

## MASTER

### Improving efficiency of the food solutions & out-of-home distribution network of Unilever

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# **Improving efficiency of the Food Solutions & Out-Of-Home distribution network of Unilever**

by

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## ABSTRACT

This thesis focuses on two initiatives that aim to increase the efficiency of the Food Solutions & Out-of-home market of Unilever. First, the concept of centralization is analyzed. Via a sample path evaluation model, logistic efficiency in terms of handling and transportation costs is predicted. This model is applied to predict cost savings for two customers of the Food Solutions & Out-of-home market and is validated using a third customer whose delivery system is recently centralized. Results show that for the two customers analyzed, centralization results in reductions of 24% and 39% in logistic costs. Second, delivery frequencies are analyzed and a model is proposed that predicts yearly logistic cost reductions for a given delivery frequency. The results show that decreasing the delivery frequencies for a selected group of customers can amount to substantial savings in yearly handling and transportation costs.

## PREFACE

This report is the result of a graduation project that has been conducted in completion of the Master Operations Management & Logistics at Eindhoven University of Technology. The project has been carried out at Unilever in Rotterdam from July 2014 till January 2015. I am grateful that I had the possibility to do research within this inspiring company and I would like to thank all the people that have made this project possible. Some people however, deserve some extra attention.

First, I would like to thank dr. Zümbül Atan. Zümbül, I really appreciate all the meetings we had and all the help you offered me. Your professional insights were really helpful, but I also enjoyed the small talk we had. I always left our meetings with great inspiration and motivation. Second, my thanks goes to dr. ir. Rob Broekmeulen. Rob, thank you for your time as second supervisor of this project. I have learned a lot from your feedback and I'm grateful that you shared your in-depth knowledge of this field of research.

Next, I would like to thank my company supervisors: Hedzer Loonstra and Oleg Simic. Hedzer, you were a great mentor to me and you could really bring me back to focus when I lost track. Your experience in logistics and practical insights have helped me so much. Oleg, you helped me especially by putting my research in a managerial perspective. I am also forever grateful that you have put faith in me and offered me a job at Unilever. By also helping me find a new apartment in Rotterdam you have helped me both professionally and personally. Furthermore, I would like to thank all my colleagues at Unilever, the people at Kuehne-Nagel and everyone else who helped me the past six months.

The end of this graduation project is also the end of my student life. Many thanks to the friends I knew before I came to Eindhoven and the friends I met during my studies. I have had a great student life and I will remember my time in Eindhoven as an incredibly happy time. However, none of this would have been possible without my parents and my sister. Their continuing and unconditional love and support throughout these years have got me where I am today.

Teun van Hal

January, 2015

## MANAGEMENT SUMMARY

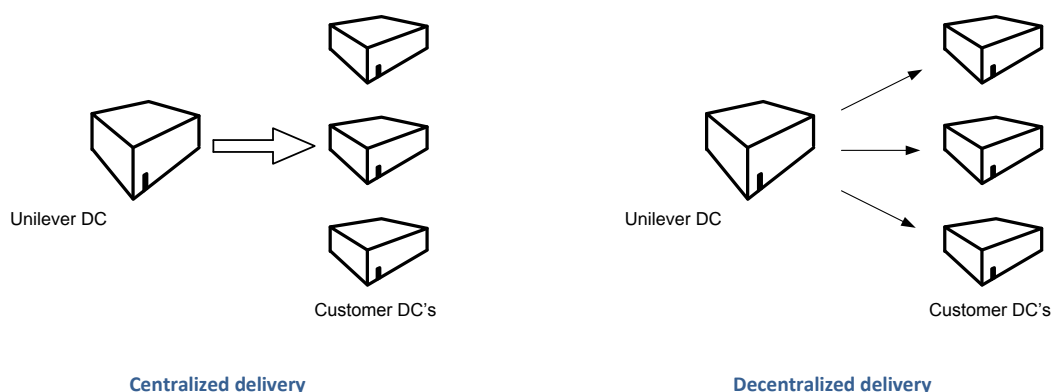
Unilever is a multinational enterprise that produces nutritional, personal care and home care products. It is responsible for production and distribution to many customers. Unilever's customers are split up in customer groups. Two of those groups are significantly different from the other groups: Food Solutions and Out-of-home. Together they are called Channel 21, while the other customer groups together are called Channel 20. Channel 21 differs from Channel 20 in market size: Channel 20 consists of a few large customers and Channel 21 consists of many small customers. Furthermore, logistic efficiency in terms of pallet loading and truck filling is higher in Channel 20. This graduation project is focused on the distribution of products from Unilever distribution centers to the customers of Channel 21.

Qualitative and quantitative analyses show that there is room for efficiency improvement in the distribution system of Unilever's Channel 21 market. Specifically, strategies for improving efficiency in pallet loading and truck filling operations need to be explored. Therefore, the research described in this report is aimed at answering the following research question proposed: *What are the potential cost savings for Unilever if the efficiency of pallet loading and truck capacity utilization in the Food Solutions and Out Of Home market is improved?*

It is decided to analyse two initiatives in detail: centralization and changes in delivery frequency. For these initiatives, the effects on pallet loading efficiency and truck capacity utilization efficiency is analyzed.

### CENTRALIZATION ANALYSIS

For customers who have multiple distribution centers, there are two options in how Unilever transports products to them. For a given customer, products can be delivered centralized or decentralized. Centralized delivery means that products demanded by a customer are transported from Unilever DC's to a single DC of the customer, i.e. to one delivery location (see the left figure below). Decentralized delivery means that products demanded by a customer are transported from Unilever DC's to the customer's DC's separately, i.e. to multiple delivery locations (see the right figure below).



A sample path evaluation model is proposed with which the costs of pallet loading (handling costs) and transportation are calculated and compared. Since centralization is particularly effective if delivery schedules are synchronized, the model is applied by using daily deliveries and by using the aggregated volume over a week. This has resulted in the evaluation of four scenarios: decentralized delivery without delivery schedule synchronization, centralized delivery without delivery schedule synchronization, decentralized delivery with delivery schedule synchronization, and centralized delivery with delivery schedule synchronization.

The centralization analysis is focused on three customers. The first customer centralized their delivery system in the end of 2013 and this case is used to evaluate the predictive accuracy of the model. The results show that the model is accurate in predicting the direct results of centralization, but that efficiency improvements due to other initiatives are (as intended) not taken into account. One of the initiatives was the introduction of financial incentives for ordering in full layers and full pallets. Results show that for the two other customers analyzed, centralization results in about 24% and 39% in yearly logistic cost savings. The results suggest that handling and transportation cost savings are larger at relatively large customers compared to relatively small customers and when demand volumes are spread evenly over the DC's in contrast to when products are already transported to a single DC for the main part. The proposed model can be used to support future centralization analyses.

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## DELIVERY FREQUENCY ANALYSIS

The delivery frequency analysis has resulted in insights about what the changes in handling and transportation costs per customer are if the delivery frequency is changed. Most delivery locations are already not visited frequently (once or less than once per week). For these locations, decrease of delivery frequency yields relatively very small cost savings and thus the focus is on the larger customers who order more often. For these other locations, decreasing the delivery frequency would be an attractive option. It would result in substantial total yearly logistic (handling and transportation) cost reductions by only rounding down the current average frequencies. When delivery frequencies are reduced more (with a minimum of once per week) the savings will be even higher. In theory, delivery frequencies could be decreased to minus infinity, and the costs would always decrease as the delivery frequency decreases. However, Unilever wants to offer some level of flexibility in customers' ordering behavior and obviously products should not reach their best-before dates before they are bought by consumers. This analysis offers insight in this trade-off of costs and service and can be used in future delivery frequency decision-making.

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## 1 INTRODUCTION & RESEARCH QUESTIONS

This first chapter starts with a description of the company background of Unilever in section 1.1. In section 1.2 the supply chain of Unilever is discussed and it includes an introduction to the concept of (de)centralized delivery. A closer look at Unilever's Channel 21 is taken in section 1.3 and in section 1.4 the relevant cost parameters are discussed. In section 1.5 the business problem is explained and in section 1.6 the relevant literature that was investigated in the literature review (van Hal, 2014) is briefly discussed. In section 1.7 the research questions to be answered in this thesis project is presented and section 1.8 is the outline of this report. Most information in this chapter is based on data from Unilever's information system and on interviews with employees from different organizational levels. Due to confidentiality reasons, some data throughout this report such as customer names are omitted. Customers are indicated by Customer 1, 2, 3, and A, B, C, etc.

### 1.1 COMPANY BACKGROUND

Unilever is a multinational enterprise that produces nutritional, personal care and home care products. It has a dual company structure with its corporate centre located in Rotterdam (Unilever N.V.) and London (Unilever PLC). Although Unilever was founded not earlier than 1930, the companies that bundled their power to create the enterprise as we know it today were established before the beginning of the 20th century. Throughout the years, Unilever's brand portfolio has made large developments and nowadays it is with products available in around 190 countries the world's third-largest consumer goods company measured by 2012 revenue, after Procter & Gamble and Nestlé. Unilever has a global workforce of about 175,000 employees and generated a €49.8 billion turnover in 2013 (Unilever, 2013). Unilever's portfolio with over 400 brands ranges from nutritionally balanced foods to indulgent ice creams, affordable soaps, luxurious shampoos and everyday household care products. Unilever produces world-leading brands including Lipton, Knorr, Dove, Axe, Hellmann's and Omo, alongside trusted local names such as Blue Band, Pureit and Suave. All products are divided into four product categories: Foods, Home care (HC), Personal care (PC), and Refreshment.

At Unilever, customers are distinguished from consumers: customers are retailers, catering companies or shops such as Albert Heijn and Jumbo who bring the products further down the supply chain to consumers. Consumers are the ultimate end-users of products, i.e. people who buy the products at a store of a customer. The Dutch customer market of Unilever is segmented in a number of groups (Albert Heijn, SuperUnie, Bijeen and Drug) of which two differ significantly from the other groups. They are called Food Solutions (FS) and Out of Home (OOH). Both serve mostly small customers: FS serves mostly chef-cooks and catering companies and the OOH market consists of other small customers like gas stations, beach pavilions, pubs and snack bars. The OOH market deals solely with products of the brands 'Ola', 'Lipton', and 'Cup-a-Soup'. Together, the FS and OOH groups are called 'Channel 21', whereas the other groups together are called 'Channel 20'. The term 'channel' does not have a specific meaning here. Historically, Unilever was divided in business units and through reorganizations this eventually grew to the two channels that are present now. For financial purposes, it was important to make a distinction between the FS/OOH market and the rest. The two channels including customer groups are presented in Table 1.1

Table 1.1: Channels and customer groups of Unilever

	Customer group	Customers included in group (not extensive)
<b>Channel 20</b>	Albert Heijn	Albert Heijn, Ethos retailers, Bol.com
	SuperUnie	Plus, Coop, Spar retailers
	Bijeen	Jumbo, C1000 retailers
	Drug	Kruidvat, DA retailers
<b>Channel 21 (FS/OOH)</b>	Food Solutions	Chef-cooks, catering companies, food service wholesalers
	Out Of Home	Gas stations, beach pavilions, shops, snackbars

Generally, customers belong to either Channel 20 or Channel 21. However, there are a few exceptions (such as Makro) that partly belong to both markets. This is because the distinction between Channel 20 and Channel 21 is nowadays based on product types and those customers order both kinds of products.

## 1.2 SUPPLY CHAIN

In this section the supply chain of Unilever is explained. First, the different stages of the supply chain are presented in section 1.2.1. After that, the concept of centralized and decentralized delivery is discussed in section 1.2.2.

### 1.2.1 UNILEVER'S SUPPLY CHAIN

The Unilever supply chain considered here starts with the inbound of raw materials at sourcing units that are transformed into products. A product is created in one of the sourcing units in the Netherlands or in one of the sourcing units abroad. Three Unilever sourcing units are located in the Netherlands: Unox (soups, sauces and smoked sausages) in Oss, Ben & Jerry's (ice cream) in Hellendoorn and Blue Band (margarine) and Calvé (peanut butter) in Rotterdam. In the next stage, the product is transported by third party logistics providers (3PLP's) to one of the five Unilever distribution centers (DC's) in the Netherlands or to another DC outside of the Netherlands. There are four DC's located in the Netherlands: Veghel, Raamsdonksveer, Bergen op Zoom and Zeewolde. Each DC is responsible for one or more of Unilever's product categories: the Foods products for the Netherlands are stored in and transported from Veghel, HC and PC in Raamsdonksveer, Ice Cream products in Bergen op Zoom and Refreshment in Zeewolde. This transport flow is called the primary transport flow. The DC's storage spaces are hired by Unilever from 3PLP's together with their transportation services. In the Unilever DC's, the 3PLP's provide storage for goods, take care of order picking and prepare products for transportation. Also, some repackaging may take place. This means that the packaging of one or more products is changed to form new products or to change the number of products per box. For example, in Raamsdonksveer, a shower gel of a certain brand is repacked with a deodorant of the same brand to a new gift package. The 3PLP's serve Unilever and assign costs to their services. These costs are based on activities in the warehouse and on transportation. Next, a 3PLP transports the product from the Unilever DC to the customer DC's. This part is called the secondary transport flow. Hereafter, the product is distributed to shops, restaurants or catering bureaus and ultimately picked up and consumed by a consumer. An important 3PLP for Unilever is Kuehne + Nagel (K+N), which is responsible for the HPC DC in Raamsdonksveer and the

Foods DC in Veghel. Figure 1.1 shows a schematic overview of the Unilever supply chain just described.

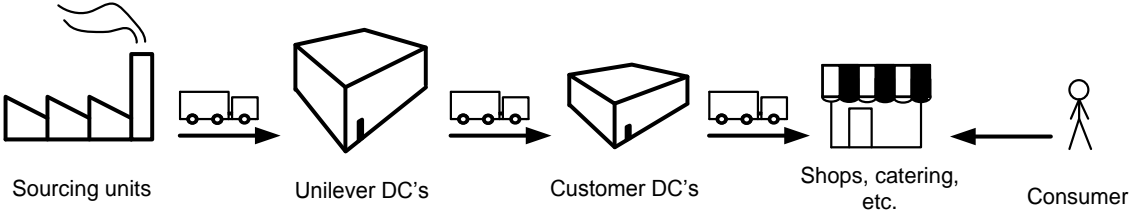


Figure 1.1: Schematic overview of Unilever's supply chain

1.2.2 (DE)CENTRALIZED DELIVERY

Many customers of Unilever, especially those with large demands, have multiple DC's. For example, in Channel 21 there are customers that have about 14 DC's. This means that there is a practical difference between customers and delivery locations. Every customer has one or more delivery locations. For customers who have multiple DC's, there are two options in how Unilever transports products to them. For a given customer, products can be delivered centralized or decentralized. Centralized delivery means that products demanded by a customer are transported from Unilever DC's to a single DC of the customer, i.e. to one delivery location (see Figure 1.2). It is then up to the customer how the supply chain continues (for example, by transshipments to other DC's). Decentralized delivery means that products demanded by a customer are transported from Unilever DC's to the customer's DC's separately, i.e. to multiple delivery locations (see Figure 1.3).

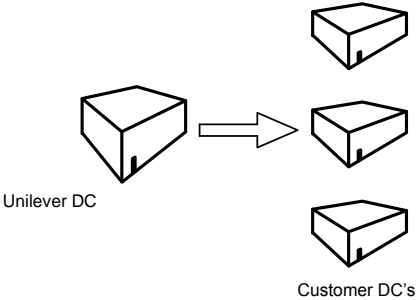


Figure 1.2: Centralized delivery

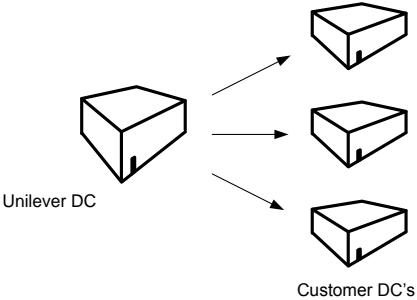


Figure 1.3: Decentralized delivery

Most customers in Channel 21 have only one delivery location and mainly large customers have multiple DC's. For example, Sligro's delivery system is fully centralized. Other customers have only a large part of their products going through one DC and the rest through several smaller DC's.

## 1.3 CHANNEL 21

In this section, Channel 21 is discussed in more detail and compared to Channel 20. Channel 21 is significantly different from Channel 20. Three relevant, inter-related differences concern the market size, pallet loading operations and truck filling operations and they are explained in sections 1.3.1, 1.3.2, and 1.3.3 respectively.

### 1.3.1 MARKET SIZE

The first difference between Channel 20 and Channel 21 concerns the market size, i.e. the number of customers and the total demand volumes delivered. Whereas the Channel 20 market mostly consists of large (groups of) retailers, Channel 21 serves many small customers. Channel 20 and Channel 21 consist of about 40 and 400 customers respectively, but as Figure B.1 in Appendix B indicates, Channel 21 is responsible for 92% of the customers, but for only 14% of the volume. This difference is inherent to the nature of the two markets. Channel 20 is mainly about large retail customers who ultimately serve many consumers, while Channel 21 contains small customers like beach pavilions and gas stations that ultimately serve relatively low numbers of consumers. To take a closer look on Channel 21's customer base, the largest customers are identified. Using a 50-50 percentage rule of thumb, the four largest customers are identified. They are responsible for about half of the total delivered volume in pallet equivalents within the FS/OOH market (see Figure B.2 in Appendix B). As these four largest customers make up for about 50% of the total demand volume of the FS/OOH market, the other half is accounted for by almost 400 customers. This latter part of the customer base attributes to a mere 3% of Unilever's total demand volume in the Netherlands and is called the 'tail' of the FS/OOH market. Figure B.3 in Appendix B gives more insight in the difference between the four largest customers and the tail. It is a part of the graph that depicts the demand volumes per customer sorted from small to large customers.

### 1.3.2 PALLET LOADING OPERATIONS

The second difference between the Channel 20 and Channel 21 markets concerns pallet loading operations. The pallet loading is about how products are put on pallets and this is dependent of order quantities in terms of full pallets, full layers and individual boxes. Normally, a customer sends an order, which is received by Unilever, processed and sent to the relevant 3PLP who plans the order for picking and transportation. Which 3PLP it is, depends on the type of product as products from different product categories are located in different Unilever DC's. Each Unilever DC is managed by a 3PLP. For example, all products from the Foods category are stored in and transported from the Unilever DC in Veghel which is managed by K+N. Usually, orders have a lead time of 24 or 48 hours. That is, all products that are ordered before a certain time will be delivered at a customers' delivery location within the next 24 or 48 hours. A delivery schedule is made in consultation with Unilever and finally the order (or a part of it) is delivered. In principle, order quantities are equal to delivered quantities. However, discrepancies between the ordered quantity and the delivered quantity may arise due to out-of-stock situations at either the Unilever sourcing units or the Unilever DC's. In 2013, the amount delivered deviated less than 0.5% on average from the quantity ordered.



As mentioned in section 1.2, a 3PLP is responsible for order picking and preparation of products for transportation at the DC too. All products are transported on pallets. When picking the orders in the Unilever DC's, it is key to create full pallets of products in order to minimize the handling effort. Pallets consist of layers that consist of individual boxes. It depends on the type of product and on the customer's requirements how many boxes are in one layer and how many layers are on one pallet. For example, the customer's requirements may dictate that a pallet may not be taller than 1.50 meters because of storage limitations in the customer's DC. When a pallet is prepared for transport at a Unilever DC, it can consist of one or multiple different products. For example, a pallet can consist of two full layers of 'Lipton forest fruits tea' products and four full layers of 'Lipton peppermint tea' products, it can be a full pallet of only 'Lipton forest fruits tea' products or it can consist of all kinds of different products. In theory, all kinds of combinations are possible but obviously they come with different costs associated. As the products that are coming from the Unilever sourcing units are transported to Unilever DC's in full pallets of one type of product, it will take the least handling effort to pick an order quantity that is exactly equal to one full pallet. It can just pass through as in a transport hub with possibly no human touch involved. When an order quantity is equal to one or more full layers, it will take more handling effort to pick an order. In some Unilever DC's such as the Foods DC in Veghel, this is automated too through means of a so-called 'automatic layer picker' (ALP). But as layers need to be picked from full pallets coming from Unilever sourcing units and combined with layers of other full pallets coming from Unilever sourcing units, it requires more handling effort. When an order quantity consists of only a few boxes, manual picking is involved which requires the most effort. The more handling effort involved, the higher the cost for the 3PLP and thus more logistic costs for Unilever.

Obviously, Unilever's supply chain management wants to reduce costs (while keeping the same service) and thus it is preferable to have as much order quantities that are equal (or close) to an integer number of full pallets as possible, or else as much order quantities that are equal (or close) to an integer number of full layers as possible. It is preferable to avoid individual box picking. This is why Unilever, in special cases (for example when the way of supplying a customer changes from decentralized to a centralized) use financial incentives to stimulate this. It will ensure that customers are motivated to order in full pallet quantities or in full layer quantities and discourages them to order individual boxes. As shown in Figure B.4 in Appendix B, there's a noticeable difference between Channel 20 and Channel 21 in the number of full pallets, full layers and individual boxes that are delivered. Whereas 74% of the products in Channel 20 is delivered in full pallets, only 58% of the products in Channel 21 is delivered in full pallets. Furthermore, instead of 2% in Channel 20, 12% of the products in Channel 21 are delivered in individual boxes.

In theory, a customer can order the amounts of products that they desire. In practice however, Unilever has influence on this. For example by offering financial rewards customers are persuaded to order only in numbers of full pallets and full layers. Moreover, by introducing ordering standards, Unilever can reject orders that do not comply with the standards. As mentioned before, the market size and the way pallets are loaded are interrelated factors. In general, for large customers it is economically more attractive to round their order size up to an integer level of full pallets than for small customers. This is because the difference between the actual needed order size and the rounded number is small relative to the size of the order, and they are better able to sell those differences. Therefore, since the customers in the Channel 20 market are on average a lot larger than in the Channel 21 market, it is for them, in general, economically more attractive to order in exact

full pallets. This explains that there are relatively more full pallets ordered in the Channel 20 market than in the Channel 21 market.

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### 1.3.3 TRUCK FILLING OPERATIONS

The third difference between Channel 20 and Channel 21 concerns the transportation of products from Unilever DC's to the customer DC's, i.e. the secondary transport flow. Specifically, what characterizes the difference is the order size of customers in terms of pallets per truck. Truck capacity ranges from 26 to 33 pallets, depending on the size of the pallets. Given the number of pallets in a truck, a truck can be characterized as full, half full, quarter full and less than a quarter full. As Figure B.5 in Appendix B shows, 38% of the orders in Channel 21 have the size of full truck loads (FTL's) while the percentage of full truck loads in Channel 20 is 75%. Furthermore, where the percentage of half truck loads (HTL's) is equal across the two channels, there are relatively more quarter truck loads (QTL's) in Channel 21 and a lot more orders that fill the truck for less than a quarter (LTQTL's). Note that this does not mean that only 38% of the trucks in Channel 21 are full. Different orders are planned into routes by 3PLP's so that truck capacity utilization is eventually optimized. However, since the costs of transportation depends on order sizes (see 1.4.2) it is important for Unilever to receive orders that are large in terms of pallets so that truck filling is efficient. It would be ideal to only have FTL's. However, as Figure B.5 in Appendix B shows, Channel 21 is far from this situation. The situation where 100% of the orders are delivered in FTL's is not very likely to happen, but this chart suggests that at least some improvement is possible. Obviously, market size and truck filling operations are related concepts. The larger the customers, the more pallets they order and the easier it is for them to round their order size up to FTL's. This is why truck filling in Channel 20 is more efficient (more FTL's and less LTQTL's) than in Channel 21.

## 1.4 RELEVANT COST PARAMETERS (K+N)

As discussed in section 1.2.1, 3PLP's manage Unilever DC's, take care of order picking, and provide transportation within the secondary transport flow. They bill Unilever for those services. Since the scope of this project is limited to the Unilever Foods DC in Veghel (see section 1.7.2), K+N is the only relevant 3PLP in this thesis. In the following sections the tariffs for warehousing and transportation operations at K+N are presented.

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### 1.4.1 WAREHOUSING TARIFFS

At K+N, there are 4 types of warehousing tariffs: 'handling in', 'storage', 'label', and 'handling out'. The costs based on these tariffs are calculated per week. 'Handling in' costs are assigned to every pallet that comes from a sourcing unit and enters the DC. Pallets can enter the DC manually or automatically. When pallets enter automatically, conveyor belts inside the truck move the pallets into the DC. 'Storage costs' are costs assigned to all pallets that are stored. It depends on the type of product whether it is stored chilled or stored normally. Every pallet that comes out of a sourcing unit and enters the DC is provided with a label with information. When something is wrong with that

label, 'label costs' are incurred. In 2013, no label costs have been charged for FS/OOH products. 'Handling out' costs are assigned to everything that leaves the DC. As discussed in section 1.3.2, this can be done through full pallets, the ALP or manual box picking.

As the order size is an important concept in this research project and strongly relates to delivery frequencies, it is important to know what kind of costs are influenced by this. Therefore, a distinction is made between costs that are dependent of the delivery frequency and costs that are independent of the delivery frequency. 'Handling in' costs are independent of delivery frequencies. This is because, given the total demand of a product, it doesn't matter in what quantities it will leave the DC: the number of pallets that enter the DC will always be the same.

