

## MASTER

### Slow moving items in grocery supply chains at Sligro Food Group

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Veghel, December 2013

# **Slow moving items in grocery supply chains at Sligro Food Group**

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in partial fulfilment of the requirements for the degree of

**Master of Science  
in Operations Management and Logistics**

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## Abstract

This master thesis describes the research done into the slow moving items in the Food retail segment of Sligro Food Group. First these items are studied in more detail, followed by the design of a theoretical model that simulates the effects of changes in the supply chain on the relevant logistical operational cost aspects. Two supply chain redesigns are based on differentiation within the supply chain on product level characteristics. These designs are evaluated on basis of the application of the model to a selection of fifteen stores out of the portfolio of EMTÉ, the format under which the Food retail is carried out. The results showed that under the current circumstances a reallocation to a centralized DC is not beneficial. However a reallocation to a separated location within the current distribution centers is beneficial for a sizable part of the assortment considered. A multivariate regression on the predicting performance of commonly used metrics and product characteristics, on the cost difference between the two locations of the last mentioned redesign, showed that the most important factors are the total sales and the case pack size. Next to these factors, average excess shelf space and number of stores carrying the corresponding product turned out to be significant additions to the model. These independent variables together explained 71,60% of the total variation of the dependent variable.

## Management Summary

In this report, the results of the master thesis carried out at Sligro Food Group are presented. Sligro Food Group carries out its food retail segment under the EMTÉ format. Which currently accounts for 2,7% of the Dutch food retail market. Within the food retail supply chain the slow moving items are studied.

### Project context

The focus of the research project is to analyze the slow moving items and on what could be improved. In the current situation, the slow moving items are ordered and handled in the same manner as the fast moving items. This resulted in the following research assignment:

*Clearly Define the Concept of Slow Moving Items for Sligro Food Group and Propose and Analyze Solutions for the Replenishment and Storage of these Items within the Sligro Supply Chain, with Primary Focus on the Retail Operations of the EMTÉ Format.*

### Analysis of slow movers in the current supply chain

The slow moving items are analyzed at two subsystems, namely at the store level and the distribution center level. At the store level the ordering policy is described, which lead to an analysis into the service level of slow moving items. This showed 51,9% of the products in the last 50% of products the reorder levels are set so high that they achieve a service level of 0,99 or higher, due to that they are set on basis of the minimum inventory norm and not determined on both demand characteristics, mean and standard deviation. In contrast almost 30% of the products in the last 50% does not achieve the target service level.

Almost two percent of the SKU's have an expected inventory on hand that accounts for more than a half year of demand and more than five percent of the SKU's have an expected inventory on hand that accounts for more than three months of demand. A high amount of days of inventory can result in problems in combination with a relatively short shelf life or a possible remediation. Another characteristic at the store level concerns the backroom inventory of products which do not belong there. Almost eighteen percent of the SKU's in one store result in the backroom and do not belong their according to their demand rate. The automatic store ordering system (ABS) gives a warning on ordering a product that will result in a shelf life problem or in backroom inventory, this warning is based on historic sales data of the corresponding product. The ABS manager can decide to act on this warning by either postponing the order or by ignoring the warning and place the generated order. The last characteristic at the store level concerns the excess shelf space, this showed that there are many products, especially slow moving items, which posses this characteristic. This is due to the amount of shelf space allocated in comparison with the shelf space that is necessary for carrying out the current operations with respect to customer service levels.

At the distribution center level the ordering process is described, there the amount of days of inventory does not turn out to be as high as at the store level. The main reasons for this are that the reorder level is solely based on the sales history and there are only two inventory locations at this subsystem instead of the one hundred considered at the store level. The main characteristic of slow movers at this level is

present at the slotting and corresponding picking of products. This is done on basis of product group characteristics, the picking aisles follow the family grouping layout which represent the aisle in the stores. The average case pack demand showed that there is a lot of spread within these product groups.

Next the relevant cost in the supply chain are explained in detail. The relevant operational logistical costs are the aspects that are considered in the model, this encompasses the following costs: (1) holding cost in store, (2) Store handling cost, (4) backroom cost, (3) lost sale cost, (5) picking cost in distribution center, (6) traveling cost in distribution center and (7) added handling/transport cost at distribution center.

In consultation with the company under research, based on the initial problem definition, the above stated information and the results of the problem analysis done over the two subsystems of the retail system the redesign direction is chosen. This is the differentiation within the supply chain between slow- and fast movers on basis of product characteristics. This requires a separation in the current flow of goods from the DC to the stores.

### **Theoretical Model**

First a theoretical model is set up which simulates the effects of possible changes that are made in the redesign solutions on a supply chain. Based on the theoretical settings which includes the use of the optimal reorder level, insights are gathered on the effects of increasing the review period and the lead time for different demand rates. During the modeling an interesting finding on the traveling cost was made. The effect of the assortment size on travelling cost is small in comparison with the other cost aspects. This possible saving therefore only plays a role for the products with a low demand rate.

Followed by the application of the relevant cost aspects. This showed that an increase in lead time leads to higher cost than an increase than in review period. Next to this an increase in review period showed to be beneficial compared to the base settings for the lower demand rates in the theoretical model.

### **Results and Discussion**

First a comparison is made within the theoretical model between the optimal reorder levels and ABS reorder levels. Due to that the ABS does not incorporate the standard deviation of demand, the target service level is not met in all cases. This however leads to cases were the lost sale costs far outweigh the other costs. For this reason both the results for the ABS generated reorder levels and the results for the optimal reorder levels are calculated.

Based on the redesign direction and in consultation with the company under research two possible redesign solutions are designed. Which enable supply chain differentiation between slow moving and regular items. The first encompasses a separated central distribution center for these items and the second encompasses a separation within the current distribution center. Next to these redesigns, the applied model settings incorporated the reorder level on basis of the ABS ordering levels and the optimal reorder levels.

For a selection of fifteen stores the effects of the redesigns are evaluated using the developed model. This showed that the redesign which encompasses a separated central distribution central is not

beneficial for almost the entire assortment. This can mostly be attributed to the added transport and handling cost occurring between the centralized and decentralized distribution centers. Another import factor is the increase in lead time in this redesign, just as the theoretical model showed.

The redesign involving the separation within the current distribution centers turned out to be beneficial for sizable part of the assortment considered. For the model settings with the ABS reorder levels, it is beneficial for 25,01% of the SKU's to be allocated to the slow moving location with the corresponding planning variables. For the model settings using the optimal reorder levels this turned out to be beneficial for 42,91% of the SKU's.

A multivariate regression is performed to test the predicting performance of common used metrics in combination with product characteristics on the difference in cost between the allocation to the two stages in the second redesign. The final model showed that the most important factors are the total sales and case pack size. Next to these factors, average excess shelf space and number of stores carrying the corresponding product turned out to be significant additions to the model. However the impact of the last two variables on the dependent variable is small (0,043 out of an overall model R-squared of 0,716). These four independent variables together explained 71,60% of the total variation of the dependent variable.

## Conclusions

The answer to the first part of the problem definition "*clearly define the concept of slow moving items*", is found in the problem analysis on both subsystems. This showed the characteristics of slow moving items in the organization under research. The theoretical model, the redesigns and the application of the model to the redesigns answered the second part, "*propose and analyze solutions for the replenishment and storage of these Items.*"

## Preface

This Master Thesis presents the result of my graduation project for the Master of Science program in Operations Management and Logistics at Eindhoven University of Technology. This project was carried out at Sligro Food Group in Veghel, Netherlands.

I have completed this master thesis with the support and motivation of many people. First of all, I would like to thank my supervisors, Dr. Dorothee Honhon and Dr. Rob Broekmeulen, for their contribution to this project. I would like to thank Dr. Honhon for her feedback, personal guidance and professional support, which were very valuable for me. During the project she emigrated to the United States of America, which required to continue our meetings via Skype, while taking into account the time difference. Additionally, I would like to thank Dr. Rob Broekmeulen for his extensive feedback and time invested. Especially for sharing his in-depth knowledge of the academic work done in the retail literature.

Within Sligro Food Group, I would like to thank Eric-Jan van Houtum and Stijn Welsing for giving me the opportunity to work on this project. Eric-Jan van Houtum did his best to attend my needs. I also would like to thank Maurice van Sonsbeek and all my other colleagues at Sligro Food Group for making my time there a very pleasant one.

Furthermore I would like to thank my family and friends for their support during my studying career, especially my parents for providing me with the opportunity to fulfill my master. Last but definitely not least I want to thank my girlfriend for her love and mental support during my master.

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## 1. Introduction

As the name suggests this chapter serves as an introduction for the project performed at Sligro Food Group. The first paragraph provides more information on the organization at which the project is done. Within this organization the project is aimed at one segment, which is described in the second paragraph. The third paragraph gives an introduction into the problem at hand. The fourth paragraph provides an outline of the report

### 1.1. Sligro Food Group N.V.

Sligro Food Group N.V. was established in 1935 and has over the years grown to become one of the main players in all the main segments of foodservice and food retail markets in The Netherlands. Within the foodservice segment it operates a network of 45 cash-and-carry stores throughout The Netherlands. Besides these cash-and-carry stores it also operates 11 delivery services providing on location service. Within the food retail segment the Sligro Food Group is known for its EMTÉ supermarkets. This is all managed from the headquarters and Central Distribution Center (from now on CDC) located in Veghel.

Central distribution centre and head office in Veghel		
Food retail	Foodservice Cash-and-carry	Foodservice Delivery service
EMTÉ	Sligro	Sligro/Van Hoeckel
130 Own and franchise outlets	Restaurants and bars, leisure, caterers, patrol outlets, large-scale users, institutional	
2 Distribution centres	National network of 45 cash-and-carry wholesale outlets	National network of 11 delivery-service wholesale outlets
<b>Sligro Fresh Partners &amp; Production</b> Specialised production facilities for convenience products (Culivers), fish (SmitVis) and meat (retail), patisserie/traiteur (Maison Niels de Veye) and participating interests in four fresh food businesses		

Figure 1: The organization structure of the Sligro Food Group (Source: Sligro Food Group N.V. Annual Report 2011)

The Sligro Food Group stocks about 60.000 food and food-related non-food items and had a year average of 5.880 employees in 2011. Over 2011 the revenue of the Sligro Food Group totaled 2.420 million euro, an increase of 5,9% compared to a year before. In Figure 2 a breakdown of the sales over the year 2011 can be found, it is categorized in foodservice delivery service, foodservice cash-and-carry stores and food retail (supermarkets). The net profit in 2011 was 78 million euro, an increase of 11,5% compared to 2010. More key figures of the Sligro Food Group can be found in Appendix A.

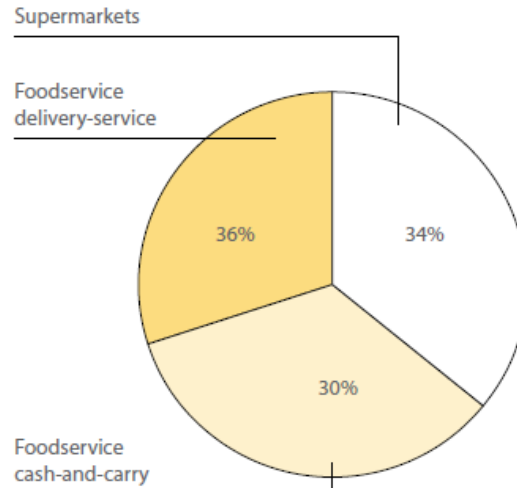


Figure 2: Breakdown of 2011 sales (Source: Sligro Food Group N.V. Annual Report 2011)

## 1.2. Food Retail EMTÉ

As can be seen in Figure 2 the food retail segment accounts for 34% of the total sales in 2011. This segment within Sligro Food Group, has grown over the years because various acquisitions have been made. The food retail segment of Sligro Food Group is operated by the EMTÉ format. The first EMTÉ supermarket was opened in 1965. In 1986 EMTÉ joined a purchasing association called Superunie, this enabled a new way of ordering. For this new way of ordering a distribution center was needed. In 2002 EMTÉ was acquired by Sligro Food Group. A consortium called S&S, formed by Sligro and Sperwer acquired 223 Edah stores in 2006. After the split of the Edah stores between Sperwer and Sligro, EMTÉ consisted of 125 stores. In 2010 Sligro Food Group acquired Sanders Supermarkets, which at the time consisted of 22 stores, a meat processing facility and a distribution center. Currently there are 130 EMTÉ stores in the south, middle and east of The Netherlands. The market share of EMTÉ in Supermarkets was 2,7 %, at the start of 2013 according to Hoofdbedrijfschap Detailhandel (other market shares can be found in Appendix B). Just like many other supermarket formats, EMTÉ tries to distinguish itself from other formats that aim at the same customers. In order to achieve this ambition, they have defined three core values which form the pillars of the EMTÉ format (Anonymous, 2012).

1. The best fresh supermarket.
2. The most personal supermarket.
3. One of the cheapest full-service supermarkets (basis high>low). This pricing strategy encompasses that the supermarkets post higher prices on some items but serve up low-price promotions on other goods.

## 1.3. Problem Introduction

Sligro Food Group sells its products to the consumers to make profit, which in foodservice are mostly other companies and in food retail are mainly end consumers. For this it is important that the right products are at the right time at the right location. This is the challenge which the inventory managers at the Sligro Food Group face, in trade off with the costs of these decisions.

The Sligro Food Group is mostly an intermediary in this process. It buys the products from the suppliers and makes them available to the end consumer. For this a supply chain from supplier to end consumer is constructed. However, within the Sligro Food Group there are a number of supply chains which exists next to each other. The Sligro Food Group has one main distribution center at Veghel (the CDC). The CDC delivers directly to the cash-and-carry stores and delivery services, where the products are sold to its customers. This makes it a two-echelon divergent inventory system, also known as the one warehouse and N retailers inventory system (Axsäter, 1990). The food retail can also be seen as a two-echelon divergent inventory system, as the largest part of the retail assortment stored at the Regional Distribution Centers (RDC) is supplied by external suppliers and shipped from there to the individual EMTÉ supermarkets.

An internal analysis on the assortment of the Food Retail showed that based on the average demand there are many products that have enough inventory to satisfy multiple months of demand. Sligro Food group wanted to know what could be changed in their current ordering, handling and storing of slow moving items and what the implications of these possible changes are.

#### **1.4. Report structure**

This report describes a master thesis project performed at the Sligro Food Group in partial fulfillment of the requirements for the degree of Master of Science in Operations Management and Logistics. This chapter serves as the name suggests as an introduction of the company and problem researched. The second chapter provides a more thorough definition of the problem with additional information on the problem environment. Consequently literature is provided on the subject of this project in chapter three, which provides a view into what has already been done in this research area. Hereafter the problem is analyzed, along with the redesign direction in chapter four. Chapter five gives a description of the cost in the supply chain. Subsequently chapter six presents the theoretical model, the possible redesign solutions and the settings used to evaluate these redesigns. The results of this are stated in chapter seven. Followed by the general conclusion of the project which is provided together with the recommendations in chapter eight.

## 2. Problem Definition

In this chapter the problem is defined in more detail. In the first paragraph the scope of the problem is set, in which the context of the problem is described. The second paragraph states the research assignment which is derived from the first paragraph.

### 2.1. Problem Scope

In this paragraph, we briefly described the current situation at Sligro Food Group, which is set as the scope of the problem. This will cover the flow of goods of the supply chain and the corresponding inventory systems which replenish the supply chain. This is followed by the description of the replenishment process, in which the working of ABS is explained and the description on how the assortment is constructed. Next we go in more depth by focusing on the slow moving items and the main problem.

#### 2.1.1. Supply Chain at Sligro Food Group

Figure 3 provides a simplified graphical representation of the flow of goods at hand within the Sligro Food Group. Note that except for the suppliers, all other elements visible in Figure 3 are part of the Sligro Food Group. The size of the arrows is roughly proportional to the size of the flow of goods and indicates the “delivers to”-relationship. The box in Figure 3 indicates on which part of the flow of goods the project is aimed. This covers the RDC’s and the EMTÉ supermarkets. Regarding the inventory systems used by the Sligro Food Group to manage the flow of these goods, the following simplified graphical representation is provided.

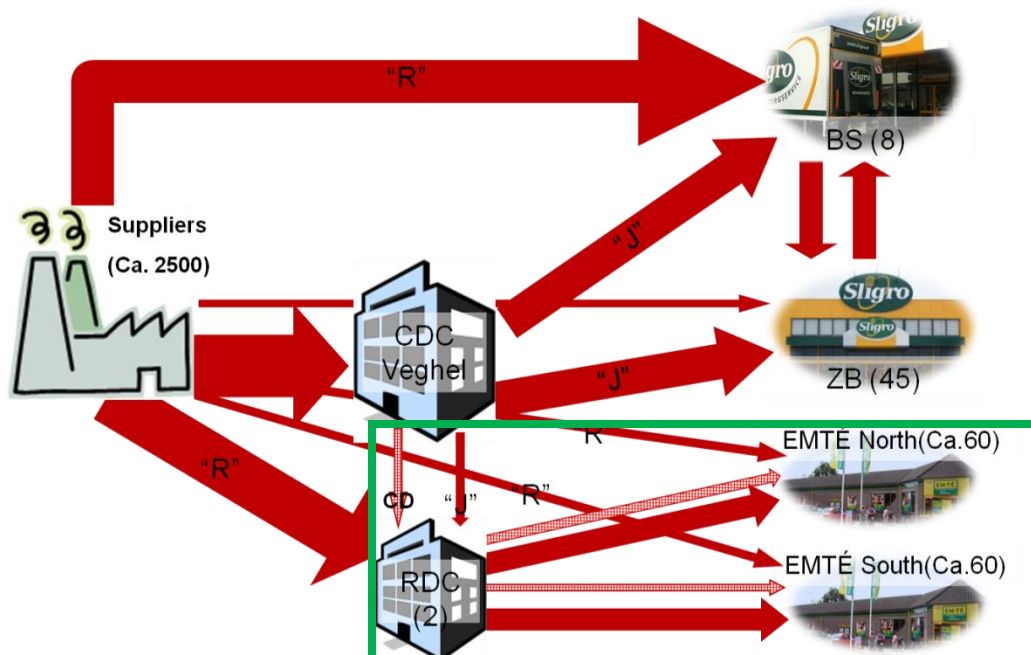


Figure 3 Simplified graphical representation of flow of goods at Sligro Food Group (adjustment on Ungerechts et al., 2011)



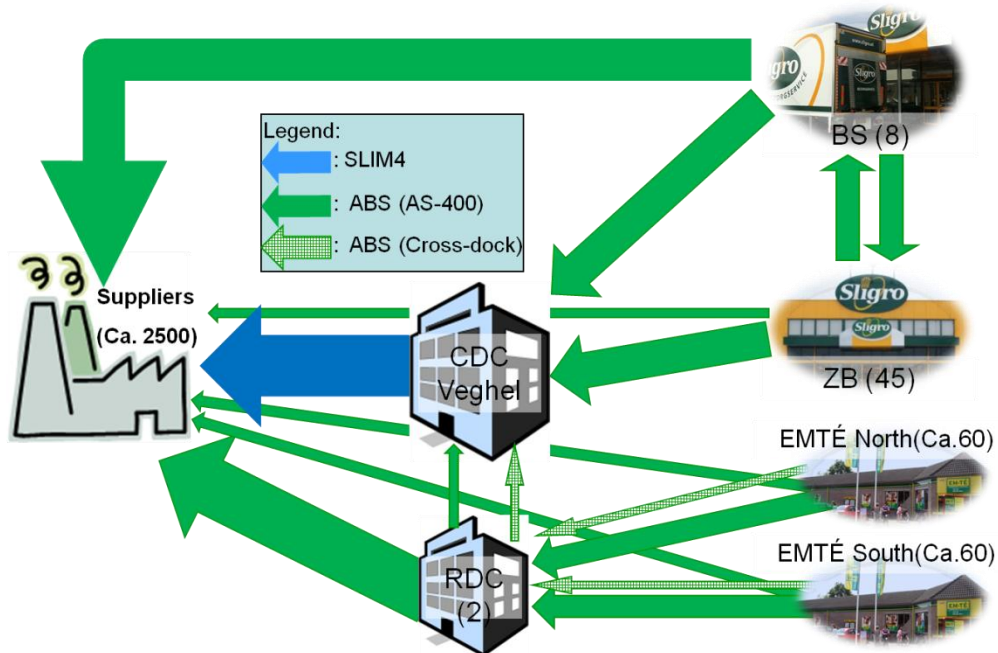


Figure 4 Simplified representation of inventory systems at Sligro Food Group (adjusted from Ungerechts et al., 2011)

As can be seen in Figure 4, most flows are being controlled by ABS i.e. Automatisch Bestel Systeem (Automatic Store Ordering System), an inventory system developed by several employees of the Sligro Food Group. Only the flow of goods between the CDC and the outside suppliers of the Sligro Food Group is controlled by Slim4, a service level-driven forecasting and inventory management system designed by Slimstock.

### 2.1.2. Replenishment process.

As shown in Figure 3 and Figure 4, there are two regional distribution centers: one for the north of the country and one for the south. These replenish the EMTÉ stores with the ordered items. The geographical distribution of EMTÉ stores is shown in Appendix C. The ordering of these store replenishments is done via ABS. For most of the products the RDC's order from the suppliers using ABS, a small proportion of the assortment is ordered by the RDC's from the CDC. The CDC then orders from the supplier using the Slim4 system. It can be stated that most of the products are ordered by the stores via the RDC using ABS. The working of this system will be described next.

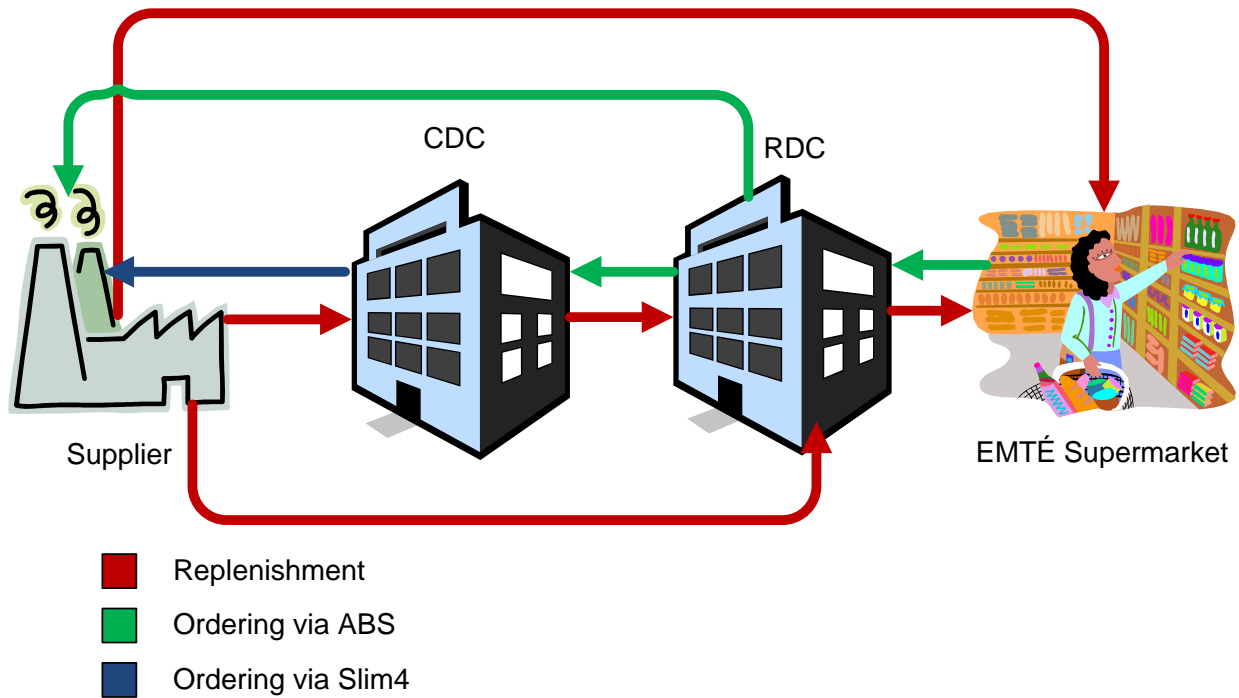


Figure 5 Simplified representation of Replenishment process EMTÉ

We start with explaining the general working of ABS, this inventory management system is developed in house by a number of employees of Sligro. This system does not make use of complex statistical calculations, it is a system built on experience. Within the system there is a lot of freedom for the Inventory Manager, also called ABS Manager.

ABS publishes a list of products that can be ordered on the current day. For these products ABS gives an advice on how many units should be ordered according to its calculations. This ordering advice has to be approved by the ABS manager before it is actually ordered. Next to this the ABS manager can change this advice on the basis of his own intuition. He is also allowed to cancel the generated order. The ordering advice generated by the ABS is based on the following three possible situations:

1. Sales expectation is smaller than the minimum ( $SE < Min$ )  
Then ABS will advice: Minimum – Stock (– Outstanding Orders)
2. Sales expectation is between the minimum and maximum ( $Min < SE < Max$ )  
Then ABS will advice: Sales expectation – Stock (– Outstanding Orders)
3. Sales expectation is greater than the Maximum ( $SE > Max$ )  
Then ABS will advice: Maximum – Stock (– Outstanding Orders)

In general this means that three situations occur. For a fast moving product (situation 3) the maximum will be the reorder level, however the generated ordering advice can be adjusted by the ABS manager if he receives the warning that the sales expectation exceeds the maximum inventory. For a non-slow moving product, the reorder level depends on the forecasted demand of the period to cover (Sales expectation). For these products (situation 2) the reorder level changes since it depends on time and the system can therefore be considered as a dynamic model. For a slow moving product, the minimum stock

level will in most cases be sufficient to cover demand until the next delivery moment. This means that the reorder level will be at a constant level (the minimum), in this case (situation 1) the system can be considered as a static model. This ordering policy resembles the  $(R,s,nQ)$ -policy (see silver et al. 1998).

An important note that applies for every situation is that the advised amount is always rounded up to the case pack size (number of items in a box). For example if the exact order advice is 8 units and the case pack size is 6 units, then an order of 12 units is advised by ABS. Next we will explain the variables named in these situations in more detail. We start with the stock, this covers both on shelf stock, backroom stock and possible deviations between system stock and actual stock. This sums up to all the stock that is assumed, by the system, to be at the store location. Outstanding Orders represent earlier placed orders, also called pipeline inventory.

The minimum of each product is determined such that it still looks nice when this number of products are in the allocated shelf (also known as Presentation quantity). In most cases this comes down to multiplying the amount of facings by three. The maximum of each product is determined by the allocated shelf space, the number of products that fit on the shelf, i.e. number of facings times depth of shelf. In some cases SKU's can be stacked on top of each other, for these products the capacity of a facing is the depth multiplied by the stacking level (height). The total number of units that fit on the shelf is the number of facings times the capacity of a facing. The store specific minimum and maximum can be adjusted by the ABS manager based on his insights.

The Sales expectation is determined on the sales history of the last 42 days (six weeks). For each day of the week the average of the corresponding weekdays in the last six weeks is calculated. Furthermore the Sales expectation is determined by the number of days until the next delivery after the delivery of this order, the number of safety days and the number of logistics days. The number of safety days can be set by the ABS manager, however for most products this is set by the headquarters. The number of logistics days represents the time it takes to get the ordered product from the delivery onto the allocated shelf. For most products this time is set to one day. ABS plans into the future from the day this orders will be placed and counts the times each weekday appears in this projection. Consequently the times that a weekday appears in the projection is multiplied by the average sales of that specific day. Then the projected sales of all weekdays is summed up to come to the sales expectation. We provided an example in Appendix D, to make it more clear how the calculation of the sales expectation is done.

### **2.1.3. Assortment**

All items in the assortment of EMTÉ are divided in different product groups, called Presentatiegroepen. As can be seen in Figure 6, which shows a small proportion of the product groups for a specific store, the amount of products varies per product group and also varies per store. The stores are classified on the amount of floor space they have available. This is given in meters per product group, for example every store has at least two meters available for the product group "Groentenconserven". For this amount of meters a basis assortment of products out of this product group is designed. For every next meter (3,4,5,etc.) available in different store sizes another assortment is designed in a planogram. This does not only include other products but also a higher amount of facings for products from the basic assortment. This increase in facings is done to cope with the higher amount of sales that occurs in most

cases in a larger store. The sourcing department in consultation with the space management department designs these different assortments based on the amount of meters.

PresentatieGroep	Aantal Artikelen	Store 1	Store 2	Store 3	Store 4	Store 5	Store 6	Store 7	Store 8	Store 9	Store 10	Store 11	Store 12	Store 13	Store 14	Store 15
GROENTENCONSERVEN	165	160	136	160	160	139	160	165	160	136	136	160	165	165	160	165
VRUCHTENCONSERVEN	49	49	49	49	49	48	41	49	49	49	49	48	49	49	49	49
RIJST, DEEGWAREN, ITALIAAANS EN MEXICAANS	216	180	192	191	205	192	203	204	191	192	190	191	216	214	204	205
OOSTERSE KEUKEN	133	92	117	122	94	94	122	122	94	121	93	94	133	133	122	122
SPECERIJEN EN ZOUT	170	119	170	170	170	119	170	169	170	170	170	167	170	169	170	169
SOEPEN	250	210	210	233	242	211	231	243	209	243	209	231	249	250	232	248
SAUZEN EN ZUREN	323	264	305	307	304	285	282	304	281	303	282	275	317	318	307	323

Figure 6 Product groups, called "Presentatiegroepen".

For each product group the amount of times per week it can be ordered is determined. Such an ordering advice moment is called a Generatie moment (ordering moment of ABS). On each weekday the ABS generates an order advice for all the products in the product groups that are assigned to be ordered on that day. For example some product groups can be ordered six times a week while others can only be ordered twice a week. Currently the amount of generating moments cannot be adjusted for an individual product within a product group, this can only be done per product group.

The standard for the number of facings per product is set such that a minimum of 1.2 case packs need to fit in the shelves. This is done to try to ensure that a case pack which arrives fits on the shelves when an order is delivered. There are products in which this standard is adjusted to cope with higher or lower demand. For some products, deviations from this standard rule are made on the basis of their demand and in some cases on the basis of their demand in comparison with other products in the same aisle. This is done to make the assortment more profitable per meter. This requires a tradeoff with on one side being a service supermarket, which is represented in carrying a wide assortment and on the other side reaching a high level of turnover per meter.

#### 2.1.4. Slow moving items

Within the wide assortment that the EMTÉ stores carry there are many slow moving items. These products have a very low demand compared to the average products. Due to batch sizes the minimum order quantity of these products can be very high in comparison with the demand. This will result in ordering and storing a large quantity of products when the inventory level drops below the ordering point. A preliminary analysis has shown that for some slow moving items the minimum order quantity is enough to satisfy demand for a whole year. This leads to high cost for the involved handling labor, backroom inventory cost, expiring cost, discount cost and cost of lost sales due to out of stocks.

A slow moving item in itself is not a problem, given that the assortment is composed of fast moving, medium moving and slow moving items. Only the supply chain has to meet the characteristics of these items. When this is not the case problems arise. This can lead to problems in the store as well as in the DC. The main problem can be defined as follows:

*The Supply Chain under Research is Inefficient when it comes to the ordering and storing of Slow Moving Items.*

As mentioned before the following order advice is provided for the ABS for slow moving items: Sales expectation is smaller than the minimum ( $SE < Min$ ), then ABS will advice: *Minimum – Stock (– Outstanding Orders)*. Again this means that the reorder level will be at a constant level, which implies that the system can be considered as a static model. Another observation that can be made is that for every product the same rules are applied to determine the Minimum and the minimum order quantity, which are based on the case pack size determined by the supplier. For the minimum this is due to the presentation quantity, which in general is set at three times the amount of facings allocated to a product. The amount of allocated facings is determined by the so-called “pack-and-a-half rule” which at EMTÉ is set at 1,2 times the case pack size divided by the facing capacity. The facing capacity represents the capacity each facing has, i.e. the depth of a shelf times the height of a shelf (both expressed in products). For slow moving items the allocated amount of facings is in general not higher than one.

As noted before the ordered amount is always rounded up to the next integer number of case packs, for slow moving items this almost always results in an order quantity of one case pack, due to the minimum order quantity based on the case pack size. Under these decision rules a retailer’s shelf space decision is effectively made by the supplier since the case pack quantity is unilaterally determined by the supplier (Curşue, et al., 2009) and not incorporating the demand rate of the product. Moreover, the supplier’s case pack quantity decision is unlikely to be optimal for the entire supply chain (Chiu, et al., 2011). Next to that, the presentation quantity factor is based on the visual appearance of the products to customers.

## 2.2. Research assignment

To solve the problem stated in the previous section, the overall research assignment is stated as follows:

*Clearly Define the Concept of Slow Moving Items for Sligro Food Group and Propose and Analyze Solutions for the Replenishment and Storage of these Items within the Sligro Supply Chain, with Primary Focus on the Retail Operations of the EMTÉ Format.*

Sligro Food Group would like to know what the possible solutions are and what the corresponding implications of these proposed solution are. The project is to focus on the retail operations but there may be interesting consequences on the food service business.

