumer units and stores receive case packs, the order advice amount is rounded up to the nearest case pack:

$$\text{Min. order advice} = \lceil \text{Min. inventory coverage} + \text{safety stock} - \text{Startposition} \rceil$$

(4.1)

Where the startposition is given by equation 4.2. Note that the system deducts all the store orders that have already came in for the day, but also extrapolates this amount to generate the

20
total expected demand (ED) for that day:

\[ \text{Startposition} = \text{Inventory on hand} + \text{Inventory in transit} - \text{ED (today)} \]  
(4.2)

The maximum order advice is generated similar to the minimum advice, but excludes the safety stock and is rounded down to the nearest casepack:

\[ \text{Max. order advice} = \left[ \text{Max. inventory coverage} - \text{Startposition} \right] \]  
(4.3)

The maximum and minimum order advice determine the range from which the final order advice will be given. The tool then uses a set of rules to determine the final order advice (Hollander Barendrecht, 2015):

1. Round off to a (multiple of) full pallet(s) when this is within the order range.
2. If the minimum order advice is smaller than 0, the final order advice will be 0.
3. If the maximum order advice is greater than the minimum order advice, the final advice will be equal to the maximum order advice.

The final order advice can be adjusted by the inventory manager and then the order can be placed. The second rule that determines the final order advice can be seen as the rule for the current reorder levels since an order will be made only if the minimum order advice is higher than 0. Since the order advice depends on the expected demand, the reorder levels are dynamic. The current reorder level can be described as follows:

\[ \text{Reorder level} = \text{ED (Lead time L)} + \text{ED (Review period)} + \text{Safety stock} - \text{Startposition} \]  
(4.4)

As mentioned in the rules for the final order advice the order tool will try to round off to a full pallet if possible. This is possible because for each SKU the amount of case pack that fit on one layer of a pallet is known and entered into RPO, as well as the amount of layers making a full pallet. For a lot of SKU’s however HB can order single case packs from their supplier, but with handling operations at HB in mind the inventory managers often order in multiples of pallet layers. This will also be the basis of the assumption for the unit size \( Q_{DC} \) in the simulation model. The amount of case packs that fit on one layer of a pallet will be seen as the unit ordering size for the DC. The current inventory management system that HB uses can thus be seen as \( (R,s,nQ) \) inventory system as well, with predetermined review periods, dynamic reorder levels and SKU specific unit pack sizes.

The final tool that the inventory management department uses is the inventory monitoring tool. This tool provides an overview of the inventory issues that might arise in the future. There are three types of alerts that are highlighted by the system. The first alert is for out of stock (OOS) situations on short term (the next day). The tool takes the inventory level and deducts the forecasted demand for the day. If this would provide an OOS situation the tools will mark the expected lost sales red in the overview. On this alert the inventory managers can decide if it is necessary to overrule to distribute the remaining inventory at the DC to the stores. Since ruling occurs when the OOS is expected, it can happen that actual orders end up being lower than expected. If in that case an allocation rule has been used already, a situation can occur where stores receive less product than they ordered, whilst the DC has a positive inventory at the end of the day. The second issue in the monitoring tool is for the OOS on the long term (until the next delivery). It works the same as the short term alert only now includes demand up to the next DC replenishment. The third alert is for expiration issues, which marks the expected amount of product that will expire. This is based on the age of the inventory and the average sales. The tool calculates the expected amount of products that will expire before they can be sent to the stores by deducting the average sales from the inventory.
level. This tool is used by the inventory managers to be able to make changes in outstanding orders or even place extra orders to ensure their target service level towards the stores. In this way the monitoring tool provides a means to prevent out OOS in the DC and by using the so called emergency shipments from the supplier. Furthermore the tool provides an insight into the expected amount of obsolete products and alert the inventory managers about this. The inventory managers then have the possibility to try and sell this soon to be obsolete inventory at a discount to PLUS stores, this to keep waste within the target range.

**Suppliers**

Since the assortment of HB contains a lot of different products, there are many suppliers. These suppliers all have a different set of supply characteristics such as the lead time, production intervals and supply frequency. A challenge that HB faces is that there is a reluctance of suppliers to share their production intervals with the DC. This holds for most suppliers, but the suppliers that deliver the XD products make them to order so these are known for HB. For the bulk product category, the production intervals and the production moments are often not known. This led to assume that in fact most suppliers produce to stock and DC replenishment is done from this stock. Analysis of the best-before dates of the products that arrive at HB has confirmed this, since for multiple SKU’s it was observed that the products delivered on consecutive days had matching best before dates. From this it was concluded that those products originated from the same production batch and thus the DC did not receive a product with a higher product freshness. Furthermore the inventory management department does not share their forecasts with the suppliers, which means that supplier makes their own forecasts on the amount of product that HB will order from them.

4.2 **Service level**

A widely used service measure in the retailing industry is the fill rate. This service measure is defined as the long-run fraction of total demand, which is being delivered from stock on hand (van Donselaar & Broekmeulen, 2014), and is also called the $P_2$ service level. It is one of the main key performance indicators (KPI) of the DC to PLUS stores. In the current situation HB has a service level agreement (SLA) with PLUS supermarkets in which they specified that for HB the obligated $P_2$ service level is 99.1%, thus being able to ship 99.1% of the total amount of demanded case packs to the stores. HB uses two types of service level; a net service level and a gross service level. The contractual agreements are based on the net service level. To explain the difference between the two measures, the calculations that are used by HB are shown in this section. For each day the amount of case packs for each SKU of the product groups included in the bulk and PTZ category is accumulated and these amounts for all SKU’s together make up the total amount of orders. However, for multiple reasons the number of case packs shipped to the store can deviate from the ordered amounts. The reasons for deviation are shown in Table 1 on the next page.

The service levels are calculated based on the number of case packs that belong to each of the order deviation, which will be denoted as deviation quantity $DQ_1$ until $DQ_9$. The total original order quantity is denoted as $Q_{tot}$. The equations for the service levels that are used are:

$$Net\ \ Service\ \ level = 1 - \frac{DQ_{40} + DQ_{4P}}{Q_{tot} - DQ_2 - DQ_6 - DQ_8 - DQ_9} \quad (4.5)$$

$$Gross\ \ Service\ \ level = 1 - \frac{DQ_{40} + DQ_{4P} + DQ_{4A} + DQ_1 + DQ_3}{Q_{tot} - DQ_2 - DQ_6 - DQ_8 - DQ_9} \quad (4.6)$$

The equation used at HB provides an overall service level for PLUS as a whole. The service level might differ from store to store and for each day of the week but the average service level is
Table 1: Deviations from the original store order amounts

<table>
<thead>
<tr>
<th>Code</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Supplier issues</td>
<td>Products that have not been delivered by the supplier</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Products that were delivered late by the supplier so could not be picked at HB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Products that have been rejected due to quality issues</td>
</tr>
<tr>
<td>2</td>
<td>Out of the assortment</td>
<td>Products that are no longer in HB’s assortment but still have been ordered by stores</td>
</tr>
<tr>
<td>3</td>
<td>Incomplete deliveries</td>
<td>Whenever incomplete orders arrive to the DC and cause shortages due to ruling is shown here</td>
</tr>
<tr>
<td>40</td>
<td>Inventory management</td>
<td>Insufficient stock</td>
</tr>
<tr>
<td>4P</td>
<td>Production</td>
<td>Products that are not in the picking location on time or inventory spillage (e.g. breakage during picking)</td>
</tr>
<tr>
<td>4A</td>
<td>Promotions</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Change in article number</td>
<td>When article numbers are changed but products are still ordered using the wrong number</td>
</tr>
<tr>
<td>6</td>
<td>Order adjustment</td>
<td>When a store decides to change their order amount after the initial order</td>
</tr>
<tr>
<td>7</td>
<td>Alternative article number</td>
<td>Whenever a substitution product is given it is displayed here</td>
</tr>
<tr>
<td>8</td>
<td>Price change</td>
<td>Changes between promotional prices and regular price</td>
</tr>
<tr>
<td>9</td>
<td>Miscellaneous</td>
<td>Any other deviations are recorded here</td>
</tr>
</tbody>
</table>

used to evaluate overall performance. Remarkable is the fact the service level equations include the items for the PTZ category. Since they are delivered to HB based on the actual store orders, they are supposed to be 100 % complete. However, some deviations might occur due to breakage or incomplete orders received from the supplier. Overall however the service level of the PTZ items is very high (99.88%), which means that the average service level is also slightly higher than it would have been for just the products kept in inventory at the DC. The terms used at HB for the net and gross service level are however counterintuitive. HB chooses to use the net service level as a means to describe the service level they would be able to achieve if all deliveries would arrive in full and on time at the DC and no breakage occurs. This instead of the actual fraction of the total amount of demanded case packs that is shipped to the stores. The latter fraction is thus called the gross service level at HB. This means that their net service level performance is the performance for events that are within their influence, which is what is important for the contractual obligations to PLUS. Figure 14 shows the net and gross service levels for the year 2016 up to week 26, with an average achieved net service level of 99.53% and average achieved gross service level of 98.00%. The figure shows a sharp decline in gross service

Figure 14: Service levels compared to SLA.
level in week 18. This can be explained by the fact that this week contained multiple holidays and the weather during this week was very good, resulting in higher orders and more deviation due to shortages. Further analysis of the actual service level performance showed that the net as well as gross service level are slightly higher in the morning delivery block, whilst those in the afternoon delivery block are slightly lower insinuating that stockout appears more frequent later on the day.

For PLUS supermarkets a minimum fill rate of 95% for customer demand will be a requirement in the simulation model. As Kock (2015) found however, the current performance and service level settings are not available for PLUS stores and are therefore left out of this analysis.

4.3 Waste

The current service of HB towards PLUS stores is at a high level, which comes at a cost. As is known in literature there is an evident trade-off between service levels and the amount of waste that is generated. For HB products that are treated as waste are those that do not meet the minimum store shelf life (SSL) restrictions. This is the minimum amount of remaining lifetime before the product is not able to be consumed anymore. Even though the maximum order advice that is generated for ordering is set to prevent products from going to waste, it occasionally happens that demand for the product is too low and inventory at HB becomes obsolete. Figure 15 shows the share of the total waste value for each assortment group of 2015 up to week 24 of 2016. The value of the products at the moment of expiration at the DC is the price at which they are purchased from the supplier. It can be seen that the two largest product groups are the deli meats and dairy products. This is partially due to large spillage during the holiday season were demand is harder to predict accurately. The amount of wasted case packs at the DC compared to the total volume of shipped case packs is however very low.