Storage costs are based on the maximum number of pallets stored in a week. One might think that delivery frequencies have an influence on this. After all, by changing the delivery frequency at the customers, you change the demand at the Unilever DC which in turn has an effect on inventory levels. However, this will not be taken into account in this thesis. Based on interviews with Unilever employees, this effect is expected to be negligible. This is because of several reasons. First, the amounts that are transported to FS/OOH customers are very small compared to the total numbers of products that are stored in the Veghel DC. This means that changes in the delivery frequency for Channel 21 customers also have a limited effect on the maximum number of pallets stored in a week. Second, and this is related to the first reason, the volumes that enter the Veghel DC follow the production quantities in the factories. These production quantities are also very large compared to what leaves the Veghel DC. So again, the effect of different delivery frequencies on the stock is very limited.

The 'handling out' costs are definitely dependent of delivery frequencies. If the delivery frequency changes, the numbers of full pallets, full layers and individual boxes that leave the DC changes. For example: say that customer X orders product A with a certain frequency. If the delivery frequency for customer X is decreased, the quantity per delivery of product A is increased. Even though the total quantity per week does not change, the composition of full pallets, full layers and individual boxes might. Because of the decrease in delivery frequency of customer X, product A might leave the DC more in full pallets and full layers and less in individual boxes and thus reduce costs.

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#### 1.4.2 TRANSPORTATION TARIFFS

The transportation costs billed by K+N are based on order sizes in terms of truck filling. Mainly, two different types of pallets are distinguished: industrial pallets and euro-pallets. Industrial pallets are sized 120cm x 100cm and euro-pallets are sized 120cm x 80cm. This means that more euro-pallets fit in a truck than industrial pallets. Specifically, 33 euro-pallets and 26 industrial pallets fit in a regular sized truck used by K+N. The curve of K+N's transportation tariffs per pallet are shown in Figure 1.4. Due to confidentiality reasons, the real cost figures are omitted. The difference in pallet size is noticeable where if the number of pallets in a truck exceeds 26, there is no cost value for industrial pallets and when it exceeds 33, there is no cost value for euro-pallets. The chart indicates that as the number of pallets in a truck increases, the cost per pallet decreases. The convex shapes also indicate that increasing the number of pallets yields the biggest savings at low numbers of pallets.

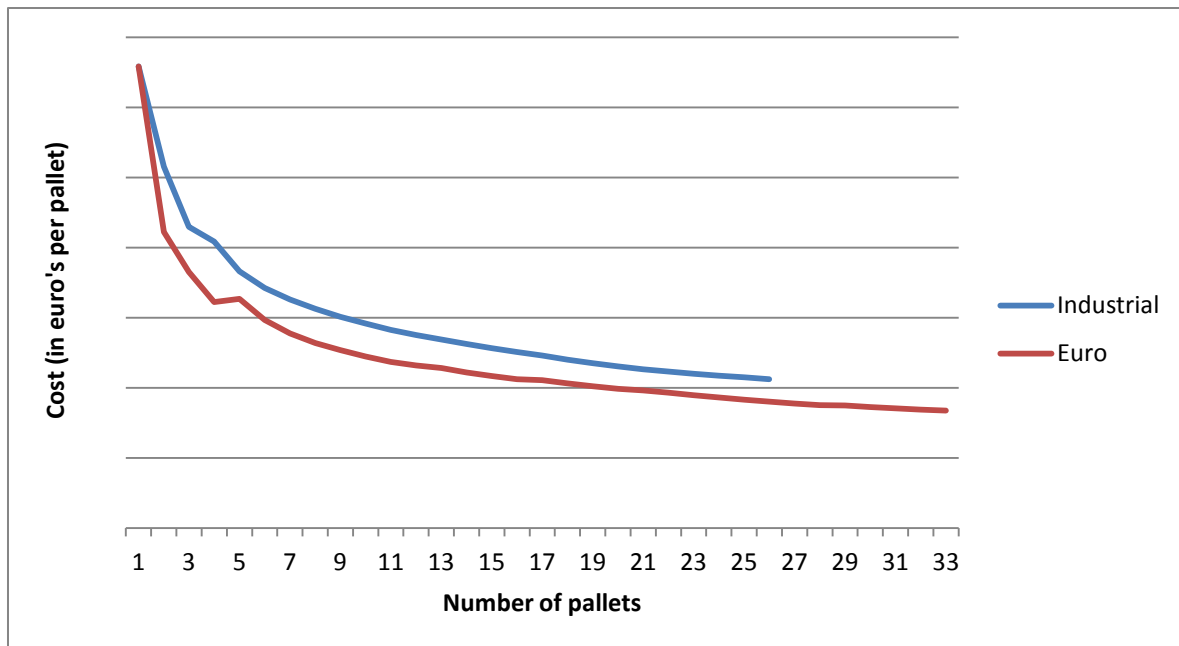


Figure 1.4: Transportation costs at K+N per industrial and euro-pallet

## 1.5 PROBLEM STATEMENT

The problem statement is based on both qualitative as quantitative data analysis. The findings coming from qualitative analysis are presented in section 1.5.1 and the quantitative information is discussed in section 1.5.2.

### 1.5.1 QUALITATIVE DATA ANALYSIS

The problem description as stated in this section is based on interviews with several Unilever employees that are active in the FS/OOH department and in the logistics department of Unilever as with K+N employees that are involved in managing warehousing and transportation operations. The main problem that comes forward from this qualitative data is that the system of warehousing and transportation in the distribution network of the FS/OOH market is inefficient.

Since Unilever operates globally, supply chain management in the Netherlands is dependent of Unilever's European and global strategies. However, specific national supply chain knowledge and models are required too because of, for example, differences in customers. Thus, the way the Dutch Unilever supply chain is managed is an interplay between modern European supply chain management and more country-specific models. One of the noticeable trends in European management is the need for increased efficiency in logistic operations. This management trend can be seen as one of the causes of this research project.

During recent years, more and more customers were added to Unilever's Channel 21 customer base. As the customer base changed, more locations were added to the distribution network which made it more complex. The logistic distribution network has been updated insufficiently which has caused

inefficiencies to arise. This problem has two relevant aspects. On the one hand, there is inefficiency in warehousing operations and on the other hand there is inefficiency in transportation. Inefficiency in warehousing means that there is potential for improvement in terms of pallet loading operations as described in section 1.3.2. Inefficiency in transportation means that there is potential for improvement in terms of truck filling operations as described in section 1.3.3.

The problem can be divided in the following two sub-problems:

**(De)centralized delivery:** for most of the Channel 21 customers, products are delivered via one DC. However, there are customers with many DC's. For a long time, Customer A was supplied through 15 DC's (i.e. 15 delivery locations). Customer A changed its delivery system from decentralized to fully centralized (except for ice cream products) in the fourth quarter of 2013. It is unclear how this exactly changed the efficiency of the distribution network. Furthermore, for Customer B about 20% of the products are delivered decentralized now. It is an option to change this to a fully centralized delivery system, but there is a lack of insight in how this would affect the efficiency of the distribution network. Given the size of Customer B, centralized delivery is an option that needs to be explored. Logic dictates that when all other things are considered equal, going from decentralized to centralized delivery will never increase costs. Thus, the question is not whether Unilever will benefit from centralized delivery, but rather how much they will benefit.

**Delivery frequencies:** as explained in section 1.3.3, products can be delivered in quantities of full pallets, full layers and individual boxes which are loaded into trucks which will then be full, half full, full for a quarter, or less than a quarter. For Unilever it would be ideal to deliver all products in full pallets and full trucks, so that no manual picking is involved and both warehousing costs and transportation costs are minimized. At the moment, Unilever management feels that this is happening insufficiently for the FS/OOH market. Especially compared to the Channel 20 market, customers in Channel 21 order a lot of individual boxes and not much full pallets. As an example to illustrate inefficiency in the distribution network, imagine a customer that orders twelve boxes of product X every Monday, Wednesday and Saturday. Let's say that 36 boxes of product X fit on one pallet. Unilever has contracts with its customers which usually ensure a 48 hour delivery. So, products are delivered every Wednesday, Friday and Monday. Instead of supplying this customer three times a week, Unilever (of course after consultation with the customer) could also supply it once week. This would mean that the customer would order  $12 * 3 = 36$  boxes every week which would perfectly fit exactly one pallet. This would reduce warehousing and transportation costs for Unilever. However, at the moment it is unclear for Unilever what those benefits would be. Of course, this is an oversimplified example and does not include all the snags of this distribution system. On a larger scale, there is a need to investigate these kind of decisions, what would be the potential gains and what are ways to increase these potential gains.

The two sub-problems mentioned above are interrelated because centralized delivery will probably result in more flexibility and potential for delivering in full pallets and full trucks. Both sub-problems are aimed at improving efficiency in the distribution network of Channel 21.

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## 1.5.2 QUANTITATIVE DATA ANALYSIS

As a quantitative data analysis, a brief estimation is made of the potential cost reductions for warehousing and transportation operations. The scope of this thesis is constrained to the Foods DC located in Veghel (see section 1.7.2). Therefore, the following quantitative analysis only covers that part of Unilever's Channel 21 data. Since the DC in Veghel is fully controlled by K+N, no data of other 3PLP's is included.

To start, the delivered quantities in number of pallet equivalents coming from the Foods DC in Veghel are determined for the four customers with the largest volumes of Channel 21 in the last quarter of 2013 and the first three quarters of 2014, and in the year before that. Since most of the volume that is delivered to one of these customers comes from other DC's than the DC in Veghel, it is not considered as one of the largest customers anymore. Therefore, only Customer 1, 2 and 3 are considered as the large customers in Channel 21. All other customers are taken together here and represented as the tail. The tail accounts for about half (47%) of the total volume. Furthermore, despite a small decrease in demand of the tail, there is a small increase of 3% in total Channel 21 demand compared to the year before. In total, K+N Veghel serves about 340 customers spread over about 440 delivery locations. In sections 1.5.2.1 and 1.5.2.2 estimations are made for the potential savings that can be realized in warehousing and transportation operations respectively.

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### 1.5.2.1 SAVINGS POTENTIAL ESTIMATION: WAREHOUSING

First, an indication is made of what efficiency improvement in warehouse operations can be expected. This is done by estimating the decrease in costs that is caused when all individual box picking would stop and all products would be delivered in full layers or full pallets. Figure C.1 in Appendix C shows how the products for the largest customers and the tail of Channel 21 are delivered in terms of full pallets, full layers and individual cases. Figure C.1 shows that of the three largest customers, Customer 1 has the highest percentage of products delivered in full pallets and the smallest percentage delivered as individual boxes. Most of Customer 2's and Customer 3's products are delivered in full layers. In total, 45% of the products delivered from the Foods DC in Channel 21 is delivered in full pallets, 37% of the products are delivered in full layers and the rest is delivered as individual boxes. When looking at the percentages of individual boxes, the reasoning that delivery locations with relatively large demands are better able to order in full pallets and full layers seems confirmed.

The cost parameters explained in section 1.4.1 are used in combination with Channel 21 demand figures from the last quarter of 2013 and the first three quarters of 2014. A hypothetical situation is considered where every customer's yearly demand is split up 50-50 in full pallets and full layers. This results in an estimation of how much potentially can be saved. This is shown in Figure C.2 in Appendix C. Due to confidentiality reasons, exact figures are omitted, but potential savings are substantial. This is due to the high number of individual boxes in the tail of the Channel 21 market. Notice that in this hypothetical situation Customer 1 would have a negative savings figure. This is because Customer 1 already has much of their products supplied in full pallets and full layers: the current situation is better for Customer 1.

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### 1.5.2.2 SAVINGS POTENTIAL ESTIMATION: TRANSPORTATION

Second, an indication is made of what efficiency improvement in transportation operations can be expected. This is done by calculating the potential savings per pallet and multiply them by the number of pallets that are to be saved by more efficient truck filling. To simulate this effect, a hypothetical situation is considered where all deliveries are larger than a LTQTL. Assuming that all LTQTL's are combined into QTL's and that the demand volumes remain unchanged in the future, the potential future are as shown in Figure C.3 in Appendix C Due to confidentiality reasons, exact figures are omitted, but the estimated potential savings are substantial: about five times larger than those estimated in the previous section. Of the total transportation cost savings, 76% is accounted for by the tail. As discussed before, this tail consists of many customers that have small demand volumes, so it makes sense that the biggest savings come from that part of the market. Since the large customers have large demands, they don't account for many LTQTL's to begin with.

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### 1.5.3 CONCLUSION OF PROBLEM STATEMENT

In conclusion, both qualitative as quantitative data analyses suggest that there is a need for analysis of the efficiency of the Channel 21 distribution network. Due to the lack of insight in the warehousing and transportation operations, it is difficult to assess the potential gains and what should be done to obtain them. Central to such an analysis are the investigation of the centralization at customers such as Customer A and Customer B and delivery frequencies. The results of the savings calculations discussed in sections 1.5.2.1 and 1.5.2.2 suggest that investigating improvement possibilities in the Channel 21 warehousing and transportation operations in more detail can result in promising cost savings. Note that the hypothetical situations considered to estimate potential cost savings do not perfectly fit reality. For example, for the calculation of the potential warehousing cost savings, it is assumed that it is possible to handle every individual box through the ALP. However, not all products are suitable for the ALP. Also, it is unrealistic to assume that every customer is able to receive larger quantities. For example, imagine a customer that usually orders 1 box of a product per week. Let's say that 20 boxes fit in one layer. This would mean that if no individual boxes are allowed, this customer would have to order 20 boxes every 20 weeks or find another way to increase the order size. The question is whether it is reasonable to ask this of a Customer and to what degree Unilever can impose measures like centralization. The customer might simply not have the capacity to order this quantity at once. He/she may encounter problems in terms of storing space capacity or financial means. Another constraining factor might be the 'best before date' of a product. This is the final date by which a product's flavor or quality is best. Even though products may still be enjoyed after this date, Unilever obviously does not want to design their supply chain in a way where products pass the best before date when they are in inventory. These and other factors may have an effect on the real potential savings. During this research project, other, unforeseen constraints might be discovered that limit the real savings. Thus, it cannot be stressed enough that the previous savings calculations are mere estimations and that real savings will most probably turn out different. In conclusion, the data analyses suggest that the system of warehousing and transportation operations is not optimized and that there is a need for creating more insight in this subject. This problem statement leads to the research question and sub-questions of this thesis which are formulated in section 1.7.

## 1.6 LITERATURE REVIEW

In this section the parts from the literature review (see Van Hal, 2014) that are most relevant for this thesis are discussed.

To apply Mentzer et al.'s framework (2001), Unilever can be characterized as a member in an ultimate supply chain. Unilever has customers who, in turn, have customers too. Unilever's customers are retailers but the ultimate customers are people who use the products. Thus, Unilever delivers service at both customers and consumers and it is important to realize what actions impact what kind of service. In addition, there are well established partnerships with several third party logistics providers who each have their own responsibilities in terms of distribution centers and product categories. To put it in terms of Huang, Lau and Mak's (2003) classification, Unilever is part of a network-structured supply chain.

Other master students have studied Unilever's supply chain too. Post (1999) has looked at BestFoods Benelux BV's distribution chain from the moment that products leave the factory until the moment they arrive at the customer (primary and secondary transport flow) to see if customers could order less in individual boxes and what can be altered with regard to the units of order. Post focused on the same DC as the one in this research project. The main result is the introduction of a new order unit, namely half a pallet. This means that between storage and the loading of products on trucks, a pallet division machine is installed that splits pallets in half. Through simulation it is calculated that this would result in a cost reduction between 150.000 and 450.000 Dutch guilders.

In Mos's thesis (2002) two problems are addressed: efficiency in the supply chain in terms of order quantities and time pressure in DC's. It is focused on the same DC as in Post's thesis and in this thesis. The picking workload at the DC was mainly determined by the processing unit (full pallet, full layer or individual box). The smaller the processed unit, the lower the productivity and the higher the workload. Mos (2002) ascertains that a lot of handling effort is caused because customers order on the basis of their own inventory position, without taking into account the pallet loading. This results in the handling of many individual boxes, which decreases productivity and efficiency. The workload can be reduced if order quantities are adapted to fit large process units as much as possible, for example full pallets. Also, when a pallet contains many individual boxes, the probability of breaking and damaging of products increases. So, not only the productivity can be increased, the changing of order quantities would also cause an increase in quality. It will also result in improvements in checking time and goods reception at customers. Through simulations, several scenarios in which the type of order reception, the delivery lead time, the option of working ahead, and the degree of large process units (without individual boxes/only full pallets) are varied, are evaluated. The main results of the thesis are presented in Table 1.2. In line with expectations, the costs of the scenarios where only full pallets are ordered are by far the lowest. However, the costs of the scenarios without individual boxes are higher than the current order flow. This is explained by the fact that apparently the workload has risen due to a correction in the order flow. This correction was made in the simulation by deleting all orders that consisted of individual boxes and adding a layer to the orders that consist of layers and/or pallets. Nowadays, the concerning DC is owned and managed by Kuehne-Nagel and the way of handling orders is different from when this master thesis is executed (for example, an ALP is in use now).



Table 1.2: Comparison of costs (indices) at different order flows (Mos, 2002)

Order flow	Order reception	Batch				Flow			
	Delivery lead time	48 hours		24 hours		48 hours		24 hours	
	Work ahead	No	Yes	No	Yes	No	Yes	No	Yes
<b>Current order flow</b>		100	100	111	108	105	100	136	108
<b>Order flow without individual boxes</b>		113	113	125	122	117	112	122	121
<b>Order flow with only full pallets</b>		26	-	26	-	26	-	26	-

Although Post's and Mos's theses are not recent and do not fully reflect current operations, the core of the problem of inefficiency at the DC is captured well and the potential solution strategies are interesting at the least. Both works recognize that there is room for improvement in terms of pallet loading (i.e. more full pallets and less individual boxes). The results give a basic overview of the behavior of flows and potential cost savings after elimination of individual box order sizes. Next to DC operations, it is important how customer ordering behavior affects warehouse operations for this research project. As De Koster et al. (2006) indicated, there is a gap between practice and academic research in this area, this research project might be able to fill up a small part of this gap.

An important choice concerning supply chain design and the reduction of costs and increase of customer service is the choice of decentralized versus centralized delivery systems. Common intuition suggests that due to the risk pooling effect, centralization will reduce total inventory costs. Das and Tyagi (1997) summarize the (dis)advantages of centralized and decentralized delivery systems as follows: the advantages in support of centralization are reduced factory-to-warehouse transport costs, improved inventory management, reduced safety stock, and better opportunity for negotiating transportation services. The factors that are mentioned to favor decentralization are: reduction in warehouse-to-customer transport cost, rapid filling of customer orders, and better availability of stock leading to increased sales. Most literature on centralized versus decentralized distribution systems focus on inventory management and on inventory reduction taking into account service level constraints. Furthermore, most inventory models are designed from the perspective of the 'customer' supply chain member. This member is supplied by the manufacturer and is also the one that makes the choice for either a centralized system or decentralized system. Moreover, most studies focus on inventory holding costs and do not include handling costs in the DC's. Viewing this problem from the supplier's perspective by comparing its handling and transportation costs in a multi-item setting has got relatively little attention. This may be due to the fact that usually the supplier is not the one that is to decide over (de)centralization issues at the customer. However, if a customer is going from a decentralized delivery system to a centralized one, it may also reduce handling costs at the supplier's DC. Researchers have paid little to no attention to this notion which indicates a potential gap in literature.

Another related, important literature topic which is currently a managerial concern is the effective coordination within supply chains (Chang & Kingsman, 2007). Supply chain synchronization theory is based on the idea that to get a good retail supply chain, downstream processes should be synchronized to upstream processes, instead of the other way around. With respect to this idea, Gudehus and Kotzab (2009) explain an important measure in handling activities, namely the filling degree. The filling degree ( $\eta$ ) says something about the efficiency of the filling strategy which is a method to allocate the units of a given filling order to a minimal number of load units while keeping

the filling restrictions and is defined as the relation of the content ( $mFo$ ) to the maximally possible content. The maximally possible content is the number of load units (for example bins or pallets), denoted by  $MFo$ , multiplied by the capacity per load unit ( $C$ ):

$$\eta = \frac{mFo}{MFo * C} * 100\%$$

By definition, the filling degree can only reach 100% if the order quantity is a whole numbered multiple of the load unit capacity. Else, each order generates at least one partly filled load unit and results in a filling degree below 100%. The most important aim of a filling strategy is to minimize the load unit demand by maximizing the filling degree (Gudehus & Kotzab, 2009). In order to increase the filling degree, Gudehus and Kotzab mention two strategies:

**Quantity adjusting strategy:** If it is allowed to adjust the order quantity, it is possible to have an order quantity that is an integer multiple of the load unit capacity and obtain a 100% filling degree by pursuing a quantity adjustment strategy. This simply means that order quantities are rounded up or down to a whole numbered multiple of the load unit capacity. This strategy is quite common in practice. For example, lot sizes of a production are adapted to the capacity of pallets, replenishment quantities are rounded due to the storage unit capacity and shipments are collected until a transport unit (i.e. truck) is completely filled.

**Capacity adjustment strategy:** If the filling quantities cannot be changed but do not vary too much, the filling degree can be optimized too. This is done by dimensionizing or selecting the load units such that the integer multiple of their capacity is slightly smaller than the order quantity. This is less practical since it requires adjusting for example pallet dimensions or transport units.

The quantity adjusting strategy and the capacity adjustment strategy are both strategies is usually pursuit by the 3PLP, but requires the buyer to cooperate. It depends on the context which of the two strategies is more appropriate and whether other strategies to improve efficiency are needed. In general, handling operations (per item) are more efficient and thus cheaper when the units that are being handled are larger. For instance, it is cheaper for a manufacturer to retrieve and dispatch a full pallet than to operate an order picking individual cases and assembling mixed pallets (Van der Vlist, 2007). This strategy is in line with the ideas in this thesis. However, as literature about the implementation of quantity adjusting strategies is limited, this might indicate a gap between practice and theory. Furthermore, it should be noted again that most literature focuses on inventory management and that usually a broad supply chain perspective is taken. A supplier's perspective with a focus on handling and transportation costs is uncommon.

For example, Dudek and Stadtler (2004) recognize that organizing operations planning in supply chains in terms of a hierarchical planning system assumes a single, centralized, planning task. However, as central coordination can usually be realized only for isolated parts of an overall supply chain, the question arises whether there are alternative ways of coordination. Dudek and Stadtler (2004) propose a non-hierarchical, negotiation-based scheme which can be used to synchronize plans between two independent supply chain partners linked by material flow. However, only production costs and inventory costs are taken into account.

In 2007, dr. P. van der Vlist wrote his doctoral thesis called 'Synchronizing the retail supply chain'. Van der Vlist advocates a system in which information is shared and the benefits of that are shared

too. Important concepts in this system are synchronizing distribution with production and the coordination of order quantities. According to van der Vlist, retailers seem to have gone too far in their inventories savings. He shows that not so much the supplier, but much more the retailer can influence the logistics costs structure at the supplier. Furthermore, handling and distribution dominate logistic costs. Instead of inventory costs, costs of picking and transporting goods are the most important elements in the retail logistics cost breakdown. On average, over two-third of the logistic cost at the supplier is dependent on the retailer's order behavior. Another observation is that cooperation can reduce costs. Because of certain order behavior of the downstream supply chain partner, costs of handling and distribution are relatively high. Changing this order behavior can reduce these costs. Based on these and other findings such as the desynchronization of production and distribution, several design choices are made and fit together into a redesign of the common supply chain (see Figure 1.5).

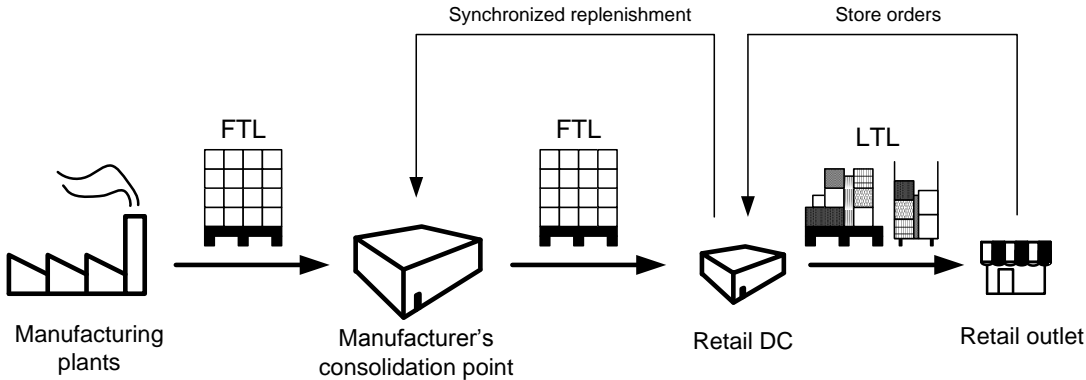


Figure 1.5: Synchronized supply chain (Van der Vlist, 2007)

The key aspect of a synchronized supply chain is that distribution is synchronized to production and store replenishment is synchronized to warehouse operations. A cost-effective retail supply chain design should have a supply chain integration focus because the main retail logistics' cost elements can only be influenced in cooperation with downstream supply chain partners. The design aims at the lowest costs for the retail supply chain as a whole, whilst increasing customer service. This is possible because it consistently reduces all main logistics cost components. However, the major cost elements can only be fundamentally reduced if the downstream supply chain partners is willing to synchronize his processes to the upstream operation. Van der Vlist recognizes that current capacity restrictions cannot be resolved overnight, but demonstrates that savings are such that it pays off to extend existing facilities or move to new ones. "Paradoxically, supply chain synchronization requires downstream supply chain partners to invest in order to allow upstream partners to save costs. It is evident that downstream supply chain partners will only be prepared to such investments, if adequate mechanisms exist to get an equal share of the cost savings. "With a good pricing system or quantity discount scheme of the supplier that properly reflects its handling and transportation costs, the retailer might find out that for many products ordering full pallets is cheaper.