### 2.2.1. Sub questions

To achieve the overall research objective stated above, answers need to be provided during the project on the following sub questions:

- *What are characteristics of slow moving items?*
- *What is a Good and Appropriate Classification Method for Slow Moving Items?*
- *What are Possible Changes in the Replenishment Policy concerning Slow Moving Items?*
- *What are Possible Changes in the Allocation of Slow Moving Items?*
- *In particular, would it make sense to create a separate DC only for slow moving items, and use a separate slow moving item replenishment system?*

### 3. Literature overview

This section provides a brief literature overview on Slow moving products in a Supermarket supply chain and related subjects. Though food retailers and wholesalers are in the fast-moving consumer goods business, a big part of their items don't move very fast (Garry, 2011). Given that this type of products have different characteristics than fast and medium moving products, it requires a different approach when it comes to managing these products at the retailer and in the supply chain that replenishes the retailer. The majority of the literature in this section is obtained from the literature study performed in advance of this project.

#### 3.1. Product classification

Stock keeping units (SKU's) can be classified in multiple categories for example based on their demand; fast, normal or slow moving. There are different ways to perform such a classification, but three main classification methods stand out in current literature; ABC, FSN and VED (Parekh, et al., 2008).

- The ABC classification gives ranks to products based on their euro usage value or an another criterion. The general idea is that A products are the high value products, the middle value products are classified as B, and the lower value products are ranked as C products.
- The FSN classification is used to make a distinction between fast, slow and non-moving products. The general idea is that the products with the highest demand are classified as fast moving and the products having the least demand are classified as non-moving.
- VED classification differentiate products as Vital, Essential, or Desirable based on the functionality aspect and efficiency aspect of the product.

Looking at these three classification methods it can be pointed out that the VED classification is not a suitable way to classify the assortment of a supermarket. Given that it is a subjective method, which would require an immense amount of time to do this for the entire assortment. The general idea of the ABC and FSN method are the same, they both rank products on quantitative measures and then set up cutoff values to separate them in different categories. The decision on the cutoffs and the criterion used is in both methods based on the user's input. The main aim of any SKU classification is to use the similarity of products with regards to different properties to systematically classify products. An overview of studies on SKU classification is provided in Appendix E Appendix (van Kampen, et al., 2012). As can be seen in the overview the industries under study are diverse but none covers the industry of this project.

Silver (1991) also points out that the ABC classification scheme is one of the fundamental concepts of inventory management and has used it in multiple papers, on slow moving items, as a classification method. He denotes that the so called C category is composed of a relatively large number of items, each with a rather low annual euro usage value (Silver, 1991).

Van der Vlist (2007) shows an additional criterion on how to decide if a differentiation should be made between fast and slow moving items. He points out that many retailers have implemented separate warehouses for fast moving products, that replenish outlets directly and warehouses for slow moving products, that replenish outlets indirectly by cross docking store ready shipments at the fast mover

warehouse. This concerns the Excess Shelf Coverage, this is measured by the number of days of forecast demand that is covered by the product stocked on the shelf in the excess shelf space (Van der Vlist, 2007). The excess shelf space concept is defined by Broekmeulen et al. (2006), as shelf space that is not required to carry out the current operations with respect to customer service and costs. They demonstrate that this is a structural property of retail shelves, which is due to case pack sizes, consumer unit dimensions and shelf space dimensions (Broekmeulen, et al., 2006).

## **3.2. Implications of Slow Moving Products**

Most of the work in the area of slow moving products is done on the inventory management. Inventory management in general searches for the balance between three types of cost: Fixed ordering costs, Holding costs and Out of stock costs. To meet the demand it is necessary to keep enough units in stock and on the other hand keeping too much in stock increases the holding cost. With the current developments in assortments the product life cycle shortens and the likelihood of obsolescence increases, inventory can easily become a liability rather than an asset (Iossifova, et al., 2009).

### **3.2.1. Inventory management**

Kocer and Tamer (2011) denote that inventory control of slow-moving items is essential to many establishments, since excess inventory leads to high holding costs and obsolescence cost and on the other side stock outs can have a great impact on the performance of operations. Spare parts are the products considered in a big part of the studies in the literature on the inventory control of slow-moving items (Kocer & Tamer, 2011 ). Next to this the amount of practical studies performed in this field is low and mostly on spare parts. Inventory management needs to determine when to order and how much to order. Next to this a third question has risen in much literature on slow moving products; whether or not to stock a product. Given the type of organization under study this third question is not applicable here. Traditionally, the question on how much to order has been answered by calculating the “economic order quantity (EOQ)”. However in practice many of the assumptions of the EOQ do not hold, especially for slow moving products.

### **3.2.2. Inventory Control Policies**

Inventory management has come a long way since EOQ models. The five most common inventory control systems are described in Appendix F, two are based on continuous review and three on periodic review. The type of organization under study controls the inventory using a periodic review system, every R units of time the inventory is checked. If it is below the reorder point s an order is placed with size Q or a multiple of Q. This is a so called (R,s,nQ) system (Broekmeulen, et al., 2006). Note that the amount needed to raise the inventory to S is divided by Q and then rounded up to an integer value to always achieve the desired service level.

Van Zelst et al. (2009) suggest that future research should involve extending these currently used reorder policies in retail companies to take into account the handling efficiency with the replenishment. Their analysis shows the need for an adapted inventory replenishment rule which takes the handling aspects into account. Curşeu et al. (2009) also state that building new inventory replenishment policies that recognize the handling efficiency offer interesting potential efficiency gains. However it should of

course consider the possible tradeoffs, such as the shelf space availability and physical constraints of the shelves, the demand pattern or restrictions with respect to possible case pack sizes.

### **3.3. The Effects of Case-Pack Size**

Academic literature has largely ignored the impact of case pack quantity on the retail supply chain, while most SKU's in retail stores are replenished in these packs (Waller, et al., 2008). As mentioned in the part on the inventory control systems, the system in use can only order a multiple of this fixed quantity. In accordance with the literature, the study done by Waller et al. (2008) finds that case pack quantity has a significant impact on retail market share, it is a key variable in a firm's logistics and distribution processes. The impact on retail market share is largely a result of case pack quantity's influence on shelf availability and subsequently shelf stock outs.

#### **3.3.1. The Effect on Order Quantity**

A regular found assumption in the study of slow moving products is the simplifying assumption that the reorder quantity is one (Karush, 1957). Hill (2006) also pointed this out by the approximation of the EOQ, which was adjusted to small demand values. Given that most SKU's in a supermarket are delivered in case packs, this is not applicable here. We will now further elaborate on this characteristic. Frequently an error is introduced into inventory formulations by ignoring the case pack size. Robb and Silver (1998) provide a model to cope with situations in which demand during its review period is relatively low compared to the vendor-specified minimum order quantity. They argue that simply rounding a recommended purchase quantity up to the minimum ordering amount will result in inferior decisions in some environments.

Yan et al. (2009) conclude that their results may motivate companies to seek a smaller delivery pack size through vendor negotiations or by allowing for packs to be split at DC's. Such decision can be evaluated by analyzing the economic consequences and associated costs. Little research was found on splitting packs. Next to this retail research lacks approaches to determine order packaging units that incorporate shelf capacity and thus reflect in-store handling efforts (Kuhn & Sternbeck, 2013). Again one approach could be to integrate handling operations in inventory decision rules applied to grocery retail, as mentioned in subsection on inventory policies.

#### **3.3.2. The Effect on Store Logistics**

Van Zelst et al. (2009) provide the cost structure of two European retail chains, in which they state that in-store operational cost account for 45%, transportation for 22% and warehousing for 33% of total operational cost of the internal part of the retail supply chain. The authors claim that future research is needed to focus on the impact of case pack quantities on a store level, but also on picking operations in the retail warehouses.

Theoretical evidence that two countervailing effects of case pack quantity exist is provided by Waller et al. (2008). The first effect is that larger case packs reduce the frequency of store replenishment and thus reduce the number of exposures to stock outs as a result of replenishment, which they term the store-level fill rate effect. The second is that larger case packs increase the probability that some units will need to be stored in the backroom of the store because they do not fit on the shelf when the ordered



case pack arrives at the store and is taken to the shelf. This increases the number of exposures to stock outs due to poor shelf replenishment from the backroom (Waller, et al., 2008). This backroom logistics effect is dominant when items have a lower rate of sale (ROS). Waller et al. (2008) suggest among their conclusions to decrease the case pack quantity for SKU's with a low rate of sale. This would mitigate the backroom logistics effect for slower ROS SKU's, decreasing the exposure of the SKU's to shelf stock outs. Next to this employees will have to make fewer trips with a given case pack from the backroom to the shelf, which offers either the opportunity to reduce handling cost. Smaller case packs result in fewer individual units being stored in the backroom, diminishing the SKU's exposure to backroom replenishment processes which are less reliable and can result in additional shelf stock outs.

### **3.3.3. The effect on assortment**

A study into stock outs documented that retail stock outs often results from shelf space allocation decisions based on heuristics. It also revealed that 91 % of retail shelf space allocations are based on a so called "packout" heuristic, such that the shelf space allocated equals the case pack quantity. This case pack quantity is typically determined by the supplier and when a retailer uses these heuristics, the shelf space allocation is driven by a supplier determined quantity. Another popular practice is to allocate shelf space equal to one-and-a-half times the case pack quantity, also known as "pack-and-a-half" rule. The reason for applying these heuristics is their simplicity, a significant disadvantage of these heuristics is that they allocate too much space for some SKU's and too little for others (Eroglu, et al., 2011). The failure of these heuristics is that they do not consider consumer demand. This potential mismatch among shelf space, case pack quantity and consumer demand has a significant impact on retail product availability due to the phenomenon known as shelf stockouts. These occur when retailers carry inventory on two locations, on the shelves and in the backroom. Although the backroom works to serve to customer better through improved product availability at the shelf, the processes followed to replenish shelves from a store's backroom are often unreliable and/or ineffective, which in turn increases the level of shelf stock outs (Eroglu, et al., 2011).

## **3.4. Integrated Logistics Networks**

Many papers denote in their conclusion and further research sections that there is a need for effective supply chain management, this would allow firms to follow through on their customer orientation in a cost-effective manner through well-reasoned decisions, such as shelf space allocation and case pack quantities (Eroglu, et al., 2011). Recently Kuhn and Sternbeck (2013) have presented an empirical research study into integrative retail logistics.

Nowadays grocery retailers usually operate distribution centers and therefore have their own vertically integrated logistics network to manage. This network can be divided in three logistic subsystems: Distribution center, Transportation, and Store see Figure 7. Many retail companies are currently in the process of better adjusting their logistic system to the requirements of the market without modifying the system at its core. However retail research lacks a comprehensive view on retail logistics networks as they have evolved over time and on the interdependent logistics planning problems (Kuhn & Sternbeck, 2013).

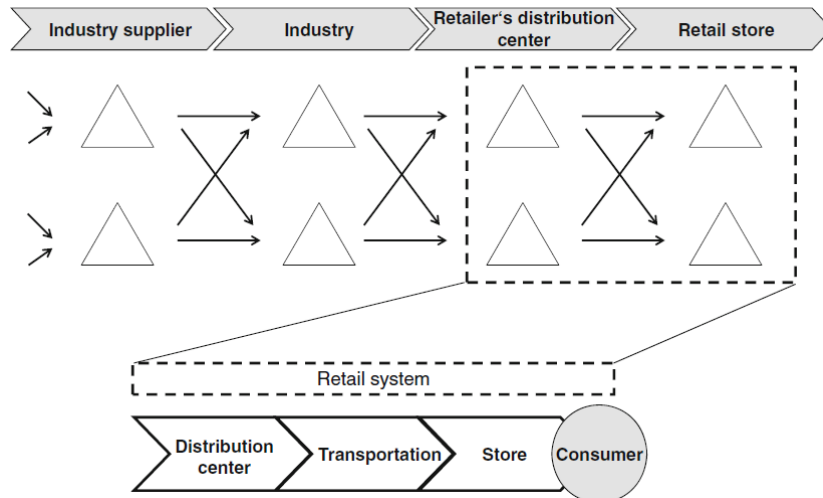


Figure 7 The part of the stationary FMCG supply chain focused on in the paper by Kuhn & Sternbeck (2013)

Kuhn and Sternbeck categorized four phenotypes of network structures used by the retailers they interviewed see Figure 8:

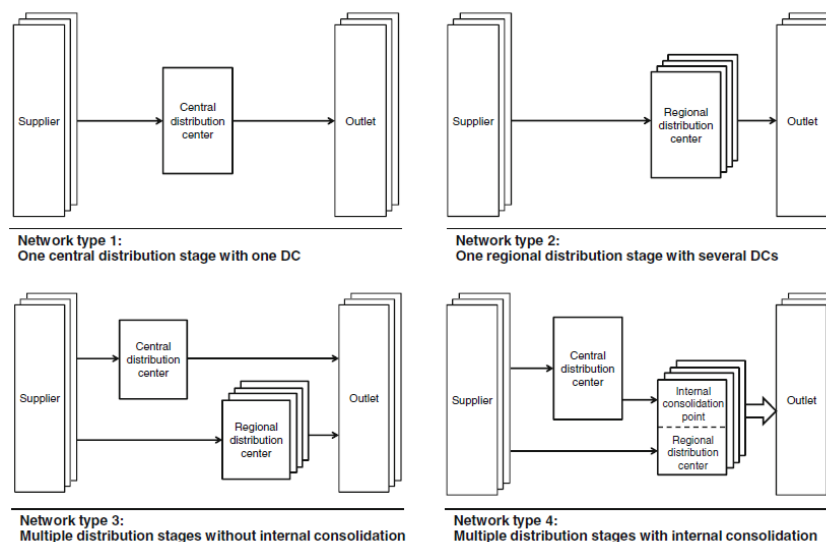


Figure 8 Categorization of retail logistics networks (Kuhn & Sternbeck, 2013)

The retailer applying network type 3 & 4 faces the inventory deployment decision, which concerns the problem where to allocate SKU's along the different distribution stages (Shapiro & Wagner, 2009). The most frequently mentioned aspect, when asked which factors the interviewees take into consideration when allocating the SKU's, is the rate of SKU turnover. Next to this allocation of SKU's on differences in the structure of the physical flow of products, the retailers were asked on the use of planning variables to control the flow of goods. In particular the store delivery patterns and the replenishment lead times in grocery retailing, these are fixed on a tactical level and the values are passed down to the execution level as parameters. This allows the retailers to create several internal supply chain segments with different specific characteristics. Varying from highly reactive segments with high store delivery frequencies and short store replenishment lead times (e.g. critical perishables), to segments with longer

lead times and lower frequencies in order to realize efficiency gains through bundling over time and quantity (e.g. slow-moving ambient products) (Kuhn & Sternbeck, 2013).

Another interesting finding from the study of Kuhn & Sternbeck (2013) is that although in-store operational cost are the biggest cost pool, only few retailers apply activity-based costing for this section of the supply chain. In most cases operations managers are not responsible for in-store logistics, this is considered as a part of the sales domain. The corresponding costs are therefore not recognized as logistic operations cost. Again, in-store logistics play a minor role in publications about retail logistics. It is required to consider the complete supply chain when making decisions that affect the logistic subsystems. Kuhn & Sternbeck verified that a comprehensive perspective on supply chain operation is of particular importance in retailing since the objectives of the in-store logistics system and upstream logistics activities are partially in conflict with one another. Again less than 40% of the companies in their sample have built up organizational units to develop a comprehensive perspective with the aim of integrating in-store logistics and upstream operations.

### **3.5. Academic Relevance**

This literature overview based on the literature review done before this thesis showed that there is gap between the current research on slow moving retail items and the work done on the effect of case packs on the order quantity. This gap offers an opportunity for further research. Next to this the research on this subject in this type of organization is scarce and the amount of practical studies performed in this field is low and almost entirely on spare parts. Future work on this topic should be aimed at considering how to manage slow moving items which are ordered in case packs in a fast moving consumer goods business supply chain. Taking into consideration that decisions made at one logistic subsystem can directly or indirectly affect other subsystems' logistics and corresponding performance in integrated logistics networks. The next chapter provides insights in the areas that are affected by slow moving items.

## 4. Problem analysis

This chapter functions as an insight in the areas that are affected by slow moving items. In this problem analysis two subsystems of the retail system are considered, the first one is the store and the second is the distribution center. This are the two subsystems where stock of products is located. This problem analysis is done on the sales data over a time span of one full year. This sales data covers all products that are ordered via the ABS by the owned stores (99 stores), excluding the franchise owned stores (30). This chapter contains the results of the analysis phase done on the EMTÉ supply chain and the relevant cost aspects.

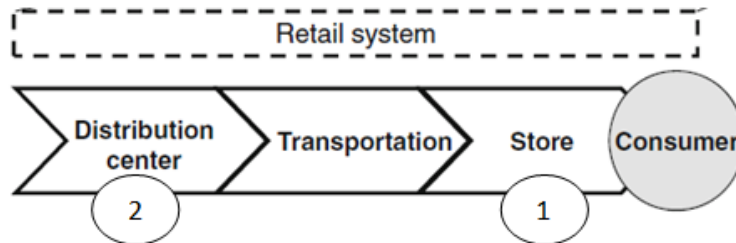


Figure 9 Numbered Subsystems in which slow moving items play a role. Kuhn & Sternbeck(2013)

### 4.1. Assortment Analysis

The received raw data consisted of all products sent from the RDC's to the stores, this included data on seasonal products, fresh products, products for store operations, sales of products that were not present in the assortment for the entire year and the promotion sales on all products. For this reason the data needed to be filtered and prepared before an proper analysis could be applied given that the products of interest are the dry grocery products.

#### 4.1.1. Data filtering

To make the data compatible for assortment analysis it is first filtered on product group level. The product groups that are not consider in this project are filtered out on basis of their group characteristics. This mainly concerns the following product groups: fresh product groups, product groups classified as seasonal groups, groups with products used for store operations and product groups sold at the checkout counters. The product groups denoted as fresh products are excluded due to that they are delivered by cooled transport and are handled in a different manner than the other product groups. The seasonal groups are left out of the data given that the amount of facings allocated differ through the year and their demand contains seasonal peaks.

On product level the decision is made to exclude the products that are in the assortment for less than an year. This is done because the data on these products is not comparable with the actual sales. This includes both product introduction and remediation. Products that are introduced during the year did not yet had the time to prove themselves during each season. Remediation is defined as the phasing out of products, in order to remove them from the assortment . Products that are remediated do not have an entire sales pattern either and possible replacement products are not recorded. Next to that the promotion sales are filtered out of the data, the sales data on promotion weeks have been replaced by the average demand of the weeks without promotion. The filtering on product group and product level

returned  $\pm 6000$  products in 67 Product Groups to be analyzed. This subset of the total assortment contained 53% of the original assortment.

#### 4.1.2. First Assortment analysis

The first step in this problem analysis is to look at the performance of the assortment in terms of sales across all the stores. By looking at the annual demand, i.e. total orders placed at both RDC's by the stores carrying the products. Given that individual stores order when their inventory reaches the re-order levels, the combined demand at the RDC's represents the customer demand at the stores. Figure 10 shows a Pareto analysis on the assortment selected for this analysis. Not all products supplied by the RDC's are carried by all the stores, as mentioned before this is due to the amount of meters assigned to each product group in the store, based on size of the store. For this reason the performance of the assortment is also represented in average demand per store which is represented by the sum of the demand of the product divided by the amount of stores carrying this product.

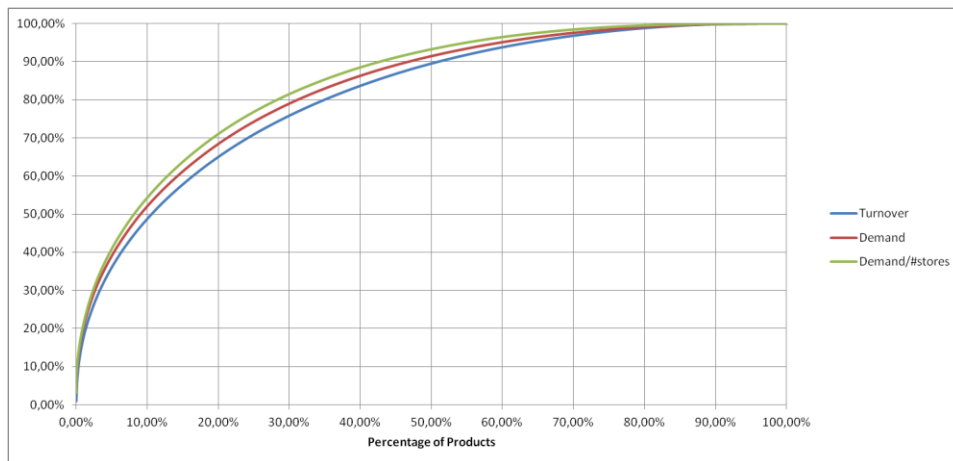


Figure 10 Pareto Analysis

As can be seen the first 20% of the products accounts for approximately 70% of the total demand. Another observation that can be made is that the last 50% of products only accounts for less than 10% of total demand and turnover. We continue this problem analysis with comparing the last 50% to the entire assortment, to give insight in the area of slow moving items. Looking at the case pack size of the products in this last 50%, Figure 11 shows that their case pack size is smaller compared to the case pack size of the entire assortment, still 65% of these products have a case pack size of six or more. The average amount of case packs sold per week per store is displayed in Figure 12, this shows that more than 70% of the products in the last 50% sells less than a quarter of a case pack per week on average per store. Appendix G shows the min, max and case coverage comparison for one store.

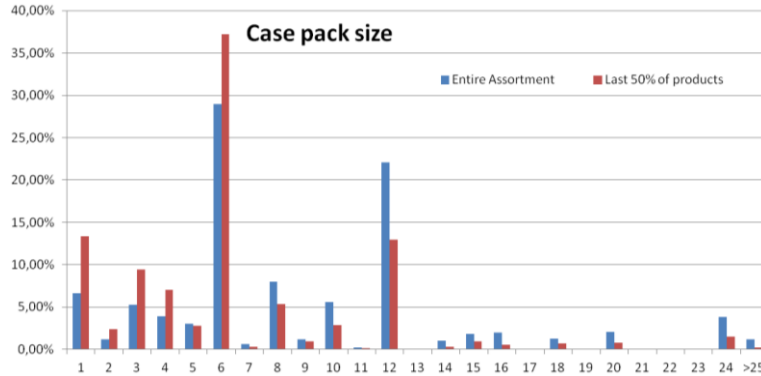


Figure 11 Case pack size comparison

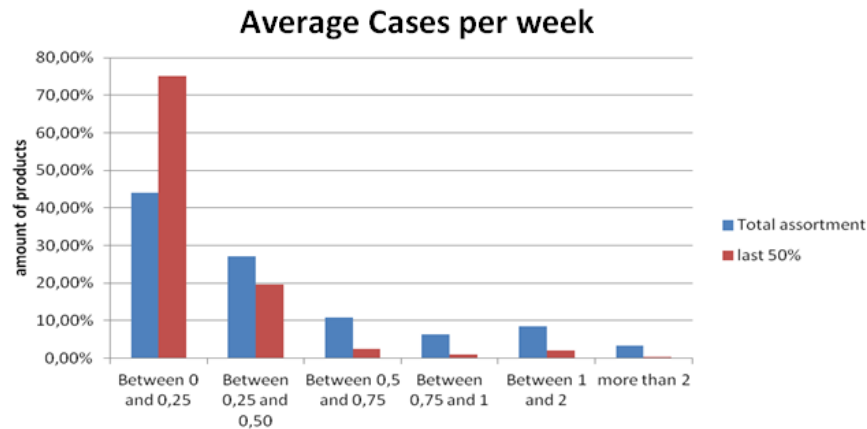
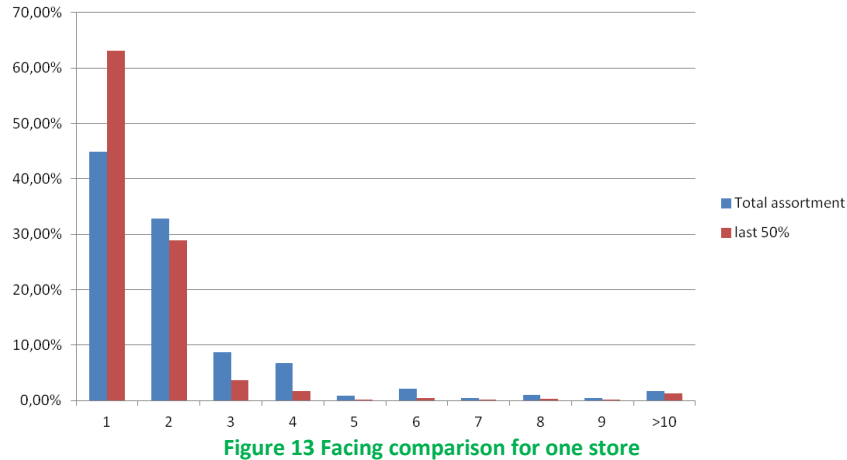


Figure 12 Average per store demand in case packs per week

## 4.2. Slow moving items at the store level

As mentioned before the store is one subsystem that has stock allocated to it to satisfy possible customer demand. We first take a look at the ordering process of the slow moving items at this subsystem, followed by looking at the service level of the products at the store level. Then characteristics of slow moving items at the store level are analyzed. In this project, planograms and assortments are assumed as given and will not be modified. For this reason the amount of facings allocated are considered as fixed as well as the corresponding minimum based on the presentation quantity. Figure 13 shows the comparison between the total assortment and the last 50% of the assortment in terms of allocated facings for one store. This suggests that in the facing allocation process the movement rate of a product is already taken into account, still more than 35% of the last 50% has two or more facings allocated to it. The following paragraphs go into more depth on the store level.



#### 4.2.1. Ordering Process at store level

Repeating what was stated in section 2.1.4; the following order advice is provided for the ABS for slow moving items: Sales expectation is smaller than the minimum ( $SE < Min$ ), then ABS will advice: *Minimum – (Stock + Outstanding Orders)*. The Sales expectation is expected to be smaller than the minimum given that in general the minimum is set by the presentation quantity at at least three times the amount of allocated facings. If the sales expectation would be bigger than this amount it would not be considered as a slow mover. This means that the reorder level will be at a constant level, which implies that the system can be considered as a static model. In general the reorder level can be seen as the Minimum, than the amount needed to bring the inventory level back to this minimum is ordered. The assumption that the products in the last 50% of the assortment will not see more than one unit of demand between two ordering moments is checked by looking at the average demand for the last 50% of the assortment over the time span of a half week. This showed that for 95% of these products the average demand per half week was lower than one. Given that the ordering has a minimum order quantity of the case pack size, this will be the amount ordered, given that for this group of products they want to order up to the minimum. Due to that both the reorder level and the maximum inventory on hand are in general static, the long run average inventory level is considered to be average of those two, this is graphically represented by the simplified representation of the inventory movement of slow moving items in Figure 14.

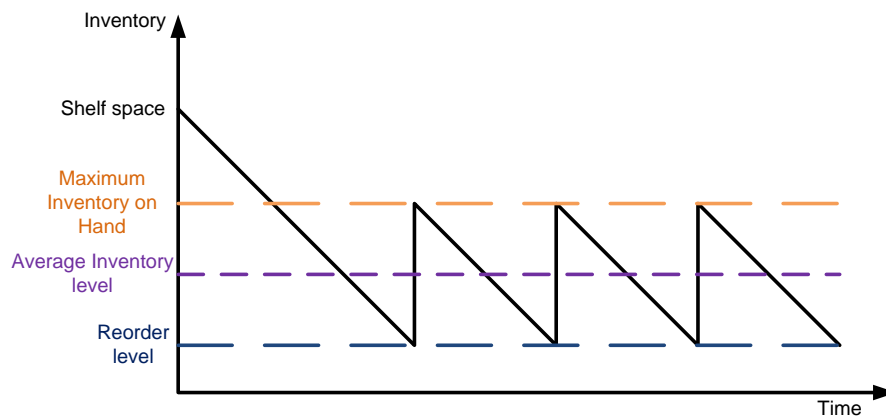


Figure 14 Simplified Inventory movement slow movers

Given that in most cases the movement rate in combination with another characteristic results in a problem area, we looked at other characteristics that combined with the low demand result in problems at the store level. In consultation with the organization under research possible problem areas were analyzed.

#### 4.2.2. Service level

The reorder level in a periodic review system using a (R,s,nQ) policy is built up by two components, the first is the expected/forecasted demand over a review interval plus a replenishment lead time. The second component concerns the safety stock, this consists of the standard deviation of errors of forecast over a review interval plus a replenishment lead time times the safety factor. This safety factor is selected to ensure the service level is reached, with service level we mean the  $p_2$  measure also known as the fill rate. The fill rate is the fraction of customer demand that is met routinely from the shelf, without backorders or lost sales (Silver, et al., 1998).

$$s = \hat{\mu}_{R+L} + SS$$

$$SS = k\hat{\sigma}_{R+L}$$

$$\text{for a } k \text{ that satisfies } G_u(k) = \frac{Q}{\hat{\sigma}_{R+L}} \left( \frac{1 - P_2}{P_2} \right)$$

The current fill rate based on the current reorder levels is calculated to see how it corresponds with the by management required fill rate. The achieved fill rate is calculated using the DoBr Tool, which is explained in section 5.2.1. Due to that EMTÉ is positioned in the Dutch retail landscape as service supermarkets, the target fill rate is 98%, which is in accordance to other service supermarkets in the Dutch retail landscape.

The fill rate calculation takes the standard deviation of demand into account, however ABS calculates the Sales Expectancy and corresponding reorder level only on the average of demand. This means the current safety stocks do not differ between two products with the same average but a difference in standard deviation. The fill rate for the last 50% of products is compared with the entire assortment in Table 1, for illustrative purposes for one store. This shows that for a proportion of these products the fill rate is very high. From this it can be concluded that if the reorder levels were set on basis of both demand characteristics they would be lower than the current levels, given that the target service level is lower. For the products with a high standard deviation the reorder levels should be increased accordingly to ensure that there is enough safety stock to cope with the high variance in demand. As can be seen from Table 1, almost 30% of the products in the last 50% of products does not achieve the target service level.

**Table 1 Fill rate comparison between last 50% and total assortment for one store**

Fill rate	% of last 50% of products	% of total assortment
<b>&gt;=0,999</b>	23,65%	15,45%
<b>&gt;=0,995</b>	38,96%	25,87%
<b>&gt;=0,99</b>	51,90%	35,80%
<b>&gt;=0,98</b>	70,33%	54,25%



### 4.2.3. Days of inventory

Products with a low demand rate can result in a high amount of days of inventory due to relatively high inventory levels resulting from relatively high reorder levels or/and relatively large case pack sizes. The days of inventory is analyzed for one store in Figure 15, the days of inventory are calculated using the expected on hand inventory divided by the average daily demand. The expected inventory on hand is calculated using the DoBr Tool. Figure 15 shows that for this store almost 2% of the SKU's have an expected inventory on hand that accounts for more than a half year of demand and more than 5% of the SKU's have an expected inventory on hand that accounts for more than three months of demand. A high amount of days of inventory can result in problems in combination with a relatively short shelf life or a possible remediation.

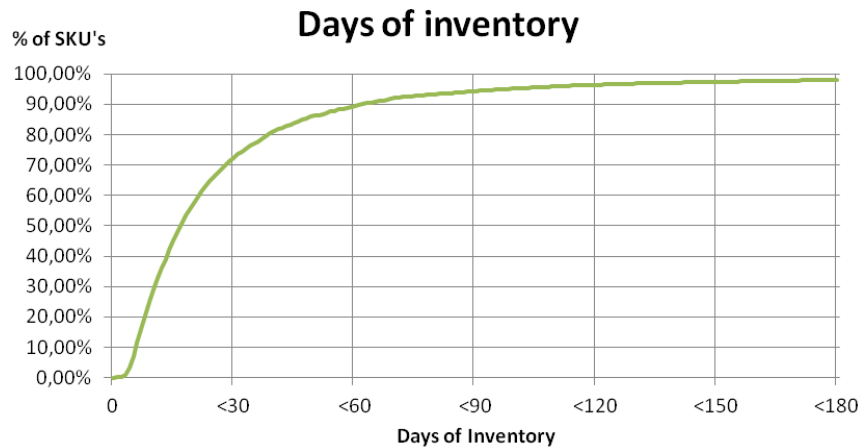


Figure 15 Days of inventory for one store

The shelf life, i.e. the amount of days the product is good for consumption when it is delivered to the store. This is guaranteed by the RDC to be at least two third of the amount of days until the best before date guaranteed by the supplier is reached. Intuitively products that move slow and are delivered in a case pack have a higher risk of exceeding this amount of days. The inventory of the product that is located in the store which has exceeded its shelf life is destroyed. In other words the total value of the inventory that is left after this date will be written off. Due to that this project is aimed at the dry grocery assortment, the SKU's with a shelf life shorter than their days of inventory is small. Note however that this problem keeps returning every time the corresponding product is ordered. It is worth mentioning that the ABS sends a warning to the store if a generated order is likely to exceed the shelf life based on the forecasted sales of the corresponding product. On this warning the ABS manager decides if he orders or postpones the order, decreasing the size of the problem.