Figure 15: Waste share per assortment group at the DC.

The waste generation in PLUS stores is at a different level than the one in the DC, where it is relatively low. The waste in the stores originate from multiple factors such as short shelf life in combination with low sales, leftovers from promotions and ordering too much. Ferguson and Ketzenberg (2006) mention possible losses for retailers of up to 15% due to wasted products. This however is not the case for PLUS, since Kock (2015) estimated that for PLUS supermarkets the average waste has a value of 2.70% of their total revenue. This can however not directly be
compared to the amount of wasted products in PLUS supermarkets but it can be noted that
the waste in supermarkets is significantly greater than the DC.
For the suppliers in the supply chain of HB no waste data is available either. However, the
work of for instance Thron et al. (2007) shows that the percentage of total waste generated in
the supply chain is low for manufacturers. Even for the different strategies they have tried, the
manufacturers of fresh products have a reasonably low waste percentage and the main cause of
waste is the retail stores.

4.4 Product selection

Selecting a product from the bulk assortment category that was fit for use as input for the
simulation experiment was done in multiple steps. To ensure that the products were still in the
assortment of HB at the time of the data gathering, an initial selection was made with products
that were sold during a period from week 12-2016 up to and including week 27-2016 (which at
that moment was the last complete week of sales). This led to an initial selection of 2742
products. Furthermore the product shelf life (PSL), the remaining lifetime just after production
of these products should be less than 30 days in order to fit within the perishable goods classi-
fication of van Donselaar et al. (2006). Since this information was not shared by the suppliers,
the minimum acceptable remaining product age for arrival at the DC was taken instead of the
PSL. The remaining product set was then further analysed and all products that were sold in
less than 150 PLUS stores were eliminated from the set. This to ensure that the degree of
distribution was sufficient so that the product is representative for the supermarket chain as a
whole. The average distribution degree for perishable products at HB (excluding promotional
periods) is 139 stores, so that a minimum of 150 stores will be sufficient. Furthermore, any
products that were shipped to stores for less than 10 out of selected 15 weeks were excluded
from the dataset as well, since these could be products that were new in the assortment of HB.
To eliminate the very slow moving goods and the fastest moving goods from the product selec-
tion, an upper and lower limit on the average order amount per store was determined. Slow
moving goods were treated as products with an average demand of under 0,5 consumer units
(CU) per day per store, and fast moving goods as those with an average of over 10 CU per day
per store. Further selection was based on the case pack size. The amount of products with a case
pack size smaller than 4 was less than 5 percent of the total bulk assortment, so it was considered
these products would not optimally represent the assortment at HB. Therefore the minimum
case pack size for products was set at 4 CU. Because of the SSL restrictions HB can only keep
products in inventory for a limited amount of time determined by $PSL - L_{DC} - R_{DC} - SSL$.
However, even though some products are not officially in the PTZ assortment group, HB sets
the maximum stay in the DC for some of these products at one day, essentially making them
PTZ. Therefore these products were eliminated as well. The feedback from the inventory de-
partment supervisor led to a final elimination of products from the vegetable assortment group,
since these could be considered to be ‘produced’ fresh every day, which meant that these were
products were out of scope. This led to a final remaining selection of 83 products that can
be found in Appendix C. This set contained a lot of products with similar characteristics. For
sensitivity reasons the final product set was selected such that the products differ on character-
istics like the store shelf life, average weekly store demand and case pack size of the products.
This led to the selection of the products that can be found in Table 2, which are all products
of the largest two waste categories.
Table 2: Final product selection

<table>
<thead>
<tr>
<th>Article no.</th>
<th>Case pack size</th>
<th>Average weekly demand (#CU)</th>
<th>SSL</th>
</tr>
</thead>
<tbody>
<tr>
<td>403293</td>
<td>6</td>
<td>2075</td>
<td>6</td>
</tr>
<tr>
<td>403488</td>
<td>4</td>
<td>2020</td>
<td>12</td>
</tr>
<tr>
<td>403626</td>
<td>12</td>
<td>10146</td>
<td>7</td>
</tr>
<tr>
<td>404474</td>
<td>4</td>
<td>885</td>
<td>8</td>
</tr>
<tr>
<td>350409</td>
<td>6</td>
<td>4698</td>
<td>7</td>
</tr>
<tr>
<td>403036</td>
<td>6</td>
<td>1359</td>
<td>8</td>
</tr>
<tr>
<td>404876</td>
<td>6</td>
<td>960</td>
<td>8</td>
</tr>
</tbody>
</table>

4.5 Demand analysis

Since point of sales data in PLUS stores are not available for this research, the store demand at the DC needed to be collected in order to perform an analysis. This was done for the period from week 29 in 2015 up to and including week 27 in the year 2016. Note that this was the demand data for regular demand only, since including promotional demand would give a distorted view of average store demand. Furthermore, the weeks including the following holidays were removed from the data as well: 2015-52 and 2015-53 due to Christmas and 2016-12 and 2016-19 due to Eastern and Pentecost respectively. The software tools used at HB automatically excluded the promotional sales, since it is known during which weeks the products were on promotion and the inventory for promotional sales is separated from the regular inventory. The demand analysis was only performed for the products mentioned in Table 2.

Store demand

PLUS store owners can independently decide whether or not they want to include the products that HB can provide in their local assortment. In order to capture the demand of the stores that meet the regular demand criterion, all demand from stores that ordered the selected products for less than 10 weeks were excluded from the data. The data showed that the amount of stores that ordered the product for at least 10 weeks, also order the product on a regular basis. A pattern in the variation in the amount of stores that order the product could not be found and the assumption that the amount of stores is adequately stable seems reasonable as seen in Figure 16.

![Amount of stores per week - SKU 403036](image)

Figure 16: Amount of stores per week for SKU 403036
For the stores that met the criteria the demand data was collected for the time period mentioned above and the demand was analysed. "Outliers" in the form of negative demand in the data, originating from changes in orders were removed. The selection for regular demand using the 10 week rule excluded some other outliers. These could have originated from the freedom that PLUS stores have to do local promotions, sponsorships or any other events such as sales of non-assortment products during holidays. In order to draw conclusions on the effects of the distribution flows on a certain type of store, all stores were given an index in the form of a sales rank. The sales rank is based on the average amount of case packs shipped to a specific store per week. For the selected products, the stores that met the demand criteria and had all the selected products in their regular assortment were chosen as the research sample. The sample contains 56 stores.

**Weekpattern**

Grocery stores often face a weekpattern in sales but since no POS data is available, the store demand at HB was analysed for the existence of weekpatterns. For the selected products a weekpattern could be observed in the demand. On Monday, Tuesday and Wednesday demand was below the mean daily demand and for Thursday, Friday and Saturday it was higher than average with the latter two having the highest demand. Sunday demand however was at an average of just 20 percent of mean daily demand even though it is a weekend day. This can be explained by the fact that the replenishment of PLUS stores on Sundays is currently for just a small number of stores. The amount of stores to receive replenishment on Sundays is expected to keep growing in the near future. Figure 17 shows the percentage of mean demand for the product with the highest and lowest weekpattern. The weekpattern is determined by dividing the weekday with the highest average demand by the weekday with the lowest average demand excluding Sundays. Due to the fact that HB replenishes few stores on Sunday even though these stores are opened on Sundays it is likely that these stores have a sort of forward buying behaviour. This means that extra products will be ordered on Friday or Saturday to cover customer demand during the entire weekend. Any conclusions on this behaviour however can not be drawn. Given the lack of POS data for the stores and the low amount of stores supplied on Sundays it was decided that the average weekly demand per store at the DC will be divided by 7 and multiplied by the case pack size to make the average demand in consumer units per store per day. The demand data that will be used for the simulation will thus not take into account a weekpattern.

![Figure 17: Products with the lowest (404474) and highest weekpattern (403626)](image)

**Fitting a discrete distribution**

The demand per store served as an important input for the model and therefore it had to be determined how this could best be modelled. This was done using the logic of Adan et al. (1995), who developed a method to fit a discrete distribution on the first two moments of a non-negative random variable. The data can be fitted in one of the following classes of discrete probability distributions: the geometric, the negative binomial, the Poisson, and the binomial distribution.
To determine which distribution can be fit, the mean daily demand and the standard deviation of the daily demand per store and SKU combination is used. Since the average demand per store per day has been determined by using the methods described in the previous section, the standard deviation of daily demand has to be determined next. Again, due to lack of POS data, the standard deviation had to be estimated.

Broekmeulen and van Donselaar (2016) describe a method in their report to derive a relationship between the mean daily demand and the standard deviation of the daily demand. This method consists of a linear regression performed on a set of demand data, and the results of the regression are then transformed to a simple relationship between the mean daily demand and the standard deviation of the daily demand. For their project this was equal to Equation 4.7.

\[ \sigma_i = 1.18 \times \mu_i^{0.77} \]  

(4.7)

For the current project a non-disclosed dataset from a research project for PLUS supermarkets was used and with the methods described by Broekmeulen and van Donselaar (2016) a similar power law relationship was tried to derive. The results of this analysis showed however that the new relation did not provide more robust outcomes than the one in Equation 4.7. It was therefore decided to use the relationship found in the ECR report (Broekmeulen & van Donselaar, 2016) as equation for the standard deviation of demand.

With the above given, the combination of store and SKU demand data were fit and all combinations have the negative binomial distribution. These findings are in line with those of Agrawal and Smith (1996), who showed that the negative binomial distribution describes retail demand well.
5. Simulation model

In this chapter the simulation model is described. First the various distribution flow elements that are used for the distribution flow scenarios in the model will be provided. Any assumptions that were made for this model are given thereafter, followed by a description of the software elements. The relevant quantitative measures are given in the last part of the chapter.