Except for the need for a good pricing system, another barrier to supply chain synchronization may be that the demand for certain products is not sufficient to round it up to full load units (i.e. full bins

or full pallets). This means that buyers cannot accept, for example, full pallets because the usage is less than that. It may cause products to pass the best-before date and the buyer might not even have enough storage space for it. Van der Vlist (2007) proposes a separation between regional DC's that cover a relatively small area of retail outlets and central DC's that cover a relatively large area of retail outlets. The idea is to let the fast-moving products flow through the central DC and store them at regional DC's and store the slow-moving products only at central DC's. If even a central DC is unable to accept a full pallet, the manufacturer should decrease their load unit size (i.e. produce smaller pallets), the retailer should not buy the product from this supplier, or it should not sell it at all.

One of the goals of the research described in this report is to extend the current body of existing research by filling potential gaps in the literature described in this section. Section 5.2 will return on this.

## 1.7 RESEARCH QUESTIONS & SCOPE

The problem(s) described in section 1.5 are transformed into research questions. The answers to these research questions are the basis for solving the business problem. In this section the research question is formulated that will be answered during this research project. Moreover, some narrower sub-questions are posed that will help answering the research question. In section 1.7.2 the scope of this thesis is discussed.

### 1.7.1 RESEARCH QUESTIONS

The research question for this thesis at Unilever is:

*What are the potential cost savings for Unilever if the efficiency of pallet loading and truck capacity utilization in the Food Solutions and Out Of Home market is improved?*

In relation to the research question 6 sub-questions are formulated that help in answering the research question:

1. *What does the FS/OOH distribution network currently look like?*
2. *What are the relevant cost parameters?*

All information that is necessary for answering these input-related sub-questions is available at Unilever. Both sub-questions are answered throughout chapter 1.

3. *What were the cost savings due to the delivery centralization of Customer A?*
4. *What are the cost savings due to increased efficiency in pallet loading and truck filling if Customer B would be fully delivered centrally?*
5. *What is the effect of delivery frequencies on the efficiency and costs of pallet loading and truck capacity utilization?*

6. *What would the optimal delivery frequencies be in order to minimize the costs of pallet loading and truck capacity utilization.*

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### 1.7.2 SCOPE

In this section the scope of this research project is demarcated. It is based on the findings described in the previous sections. This project focuses on the distribution network of Unilever and in particular on the secondary transport flow: the distribution of products from Unilever DC's to customer DC's. The rest of the supply chain as described in section 1.2.1 is left out of scope. This means that any influences from the primary transport flow or what happens in the sourcing units is not taken into account. The same goes for everything that happens after a product has reached the customer's DC. While only a part of the supply chain is considered inside the scope, interactions with the other parts will be discussed if they play a role at solving the research problem. Given the problem description, it follows that only the customers of the FS/OOH market should be included. As discussed in section 1.1, there are customers who belong to both Channel 20 as Channel 21. They will be included too, but only for the products that belong to FS/OOH.

Only the Dutch market is considered. Even though Unilever is a global company and the Dutch supply chain is dependent of the European decision-making body, all customers outside of the Netherlands are excluded from the scope. Whereas the primary transport flow crosses borders a lot, the secondary transport flow is a more local one. All customers in the Netherlands are supplied by DC's that are located in the Netherlands and. Thus, concerning the secondary transport flow, this distribution network can be decoupled and is independent of distribution activities abroad.

Given the amount of time available for this project, it is decided that of the four product categories (Foods, HC, PC, and Refreshment) only the largest category (Foods) is focused on. As discussed in section 1.3.2, all products from the Foods category are stored in and transported from the Unilever DC in Veghel which is managed by K+N. Thus by limiting to this product category, the number of involved Unilever DC's is reduced to one, namely the Foods DC in Veghel. As discussed in section 1.2.1, repackaging takes place in some DC's. However, since this is not the case in the Foods DC in Veghel, these activities will be left out of scope. In conclusion, this project focuses on the secondary transport flow of the Foods product category in the Dutch FS/OOH market.

## 1.8 OUTLINE

The remainder of this report is structured as follows: in chapter 2 the analysis of the effects of centralization is presented. It includes a description of the model, a validation of this model by evaluating the effects for Customer A and a description of the application of the model for two customers: Customer B and Customer C. In chapter 3, the delivery frequency analysis is described. It includes a description of the model and the application of it on all customers of Channel 21. Chapter 4 presents an implementation plan and finally the conclusions, reflections on existing literature and ideas for future research are described in chapter 5. A bibliography is added and Appendices A to H provide extra information.

## 2 CENTRALIZATION ANALYSIS

As discussed in section 1.5.2, there is room for efficiency improvement in the distribution system of Unilever's Channel 21 market. Specifically, strategies for improving efficiency in pallet loading and truck filling operations are explored. Some customers in the Channel 21 market have several DC's located on different locations. In this chapter, the effects of centralization on pallet loading and truck filling are analyzed and sub-questions 3 and 4 will be answered.

### 2.1 INTRODUCTION

In the following sections, the focus is on three customers of Unilever's FS/OOH market. Due to confidentiality reasons, they are named Customer A, Customer B, and Customer C. Although initially Unilever was only interested in Customer A and Customer B, it has become clear that centralization analysis for a relatively small customer such as Customer C was desired as well. Cost savings are expected to be larger at customers with large demands, but for a complete analysis, the effects of centralization at a relatively small customer need to be analyzed too. By sample path evaluation, the cost reductions due to efficiency improvements are estimated (see section 2.2). Recently, Customer A's delivery system was changed from a decentralized one to a centralized one. With data from before and after this change, the predictive accuracy of the path evaluation method is assessed. This is discussed in section 2.3. Next, the model is used to predict cost savings due to centralization for Customer B and Customer C in sections 2.4 and 2.5 respectively. Finally, in section 2.6 it is discussed how the cost savings differ from customer to customer and what the underlying causes are. Section 2.7 concludes this chapter.

### 2.2 SAMPLE PATH EVALUATION MODEL

In this section, the model that is used to evaluate cost savings that result from centralization is explained. The model is designed to evaluate several kinds of improvement measures. It starts with an explanation of the path evaluation model and the assumptions in section 2.2.1. Next, the relevant sets (section 2.2.2), input data (section 2.2.3), coefficients (section 2.2.4) and cost components (section 2.2.5) are defined. Section 2.2.6 states two mathematical functions that are used in the centralization model. The calculations of the model are explained in section 2.2.7. A summary of the model is given in Appendix D.

#### 2.2.1 MODEL EXPLANATION & ASSUMPTIONS

The basic effect of centralization is clear. Because of centralization, orders are aggregated into less, but larger orders which will result in more full pallets and less individual boxes. Instead of delivering a few boxes to each of the separate DC's, one or multiple full pallets can be delivered to one DC. Furthermore, instead of sending multiple half- or quarter filled trucks to the separate DC's, one or multiple full trucks can be send to a single DC. This aggregation of demand would typically result in more efficiency in warehousing and transportation operations and in a decrease in overall costs.

The model that is used to evaluate the cost savings due to centralization is based on the activity-based tariff structure of the 3PLP (K+N) described in section 1.4. This means that the total logistic costs are based on warehousing operations (handling different load units) and transportation operations and their associated tariffs. In short, the model works in two steps: 1) converting demand figures into numbers of loading units (full pallets, full layers, and individual boxes) and determining truck fill, and 2) assigning costs to these numbers of loading units. The model can be used in practice for spreadsheet analysis where information such as demand and K+N's tariffs are taken as input and logistic efficiency and total cost figures are the output. The model is based on a number of assumptions and principles:

1. As a starting point, a sample of delivered pallet equivalents over a certain period of time is collected and used as input data. The model assumes that these quantities are given in production pallet equivalents. In reality, demand in production pallet equivalents differs from demand in 'customer' pallet equivalents. The difference is caused by customer requirements, which are discussed in section 1.3.2. For example, if a customer requires a certain maximum pallet height and this is implemented in the 3PLP's information system, pallets might need to be restacked. This results in extra handling effort in the Unilever DC. This is how the demand in customer pallet equivalents can differ from the demand in production pallet equivalents. However, customer requirements are not taken into account in this model. The effect of this assumption will be discussed in section 2.6.
2. Thus, the input data is the number of production pallet equivalents delivered per time unit for certain period of time. An important choice here is on which time period the model should be based. In the model this period will be noted by  $T$ . Obviously it should be recent data and it should be in line with the expected demand data of the next period. For example, for Customer B the last quarter of 2013 and the first three of 2014 are used to predict the yearly cost savings for the next four quarters (the last quarter of 2014 and the first three of 2015). Note that it is assumed that the volumes delivered in the selected period of time are representative for the future and that it is assumed to be constant. In other words, stochasticity in demand is ignored in this model. As the sample time periods in the application of this model will have the length of a full year, seasoning effects in demand are ignored too.
3. Reorder levels and/or safety stocks are independent of replenishment or customer order patterns. As discussed in section 1.4.1, the amounts that are transported to FS/OOH customers are very small compared to the total numbers of products that are stored in the Veghel DC. Furthermore, volumes that enter the Veghel DC follow the production quantities in the factories. These production quantities are also very large compared to what leaves the Veghel DC for Channel 21 customers. Therefore, average inventory levels are not influenced and left out of scope.
4. Another assumption here is that all products delivered on a certain day on a certain location are delivered at once. There may be multiple trucks involved, but all products are delivered at once. This assumption is fairly realistic, since K+N usually combines orders for a certain day and location. This model also assumes that all goods that are delivered on the same day at the same location are consolidated as much as possible into the same load units. This means that if 10

boxes of product X is delivered on 01-01-2013 at location Y, and 8 boxes fit in one pallet layer, the boxes are in the same truck and consist of 1 full layer and 2 individual boxes, instead of, for example 4 boxes in one truck and 6 in another. In reality, this 'rule' is only violated when truck capacity boundaries are reached.

5. In reality, when products are combined onto a pallet, filling inefficiencies arise. This is because the boxes may have different dimensions. To correct for these inefficiencies, a capacity adjustment is introduced. This is done by constraining the amount of layers on a pallet to a maximum of 5 layers.
6. Another assumption in this model concerns the consolidation of products of an order. In reality, products are delivered on different types of pallets. However, instead of differentiating between euro-pallets and industrial pallets, orders for a delivery location for a certain time unit are consolidated into an 'average pallet'. Euro-pallets have a size of 120cm x 80cm = 9600cm<sup>2</sup> and industrial pallets have a size of 120cm x 100cm = 12000cm<sup>2</sup>. As 33 euro-pallets and 26 industrial pallets fit in a truck, the average floor space used is  $\frac{9600\text{cm}^2 \cdot 33 + 12000\text{cm}^2 \cdot 26}{2} = 314400\text{cm}^2$ . Thus, on average,  $\frac{314400\text{cm}^2}{(9600\text{cm}^2 + 12000\text{cm}^2)/2} = 29.11 \approx 29$  average pallets fit in a truck and they have a size of somewhat more than  $\frac{(9600 + 12000)\text{cm}^2}{2} = 10800\text{cm}^2$  (or somewhat larger than 120cm x 90cm). Furthermore, average values are used for the transportation tariffs and truck capacities. Thus, any efficiency losses that arise due to combining euro- and industrial pallets are ignored.
7. Concerning truck capacity, the number of pallet equivalents that is to be delivered on a certain day at a certain location is usually not an integer number. This is because (unfortunately) customers usually do not order in quantities of full pallets. However, to associate transportation costs, integer numbers need to be used. Furthermore, say that a customer has ordered 2.3 pallets. This would mean that still 3 'spots' in the truck are filled: two full pallets and one that is not full. In practice, it sometimes happens that pallets are stacked, but this will not be taken into account here because it is not part of normal business. Thus, another assumption is that an order with a non-integer size uses truck capacity of an integer size, namely the nearest integer not smaller than the order size.
8. The results of the model are dependent of the 3PLP's logistic tariffs. They are assumed fixed, and if they change, the cost savings due to centralization might change too. Over the years, the tariffs have barely changed, but one might wonder: if radical logistic changes are realized (for example, if all handling of individual boxes would be eliminated), the costs for the 3PLP change, but will this change the tariffs too? Obviously, it is unfortunate for Unilever if they are able to realize large savings, and due to increases in K+N's tariffs, the savings are offset. In other words, the cost structure of K+N might be optimized, but this does not automatically mean that the tariffs for Unilever are optimized too. Fortunately, according to Unilever management, the tariff structure reflects the cost structure pretty closely. If the amount of manual handling can be decreased, the workforce at K+N can be reduced too and those savings are reflected in the tariffs.

Due to centralization, demand is aggregated over locations. However, the true power of centralization is in the synchronization of delivery schedules. Instead of delivering on Monday and



Wednesday at DC A and on Tuesday and Friday at DC B, efficiency improvements are made by visiting both DC A and B on the same days. In fact, centralization alone will have no effect if all DC's involved are visited on separate days. To include the effects of aggregation of demand over time, another choice is introduced, namely daily vs. weekly delivery. Daily delivery is represented by using a 'day' time unit, which is how products are really delivered. To evaluate synchronization of delivery schedules, a 'week' time unit is used by aggregating the delivery quantities per week.

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### 2.2.2 SETS

In the centralization model, three sets are relevant: the set of all products where a product in practice is represented by its unique EAN code; the set of all delivery locations which in practice are identified by the name of the DC (for example 'Customer A Amsterdam'); and the set of all time units. The latter set represents the collection of every day in the sample data. For example,  $\mathbb{T}$  could be equal to {01-01-2013, 02-01-2013, ..., 31-12-2013} if the sample data is from the year 2013.

$\mathbb{P}$  := The set of all products

$\mathbb{L}$  := The set of all delivery locations (i. e. DC's)

$\mathbb{T}$  := The set of all time periods.

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### 2.2.3 INPUT DATA

The following symbols indicate input parameters. All this information is available at Unilever's information system.

$D_{plt}$  := Demand of product  $p$  at location  $l$  at time period  $t$  in production pallet equivalents

$C_{fullpallet}$  := 3PLP's tariff for handling one full pallet

$C_{fulllayer}$  := 3PLP's tariff for handling one full layer with the ALP

$C_{indivbox}$  := 3PLP's tariff for handling one individual box

$r_x$  := the logistic cost of transporting  $x$  pallets

$a_p = \begin{cases} 0 & \text{if it is impossible to handle product } p \text{ through the ALP} \\ 1 & \text{if it is possible to handle product } p \text{ through the ALP} \end{cases}$

$x_p$  := Number of individual boxes that fit in a full pallet of product  $p$

$y_p$  := Number of individual boxes that fit in a full layer of product  $p$

$z_p$  := Number of full layers that fit in a full pallet of product  $p$

From the definitions it follows that:

$$z_p = \frac{x_p}{y_p} \quad \forall p \in \mathbb{P} \quad (1)$$

Note that the transportation cost function ( $r_x$ ) is non-linear. For every  $x$  number of pallets in a truck, there is a certain associated tariff per truck. The more pallets in a truck (i.e. the fuller the truck), the lower the transportation cost per pallet. This is shown in section 1.4.2.

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#### 2.2.4 COEFFICIENTS

The coefficients defined here depend on the input data.

$X_{pt}^{dec}$  := Number of full pallets of product  $p$  delivered decentralized at time unit  $t$

$Y_{pt}^{dec}$  := Number of boxes in full layers of product  $p$  delivered decentralized at time unit  $t$

$Z_{pt}^{dec}$  := Number of individual boxes of product  $p$  delivered decentralized at time unit  $t$

$X_{pt}^{cen}$  := Number of full pallets of product  $p$  delivered centralized at time unit  $t$

$Y_{pt}^{cen}$  := Number of boxes in full layers of product  $p$  delivered centralized at time unit  $t$

$Z_{pt}^{cen}$  := Number of individual boxes of product  $p$  delivered centralized at time unit  $t$

$$X_{pt}^{dec}, Y_{pt}^{dec}, Z_{pt}^{dec}, X_{pt}^{cen}, Y_{pt}^{cen}, Z_{pt}^{cen} \in \{0, 1, 2, \dots\} \quad \begin{array}{l} \forall p \in \mathbb{P}, \\ \forall t \in \mathbb{T} \end{array} \quad (1)$$

$N_{lt}^{dec}$  := Number of pallets to be transported after deduction of full trucks to location  $l$  at time unit  $t$  in a decentralized delivery system

$N_t^{cen}$  := Number of pallets to be transported after deduction of full trucks at time unit  $t$  in a centralized delivery system

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#### 2.2.5 COST COMPONENTS

$HC^{dec}$  := Total handling costs in a decentralized delivery system

$HC^{cen}$  := Total handling costs in a centralized delivery system

$TC^{dec}$  := Total transportation costs in a decentralized delivery system

$TC^{cen}$  := Total transportation costs in a centralized delivery system

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#### 2.2.6 SPECIAL FUNCTIONS

Two mathematical operations that are used in this model are rounding down to the nearest integer and rounding up to the nearest integer. This is modeled by the floor function and ceiling function respectively:

$\lfloor x \rfloor$  := the floor function of  $x$  (i.e. rounding down): the largest integer not greater than  $x$

$\lceil x \rceil$  := the ceiling function of  $x$  (i.e. rounding up): the smallest integer not smaller than  $x$

## 2.2.7 CALCULATIONS

This section describes the reasoning of the calculations of the model. First, the handling costs are formulated. This starts by calculating load unit quantities that are derived from the average daily demand. This is done for two situations: one where there is a decentralized delivery system and one where there is a centralized delivery system.

To clarify the reasoning, an example is given about how demand given in pallet equivalents is broken down to load units (i.e. full pallets, full layers and individual boxes). Say the demand for product X on day 01-01-2013 is 3.45 pallet equivalents, 20 boxes of product X fit in one pallet layer and that 6 layers of product X fit on one pallet. This means that 120 boxes of product X fit on one pallet. Because the demand is 3.45 pallet equivalents, there are 3 full pallets of product X demanded. The remaining part (3.45 pallets – 3 pallets = 0.45 pallets) consists of full layers and possibly individual boxes. As there are 6 layers in one pallet, the number of layers is 0.45 pallets \* 6 layers/pallets = 2.7, thus 2 full layers. The remaining part is now 0.45 pallets – (2 layers)/(6 layers/pallet) = 0.1167 pallets. This last part is the number of remaining individual boxes, measured in full pallets. Thus, measuring in individual boxes, the remaining part is 0.1167 pallets \* 120 boxes/pallet = 14 boxes. Thus, 3.45 pallet equivalents of product X is equal to 3 full pallets, 2 full layers and 14 individual boxes of product X. The demand in pallet equivalents is just a measure that needs to be broken down to load units. As a check, notice that 3.45 pallets is equal to 3.45 pallets \* 120 boxes/pallet = 414 boxes and that 3 full pallets + 2 full layers + 14 individual boxes is also equal to 3 pallets \* 120 boxes/pallet + 2 layers \* 20 boxes/layer + 14 boxes = 414 boxes. This principle of breaking down demand values will be used in the centralization model, but also in the analysis of delivery frequencies.

The number of full pallets is based on the largest integer not greater than the demand. However, in a decentralized delivery system the sum is taken over all rounded down demands per location and in a centralized delivery system the sum of all demands per location is taken and then rounded down. This represents that in a centralized delivery system, all demand goes through one DC and demand is aggregated.

$$X_{pt}^{dec} = \sum_{l \in \mathbb{L}} \lfloor D_{plt} \rfloor \quad \begin{array}{l} \forall p \in \mathbb{P}, \\ \forall t \in \mathbb{T} \end{array} \quad (2)$$

$$X_{pt}^{cen} = \left\lfloor \sum_{l \in \mathbb{L}} D_{plt} \right\rfloor \quad \begin{array}{l} \forall p \in \mathbb{P}, \\ \forall t \in \mathbb{T} \end{array} \quad (3)$$

For example, say that there are three DC's with all separate demands for product X on day 01-01-2013 equal to 3.45 pallet equivalents (in this and the following examples, the same properties of product X as described before uphold: 20 boxes in a layer and 6 layers in a pallet). In a decentralized delivery system, the total number of full pallets is  $\lfloor 3.45 \rfloor + \lfloor 3.45 \rfloor + \lfloor 3.45 \rfloor = 3 + 3 + 3 = 9$ . This is obtained by first rounding down the separate demand volumes and then adding them up. However, in a centralized delivery system, the demand volumes will be aggregated through one DC. This means that the total number of full pallets is  $\lfloor 3.45 + 3.45 + 3.45 \rfloor = \lfloor 10.35 \rfloor = 10$ .

Next, the number of full layers is derived. This is done by multiplying the number of pallet equivalents that remains after it is reduced by the number of full (i.e. an integer number) pallets,

with the number of layers per pallet. Depending on whether it is a decentralized or a centralized delivery system, this is first rounded down and then summated over all locations or first summated and then rounded down, respectively. Ultimately, to arrive at the number of individual boxes a multiplication with the number of individual boxes per layer is done.

$$Y_{pt}^{dec} = \left( \sum_{l \in \mathbb{L}} [(D_{plt} - \lfloor D_{plt} \rfloor) * z_p] \right) * y_p \quad \begin{array}{l} \forall p \in \mathbb{P}, \\ \forall t \in \mathbb{T} \end{array} \quad (4)$$

$$Y_{pt}^{cen} = \left[ \left( \sum_{l \in \mathbb{L}} D_{plt} - \left\lfloor \sum_{l \in \mathbb{L}} D_{plt} \right\rfloor \right) * z_p \right] * y_p \quad \begin{array}{l} \forall p \in \mathbb{P}, \\ \forall t \in \mathbb{T} \end{array} \quad (5)$$

Returning to our example with three DC's, in a decentralized delivery system, the number of full layers is equal to  $\lfloor (3.45 - \lfloor 3.45 \rfloor) * 6 \rfloor + \lfloor (3.45 - \lfloor 3.45 \rfloor) * 6 \rfloor + \lfloor (3.45 - \lfloor 3.45 \rfloor) * 6 \rfloor = \lfloor 2.7 \rfloor + \lfloor 2.7 \rfloor + \lfloor 2.7 \rfloor = 2 + 2 + 2 = 6$ . Here, the value  $\lfloor (3.45 - \lfloor 3.45 \rfloor) * 6 \rfloor$  is the demand minus the number of full pallets multiplied with the number of layers per pallet and thus the number of full layers in one DC. In a centralized system the number of full layers is  $\lfloor (3.45 + 3.45 + 3.45 - \lfloor 3.45 + 3.45 + 3.45 \rfloor) * 6 \rfloor = \lfloor 2.1 \rfloor = 2$ . To obtain the number of boxes in full layers, these numbers are simply multiplied by the number of boxes per layer.

To calculate the number of individual boxes, i.e. the rest, the following measures are used. First of all, notice that again the difference between a decentralized and a centralized delivery system is represented by switching the order of summation and rounding down. The measures are built up as follows: (number of individual boxes after reducing the total demand with the full pallets) – (number of individual boxes in full layers). Notice that the second part of this is equal to  $Y_p^{dec}$  and  $Y_p^{cen}$ , respectively.

$$Z_{pt}^{dec} = \sum_{l \in \mathbb{L}} \left( (D_{plt} - \lfloor D_{plt} \rfloor) * x_p - \lfloor (D_{plt} - \lfloor D_{plt} \rfloor) * z_p \rfloor * y_p \right) \quad \begin{array}{l} \forall p \in \mathbb{P}, \\ \forall t \in \mathbb{T} \end{array} \quad (6)$$

$$Z_{pt}^{cen} = \left( \sum_{l \in \mathbb{L}} D_{plt} - \left\lfloor \sum_{l \in \mathbb{L}} D_{plt} \right\rfloor \right) * x_p - \left[ \left( \sum_{l \in \mathbb{L}} D_{plt} - \left\lfloor \sum_{l \in \mathbb{L}} D_{plt} \right\rfloor \right) * z_p \right] * y_p \quad \begin{array}{l} \forall p \in \mathbb{P}, \\ \forall t \in \mathbb{T} \end{array} \quad (7)$$

To apply this in the example, let's first look at the decentralized delivery system. At each DC, the number of remaining individual boxes is  $(3.45 - \lfloor 3.45 \rfloor) * 120 - \lfloor (3.45 - \lfloor 3.45 \rfloor) * 6 \rfloor * 20 = 54 - 40 = 14$ . Thus in total, the number of remaining individual boxes is  $14 + 14 + 14 = 42$ . However, in a centralized delivery system this number is  $(3.45 + 3.45 + 3.45 - \lfloor 3.45 + 3.45 + 3.45 \rfloor) * 120 - \lfloor (3.45 + 3.45 + 3.45 - \lfloor 3.45 + 3.45 + 3.45 \rfloor) * 6 \rfloor * 20 = 0.35 * 120 - 2 * 20 = 42 - 40 = 2$ .