Remediation is the process of removing products from the assortment. Slow moving products have a higher chance of being remediated from the assortment based on their demand rate. During a research project done at the organization under research in 2012 the number of articles in the assortment during Easter 2012 and the percentage of these items which were already in the assortment during previous years were determined. As can be seen in Table 2 there is high level of product replacement, removing products to create space for product introductions. This high level of product replacement is a characteristic of supermarket assortments (Dankers, 2012).

Table 2 Product replacement (source: master thesis H. Dankers)

Year	# SKU's	Percentage of current Assortment
2012	13696	100,0%
2011	10480	76,5%
2010	7820	57,1%
2009	6003	43,8%
2008	4713	34,4%

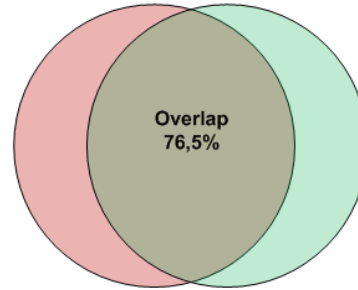


Figure 16 Overlap between 2011 and 2012

After the decision is made to remediate a product the stores have seven weeks to sell out the remaining amount of inventory in the store. After this period the products will be sold at a discount percentage of 50%. Intuitively slow moving items in combination with their average inventory levels have problems to sell the products before this period is over. Figure 15 shows us that more than almost 12% of the SKU's in this store would not have sold out their expected on hand inventory before the seven weeks are past and therefore need to be discounted.

#### 4.2.4. Backroom Inventory

Another store characteristic is that for some products the allocated shelf space is too small to cope with an incoming order, which results in backroom inventory. The backroom of the store is meant to provide extra storage for products which require multiple replenishments a day, to cope with their high demand. Therefore ideally backroom inventory should not occur for slow moving items. However due to incorrect setting of reorder levels or/and allocated shelf space, backroom inventory can occur. The backroom inventory for products which do not require multiple replenishments a day is analyzed for one store. This is analyzed by looking at two criteria, the first concerns the occurrence of backroom inventory and the second is to ensure the items considered are not the ones which require concurrent replenishments. The backroom inventory is calculated using the DoBr tool. The items that require concurrent replenishment have a daily demand on the peak days of the week that exceeds the shelf space. For most products Friday or Saturday is the peak day.

- I. *Backroom inventory occurs*
- II. *Not consider as item requiring concurrent replenishment*

Looking at the planogram parameters, the minimal inventory norm and shelf space of one store, 43,80% of the SKU's in one store would result in backroom inventory without the requirement for concurrent replenishment. Again the comparison is made, 45,07% of the last 50% of products would result in backroom inventory. If the ABS parameters are used in this computation, the actual Min instead of Minimal inventory norm and Max instead of Shelf space set in planograms, this comes down to 17,70 % of the SKU's in one store, which would result in backroom inventory without the requirement of concurrent replenishment. This reveal that 20,57% of the last 50% of products would result in backroom inventory.

The difference between the two situations can be explained by the rules used by the space management when designing the planogram and the ordering policy used by the ABS. The space managers assign at

least 1,2 times the case pack size as shelf space to each product. The reorder level in ABS for slow moving items is set at the minimum inventory level. The following example will illustrate this phenomenon; a case pack size of six and a facing capacity of 7, results in an allocated shelf space of  $6 \cdot 1,2 = 7,2$  which is rounded to seven. The product is ordered at  $3 - 1 = 2$  items, when the ordered case pack arrives five items will fit on the shelf and one has to be moved to the backroom. The ABS managers at the store can adjust the Min and Max in the ABS to match their adjustments on the shelf space or reorder level to reduce backroom inventory. For this example the min or max could be adjusted to ensure the ordered case pack will fit on the shelf entirely and no backroom inventory emerges.

To get insight in the amount of difference between the planograms and actual ABS characteristics, the planograms min and max are compared with the ABS min and max. On average 75,33% of the Planograms min differed from the ABS min, for the max this comes down to 64,70% and on average in 53,10% of the SKU-store combination both the min and max differ. Looking at the case where both min and max differ between planograms and ABS, across the stores, the store with the lowest difference showed a difference of 20,57% and the store with the highest difference showed a difference of 71,86%. There can be different reasons for changing either the min or/and max, one of them is changing the min and max to prevent backroom inventory.

In conclusion almost 18% of the SKU's in one store which do not belong in the backroom will result in backroom inventory after ordering. Restating Waller et al. (2008), this increases the number of exposures to stock outs due to poor shelf replenishment from the backroom. This backroom logistics effect is dominant when items have a lower rate of sale (ROS). For low-ROS items that require a downward adjustment in case pack quantity, the retailer is better off because of better service levels and reduced labor costs due to fewer units going to the backroom (Waller, et al., 2008). Again the ABS sends a warning to the store if a generated order is likely to result in backroom inventory. On this warning the ABS manager decides if he orders or postpones the order, decreasing the size of the problem.

#### **4.2.5. Excess shelf space**

Broekmeulen et al. (2006) note that marketing and operations responsibilities meet in retail on the shelves. This is the location where the products meet the consumer, whereas the shelf is also the final inventory location in the retail supply chain. Marketing assumes that the presence of inventory drives demand and therefore requires excellent operations. In operations, the main concern is with the trade-off between inventory holding cost on the shelf and the cost of replenishment. They performed an empirical assessment which showed that excess shelf space in the presence of a non-linear cost of replenishment offers enormous opportunities for the development of new supply chain coordination mechanisms. They conclude that the excess shelf space, the available space on the shelf is strongly influenced by the physical dimensions of the product, the case pack size and the shelf dimensions. Since these are exogenous to the replenishment process parameters, the excess shelf space is an important and relevant phenomenon in retail operations.

We follow the same definition for Excess Shelf Space (ESS) as defined by Broekmeulen et al. (2006), which is defined as the part of the total shelf space for a SKU, in consumer units, that is not necessary

for carrying out the current operations with respect to customer service and costs. Current operations concerns the inventory control policy for the SKU, considering the target customer service, the review period and the case pack size.

Given that the Shelf is the location where each product meets consumer demand this is the location where the performance of supply chain is measured. According to supply chain synchronization ideally all inventory should be shifted to the retail outlets. From a supply chain perspective positioning more inventory in the stores does not mean more inventory costs, because once the inventory is in the supply chain the associated inventory cost already are being incurred (Van der Vlist, 2007). Next to this handling cost are significantly higher than inventory costs, supported by the findings of Van Zelst et al. (2009), see for example the operational logistical costs found by them for non-perishables in Figure 17. This makes it worthwhile to look at the excess shelf space to improve the operations (Van Zelst, et al., 2009).

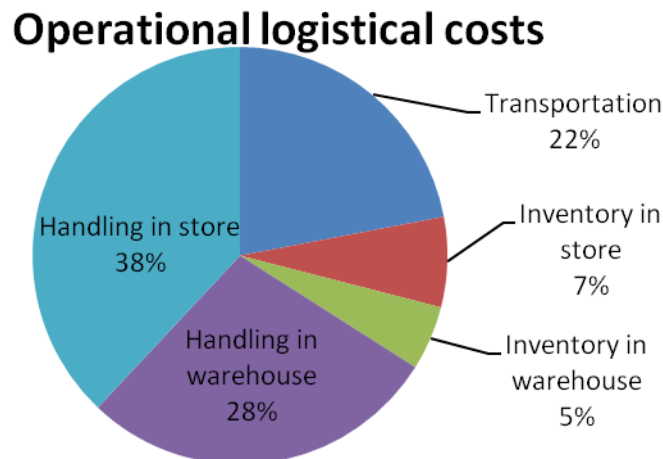


Figure 17 Operational logistical costs in the retail supply chain for non-perishables (Van Zelst et al (2009)).

#### 4.2.5.1. Excess shelf space analysis

The excess shelf space (ESS) represents the difference between the shelf capacity of a product and its maximum on hand inventory (Broekmeulen, et al., 2006). We analyzed the ESS for one store, to get insights on the presence of this phenomenon. The reorder levels used in this analysis depend on the average sales expectancy, to match the ordering policy currently in use. The average sales expectancy based on demand during lead time and review period depends on the delivery schedule for the SKU which may depend not only on the SKU but also on the store.

Again the comparison is made between the entire assortment and the last 50% of the assortment on the excess shelf space of one store in Figure 18, to give insight into the distribution of the ESS values. This shows that the last 50% of products are mainly located on the right side of the zero. Note also that the products with a negative ESS value are the ones that create backroom inventory when ordered. The Excess shelf coverage (ESC) is presented in Figure 19, this represents the excess shelf space divide by the average day demand. Again a comparison is made to gain more insight in this characteristic for slow movers. From this it can be concluded that for the corresponding store almost half the products in the last 50% of the assortment have an ESC value of more than nine days. Next to this more than 20% of the

products in the last 50% of the assortment have an ESC value of less than -9 days, which represent the products which create backroom inventory on ordering for more than 9 days. This excess shelf coverage leaves room for improvement, for example one could decide that this phenomenon could be exploited to improve operations without decreasing the service level.

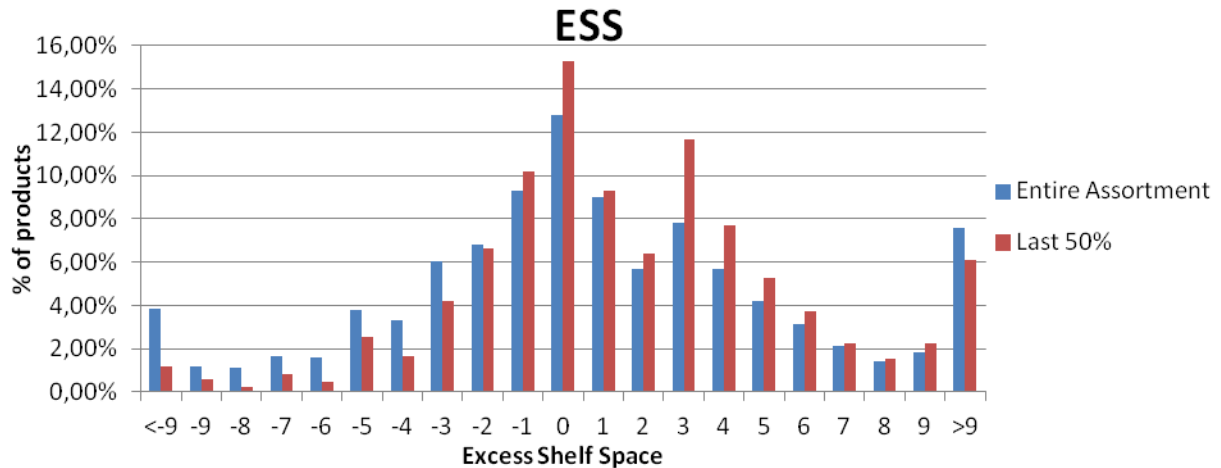


Figure 18 Excess Shelf Space Comparison for one store

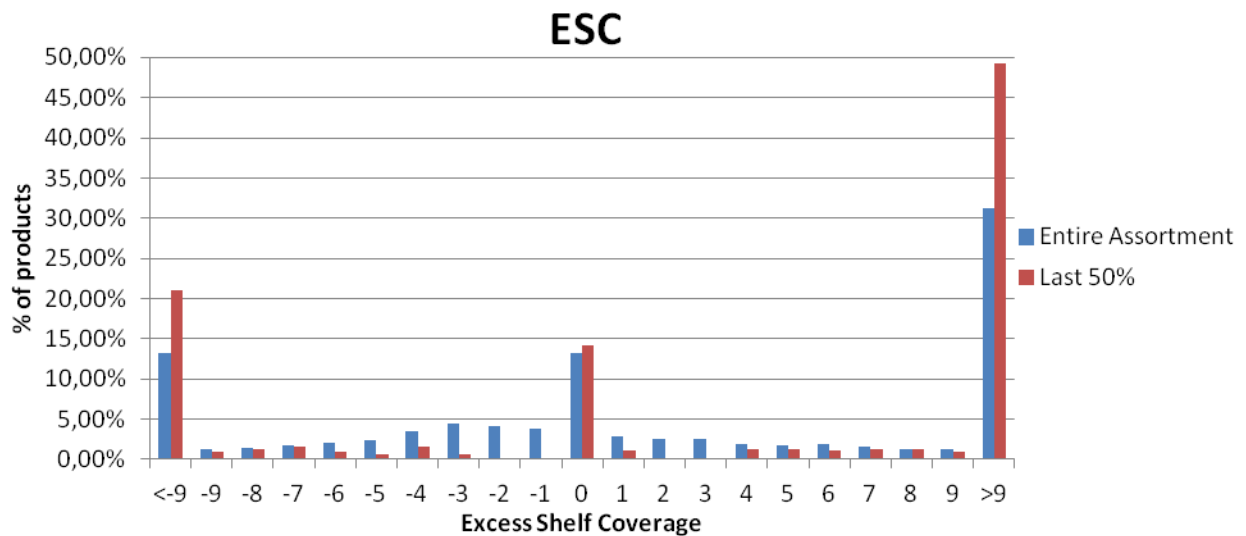


Figure 19 Excess Shelf Coverage Comparison for one store

#### 4.2.6. Conclusion slow moving items at store level

The results of the analysis at the store level can be summarized in the following sub conclusions:

- The fill rate analysis showed that for a proportion of the products in the last 50% of products the reorder levels are set too high due to that they are set on basis of the minimum inventory norm and not determined on both demand characteristics, mean and standard deviation. This leaves room for improvement, which also goes for the products that, according to the target fill rate, have a too low reorder level due to high standard deviations.
- Almost 2% of the SKU's have an expected inventory on hand that accounts for more than a half year of demand and more than 5% of the SKU's have an expected inventory on hand that

accounts for more than three months of demand. A high amount of days of inventory can result in problems in combination with a relatively short shelf life or a possible remediation.

- The backroom inventory analysis showed that almost eighteen percent of the SKU's that do not belong there according to their demand, result in backroom inventory after ordering.
- The ABS manager gives a warning on ordering a product that will result in a shelf life problem or in backroom inventory, this warning is based on historic sales data of the corresponding product. The ABS manager can decide to act on this warning by either postponing the order or by ignoring the warning and place the generated order.
- The last store characteristic concerns the excess shelf space, this showed that there are many products, especially slow moving items, which have this characteristic. This is due to the amount of shelf space allocated in comparison with the shelf space that is necessary for carrying out the current operations with respect to customer service levels. This leaves room for improving operations without decreasing the service levels.

### 4.3. Slow moving items at the Distribution Center level

The regional distribution center is the second subsystem, which has stock allocated to it to satisfy possible demand of the stores. Again we first take a look at the ordering process of the slow moving items at this subsystem. Followed by the characteristics of slow moving items at this level. One RDC delivers 49 of the own stores and other RDC delivers the remaining 51 own stores. Figure 20 shows one of the traditional supply chains according to Van der Vlist (2007), which is the best match to the supply chain under research.

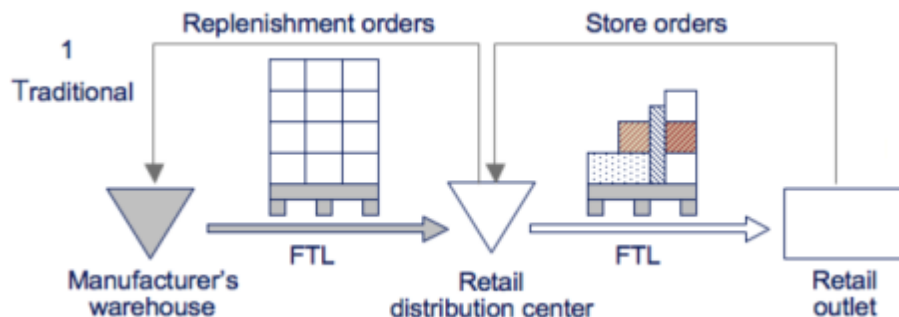


Figure 20 Traditional supply chain according to Van der Vlist, (2007)

#### 4.3.1. Ordering Process at Distribution Center level

In the current situation almost all products have stock allocated in both RDC's, to satisfy possible demand of the stores assigned to the specific RDC. Both RDC's order independently of each other, using their own order policies based on corresponding order levels. The reorder levels are set to cope with the possible demand during the replenishment, which consists of the lead time, safety days and the review period. The majority of items that are stored at the RDC's have a minimum order quantity set by the supplier. The movement pattern over time of slow moving items at the DC level much resembles the pattern shown on the movement slow moving items at the store level. The main difference is that the reorder level at the DC does not share the restriction of the presentation quantity that is present in the stores, due to that customers do not see DC inventory. This results in a reorder level that can be solely

based on the order history of the products. As mentioned before the ordering of the RDC's at the suppliers is left out of the scope for this project.

The review period of a product at the store level is restricted by the corresponding product group. The order generating moment for the product groups is store dependent. Due to this the slow – and fast moving items in a product group share the same ordering settings, which implies that they can be ordered on the same days, are handled with the same priority and share the same lead time. Next to this every product that has inventory located at the RDC is delivered the day after it is ordered except for the ordering on Saturday, resulting in a lead time of one day for the weekdays and two days for Saturday.

#### **4.3.2. Days of inventory**

The inventory at both subsystems also share the resemblance that they are faced with the best before date of items. As mentioned earlier the shelf life at the DC should not surpass one third of the supplier guaranteed best before date. This to ensure that the items spend at least two third of the best before date guaranteed by the supplier at the store level. When the same analysis as presented at the store level section is applied at the DC level, the amount of days of inventory does not turn out to be as high as at the store level. The main reasons for this are that the reorder level is solely based on the sales history and there are only two inventory locations at this subsystem instead of the one hundred considered at the store level. Another reason is that if a minimum order quantity would result in a problem in combination with the shelf life, the supplier would be contacted to discuss the minimum order quantity at the distribution center level.

However one RDC site manager noted that the shelf life problem is present when a promotion is set up for a slow moving item and sales turn out to be lower than expected in combination with a high order quantity. This would result in high inventory levels at both RDC's due to the promotion and later on even further increasing due to possible returns from the stores due to low promotion sales.

The remediation process at the RDC does not resemble the process at the store level. When a product is remediated at the RDC level it will no longer be delivered to the stores, in contrast to the stores the entire inventory of the RDC's is send to the CDC. At the CDC it is then decided what will be done with the remainder of both RDC inventories. This inventory can either be sold in the Foodservice stores, in a markdown store or sold to a wholesale dealer. Again when a product remediation is discussed the inventory in the chain is taken into consideration.

#### **4.3.3. Order picking process**

Just as many other retailers the retailer under research uses family grouping in the warehouse layout. This implies that the product groups that are presented on the shelves together as a family, are grouped in the same manner in the warehouse. When products are picked according to this layout, filling the shelves in the shops is easier. Given that due to this layout, the rolling containers with picked products only contain products belonging to the same store aisle.

Instead of moving through the picking lanes with one rolling container at the time, the warehouses have recently implemented a picking system that moves three rolling containers per picker through a picking

lane. The picker works on one batch containing three orders from three different stores. This is implemented to increase the picking efficiency of the RDC, given that the drive and pick time per product are both lower in comparison with moving through the picking lanes with one container at the time. The current warehouse layout and picking method are visualized in Figure 21, the different colors represent different family groups. Note that every item in the RDC can be picked every day for different stores based on the family grouping layout and the entire family route has to be travelled every time an order list is printed. As mentioned before in this section, there are items with different movement speeds in the same family, fast movers that need to be picked and delivered daily and slow movers that could be picked and delivered only once a week. This phenomenon cannot be changed as long as the ordering and picking is done only on the family group characteristics.

This phenomenon is made visible in Figure 22, which shows the aggregated demand for the products in one product family. This shows that the fastest moving product requires on average 176 case packs picked per week and the slowest moving product requires on average 4 case pack per week. Figure 23 shows the average per store demand for the products in one product family. Again the fastest moving product requires on average 1,8 case packs per week and the slowest moving product requires on average 0.04 case pack per week. The aggregated average demand as well as the average per store demand shows that there is a lot of spread between the products in a product family.

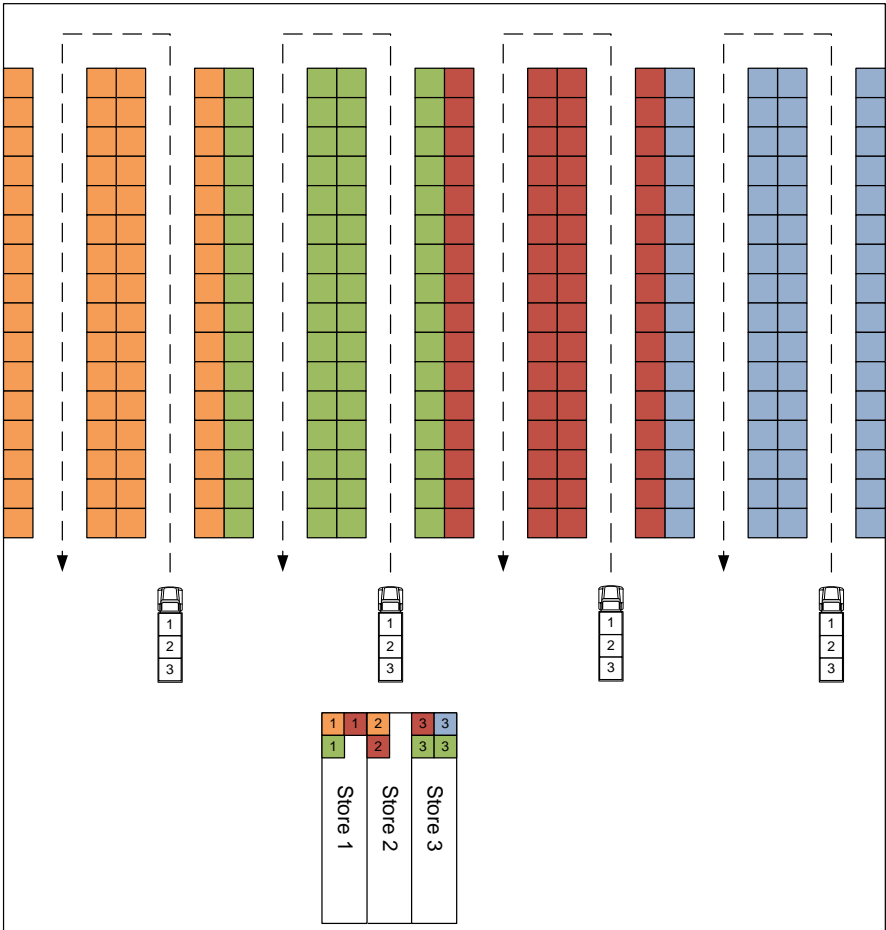


Figure 21 Simplified representation of warehouse (RDC) with family grouping layout and picking method



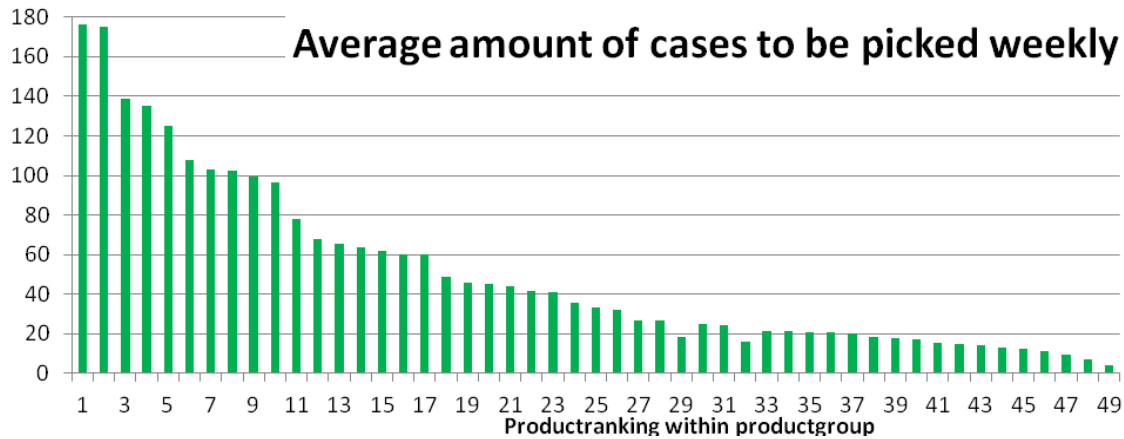


Figure 22 Average aggregated case demand per week for one product family.

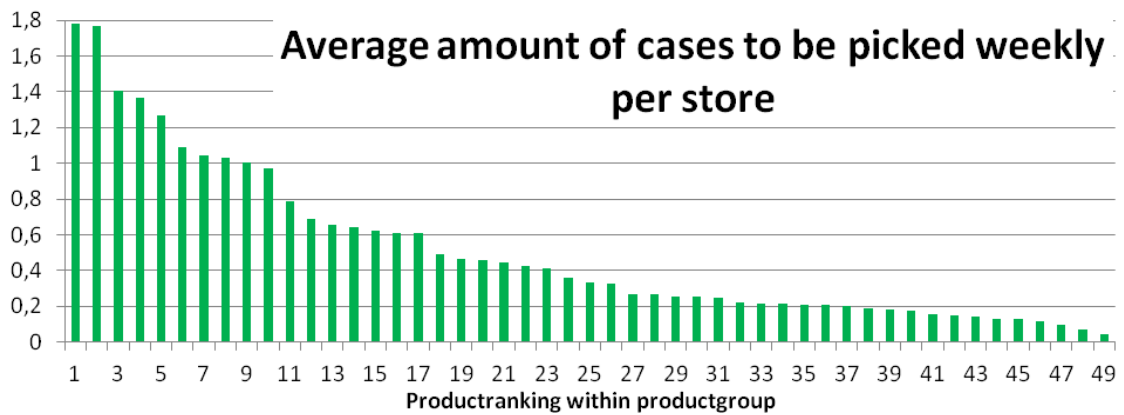


Figure 23 Average case demand per week for one product family per store

#### 4.3.4. Conclusion slow moving items at Distribution Center level

The results of the analysis at the store level can be summarized in the following sub conclusions:

- The ordering process at the DC is not influenced by presentation quantities given that they are not exposed to customer demand. For this reason the reorder point can be set mainly on demand characteristics.
- The analysis showed that many products could be delivered less frequent than the offered frequency by the current system. However this would require a deviation from the current DC layout which is only based on the family group characteristics.
- The average case pack demand showed that there is a lot of spread within a product family, however the picking and delivering schedule is only based on product family characteristics.

#### 4.4. Costs in the supply chain

Continuing on the previous sections this section contains an analysis of the relevant cost aspects of the supply chain of Sligro Food Group. This cost analysis is done to capture the total operational logistical cost from the distribution center to the customer. As mentioned before the goods of interest are the dry grocery products. We again follow the subsystems of the retail system approach used by Kuhn & Sternbeck (2013); distribution center, transportation and store. We first look at the aspects that are

present at the store level, the first subsystem. Followed by the aspects that are present at the distribution center level, the second subsystem.

The operational logistical cost in the supply chain; from the pick location in the distribution centers to the shelves in the stores, which are influenced by the two possible redesign solutions consist of the following aspects: (1) holding cost in store, (2) Store handling cost, (4) backroom cost, (3) lost sale cost, (5) holding cost in distribution center, (6) picking cost in distribution center, (7) traveling cost in distribution center and (8) added handling/transport cost at distribution center.

#### 4.4.1. Costs at the store level

The relevant costs at the store level are the holding costs, store handling costs, backroom costs and lost sale costs. Other costs that are made at the store level are excluded from this research, given that they are not influenced by the redesign direction. This holds for depreciation costs of the building, energy costs, labor cost at the checkouts, etc.

##### 4.4.1.1. Inventory holding costs

The expected annual inventory holding cost is calculated by multiplying the inventory carrying cost percentage times the value of the corresponding product, this follows the notation used by Eroglu et al. (2013). The inventory carrying cost percentage is provided by the organization under research.

##### 4.4.1.2. Store handling costs

The store handling cost is represented by a cost per product order that has to be filled on the shelves. This is represented the average hourly pay of a store employee times the average time spent per order line. The organization under research could not provide this average time spent per order line, however the average time per case pack was available. To convert this into an average time spent per order line it is multiplied with the average number of case packs per order line. This resulted in an average time spent per order line in seconds. In combination with the hourly pay this results in a store handling cost per order line in euro. We followed the findings of Van Zelst et al. (2009), which showed that the store handling time is dependent on the number of order lines. The figure below shows the distribution of time of the stacking process (Van Zelst, et al., 2009).

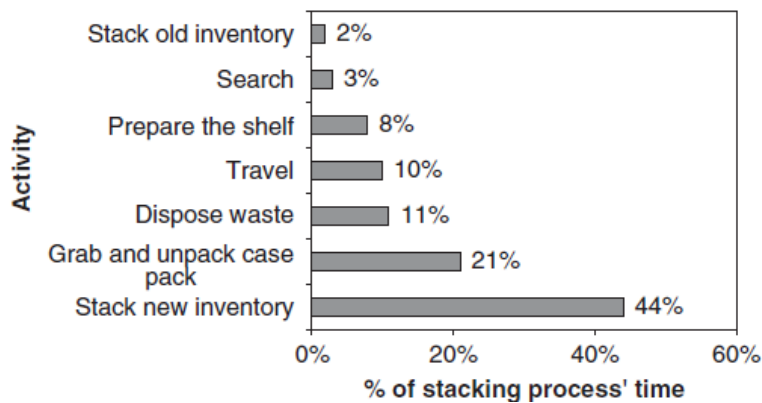


Figure 24 Distribution of time of the stacking process (Van Zelst, et al., 2009)

#### 4.4.1.3. Backroom costs

As mentioned before the backroom effect is a consequence of misalignment of case pack size, shelf space and reorder point. This backroom effects is expressed in a cost by adding a cost for each item that does not fit on the shelf at the time of replenishment and has to be returned to backroom for a later replenishment. This follows the method used by Eroglu, et al. (2013). They have shown that ignoring the backroom effect can lead to considerably higher operational costs. Due to that the overflow can have effects on labor requirements, shelf stock outs, and inventory record inaccuracy costs.

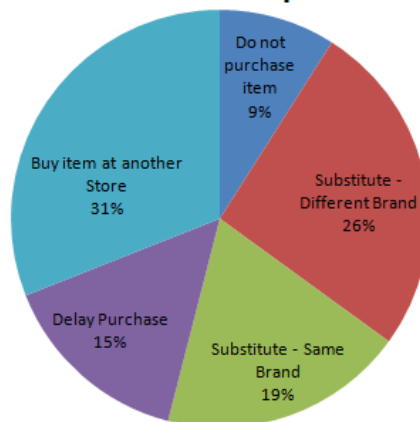
This cost is based on the idle replenishment process, which represents the replenishment of items which have backroom inventory. This idle replenishment takes place before the regular replenishment is performed. However the backroom inventory has to be moved to the corresponding shelf to see if this inventory can be stacked on the shelf. If this inventory does not fit on the shelf it is returned to the backroom. This idle replenishment and storage in the backroom is very inconvenient and disorderly, which in turn makes it a costly process. Based on the norm times for filling backroom inventory of the organization under research, this is set at a cost in euro per unit.

#### 4.4.1.4. Lost sales costs

Given that a possible change in the review period and lead time results in different service levels, the expected lost sales are incorporated in the store costs. Due to that the lost sale cost is not available at the organization under research it is based on the ratio of the target fill rate and the inventory holding cost. Given that EMTÉ is positioned in the Dutch retail landscape as service supermarkets, the target fill rate is 98%, which is in accordance to other service supermarkets in the Dutch retail landscape. In combination with the inventory holding cost this results in a lost sales cost per lost sale, to represent all possible effects of a lost sale in a service supermarket.

To show the possible effects of a lost sale in a service supermarket, a reference is made to the work of Corsten and Gruen (2003). They have looked at a worldwide study of more than 71,000 consumers that was conducted in a series of 29 studies across 20 countries across a variety of categories. They found five primary responses to an shelf out-of-stocks, which are displayed in Figure 25.

**Worldwide consumer response to out of stock**



**Figure 25 Worldwide consumer response to out of stock (Corsten and Gruen (2013))**

#### **4.4.2. Costs at the Distribution center level**

The relevant costs at the distribution center level are the holding costs and handling cost. Due to that we want to see the influence on the handling costs, we split this aspect in picking costs and travelling costs. One possible redesign requires the allocation of slow moving items to one centralized location instead of the current two decentralized locations. For this reason an extra aspect is incorporated to capture the possible added cost for extra handling and transport. Other costs that are made at the distribution center level are excluded from this research, given that they are not influenced by the redesign direction. This holds for depreciation costs of the building, energy costs, replenishment etc.

##### **4.4.2.1. Holding costs**

The expected annual inventory holding cost is calculated by multiplying the inventory carrying cost percentage times the value of the corresponding product, this follows the notation used at the store holding costs. We apply the same inventory carrying cost percentage, as at the store level.