The simulation is programmed in the Visual Basic for Applications programming language and a Microsoft Access database is used to run the simulation and generate the results. The design and programming of this database was done by dr. ir. R.A.C.M. Broekmeulen and the software was handed to the researcher for use in this project.

5.1 Distribution flow descriptions

Following the research directions provided in Section 3.2, there are three main distribution flow elements that the model will incorporate. For each of the distribution flows containing a combination of the elements, the model will assume the EWA-replenishment policy for PLUS stores with FIFO consumer withdrawal behaviour. The three flow elements are:

1. The allocation policy at the DC. When facing OOS at the DC, the allocation is based on the order sequence or on the new allocation rule based on runout times.
2. Order and supply synchronisation between the DC and the supplier. The review period at the DC and production interval at the supplier can be in $R_{DC} = R_P$ or out $R_{DC} < R_P$ of sync, resulting in different product freshness upon arrival at the DC.
3. Production strategy. When order and supply between the DC and supplier is in sync, and the order of the DC is placed at the start of production, this results in a MTO strategy. For the other scenarios the supplier uses a MTS production strategy.

In order to give a clear description of the methods used in the model, Table 3 gives an overview of the variables and parameters used. Section 5.3 will provide the underlying elements that are used in the software, for which each simulation period is equal to one day.

Table 3: Parameters and variables

<table>
<thead>
<tr>
<th>Sets</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SKUS</td>
<td>Set of selected products</td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>Set of locations including the DC</td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>Set of days in the simulation</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Indices</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>Index for the product ($\in$ SKUS)</td>
<td></td>
</tr>
<tr>
<td>j</td>
<td>Index for the location ($\in$ J)</td>
<td></td>
</tr>
<tr>
<td>t</td>
<td>Index for the time in day since the start of the simulation($\in$ T)</td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>Index for the remaining lifetime of the product</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variables</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_{t,i,j}$</td>
<td>Demand at location j, for product i, during day t</td>
<td></td>
</tr>
<tr>
<td>$O_{t,i,j}$</td>
<td>Amount of outdating at location j, for product i, at the end of day t</td>
<td></td>
</tr>
<tr>
<td>$I_{t,i,j,a}$</td>
<td>Inventory on hand at location j, for product i with remaining lifetime a, at the end of day t, after outdating and sales</td>
<td></td>
</tr>
<tr>
<td>$IP_{t,i,j}$</td>
<td>Inventory position at location j, for product i at the end of day t</td>
<td></td>
</tr>
<tr>
<td>$OQ_{t,i,j}$</td>
<td>Amount of ordered casepacks by location j, for product i, on day t</td>
<td></td>
</tr>
<tr>
<td>$DQ_{t,i,j,a}$</td>
<td>Delivered casepacks of product i, to location j, at day t with remaining shelf life a</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameters</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu_{i,j}$</td>
<td>Mean daily demand for product i at location j</td>
<td></td>
</tr>
</tbody>
</table>
5.1.1 Order of events

In order to gain an understanding of how the model is executed the order of events is provided in this section. For the stores the order of events and a sample path of the inventory in a store is given in the figures and explanation below.

1. At the first review moment the store places an order at the DC. The stores use the EWA replenishment policy. Broekmeulen and van Donselaar (2009) provided the following equation for the amount of casepacks to be ordered, shown in Equation 5.1.

   \[
   \text{if } IP_t - \sum_{i=t+1}^{t+L+R-1} \hat{O}_i < s_t \text{ then } n_t = \left\lceil \frac{s_t - IP_t + \sum_{i=t+1}^{t+L+R-1} \hat{O}_i}{Q} \right\rceil 
   \]

   where
   - \( IP_t \) = inventory position on day \( t \);
   - \( Q \) = Case pack size;
   - \( s_t \) = Reorder level at day \( t \);
   - \( \sum_{i=t+1}^{t+L+R-1} \hat{O}_i \) = estimated amount of outdating during \( L+R-1 \) days.

   For which the reorder level has been determined by using equation 5.2.

   \[
   s_t = SS + \sum_{i=t+1}^{t+L+R} E[D_i] \]

   where
   - \( SS \) = safety stock;
   - \( \sum_{i=t+1}^{t+L+R} E[D_i] \) = expected demand during the lead time and review period.

2. After lead time period \( L \) the delivery from the DC takes place. If the DC face OOS, the delivered amount of case packs can be less than the ordered amount of case packs. The inventory position of the store is corrected for this deviation in such case.

3. Customer demand takes place during the day.

4. If customer demand was not sufficient for a batch to be sold before reaching the expiration date, these products are removed from inventory due to outdating.

The order of events in the model for the central DC are displayed in Figure 19. The sequence is as follows:

Figure 18: Order of events and sample path of store inventory.
1. At the first review moment the DC places an order at the supplier. The order is based on the reorder level, inventory position and the expected demand during the order horizon \((R_{DC} + L_{DC})\).

2. A delivery from the supplier is made after \(L\) time. If the DC order was larger than remaining inventory of the supplier in a MTS scenario, the maximum available amount is shipped to the DC.

3. Store orders are received and the total demand at DC is calculated.

4. The allocated case packs are picked in FIFO manner and are shipped to stores.

5. If store demand was not sufficient for a batch to be shipped before reaching the SSL, these products are removed from inventory due to outdating.

Note that when the review period of the DC is longer than the lead time, the cycle of allocating inventory, shipping goods and outdating occurs multiple time before reaching the next review moment.

The most upstream supply chain actor in the chain is the supplier. The events at the supplier are displayed below, where a distinction is made between the MTO and MTS scenarios.

1. At the first production moment the supplier produces the first batch of products for the DC and stores them at their facility. In a MTS scenario this is based on the shared forecast of the DC which is produced and put in stock at the supplier. For the MTO scenarios this is the actual order that the DC places and this is shipped to the DC.
2. In between production moments, the DC orders are shipped by the supplier. Note that if \( R_{DC} < R_P \) shipments are done multiple times between production moments. In the case of synchronised order and supply, DC demand is shipped right after production.

3. For the MTS scenarios, any leftover inventory at the supplier will be outdated just before the new production run due to the constraints on the minimum acceptable lifetime upon arrival in the DC.

5.2 Model assumptions

To achieve a model that is more generalisable and applicable than just the business case for HB, some modelling assumptions have been made:

- The reorder policy for stores is the EWA-replenishment policy as explained in the previous section, with the following subset of assumptions:
  - Reorder levels are determined by a 95% target service level in the stores.
  - Customer withdrawal behaviour is in a FIFO manner.
  - The store order size is equal to a multiple integer of the case pack size \( Q_i \).
  - A lost sales environment is in place, no backorders are therefore allowed.
  - Customer demand at the store can be approximated with a discrete distribution with a fixed mean and standard deviation per store per day.
  - A week pattern in store sales is ignored.
  - Lead time for stores is \( L \) days.

- The reorder policy for the DC is a \((R,s,nQ)\) replenishment policy with review period \( R_{DC} \). The supplier is able to ship goods to the DC with a fixed lead time of \( L_{DC} \).

- Inventory at the DC is withdrawn in a FIFO manner.

- The DC order size is equal to a multiple integer of the DC unit size for the \((R,s,nQ)\) replenishment policy.

- The model is based on a lost sales environment, no backorders are therefore allowed for the DC or supplier.

- The warehouse has unlimited capacity for storing inventory.

- Information sharing between the stores and DC is in place. The DC has access to the mean and standard deviation of sales per day per store per SKU and to the inventory levels per store as well as the outdated for each day.

- The forecast of the DC is shared between the DC and supplier.

- The supplier has unlimited capacity and raw materials to produce their product.

5.3 Software elements

**Stores**

The model is designed with a service level constraint in the stores of 95%. To meet this service level, for each store and SKU combination the reorder level was set using the methods described by Broekmeulen and van Donselaar (2009); van Donselaar and Broekmeulen (2013) and such that the expected fill rate is equal to or above the target fill rate. Furthermore the expected relative outdated \( E[Z_{i,j}] \) given the expected fill rate for each store and SKU combination was determined using the methods described by van Donselaar and Broekmeulen (2012). Assuming that the products that arrive in the store are either sold or outdated, the approximations above
were used to generate the average daily desired supply per store for each SKU \((S_{i,j})\). The desired amount of CU's is given by equation 5.3.

\[
S_{i,j} = \mu_{i,j} \cdot (P_{2_{i,j}} + E[Z_{i,j}]) \tag{5.3}
\]

When the simulation is run, the events at the store are simulated in the order described in the previous section. For each day, the sales in the store are determined and the products that cannot be sold the next day are outdated and removed from inventory. Next the inventory in the store is determined and registered and a new order \(OQ_{t,i,j}\) is generated according to the EWA-policy.

**DC Allocation**

When all orders have been generated in the stores, the DC will evaluate if it is able to fulfill all store demand. If the total demand for a product at the DC exceeds the available inventory at the DC, an allocation rule is used. The allocation policies that are used in the simulation are the sequential allocation or the allocation based on runout time. When the simulation is run using the sequential allocation, the order of a store is filled with the oldest available case packs at the DC. This process is done iteratively for stores 1 until \(J\) as long as there is inventory at the DC. When the inventory of the DC is depleted all remaining store demand is lost.

When the allocation is based on runout times, the procedure is different. First the software determines the runout time for each store that placed an order by dividing the inventory of each store by the store's mean daily demand. This results in a ranking where the store that will run out fastest is ranked highest and the store that runs out slowest is lowest.

The highest ranking store will receive goods from the oldest batch that is available at the DC, and when the batch size is sufficient to fill the store order, the next store in order is taken by the model. This process repeats until the batch is depleted and if the store order at that point is not filled fully, the store will receive goods from the next batch. Again, this process is repeated until either no more inventory at the DC is available, or all store orders have been filled. At the end of the allocation process the amount of case packs that will be shipped to each stores is known and this amount will be put in the store’s inventory on the end of the next day. Orders allocated 0 case packs can be seen as lost sales for the DC.