In summation, the numbers of load units for the decentralized and centralized delivery systems from the example can be found in Table 2.1. It immediately shows that the centralized delivery systems results in less individual boxes and more full pallets.

Table 2.1: Total amounts of load units for (de)centralized delivery systems (example)

	Decentralized	Centralized
<b>Full pallets</b>	9	10
<b>Full layers</b>	6	2
<b>Individual boxes</b>	42	2

Finally, by multiplying the number of full pallets, full layers and individual boxes with their associated cost parameters, the total handling costs can be calculated. However, the second terms in the following expressions are less straightforward. They depend on  $a_p$  which is a binary variable that depends on whether a product  $p$  can be handled with the ALP. If this is possible, the cost per individual box in full layers is  $C_{fulllayer}$ . If not, then the boxes are, although they are in a full layer, handled as individual boxes and result in associated costs  $C_{indivbox}$ .

$$HC^{dec} = \sum_{t \in \mathbb{T}} \sum_{p \in \mathbb{P}} \left( C_{fullpallet} * X_{pt}^{dec} + \left( C_{fulllayer} * a_p + C_{indivbox}(1 - a_p) \right) * Y_{pt}^{dec} + C_{indivbox} * Z_{pt}^{dec} \right) \quad (8)$$

$$HC^{cen} = \sum_{t \in \mathbb{T}} \sum_{p \in \mathbb{P}} \left( C_{fullpallet} * X_{pt}^{cen} + \left( C_{fulllayer} * a_p + C_{indivbox}(1 - a_p) \right) * Y_{pt}^{cen} + C_{indivbox} * Z_{pt}^{cen} \right) \quad (9)$$

Second, the transportation costs ( $TC^{dec}$  and  $TC^{cen}$ ) are calculated: see expressions (11) and (13). This is done by adding the costs for transporting full trucks to the costs of transporting the remaining pallets. For a decentralized delivery system this goes as follows: first of all, the total demand per location per time unit is obtained by summing up the demands per product and rounding them up to the nearest integer:  $\lceil \sum_{p \in \mathbb{P}} D_{plt} \rceil$ .

So, if at location 'L' on day 'D', three products are delivered: 12.3 pallet equivalents of product 'X', 23.6 pallet equivalents of product 'Y' and 11.4 pallet equivalent of product 'Z'. The number of pallet equivalents that needs to be transported on day 'D' at location 'L' is  $\sum_{p \in \mathbb{P}} D_{plt} = 12.3 + 23.6 + 11.4 = 47.3$  pallet equivalents. However, this will require  $\lceil \sum_{p \in \mathbb{P}} D_{plt} \rceil = \lceil 47.3 \rceil = 48$  pallet 'spots' in the truck: Seven full pallets and a non-full pallet.

With these summed up and rounded up demands the number of full trucks is calculated. On a certain day, the number of full trucks at a certain delivery location is equal to the total demand of that location, divided by the truck capacity (which is the average of 29 pallets) and rounded down to the nearest integer:  $\left\lfloor \frac{\lceil \sum_{p \in \mathbb{P}} D_{plt} \rceil}{29} \right\rfloor$ . So, at location 'L' on day 'D'  $\left\lfloor \frac{\lceil \sum_{p \in \mathbb{P}} D_{plt} \rceil}{29} \right\rfloor = \left\lfloor \frac{48}{29} \right\rfloor = \lfloor 1.6 \rfloor = 1$  full truck is needed.

The remaining number of pallets ( $N_{lt}^{dec}$ ) is the total demand rounded up at that location on that day minus the number of full trucks multiplied by the average capacity of a truck (which is 29). The total costs consist of the number of full trucks multiplied by the cost of transporting a full truck ( $r_{29}$ ) and the number of remaining pallets ( $N_{lt}^{dec}$ ) multiplied by the cost of transporting that number ( $r_{N_{lt}^{dec}}$ ).

$$N_{lt}^{dec} = \left\lceil \sum_{p \in \mathbb{P}} D_{plt} \right\rceil - \left\lfloor \frac{[\sum_{p \in \mathbb{P}} D_{plt}]}{29} \right\rfloor * 29 \quad \forall l \in \mathbb{L}, \forall t \in \mathbb{T} \quad (10)$$

$$TC^{dec} = \sum_{t \in \mathbb{T}} \sum_{l \in \mathbb{L}} \left( \left\lfloor \frac{[\sum_{p \in \mathbb{P}} D_{plt}]}{29} \right\rfloor * r_{29} + r_{N_{lt}^{dec}} \right) \quad (11)$$

So, back to the example:

$$N_{LD}^{dec} = \left\lceil \sum_{p \in \mathbb{P}} D_{plt} \right\rceil - \left\lfloor \frac{[\sum_{p \in \mathbb{P}} D_{plt}]}{29} \right\rfloor * 29 = [47.3] - [1.6] * 29 = 48 - 1 * 29 = 18 \text{ pallets}$$

This is the number of pallets that remains after ‘taking out’ all the pallets in full trucks, which is in this case 29. It is just a matter of splitting up the demand into full trucks and the remaining. In this case, 48 ‘pallet spots’ are needed, of which 29 pallets will be put in one full truck and 18 pallets remain. This principle is repeated for all days and all locations, costs ( $r_x$ ) are assigned and everything is summed up.

For a centralized delivery system, a similar calculation is made. However, since there is only one delivery location, demand is summed not only over all products, but also over all locations. Thus, demand of all locations is aggregated.

$$N_t^{cen} = \sum_{l \in \mathbb{L}} \left\lceil \sum_{p \in \mathbb{P}} D_{plt} \right\rceil - \left\lfloor \frac{\sum_{l \in \mathbb{L}} [\sum_{p \in \mathbb{P}} D_{plt}]}{29} \right\rfloor * 29 \quad \forall t \in \mathbb{T} \quad (12)$$

$$TC^{cen} = \sum_{t \in \mathbb{T}} \left( \left\lfloor \frac{\sum_{l \in \mathbb{L}} [\sum_{p \in \mathbb{P}} D_{plt}]}{29} \right\rfloor * r_{29} + r_{N_t^{cen}} \right) \quad (13)$$

It should be noted that in a centralized system it would be more accurately fitting reality if the demands of the different delivery locations would up summed up before rounding the total number up (now it is the other way around: demands of separate locations are rounded up and then aggregated). However, due to rounding errors, this could in many situations result in the fact that in modeling the centralized system, less pallets are shipped to the customers. For instance, in continuation of the previous example, let’s say that the total demand at each of the three delivery locations is  $\sum_{p \in \mathbb{P}} D_{plt} = 70.2$ . This would mean that  $[\sum_{p \in \mathbb{P}} D_{plt}] = 71$  pallets. This is, following the assumptions and the reasoning of the model, accurate: 71 ‘pallet spots’ would be needed for one delivery location, or  $3 * 71 = 213$  in total. In the centralized delivery system it would be more realistic to say that  $70.2 + 70.2 + 70.2 = 210.6$  pallets is the demand for the one delivery location and that  $[210.6] = 211$  ‘pallet spots’ are needed. However, this would mean that 2 pallets are shipped more in the decentralized delivery system. Therefore, to be able to compare the decentralized and the centralized delivery system, demands of separate locations are rounded up and then aggregated.

Ultimately, the total logistic costs are determined by adding the total handling costs and the total transportation costs. The total savings are as follows:

$$total\ costs^{dec} = HC^{dec} + TC^{dec} \quad (14)$$

$$total\ costs^{cen} = HC^{cen} + TC^{cen} \quad (15)$$

$$TOTAL\ SAVINGS\ DUE\ TO\ CENTRALIZATION = total\ costs^{dec} - total\ costs^{cen} \quad (16)$$

An important property of centralization that follows from this model is the following: the larger the demand in a decentralized delivery system, the larger the savings due to centralization.

## 2.3 CUSTOMER A

In this section, the focus is on Customer A. As Customer A recently switched from a decentralized delivery system to a centralized delivery system, this is the ideal customer to validate the model with. First, Customer A is introduced in terms of demand properties (section 2.3.1). Next the cost savings are predicted with the model and finally these are compared to the real cost realizations (sections 2.3.2 and 2.3.3). Specifically, this section aims to answer sub-question 3.

### 2.3.1 DEMAND PROPERTIES

Customer A is a relatively large customer of Unilever. Up to the end of 2013, Customer A was supplied decentralized through 14 DC's. The total demand of Customer A was spread across several DC's. To illustrate this, see Figure E.1 in Appendix E that displays the distribution of demand in October 2013. One of the DC's has a large share (26%) of the demand, but for the rest the demand is divided quite evenly. This illustrates the typical decentralized delivery system from that time. At the end of the fourth quarter of 2013 the way of supplying was changed to a centralized delivery system. From then on, the products that come from the Unilever Foods DC are transported to one DC.

Figure E.2 in Appendix E depicts the curve of Customer A's demand for Unilever Food products from January 2013 till September 2014. Over the years, it has had a fairly steady monthly demand with some recognizable peaks. Since the switch to centralized delivery in January 2014, there is no clear recognizable growth or declining trend in monthly demand. However, the total demand in 2014 is expected to be larger than in 2013. When the demand up till and including September is extrapolated to a full year, a 14% increase is noticed.

### 2.3.2 APPLICATION OF THE MODEL

To verify the model, the set of time units needs to be defined first. Most logically here is to use the data most recent to the centralization, which is the year 2013. As discussed in section 2.2.1, both daily deliveries and weekly deliveries will be evaluated. Thus,  $\mathbb{T}$  is equal to {01-01-2013, 02-01-2013, ..., 31-12-2013} or equal to {2013 week 1, 2013 week 2, ..., 2013 week 52}. In fact, there are four scenarios to be analyzed: decentralized delivery per day, centralized delivery per day, decentralized delivery per week and centralized delivery per week. The latter two scenarios are included to evaluate the effects on delivery schedule synchronization. All other necessary input data is extracted from Unilever's information system. The predicted results of the pallet loading and the truck filling are presented in sections 2.3.2.1 and 2.3.2.2 respectively. The total costs are presented in section

2.3.2.3. Note that the centralization results are presented in Appendix F and they should be read as follows: the upper left box represents the situation before centralization, the upper right box represents the situation after centralization, but where goods are still delivered every day. The lower boxes represent the situations with decentralized and centralized deliveries and weekly deliveries. In the remainder of this report, centralization results are presented similarly. Note that all cost savings are yearly figures.

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#### 2.3.2.1 PREDICTED RESULTS: PALLET LOADING

Figure F.1 in Appendix F shows the yearly handling cost reductions due to centralization in percentages. The figure confirms that due to centralization, costs are reduced, but it depends on whether delivery schedules are synchronized too. Through centralization, a mere 2% yearly handling cost reduction can be realized according to this model. By aggregating the volumes over weeks, another 12% can be realized. The results in terms of efficiency in pallet loading are clear too: by centralizing the delivery system, more full pallets and full layers and less individual boxes are realized. However, changes in percentages are small. When delivery schedules are synchronized (weekly delivery), similar effects are present.

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#### 2.3.2.2 PREDICTED RESULTS: TRUCK FILLING

Figure F.2 and Figure F.3 in Appendix F are the frequency charts of the truck fill (i.e. the number of pallets in a truck) needed in (de)centralized daily and weekly delivery systems for Customer A, respectively. When delivery takes place daily and comparing a centralized delivery system with a decentralized one, a clear upward shift is to be recognized in the chart. It is clear that, in general, trucks are fuller in a centralized delivery system. The same goes for weekly aggregated deliveries, but the effect is even stronger there. It seems that almost all demand is transported in full trucks when delivery is centralized. Figure F.4 in Appendix F shows the transportation cost reductions in percentages. This figure confirms that due to centralization, cost reductions can be made in transportation. Again, it depends on whether changes are made in the scheduling too (i.e. whether demand is aggregated over time). Compared to the handling costs, the savings are much larger. Through centralization, a 34% yearly transportation cost reduction can be realized according to this model. By aggregating demand over weeks, 48% yearly cost reductions can be realized.

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#### 2.3.2.3 PREDICTED RESULTS: TOTAL COSTS

Figure F.5 in Appendix F shows the total yearly cost reductions in percentages and is essentially the addition of the cost reductions in handling costs and the cost reductions in transportation costs. Pure centralization results in a total decrease in costs of 22%. This is mainly because the total costs consist for the larger part of transportation costs which make up for the small reductions in handling costs. Furthermore, 35% cost reduction can be realized by synchronizing delivery schedules.



### 2.3.3 MODEL VALIDATION

In this section the actual results of Customer A's switch to centralized delivery are presented and compared to the estimations. In section 2.3.3.1, the effects on pallet loading are shown and in section 2.3.3.2, the effects on truck filling are presented. To study the effects of the supply centralization of Customer A and to validate the model, data about how Customer A has been supplied recent years is analyzed. From Unilever's information system, the numbers of FTL's, HTL's, etc. and the number of pallet equivalents that are delivered per day for 2013 and 2014 (till September) are obtained. Through a comparison of the numbers of full pallets, full layers, individual boxes, FTL's, HTL's, etc. the impact of Customer A's delivery centralization on logistical operations is made insightful. It is simply a matter of comparing data before and after the point of delivery centralization.

#### 2.3.3.1 VALIDATION: PALLET LOADING

In Figure 2.1 the pallet loading in terms of full pallets, full layers and individual boxes before and after Customer A's switch to centralized delivery is presented. Before centralization (December 2013), the percentage of boxes on full pallets is low: about 5%. In contrast, the percentage of individual boxes is rather high: about 55%. The percentage of boxes in full layers is about 40-45%. Comparing the values predicted by the model (4% in full pallets, 35% in full layers and 61% as individual boxes) with these results, the model seems to describe reality (before centralization) quite accurately. From the point that Customer A stopped decentralized delivery, the average composition of pallets changed radically. This is clearly visible in Figure 2.1. The percentage of boxes on full pallets increases to about 50%. This is above the average of Channel 21 Foods products of 41%. The percentage of individual boxes drops to about 8%. The percentage of boxes in full layers continues to be around 40-45% but one might notice a small increase. These findings confirm the hypothesis that due to centralization, boxes are loaded less as individual boxes and more in full pallets and thus the efficiency of warehousing operations increases. In that sense, the model predicts the right changes. However, taking the predicted results in mind, the actual results are unexpected. The real efficiency improvements greatly exceed the improvements predicted by the model. Section 2.3.4 will elaborate on this.

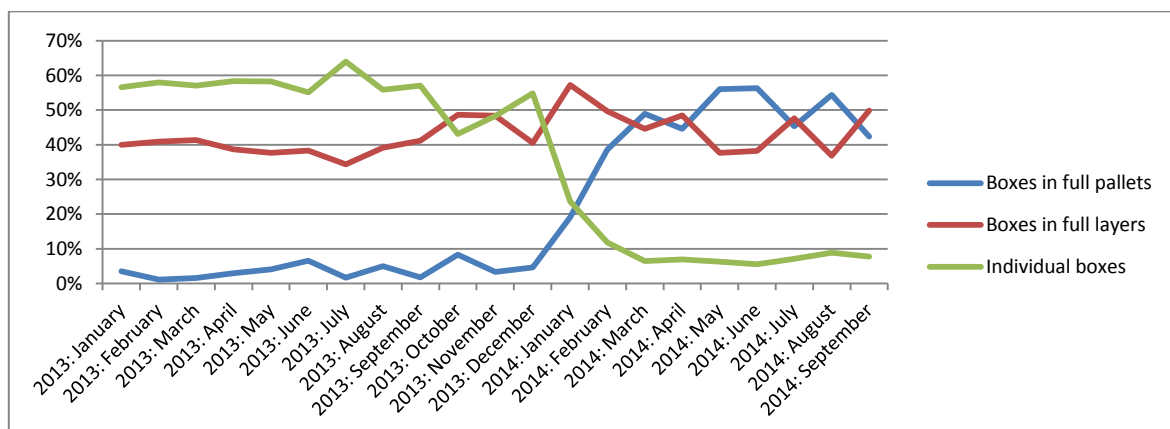


Figure 2.1: Pallet loading of Customer A (Jan '13 till Sep '14)

To express the effects in cost figures, the logistic costs for handling full pallets, full layers and individual boxes are added. Figure F.6 in Appendix F shows the course of logistic costs of Customer A associated with the pallet loading before and after the point of delivery centralization. In line with expectations, the costs for handling individual boxes decrease, costs for handling full layers increased slightly and the costs for handling full pallets increase. The total costs tend to vary a lot from month to month and comparing this trend with the trend in Figure E.2 indicates that this is largely influenced by the demand volumes. This is not surprising. However, given this dependency, a decrease in total costs after January 2014 can be noticed. This is more clearly visible in Figure F.7 In Appendix F where the average pallet loading costs in 2013 are compared to the average monthly costs from January 2014 till September 2014. Again, there is a large decrease in costs due to individual box handling and increases in costs due to layer and pallet handling. The average monthly cost reduction is about 27%. This is far more than the model predicts. Again, section 2.3.4 will elaborate on this.

**2.3.3.2 VALIDATION: TRUCK FILLING**

Figure 2.2 shows the order sizes in terms of FTL’s, HTL’s, QTL’s and LTQTL’s before and after Customer A’s switch to centralized delivery. Although the percentages can vary quite a lot from month to month, certain trends are noticeable. Before centralization (January 2014), the percentage of FTL’s is rather low and does not exceed 40%. The percentage of HTL’s fluctuates around 17% and the percentage of QTL’s moves roughly around 20-30%. The percentage of LTQTL’s is rather high and is about 40%. As soon as Customer A initiated centralized delivery, the view changes dramatically. The percentage of FTL’s increases to a staggering 60-80%. A small increasing trend can be recognized in the percentage of HTL’s and the percentage of QTL’s decreases clearly. The percentage of LTQTL’s drops significantly to almost zero. These findings confirm the hypothesis that due to centralization, deliveries are larger in terms of FTL’s, HTL’s, etc. and that the efficiency of truck filling is increased through centralization. These findings are also in line with the predicted results of the model.

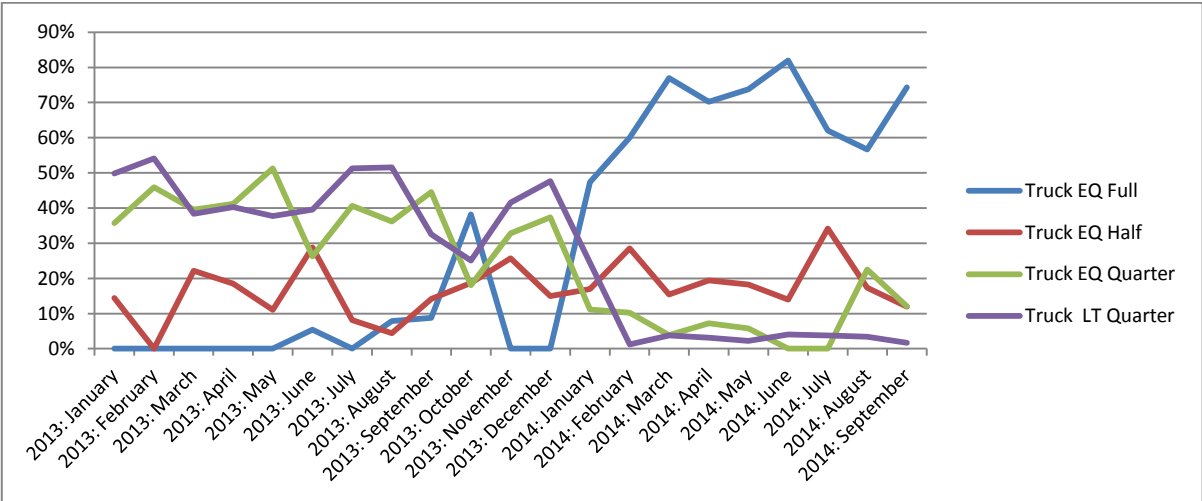


Figure 2.2: Truck filling at Customer A (Jan '13 till Sep '14)

To express the effects of centralization in cost figures, the transportation tariffs are added. This is done by taking the number of pallet equivalents and multiplying them with average K+N tariffs for

FTL's, HTL's, etc.. Figure F.8 in Appendix F shows the course of transportation costs of Customer A before and after delivery centralization. In line with expectations, the costs for transportation decrease. On average the yearly transportation costs are decreased by about 30%. This is quite in line with the results predicted by the model. Predicted transportation cost reductions amount to 34%.

2.3.4 COMPARISON OF PREDICTED AND ACTUAL RESULTS

The centralization analysis for Customer A is performed to have an indication of the potential benefits of delivery centralization and to validate the proposed model. In summary: the model predicts for Customer A a decrease of 2% in yearly handling costs and a decrease of 34% in yearly transportation costs due to centralization. Relatively small changes are made in the numbers of full pallets, full layers and individual boxes, but trucks clearly become fuller. Centralization enables potential for more savings by synchronizing delivery schedules. Concerning total costs, a 22% reduction due to centralization is predicted and when all demand of a week is aggregated, the savings are about 36%. This model is compared to the real numbers representing pallet loading and truck filling efficiency and costs. Those numbers show that the decrease in handling costs was about 27% and the decrease in transportation costs was 30%. This means that the model, though somewhat overestimating it, gives a fairly good estimation of the transportation cost savings. The model, however, greatly underestimates the handling cost savings.

To check whether the changes in this validation are ceteris paribus, the costs per box are calculated to account for changes in demand. The course of costs per box is visualized in Figure 2.3. This shows that real cost reductions are in line with the predicted cost reductions. The costs per case decrease with 37% which is very similar to the predicted total cost savings of 35%.

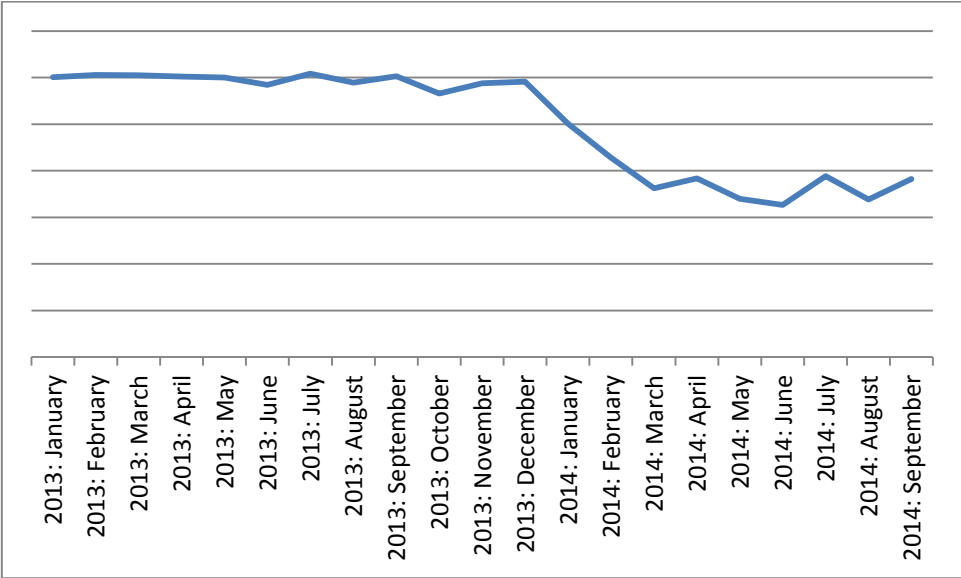


Figure 2.3: Total costs per case for Customer A (Jan '13 till Sep '14)

The seemingly inaccurate prediction of the mathematical concerning handling costs can be explained. The negotiations about centralization are a great moment to persuade (or force) customers to order more efficiently. It turns out that next to the centralization, another measure may have initiated to reduce the number of individual boxes too. As the aim of centralization is to deliver more products in full layers and full pallets, Unilever offers financial incentives to realize this. Thus, by rounding up the order sizes for their products, more full pallets and full layers were ordered. This explains the strong increase in efficiency. Furthermore, by looking closely at the demand, a difference in total yearly demand is noticeable between 2013 and 2014: it raised about 4%. This is explainable by the small order increases that were made to round up order sizes. The introduction of financial incentives next to centralization also explains why the model is inaccurate for handling costs, but accurate for transportation costs. Namely, the increases in demand have a relatively large impact on the handling efficiency, but are too small to make a substantial difference in truck filling efficiency. In other words, only a small demand increase for most of the SKU's may have a large impact on the numbers of products handled in full pallets, full layers or as individual boxes, but in total, but the impact on how many pallets the trucks contain is relatively small.

The case of Customer A illustrates that the model may be fairly accurate, but that more important are the potential savings that are enabled by centralization. As the demands of the separate DC's may be too small to 'round up' to full pallets or full layers, after centralization the aggregated demands can be sufficiently to persuade (or stimulate by financial incentives) the customer to only order in full pallets or full layers.

## 2.4 CUSTOMER B

In this section, the focus is on Customer B. Customer B is a relatively large customer of Unilever Channel 21 market and is with about 12 DC's a perfect candidate for centralization. In the following sections, the demand properties are discussed (2.4.1), and the predicted effects of centralization on pallet loading and truck filling are presented (sections 2.4.2 and 2.4.3 respectively). The total cost savings are presented in section 2.4.4. The results will be discussed in more detail together with the results of Customer C in section 2.6. The aim of this section is to answer sub-question 4.