##### **4.4.2.2. Picking costs**

Due that we model the traveling in the DC separate from the picking, the time needed to pick a product in the DC is dependent on the number of order lines. The picking cost is determined by the amount of time allocated to pick an order line of a product, translated into a cost by multiplying it with the salary of a picker. The picking time is based on data provided by the organization under research in seconds per order line in the dry groceries zone of the DC. The hourly cost of a picker at the distribution center level is also provided. This salary is provided by the organization under research and validated by a DC site manager. This results in a picking cost of euro per order line.

##### **4.4.2.3. Travelling costs**

The second part of the dc handling costs is represented by the travelling cost. This travelling cost is represented by the time spent walking multiplied by the hourly cost of a picker. To calculate the time spent walking, the allocated length per SKU is required. Due to that this not available at the organization under research, we converted the allocate space, expressed in the size of pallet facing into a length. The length of a pallet is multiplied with the portion of the pallet facing that is allocated to the corresponding SKU. For example; a SKU has 1/12 of pallet facing allocated to it, this is then multiplied by the length of a pallet (1,2 meter) to get the allocated length which in this case is 0,1 meter. This calculation is based on the data of one regional distribution center provided by the organization under research.

To express the amount of meters in a time measure, the walking speed is required. Based on order picking history and the allocated length, this is determined in meter per second. Next to the walking speed, the frequency that the aisles are visited per week is required. This is expressed in the ordering moments, within the organization under research these are currently set on product family, which corresponds with the current layout in the DC. The ordering moments are multiplied by the allocated length to get the travelled meters per SKU per week.

To get insight in the handling concerning the picking process, data is analyzed on the time spent by the order pickers. As mentioned before the orders are picked in a batch of combined three rolling containers. The average time distribution spent on a batch picked in the dry grocery area is presented in Figure 26. If we compare this with the typical distribution of an order picker's time by Tompkins et al.

(2003) shown in Figure 27, the ratio between picking and traveling time is smaller than the ratio found by Tompkins et al. This difference can be explained by the implementation of order batching; i.e. travelling through the DC with multiple rolling containers at the same time, which reduces the travelling time in relation to picking time.

### Average time distribution of picked batch

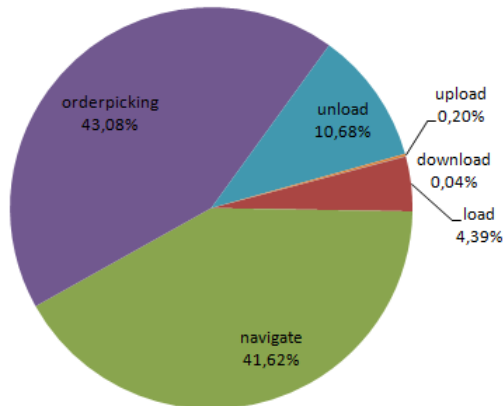


Figure 26 Average time distribution of picked batch

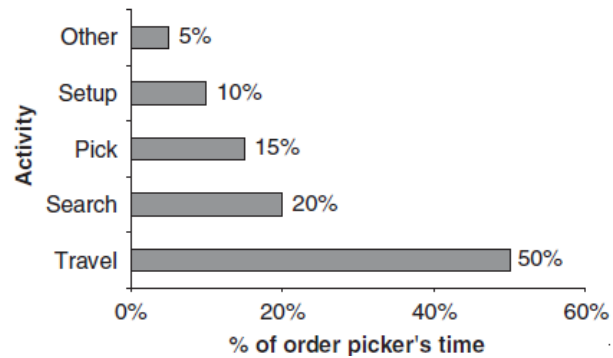


Figure 27 Typical distribution of an order picker's time (Tompkins, et al., 2003)

#### 4.4.2.4. Extra handling/transport cost

One possible redesign requires the allocation of slow moving items to one centralized location instead of current two decentralized locations, for this reason an extra aspect is incorporated to capture the possible added cost for extra handling and transport. This extra aspect consists of loading at the centralized location, transport to the decentralized locations and unloading at the decentralized locations. To express this as a cost, we used the cost to transport a full truck between the current regional distribution centers provided by the organization under research. If we take into account that the capacity of a truck is 54 containers and an average of 40 case packs are stacked on a container, this resulted in a cost per case pack for a full truck. However if the truck is not full the truck still needs to travel to the regional distribution centers, which would result in higher cost per case pack and therefore it is not expressed per order line.

## 4.5. Summary

This summary marks the end of the analysis phase and is based on the previous sections. Which consists of the problem definition, problem analysis and the cost in the supply chain. In which the supply chain is analyzed, followed by the characteristics concerning the slow moving items and ending with the relevant operational logistical costs. The next phase concerns the modeling phase for which the most important findings are listed:

- The supply chain considered consists out of two regional distribution centers and 100 stores.
- The products considered are dry groceries stored at both regional distribution centers.

- Currently the stores order using the ABS system which applies a (R,s,nQ) periodic review policy. This system uses the sales forecast, minimum - and maximum inventory as input settings for determining the reorder level.
- The sales forecast (sales expectation) used in this policy is based on the average demand data of the last 6 weeks applied to the review period, lead time and safety days. The variance of the demand is not taken into account in this calculation.
- The minimum inventory (Min), results in high service levels (fill rate) for a portion of the slow moving items that exceed the target fill rate.
- The order generating by the ABS, the DC layout and corresponding review period is determined on product group level.
- The operational logistical cost are; holding cost at both store and distribution center, store handling cost, backroom cost, lost sale cost, picking cost and traveling cost in distribution center and added handling/transport cost at distribution center.

#### **4.6. Redesign direction**

In consultation with the company under research, based on the initial problem definition, the above stated information and the results of the problem analysis done over the two subsystems of the retail system the redesign direction is chosen. This is the differentiation within the supply chain between slow- and fast movers on basis of product characteristics. This requires a separation in the current flow of goods from the DC to the stores.

This encompasses modeling the effects of a separation between slow and fast movers at the distribution center level on the relevant operational logistical costs. This is first expressed in a theoretical model which is tested for different replenishment policies over varying demand rates. After which two possible redesign solutions are designed and modeled for the separated slow movers to match their product characteristics. Clear metrics are tested against the operational logistical costs by which products can be classified either as a slow- or as a fast mover, for the purpose of differentiation in the supply chain.

The development of the model will be the start of the modeling phase, which will be described in the next chapter.

## 5. Modeling phase

We first set up a theoretical model which calculates the effects of possible changes that are made in the redesign solutions on a supply chain. This section follows a step by step approach, in which we continue to add new aspects to the model to incorporate the full effect on a supply chain. Thereafter the research methodology and input parameters are stated, which are used to apply the model to the redesign solutions.

### 5.1. Scoping and Modeling Assumptions

Before the model is developed to simulate the effects of possible changes within the supply chain, the scope of the model is defined. To model the scenarios of the current and the redesigned supply chain the scope is narrowed to the aspects that are influenced by a possible redesign solution. The products considered are those which are denoted as dry groceries and are on the shopping list of the customer throughout the whole year and are currently stored in the RDC's. Therefore, promotions and seasonal products are out of scope.

We excluded the holding cost at the distribution center from the calculations due to that the changes in inventory between the redesigns are very small. One of the redesigns involves the allocation to a centralized storage in comparison with the current decentralized storage. The square root principle (Maister, 1976) states that the inventory held in a larger number of locations ( $n_2$ ) relative to a smaller number of locations ( $n_1$ ) serving the same overall demand is equal to the square root of  $n_2/n_1$ . This would decrease the safety stock held at one location instead of two, by the square root of two. This would mean a small decrease in the safety stock which in turn is only small part of the inventory on hand.

$$SS_{n_1} = \frac{SS_{n_2}}{\sqrt{2}}$$

Transportation from DC to store is excluded from the cost aspects given that this cost aspect is assumed to be independent of the redesign direction. We also make this assumption for the costs for shelf space in both the supermarket and distribution center, since we look at fixed assortment in existing stores (Broekmeulen, et al., 2006).

#### 5.1.1. Modeling assumptions

The assumptions concerned with the modeling of the effects on the supply chain are enumerated in this section:

- The regional distribution centers can be seen as equal in terms of size, picking methods, allocated space and assortment.
- Products classified as slow movers can be ordered separately in the ordering system.
- The sales week pattern is not incorporated in the model due to that the project is aimed at the slow moving items.

## 5.2. Model description

To evaluate the relevant aspects of the supply chain we use a step by step approach for building the model. We start the modeling at the store level, followed by the relevant aspects at the distribution center. First the theoretical model is described which is later on applied to the specific settings of the organization under research. In theoretical model we test the effects of an increase in review period and lead time.

### 5.2.1. DoBr tool

To calculate the output parameters that serve as cost drivers in the model, we made use of the DoBr Tool. The DoBr Tool is an Excel file with approximations coded in VBA for the  $(R,s,nQ)$  policy. In this tool the demand is assumed to be discrete. The DoBr tool is developed by Broekmeulen (2013).

### 5.2.2. Settings theoretical model

The outcome of theoretical model is displayed for different demand rates, to show the influence of the demand rate on each aspect included. For the theoretical model the following settings are used:

- The demand used follows a Poisson distribution, which is varied between a demand rate of 0.05 and 2 units per day.
- The reorder level(s) used is the optimal reorder level, which is approximated via the DoBr Tool based on the target fill rate of 95%.
- The value of the product considered is set at 1 euro.
- The case pack size is set at 6 units.
- The shelf space is set at 8 units.
- The allocated length is 0,2 meters
- The base set assumes that each product can be ordered daily (review period is one day).
- If a product group has an ordering moment the corresponding product group aisle in the distribution center is visited with one rolling container per store.

### 5.2.3. Store operations

The first aspect introduced is the inventory level, this is expressed as the expected inventory on hand. The expected inventory on hand is calculated using the DoBr tool, this uses approximation based on the formula presented below. Which requires the lead time, review period, average demand, standard deviation, reorder level and case pack size. In which  $\Delta$  is defined as the difference between the inventory at the end of an arbitrary review period minus  $s-1$ , for which we know that  $\Delta \approx U[1, \dots, Q]$ .

$$E[I_{i,j}^{OH}] = \frac{1}{2} \left( E \left[ (s - 1 + \Delta - X(L))^+ \right] + E \left[ (s - 1 + \Delta - X(L + R))^+ \right] \right)$$

Given that the reorder level plays a prominent role on the inventory level, Figure 28 shows the effects on the optimal reorder level, in relation to the target fill rate, of increasing the review period and of increasing the lead time by one day. From this it can be concluded that an increase in the lead time has bigger influence on the optimal reorder level than an increase in the review period. The effects on the expected inventory on hand are displayed in Figure 29, from this it can be seen that as expected both an increase in review period as well as an increase in lead time result in a higher inventory on hand.



However for low demand rates the difference are small and the inventory levels interchanges between the three policies. From the added linear trend lines it can be concluded that the base settings result in the lowest inventory. The differences between the increase in review period and increase in lead time are small.

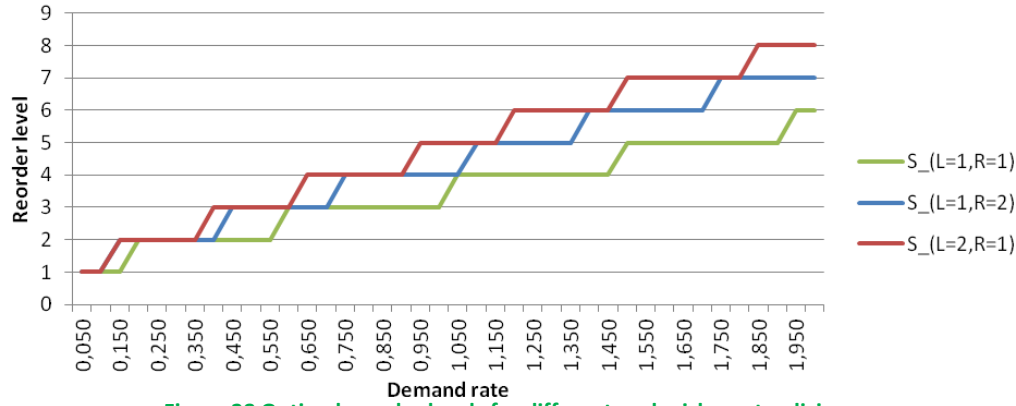


Figure 28 Optimal reorder levels for different replenishment policies

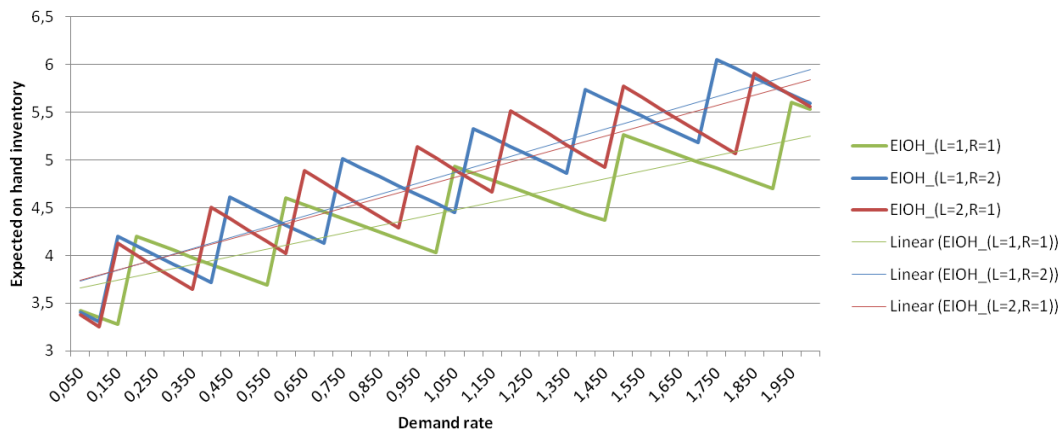


Figure 29 Expected on hand inventory for different replenishment policies

Inventory is held to meet possible demand, without a penalty for not meeting this demand no inventory would be held. This leads to the next aspect that is added to the model; the lost sales, i.e. the expected part of the demand that is not met from the shelves. To determine the expected lost sales the achieved fill rate is needed.

The achieved fill rate ( $\beta^{LS2}$ ) is calculated using the DoBr Tool, for this calculation it requires the review period, lead time, average demand, standard deviation, reorder level and case pack size. In which  $nOO$  represents the measure to take into account the number of outstanding orders (Van Donselaar & Broekmeulen, 2013). The part of the demand that is not met from the shelves is then found by deducting the fill rate from 100%. This fraction is then multiplied by the demand to calculate the expected lost sales over this demand. The expected lost sales are showed for the three replenishment policies in Figure 30. Due that the optimal reorder level is based on the target fill rate, the expected lost sales are low, therefore the increase in review period and lead time are already captured by an increase in the reorder level computation. However due to that the reorder level is already computed to achieve the target fill rate, the costs for lost sales are not incorporated in the theoretical model.

$$E[LS] = (1 - \beta^{LS2}) * \mu$$

$$\beta^{LS2} = \begin{cases} \frac{(\beta^{LS1} + 0.062 * nOO - 0.128)}{0.062 * nOO + 0.87} & nOO < 5 \\ \frac{(\beta^{BO} - 1.0172 - 1.3218 * (C_{L+R})^{-0.552})}{1.3218 * (C_{L+R})^{-0.552}} & nOO \geq 5 \end{cases}$$

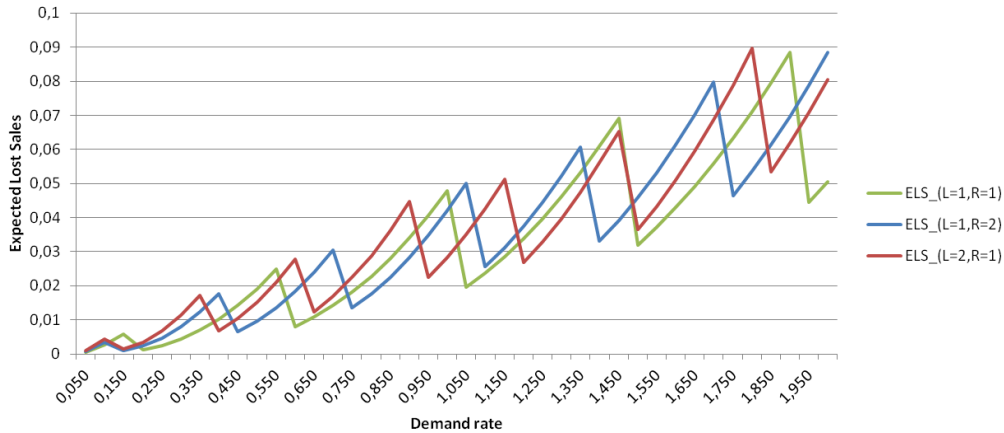


Figure 30 Expected lost sales for different replenishment policies

Next to the inventory that is on the shelves there is also a part of the inventory that is kept in the backroom. This is due to the fact that the ordered amount did not fit on the shelves at the regular replenishment moment. This so-called backroom inventory is the third aspect that is added to the model, which decreases the willingness to increase the inventory level at the replenishment moment beyond the capacity of the shelf. The expected overflow at the replenishment moment is approximated in the same manner by the DoBr tool as the expected inventory on hand. This requires the lead time, average demand, standard deviation, reorder level, shelf space and case pack size. This aspect is also compared with the increase in lead time and increase in review period in Figure 31, which shows that an increase in lead time leads to higher expected backroom inventory. This can mainly be ascribed to the higher reorder levels compared to the other replenishment policies, which is already mentioned earlier in this section.

$$E[I^{BR}] = E[(s - 1 + \Delta - X(L) - V)^+]$$

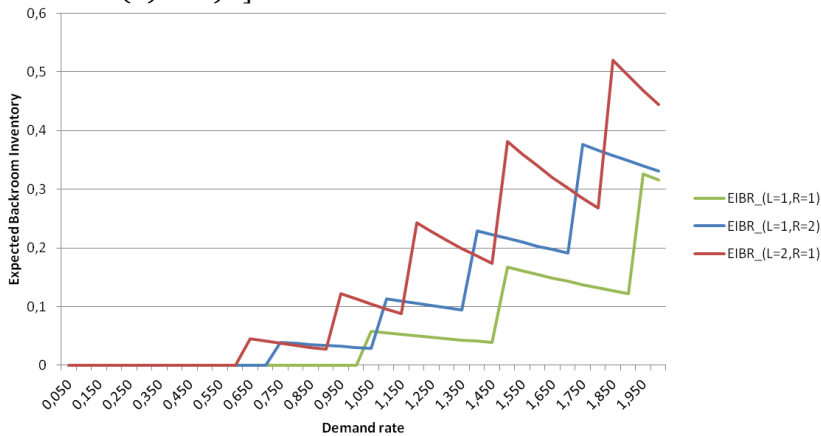


Figure 31 Expected backroom inventory for different replenishment policies

The fourth and last aspect that is added to the store operations part of the model is the handling concerning the regular replenishments. We follow the findings of Van Zelst (2009), which showed that the store handling time is dependent on the number of order lines. The expected order lines per order moment is approximated using the DoBr tool, which uses the following input; review period, average demand, standard deviation and case pack size. Which depends on the probability that the inventory position minus the demand during the review period is below the reorder level (Broekmeulen, 2013). The expected order lines are only influenced by the increase in review period, when the demand rate increases the ratio between the expected order lines of the base set and the review period increase gets smaller. Figure 32 shows that the expected order lines per day graphs overlap, however for higher demand rates the expected order lines per day drop for the scenario with the increase in review period. This is as expected given that at higher demand rates you need to order more often, but due to the longer review period this is postponed possibly resulting in an increase in order size per order line.

$$E[OL] = P[s - 1 + \Delta - X(R) \leq s - 1] = P[X(R) \geq \Delta]$$

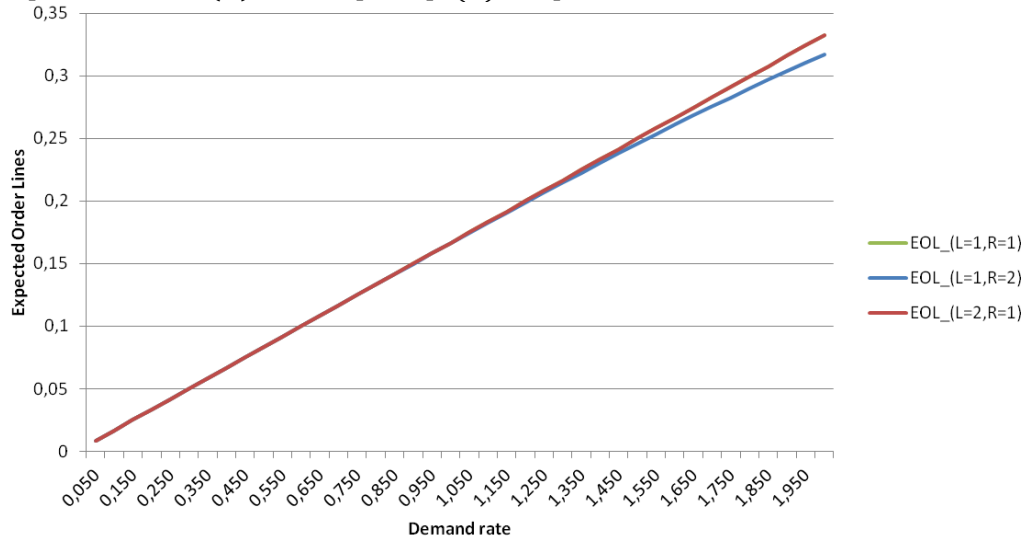


Figure 32 Expected order lines for different replenishment policies

#### 5.2.4. Distribution center operations

Following on the aspects added at the store level, the relevant aspects at the distribution center are added. The first aspect concerns one of the handling activities at the DC; the travelling. As mentioned before each product has an allocated length  $w$  expressed in meters [m] and a review period  $R$  expressed in days. A review period of one day at the store level results in seven ordering moments  $OM$  a week, which in turn leads to visiting each aisle in the DC each day. The aisles are the sum of the lengths  $L$  allocated to each product in the corresponding product group, which is visualized in Figure 33. The distribution center is modeled in such a way that it is assumed that each product group represents one aisle in the DC. This is done to ensure the traveling does not result in a deterministic case in which adding one product could result in adding an extra aisle. We assume that orders are only collected in the aisle at the corresponding order moments and that we have to visit all locations of the  $N$  products that are assigned to the corresponding aisle. With a walking speed  $v$  [m/s], it will take an order picker  $L/v$  seconds to visit all locations in the corresponding aisle. With a cost parameter  $c$  [€/s], the total cost per order moment is  $cL/v$ . The total travelling cost per day is  $cL/Rv$ , regardless of the specific order lines.

The clear saving of an increase in review period is that it decreases the amount of order moments per week which in turn results in a decrease in the number of times this distance in the corresponding aisle travelled. The incremental travelling cost of adding an individual product to the aisle is therefore  $\frac{cw}{Rv}$ . With  $w = 0.36, v = 0.36, R = 1$  and  $c = 0,005$ , the incremental cost per day is just 0,005 [€/day]. This shows that the effect of the assortment size on travelling cost is small in comparison with the other cost aspects. This possible saving therefore only plays a role for the products with a low demand rate.

When a order picker arrives at the location of the SKU the ordered amount of case packs has to be picked. This is the second aspect of the handling at the distribution center that is added to the model. Just as the modeled handling at the store the picking is also dependent on the number of order lines per SKU. The calculation of expected number of order lines is already explained in the previous section.

The last aspect that is added to the model is the extra handling and transport that occurs at one of the redesigns due to the allocation to a centralized storage in comparison with the current decentralized storage. This is dependent on the amount of trucks that are loaded at the centralized storage.

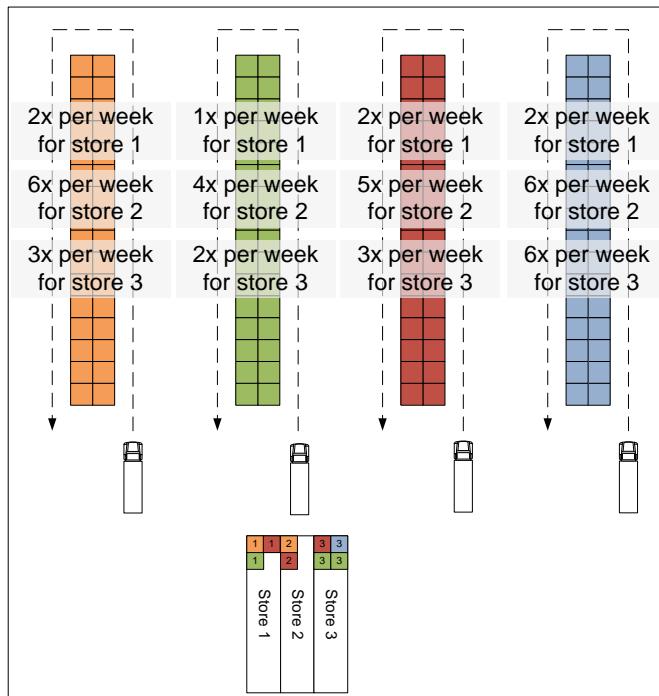


Figure 33 Theoretical representation of distance travelled in distribution center

### 5.2.5. Cost application

First the costs of the store operations part are presented for the different demand rates, for this we apply the costs parameters as described earlier. The store operations costs are displayed for the base set, the increase in review period and the increase in lead time for different demand rates. Appendix H provides a more detailed distribution of the store operational costs. This shows that the store costs are mainly driven by the handling costs, the patterns of the store cost follow the pattern of expected order lines on which the handling is dependent. Next to that it is driven by the handling cost the backroom inventory plays a role for the higher demand rates. Especially for the scenario where the lead

time is increased, this results in a higher reorder level, which in return results in higher expected backroom inventory. This effect is already shown in Figure 31. To compare the costs for the different demand rates, the store costs are shown per unit demand is presented in Figure 34, in which the costs are divided by their corresponding demand rate. This turns out to be a better measure to compare the cost over the different demand rates. A more in depth distribution of the store operational costs per unit demand is also provided in Appendix H.

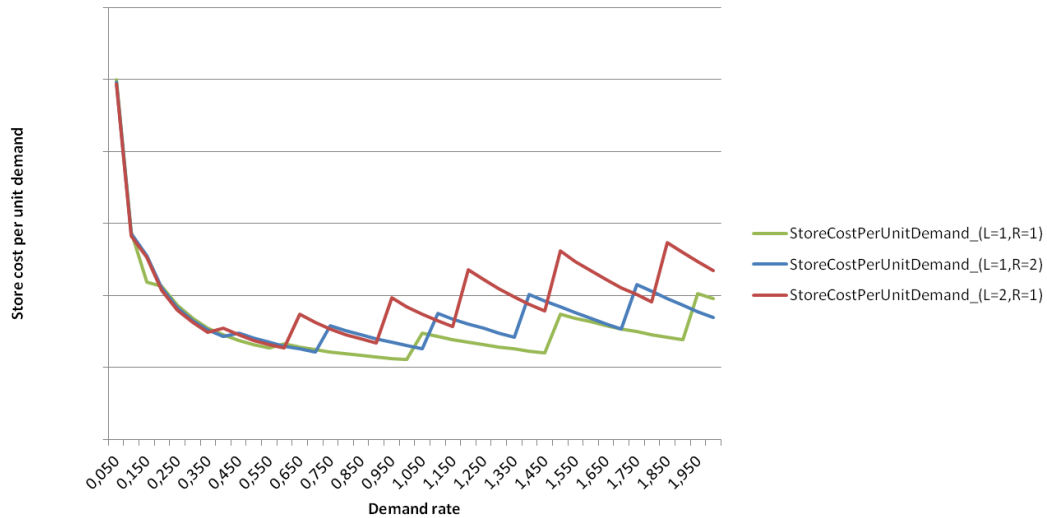


Figure 34 Store costs per unit demand for different replenishment policies

The operational costs at the distribution center are added next, the scenario with an increase in lead time represents the centralized allocation. The extra handling/transport occurs at this replenishment policy, to model this as a cost per SKU it is assumed in the theoretical model that there are only full truck loads. The distribution center costs shows that the added handling/transport is the main cost driver for that scenario. The other two scenarios seem to follow the same pattern, however if they are compared on the DC cost per unit demand in Figure 35, the increase in review period clearly outperforms the base set on the lower demand rates. This difference is caused by the difference in the travelling cost between the two scenarios. Again a more in depth distribution of the distribution center operational costs per unit demand is provided in Appendix H.

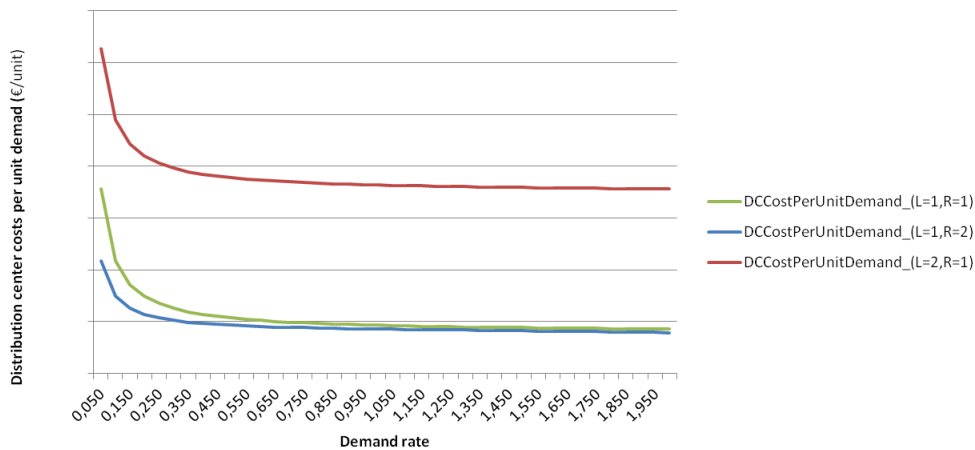


Figure 35 DC cost per unit demand for different replenishment policies

To see the full effect of the increase in review period and lead time the costs at both subsystems are combined into the total costs per unit demand, which are displayed in Figure 36. This shows that the extra cost added at the distribution center level also plays a dominant role in the total cost comparison.

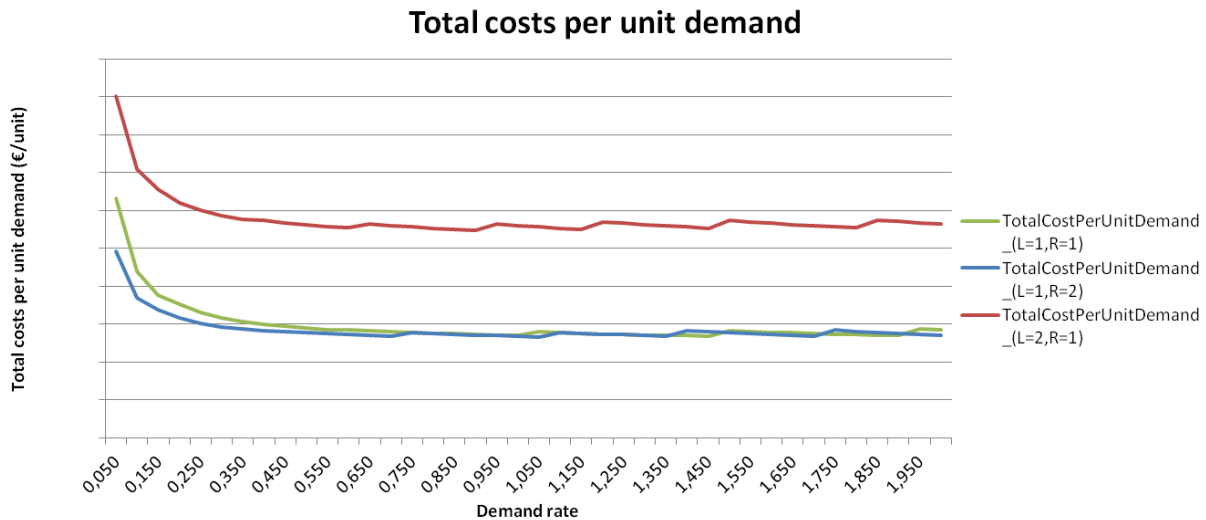


Figure 36 Total cost per unit demand for different replenishment policies

The following observations can be made from the theoretical model on basis of the three scenarios:

- An increase in lead time has a greater impact on the optimal reorder level than an increase in the review period.
- The lowest expected inventory on hand fluctuates between the three scenarios when increasing the demand rate. For higher demand rates the base set outperforms the others.
- Due to that the target fill rate is already incorporated in the determination of the optimal reorder level the lost sales cost are not incorporated in the theoretical model.
- The increase in lead time shows the highest levels of backroom inventory given a fixed shelf space, followed by the increase in review period. Which can be explained by the increase in reorder level due to the increase in safety stock for the lead time increase. The increase in review period results in a lower increase in reorder level which in turn results lower levels of backroom inventory compared to lead time increase.
- The store handling is the biggest cost at the store level for the different demand rates.
- The picking cost mainly determines the pattern of the cost graphs at the distribution center.
- The extra handling/transport cost only plays a role in the costs of the scenario where the lead time is increased. Due to this extra cost, the lead time increase scenario performs worst than the other two at the distribution center level.
- The decrease in travelling cost at the scenario of the review period increase, is mainly present at the lower demand rates.
- The increase in review period seems to outperform the base set for the lower demand rates in terms of total costs per unit demand. For the higher demand rates the cost lines coincide.