**DC ordering**

The DC is replenished using the \((R,s,nQ)\) replenishment policy. The reorder levels for this policy are determined in the simulation. The model uses the initial forecast for SKU \(i\) in Equation 5.4 multiplied by the DC lead time plus DC review period as the base reorder level and the model further determines the expected fill rate at the DC for this reorder level. Then the reorder level is decreased by 1 and expected fill rate is determined again. This process is done iteratively until the expected fill rate of the is below 0.8. The same is done starting at the base reorder level but upwards, until an expected fill rate is above 0.99. All the reorder levels in between this range will be used for the simulation of a given supply chain scenario. The orders generated by the DC will be filled by the supplier when there is enough inventory. For the MTS scenarios this means that the DC receives inventory from the latest production, for a MTO scenario this means that the DC order is produced and then shipped to the DC.

**Production**

The forecasting process at the DC is an important component of the model. The model assumes that information is shared between stores and DC and therefore that the forecast of the DC \(F_{t,i}\) for SKU \(i\) is based on events in the store. Since for each store a desired supply is determined in Equation 5.3, the initial simulation forecast for the DC in order to satisfy the desired supply
for all stores for a given SKU is provided in Equation 5.4.

\[ F_{i,0} = \sum_{j \in J \setminus \{DC\}} S_{(i,j)}/Q_i \]  

(5.4)

In the simulation, after all store demand and outdating is known for the day the forecast is updated using a simple exponential smoothing method as shown in equation 5.5. The exponential smoothing method incorporates the actual sales and outdating in the stores to construct the new forecast for SKU \( i \) at day \( t \).

\[ F_{i,t} = \alpha \sum_{j \in J \setminus \{DC\}} ((D_{t,i,j} + O_{t,i,j})/Q_i) + (1 - \alpha) \cdot F_{i,t-1} \]  

(5.5)

The forecast is then shared with the supplier in a MTS scenario. When a production moment of the supplier occurs, the supplier will use the DC forecast at day \( t \) to determine the production amount for the production run. The production amount for product \( i \) at time \( t \) (\( PQ_{i,t} \)) is equal to equation 5.6 where the amount is rounded to the nearest unit size \( Q_{DC} \).

\[ PQ_{i,t} = \left( (F_{i,t} \cdot R_P + k \cdot \sqrt{R_P} \cdot 15)/Q_{DC} \right) \]  

(5.6)

These products are produced and then stocked at the suppliers facility. The orders made by the DC are shipped from this stock as long as inventory is sufficient. It should be noted here that the supplier is assumed to reserve the product for HB only, so the stock is not depleted for replenishment of other customers of the supplier. On the other hand in case of shortage at the supplier, HB will not receive products from batches made for other customers of the supplier. When a MTO strategy is in place, the supplier will receive the order before the production and will produce the entire order, maximising the availability of products. These are also directly shipped to the DC since the order and replenishment is synchronised and the supplier acts as a stockless point in the supply chain, which maximises freshness.

### 5.4 Simulation properties

**Warm up period**

In the simulation experiment, the initiated DC forecast is used to develop the DC forecast over time using the exponential smoothing method. The initial setting has an influence on the forecast amount of the consecutive periods. To make sure that the initial situation does not influence the results anymore, van der Aalst (1995) suggest using a warm up period. This period ensures the stabilisation of results and fades the influence of the initial setting. For this part of the simulation the outcomes are not recorded. Since the system does not start out empty but the inventory of the DC and the stores is set at their respective reorder levels, a length of 500 days should be sufficient to remove the influence of the initial settings for the inventory levels, order amounts and DC forecast.

**Simulation length**

After the warmup period, the model output is recorded for a specified period of time. According to van der Aalst (1995) the run length should be sufficient to provide representative results. Since the study has a strategic horizon, there is no need for short term simulation only (1 year). Furthermore, after determination of the duration of a simulation run, it could be concluded that computation speed is high enough to simulate long periods of time. The simulation length has therefore been set at 20,000 days.
Simulation replications

In simulation research multiple authors e.g. van der Aalst (1995); Carson (2002) stress the importance of multiple replications of the simulation experiment instead of one long run that generates the data. To determine the amount of simulation runs that are necessary for accurate results, a specified relative precision can be set for the replications (Law & Kelton, 2000). Since the simulation runs are independent, which means that the terminating value of the preceding run does not influence the values of the next run, the model is run for a small number of replications (for this simulation it is set at 10 replications). For these runs the confidence interval half width is calculated and if this value is less than the specified relative precision value there is no need for further replications (Itami et al., 2005). The confidence interval half width is determined using equation 5.7. For this model $\alpha$ is set at 0.05.

$$t_{1-\alpha/2} \sqrt{\frac{S^2(n)}{n}}$$

(5.7)

Where:

$t_{1-\alpha/2} =$ the $(1-\alpha)$ percentile of the t-student distribution with $n - 1$ degrees of freedom

$S^2(n) =$ sample variance of the DC fill rate in $n$ replications.

5.5 Relevant quantitative measures

Since the goal of the model is to determine the relative freshness of the products at the retail outlet by varying distribution flow elements in the perishable goods supply chain, it should be determined which further outcomes of the model are relevant to the stakeholders in the supply chain. The freshness of products might be increased at the expense of other KPI's so first a classification will be made for the relevant outcomes of the model.

Product freshness

The product freshness is the most important outcome of the model to evaluate which distribution flow elements are best suited for a certain type of product. The outcomes are given in either a freshness indicator that gives the remaining product lifetime or a relative freshness, given in a percentage of the total product lifetime for the chosen SKU. The model provides the freshness of goods at the DC and the stores where the freshness is the average remaining shelf life of the product that is shipped to the store or sold to a customer respectively.

Fill rate

The fill rate for the DC is an important measure since HB is contractually obliged to meet a predetermined fill rate. However lowering the fill rate i.e. choosing a lower reorder level for the DC will have an influence on the inventory level in the DC and therefore on the amount of inventory that is available for allocation. Since lower inventory might lead to increased freshness it is important to determine how low the fill rate can be for the DC to still ship enough product to stores in order for the stores to reach the target fill rate. Therefore the fill rate is also a KPI for the stores. Since there is a store service level constraint, the output of the model can be used to determine whether the model meets the constraints or that adjustments are necessary. The fill rate for the location, whether DC or store per SKU is given in Equation 5.8 respectively.

$$P_{2,i}(J) = 1 - \frac{\sum_{t=1}^{T}(D_{t,i,j} - \sum_{a \in N}(I_{t-1,i,j,a} + D_{Q(t-1,i,j,a)})^+)}{\sum_{t=1}^{T}D_{t,i,j}}$$

(5.8)

Number of order lines at DC

The number of order lines represent the average amount of shipments per period that are made
from the DC to the supplier. Since this not only implies costs for the pick up of goods at the supplier and shipment to the DC, the costs for incoming handling operations at the DC are also linked to the amount of order lines. Reducing these order lines might therefore be beneficial to the amount of man hours spent on loading and unloading trucks, inbound goods controls and placement of received goods in the DC storage facilities. The number of order lines is determined by the amount of order lines placed over the simulation horizon divided by the amount of days in the simulation.

**Average inventory**
The products that HB orders from their supplier are stored at specific locations in the cooled warehouse. It is assumed that the warehouse has enough storing capacity to put away the inventory of the products, but for the different scenarios the average amount of inventory of the DC is expected to vary. Furthermore, the stores and the DC might have opportunity costs for the product. This is related to the fact that the money spent on inventory could also be used otherwise. To gain an insight in the amount of stock that is kept in the DC the average inventory is determined by the model. The model provides the average physical inventory after sales and outdating, but before the arrival of a new batch of produce. This measure is chosen so that it could also be determined what percentage of time the store will have a positive inventory at the end of the day (the ready rate).
6. Model Solving

In this chapter the results of the analysis of the data from the conceptual model as described in the previous chapter will be provided. The input parameters, output parameters and KPI's of the model will be provided, these represent the different distribution flow elements for the supply chain. Sensitivity analysis is performed to see what the effect of potential changes in the supply chain might have on the performance of the model.

6.1 Input parameters

In this section the input parameters of the model will be discussed. The following data was necessary as input for the model:

- Product Information (SKU number, name)
- Case pack size (in CU’s)
- Store Information (Salesrank, Owner, StoreID)
- Store reorder level (per store per product)
- Acceptable Store Shelf life (SSL)
- Mean of customer demand (per store per day per SKU)
- Standard deviation of demand (per store per day per SKU)
- Store lead time (in days)
- Store review period (in days)
- Review period of DC (in days)
- DC lead time (in days)
- DC unit size (in case packs)
- Production interval of supplier (in days)
- Shelf life just after production (PSL)

In order to generate the results, the model needs some further input that is based on calculations and assumptions. The input parameters that were filled in this way are given below:

- Expected fill rate (per store per SKU)
- Expected outdating (per store per SKU)
- Production on forecast parameter
- Inventory allocation parameter
- Exponential smoothing factor $\alpha$
- Target precision

6.2 Output parameters

The simulation model provides different output measures for the distribution flow designs. The output is generated for each experiment, for every location (supplier, DC, stores) per SKU.

Output measures per location:

- Fill rate (or $P_2$)
- Average inventory (in location unit size)
- Average number of batches
- Average order size (in location unit size)
- Average number of orders
- Average outdating (in location unit size)
- Average freshness (in days)

Overall output measures:

- Simulation precision (confidence interval half width)
6.3 Scenario analysis

In this section, the model output for the different scenarios for the supply chain of HB will be analysed. From this analysis a comparison between distribution elements will provide an insight in the retail product freshness (RPF) of products given the scenarios.

6.3.1 Baseline scenario

The first scenario uses the input parameters for production and the DC that would best approximate the current distribution flow at HB. The main difference between the model and the current situation is that in the model the stores use the EWA-replenishment policy and information sharing is in place between the store, DC and supplier whilst this is not the case in real life. The products used for the simulation are, as stated in Section 4.4, and the complete set of product characteristics, are given in Table 4.