### 2.4.1 DEMAND PROPERTIES

Currently, Customer B is delivered through about 12 DC's spread across the Netherlands. At Customer B, about 80% of the products are delivered centralized, and about 20% decentralized. Figure E.3 in Appendix E shows the distribution of demand in November 2014. One DC has by far the largest share: 82% of the delivered volume. This means that although technically Customer B's delivery system is decentralized, it actually has a strongly centralized character. As mentioned in section 2.2.7, the larger the volumes handled and transported in a decentralized delivery system, the larger the savings resulting from centralization. Thus, although Customer B is a large customer, benefits due to centralization might be relatively small since the delivery system will not change radically. Figure E.4 in Appendix E depicts the curve of Customer B's demand for Unilever Food products from January 2013 till September 2014. Comparing 2013 to 2014, no recognizable growth

or declining trend in demand can be discovered. Note that compared to Customer A, Customer B is a larger customer in terms of demand.

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#### 2.4.2 PREDICTED RESULTS: PALLET LOADING

In Figure F.9 in Appendix F, the yearly handling cost reductions due to centralization for Customer B are presented in percentages. Similar to the results for Customer A, only a small decrease of costs is realized purely due to centralization. Moreover, the cost reductions in percentages are very similar to the case of Customer A. Purely looking at centralization, the percentage of individual boxes slightly decreases and the number of full pallets slightly increases. However, since the handling (and transportation) costs are larger at Customer B, the absolute cost reductions are larger. Still, the yearly savings are relatively small and this is as expected, due to the fact that Customer B is practically already largely centralized. Centralization can save a mere 1% per year and in combination with synchronization of delivery schedules up to 14% per year.

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#### 2.4.3 PREDICTED RESULTS: TRUCK FILLING

Figure F.10 and Figure F.11 in Appendix F are the frequency charts of the truck fill (i.e. the number of pallets in a truck) needed in (de)centralized daily and weekly delivery systems for Customer B, respectively. When delivery takes place daily and comparing a centralized delivery system with a decentralized one, a clear upward shift is to be recognized in the chart again. It is clear that, just like in the case of Customer A, trucks are fuller in a centralized delivery system. However, the current situation at Customer B is better than the situation of Customer A before the centralization in the sense that there already are relatively many full trucks (of 29 pallets). However, efficiency improvement is clearly visible: the number of deliveries that fill the truck for a small part (1 to 3 pallets) is reduced and products for Customer B fill a truck to the fullest more often. Concerning weekly aggregated deliveries, a similar effect takes place.

Figure F.12 in Appendix F shows the yearly transportation cost reductions for Customer B (in percentages). Whereas the predicted yearly transportation cost savings for Customer A are about 34%, the savings at Customer B amount to 25%. Given the size of Customer B and the fact that 82% of the products already go to one DC, this is not an unexpected result. Synchronization of delivery schedules adds a small 7% of cost reduction in yearly transportation costs.

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#### 2.4.4 PREDICTED RESULTS: TOTAL COSTS

Adding the transportation costs to the handling costs results in the total costs (see Figure F.13 in Appendix F for the total yearly cost reductions in percentages). This shows that in total, centralization at Customer B results in a 16% cost reduction. Moreover, aggregating delivery schedules can save up to 23%.

## 2.5 CUSTOMER C

The last customer of Unilever that is discussed in this chapter about centralization is Customer C. In contrast to Customer A and Customer B, Customer C is a relatively small customer. Unilever is interested in what the cost savings due to centralization for this Customer are too. This will give insight in what the benefits for a customer in the 'tail' of the customers can be. Section 2.5.1 will elaborate on Customer C's demand. Section 2.5.2, 2.5.3, and 2.5.4 will discuss the results that are predicted by the model.

### 2.5.1 DEMAND PROPERTIES

Figure E.5 in Appendix E shows the distribution of demand across the DC's of Customer C in November 2014. This shows that the transported products for Customer C are spread quite evenly over the DC's. Percentages range from 8% to 18%, except for one DC that makes up for 27% of the demand. This means that Customer C has a practically decentralized delivery system, just like Customer A. In Figure E.6 in Appendix E the curve of demand for Unilever Food products from January 2013 till November 2014 of Customer C is presented. Demand data shows that Customer C is a very small customer compared to Customer A and Customer B and that it belongs in the tail of the Channel 21 market. Just like the demand of Customer B, there is no obvious trend to be recognized. Since Customer C is such a small customer, the expectation is that only very small absolute cost reductions are possible.

### 2.5.2 PREDICTED RESULTS: PALLET LOADING

Figure F.14 in Appendix F shows the yearly handling cost reductions due to centralization for Customer C (in percentages). It is safe to say that centralization has no substantial effect on the handling costs at Customer C. Whereas only a 3% cost reduction is possible by centralizing and synchronization of delivery schedules, the absolute savings due to centralization are negligibly small. These cost reductions are so small, that centralization cannot be considered a suitable option to save handling costs at Customer C.

### 2.5.3 PREDICTED RESULTS: TRUCK FILLING

Figure F.15 and Figure F.16 in Appendix F depict the frequencies of truck fills at Customer C for (de)centralized daily and weekly delivery respectively. They show the improvement in efficiency in terms of truck filling. When delivery happens daily, a small shift to fuller trucks is visible. Trucks are not full in a centralized delivery system but this is most probably due to the small demand volumes at Customer C. When demand is aggregated over weeks, the shift to fuller trucks is more obvious and even results in full trucks. In Figure F.17 in Appendix F, the yearly transportation cost reductions for Customer C are shown. Compared to the savings in percentages in yearly handling costs, the transportation cost reductions in percentage are larger. Because of centralization about 27% can be saved per year. When moving from daily to weekly delivery, another 39% can be saved per year. Although Customer C is a small customer, the savings in percentages are not small. In the case of

Customer B, already many products were transported in full trucks. However, in the case of Customer C, no product is transported in full trucks yet. Therefore, the savings potential is larger and this is visible in the results of the model.

#### 2.5.4 PREDICTED RESULTS: TOTAL COSTS

The total cost reductions (yearly handling cost reductions plus yearly transportation cost reductions) are displayed in Figure F.18 in Appendix F. This shows again, just like at Customer A and Customer B, that the transportation costs are the main driver of the logistic costs, and that the handling costs clearly play a smaller part. This is why the reductions in handling costs may be small, but due to the larger transportation cost reductions, the total cost reductions are, in percentages, not small. Purely due to centralization a reduction of about 17% on a yearly basis can be realized. Moreover, synchronizing delivery schedules can save up to 39% at Customer C.

## 2.6 DISCUSSION

As discussed in section 2.3.4, the model that is used to predict the logistic cost savings is quite accurate concerning transportation costs. However, concerning the handling costs the model seems to underestimate the benefits of centralization. The most obvious explanation for this is that at the same time that centralization was initiated, financial incentives to order in full pallets and full layers have changed customer order behavior. This has resulted in cost reductions that greatly exceed the benefits of centralization alone. Thus, the model might be fairly accurate, but centralization alone does not cause all the benefits that can be realized. Moreover, centralization can be seen as an 'enabler' with which other initiatives can have stronger effects. It is hard to predict how customer order behavior will change due to introduction of financial incentives. It is the customer's choice to what degree they will increase their demand. For example, the customer might do this for 75% of their products, and keep the demand for the remaining 25% the same. This can be determined by evaluating which products only need a small increase in demand and which products need a large one. It is also possible that a new contract is closed that states that the customer will only order in full layers or full pallets. If Unilever's bargaining position is powerful enough, it can impose ordering constraints like that.

Taking the idea of financial incentives into account, a different indication of the benefits can be made for Customer B and Customer C. Let us consider the hypothetical situation where Customer B stops ordering individual boxes. Let's say that half of the individual boxes will instead be delivered in full layers and the other half in full pallets. Figure F.19 in Appendix F shows the yearly savings in handling costs if Customer B decides to order a certain percentage of their current number of individual boxes in full layers and full pallets. It shows that if Customer B would fully stop the ordering of individual boxes, somewhat over 5% will be saved in yearly handling costs. If Customer B would do this with half of the boxes, the yearly handling cost savings will be around 2.5%. Note that the handling cost savings purely caused by centralization would be a mere 1% per year according to the model. The same can be done for Customer C (see Figure F.20 in Appendix F). If Customer C would fully stop ordering individual boxes (100%), yearly handling cost reductions amount to over 12%. Of course, these savings are partly offset by the financial incentives themselves. These financial incentives

should be determined by Unilever or negotiated with the customer. As long as they are smaller than the increased cost savings, initiatives like this are estimated to be beneficial.

The difference in savings of Customer B and Customer C can be explained by relating the transportation cost reductions to K+N's transportation tariffs, which are discussed in section 1.4.2. In percentages, Customer B and Customer C can save about 22% and 27% in transportation costs. As discussed, it might be surprising that although it is a relatively small customer the savings are higher in percentage, but this is explained by the fact that about 80% of Customer B's products already go to one single DC and by the fact that Customer B's products are already mostly transported in full trucks. Besides these explanations, there is also a more subtle reason. Namely, as mentioned in section 1.4, increasing the number of pallets yields the biggest savings at low numbers of pallets. Thus, since Customer C is a small customer, its orders consist of low numbers of pallets. Therefore, by centralizing, demands are aggregated over all DC's, order sizes are increased, and savings are larger than they would be at larger customers like Customer B.

The sample path evaluation model is based on a number of assumptions described in section 2.2.1. Here, the effects of these assumptions are discussed per point:

1. In this model, customer requirements are ignored. The effect of this assumption is that in reality, handling costs are higher than what the model takes into account. For example, if a customer requires a certain pallet height which causes a full pallet to be broken down into an almost full pallet and one layer, the costs are higher than when a full pallet is picked directly. Due to centralization, demand is aggregated and orders are larger. This means that there are more full pallets and less individual boxes. Therefore, the constraints of customer requirements are probably reached 'sooner'. Thus, the benefits of centralization are partly canceled. As the predicted cost reductions due to centralization were already relatively small, this assumption has no effect on the conclusion that centralization savings are insufficient for Customers B and C.
2. It is assumed that the demand sample is representative for the future and stochasticity is ignored. Since the yearly demand only increases a few per cent each year. The effect of this assumption is very small.
3. Average inventory levels are not influenced and left out of scope. For the reasons given in section 2.2.1, this assumption is considered realistic and has a negligible effect on the end results of this analysis.
4. All products delivered on a certain day on a certain location are delivered at once and goods that are delivered on the same day at the same location are consolidated as much as possible into the same load units. For the reasons given in section 2.2.1, these assumptions are considered realistic and have a negligible effect on the end results of this analysis.
6. An average pallet is introduced of which 29 fit in a truck. Furthermore, any efficiency losses that arise due to combining euro- and industrial pallets are ignored. This assumption affects all scenarios, but the impact is dependent of the scenario. Efficiency losses are expected to be larger when more pallets are loaded in a truck. Since centralization results in fuller trucks, the efficiency losses are expected to be larger in centralized delivery systems. This causes the model to



overestimate benefits due to centralization. However, since the cost reductions for Customers B and C are already considered small, this assumption only favors his conclusion.

7. To associate transportation costs, numbers of pallets in a truck are rounded up to the nearest integer. This assumption is considered realistic as K+N also bills Unilever this way.
8. The results of the model are dependent of the 3PLP's logistic tariffs. However, as mentioned in section 2.2.1, according to Unilever management, the tariff structure reflects the cost structure pretty closely. Therefore, this assumption is considered to have limited impact on the results of this analysis.

In conclusion, the assumptions made for this model have made it less accurate in the sense that it resembles reality in a lesser degree. However, in general, the assumptions seem to cause the model to overestimate the benefits of centralization. As the savings are already considered relatively small, the model's assumptions favor the conclusion that centralization at Customers B and C does not result in substantive savings.

## 2.7 CONCLUSION

The results in this chapter are in line with the hypothesis that, all other things considered equal, the logistic costs of a centralized delivery system are lower than the logistic costs of a decentralized delivery system. Because demand of separate DC's is aggregated, more full pallets, more full layers, less individual boxes, and fuller trucks are realized. Furthermore, results show that if delivery schedules are synchronized and order volumes are aggregated over the weeks, savings due to centralization increase. Obviously all cost savings are welcome. Besides, centralization is an attractive option business-wise too since processes become less complex (for example, think about ordering processes: instead of 12 orders, only 1 order has to be processed). However, because of centralization, customers experience less flexibility and the customer may have to incur more logistic costs itself because they need to change their distribution system. Customers will only agree to centralization if it will save them costs too. This is why Unilever is willing to offer financial incentives. In the past, Customer B has given an indication of what they expect as a fair compensation and indicated that €500.000 would suffice. Unfortunately, the cost savings do not come near this figure. Furthermore, due to the assumptions of the model, real savings are probably even smaller. Thus, from a cost perspective and from a service perspective, centralization at Customer B is not advisable. Centralization at Customer C will result in even smaller cost savings, and that too is unadvisable.

## 3 DELIVERY FREQUENCY ANALYSIS

Next to centralization, changing delivery frequencies is another initiative that potentially improves efficiency of the Channel 21 distribution system. Again, the effects on pallet loading and truck filling and the effects on handling and transportation costs are explored. The aim of this chapter is to answer sub-questions 5 and 6.

### 3.1 INTRODUCTION

In this chapter, the focus is on all customers of Channel 21. It starts with the introduction of a model that is used to estimate the cost reductions due to changes in delivery frequencies (section 3.2). In section 3.3 the application of the model is described and the results are presented. Section 3.4 discusses these results and section 3.5 concludes this chapter.

### 3.2 MODEL

In this section, the model that is used to predict the cost savings that result from delivery frequency adjustments is described. It starts with an explanation of the model and the assumptions in section 3.2.1. Next, the relevant sets (section 3.2.2), input data (section 3.2.3), and coefficients (3.2.4) are defined. The calculations of the model are explained in section 3.2.5. A summary of the model is given in Appendix G.

#### 3.2.1 MODEL EXPLANATION & ASSUMPTIONS

This model has overlap with the model that is used to calculate the centralization cost savings. All assumptions discussed in section 2.2.1 apply here too. Again, the cost calculations are based on the activity-based cost structure of the 3PLP (K+N). The way the number of full pallets, full layers and individual boxes and the truck filling is calculated is similar. However, where the centralization analysis is about evaluating different scenarios, this model is about creating insights in how the delivery frequency relates to the logistic costs per customer. In contrast to the centralization analysis, the delivery frequency analysis is less detailed and instead of doing calculations per day and per product, the following calculations will be on a customer level. This means that demand is one of the input parameters, but in this model the average number of a certain product delivered per week will be used. The delivery frequency is defined as the average number of drops per week at a certain delivery location. The delivery frequency can practically be an integer number (once a week, twice a week, etc.), and a fraction where the nominator is equal to 1 (once every 2 weeks, once every 3 weeks, etc.). Thus the range of practically possible delivery frequencies is  $(\dots \frac{1}{4}, \frac{1}{3}, \frac{1}{2}, 1, 2, 3, 4, \dots)$ . To be precise, in theory a larger range of delivery frequencies is possible too. For example, a delivery frequency of 2.5 can be obtained by supplying a customer five times in two weeks. However, for practical purposes, this range of possible delivery frequencies is used. Note that the demand is independent of the delivery frequency.

The used time unit is given in number of weeks. This is because customers tend to have fixed days in the week to be supplied. Thus, the model will work with demand per week and delivery frequency per week. Note that the delivery frequency does not say anything about on which days products are delivered. The aim of the model is to determine per customer what the average yearly logistic costs will be given a certain delivery frequency.

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### 3.2.2 SETS

In contrast to the centralization analysis, this model is about providing insights per delivery location. Furthermore, because of the use of average demands, a set of time units is no longer necessary. This is why the only relevant sets are the following:

$\mathbb{P}$  := The set of all products

$\mathbb{L}$  := The set of all delivery locations (i. e. DC's)

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### 3.2.3 INPUT DATA

$D_{lp}$  := Average weekly demand of product  $p$  at location  $l$

$C_{fullpallet}$  := 3PLP's tariff for handling one full pallet

$C_{fulllayer}$  := 3PLP's tariff for handling one full layer with the ALP

$C_{indivbox}$  := 3PLP's tariff for handling one individual box

$\bar{x}_l$  := Average number of individual boxes that fit in a full pallet at location  $l$

$\bar{y}_l$  := Average number of individual boxes that fit in a full layer at location  $l$

$\bar{z}_l$  := Average number of full layers that fit in a full pallet at location  $l$

From the definitions it follows that:

$$\bar{z}_l = \frac{\bar{x}_l}{\bar{y}_l} \quad \forall l \in \mathbb{L} \quad (18)$$

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### 3.2.4 COEFFICIENTS

$\bar{D}_l$  := Average weekly demand at location  $l$  (in production pallet equivalents)

$F_l$  := Delivery frequency (i. e. the number of drops per week)

$S_l(F)$  := Average dropsize (in pallet equivalents)

$X_l(F)$  :=

Number of full pallets that are delivered at location  $l$  per drop if the delivery frequency is  $F$

$Y_l(F)$  :=

Number of full layers that are delivered at location  $l$  per drop if the delivery frequency is  $F$

$Z_l(F) :=$

Number of individual boxes that are delivered at location  $l$  per drop if the delivery frequency is  $F$

$HC_l(F) :=$  Total yearly handling costs of location  $l$

$TC_l(F) :=$  Total yearly transportation costs of location  $l$

$N_l(F_l)$

$:=$  Average number of pallets to be transported after deduction of full trucks to location  $l$  per drop

$TC_l(F_l)$

$:=$  Average number of pallets to be transported after deduction of full trucks to location  $l$  per drop

*average yearly costs*  $(F_l) = H_l(F_l) + TC_l(F_l)$

$$X_p, Y_p, Z_p \in \{0, 1, 2, \dots\} \quad \forall p \in \mathbb{P} \quad (19)$$

Notice that  $F_l$  is the decision variable.

### 3.2.5 CALCULATIONS

Note that, as delivery frequencies and order sizes do not change the demand  $D_{lp}$ , so:  $D_{lp} = F_l * S_l$ ,  $\forall p \in \mathbb{P}$ . To start calculations, the average weekly demand is calculated by taking the sum of all product demands for every location.

$$\bar{D}_l := \sum_{p \in \mathbb{P}} D_{lp} \quad \forall l \in \mathbb{L} \quad (20)$$

Notice that since  $\bar{D}_l$  is the average demand per week and  $F_l$  is the delivery frequency per week, the average drop size is equal to:

$$S_l(F_l) = \frac{\bar{D}_l}{F_l} \quad \forall l \in \mathbb{L} \quad (21)$$

If the drop size is known, it can be split up in the average numbers of full pallets, full layers and individual boxes. Just like in the centralization analysis, the number of full pallets is the number of pallet equivalents rounded down to the nearest integer. The number of full layers is that what remains after subtracting  $X_l(F_l)$  from the demand and rounding it down to the nearest integer and multiplying it with the number of layers per pallet. Multiplying the number of full layers with the number of boxes per layer yields the number of boxes in full pallets. To calculate the number of individual boxes, the remaining part of the demand is calculated, i.e. the demand minus the boxes in full pallets minus the boxes in full layers. However, instead of the demand, the drop size is used.

$$X_l(F_l) = \lfloor S_l(F_l) \rfloor \quad \forall l \in \mathbb{L} \quad (22)$$

$$Y_l(F_l) = \lfloor (S_l(F_l) - \lfloor S_l(F_l) \rfloor) * \bar{z}_l \rfloor * \bar{y}_l \quad \forall l \in \mathbb{L} \quad (23)$$

$$Z_p(F_l) = (S_l(F_l) - \lfloor S_l(F_l) \rfloor) * \bar{x}_l - \lfloor (S_l(F_l) - \lfloor S_l(F_l) \rfloor) * \bar{z}_l \rfloor * \bar{y}_l \quad \forall l \in \mathbb{L} \quad (24)$$

Finally, by multiplying the number of full pallets, full layers and individual boxes with their associated cost parameters, the total yearly handling costs ( $HC_l(F_l)$ ) can be calculated. The calculations are based on average demands and the fact that some products may not be able to be handled through the ALP is not incorporated. The expression ( $C_{fullpallet} * X_l(F_l) + C_{fulllayer} * Y_l(F_l) + C_{indivbox} * Z_l(F_l)$ ) is the average cost per drop. Since there are  $F$  drops per week and a 52-week year is assumed, the total yearly handling costs are as follows:

$$HC_l(F_l) = \left( C_{fullpallet} * X_l(F_l) + C_{fulllayer} * Y_l(F_l) + C_{indivbox} * Z_l(F_l) \right) * F * 52 \quad \forall l \in \mathbb{L} \quad (25)$$

The transportation costs calculations are similar to those in the centralization analysis too. They are split up in numbers of full trucks and a 'remainder' truck with the remaining number of pallets.

$$N_l(F_l) = \lfloor S_l(F_l) \rfloor - \left\lfloor \frac{\lfloor S_l(F_l) \rfloor}{30} \right\rfloor * 29 \quad \forall l \in \mathbb{L} \quad (26)$$

$$TC_l(F_l) = \left( \left\lfloor \frac{\lfloor S_l(F_l) \rfloor}{29} \right\rfloor * r_{29} + r_{N_l(F_l)} \right) * F_l * 52 \quad \forall l \in \mathbb{L} \quad (27)$$

Note that the expression  $\left\lfloor \frac{\lfloor S_l(F_l) \rfloor}{29} \right\rfloor * r_{29} + r_{N_l(F_l)}$  alone is the transportation cost per drop. That's why it is multiplied by the number of drops per week and the number of weeks per year so that the yearly transportation costs are known. Now both the average handling and transportation costs per year are calculated, the total costs is obtained by adding them up.

$$average\ yearly\ costs(F_l) = HC_l(F_l) + TC_l(F_l) \quad \forall l \in \mathbb{L} \quad (28)$$

Expression (28) is the function that outputs the average yearly costs for a delivery location  $l$ , given a delivery frequency for that customer ( $F_l$ ).

### 3.3 APPLICATION

The model described in the previous section can be used to determine per customer what the average yearly logistic costs will be given a certain delivery frequency. Thus, it can also be used to determine the costs in the current situation (with current delivery frequencies). Comparing the current and hypothetical costs gives insight in what the potential savings will be if the delivery frequency for a certain delivery location is reduced. This is applied in a spreadsheet tool as follows.

Order data is collected from 01-01-2014 till 30-06-2014 and contains information about demands and when a delivery took place for all customers in Channel 21 that are supplied from the Foods DC. This is a recent period and assumed representative for the near future. For every customer the average number of individual boxes per pallet ( $\bar{x}_l$ ) and the number of layers per pallet ( $\bar{z}_l$ ) is calculated. This data is used as input for the model described in section 3.2. To illustrate the results of this model, two example delivery locations are discussed. Due to confidentiality reasons, the

customers remain anonymous and are named Customer D and E. First, Customer D is discussed in section 3.3.1 and second, Customer E is discussed in section 3.3.2.

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### 3.3.1 RESULTS: CUSTOMER D

Customer D is a relatively small customer in Channel 21 and orders on average 0.29 times a week (or about once every 3.5 weeks). The current logistic costs are relatively small. Using the delivery frequency model, the costs savings due to delivery frequency adjustments can be calculated. As mentioned before, increasing the delivery frequency will never result in lower logistic costs. Therefore, it is only interesting for Unilever to evaluate the results of decreasing the delivery frequency. For three scenarios, the cost savings are calculated but are omitted from this report due to confidentiality reasons. The three scenarios represent the situations where once every 4, 5, and 6 weeks a delivery takes place. Results show that for this relatively small customer, the cost reductions are small too. Whereas the cost savings range from 12% to 24%, depending on how much the delivery frequency is decreased, the absolute yearly logistic cost savings are not substantial.

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### 3.3.2 RESULTS: CUSTOMER E

Compared to Customer D, Customer E is a large customer. Customer E is visited 4.3 times per week on average and has a much larger demand. Again, it is only interesting for Unilever to evaluate the results of lowering the delivery frequency and three scenarios are evaluated: reducing the delivery frequency to 4, 3, and 2 times per week. The results show that yearly logistic cost savings in absolute figures for Customer E are about ten times higher than at Customer D. In percentages, savings range from 5% to 28% in yearly logistic costs, depending on how much the delivery frequency is decreased.

## 3.4 DISCUSSION

In the previous section, two delivery locations (Customer D and Customer E) are evaluated in detail. Results show that for a typically small customer, the yearly logistic cost savings are relatively very small. For a typically large customer, the savings are considerably larger. However, by reducing delivery frequencies, service to the customer is decreased because ordering flexibility is reduced. For this reason, and the fact that products should not reach their best-before date before they are bought by the consumer, delivery frequencies can not be too low. Whatever is too low, should be determined by Unilever management, and this analysis supports decision-making in this tradeoff between service and costs.

Besides evaluating the cost reductions per customer, Channel 21 should also be evaluated in a broad perspective. Although the yearly logistic cost reductions per customer are relatively small, reducing the delivery frequency of all customers a little bit (for example from 3 times per week to 2 times per week) might yield substantial reductions on a larger scale. To quantify this idea, an analysis on a larger scale is done as follows.

Unilever has indicated that the delivery frequency should not be lowered to less than once per week. Furthermore, if delivery frequencies are too small, products might reach their best-before date too soon. The logistic cost savings for these small customers are unsubstantial too. Thus, delivery locations that are visited once a week or less are not taken into account. The delivery frequency would be perceived too low by the customer. From the initial 390 delivery locations taken into account, 170 remain after this selection. From the 170 delivery locations there are 58 locations that are, based on the sample data, visited only once in the selected time period. Since the model is based on working with averages, this results in an average delivery frequency of 7 days per week. Obviously, this small amount of data is insufficient to make valid statements. Therefore, it is important to keep in mind that the average number of deliveries is based on sufficient data. For example, only delivery locations with 10 or more data points are taken into account.