### 5.2.6. Sensitivity analysis

To assess the results and the reliability of the observations made on the theoretical model, a sensitivity analysis is performed. We evaluated the total cost on different values for key cost parameters, to test the sensitivity of the theoretical model to these parameters. The parameters are evaluated by halving and doubling them. The key parameters which will be tested in the sensitivity analysis are:

- $ICC_{st}$  = Inventory carrying cost store(%)
- $\beta$  = target fill rate
- $k$  = BackroomCost
- $y$  = Store handling cost
- $CD$  = Added transport/handling Cost
- $Q$  = Case pack size
- $W$  = Walking speed
- $V$  = Shelf space (in ratio to the case pack size)

The graphical results of this sensitivity analysis on the total cost is displayed in Appendix I. The changes in inventory carrying cost percentage does not seem to have a influence on the pattern total costs graphs. As mentioned before the target fill rate is in used in the computation of the optimal reorder level. The higher the fill rate the higher the reorder levels to meet the targeted service. This increase in reorder levels results in higher inventory and backroom inventory costs. The changes in backroom costs do not have influence on the low demand rates due to that there is no backroom inventory occurring. At the higher demand rates where in this theoretical model the backroom inventory occurs the pattern of the backroom cost amplifies at a higher backroom inventory cost. The variation in store handling costs does not show a pattern change, it only changes the height of the total cost. The same can be concluded for a change in the added transport/handling cost. The effect of the case pack size is evaluated by setting it at 4 and 12 items per case pack, while maintaining the shelf space allocation ratio of 1,2 times the case pack size. The decrease in case pack size resulted in higher backroom inventory cost due that the allocated shelf space decreased accordingly. Doubling the case pack size results in less backroom inventory across the demand rates again due to that the shelf space increases accordingly. For case pack sizes of six or more units, the 0.2 in the ratio starts to play a more dominant role. Due to that it is then rounded up to 2 or more ( $6 \cdot 0.2 = 1,2 \approx 2$ ). When the walking speed is halved, the scenario with an increase in review period further outperforms the other two, due to that the less frequent travelling becomes more beneficial at a higher walking cost. The opposite happened when the walking speed is doubled, namely the saving becomes smaller. The shelf space is varied by applying different values for the shelf space ratio, the ratio between the shelf space and case pack size. When the shelf space ratio is set to one, it corresponds to a shelf space equal to the case pack size. This resulted in a dominant role for the backroom inventory cost, given that every order has the size of the shelf space. An increase in the shelf space ratio to 1,4 resulted in a more smoothed cost graph. Due to that the backroom inventory effect becomes less present due to the increased allocated shelf space.

### 5.2.7. Applicability of the model

The model enables one to compare the effects of different replenishment policies on the relevant cost aspects, in terms of review period and lead time. It can serve as a decision tool to decide to which of the

compared replenishment policies a product should be allocated. Which is based on the resulting total relevant supply chain costs of each policy for the corresponding product.

### 5.3. Research methodology

To calculate the relevant cost aspects for the products in the supply chain, it is chosen to use MS Excel supported by Visual Basic. The model is not run for all 100 stores, the reason for this and on which stores the model is run is described in the first section. Followed by the settings of the applied model.

#### 5.3.1. Store selection

A selection of fifteen stores is made to execute the logistic process modeling, the output of these stores is extrapolated to simulate the output of the full range of stores. The stores are chosen in such a way that they are a representative reflection of the supermarkets in the range of stores. The reasons why a subset of the entire range is taken for modeling purposes are among others, the difficulty with gathering data for the full assortment over all stores. The description of the selected stores are given in Table 3, next to the size of the store, the weekly turnover was also taken into consideration during the selection.

Table 3 Descriptives of selected stores (S=Small, M=Medium, L=Large)

Store	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Store size	XS	S	S	S	XS	M	M	M	M	M	L	XL	L	L	XL
Weekly turnover	S	S	S	S	S	M	M	M	M	M	L	L	L	L	L

#### 5.3.2. Settings applied model

In this section the settings which are used in the applied model are described. In comparison with the theoretical model some settings are adjusted to better match the supply chain of Sligro Food Group. The following settings are adjusted, which correspond with the current supply chain:

- The reorder level used in the model is computed by approximating the automatic store ordering system calculations, first the sales expectancy is calculated on basis of the average demand, review period, lead time and the safety days allocated to the corresponding product. Based on the sales expectancy, the reorder level is determined on the min and max settings extracted from the automatic ordering system.

$$r_{i,j} = \begin{cases} Min & \text{if } SE \leq Min \\ SE & \text{if } Min < SE < Max \\ Max & \text{if } SE \geq Max \end{cases}$$

- When a product can be ordered by the store it is passed by in the order picking process, i.e. each time a product has an ordering moment for a store it's allocated length is travelled by the order picker in the distribution center.

### 5.4. Input parameters

To be able to calculate the costs stated in the model, the following data input is required:

- $\mu_{i,j}$  = Average demand of SKU  $i$  in store  $j$  (week)



- $\sigma_{i,j}$  = Standard deviation of demand of SKU  $i$  in store  $j$  (week)
- $Q_i$  = Case pack size of SKU  $i$
- $R_{i,j}$  = Review period of SKU  $i$  in store  $j$  (days)
- $L_{i,j}$  = Lead time of SKU  $i$  in store  $j$  (days)
- $c_i$  = Price of SKU  $i$
- $S_{i,j}$  = Shelfspace of SKU  $i$  in store  $j$  (Units)
- $L_i$  = Allocated length to SKU  $i$  in DC (meters)
- $OM_{i,j}$  = Ordering moments for SKU  $i$  in store  $j$
- $Min_{i,j}$  = min set in ABS
- $Max_{i,j}$  = max set in ABS
- $Safety\ days_{i,j}$  = safety days set in ABS

The average demand and standard deviation are based on the sales data available over the year 2012. To increase the reliability of the one year based estimate of the standard deviation, the standard deviation is approximated by the use of the power law. This involves applying regression on the sales data to predict the standard deviation on basis of the average demand. This power law regression is done for each product group, given that the products in these groups share the same characteristics. This regression provides the values  $c_1$  and  $c_2$  for each product group, which can then be inserted in combination with the average demand for each SKU-Store combination in the formula below to get the estimated standard deviation for each product in each store (Silver, et al., 1998).

$$\sigma_{i,j} = c_1 * \mu_{i,j}^{c_2}$$

The allocated space to a SKU in the DC is provided by the organization under research. This allocated space is converted into an allocated length per SKU, by multiplying the allocated portion of a pallet facing by the length of a pallet. Case pack size, price, minimal and maximal inventory levels, shelf space, safety days, review periods, lead times and ordering moments are extracted from the automatic store ordering system. Based on section 4.2.3 the maximum inventory is used as the shelf space parameter. The next chapter describes the model results of the application of the two redesign solutions on the basis of the model description, the redesign solutions and the input parameters.

## 6. Results & Discussion

This chapter describes the redesigns and the model results of the application of the redesign solutions on the assortment carried out by the organization under research. This application is done on basis of model description, the redesign solutions and the input parameters stated at the end of the previous chapter. The results of both redesigns is showed and explained in detail.

### 6.1. Reorder levels

First a comparison is made between the optimal reorder levels used in the theoretical model and the reorder levels generated by the automatic store ordering system.

As stated at the settings of the applied model, the reorder level is calculated on basis of the sales forecast, minimum and maximum inventory. The ABS generated reorder level is compared with the optimal reorder level, on basis of the delta reorder level is computed which represents the ABS reorder level minus the optimal reorder level. Figure 37 shows that for the low demand rates the ABS reorder level is higher than the optimal reorder level based on target fill rate of 95%, which can mainly be explained by the minimum inventory in the ABS, which is set on basis of the presentation quantity. Next to this the reorder level generated by the ABS does not differ between an increase in review period and an increase in lead time, given that it does not incorporate the standard deviation of demand during lead time in the computation of safety stock.

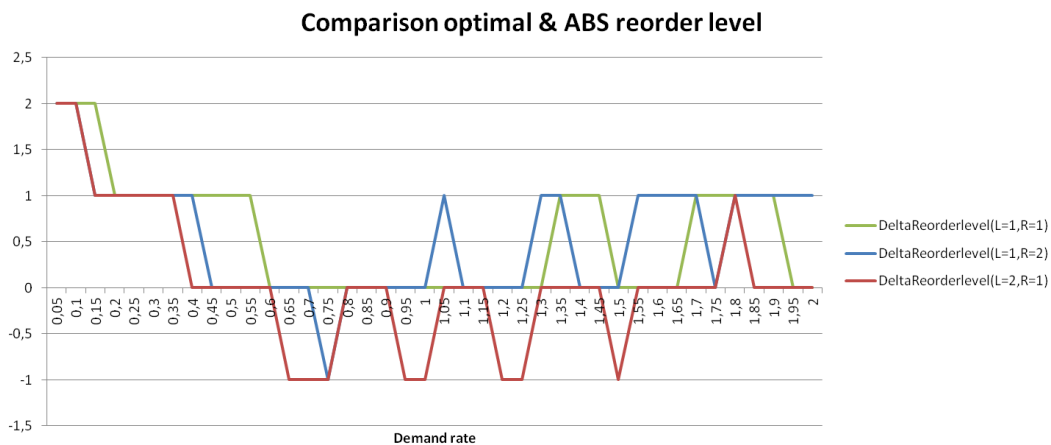
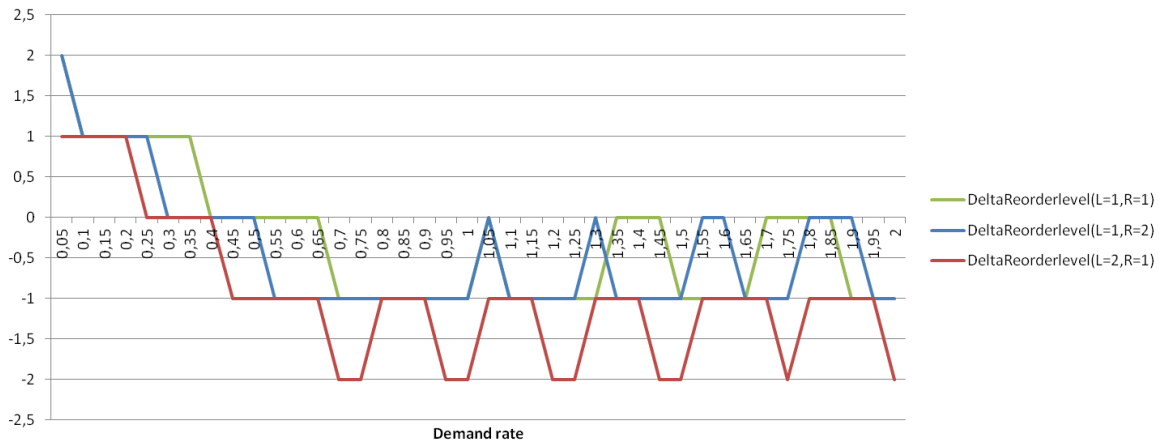


Figure 37 Comparison of Delta (ABS reorder level – optimal reorder level (95%)) for different replenishment policies.

Next the ABS reorder levels are compared with the optimal reorder levels based on the target fill rate of 98%. Again the delta is computed to make the comparison between the ABS and optimal reorder levels in Figure 38. This shows that the ABS generates reorder levels that are lower than the optimal reorder levels. Only for the low reorder levels the ABS generates higher reorder levels than the optimal reorder levels, again due to the minimum inventory norm. This implies that the ABS generated reorder levels are not always achieving the target service level, especially for the scenario of the increase in lead time. This is shown in Figure 39, where the resulting service levels of the ABS reorder levels are visualized. Due to that the ABS does not always generate the target service level the lost sales costs are taken into account. This however leads to cases were the lost sale costs far outweigh the other costs. For this reason both the results for the ABS generated reorder levels and the results for the optimal reorder

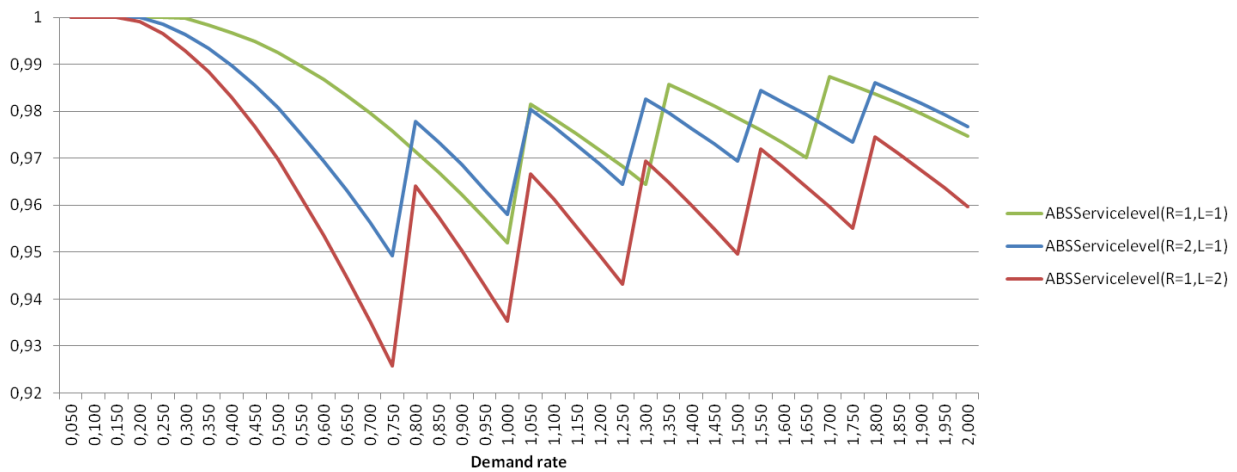
levels are displayed in the next sections. The lost sales costs are incorporated for the cases where the reorder levels do not achieve the target service level.

**Comparison optimal & ABS reorder level**



**Figure 38 Comparison of Delta (ABS reorder level – optimal reorder level (98%)) for different replenishment policies.**

**ABS servicelevels**



**Figure 39 Service levels for ABS reorder levels for different replenishment policies**

## 6.2. Redesign Solutions

The redesign direction formulated at the end of the problem analysis chapter is aimed at the differentiation between goods in the supply chain on the specific product characteristics. The purpose of this differentiation is to design a supply chain that matches the characteristics of the slow moving items, separated from the current supply chain for the fast moving items.

A differentiation between slow- and fast moving SKU's in the supply chain requires that there is differentiation within the replenishment, via different routings which are tailored to better match the characteristics of both classes. To fully profit from the benefits of such a differentiation, the slow- and fast movers also require separate locations at the distribution center level, to ensure that they do not interfere each other's operations. In consultation with the organization under research, we propose two possible network redesigns which are analyzed according to the described relevant operational logistical

aspects influenced by the corresponding redesign. We express both redesigns in the phenotypes of network structures categorized by Kuhn & Sternbeck (2013).

### 6.2.1. Separated central distribution center for Slow moving items (Redesign 1)

The first redesign solution is aimed at adding an extra distribution stage to the supply chain, this added central distribution center facilitates the storage of, operations needed for and distribution of the products classified as slow movers. Figure 40 shows the current and the redesigned supply chain translated into the network types of Kuhn & Sternbeck (2013). This shows that the current supply chain resembles the most with network type 2 and this redesign resembles the most with network type 4.

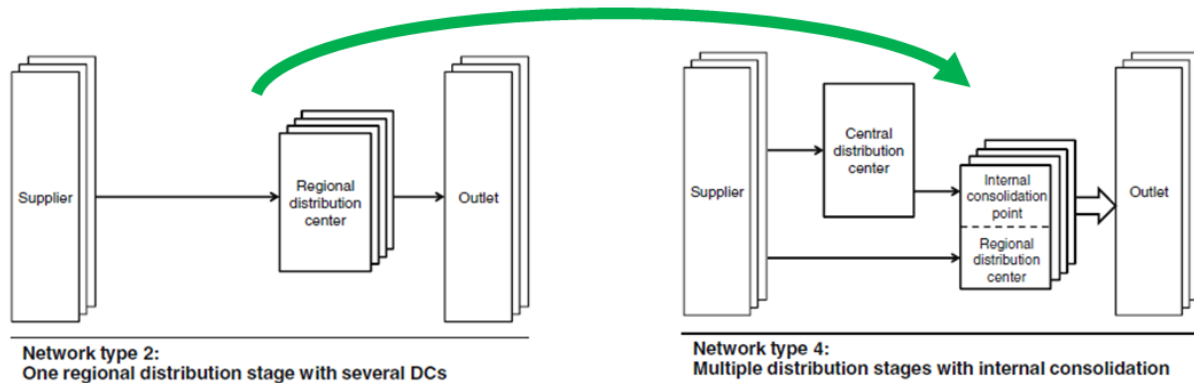


Figure 40 Current supply chain and redesign expressed in network types of Kuhn & Sternbeck (2013)

This redesigned network requires that there is allocation on product level, i.e. which product is classified as slow mover and located and replenished as such. This redesign is comprised of two separated routings, the first follows the settings of the current replenishment and allocation. The second, aimed at the slow movers, follows settings that better match the products classified as such. Given that the project is focused on the slow moving items, the settings for the fast moving items are not subjected to change. This encompasses the allocation, ordering- and replenishment policy. These aspects are adjusted for the slow moving items, which will be explained in more detail in the following paragraphs.

#### 6.2.1.1. Change in Allocation

In this redesign solution the storage of slow movers will be shifted from the current two regional locations to one central location. The adapted physical flow of both fast - and slow movers is shown in Figure 41.

#### 6.2.1.2. Change in Ordering - and Replenishment Policy

Next to the explained changes in allocation of slow movers, the ordering and replenishment policy is also subject to change. In this redesign solution the slow movers are ordered once a week, in accordance with an once a week replenishment. Due to that in this redesign solution the slow movers are stored centrally, when a product is ordered by a store they need to be picked and transported to the regional distribution centers. Where they are consolidated with the regional stored products which are picked for the same store. Given that orders are only picked during daytime, this cross docking lengthens the store replenishment lead time by an extra 24 hours on top of current store replenishment lead time for the RDC.

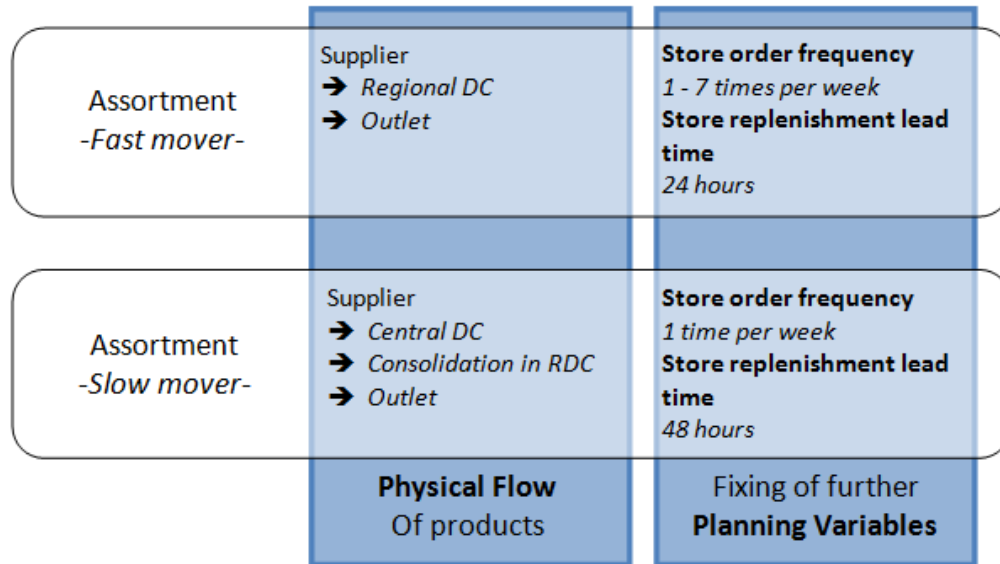


Figure 41 Differentiation of supply chain in first redesign solution.

### 6.2.2. Separation within the current distribution centers (Redesign 2)

The second redesign solution is aimed at separating one distribution stage in the current supply chain, this separation facilitates the storage of and operations needed for the products classified as slow movers. This redesign is showed in respect to the current supply chain in Figure 42, both translated into the network types of Kuhn & Sternbeck (2013). This shows that both resemble most with network type 2, maintaining one distribution stage but with an internal separation of products.

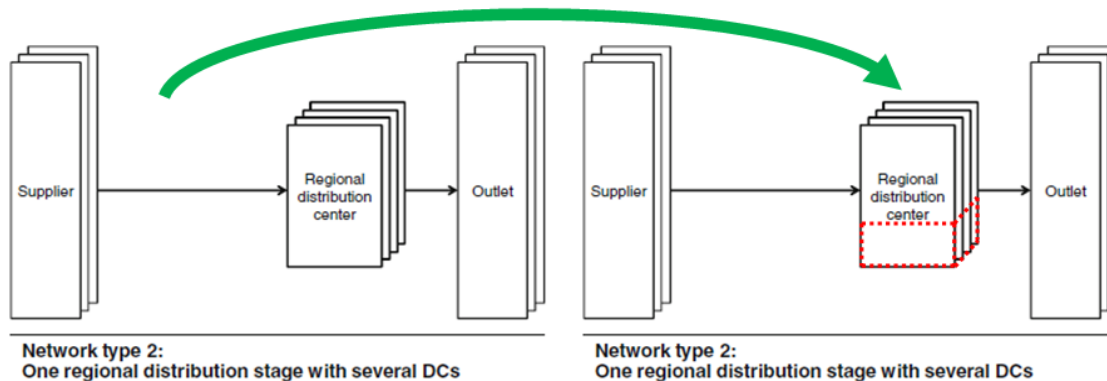


Figure 42 Current supply chain and second redesign expressed in network types of Kuhn & Sternbeck (2013)

This redesigned network again requires that there is allocation on product level, i.e. which product is classified as slow mover and located and replenished as such. This redesign is comprised of two separated internal routings, the first follows the settings of the current replenishment and allocation. The second, aimed at the slow movers, follows settings that better match the products classified as such. Again the aspects; allocation, ordering - and replenishment policy are adjusted for the slow moving items, which will be explained in more detail in the following paragraphs.

#### 6.2.2.1. Change in Allocation

In comparison with the first redesign this redesign keeps the storage of slow movers in the regional distribution centers. However there is a clear separation between the fast – and slow moving items, to

prevent that the operations of both interfere each other. The benefit of the allocation to the same distribution center will be explained in the next paragraph. The adapted physical flow of both fast - and slow movers is shown in Figure 43.

### 6.2.2.2. Change in Ordering – and replenishment policy

In this redesign solution the slow movers are ordered once a week, in accordance with an once a week replenishment. Given that both fast – and slow movers are stored at the same location no extra transport is needed as in the case of the first redesign. This has the apparent benefit that the store replenishment lead time stays at 24 hours in comparison with the double amount at the first redesign solution.

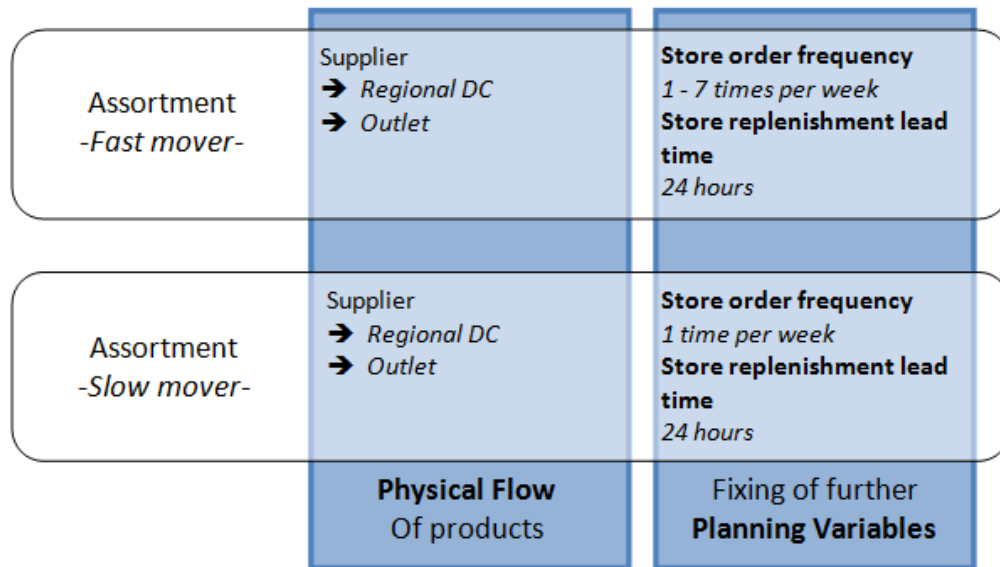


Figure 43 Differentiation of supply chain in second redesign solution.

## 6.3. Model solving

The model is applied to both redesign solutions, for both redesigns the allocation is determined on basis of the total costs of the corresponding SKU in the selected stores. As stated before this is done over a selection of fifteen stores, the sum of the total cost over these fifteen stores is used. Which is then compared between the current and redesigns to make a decision on the allocation. In both redesign solutions there are two possible locations to store a SKU, denoted as RDC and SDC. The RDC represents the allocation under the current planning variables and the SDC differs between the redesigns as stated in section 6.2. In which both redesigns have their own planning variables for the slow moving items.

### 6.3.1. Separated central distribution center for Slow moving items

First the results of the separated central distribution center for slow moving items are presented. For this redesign the model compares the operational logistical cost for both locations. In which the “RDC” represents the current supply chain and the “SDC” represents the replenishment policy via a separated central distribution center.

**Table 4 Percentage of SKU's allocated by model to either RDC or SDC in first redesign**

	ABS generated reorder levels	Optimal reorder levels
<b>RDC</b>	97,91%	99,27%
<b>SDC</b>	2,09%	0,73%

Table 4 presents the allocation on basis of the total relevant logistical operational costs over the selected stores for this redesign. This shows that in both modeling settings only a small percentage of products are allocated to the “SDC”. This is due to that the increase in lead time and the added extra transport/handling costs in this redesign weigh heavily on the costs and are therefore not easily outweighed by the possible savings. The increase in lead time results in higher lost sales at the ABS generated reorder level setting and in higher inventory and backroom inventory at the optimal reorder level setting. Due to the optimal reorder levels the cost difference gets smaller and the added extra transport/handling cost plays even a bigger role, resulting in a very low percentage of products allocated to the “SDC”.

Both modeling settings results follow the outcome presented in the theoretical model section, namely that these results show that for only a small part of the assortment considered the “SDC” is more favorable in terms of relevant costs. Note that the required investment in a new separated distribution center is not incorporated in these costs, which would make it an even less profitable redesign solution.

### **6.3.2. Separation within the current distribution centers**

Next the results of the separation within the current distribution centers are presented. For this redesign the model compares the operational logistical cost for both locations within the same distribution center. In which the “RDC” represents the current supply chain and the “SDC” represents the replenishment policy via a separated location within the same distribution center with its corresponding planning variables.

**Table 5 Percentage of SKU's allocated by model to either RDC or SDC in second redesign**

	ABS generated reorder levels	Optimal reorder levels
<b>RDC</b>	74,99%	57,09%
<b>SDC</b>	25,01%	42,91%

Table 5 presents the allocation on basis of the total relevant logistical operational costs over the selected stores for this redesign. In comparison with the allocation of the previous redesign, this allocation shows a bigger percentage of the assortment being allocated to the “SDC”. This is due that there is no added extra transport/handling cost at this redesign.

There is also a notable difference between the percentages of SKU’s allocated to the “SDC” for the two modeling settings. The modeling setting with the ABS generated reorder levels results in a lower percentage of products allocated to the “SDC”. This is due to that achieved service level resulting from the ABS reorder levels does not always meet the target service level and therefore results in higher lost sales costs. These high lost sale costs then outweigh the possible savings from an allocation to the “SDC”.

The results of both model settings show that there is a part of the assortment that would benefit from being allocated to the “SDC”. When the optimal reorder levels are used more than 40% of the assortment considered could be allocated to the separated section in the current distribution centers. When the ABS generated reorder levels are used this goes for 25% of the assortment considered.

#### **6.4. Classification metrics**

Ideally the products should be allocated on basis of the relevant operational logistical costs comparison between the slow – and fast mover allocation. However such a classification would require a lot of computational effort and cannot be seen as a clear metric. Therefore clear and easy to compute metrics are selected which could be used to classify products. These metrics are analyzed via regression to see if they approximate the cost difference (delta) between the “RDC” and “SDC”. This shows how well they can be used as a decision variable for the allocation of SKU’s.

The regression is applied to the redesign concerning the separation within the current distribution centers, given that the other redesign did turn out to be only favorable for a small part of the assortment considered. The model settings with the ABS generated reorder levels are considered in this regression, due to that this represents the ABS of the organization under research. The following metrics are selected on basis of the relevant metrics found in the literature review done in advance of this project.

- ***Total Sales***

The first metric which is tested is defined as the total sales of a product, this represents the total sales volume over the stores included in this research.

- ***Average Sales per store***

The second metric which is tested resembles with the first, however it takes into account the amount of stores carrying the corresponding product. This is defined as the average sales per store, which is determined by dividing the total sales by the stores carrying the product.

- ***Price***

The third metric which is tested is the selling price of the corresponding product. This product characteristic has no roots in the actual operations, still it is used in multiple organizations as a classification metric.

- ***Total Turnover***

The fourth metric which is tested combines the first and third metric, this represents the total turnover. Also known as the total demand value.

- ***Average Turnover per store***

The fifth metric which is tested is a combination of the second and third metric, again the amount of stores carrying the product are taken into account to determine the average turnover per store for the corresponding product.



- **Total Case packs**

The sixth metric which is tested resembles with the first, however this metric is expressed in case packs. Given that this represents the quantity in which products are ordered and move through the supply chain until they are unpacked at the store level.

- **Average Case packs per store**

The seventh metric which is tested again takes into account the amount of stores carrying the corresponding the product. This is determined by dividing metric six by the amount of stores carrying the product.

Next to the stated classification metrics multiple other product characteristics are added to the regression analyses to test their if they result in a significant effect in the regression equation. The following product characteristics are tested: Average Excess shelf space, Average Excess shelf coverage, Case pack size and number of stores carrying the product.

#### **6.4.1. Multivariate regression**

First the dependent variable and independent variables are tested for outliers. A small amount of observations are detected, which have values that are far from the other dependent variable and independent variables values. These values have a high influence on the results of the regression and are there deleted from the regression analysis. Based on the visual portrayal of the dependent variable and the empirical measures of the distribution's shape characteristics (skewness and kurtosis), it required a transformation to achieve normality. The inverse transformation showed the best results on visual portrayal and both empirical measures.

It was chosen to use the Stepwise method in SPSS to perform the regression, so the possible factors are added in order of relevance (strength of correlation) and the irrelevant factors, not per se adding value to the model, will be left out of the model. After the first run several independent variables also required transformation to correct for Heteroscedasticity, i.e. independence of the error terms.

The value of the multiple correlation (R) indicates the relationship between the dependent and the predicting variables. Where a value of one indicates a perfect relationship and a value of zero indicates that there is no relation at all. As the squared multiple correlation (R Square) overestimates the population, R Square is adjusted downwards. The adjusted squared multiple correlation (Adjusted R Square) indicate the percentage of the variance that can be accounted for by the linear relationship with the predictor variables and protects the model against over fitting.

The final model showed that the most important factors are the total sales and case pack size. Next to these factors, average excess shelf space and number of stores carrying the corresponding product turned out to be significant additions to the model. However the impact of the last two variables on the dependent variable is small (0,043 out of an overall model R-squared of 0,716). The adjusted R-squared of 0,716 indicated no overfitting of the model and that the results should be generalizable from the perspective of the ratio of observations to variables in the equation. The model summary of the stepwise method is shown in Table 6, followed by the coefficients shown in Table 7. This shows that the final model explained 71,60% of the total variation of the dependent variable. The resulting model

showed low VIF values (all >1,5) and high tolerance values, which imply a small degree of multicollinearity (i.e. the other independent variables do not collectively have any substantial amount of shared variance). The outcome of the regression analysis on the untransformed variables is provided in Appendix J.