Table 4: Simulation product parameters

<table>
<thead>
<tr>
<th>Article no.</th>
<th>Case pack size</th>
<th>Unit size</th>
<th>PSL</th>
<th>SSL</th>
</tr>
</thead>
<tbody>
<tr>
<td>350409</td>
<td>6</td>
<td>8</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>403036</td>
<td>6</td>
<td>25</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>403293</td>
<td>6</td>
<td>24</td>
<td>9</td>
<td>9</td>
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<td>403488</td>
<td>4</td>
<td>12</td>
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<td>12</td>
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<td>403626</td>
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<td>18</td>
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<td>7</td>
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<td>404474</td>
<td>4</td>
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<tr>
<td>404876</td>
<td>6</td>
<td>11</td>
<td>12</td>
<td>8</td>
</tr>
</tbody>
</table>

The baseline experiments provide results for a scenario with sequential allocation, unsynchronised supply and where the supplier uses a make to stock production strategy. Table 5 shows the outcomes for the different SKUs in a situation where $R_{DC} = 1$ and $R_P = 2$. The table provides an overview of the model outcomes with the highest DC fill rate of the experiment, in line with the current SLA. Note here that the current target service level is not met for all SKUs in the experiment. As stated before, the model increases the reorder levels until a maximum fill rate of 99% in the DC is reached. If this target was not met, increased reorder levels for these SKUS did not lead to a higher fill rate but instead to more wasted products.

Table 5: Baseline experiment outcome

<table>
<thead>
<tr>
<th>SKU</th>
<th>Minimum $P_2$ Stores</th>
<th>Weighted $P_2$ Stores</th>
<th>Relative Waste Stores</th>
<th>Fraction RPF</th>
<th>$P_2$ DC</th>
</tr>
</thead>
<tbody>
<tr>
<td>350409</td>
<td>0.935</td>
<td>0.951</td>
<td>0.007</td>
<td>0.575</td>
<td>0.992</td>
</tr>
<tr>
<td>403036</td>
<td>0.945</td>
<td>0.958</td>
<td>0.057</td>
<td>0.473</td>
<td>0.989</td>
</tr>
<tr>
<td>403293</td>
<td>0.940</td>
<td>0.953</td>
<td>0.076</td>
<td>0.468</td>
<td>0.987</td>
</tr>
<tr>
<td>403488</td>
<td>0.943</td>
<td>0.956</td>
<td>0.001</td>
<td>0.676</td>
<td>0.991</td>
</tr>
<tr>
<td>403626</td>
<td>0.929</td>
<td>0.946</td>
<td>0.011</td>
<td>0.557</td>
<td>0.977</td>
</tr>
<tr>
<td>404474</td>
<td>0.940</td>
<td>0.961</td>
<td>0.083</td>
<td>0.472</td>
<td>0.990</td>
</tr>
<tr>
<td>404876</td>
<td>0.943</td>
<td>0.960</td>
<td>0.087</td>
<td>0.460</td>
<td>0.991</td>
</tr>
</tbody>
</table>

Furthermore, the experiments show that a lower DC reorder level has a positive effect on freshness of products sold in the store, except for SKU 403293, see Table 5. Reduction of reorder level is however restricted to the point where the weighted store fill rate remains above the restriction of 95%. For SKU 403626 this is not possible since the maximum DC fill rate is not sufficient to reach the target fill rate for stores. An additional experiment where $R_{DC} = 1$ and $R_P = 3$ was performed and results showed that this would lead to worse performance than the outcomes provided in Table 5. Given this decreased performance and the currently unknown
Table 6: Baseline experiment outcome with lowered DC fillrate

<table>
<thead>
<tr>
<th>SKU</th>
<th>Minimum $P_2$ Stores</th>
<th>Weighted $P_2$ Stores</th>
<th>Relative Waste Stores</th>
<th>Fraction RPF</th>
<th>$P_2$ DC</th>
<th>$\Delta$ RPF</th>
</tr>
</thead>
<tbody>
<tr>
<td>350409</td>
<td>0.931</td>
<td>0.951</td>
<td>0.007</td>
<td>0.577</td>
<td>0.990</td>
<td>0.26%</td>
</tr>
<tr>
<td>403036</td>
<td>0.943</td>
<td>0.957</td>
<td>0.050</td>
<td>0.492</td>
<td>0.981</td>
<td>4.01%</td>
</tr>
<tr>
<td>403293</td>
<td>0.928</td>
<td>0.952</td>
<td>0.075</td>
<td>0.467</td>
<td>0.978</td>
<td>-0.23%</td>
</tr>
<tr>
<td>403488</td>
<td>0.929</td>
<td>0.954</td>
<td>0.001</td>
<td>0.682</td>
<td>0.971</td>
<td>0.80%</td>
</tr>
<tr>
<td>403626</td>
<td>0.929</td>
<td>0.946</td>
<td>0.011</td>
<td>0.557</td>
<td>0.977</td>
<td>0.00%</td>
</tr>
<tr>
<td>404474</td>
<td>0.925</td>
<td>0.957</td>
<td>0.069</td>
<td>0.490</td>
<td>0.939</td>
<td>3.79%</td>
</tr>
<tr>
<td>404876</td>
<td>0.856</td>
<td>0.951</td>
<td>0.068</td>
<td>0.486</td>
<td>0.908</td>
<td>5.67%</td>
</tr>
</tbody>
</table>

Production intervals, the first experiment was chosen as the baseline. Given that the weighted customer fill rate in the stores is met for most SKUs, further analysis of the outcomes shows that the random allocation (sequence determined by store number) performs poorly when DC fill rate is lowered for a number of stores. Those with a high store number are last to receive goods in the sequential allocation procedure, and with a lower fill rate in the DC they receive only few products (supply rates as low as 0.108). The trend in store service level is shown for SKU 350409 in Figure 21. The results are similar for other products except for SKU 403036 and 404474 where the minimum fill rates in the stores are near the target fill rate for most stores, independent of their store number.

Figure 21: Comparison of minimum fill rate per store for different reorder levels.

6.3.2 Allocation based on runout times

The first element in the management of the distribution flow that is tested is the inventory allocation rule at the DC. For the same input parameters as the previous section the results are presented figure 22. The values for waste level and the RPF are compared using the reorder level at the DC (for high fill rates) as a constant. The difference in the two allocation policies is minor for both waste and freshness, but overall the improved allocation method slightly outperforms the random method on these two measures. The biggest difference that the allocation procedure makes is the average service level in stores. In contrast with figure 21 there is no sharp decline in store service levels for any particular stores when the service level of the DC is lowered, showing potential for
decreasing reorder levels at the DC without violating the restriction on store service levels. The increased performance of this allocation method over the base method holds for all SKUs. In table 6 it was shown that a lower DC fill rate increased freshness. This was for the combination of allocation based on runout times and lowered DC service levels as well. The lowered DC reorder level is chosen such that the weighted store fill rate is at or above the store service level restriction. The effect of lowering the reorder level to a minimum acceptable standard is shown in Table 7. The table provides an insight in the RPF gains and the change in waste for the system as a whole.

Table 7: Results for lowered service levels using runout based allocation and the difference with high service level at the DC.

<table>
<thead>
<tr>
<th>SKU</th>
<th>Rel. Waste Stores</th>
<th>Rel. Waste DC</th>
<th>Rel. Waste Supplier</th>
<th>Δ RPF</th>
<th>Δ Avg. DC Inventory</th>
<th>Δ Rel. Waste system</th>
</tr>
</thead>
<tbody>
<tr>
<td>350409</td>
<td>0.005</td>
<td>0.000</td>
<td>0.053</td>
<td>1.3%</td>
<td>-43.6%</td>
<td>-0.8%</td>
</tr>
<tr>
<td>403036</td>
<td>0.047</td>
<td>0.040</td>
<td>0.713</td>
<td>5.0%</td>
<td>-29.9%</td>
<td>-0.8%</td>
</tr>
<tr>
<td>403293</td>
<td>0.073</td>
<td>0.100</td>
<td>0.000</td>
<td>0.0%</td>
<td>-60.6%</td>
<td>0.1%</td>
</tr>
<tr>
<td>403488</td>
<td>0.001</td>
<td>0.000</td>
<td>0.133</td>
<td>0.8%</td>
<td>-34.8%</td>
<td>-1.3%</td>
</tr>
<tr>
<td>403626</td>
<td>0.010</td>
<td>0.056</td>
<td>0.000</td>
<td>0.0%</td>
<td>-26.3%</td>
<td>-0.2%</td>
</tr>
<tr>
<td>404474</td>
<td>0.065</td>
<td>0.001</td>
<td>0.215</td>
<td>4.3%</td>
<td>-51.8%</td>
<td>-2.2%</td>
</tr>
<tr>
<td>404876</td>
<td>0.054</td>
<td>0.000</td>
<td>0.091</td>
<td>7.5%</td>
<td>-79.6%</td>
<td>-52.6%</td>
</tr>
</tbody>
</table>

Freshness is equal or increased for all SKUs and a drop in average inventory at the DC is also realised for all products. With an inventory decrease between 29.9% and 79.36% the allocation rule shows to be effective in reducing average inventory. The difference in the relative waste of the system as a whole is remarkably high for SKU 404876. Further analysis of the experiment outcomes found that this is due to a large reduction of waste at the supplier due to a decrease in the production amount, leading to less inventory going to waste. Producing less is thus better for these products, since any extra production will just be outdated.

6.3.3 Synchronisation of production and replenishment

The effects of optimising freshness by improving collaboration between the supplier and the DC is researched in this section. The production at the supplier and replenishment of the DC are synchronised for this distribution flow element. For the set of experiments this means that $R_{DC} = R_P$ with a review and production period of 1, 2 and 3 days.
synchronisation for the SKUs at a high service level for the DC, given a 2 day period are given in Table 8. The difference in the amount of order lines amount for scenarios is compared for this supply chain element as well, since the review period in the DC is changed.

Table 8: Outcomes for synchronised production and replenishment and comparison to baseline.