Only the remaining delivery locations are taken into account. For these delivery locations, the delivery frequency is rounded down to the nearest integer. This means that if, for example, delivery location X is visited 2.19 times per week on average, the proposed delivery frequency would be 2. To illustrate the practical meaning of this: instead of 2 deliveries per week and some extra deliveries now and then, Unilever and the customer decide on two fixed delivery days. Arranging this for all selected delivery locations would result in substantial total yearly handling and transportation cost reductions in absolute number and a decrease of 4% in total yearly logistic costs in Channel 21. When decreasing the delivery frequencies for all those locations with one time per week less, with a minimum of once per week, the savings would be almost doubled. Thus, while savings for most customers alone are small, when delivery frequencies can be reduced of a selected group of large customers, potential savings are substantial. Note that this model is based on average values with sometimes limited sample data. This means that the savings on a large scale should be regarded as an indication of the potential real savings. In practice, Unilever needs to evaluate the effects of delivery frequency adjustment for each customer separately. The results of this analysis also give insights in at which customers the most potential savings lie.

### 3.5 CONCLUSION

The results in this chapter are in line with the hypothesis that, all other things considered equal, the logistic costs will never increase if the delivery frequency is decreased. The centralization analysis showed that a centralized delivery system is more cost efficient than a decentralized delivery system due to the aggregation of demands. The same principle is applied here, but here demand is aggregated over time. Decreasing the delivery frequency results in larger deliveries. This means that products are delivered more in full pallets and full layers, and less in individual boxes. Per visit, the number of pallets increase too, resulting in 'fuller' trucks and less transportation costs. The analysis also gives insights in the current situation. It shows that more than half of the delivery locations are visited once or less than once per week on average. This is reasonable for those delivery locations because their demands are that low, but further reducing the delivery frequencies is unadvisable for Unilever because it reduces ordering flexibility for the customers and the cost savings are relatively small. For the other selected locations, substantial improvements are possible and potentially 8% can be saved in total yearly logistic costs. As discussed in the previous section, substantial savings can be realized by taking the current delivery frequency, rounding it down to the nearest integer and

detracting one delivery per week (while holding a minimum of one delivery per week). This analysis supports decision-making on delivery frequencies on a customer level.



## 4 IMPLEMENTATION

The problem description presented in section 1.5 states that the system of warehousing and transportation operations in the distribution network of the FS/OOH market is inefficient. The quantitative data analysis shows that there is a large potential in logistic cost savings by reducing the number of small deliveries. There is a lack of knowledge about what kind of initiatives increase efficiency and what the cost reductions would be. In this report, centralization and delivery frequencies are analyzed and cost reductions are calculated. This chapter discusses how the results of these analyses can be used to solve the business problem.

As discussed in section 2.7, cost reductions due to centralization are unsubstantial for Customers B and C, when compared to what Customer B indicated as expected financial reward for centralization. Based on the results of chapter 2 it is unadvisable to centralize Customer B or C's delivery system. The model described in section 2.2 can be used in the future to estimate cost savings for other customers. However, as Unilever suggested, Customer B was an obvious candidate for centralization due to its size and number of separate DC's. This makes it questionable whether centralization will be favorable in the near future at all.

Results from the delivery frequency analysis show that many delivery locations are visited once or less than once per week. For these customers it is not advisable to decrease the delivery frequency. The cost reductions realized by doing this are relatively very small. The delivery locations that are visited more than once per week on average (and where the average delivery frequency is based on more than ten data points), are interesting candidates for delivery frequency adjustment. Results show that on a larger scale, the total yearly logistic costs are substantial. To implement the delivery frequency adjustments, Unilever needs to address every selected customer separately and persuade (or force) them to reduce delivery frequencies to certain fixed number per week. Financial reward systems can be put in place, but this lies outside of the scope of this thesis. While the suggested total potential savings are substantial, decisions are always made on a customer (location) level and this analysis supports this kind of decision-making.

## 5 CONCLUSION

In this final chapter the conclusions of this research are presented. The chapter starts with presenting the main findings and providing answers to the research questions and the sub-questions posed in section 1.7.1. Next, the related literature discussed in section 1.6 is briefly reflected upon and reviewed in the light of the results of this thesis (section 5.2). Finally, the limitations of this research and suggestions for future research are discussed in section 5.3.

### 5.1 MAIN FINDINGS

The research described in this report is aimed at answering the research question proposed in section 1.7.1: *What are the potential cost savings for Unilever if the efficiency of pallet loading and truck capacity utilization in the Food Solutions and Out Of Home market is improved?* In consultation with Unilever, it is decided to analyse two initiatives in detail: centralization and changes in delivery frequency. For these initiatives, the effects on pallet loading efficiency and truck capacity utilization efficiency is analyzed.

The centralization analysis focused on three customers: Customer A, Customer B and Customer C. A sample path evaluation model is proposed with which the costs of handling (pallet loading) and transportation (truck capacity utilization) can be estimated and compared. Customer A centralized their delivery system in the end of 2013 and this is used to evaluate the accuracy of the model. The results show that the model is accurate in predicting the direct results of centralization, but that (as intended) other initiatives are not taken into account. One of the initiatives was the introduction of financial incentives for ordering in full layers and full pallets. A further analysis that includes the possibility of financial rewards shows that for Customer B and Customer C the savings are not substantial (24% and 39%) and considered as insufficient to advocate centralization implementation, when absolute figures are compared to what Customer B has expected to receive as financial incentive in the past. Furthermore, implementation of centralization is an example of a change that requires downstream supply chain partners to invest in order to allow upstream partners to reduce costs. Customers need to adjust the way they are supplied while Unilever reduces logistic costs. Only when customers expect that centralization is financially beneficial for them, it can be implemented. The trade-off between investments and cost reductions is the core of centralization negotiations and this research can aid in decision-making and be used to support possible future centralization negotiations.

The delivery frequency analysis has resulted in an oversight of all delivery locations of Channel 21 and gives insights in what the changes in logistic costs per customer are if the delivery frequency is changed. It can be concluded that for most delivery locations, decreasing the delivery frequency is not a suitable option because they are already not visited frequently (once or less than once per week) and potential savings are relatively small. For the other selected locations decreasing the delivery frequency would be a suitable option. It would result in a substantial total yearly logistic (handling and transportation) cost reduction of 4% by only rounding down the current average frequencies. When decreasing the delivery frequencies for those locations with one time per week less, with a minimum of once per week, the savings would be almost doubled. In theory, delivery frequencies could be decreased to minus infinity, since the costs will always decrease as the delivery

frequency decreases. This means that there is no theoretical optimum. However, savings will be relatively small for most customers and involves a tradeoff between logistic cost reduction and some kind of investment at downstream supply chain partners. Imposing constraints in order frequencies on customers means less flexibility for those customers. Thus, as described in chapter 3 it requires managerial decision-making to decide on the delivery frequency on a customer level and this analysis helps in making this kind of decisions.

## 5.2 REFLECTION ON LITERATURE REVIEW

One of the aims of the research described in this report is to attribute knowledge to the existing body of literature. In this section, the relevant literature discussed in section 1.6 is reviewed in the light of this thesis.

First of all, it is noteworthy that the business problem described in this thesis shows similarities with business problems described in theses from more than 10 years ago (Post, 1999; Mos, 2002). This indicates that it is a lively subject and that it is a returning topic in logistic business problems.

As described in section 1.6, most inventory models about centralization are designed from the perspective of the 'customer' supply chain member. This member is supplied by the manufacturer and is also the one that makes the choice for either a centralized system or decentralized system. Moreover, most studies focus on inventory holding costs and do not include handling costs in the DC's. Viewing this problem from the supplier's perspective by comparing its handling and transportation costs in a multi-item setting has thus far got relatively little attention. In this thesis the focus is on handling and transportation costs and logistic efficiency is evaluated from the supplier's perspective.

In their research, Gudehus and Kotzab (2009) discuss two strategies for reaching a 100% filling degree. With the quantity adjusting strategy, order quantities are manipulated to an integer multiple of the load unit, and with the capacity adjustment strategy, load units are chosen/changed so that the integer multiples of their capacity are in line with order quantities. Note that research in this report is about following a quantity adjusting strategy. The load units (individual boxes, full layers and full pallets) are considered a given. Therefore, order quantities are manipulated by aggregating demand over locations (centralization) and over time (changing delivery frequencies). According to Gudehus and Kotzab, the quantity adjusting strategy is also the most common and practical way of pursuing a 100% filling degree. As mentioned in section 1.6, the implementation of quantity adjusting strategies is limited and this might indicate a gap between practice and theory. Furthermore, most literature focuses on inventory management and that usually a broad supply chain perspective. This thesis describes two variants of implementation of a quantity adjusting strategy with a focus on handling and transportation costs and thus might attribute to filling this gap.

## 5.3 LIMITATIONS & FUTURE RESEARCH

This section describes the limitations of this research and suggestions for future research. Section 5.3 describes a suggestion for future research in more detail: the location-based order behavior adjustment analysis.

**Demand sample data:** the centralization analysis is based on demand of 2013 and 2014. This is used to predict the cost savings for the following year. It is assumed that the sample data is representative for following time periods. In the model, stochasticity and seasonal patterns are ignored. Demand only varies a few per cent each year, but the effects of this, however small, are not incorporated in the model. This also means that the calculated yearly cost reductions are not durable, i.e. as the demand changes over time, the cost reduction will change too.

**Unilever's cost structures:** all analyses in this research only evaluate handling costs and transportation costs. However, there are other cost elements that may be affected by centralization, delivery frequency, or MOQ adjustments. For example, most initiatives have an impact on the number of orders processed by Unilever., which can change the order costs. Through centralization of Customer A, the number of incoming orders is reduced as all orders of the separate DC's are aggregated. However, at Unilever, cost structures are very unclear, meaning that it is very difficult to associate the different cost parts of selling prices with the actual causers of the costs. This is one of the reasons that this research is focused on only the handling and transportation costs. It would be very interesting and valuable for Unilever to make an assessment of all the cost figures that play a role in their product prices. Instead of just reducing costs, one can go a little deeper and analyze Unilever's cost-price structure as a whole.

**Business changes at K+N:** related to the previous suggestion for future research about the cost structure is the partnership with the 3PLP. Specifically, the effects of logistic cost reductions on the tariffs that K+N applies are underexposed in this research. Most of the storage space in the Foods DC in Veghel is used by Unilever. This means that if Unilever is able to change their entire operations so that no more individual boxes are ordered, the business of K+N changes too. Although Channel 21 is only a small part of Unilever's total Foods products in stock, it is unclear how business changes like that affect the tariffs that K+N uses. An interesting suggestion for future research is to analyse the influence of large restructures in the distribution network of Unilever on the operations of K+N.

**Financial incentives:** a concept that is briefly discussed in this research is the use of financial incentives for customers to only order in full layers and full pallets. There are several ways to implement this. For example, it can be agreed upon that a customer can only order in full layers or full pallets and receives a fixed reward for that, or the customer can order in quantities that it prefers and receives a reward per pallet/layer. The influence of rewards on customers order behaviour is an interesting topic for future investigation. Also the determination of the size of financial rewards can use additional analyses.

**Supply chain optimization:** all analyses in this research project are done from Unilever's perspective. However, as discussed before, collaboration with downstream supply chain partners is necessary to optimize the supply chain as a whole. Even for initiatives like centralization, it is required that downstream supply chain partners make investments while upstream members reap the benefits. As suggested in the literature by, among others, Van der Vlist (2007), a supply chain in which information is shared and the benefits of that are shared too is the best way to optimize the chain as a whole. Currently, Unilever, 3PLP's and some customers are involved in so-called partnerships, but a focus on full supply chain optimization is not (yet) present. Thus, another interesting area of future research is supply chain optimization at Unilever's supply chain.

**Minimal order quantities (MOQ's):** the results of the centralization analysis and the delivery frequency analysis suggest that centralization and delivery frequency adjustment measures should, if used, be focused at large customers. Only then substantial savings are possible (although centralization analysis showed that even for large customers, the cost reductions are relatively small). However, as the Channel 21 market consists of mostly small customers, initiatives that focus specifically on small customers are worth evaluating too. The introduction of MOQ's is an example of such initiative. Implementation of MOQ meant that all orders that did not comply with MOQ requirements, were not accepted anymore. MOQ requirements consist of a quantity level and a sales level. Those levels differ per Unilever DC. In principle the effects of MOQ's are straightforward: a customer's order (to be precise: an order that belongs to a delivery location) either meets or does not meet MOQ requirements. If a customer's order meets MOQ requirements, the order is accepted and business is as usual. But, if a customer's order does not meet MOQ requirements, the customer can choose to increase its order so that it does meet MOQ requirements, or that it accepts that Unilever will not supply it. However, the strictness of Unilever in applying MOQ's have changed over the years. Until 2010, MOQ's have been respected and were monitored closely. But since 2011, Unilever lost momentum on this and more orders that did not meet MOQ levels were accepted anyway. The introduction of MOQ's was a successful initiative to control order sizes and thus the efficiency of warehousing and transportation operations in Channel 21. Since MOQ requirements are respected less strict nowadays, Unilever is interested in an updated review analysis of current MOQ levels. A brief analysis of the current MOQ situation shows that substantial savings are realizable by (re)implementing MOQ's strictly. For customers whose orders structurally do not comply with MOQ levels, other logistic arrangements can be made. For example, they can be supplied by a wholesaler that is supplied by Unilever.

**Location-based delivery schedules:** Figure H.1 in Appendix H shows the delivery locations of all customers in Channel 21. It shows that customers of the Channel 21 market are spread across the Netherlands. There are customers located in all outposts of the Netherlands: from the north of Groningen till the south of Limburg. Currently, the logistic tariffs for Unilever are based on the demands of their customers, not on where those customers are located. If a customer orders two times a week, it does not make a difference, cost-wise, whether this is on Monday and Thursday or on Tuesday and Wednesday. This means that there is no incentive for Unilever to motivate (or force) customers to adjust their ordering behavior so that it takes driving distances into account. The following example illustrates the kind of inefficiency that arises because of this: imagine two customers A and B. Customers A and B are both located in Groningen (in an outpost of the Netherlands), but Customer A is supplied on Wednesday and customer B on Thursday. In the current situation the orders are delivered by two trucks whereas if customers A and B would both be supplied on Wednesday, the orders could be delivered by a single truck. Although supplying A and B on the same day is more efficient in terms of driven kilometers and CO<sub>2</sub> emissions, concerning the logistic costs for Unilever, there is no difference. Intuitively, this sounds inaccurate because it ignores logistic efficiency aspects. Thus, it is required that contractual agreements with K+N include driving distances in the cost structure too. Only then will Unilever be financially motivated to change their customers' ordering behavior. Of course, a trade-off between costs and service is at stake in this case. Forcing customers to change their ordering frequencies decreases the flexibility. As soon as driving distances are incorporated as logistic costs, potential cost savings can be calculated. For example, this can be done by clustering groups of customers by location and aligning delivery

schedules within these schedules. It is advisable to use these ideas as input for future research at Unilever.

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## APPENDIX A: LIST OF ABBREVIATIONS

<b>3PLP</b>	Third party logistics provider
<b>ALP</b>	Automatic Layer Picker
<b>DC</b>	Distribution Centers
<b>FS</b>	Food Solutions
<b>FS/OOH</b>	Food Solutions and Out of Home, also known as Channel 21
<b>FTL</b>	Full Truck Load
<b>HC</b>	Home care: one of Unilever's four product categories
<b>PC</b>	Personal care: one of Unilever's four product categories
<b>HTL</b>	Half Truck Load
<b>K+N</b>	Kuehne + Nagel
<b>LTQTL</b>	Less Than Quarter Truck Load
<b>OOH</b>	Out Of Home
<b>QTL</b>	Quarter Truck Load
<b>The tail</b>	The large group of small customers in the Channel 21 market.
<b>MOQ</b>	Minimum order quantity



## APPENDIX B: CHANNEL 21 BACKGROUND

This appendix provides some background information of Channel 21's market size and customer base. Note that because of confidentiality reasons, some information such as axis details and customer names is omitted.

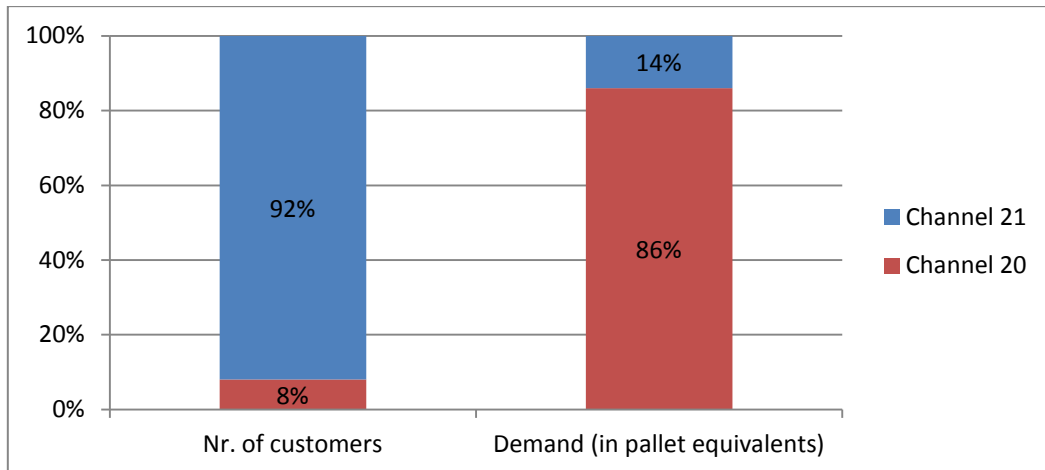


Figure B.1: Number of customers and total demand of Channel 20 & 21 (Jan '13 to Jul '14)

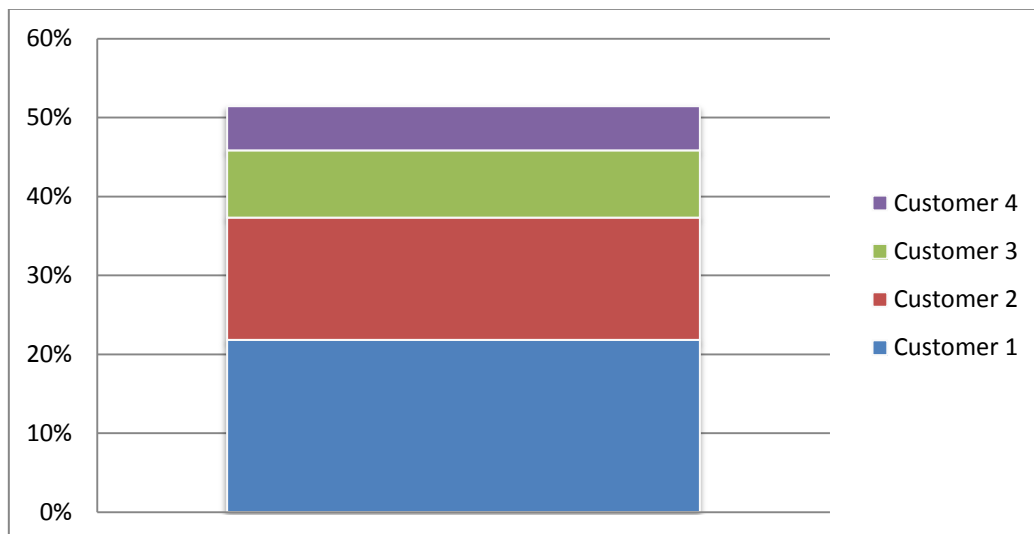


Figure B.2: Delivered volumes of the largest customer of Channel 21 (Jan to Sep '14)

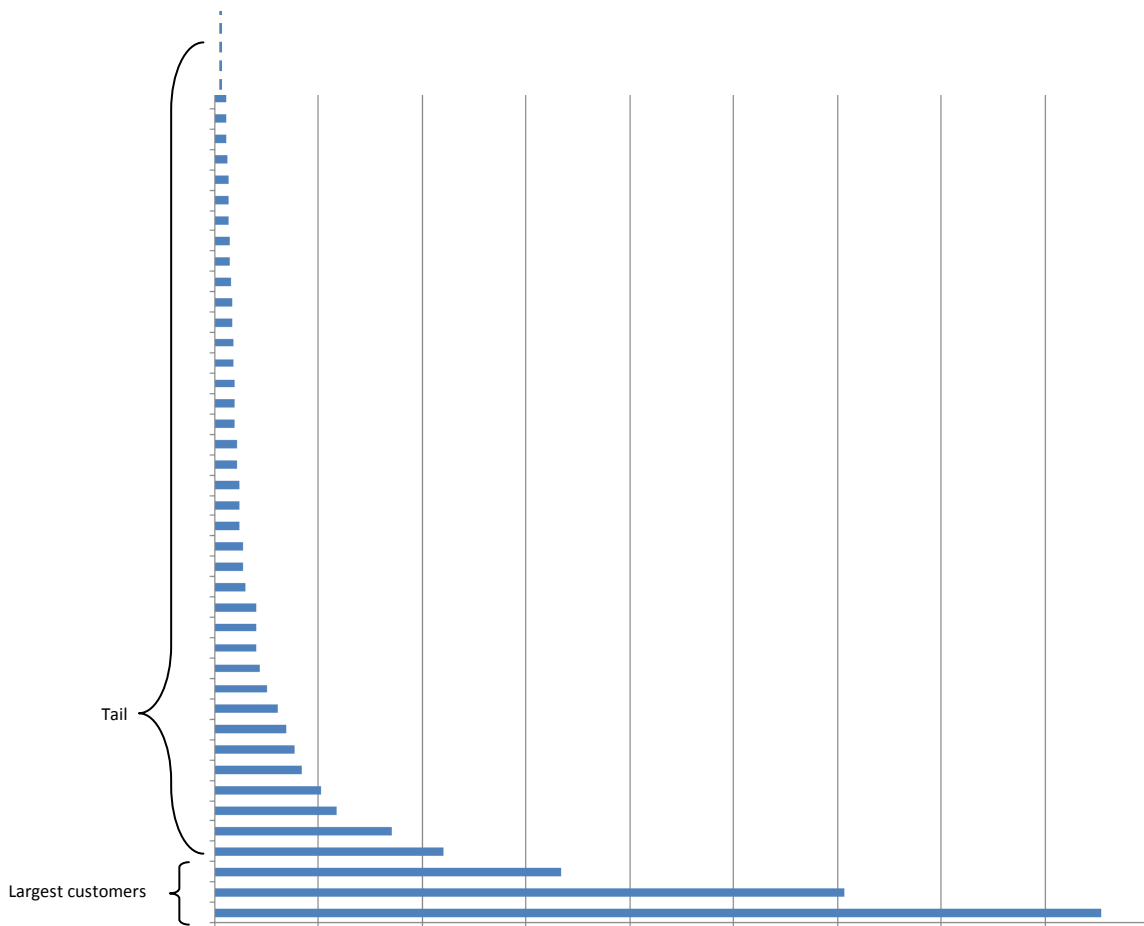


Figure B.3: Demand of Channel 21 (Jan to Sep '14)

\* This graph is cut off because what follows on top is a two page long list of small customers. Instead, the small customers are indicated by the tail.