**Table 6 Model summary of stepwise method**

Model Summary <sup>e</sup>			
Model	R	R Square	Adjusted R Square
1	0,742 <sup>a</sup>	0,550	0,550
2	0,820 <sup>b</sup>	0,673	0,672
3	0,834 <sup>c</sup>	0,696	0,695
4	0,846 <sup>d</sup>	0,716	0,716

a Predictors: (Constant), TotalSalesSqrt

b Predictors: (Constant), TotalSalesSqrt, Case Pack Size

c Predictors: (Constant), TotalSalesSqrt, Case Pack Size, Average ESS

d Predictors: (Constant), TotalSalesSqrt, Case Pack Size, Average ESS, Stores carrying

e Dependent Variable: DrInv

**Table 7 Regression coefficients of stepwise method**

Coefficients <sup>a</sup>							
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
1 (Constant)	,860	,005		186,204	,000		
TotalSalesSqrt	-,114	,002	-,742	-74,935	,000	1,000	1,000
2 (Constant)	,758	,005		163,116	,000		
TotalSalesSqrt	-,134	,001	-,869	-96,751	,000	,883	1,133
Case Pack Size	,016	,000	,373	41,494	,000	,883	1,133
3 (Constant)	,739	,005		160,920	,000		
TotalSalesSqrt	-,138	,001	-,893	-102,001	,000	,863	1,158
Case Pack Size	,016	,000	,391	44,847	,000	,872	1,147
Average ESS	,007	,000	,154	18,675	,000	,974	1,026
4 (Constant)	,625	,008		81,484	,000		
TotalSalesSqrt	-,150	,001	-,973	-102,039	,000	,680	1,470
Case Pack Size	,017	,000	,413	48,552	,000	,853	1,172
Average ESS	,007	,000	,152	19,123	,000	,974	1,026
Stores carrying	,010	,001	,161	18,104	,000	,782	1,278

a. Dependent Variable: DrInv

## 6.5. Discussion

The holding costs at the distribution center level are excluded from the analyses due to that the risk pooling effect from going from two to one location at the redesign one is marginal. Normally the allocation to a central location would be less costly than to a decentralized location, in holding cost terms. Due to that the decentralized locations would be restricted to capacity constrain. If this were the case than the savings from central storing would increase and it would become a more beneficial redesign solution.

The travelling cost difference at the distribution center level between redesign two and the current situation would become greater if the separated slow moving items would be allocated further away from the starting and ending point of the picking trips. This would decrease the travelling that is done outside the aisles for the more frequent picked product groups.

In the current replenishment policy there is already a differentiation made on product group level. Although this differentiation is made on basis of characteristics of the entire group, it still takes away a large part of the savings that result from the decrease in travelling which would be present if each product in the current replenishment policy could be ordered daily.

The effect of removing the slow moving items from the family grouping at the distribution center level could result in extra handling in the store. This possible effect could be largely reduced by combining this handling with the already required trips from the backroom to the shop floor for the handling of the backroom inventory.

## 7. Conclusions & Recommendations

This chapter contains the main conclusions and recommendations that resulted from the research project. First the general conclusions will be drawn regarding the phases of the project. Followed by the recommendations for Sligro Food group. Thereafter the academic relevance is considered and the chapter is concluded by the limitations and areas for further research.

### 7.1. Conclusions

Within this section conclusions are drawn regarding the different phases of the research project. Within this conclusions section the sub questions are answered.

#### 7.1.1. Problem analysis

In the problem analysis the first sub question is answered: *What are characteristics of slow moving items?* In this problem analysis two subsystems of the retail system are considered, the first one is the store and the second is the distribution center. The cost analysis explains the relevant cost aspects, followed by the redesign direction.

- The fill rate analysis showed that for 51,9% of the products in the last 50% of products the reorder levels are set so high that they achieve a service level of 0,99 or higher. This due to that they are set on basis of the minimum inventory norm and are not determined on both demand characteristics, mean and standard deviation. This leaves room for improvement, which also goes for the products that, according to the target service level, have a too low reorder level due to high standard deviations. Almost 30% of the products in the last 50% does not achieve the target service level.
- Almost 2% of the SKU's have an expected inventory on hand that accounts for more than a half year of demand and more than 5% of the SKU's have an expected inventory on hand that accounts for more than three months of demand. A high amount of days of inventory can result in problems in combination with a relatively short shelf life or a possible remediation.
- The backroom inventory analysis showed that almost eighteen percent of the SKU's that do not belong there, result in backroom inventory after ordering.
- The average case pack demand showed that there is a lot of spread within a product family, however the picking and delivering schedule is only based on product family characteristics.
- In the current replenishment policy there is already a differentiation made on product group level, however this differentiation is made on basis of characteristics of an entire group. Within each group there can be a wide spread of product characteristics on product level.

#### *Cost analysis*

This cost analysis is done to capture the total operational logistical cost from the distribution center to the customer. The operational logistical cost in the supply chain; from the pick location in the distribution centers to the shelves in the stores, which are influenced by the two possible redesign solutions consist of the following aspects: (1) holding cost in store, (2) Store handling cost, (4) backroom cost, (3) lost sale cost, (5) holding cost in distribution center, (6) picking cost in distribution center, (7) traveling cost in distribution center and (8) added handling/transport cost at distribution center.

### **Redesign direction**

In consultation with the company under research, based on the initial problem definition, the above stated information and the results of the problem analysis done over the two subsystems of the retail system the redesign direction is chosen. This is the differentiation within the supply chain between slow- and fast movers on basis of product characteristics. which requires a separation in the current flow of goods from the DC to the stores.

#### **7.1.2. Model**

Based on relevant operational logistical costs a theoretical model is created, which evaluates the effects of changes in the replenishment policy in terms of review period and lead time. During the modeling an interesting finding on the traveling cost was made. The effect of the assortment size on travelling cost is small in comparison with the other cost aspects. This possible saving therefore only plays a role for the products with a low demand rate.

The outcome of the theoretical model is shown for three scenarios, which are varied over different demand rates to show the full effect of a possible change in the supply chain. A sensitivity analysis is done on the key parameters, to assess the results and the reliability of the observations made on the theoretical model.

#### **7.1.3. Results**

For a selection of fifteen stores out of the supermarket range of EMTÉ, the redesign solutions are evaluated on basis of the presented model. Due to that the reorder levels generated by the ABS do not take the standard deviation of demand into account, these reorder levels can result in a service level that is lower than the target service level.

Following on the problem analysis and the theoretical model, two redesign solutions are designed in consultation with the organization under research, which enable differentiation within the supply chain. The first encompasses a separated central distribution center for the slow moving items and the second encompasses a separation within the current distribution center. Within these two redesign the answer to third sub question: *What are Possible Changes in the Replenishment Policy concerning Slow Moving Items?* and the answer to the fourth sub question: *What are Possible Changes in the Allocation of Slow Moving Items?* is provided.

Both the theoretical model results as well as the applied model results show that the first redesign is not beneficial for almost the entire assortment. However the second redesign concerning the separation within the current distribution center turned out to be beneficial for sizable part of the assortment, especially when the optimal reorder levels are used. These results answered the fifth sub question: *Would it make sense to create a separate DC only for slow moving items, and use a separate slow moving item replenishment system?*

Next to the results of the application of the model to the two redesigns, a multivariate regression is performed to test the predicting performance of common used metrics in combination with product characteristics on the difference in cost between the allocation to the two stages in the second redesign. The final model showed that the most important factors are the total sales and case pack size. Next to

these factors, average excess shelf space and number of stores carrying the corresponding product turned out to be significant additions to the model. However the impact of the last two variables on the dependent variable is small (0,043 out of an overall model R-squared of 0,716). Answering the second sub question: *What is a Good and Appropriate Classification Method for Slow Moving Items?* The final model explained 71,60% of the total variation of the dependent variable.

## **7.2. Recommendations for Sligro Food group**

The recommendations are based on the results and knowledge obtained throughout this project and can be seen as an advice for Sligro Food Group.

### **7.2.1. Variance**

The variance of demand is a demand characteristics which should be used next to the currently used average of demand. Taking the variance into account would result in higher service levels and therefore decrease the number of out of stocks.

### **7.2.2. Costs**

To fully benefit from the presented model, the costs occurring at both the Store and DC level should be studied in more detail.

### **7.2.3. Input data**

The input parameters required for the presented model should be more easily available, to decrease the time needed to gather the required data. Next to this the settings in the ABS should represent the actual settings used in the store, especially for the minimum inventory, the maximum inventory and the shelf space.

### **7.2.4. Automated Store Ordering system (ABS)**

To maintain the management of the product flow on product group level, a separate group for slow moving items should be set up in the ABS. Via this approach the products allocated to this group could be managed according to the specific planning variables.

## List of Abbreviations

- CDC: Central Distribution Center in Veghel
- RDC: Retail Distribution Center
- ZB: Cash-and-carry wholesale outlet of the Sligro Food Group
- BS: Delivery Service of the Sligro Food Group
- R: Direct delivery from Suppliers
- J: Delivery from CDC
- CD: Cross dock flow from CDC via RDC to EMTÉ retail stores
- SKU: Stock Keeping Unit
- ABS: Automatisch Bestel System (Automatic Store Ordering system)

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## Appendices

### Appendix A

(Amounts x €1,000)

	2011	2010
<b>Result</b>		
Net sales	2,420,216	2,286,261
Operating profit before depreciation and amortisation (EBITDA)	158,971	145,519
Operating profit (EBIT)	104,970	90,928
Profit for the year	78,207	70,196
Net cash flow from operating activities	123,799	106,858
Proposed dividend	46,157	30,874
<b>Equity and liabilities</b>		
Shareholders' equity	540,566	500,073
Net interest-bearing debt	112,897	156,106
Total equity and liabilities	931,116	937,310
<b>Employees</b>		
Year average (full-time equivalents)	5,880	5,513
Salaries, social security charges and pension expenses	217,121	203,280
<b>Ratios</b>		
Increase in sales on previous year (%)	5.9	1.3
Increase in net profit on previous year (%)	11.4	(5.5)
As a percentage of sales:		
Gross margin	23.2	23.1
Gross operating profit	6.6	6.4
Operating profit	4.3	4.0
Profit for the year	3.2	3.1
Return as % of average shareholders' equity	15.0	14.3
Operating profit as % of average net capital employed	16.2	14.8
Shareholders' equity as % of total equity and liabilities	58.1	53.3
<b>Figures per €0.06 share</b>		
Number of shares outstanding (year-end x 1,000)	43,959	44,106

(Amounts x €1)

Shareholders' equity	12.30	11.34
Profit after tax	1.78	1.59
Cash flow	3.01	2.83
Proposed dividend	1.05	0.70
Year-end share price	20.75	23.20

## Appendix B

### Marktaandeelen van supermarktketens (op basis van ketenstructuur begin 2013)

Bron: Nielsen

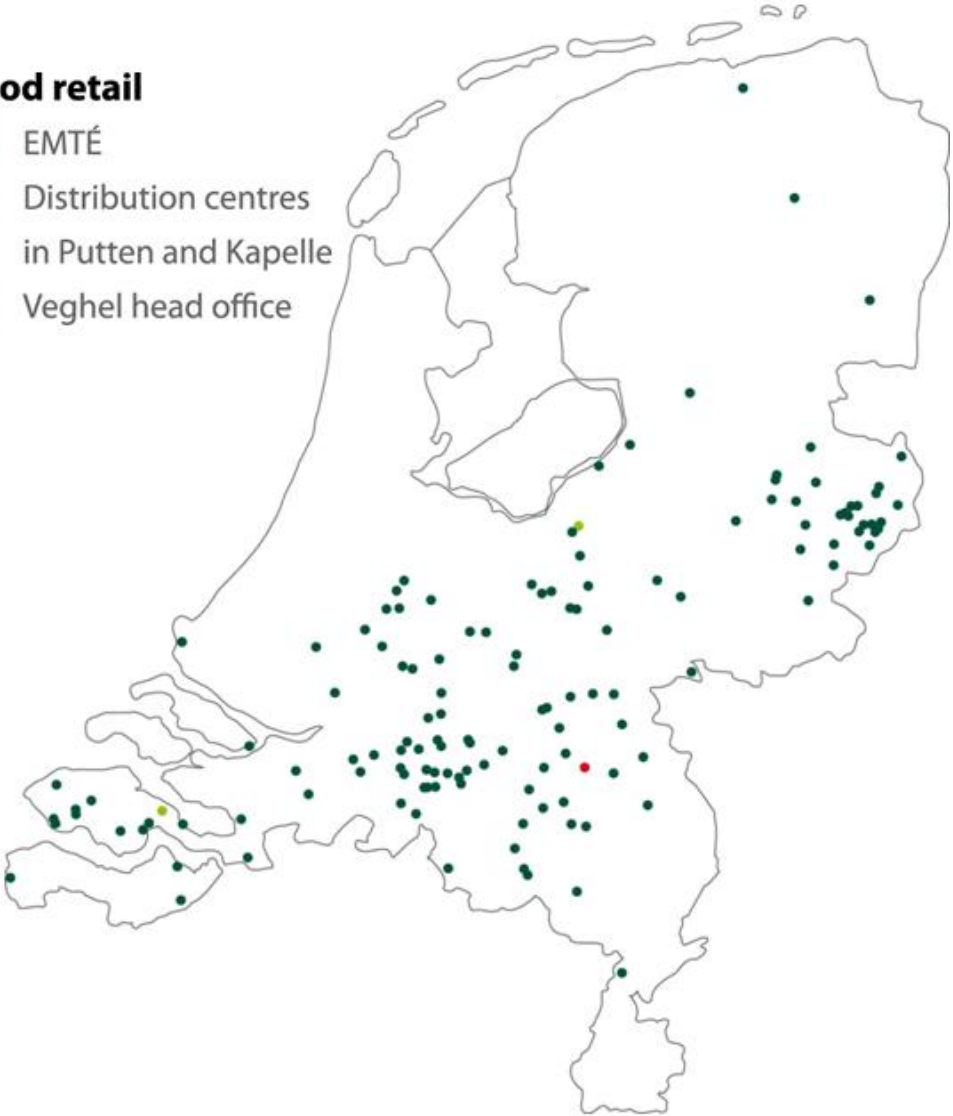
	2007	2008	2009	2010	2011	2012
Albert Heijn	29,5%	31,3%	32,8%	33,6%	33,5%	33,7%
C1000	14,3%	13,2%	11,7%	11,5%	12,1%	12,0%
Super de Boer	7,3%	6,8%	6,5%	5,5%	2,4%	0,1%
Jumbo	4,4%	4,8%	4,9%	5,5%	7,4%	9,6%
Superunie (totaal)	30,0%	30,7%	29,6%	29,6%	29,2%	29,0%
- Coop	2,4%	2,5%	2,4%	2,5%	2,6%	2,7%
- Deen	1,9%	1,9%	1,9%	2,0%	2,0%	2,0%
- Detailresult	-	-	-	-	5,8%	5,6%
- Sligro Foodretail (Em-Te)	2,3%	2,6%	2,9%	2,8%	2,7%	2,7%
- Hoogvliet	1,9%	1,9%	1,9%	2,0%	2,0%	2,1%
- Jan Linders	1,0%	1,0%	1,0%	1,0%	1,0%	1,0%
- Plus	6,0%	6,1%	6,0%	6,0%	5,9%	5,8%
- Poiesz	0,9%	0,9%	0,9%	1,0%	1,0%	1,0%
- Spar	1,9%	2,2%	2,3%	2,2%	2,1%	1,9%
- Vomar	-	1,6%	1,7%	1,7%	1,6%	1,6%
Aldi	8,9%	8,5%	8,3%	7,9%	7,9%	7,6%
Lidl	4,0%	4,8%	5,4%	5,6%	6,7%	7,5%
Overig	1,5%	0,7%	0,8%	0,8%	0,8%	0,6%

(Bijgewerkt: 19 februari 2013)

Appendix C

**Food retail**

- EMTÉ
- Distribution centres in Putten and Kapelle
- Veghel head office





## Appendix D

Example on Sales expectation calculation:

The table below shows the amount of days in the period between two orders.

Days in period between orders	
Days till delivery of next order moment	3
Safety days	1
Logistics days	1
<b>Total days in period</b>	<b>5</b>

The next table shows the calculation of the Sales expectation, starting with the counting of the amount of each weekday in the above calculated period. For this example it is assumed that the order is placed on Monday before 9 AM, this implies that the Monday on which the order is placed is taken in to account to. The amount of weekdays that are in this period are multiplied by the average sales of the last six weeks on that weekday, this gives the Sales expectation for this weekday in this period. These Weekday's Sales expectation are summed up to generate the Sales expectation for the period.

	Number days in period	Amount	Average Sales on Weekday	Sales expectation on weekday
Monday	1	1	0,4	0,4
Tuesday	2	1	0,7	0,7
Wednesday	3	1	0,9	0,9
Thursday	4	1	1,8	1,8
Friday	5	1	1,6	1,6
Saturday		0	2,3	0
Sunday		0	0	0
<b>Total</b>		<b>5</b>	<b>7,7</b>	<b>5,4</b>

This ordering advice will be generated by ABS, rounded up to the size of the case pack and presented to the ABS manager, he can then check the advice and accept it or adjust the size of the order. Overall the working of this system can best be seen as a periodically reviewed base stock control system with batch sizes, which are in most cases determined by the size of the box in which the products are transferred. However it is a special kind of base stock system, given that the base stock level does not only vary due to a varying sales expectation, but also due to that in some situations the base stock level is set according to the minimum and maximum of the product.

## Appendix E

Study	Aim	Industry	Characteristics			
			Volume	Product	Customer	Timing
Aitken <i>et al.</i> (2003)	PS	Lighting	Demand volume	Product variety, order winners, market qualifiers, product life cycle	-	-
Bhattacharya <i>et al.</i> (2007)	IM	Pharmaceutical industry	Demand volume (daily)	Unit costs, lead time, perishability, storage costs	-	-
Boylan <i>et al.</i> (2008)	IM/ FOR	Automotive, aerospace, chemical	Demand volume (mean+ Coefficient of Variation (CoV))	-	-	Mean inter-demand interval
Canen and Galvao (1980)	IM	Manufacturing	Demand volume* (annual)	Unit cost*	-	-
Canetta <i>et al.</i> (2005)	IM	Electronics - component inventory	Demand volume (monthly (mean + CoV))	Commonality, supply lead time (mean + CoV), unit cost	-	Frequency
Cavalieri <i>et al.</i> (2008)	IM	Process industry (spare parts)	Demand volume	Unit cost	Criticality, number of installations	-
Chakravarty (1981)	IM	General	Demand volume	Unit cost	-	-
Chen <i>et al.</i> (2008)	IM	General	Demand volume* (annual)	Unit cost*, criticality, lead time	-	-
Chrisman (1985)	IM	Cylinder parts	Demand volume* (annual)	Unit cost*	-	-
D'Alessandro and Baveja (2000)	PS	Chemical	Demand volume (weekly, mean + CoV)	-	-	-
Duchessi <i>et al.</i> (1988)	IM	Spare parts	Demand volume* (annual)	Unit cost*	Criticality	-
Eaves and Kingsman (2004)	FOR	Air Force	Demand size variability	Lead time variability	-	Transaction variability
Ernst and Cohen (1990)	IM	Automotive (spare parts)	Demand volume (monthly, mean + CoV), Returns volume (annual)	Unit cost, product life cycle, lead time (actual + late+ CoV), used in number of vehicles	Criticality	Seasonality factor
Fisher (1997)	PS	General	Demand predictability	-	-	-
Flores and Whybark (1986)	IM	Manufacturing	Demand volume*	Unit cost*, lead time	-	-
Flores and Whybark (1987)	IM	Manufacturing and service firm (spare parts)	Demand volume*	Unit cost*	Criticality	-
Flores <i>et al.</i> (1992)	IM	General	Demand volume* (annual)	Unit cost*, unit cost (mean), lead time, criticality (scarcity, substitutes)	Criticality (impact)	-
Gajpal <i>et al.</i> (1994)	IM	Manufacturing (spare parts)	-	-	Criticality (alternative production facility available, availability of spare parts, lead time)	-
Gardner (1990)	FOR	Military (spare parts)	Demand volume	-	-	-
Gelders and van Looy (1978)	IM	Petrochemical industry	Demand volume (annual)	Unit cost	-	-
Ghobbar and Friend (2002)	FOR	Aviation (spare parts)	Demand size (squared CoV)	-	-	Mean inter-demand interval

Güvenir and Erel (1998) (example 1)	IM	University	Demand volume* (annual)	Unit cost*, lead time	Replaceability	Number of requests for the item in a year
Güvenir and Erel (1998) (example 2)	IM	Mining	Order size requirements	Unit cost, lead time, scarcity, durability, substitutability, reparability, stockability, commonality	-	Number of requests for the item in a year
Harhalakis <i>et al.</i> (1989)	IM	Infant care equipment	Demand volume* (monthly)	Unit Cost*, unit volume	-	-
Hautaniemi and Pirttilä (1999)	IM	Assembly	Demand volume* (annual), demand pattern (singular/lumpy/continuous)	Unit cost*, supplier lead time (in relation to time needed)	-	-
Huiskonen (2001)	IM	Spare parts	Demand volume	Specificity, unit cost	Criticality	Inter-demand interval predictability
Huiskonen <i>et al.</i> (2005)	IM	Construction company	Demand volume (annual)	Annual sales of A/B products in the same order as the C-product	Proportion of C product sales to customer types	Number of orders (annual)
Kobbacy and Liang (1999)	IM	High-tech manufacturing and airline (both spare parts)	Demand volume (mean + variance), randomness	Lead time (mean + variance)	-	Seasonal patterns, trend
Mukhopadhyay <i>et al.</i> (2003)	IM	Mining (spare parts)	Demand volume (annual*, during replenish lead time)	Unit cost*	Criticality to production process	-
Ng (2007)	IM	General	Demand volume* (annual)	Unit cost*, lead time	-	-
Onwubolu and Dube (2006)	IM	Mining	Demand volume* (annual)	Unit cost*	-	-
Partovi and Anandarajan (2002)	IM	Pharmaceutical industry (spare parts)	Demand volume (annual)	Unit cost, ordering cost, lead time	-	-
Partovi and Burton (1993)	IM	Pharmaceutical industry (spare parts)	Demand volume (annual)	Unit cost, lead time	Criticality	-
Partovi and Hopton (1994)	IM	General (spare parts)	Demand volume	Unit cost, lead time	Criticality	-
Porras and Dekker (2008)	IM	Oil refinery (spare parts)	Demand volume (monthly)	Unit cost	Criticality	-
Portougal (2002)	FOR	Catalogue fashion retailing	Demand volume	Profit margin	-	-
Ramanathan (2006)	IM	General	Demand volume* (annual)	Unit cost*, criticality, lead time	-	-
Reid (1987)	IM	Health care	Demand volume (annual)	Unit cost	-	-
Ritchie and Kingsman (1985)	IM	Wholesaling	Demand volume (weekly, empirical distribution)	-	-	-
Sani and Kingsman (1997)	FOR	Agricultural machinery (spare parts)	Demand volume (annual)	-	-	-
Stanford and Martin (2007)	IM	Machine parts	Demand volume (annual)	Unit cost	-	-
Syntetos <i>et al.</i> (2005)	FOR	Automotive	Demand size (squared CoV)	-	-	Mean inter-demand interval
Williams (1984)	IM/ FOR	Public utility	Demand (lumpiness)	-	-	Mean number of lead times between demands, variance of lead time
Wu <i>et al.</i> (2006)	FOR	Short lifecycle tech products	Demand pattern (lifecycle)	-	-	-
Zhou and Fan (2007)	IM	General	Demand volume* (annual)	Unit cost* (mean), lead time	-	-

Aim = The dominant application purpose: Inventory Management (IM), Forecasting (FOR) or Production Strategy (PS)

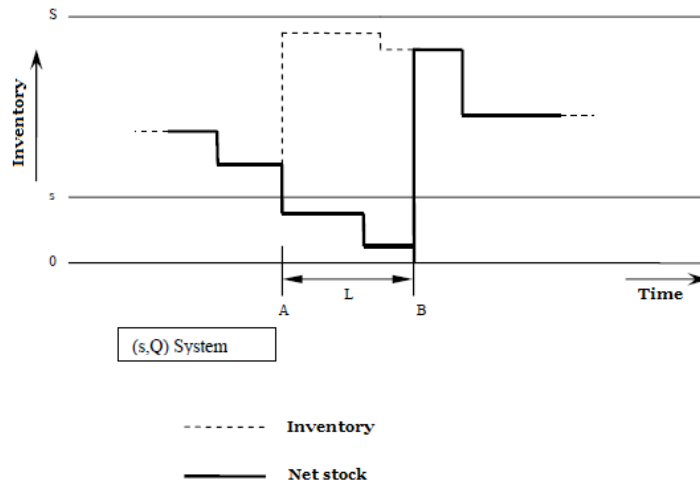
\* The study uses (annual) demand value; we have converted this to demand volume and unit cost

(van Kampen, et al., 2012)

## Appendix F

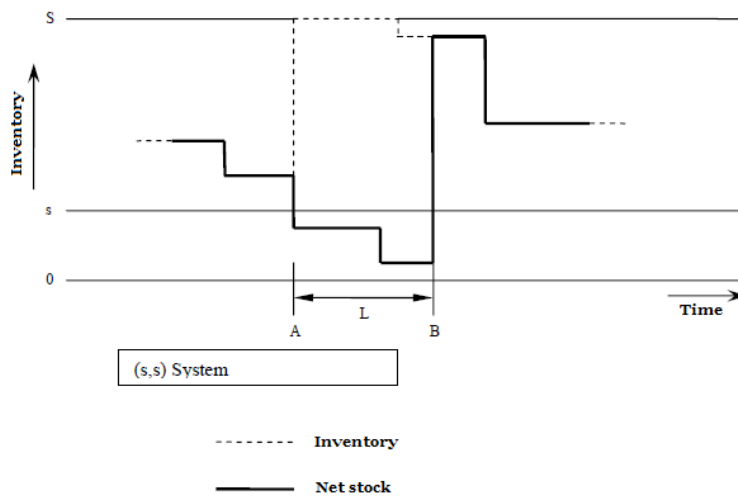
### Order-Point, Order-Quantity ( $s,Q$ ) System

This is a continuous review system, often called a two-bin system because one physical form of implementation is to have two bins for storage of an item. A fixed quantity  $Q$  is ordered whenever the inventory position drops to or below the reorder point  $s$ . Inventory position in this setting stands for net stock plus on-order stock.



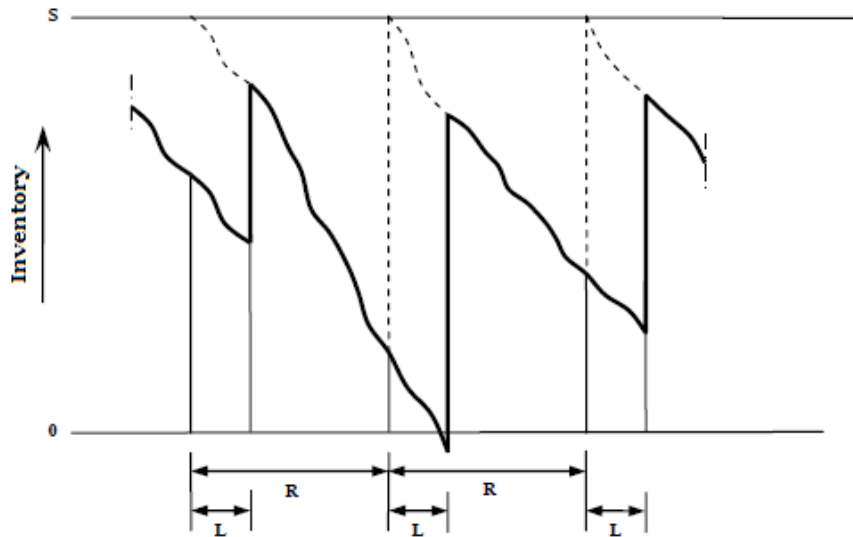
### Order-Point, Order-Up-to-Level ( $s,S$ ) System

This is again a continuous review system and like the  $(s,Q)$  system a replenishment is made whenever the inventory position drops to or below the order point. However in contrast to the  $(s,Q)$  system, a variable replenishment quantity is used, ordering enough to raise the inventory position to the order-up-to-level  $S$ . If all demand transactions are unit-sized, the two systems are identical because the replenishment requisition will always be made when the inventory position is exactly at  $s$ : that is,  $S=s+Q$ .



### *Periodic-Review, Order-Up-To-Level (R,S) System*

This Periodic Review system follows the procedure that every  $R$  units of time (that is each review instant) enough is ordered to raise the inventory position to level  $S$ . This system is also known as a replenishment cycle system.



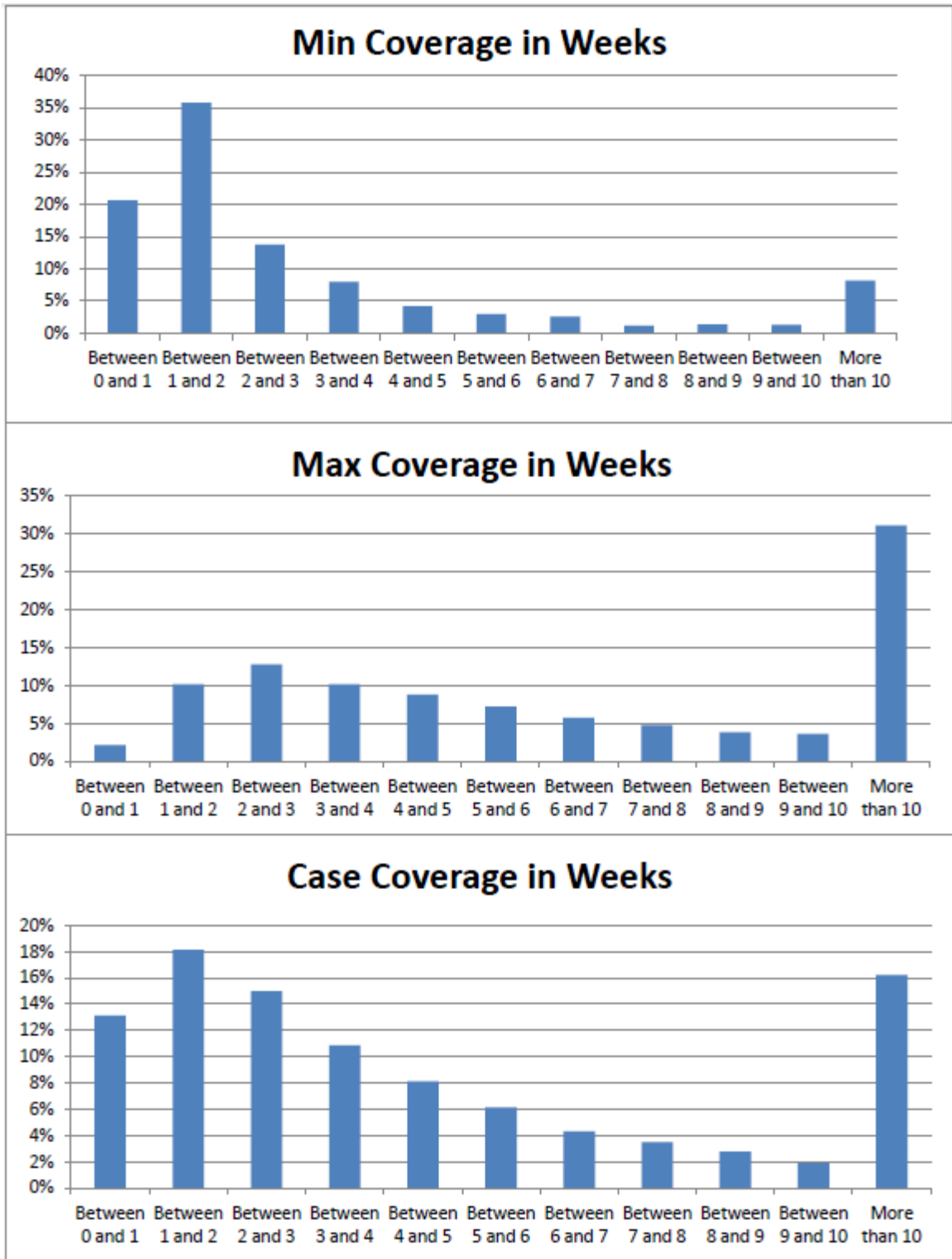
### *(R,s,S) System*

This system is a combination of the  $(s,S)$  and the  $(R,S)$  systems. The idea is that every  $R$  units of time we check the inventory position. If it is at or below the reorder point  $s$ , we order enough to raise it to  $S$ . If the position is above  $s$ , nothing is done until at least the next review. This system can be seen as the periodic version of the  $(s,S)$  system.

### *(R,s,nQ) System*

This is a combination of the  $(s,Q)$  and the  $(R,S)$  systems. The idea is that every  $R$  units of time we check the inventory. If it is at or below the reorder point  $s$ , we order a fixed quantity  $Q$ . If the position is above  $s$ , nothing is done until at least the next review. This system can be seen as the periodic version of the  $(s,Q)$  system (Silver, et al., 1998).