<table>
<thead>
<tr>
<th>SKU</th>
<th>Rel. Waste Stores</th>
<th>Rel. Waste DC</th>
<th>Rel. Waste Supplier</th>
<th>Δ RPF</th>
<th>Δ Avg. DC Inventory</th>
<th>Δ Rel. Waste System</th>
<th>Δ Order lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>350409</td>
<td>0.007</td>
<td>0.000</td>
<td>0.053</td>
<td>0.3%</td>
<td>187.9%</td>
<td>0.1%</td>
<td>-50%</td>
</tr>
<tr>
<td>403036</td>
<td>0.055</td>
<td>0.133</td>
<td>0.615</td>
<td>1.4%</td>
<td>35.4%</td>
<td>-0.4%</td>
<td>-27%</td>
</tr>
<tr>
<td>403293</td>
<td>0.076</td>
<td>0.096</td>
<td>0.000</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>-50%</td>
</tr>
<tr>
<td>403488</td>
<td>0.001</td>
<td>0.000</td>
<td>0.134</td>
<td>0.2%</td>
<td>110.6%</td>
<td>-0.1%</td>
<td>-50%</td>
</tr>
<tr>
<td>403626</td>
<td>0.011</td>
<td>0.056</td>
<td>0.000</td>
<td>0.0%</td>
<td>0.5%</td>
<td>0.0%</td>
<td>-50%</td>
</tr>
<tr>
<td>404474</td>
<td>0.080</td>
<td>0.004</td>
<td>0.202</td>
<td>1.0%</td>
<td>75.8%</td>
<td>-0.3%</td>
<td>-50%</td>
</tr>
<tr>
<td>404876</td>
<td>0.086</td>
<td>0.015</td>
<td>0.204</td>
<td>0.6%</td>
<td>44.0%</td>
<td>-2.3%</td>
<td>-46%</td>
</tr>
</tbody>
</table>

The results show that this distribution flow element has little effect on the product freshness, but does not worsen the freshness of products. The waste in the system is not reduced to a high degree either. The average inventory in the DC does increase significantly for most products. For SKUs 350409 and 403488 this is caused by the low relative waste in the DC, and for all SKUs it is also the result of taking in the inventory for multiple periods at once. The decline in the amount of order lines placed by the DC is a direct effect of the review period being synchronised with the production intervals. Since the DC now orders every other day, the amount of order lines decreases to around 0.5 per day, which will lead to a reduction in operational handling for both the supplier and DC.

6.3.4 MTO vs. MTS production

The analysis of the service level determination for HB has shown that supplier stockouts or incomplete deliveries are one of the factors that influence the performance of HB. To evaluate what an increase in availability from the supplier would lead to, it has been decided to test the effects of a MTS versus MTO policy at the supplier, whilst choosing a low fill rate at the DC. The comparison of the baseline and a MTO scenario where $R_{DC} = R_P = 2$ is given in Table 9. The table shows that for SKU 403626 the relative waste of the system increases steeply. This is due to an increase in the relative waste levels at the DC, as can be derived from increasing waste and near equal average inventory levels. However, it should be noted that for this SKU the DC was not able to realise the SLA fill rate in the baseline scenario. For the MTO policy this SKU now does reach the target fill rate, but at the cost of generating extra waste. The freshness of the products that are shipped to the stores increases with nearly 10% for three SKUs which is a promising result.

Table 9: Outcomes for the supply chain using MTO production and comparison to baseline

<table>
<thead>
<tr>
<th>SKU</th>
<th>Rel. Waste Stores</th>
<th>Rel. Waste DC</th>
<th>Rel. Waste Supplier</th>
<th>Δ RPF</th>
<th>Δ Avg. DC Inventory</th>
<th>Δ Rel. Waste System</th>
<th>Δ Order lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>350409</td>
<td>0.007</td>
<td>0.000</td>
<td>0.000</td>
<td>0.8%</td>
<td>-5.7%</td>
<td>-88.7%</td>
<td></td>
</tr>
<tr>
<td>403036</td>
<td>0.036</td>
<td>0.006</td>
<td>0.000</td>
<td>9.5%</td>
<td>-36.5%</td>
<td>-94.7%</td>
<td></td>
</tr>
<tr>
<td>403293</td>
<td>0.073</td>
<td>0.100</td>
<td>0.000</td>
<td>0.5%</td>
<td>-3.2%</td>
<td>0.4%</td>
<td></td>
</tr>
<tr>
<td>403488</td>
<td>0.001</td>
<td>0.000</td>
<td>0.000</td>
<td>1.3%</td>
<td>-27.5%</td>
<td>-99.3%</td>
<td></td>
</tr>
<tr>
<td>403626</td>
<td>0.011</td>
<td>0.375</td>
<td>0.000</td>
<td>-0.1%</td>
<td>3.3%</td>
<td>480.1%</td>
<td></td>
</tr>
<tr>
<td>404474</td>
<td>0.048</td>
<td>0.000</td>
<td>0.000</td>
<td>9.4%</td>
<td>-42.1%</td>
<td>-83.3%</td>
<td></td>
</tr>
<tr>
<td>404876</td>
<td>0.056</td>
<td>0.000</td>
<td>0.000</td>
<td>9.7%</td>
<td>-36.3%</td>
<td>-82.1%</td>
<td></td>
</tr>
</tbody>
</table>
6.3.5 Combining distribution flow elements

For each of the distribution flow elements that have been tested above, potential gains have been identified on the relevant measures. Inventory allocation based on run-out times provides the possibility to achieved the weighted customer service level in the stores, whilst decreasing the reorder level in the DC. Synchronisation of production and replenishment of the DC indicated the possibility of reducing the amount of handling for the supplier and DC. Making the products to order has provided the realisation of the target DC service levels for some SKUs, but at the cost of generating extra waste. Furthermore this provided an increase in freshness when combined with lower service levels at the DC. For the latter two categories, the experiment results have suggested that the increase in inventory as well as the increase in the amount of waste produced by choosing a different distribution flow element might be reduced by choosing lower reorder levels at the DC. The effects that combining different distribution flows will have on the supply chain performance is therefore considered in this subsection. Figure 23 shows the baseline scenario outcomes compared to the scenario with the combination of distribution flow elements that performs best per SKU. The distribution flow elements that make the scenario

![Figure 23: Difference between scenarios for system waste](image)

![Figure 24: Difference between scenarios for retail product freshness](image)

with the best performance per SKU are shown in Table 10. The outcomes also depend on the reorder level of the DC for the chosen SKU and scenario. The reorder levels are chosen such that for the scenarios the weighted store fill rate is at or above the target fill rate. Figure 25 provides an overview of the performance per reorder level for SKU 404876. Appendix D provides an overview of all SKUs. The outcomes for the chosen reorder levels were then used to compare the relative system waste, the retail product freshness, the average DC inventory and the amount

42
of order lines. The experiment outcomes show that the combination of a MTO production policy will lead to 0% waste at the supplier. This is in line with expectations since in this scenario the supplier is a stockless location, as is depicted in the solution directions. For the new SKU scenarios the DC benefits from an equal or reduced amount of order lines, and for the average inventory levels at the DC all SKUs outperform the baseline levels.

The stores receive a fresher product in all cases where MTO and synchronisation is in place, combined with the runout based inventory allocation at the DC. The exceptions to this are SKUs 350409 and 403488 in the scenario where the interval of production and review is equal to three days (this scenario is also non-optimal for all other SKUs). Choosing this scenario for the SKU would lead to a decrease in freshness of up to 4% and disproportional increases in inventory at the DC.

For the stores, the average weighted service level for customers is met. However, given the differences between stores in demand, the service level for stores is not always equal. To test if the model works equally for all stores, the best performing scenario was analysed for the amount of stores that do not reach the 95% service level requirement in the initial setting. The stores that are not replenished often enough to meet the service level requirement in the stores, need adjustment of the store parameters to be able to perform well enough. The reorder level of the store has to be raised so that replenishment will occur at a higher remaining inventory level for that store. The adjustment of the store reorder levels is a repetitive trial and error process. For most of the stores that underperformed the deviation from the target level was not very high. However, since they did not meet the required service level adjustment was necessary.

Table 10: Baseline scenario parameters

<table>
<thead>
<tr>
<th>Exp. nr.</th>
<th>Allocation</th>
<th>Production Policy</th>
<th>$R_{DC}$</th>
<th>$R_P$</th>
<th>Best for SKU</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Runout</td>
<td>MTO</td>
<td>1</td>
<td>1</td>
<td>350409, 403293, 403488, 403626, 404876</td>
</tr>
<tr>
<td>3</td>
<td>Runout</td>
<td>MTO</td>
<td>2</td>
<td>2</td>
<td>403036, 404474</td>
</tr>
</tbody>
</table>

The stores receive a fresher product in all cases where MTO and synchronisation is in place, combined with the runout based inventory allocation at the DC. The exceptions to this are SKUs 350409 and 403488 in the scenario where the interval of production and review is equal to three days (this scenario is also non-optimal for all other SKUs). Choosing this scenario for the SKU would lead to a decrease in freshness of up to 4% and disproportional increases in inventory at the DC.
6.4 Sensitivity analysis

The performance of the suggested distribution flow elements in the perishable supply chain has been tested in the previous section. To determine how the model performs for different input values a sensitivity analysis has been performed. In general, the model has proved to be effective for all SKUs regardless of the input parameters of the products that were used. Especially the combination of the three elements shows that the model could work for products with short and longer PSL, different pack sizes and deviation in the daily demand from stores. To determine the performance of the model when store demand deviates from the current situation, a different demand is tested for SKU 404876. The model outcomes for a store demand 1.5 times the usual average daily demand was tried as well as an increased standard deviation for demand in the store. For both input values the design performed in line with the findings of the previous chapter. The waste however was much greater, due to an increase in the waste at the DC for higher service levels. The results of these tests are shown in Appendix E as are the results for the other sensitivity analysis.

Since the model is only tested using the stores that have all seven SKUs in their assortment, the total amount of stores used was 56. In the current situation the average distribution degree for products is much higher, as stated before. Therefore the model performance has been tested for SKU 403036 with all 176 stores that met the specified demand criteria. For the large number of stores, the model produced outcomes similar to the sample size outcomes. The number of stores that performed below the specified customer service level increased, but proportional to the number of stores, indicating that the sample is a good representation for the population. The case pack size of the product might have an influence as well on the performance of the perishable supply chain. Literature suggest that using a smaller case pack size is beneficial for the amount of waste produced in stores. The transition to smaller case pack is tested for SKU 404474, of which the results are shown in Figure 26. For the experiments, the design specification of minimum 80 per cent service level in the DC has not proved to be a limiting factor on the possibilities of the model. Meeting the weighted fill rates in the stores was possible only with a reorder level that led to a higher DC fill rate than 80%. Going below 80% service level would imply accepting lower fill rates in the stores. This might not be a problem for some products due to substitution effects, but for products with very specific characteristics it might be. Using a safety factor of 0.5 instead of 0 for the DC forecast is also tested for the model. However, in this scenario the model performed poorly for low DC service levels since the weighted store fill rate decreases significantly. Using an extra safety factor is therefore not recommended nor is it necessary since the model performs adequate already.