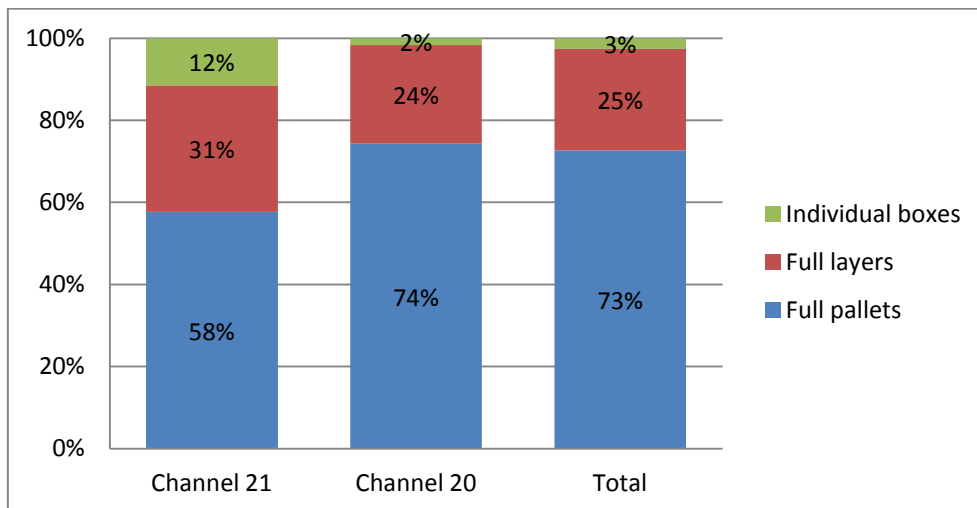


Figure B.4: Pallet loading of Channel 20 and Channel 21 (Jan '13 to Jul '14)

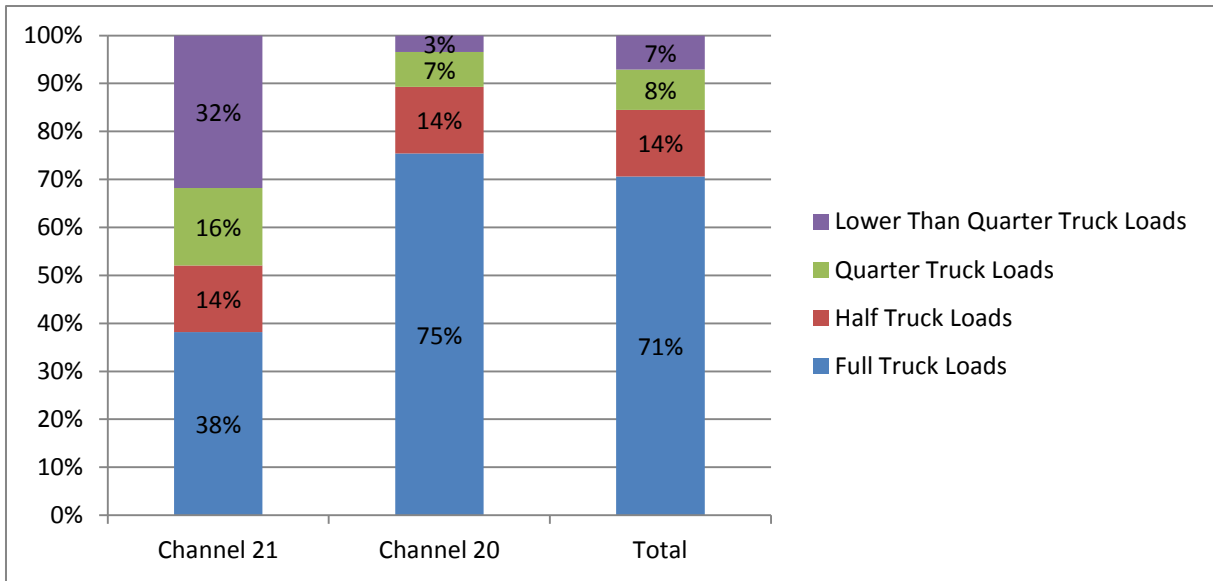


Figure B.5: Truck filling of Channel 20 and Channel 21 (Jan '13 to Jul '14)

## APPENDIX C: QUALITATIVE DATA ANALYSIS

This appendix provides information about the qualitative data analysis. Only data about products coming from the Foods DC in Veghel going to Channel 21 customers is considered here. Due to confidentiality reasons, some information like axis details and customer names is omitted.

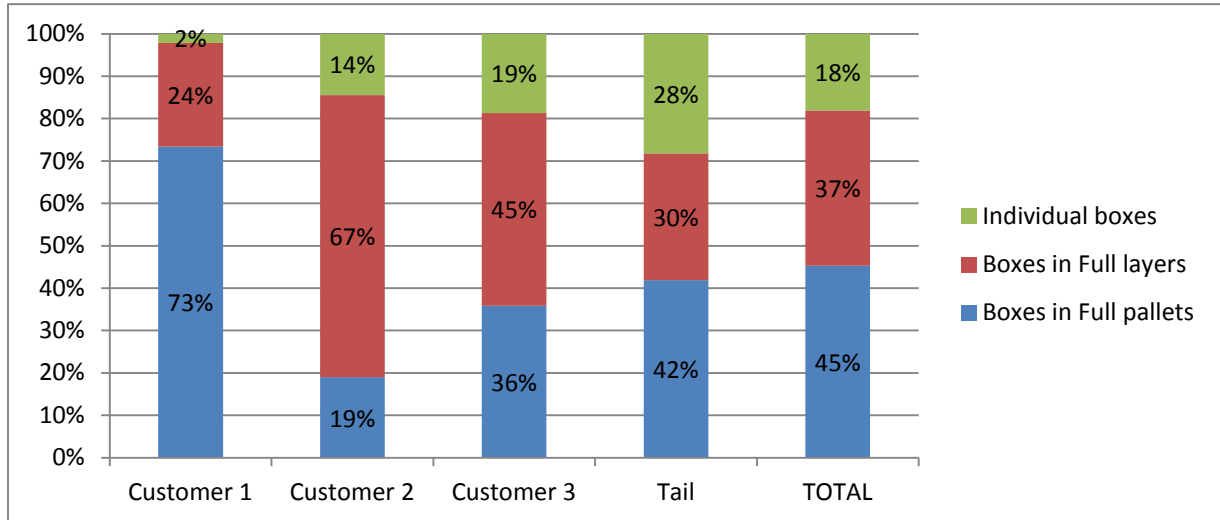


Figure C.1: Pallet loading in Channel 21 from the Veghel DC (Q4, 1, 2, 3, 2013/2014)

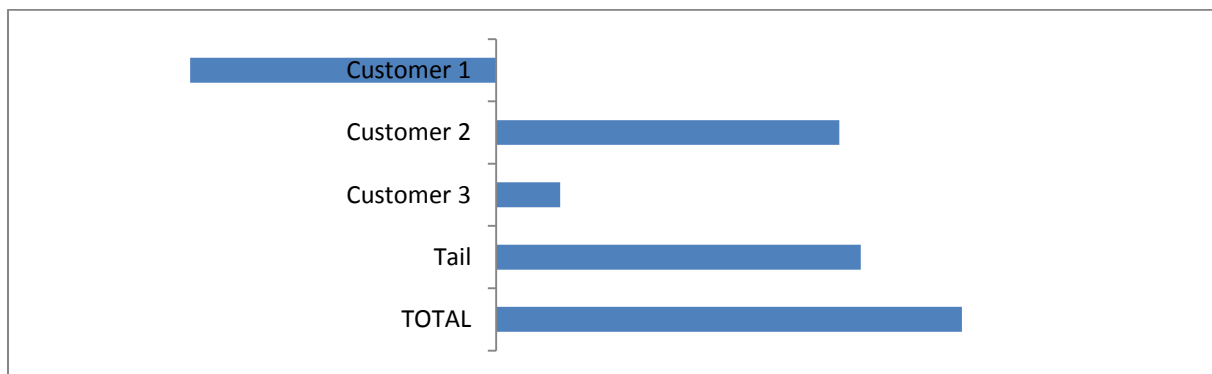


Figure C.2: Handling cost savings when products are delivered only in full pallets/layers

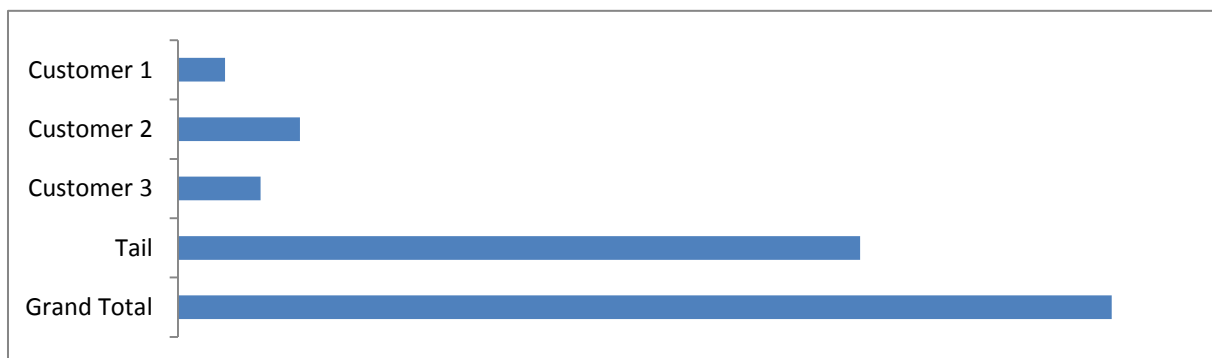


Figure C.3: Transportation cost savings when LTQTL's are combined into QTL's

## APPENDIX D: SUMMARY OF THE CENTRALIZATION MODEL

Here, the full centralization model is summarized in two parts: the symbol definitions and the calculations of the model.

### SYMBOL DEFINITIONS

$\mathbb{P} :=$  The set of all products

$\mathbb{L} :=$  The set of all delivery locations (i. e. DC's)

$\mathbb{T} :=$  The set of all time units.

$D_{plt} :=$  Demand of product  $p$  at location  $l$  at time period  $t$  in pallet equivalents

$C_{fullpallet} :=$  Logistic handling cost of one full pallet

$C_{fulllayer} :=$  Logistic cost of handling a box in a full layer with the ALP

$C_{indivbox} :=$  Logistic handling cost of one individual box

$r_x :=$  the logistic cost of transporting  $x$  pallets

$a_p = \begin{cases} 0 & \text{if it is impossible to handle product } p \text{ through the ALP} \\ 1 & \text{if it is possible to handle product } p \text{ through the ALP} \end{cases}$

$x_p :=$  Number of individual boxes that fit in a full pallet of product  $p$

$y_p :=$  Number of individual boxes that fit in a full layer of product  $p$

$z_p :=$  Number of full layers that fit in a full pallet of product  $p$

$$z_p = \frac{x_p}{y_p} \quad \forall p \in \mathbb{P} \quad (1)$$

$X_{pt}^{dec} :=$  Number of full pallets of product  $p$  delivered decentralized at time unit  $t$

$Y_{pt}^{dec} :=$  Number of boxes in full layers of product  $p$  delivered decentralized at time unit  $t$

$Z_{pt}^{dec} :=$  Number of individual boxes of product  $p$  delivered decentralized at time unit  $t$

$X_{pt}^{cen} :=$  Number of full pallets of product  $p$  delivered centralized at time unit  $t$

$Y_{pt}^{cen} :=$  Number of boxes in full layers of product  $p$  delivered centralized at time unit  $t$

$Z_{pt}^{cen} :=$  Number of individual boxes of product  $p$  delivered centralized at time unit  $t$

$$X_{pt}^{dec}, Y_{pt}^{dec}, Z_{pt}^{dec}, X_{pt}^{cen}, Y_{pt}^{cen}, Z_{pt}^{cen} \in \{0, 1, 2, \dots\} \quad \forall p \in \mathbb{P}, \forall t \in \mathbb{T} \quad (2)$$

$N_{lt}^{dec}$  := Number of pallets to be transported after deduction of full trucks to location  $l$  at time unit  $t$  in a decentralized delivery system

$N_t^{cen}$  := Number of pallets to be transported after deduction of full trucks at time unit  $t$  in a centralized delivery system

$HC^{dec}$  := Total handling costs in a decentralized delivery system

$HC^{cen}$  := Total handling costs in a centralized delivery system

$TC^{dec}$  := Total transportation costs in a decentralized delivery system

$TC^{cen}$  := Total transportation costs in a centralized delivery system

---

## CALCULATIONS

$$X_{pt}^{dec} = \sum_{l \in \mathbb{L}} \lfloor D_{plt} \rfloor \quad \forall p \in \mathbb{P}, \quad \forall t \in \mathbb{T} \quad (3)$$

$$X_{pt}^{cen} = \left\lfloor \sum_{l \in \mathbb{L}} D_{plt} \right\rfloor \quad \forall p \in \mathbb{P}, \quad \forall t \in \mathbb{T} \quad (4)$$

$$Y_{pt}^{dec} = \left( \sum_{l \in \mathbb{L}} [(D_{plt} - \lfloor D_{plt} \rfloor) * z_p] \right) * y_p \quad \forall p \in \mathbb{P}, \quad \forall t \in \mathbb{T} \quad (5)$$

$$Y_{pt}^{cen} = \left[ \left( \sum_{l \in \mathbb{L}} D_{plt} - \left\lfloor \sum_{l \in \mathbb{L}} D_{plt} \right\rfloor \right) * z_p \right] * y_p \quad \forall p \in \mathbb{P}, \quad \forall t \in \mathbb{T} \quad (6)$$

$$Z_{pt}^{dec} = \sum_{l \in \mathbb{L}} \left( (D_{plt} - \lfloor D_{plt} \rfloor) * x_p - [(D_{plt} - \lfloor D_{plt} \rfloor) * z_p] * y_p \right) \quad \forall p \in \mathbb{P}, \quad \forall t \in \mathbb{T} \quad (7)$$

$$Z_{pt}^{cen} = \left( \sum_{l \in \mathbb{L}} D_{plt} - \left\lfloor \sum_{l \in \mathbb{L}} D_{plt} \right\rfloor \right) * x_p - \left[ \left( \sum_{l \in \mathbb{L}} D_{plt} - \left\lfloor \sum_{l \in \mathbb{L}} D_{plt} \right\rfloor \right) * z_p \right] * y_p \quad \forall p \in \mathbb{P}, \quad \forall t \in \mathbb{T} \quad (8)$$

$$HC^{dec} = \sum_{t \in \mathbb{T}} \sum_{p \in \mathbb{P}} \left( C_{fullpallet} * X_{pt}^{dec} + (C_{fulllayer} * a_p + C_{indivbox}(1 - a_p)) * Y_{pt}^{dec} + C_{indivbox} * Z_{pt}^{dec} \right) \quad (9)$$

$$HC^{cen} = \sum_{t \in \mathbb{T}} \sum_{p \in \mathbb{P}} \left( C_{fullpallet} * X_{pt}^{cen} + (C_{fulllayer} * a_p + C_{indivbox}(1 - a_p)) * Y_{pt}^{cen} + C_{indivbox} * Z_{pt}^{cen} \right) \quad (10)$$

$$N_{lt}^{dec} = \left\lfloor \sum_{p \in \mathbb{P}} D_{plt} \right\rfloor - \left\lfloor \frac{\left[ \sum_{p \in \mathbb{P}} D_{plt} \right]}{29} \right\rfloor * 29 \quad \forall l \in \mathbb{L}, \quad \forall t \in \mathbb{T} \quad (11)$$

$$TC^{dec} = \sum_{t \in \mathbb{T}} \sum_{l \in \mathbb{L}} \left( \left\lfloor \frac{|\sum_{p \in \mathbb{P}} D_{plt}|}{29} \right\rfloor * r_{29} + r_{N_t^{dec}} \right) \quad (12)$$

$$N_t^{cen} = \sum_{l \in \mathbb{L}} \left[ \sum_{p \in \mathbb{P}} D_{plt} \right] - \left\lfloor \frac{|\sum_{l \in \mathbb{L}} [\sum_{p \in \mathbb{P}} D_{plt}]|}{29} \right\rfloor * 29 \quad \forall t \in \mathbb{T} \quad (13)$$

$$TC^{cen} = \sum_{t \in \mathbb{T}} \left( \left\lfloor \frac{|\sum_{l \in \mathbb{L}} [\sum_{p \in \mathbb{P}} D_{plt}]|}{29} \right\rfloor * r_{29} + r_{N_t^{cen}} \right) \quad (14)$$

$$total\ costs^{dec} = HC^{dec} + TC^{dec} \quad (15)$$

$$total\ costs^{cen} = HC^{cen} + TC^{cen} \quad (16)$$

$$TOTAL\ SAVINGS\ DUE\ TO\ CENTRALIZATION = total\ costs^{dec} - total\ costs^{cen} \quad (17)$$

## APPENDIX E: DEMAND PROPERTIES OF CUSTOMERS A, B, AND C

This appendix provides information about how the demands of customers Customer A, Customer B and Customer C are spread across their delivery locations (i.e. DC's). All percentages shown in the following charts are rounded to the nearest integer. This is why they may not always add up to 100%. Due to confidentiality reasons, some information like axis details and customer names is omitted.

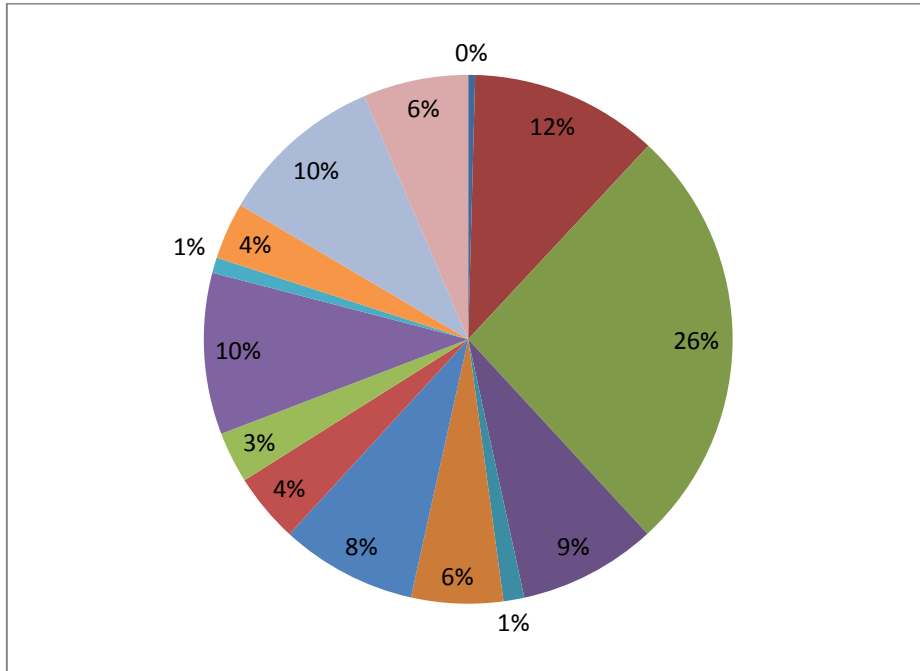


Figure E.1: Demand distribution across Customer A DC's in Oct '13

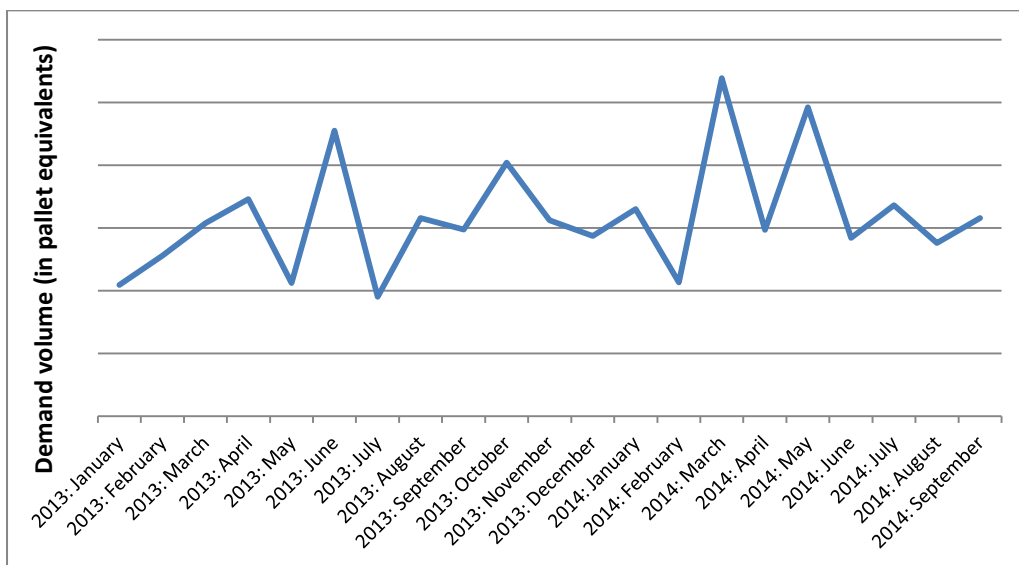


Figure E.2: Total demand volumes (in pallet equivalents) of Customer A (Jan '13 till Sep '14)



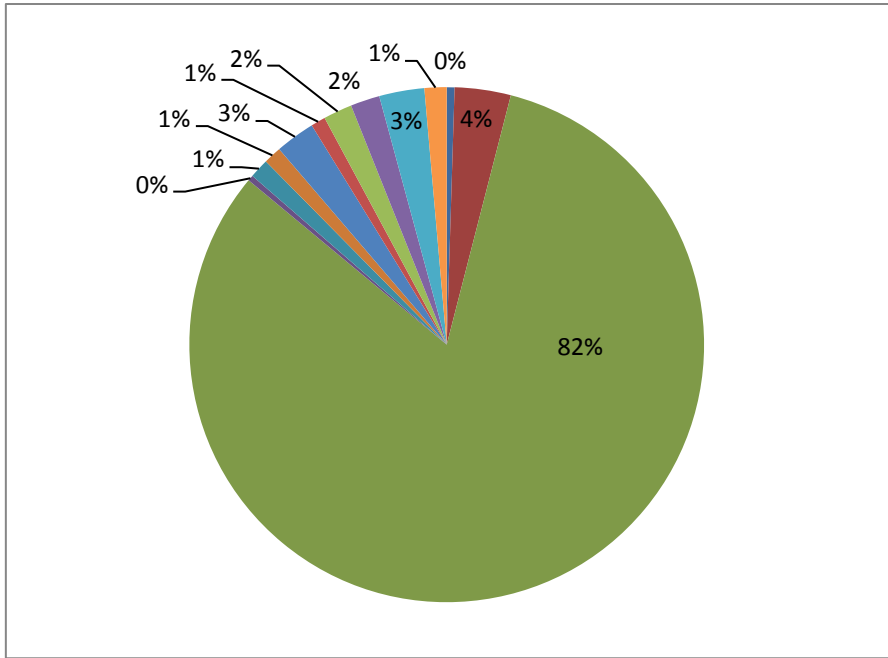


Figure E.3: Demand distribution across Customer B DC's (Nov '14)

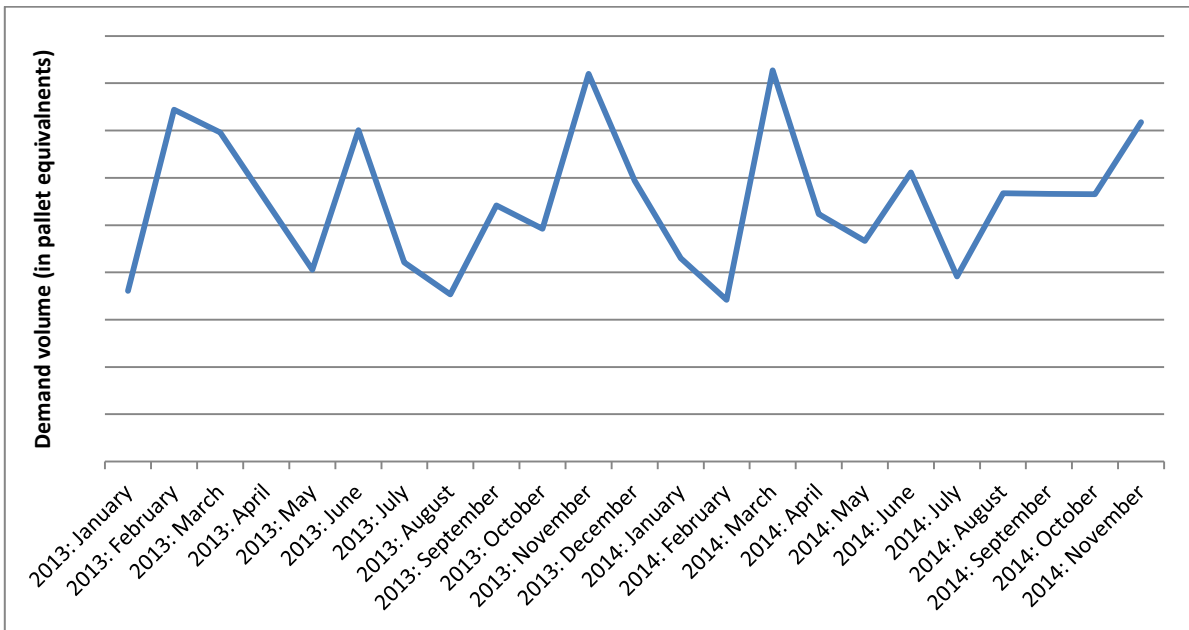


Figure E.4: Total demand volumes of Customer B (Jan '13 till Nov '14)

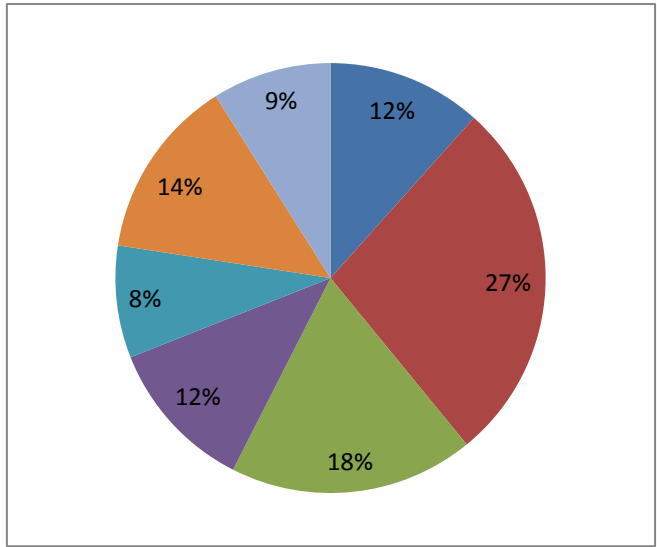


Figure E.5: Demand distribution across Customer C DC's in Nov '14

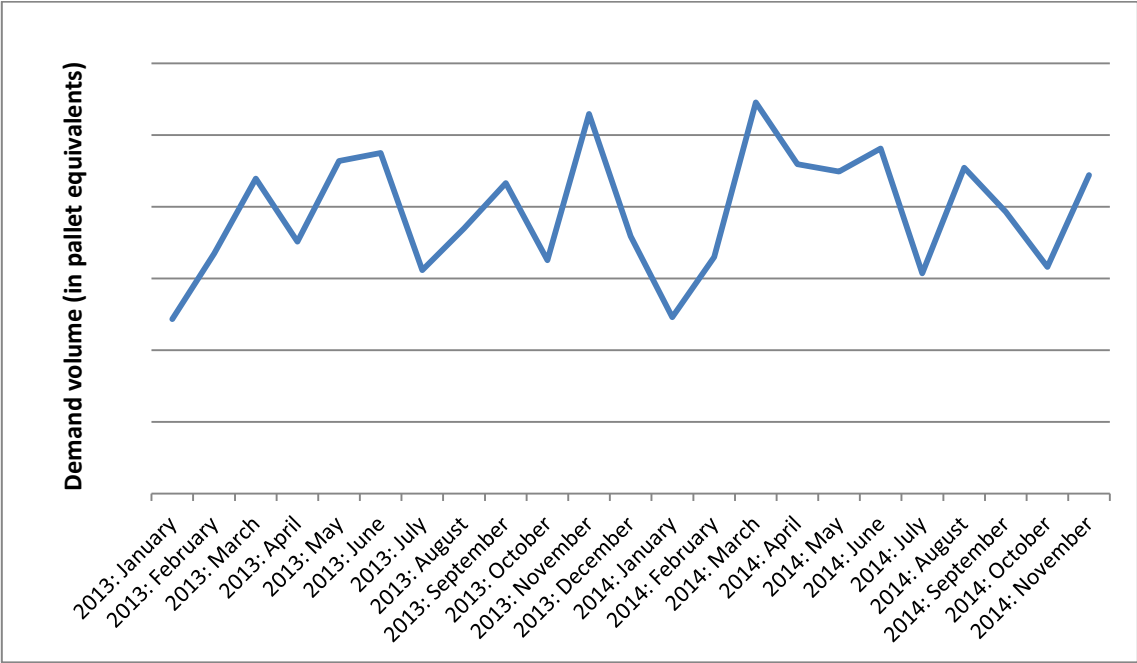


Figure E.6: Total demand volumes of Customer C (Jan '13 till Nov '14)

## APPENDIX F: RESULTS OF CENTRALIZATION ANALYSES

This Appendix provides the results of the centralization analyses for Customer A, Customer B and Customer C. Due to confidentiality reasons, absolute cost figures are omitted here.