## Appendix G



## Appendix H





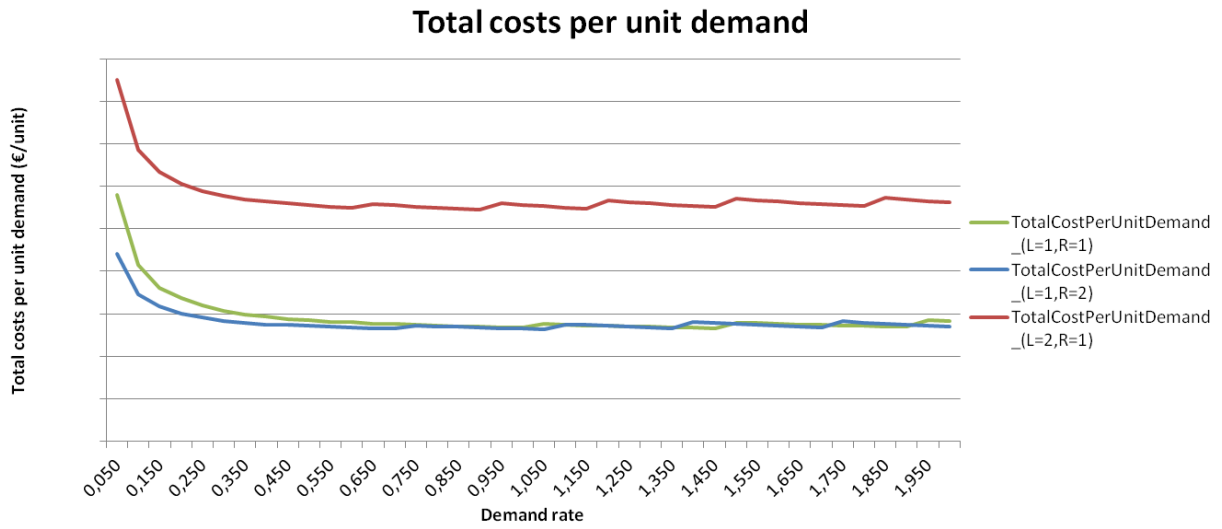
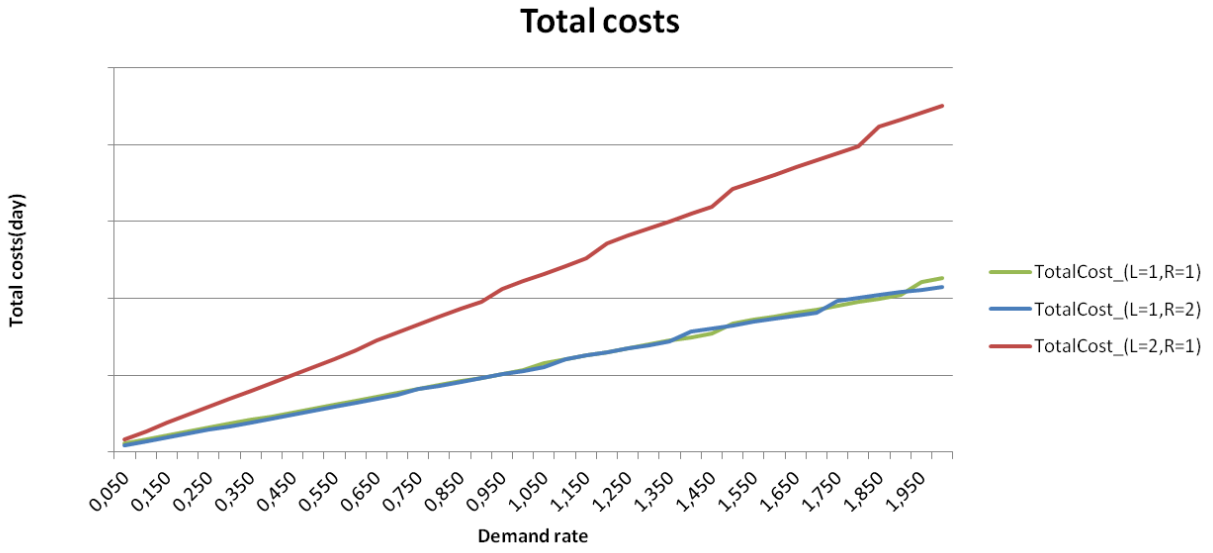




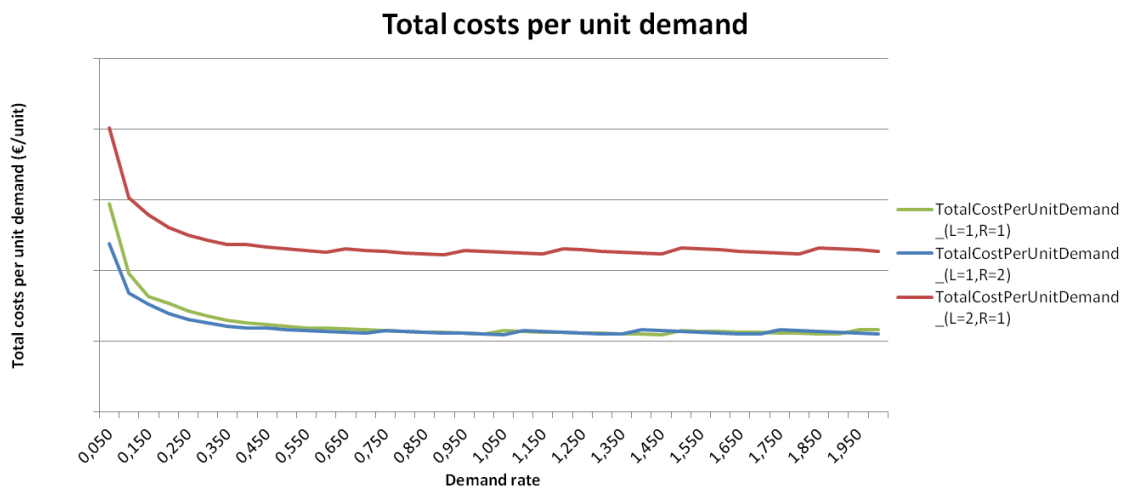
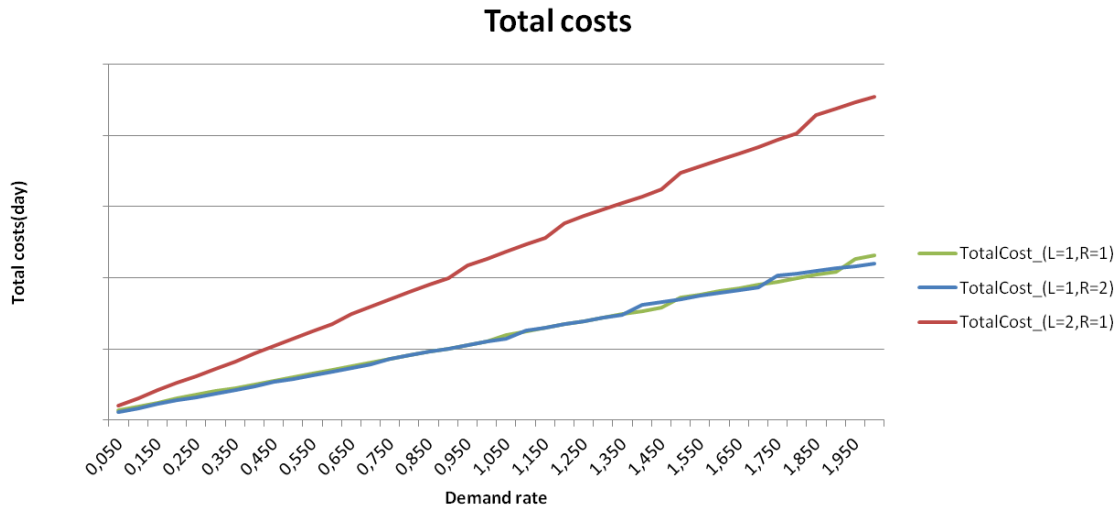
# Appendix I

## Sensitivity analysis

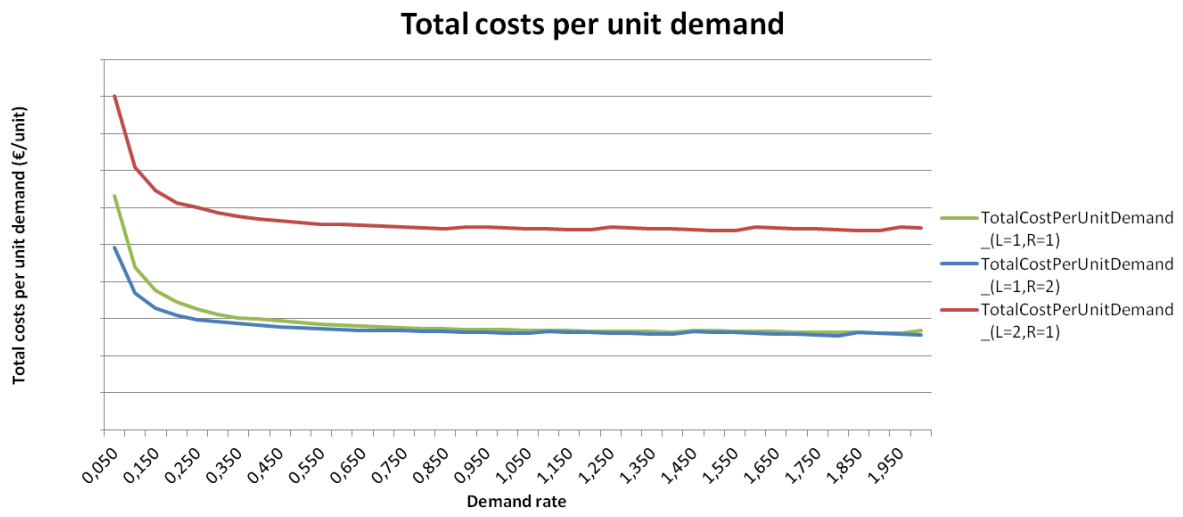
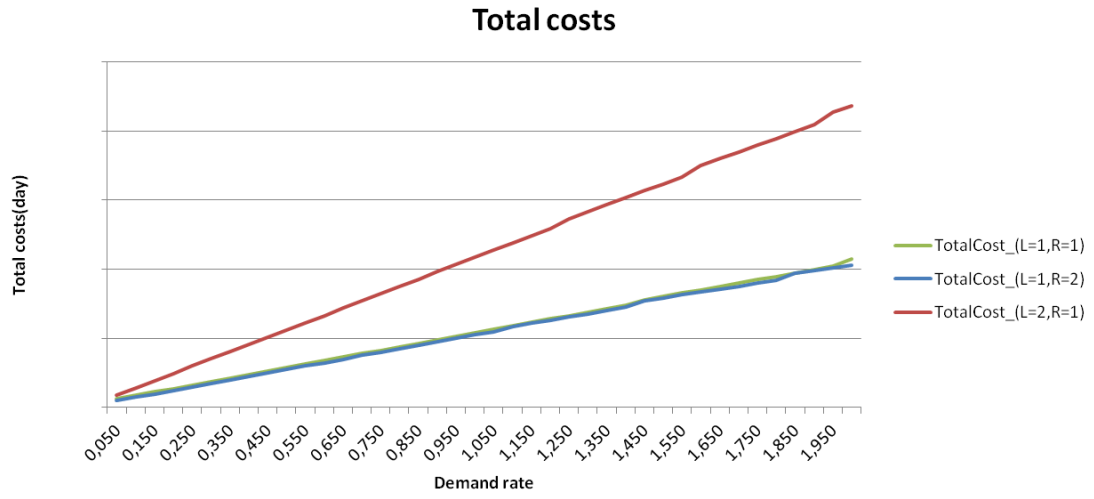
ICC= halved



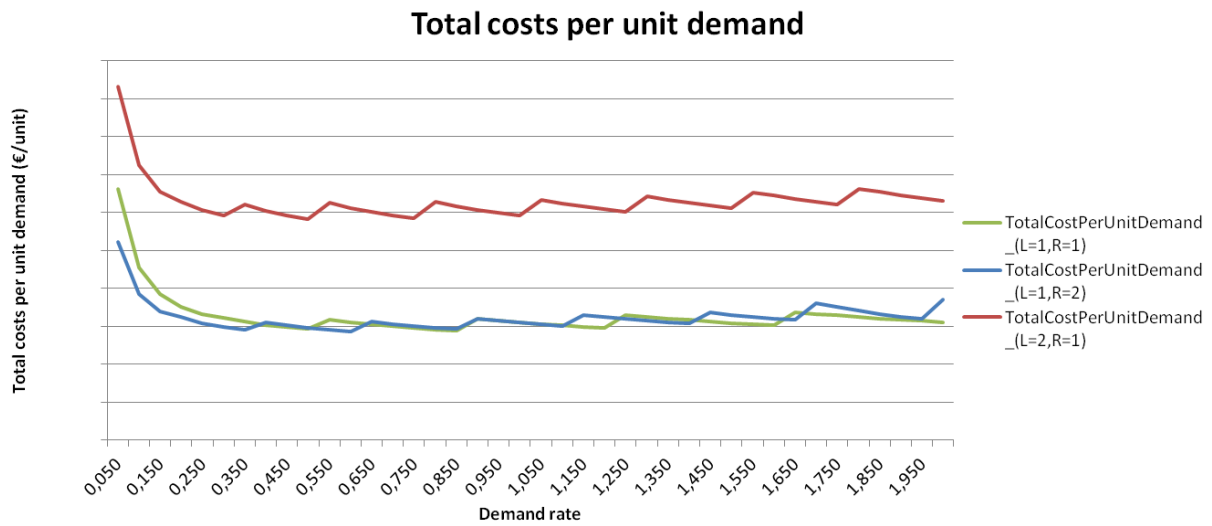
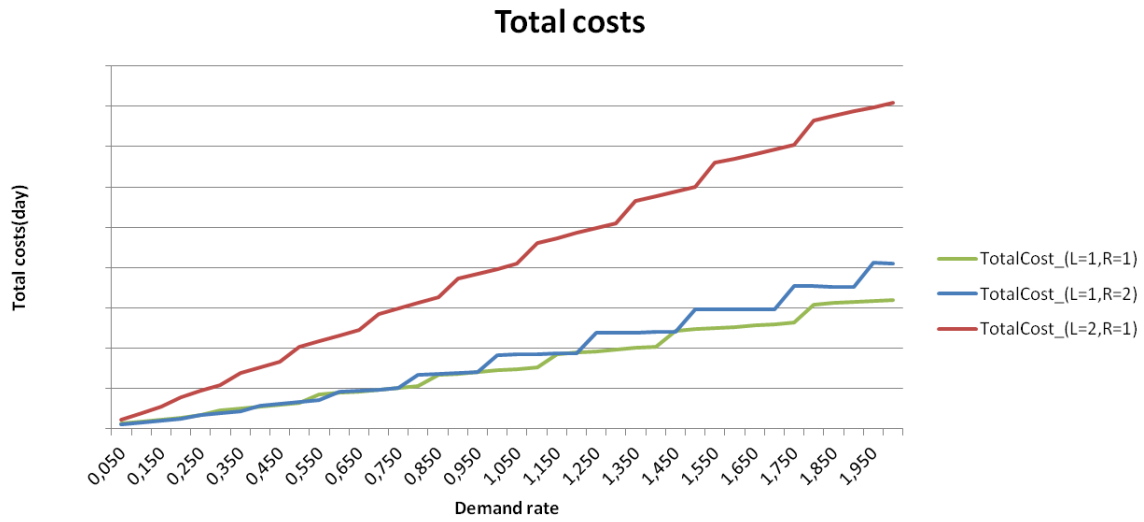
ICC doubled



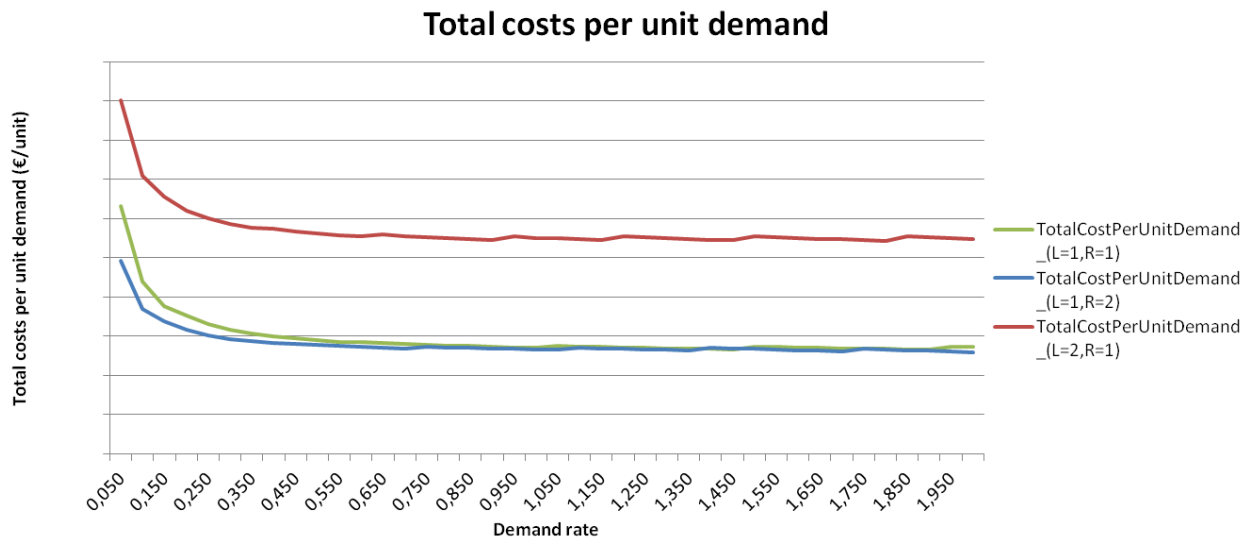
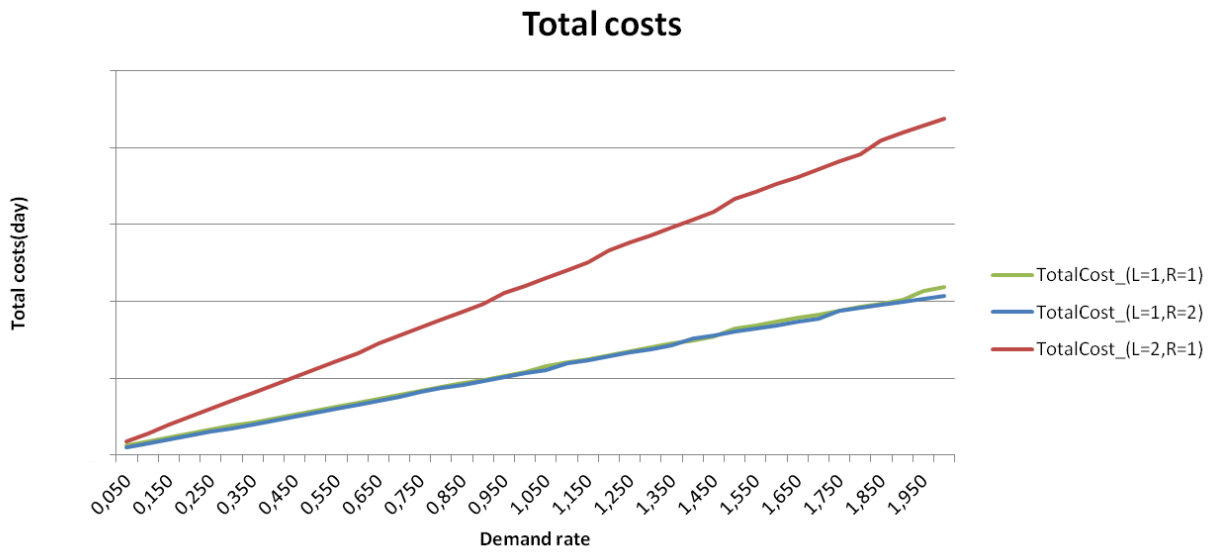
Target fill rate decreased



Target fill rate increased

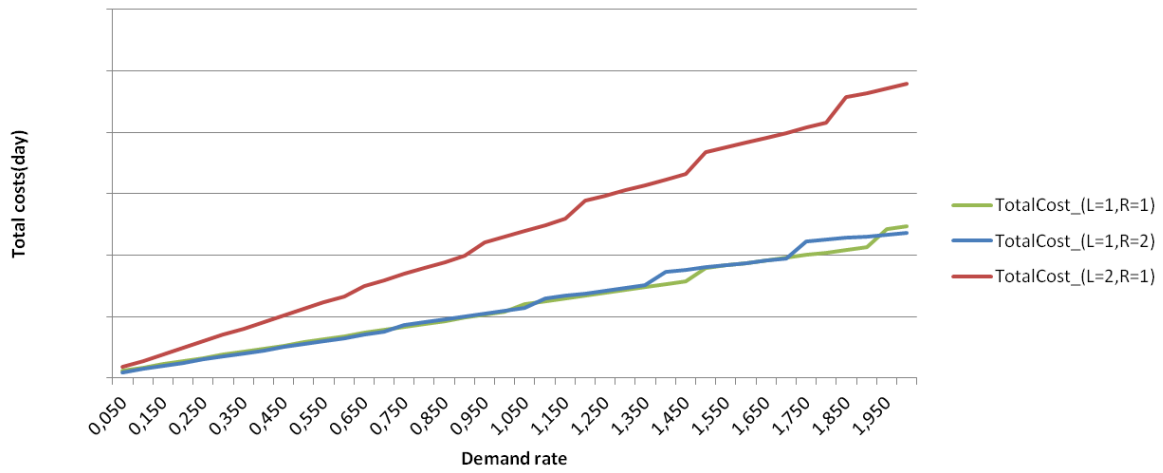


Backroom inventory cost halved

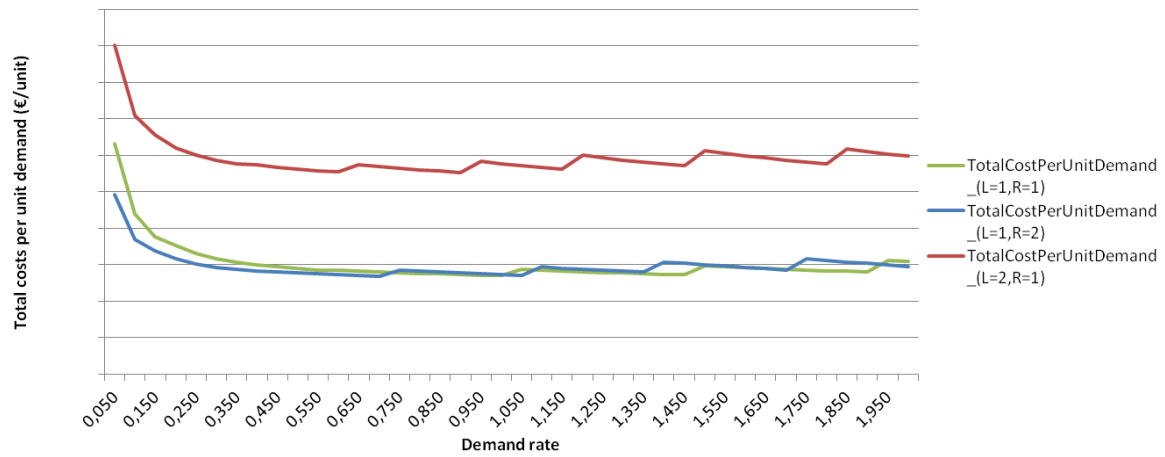


Backroom inventory cost doubled

### Total costs

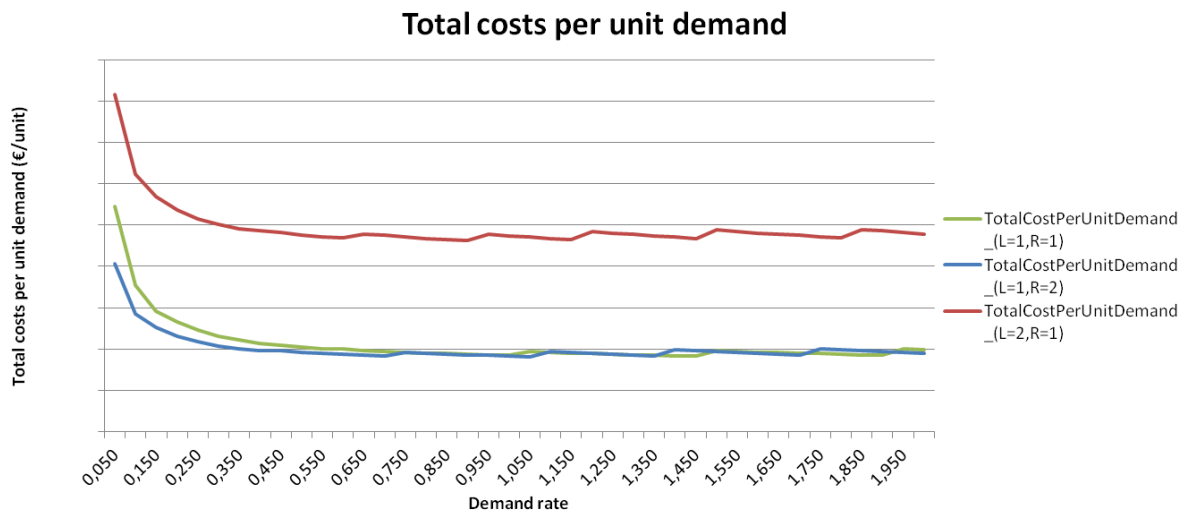
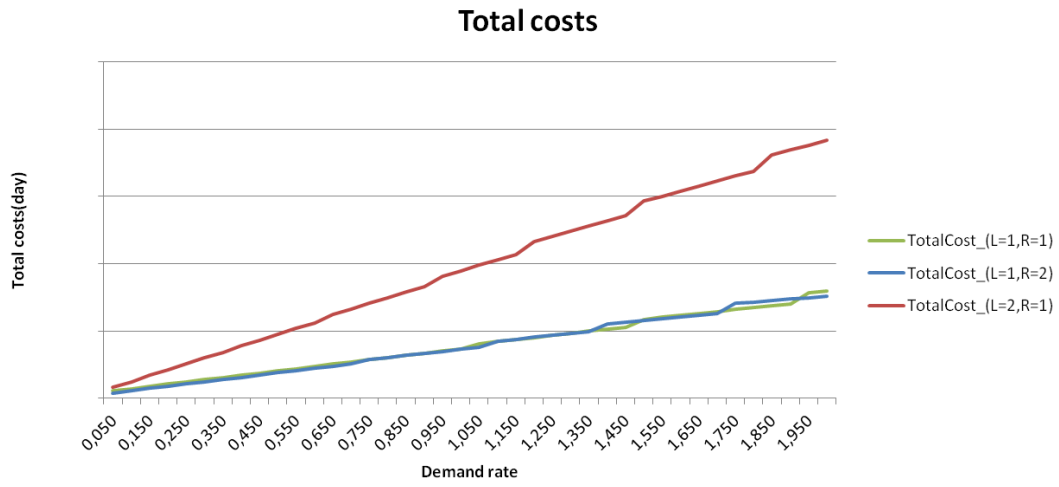


### Total costs per unit demand

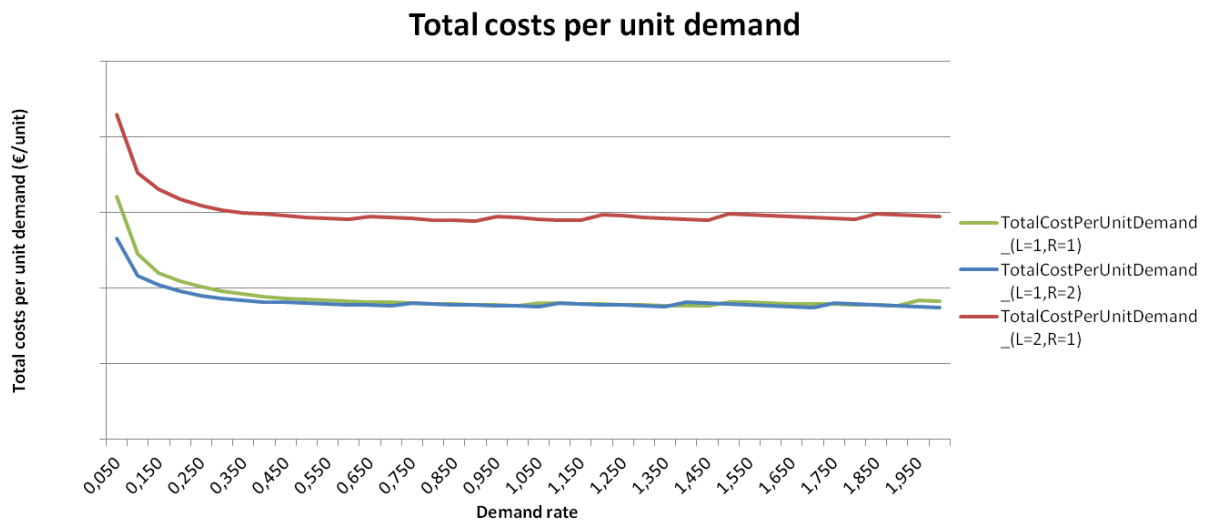
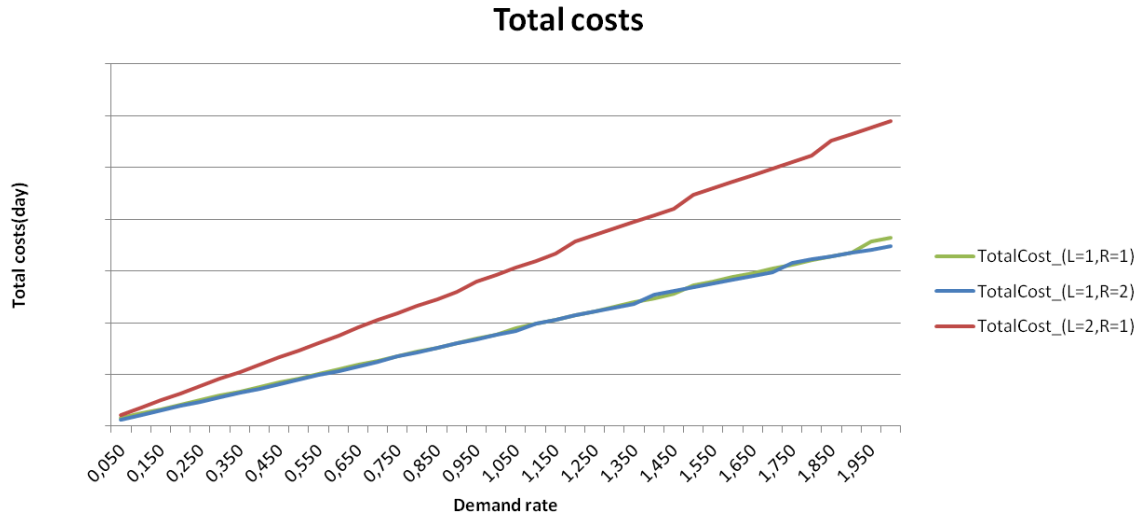