![Figure 26: Performance of model with smaller case pack size](image-url)
7. Implementation

In order for the supply chain actors to use the suggested design, some elements of the supply chain will have to change. From the results of chapter 6, it can be concluded that this change is worthwhile and improvement on almost all relevant measures is achieved. This chapter will provide a brief overview of the necessary changes and how any reservations and obstacles for stakeholders can be overcome.

7.1 Information Technology

The importance of information sharing between the supply chain actors has been demonstrated in the previous chapters. One of the crucial requirements for implementation is the possibility for the DC to have access to store data. Since it is assumed that over the strategic horizon PLUS will use SAP as their new BIS, combined with the ongoing SAP implementation within the companies of the Greenery, the assumption that the systems can be linked in the future is very realistic. Furthermore, SAP provides software packages with realtime inventory visibility which is a key element for store and DC order generation. Even though there is no specific EWA-policy package for the stores readily available, the use of the methods as described by Broekmeulen and van Donselaar (2009) would not be excluded from the technological possibilities.

For the allocation procedure to work correctly the stores have to build up sales patterns for regular sales for the products that will be supplied with use of the suggested methods. This will happen over time and the most important task for PLUS stores is that the products have to be sold and scanned correctly at the register. If this were not the case, no point of sale data will be generated and the inventory will not be corrected for the sale. Furthermore, a correct inventory position in the store is required. Store owners will have to perform regular checks on inventory levels to prevent OOS or generation of orders whilst inventory is sufficient.

Besides the use of sales data in the store to determine the allocation amounts for stores, this data is used to generate the forecast for production of products. Furthermore it is key information for inventory management at the DC, especially important in MTO scenarios where the production amounts directly depend on the DC order. In a scenario where this is not possible and the supplier will have a MTS policy, the forecast of the DC should still be shared with the supplier, this could be as simple as an email per day with the most recent estimates but a fully integrated system could be possible as well.

7.2 Stakeholders

For each of the stakeholders in the supply chain the new distribution flow management will have some implications in terms of involvement and control options. Since the analyses have shown that the best performance is realised when all distribution flow elements are used in a collaborative manner, the involvement of all the stakeholders is required. This section will show the incentives for the stakeholders to participate in the collaborative supply chain.

PLUS store owners

For PLUS the new design will have some visible effects in the stores with regards to the availability of products. Due to the inventory position adjustment of the EWA-policy, stores will not face empty shelves due to outdated batches anymore. Usually products are outdated and the shelf will be empty until the next order moment calls for replenishment. In the new situation, the order is generated and placed for the day that the older batch will be outdated. Furthermore, the product that the store can offer their client has an increased RPF. To achieve this improved freshness, the reorder level at the DC has to be brought down and therefore it
is a possibility that a store will not receive the amount of ordered goods. Whilst this might be perceived as undesirable by the store owner, it should be clearly mentioned that the service level constraint for stores is still in place. For the system to work properly the store clerks will have to accept this and not manually adjust their inventory to generate more orders. This will lead to distortion in the system and inventory might be allocated to a store with enough actual inventory whilst one of their colleagues has to disappoint their customers. This might optimise local performance of a store, but will decrease overall performance for PLUS as a supermarket chain as well as supply chain wide performance.

**DC inventory management**

For the inventory management department at HB a shift in focus should be made. Manual ordering and continuously monitoring of inventory levels at the DC should not be the main focus anymore, since for the regular assortment the order generation and placement could be mostly automated. This is possible since the forecast is based on POS data instead of store orders and gives a more precise image of when inventory is needed at what place. This does not mean that the inventory department will become obsolete. Since the forecast is only based on average daily sales, any serious deviations will have to be manually adjusted. Good weather, holidays, promotional periods and other influences are not incorporated into the model and therefore need the inspection of an inventory manager. Furthermore, the inventory managers will remain to be the communication point for the supplier. Any deviation due to tardiness of trucks or production problems will have to be communicated and a solution will have to be found. This is not something the system provides for. Decreasing the service levels in the DC will lead to a lower amount of inventory, waste and an increased freshness of products which is all beneficial for HB. The downside of reduced waste in stores combined with lower service levels in the DC is that there will also be a decrease in the amount of case packs shipped to the stores. Since this is the main basis for compensation of HB, an alternative compensation structure will have to be negotiated with PLUS. It should be evident that the SLA between HB and PLUS should changed as well.

**Suppliers**

In order for the design to work, suppliers will have to cooperate to some extent with HB. The model provides for a MTS and MTO strategy, for which the MTO strategy provides an opportunity for suppliers to operate as a stockless unit. In this scenario the supplier should be able to produce and ship all goods to HB. They will receive the order before production and do not have any waste and for longer review periods at the DC have less handling per week for shipping goods to HB. Receiving an exact order on time could be beneficial for planning and also for the availability, since knowing the demand ensures for the maximum amount of sales to the client. This holds for situations where reserved production capacity is lower than the client requires. When HB would require more product than planned the supplier should be willing to increase production. This could be hard since it might disrupt production schedules at the plant, and raw materials be insufficient to produce the order. The MTS scenario assumes that the supplier is willing to use the shared forecast and adapt its production amount to it. This scenario however also assumes that the products that are produced in a previous batch are outdated, i.e. HB never accepts products with a day less freshness, leading to more costs for the supplier. Another crucial factor in achieving increased freshness is that the production and replenishment of the DC are in sync. However, this seems to be the part of information that most suppliers are reluctant to share. Producers might be afraid that once their client knows their schedule, they assume that they always get the complete order. Furthermore, giving away the production schedule might be detrimental to the flexibility of the supplier. Once the client knows when something is produced, deviations are noticed more easily. However, when a supplier and HB come to the agreement that deviations from optimal scenarios occur, and work together towards more freshness, both supply chain actors will benefit.
8. Conclusion and discussion

This chapter will provide the answers to the research question and the subquestions raised in chapter 3. Next an overview of the research boundaries and the limitations for applicability of the results will be provided and the recommendations for HB will be given. The chapter ends with suggestions for future research that the current research assignment has brought forward.

8.1 Conclusions

The findings of the research assignment as presented in previous chapters are all building blocks of the answer to the research question. First the answers for all the sub research questions will be given, followed by the answer to the question:

“How should the flow of perishable goods be managed by the central DC, to improve retail product freshness?”

1.) How is the current distribution flow designed at Hollander Barendrecht?
In the perishable goods supply chain of HB the management of the flow of goods is different for the three product categories. For XD items HB only performs handling operations which make sure the products get to the correct stores. For PTZ items, the orders are bundled automatically two times per day and the orders are placed at the suppliers. The inventory managers do not change these orders and products are processed in the DC and at the end of a delivery cycle the inventory is depleted. For the bulk product category, HB does the ordering, inventory management and the order pick. Inventory in the DC is managed using a \((R,s,nQ)\) replenishment model with fixed review period, order quantities and dynamic reorder levels. Demand forecasting is done using a custom built forecasting tool, combined with inventory management adjustments. The orders originate from the PLUS stores where these are manually put in the system by store clerks, on which the order amounts heavily depend (Kock, 2015). Suppliers deliver goods according to the predetermined order and delivery schedule and the goods are shipped from the supplier demand. Incoming goods are found to be of the same batch for multiple order dates, confirming the delivery from stock. In case orders deviate or suppliers arrive late, DC stock can be insufficient to fulfil all store orders for the day. Current allocation in case of (expected) OOS in the DC is decided by the inventory managers and the rules used are very basic. Stores either receive a maximum determined amount of case packs, a percentage of their original order amount, or a delivery block receives no replenishment at all. Between the actors in the supply chain for the perishable bulk assortment no information is shared. The supply chain is pull driven, so that orders flow through the system consecutively and each actor waits for the preceding one to make an order or produce. Therefore it can be concluded that in the current situation HB has little control over the distribution flow as a whole. There is no active management of the flow besides from inventory management at the DC and reactive allocation in case of OOS.

2.) How can the alignment of information throughout the supply chain improve the supply chain performance?
Sharing information from stores to the DC provides for the possibility to shift from the DC basing their forecast on store orders, to a forecast based on store sales and actual outdating. This will give a better insight in the actual events in the stores. This information can then be used to lower the reorder levels in the DC in a controlled way and make the use of an allocation rule
possible. Furthermore sharing information between the DC and supplier allows for production based on a forecasted amount of events in the stores instead of the supplier making their own forecast based on DC orders in MTS scenarios. Synchronisation of production and DC replenishment involves sharing the production intervals with the DC. The DC then orders before this production moment and together these make for a maximum availability and freshness.

3.) What is the effect of using an allocation rule for out of stock situations in the DC on the service level and waste in the stores?

The experiments that were performed to test the use of the allocation rule based on runout times compared to the random allocation rule have shown that for the product sample set improvement is possible. The performance of the random allocation rule for high service levels at the DC is good enough to ensure the store target service level for PLUS stores. However, when lowering reorder levels and subsequently DC fill rate, the store performance drops below the required levels for the stores that are allocated inventory last. With the allocation based on runout times, this does not happen and stores receive replenishment in a structured way which once again ensures the required weighted store service levels. The outcomes show that allocation works for the chosen sample size and sensitivity analysis has confirmed that it also behaves well for a large number of stores. It is however important that the system is evaluated when implemented and that for underperforming stores, the store reorder levels have to be set higher so that these stores receive replenishment as well. The waste levels in the stores have shown a minor decrease when inventory is allocated using the runout times. This results is in line with the inventory theory behind the allocation rule since stores that will run out of inventory faster, receive goods and stores that have sufficient inventory will not receive new batches. The best performing scenarios using the allocation rule required a lowered DC fill rate. On a strategic level, the implementation of an allocation rule would require PLUS store owners to embrace the improved performance of the supply chain as whole, instead of focusing on their local optimisation.