Store handling cost halved

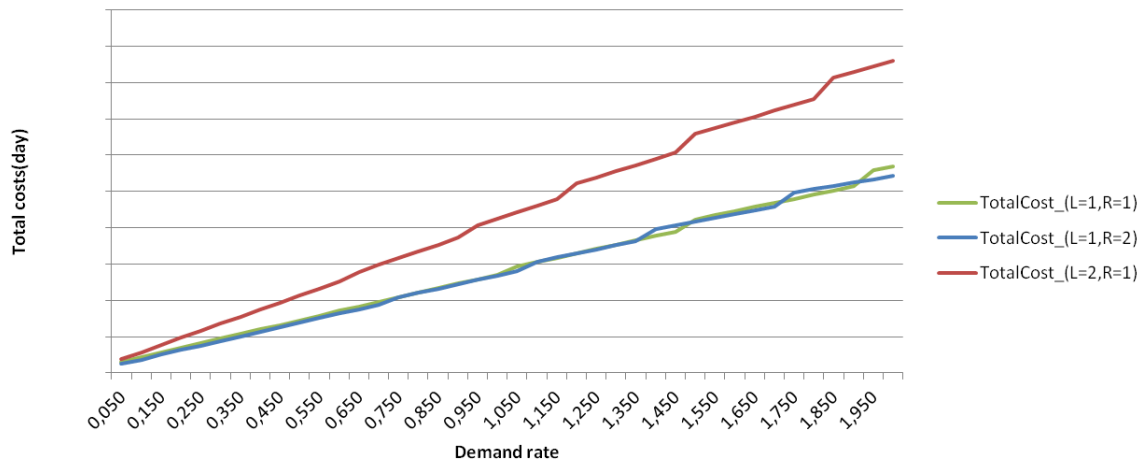


Store handling cost doubled

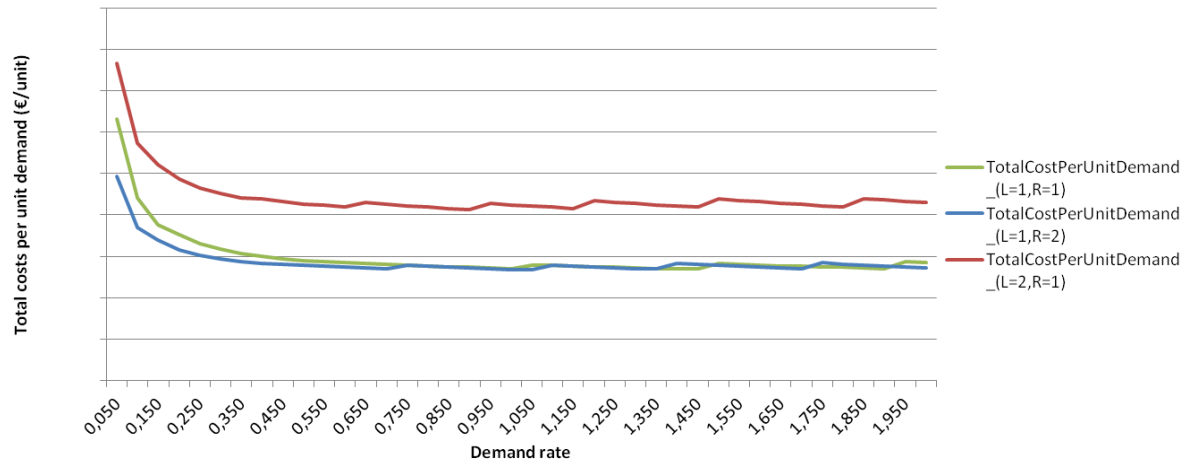


Extra transport/handling cost halved

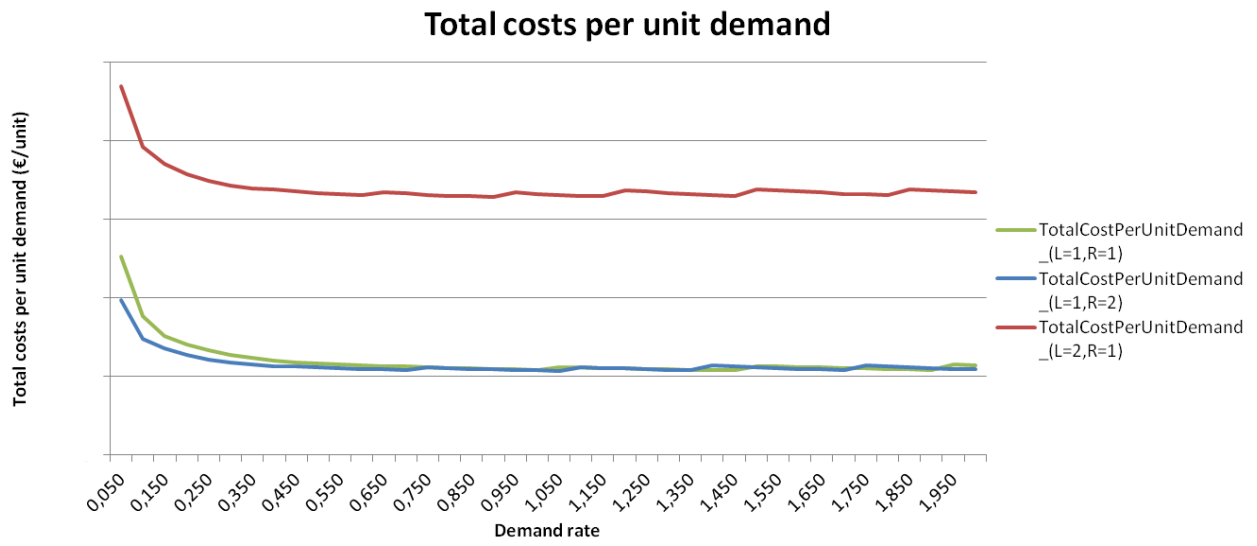
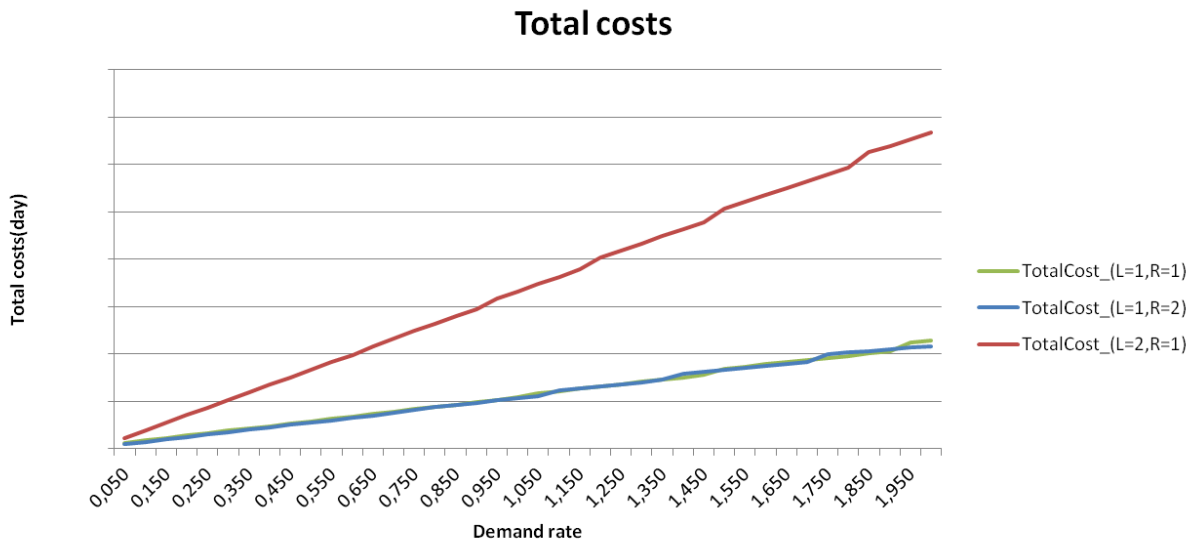
### Total costs



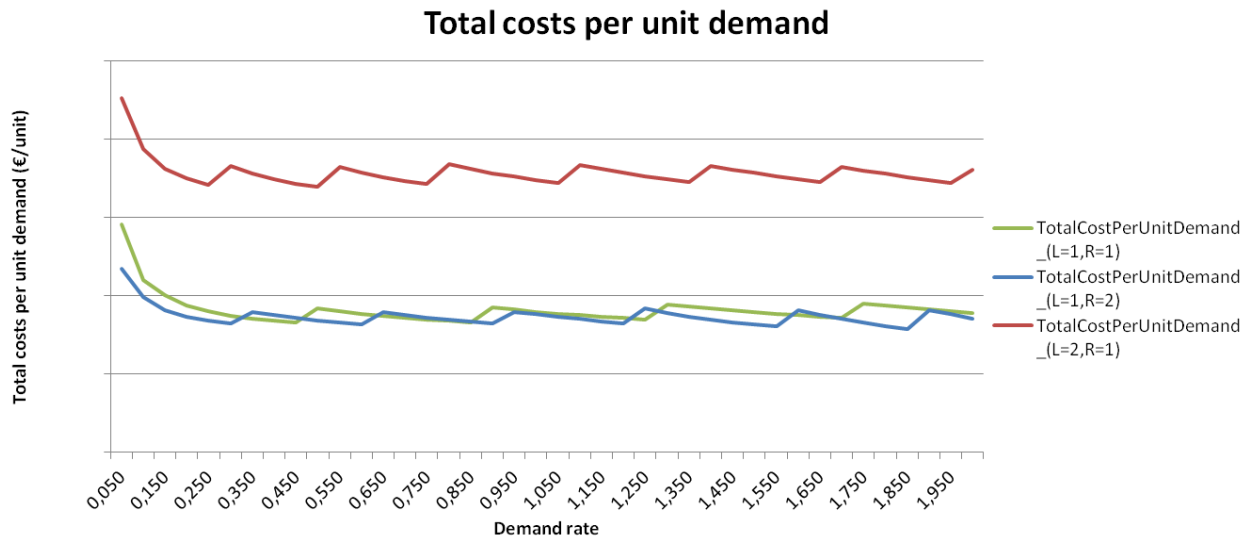
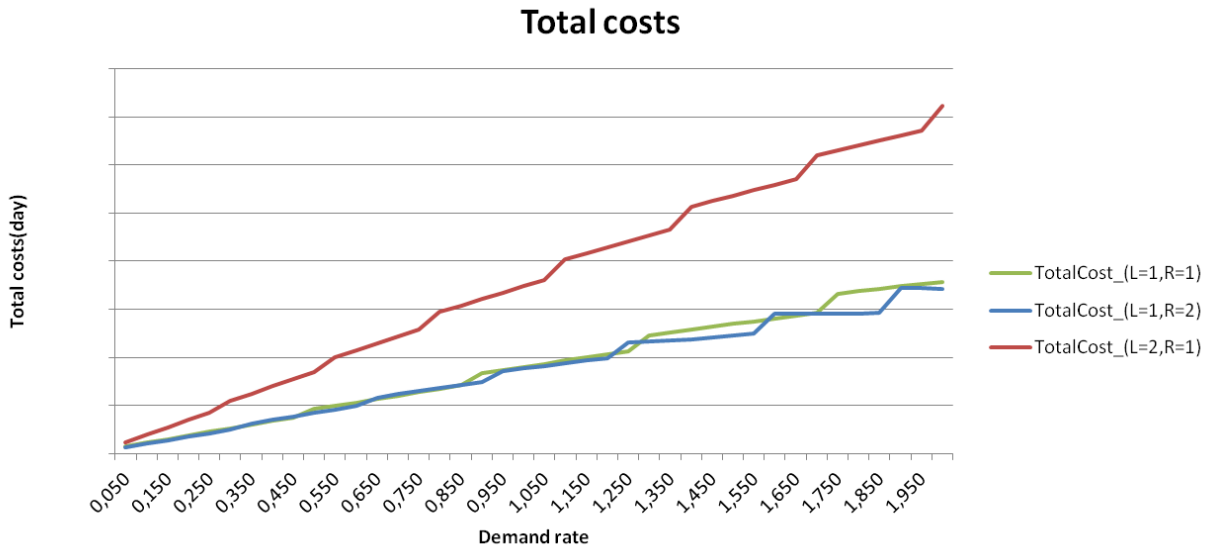
### Total costs per unit demand



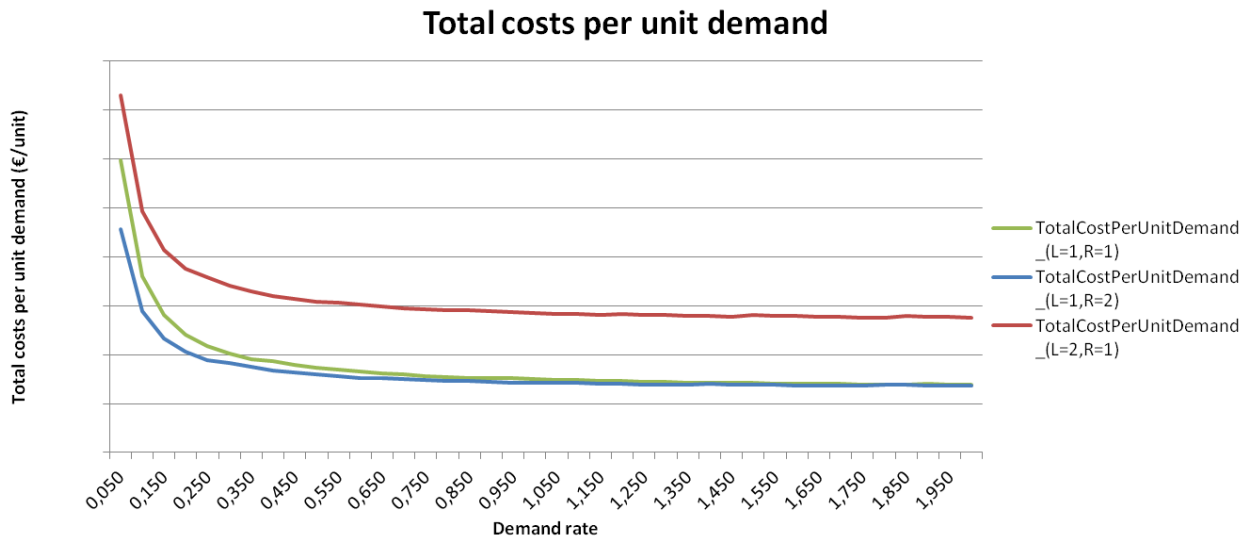
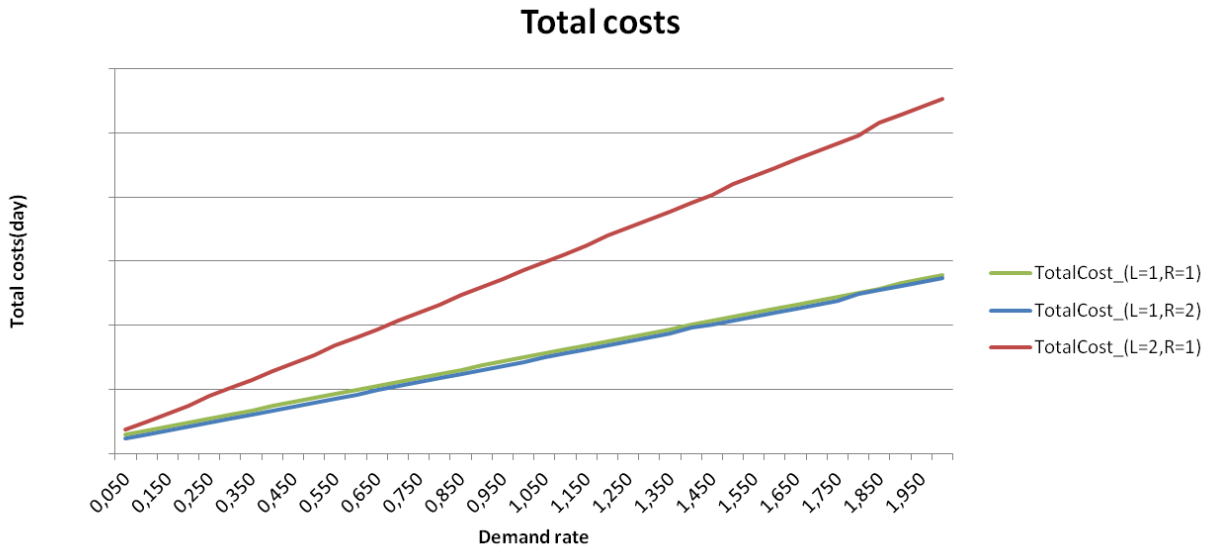
Extra transport/handling cost doubled



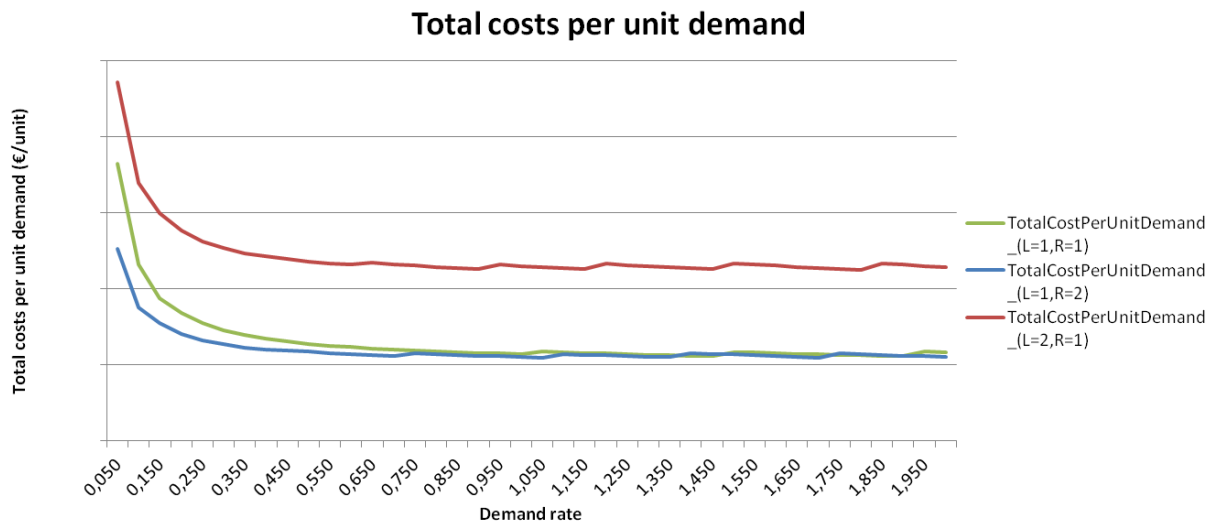
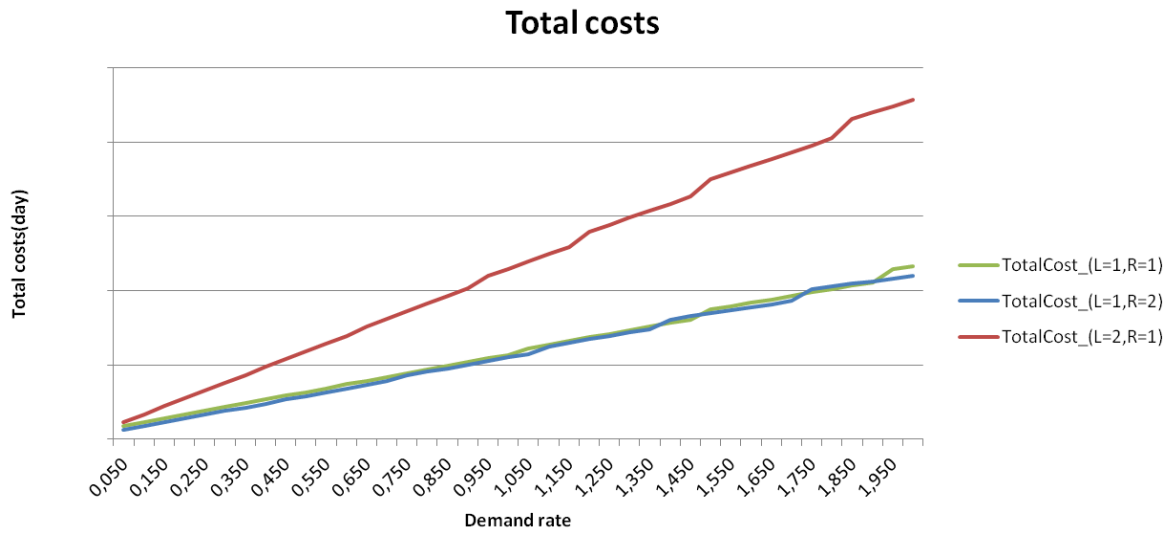
Case pack size = 4 items (shelf space  $4 \times 1.2 \approx 5$ )



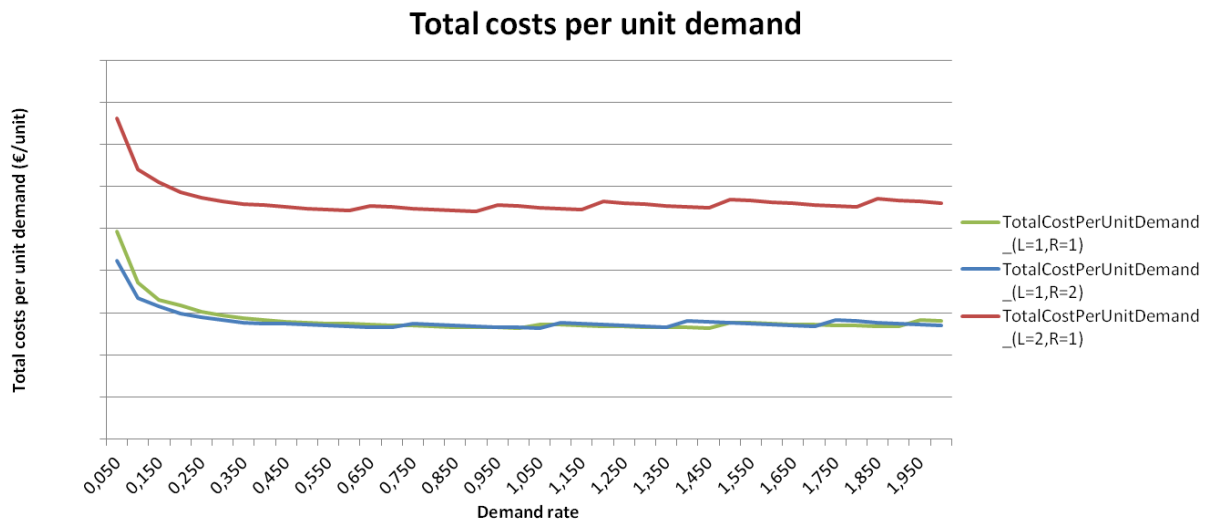
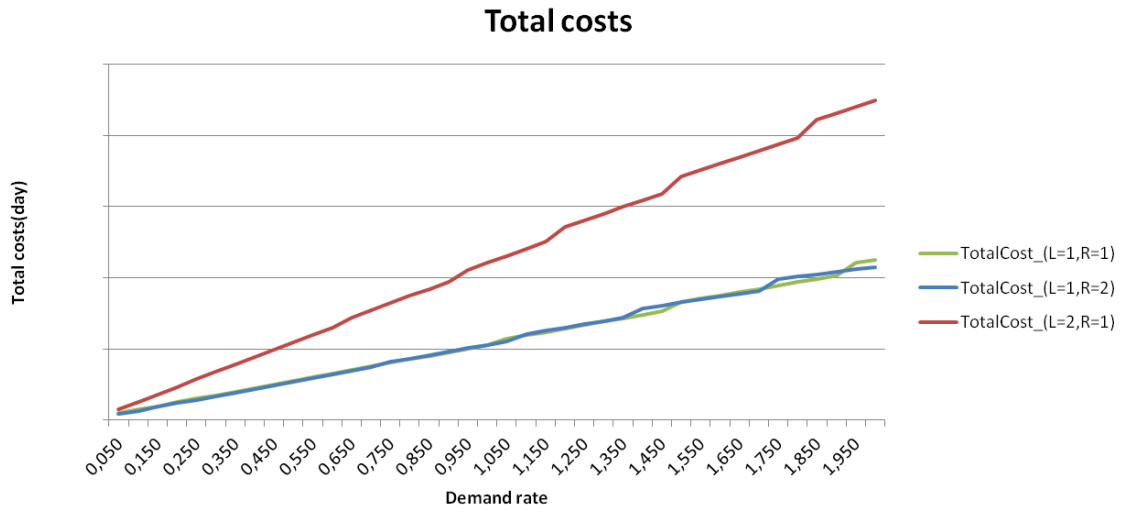
Case pack size = 12 items (shelf space  $12 * 1.2 \approx 15$ )



Walking speed halved

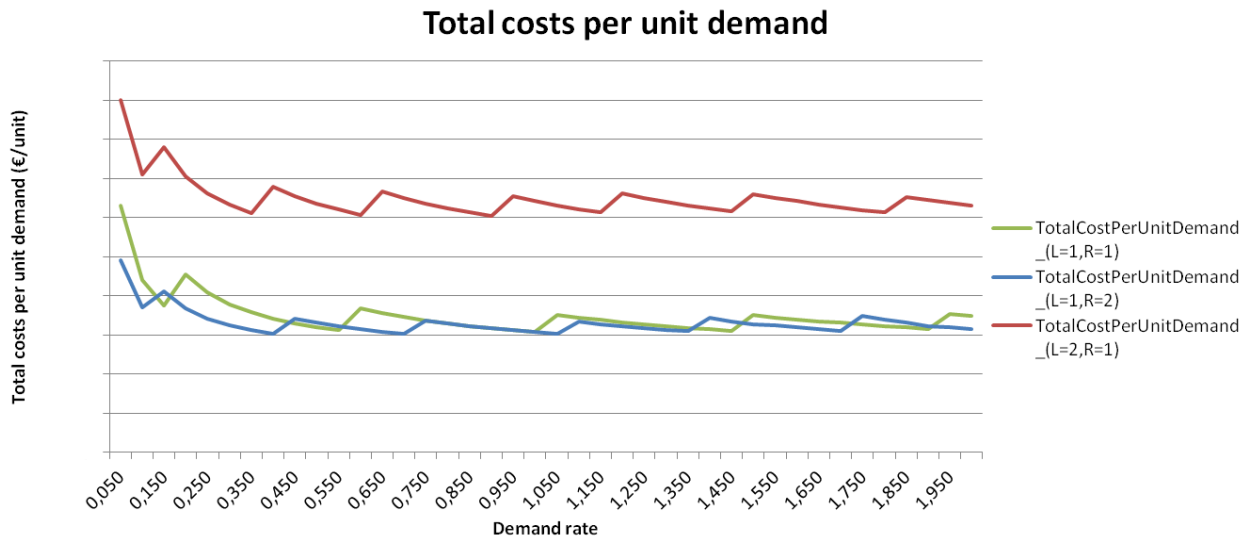
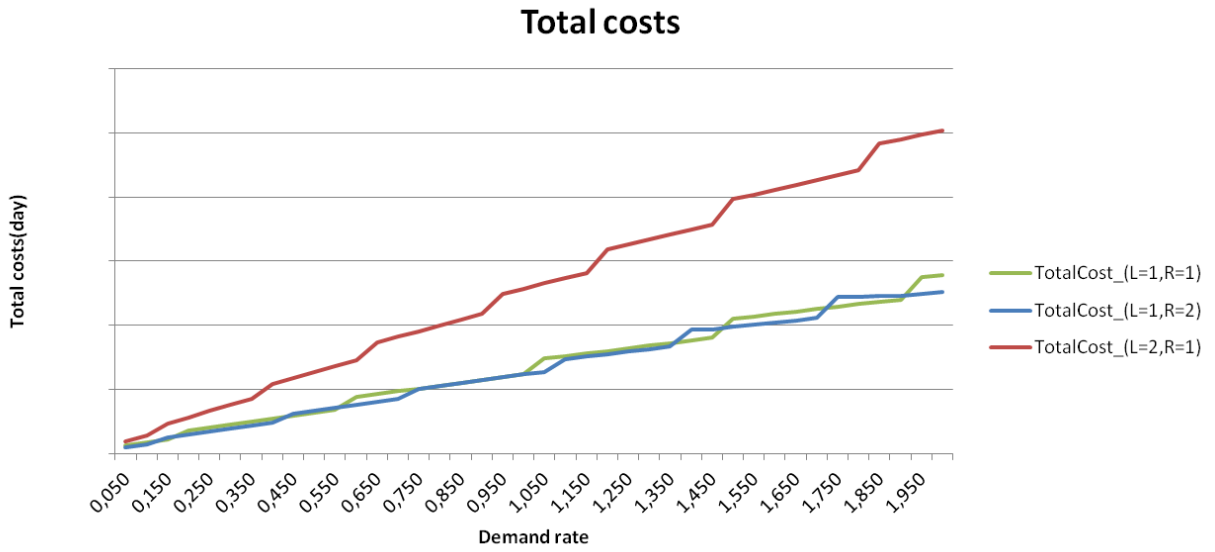


Walking speed doubled

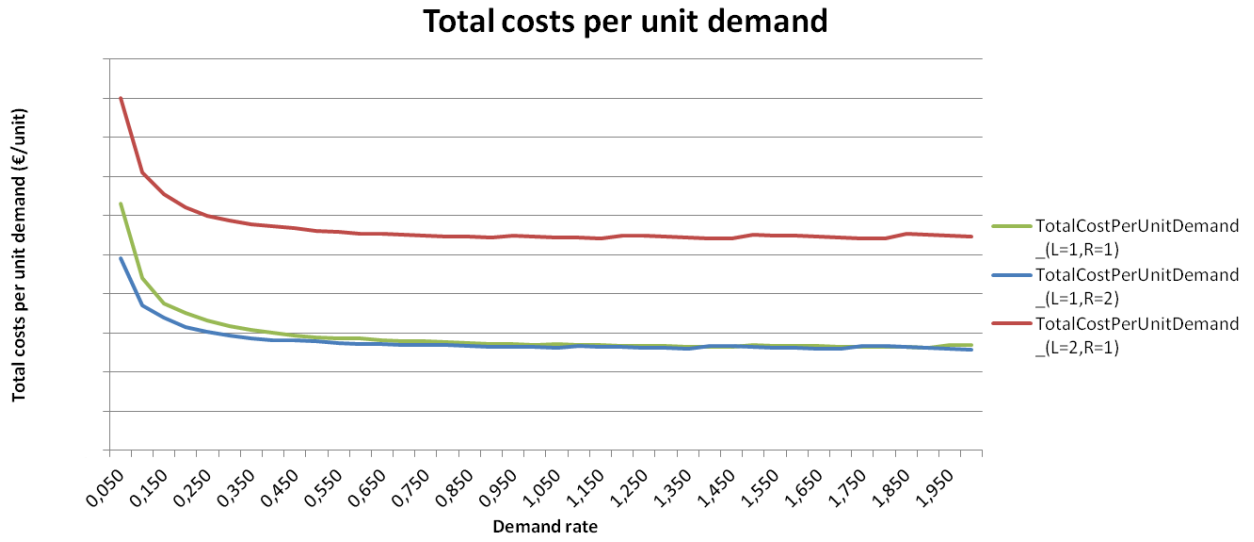
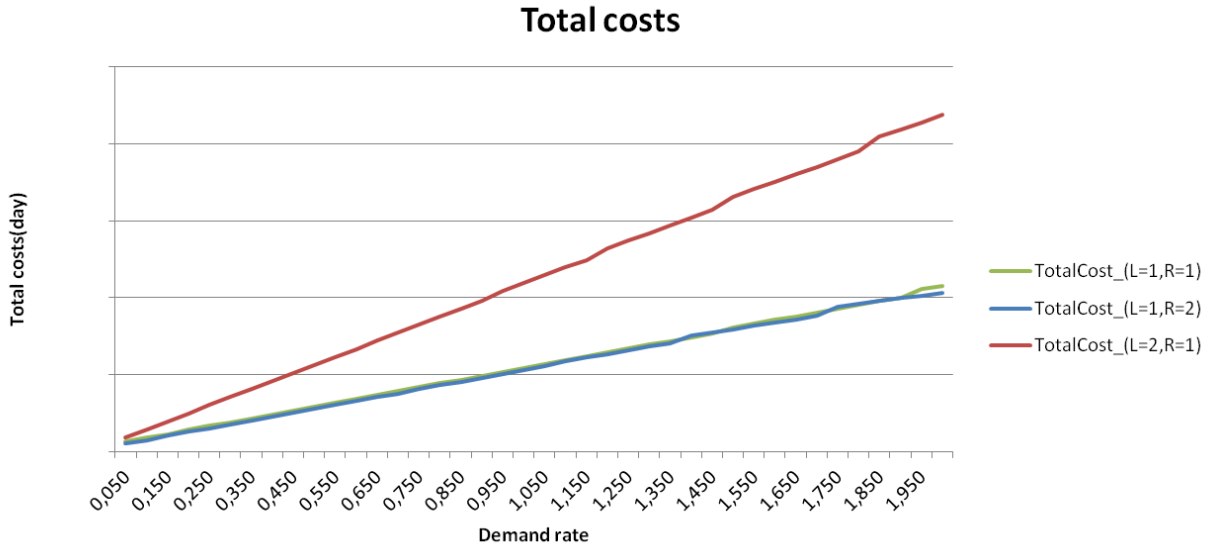




Shelf space ratio = 1 case pack size



Shelf space ratio = 1,4 case pack size



## Appendix J

**Model Summary<sup>e</sup>**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,743 <sup>a</sup>	,552	,552	5,57976914663 7159	
2	,766 <sup>b</sup>	,587	,587	5,36036587620 1778	
3	,778 <sup>c</sup>	,605	,604	5,24375899221 5047	
4	,786 <sup>d</sup>	,618	,617	5,15681016373 0007	1,764

a. Predictors: (Constant), Total Sales

b. Predictors: (Constant), Total Sales, Case Pack Size

c. Predictors: (Constant), Total Sales, Case Pack Size, Stores carrying

d. Predictors: (Constant), Total Sales, Case Pack Size, Stores carrying, Average ESS

e. Dependent Variable: DeltaRed2

**Coefficients<sup>a</sup>**

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
1 (Constant)	2,837	,110		25,805	,000		
Total Sales	-,598	,008	-,743	-75,275	,000	1,000	1,000
2 (Constant)	,300	,167		1,795	,073		
Total Sales	-,648	,008	-,805	-80,528	,000	,899	1,112
Case Pack Size	,305	,016	,196	19,620	,000	,899	1,112
3 (Constant)	-3,957	,338		-11,722	,000		
Total Sales	-,688	,008	-,855	-82,452	,000	,801	1,249
Case Pack Size	,323	,015	,208	21,162	,000	,893	1,120
Stores carrying	,336	,023	,142	14,409	,000	,890	1,124
4 (Constant)	-4,490	,335		-13,415	,000		
Total Sales	-,700	,008	-,870	-84,741	,000	,789	1,267
Case Pack Size	,342	,015	,220	22,690	,000	,884	1,132
Stores carrying	,326	,023	,137	14,208	,000	,889	1,125
Average ESS	,207	,017	,116	12,539	,000	,976	1,025

a. Dependent Variable: DeltaRed2