4.) What availability level should be achieved by the DC in order to realise an aggregate service level of 95 per cent in the stores?

In the outcomes of the simulation experiment it is shown that the DC reorder levels can be lowered significantly whilst maintaining the store service levels. The degree to which the service level can be lowered differs for the chosen distribution flow elements and is therefore not generalisable. For some SKU's the fill rate could approach the minimum of 80% fill rate whilst still maintaining the service level in the stores. Other products have to be maintained at a higher service level to ensure performance. One common outcome however is that service level in the DC can be lowered. If one is reluctant to lower the DC rate to achieve maximum freshness, one could follow the generated waste levels down to a low point where, as required, the stores still meet service levels. This point lies beyond the minimum fill rate and the 95% fill rate in the DC for most scenarios.

5.) What is the effect of a different design for the stakeholders in the supply chain?

The results of the experiments have shown that for optimal performance of the supply chain all effort from all stakeholders involved is necessary. Information should be openly shared to allow for adequate allocation, supply chain synchronisation and a MTO policy for the supplier. If the efforts are aligned each supply chain actor will benefit from the improved distribution flow management of the supply chain. The stores will receive a product with increased retail product freshness, giving the opportunity for increased customer satisfaction. Inventory management at the DC will become more automated and will give inventory managers the opportunity to focus on increasing the accuracy of predictions for deviating periods of sales. Furthermore, due to the decreased amount of order lines, the DC will have less handling for incoming products and
might realise some cost savings on handling, but also transportation since some trucks pick up goods from the supplier using the concept of backhauling. The supplier will benefit from the increased collaboration in the supply chain as well. Sharing the production moment with the DC and subsequently synchronising this with replenishment leads to a stockless situation for the supplier, removing their risk of obsolete inventory. Furthermore, not only the supermarket might benefit from stating that the products they sell are fresher, the brand image of the supplier might also benefit from a fresher product in the store.

With all the subquestions answered the baseline for the main research question is provided. efforts should be aligned in the supply chain to make optimal use of the distribution flow elements that are used in this research assignment. The focus of the DC for the management of the supply to stores should be in deciding the reorder levels for the products in the DC so that they can guarantee the required service levels in the store. Furthermore an important task of the DC is to get their suppliers involved in the synchronisation of the supply and convince them of the benefits that sharing their production information with the DC has for all supply chain actors involved.

8.2 Limitations

The model used to simulate the events in the supply chain of HB are based on a few assumptions and approximations. The outcomes of the research therefore has some limitations that are discussed this section.

Store events

For PLUS stores the EWA-replenishment policy was used to generate store orders and correct inventory based on the expected outdating. This is based on the assumption that the age of inventory is known in the store. In real life, this data will probably not be available since system such as RFID to track products with detailed information will not be available in PLUS stores. Furthermore the outdating is based on 100% customer FIFO withdrawal behaviour. If this is not the case in the future situation (which is known to be the case for supermarkets in general) the expected outdating for the EWA-policy will be an approximation. Furthermore the store sales pattern has not been taken into account in this research assignment. Given the analysis of the store orders at the DC, there is a possible weekpattern in the stores as well but this would have to be analysed using store POS data. If a weekpattern would be found, an expected customer demand could be derived for each day and this would mean that the reorder levels for the store would become dynamic as well, increasing the complexity of the model.

DC Events

For the DC component in the simulation several assumptions have been made that limit applicability of the outcomes for the future scenario. The most import assumptions made is the timing of events. In the simulations events are discrete and follow each other in a predetermined sequence, whilst in real life the events often occur simultaneously. The simulation assumes only one supply cycle per day, whereas HB uses two replenishment blocks for their stores. Subsequently order picking, order arrivals from store and replenishment from suppliers happen at multiple times during the day. Deciding when to use an allocation rule might therefore depend on the time that a new replenishment occurs in the current situation whilst the decision in the model is based on the reorder level of the DC and assumes the runout based allocation for all situations.
Supplier limitations

In the modelling of the supplier element for the supply chain, the lead time has been set equal to one day. In current situation, the supply lead time might vary from a few hours to multiple days. The design choice has been made because it is known that for some suppliers lead time is equal to two days whilst the DC is replenished from supplier stock, indicating possibilities for lead time reduction. Having longer lead times would increase demand uncertainty during the lead time period, which will influence model outcomes. This is however not taken into account for this research assignment. The last supply limitations to the supply element of the supply chain is that the deliveries made by the supplier are at a given moment after order fulfilment. In the current situation, replenishment happens during the day since the capacity for handling incoming goods is limited. Furthermore the supply at different times during the day means that at hand inventory changes during picking cycles and might therefore give different results for the allocation of goods. Furthermore, the scenarios provide different production intervals for the production of goods. It might not be realistic for all the current products to be produced on a daily basis since supplier will probably benefit from producing large batches with a lower frequency. Willingness to change the production intervals will vary between suppliers, since private label products cannot be sold to other clients, whilst A-brand products can be sold to competing supermarket chains.

8.3 Future research

This research assignment has aimed to contribute to supply chain management literature for perishable inventory by exploring new ways to improve retail product freshness. The subject has not been researched intensively yet, but using supply chain elements and research suggestions from research as Broekmeulen and van Donselaar (2009), Ferguson and Ketzenberg (2006) and Mertens (2016) has given this research assignment a basis for the development of a method that has in my opinion reached the set goals.

In line with what the research of Thron et al. (2007) found, this research also found a relation between collaborative behaviour in the perishable supply chain and an increased freshness of perishable products at the moment of purchase. Reducing time spent in the supply chain for products by means of synchronisation should motivate a central DC to shift from a service level oriented to a freshness oriented method of managing the distribution flow. The allocation method presented in this thesis, combined with the collaborative forecasting and production and replenishment differs from methods used by Mertens (2016) and Thron et al. (2007) and can therefore be seen as a contribution to literature. An adaptation in the determination of the amount of case packs received by a store could be used for future research. Since this project allocated the full order or nothing, exploring what the effect of any allocating partial orders would have would be interesting.

Possibilities for extending the work of this thesis would be researching the effects of a weekpattern on the performance of the presented model. Furthermore, different allocations could be explored by future research. Since the DC is assumed to have access to store data and results show the existence of batches with different ages in the DC, possibilities arise. Possibly an inventory allocation procedure that uses both prioritisation for the stores that most urgently need replenishment in combination with allocating products of different ages would be an interesting way to find waste reduction possibilities at the DC. Testing the model with sales data from stores could also contribute to the verification of the suggested model, as well as provide an insight in the behaviour of the model compared to a real life situation.
References


Appendix A: Load carriers

Figure 27: Pallet  
Figure 28: Roll container  
Figure 29: Dolly

The load carriers shown above are widely used in the retailing industry. The carriers are used for the handling of goods in the DC.
Appendix B: Forecasting tool

Figure 30: Image capture of the parameter setting in the forecasting tool.

2. Bepalen wanneer er wel of niet een prognose word getoond (zijn de resultaten goed genoeg om te laten zien of is de veronderstelling dat de gebruiker een betere inschatting kan maken)

- Number of contiguous weeks before forecast week: Aantal weken voorafgaand aan de huidige week waarin de historische verkopen representatief zijn.
- Number of week in preceding 4 weeks before forecast: Aantal weken, in de laatste vier weken, voorafgaand aan de huidige week waarin de historische verkopen representatief zijn.
- Volatility: Standaard afwijking gedeeld door de gemiddelde verkopen van de gehele historie geeft de volatilitheid van een artikel aan. Indien dit hoger is dan een bepaald percentage wordt er geen prognose getoond.
- Maximum MAPE: Gemiddelde foutpercentage. Indien een artikel een hoger foutpercentage heeft dan dit percentage wordt er geen prognose getoond.
- Maximum number of gaps %: Aantal "gaten" in de historie zoals uitgesloten actie- en feestweken. Indien dit percentage boven een bepaald maximum komt wordt er geen prognose van dit artikel getoond.
- Lowest sales level: Extreme langzaamlopers kunnen worden uitgesloten. Indien een bepaald artikel minder x consumenten eenheid verkoop wordt er geen prognose van dit artikel getoond.
- End MAPE Weight: In hoeverre de recentere weken zwaarder meetellen dan weken verder in het verleden. Eén houd in dat alle weken even zwaar meetellen. Tien houd in dat de laatste week 10 keer meetelt en de eerst beschikbare week 1 keer, de tussennagelende weken nemen iedere keer in gelijke stappen toe.
- Number of Error weeks: Aantal weken waarin de forecast fout hoger is dan het gedefinieerde maximale foutpercentage. Indien dit aantal boven deze parameter uitkomt wordt er geen prognose getoond in dit artikel.

3. Grafische weergave

- Range of acceptable daily error: Indien het een foutpercentage op dagniveau boven deze parameter uitkomt wordt het artikel niet grafisch weergegeven.
- Range of acceptable weekly error: Indien het foutpercentage op weekniveau boven deze parameter uitkomt wordt het artikel niet grafisch weergegeven.

Figure 31: The exclusions that determine whether or not a forecast is displayed.
Appendix C: Selected product set

Figure 32: The final set of products after selection.
Appendix D: Overview of performance per ROL per SKU

Figure 33: Results for SKU 350409 per DC reorderlevel.

Figure 34: Results for SKU 403036 per DC reorderlevel.
Figure 35: Results for SKU 403293 per DC reorderlevel.

Figure 36: Results for SKU 403488 per DC reorderlevel.
Figure 37: Results for SKU 403626 per DC reorderlevel.

Figure 38: Results for SKU 404474 per DC reorderlevel.
Figure 39: Results for SKU 404876 per DC reorderlevel.
Appendix E: Sensitivity analyses

Figure 40: Performance of model with increased store standard deviation

Figure 41: Performance of model with increased store demand
Figure 42: Performance of model with higher amount of stores

Figure 43: Performance of model with k factor equal to 0.5