### CUSTOMER A: PREDICTED

This section presents the predicted cost savings due to centralization for Customer A.

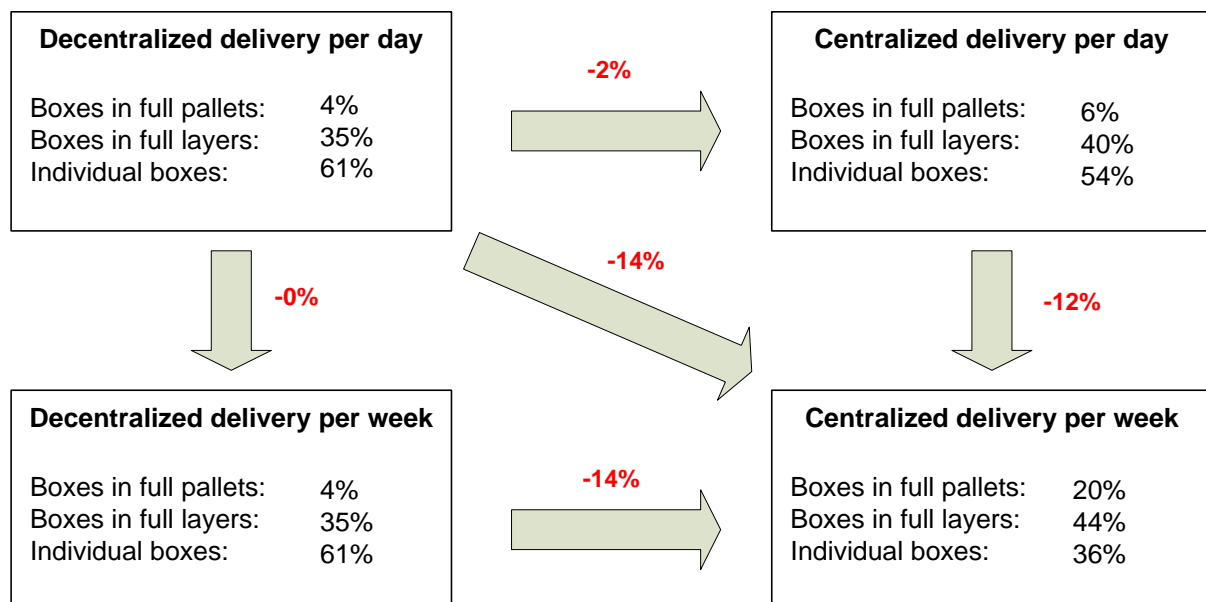


Figure F.1: Estimated handling cost reductions due to centralization at Customer A

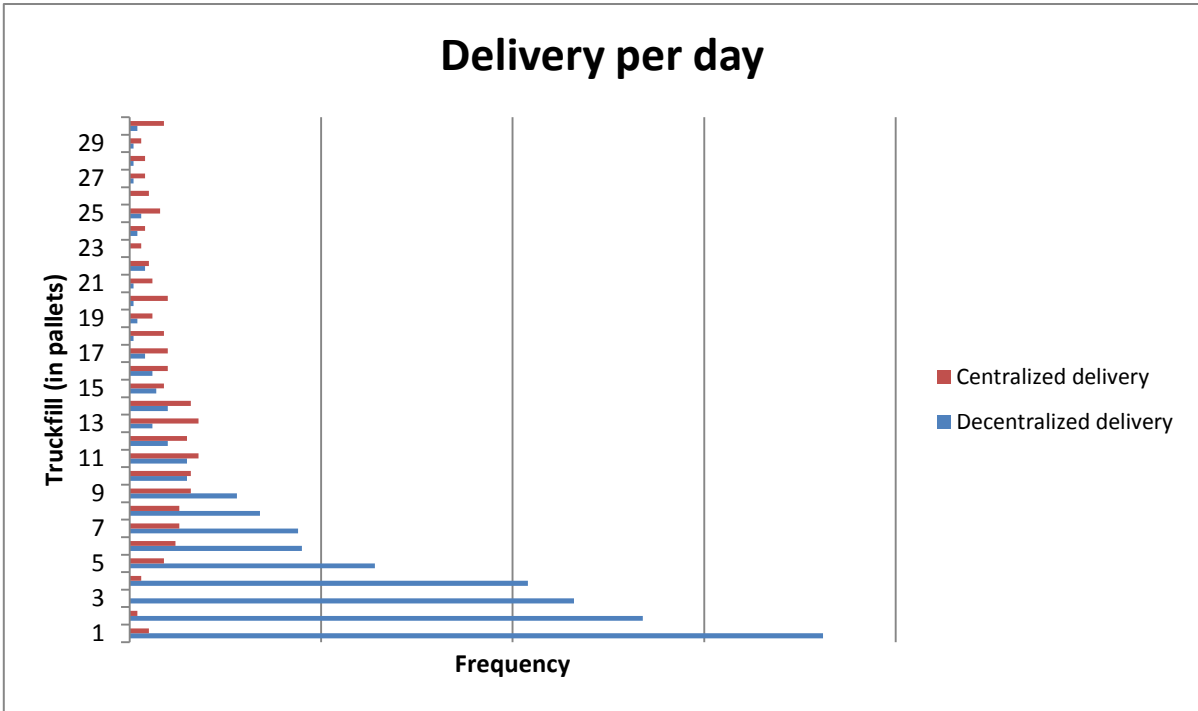


Figure F.2: Truck fill frequencies in a daily (de)centralized delivery system at Customer A

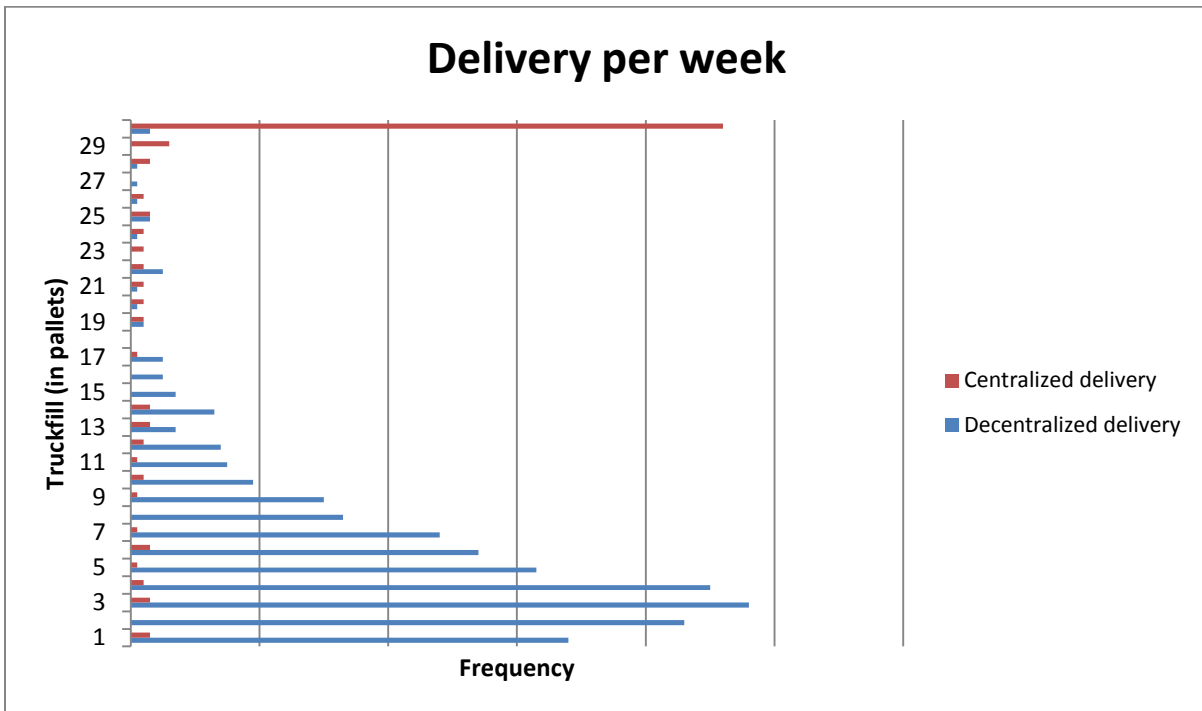


Figure F.3: Truck fill frequencies in a weekly (de)centralized delivery system at Customer A

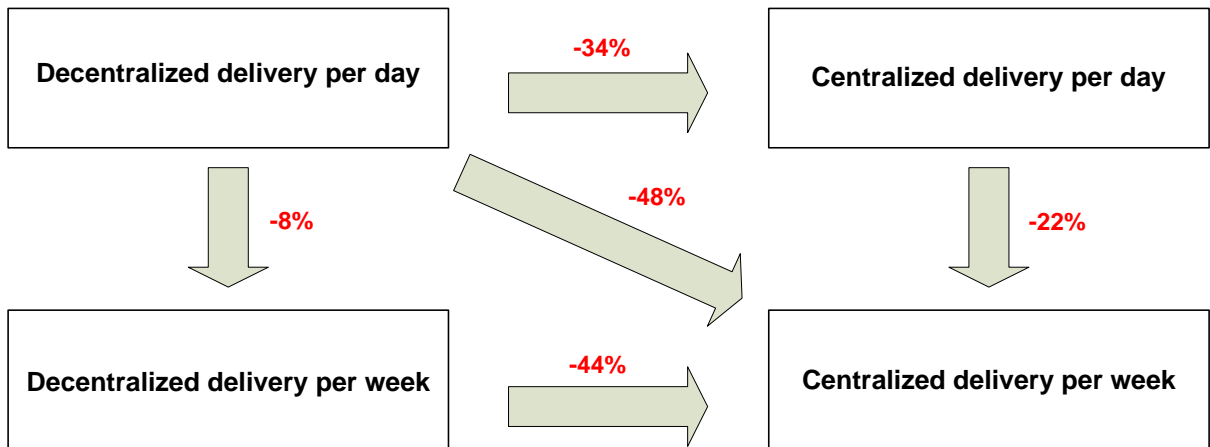


Figure F.4: Estimated transportation cost reductions at Customer A due to centralization

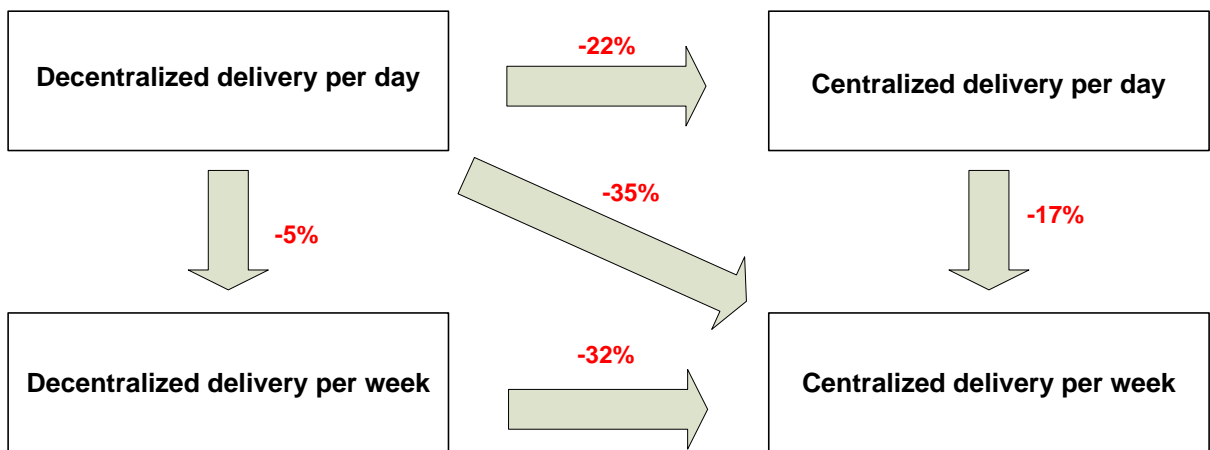


Figure F.5: Estimated total cost reductions at Customer A due to centralization

CUSTOMER A: ACTUAL

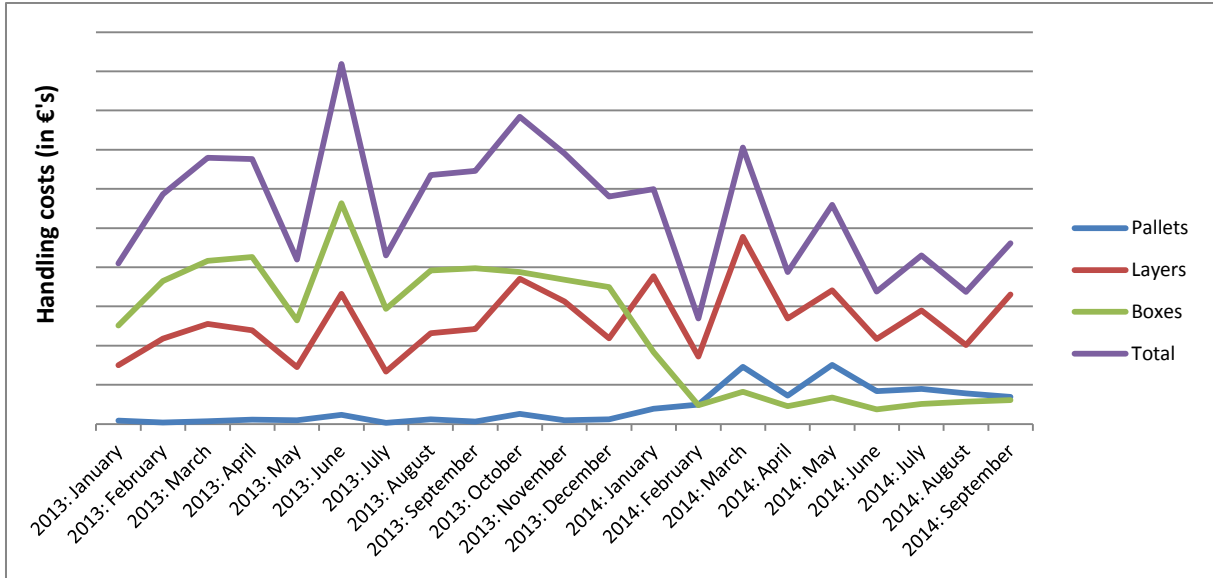


Figure F.6: Monthly handling costs for pallet loading for Customer A (Jan '13 till Sep '14)

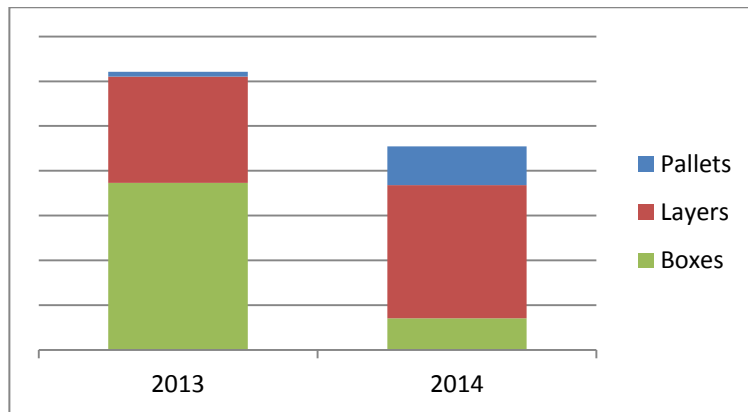


Figure F.7: Average monthly logistic handling costs per load unit at Customer A

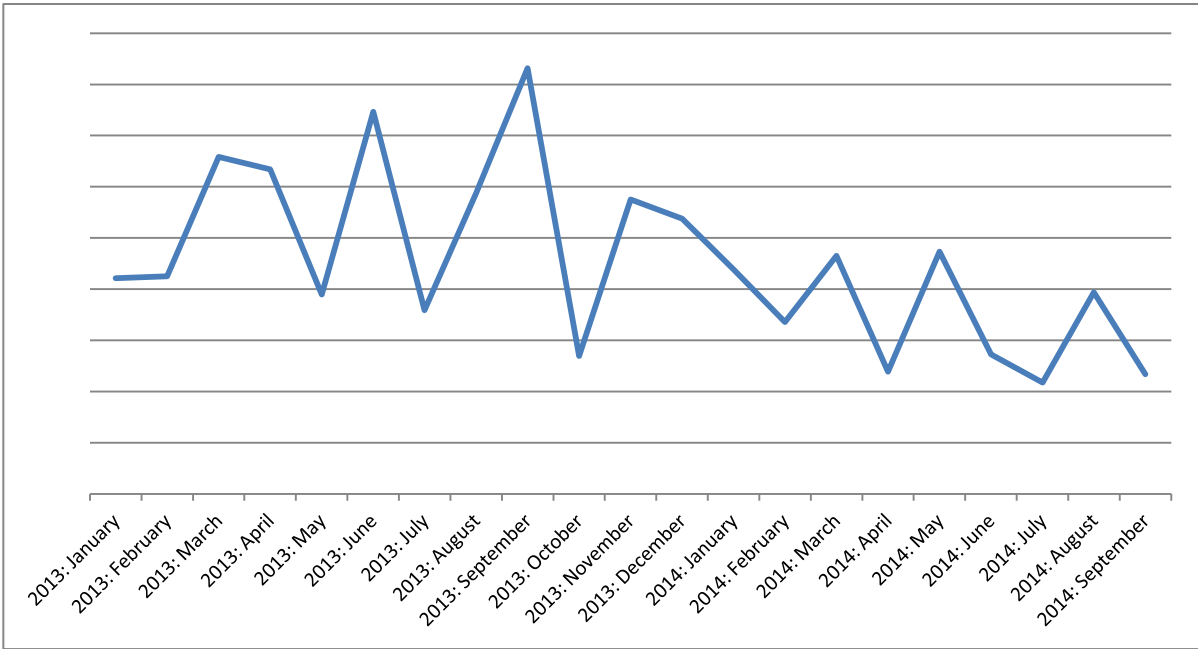


Figure F.8: Monthly transportation costs for Customer A (Jan '13 till Sep '14)

CUSTOMER B

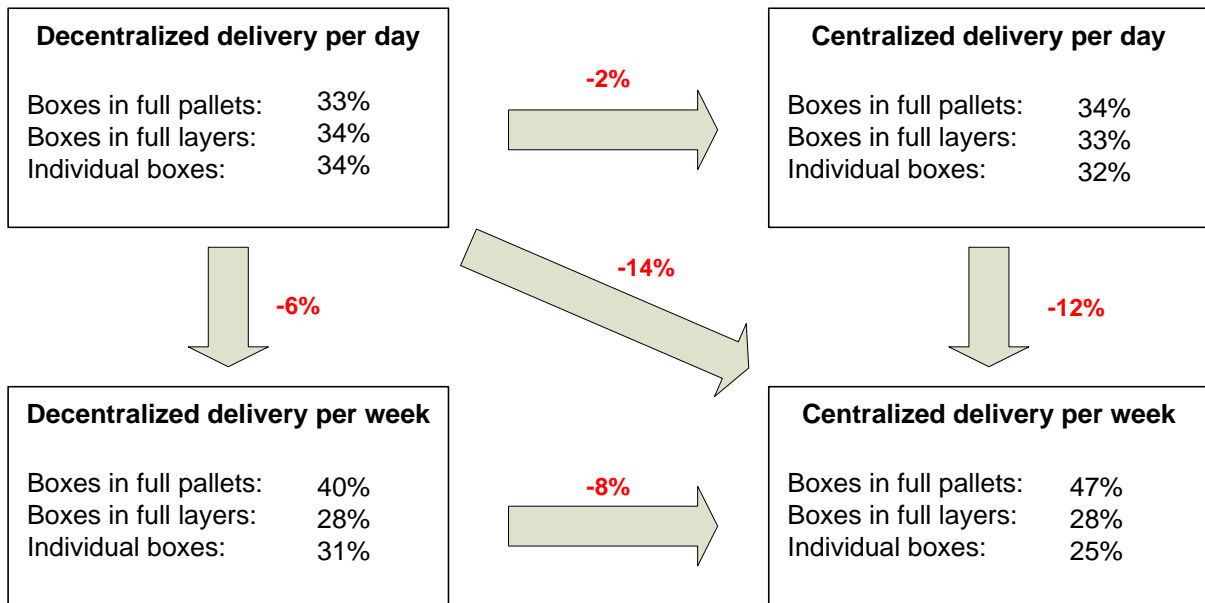


Figure F.9: Estimated handling cost reductions due to centralization at Customer B

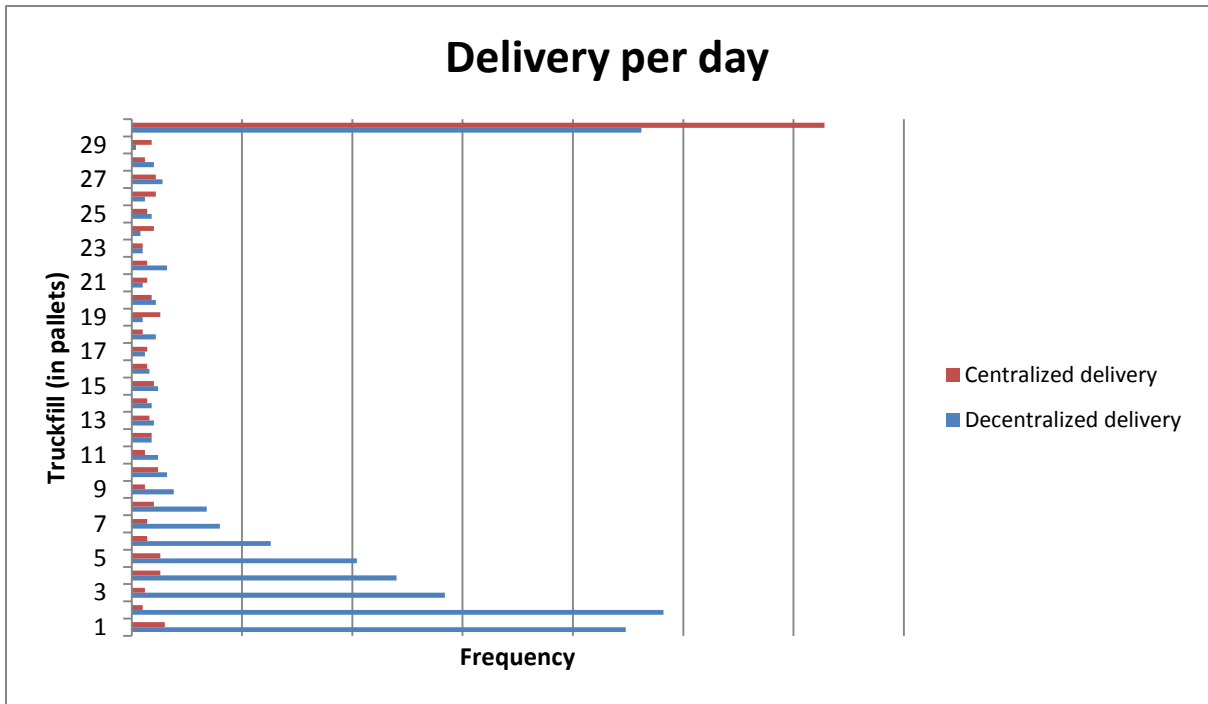


Figure F.10: Truck fill frequencies in a daily (de)centralized delivery system at Customer B

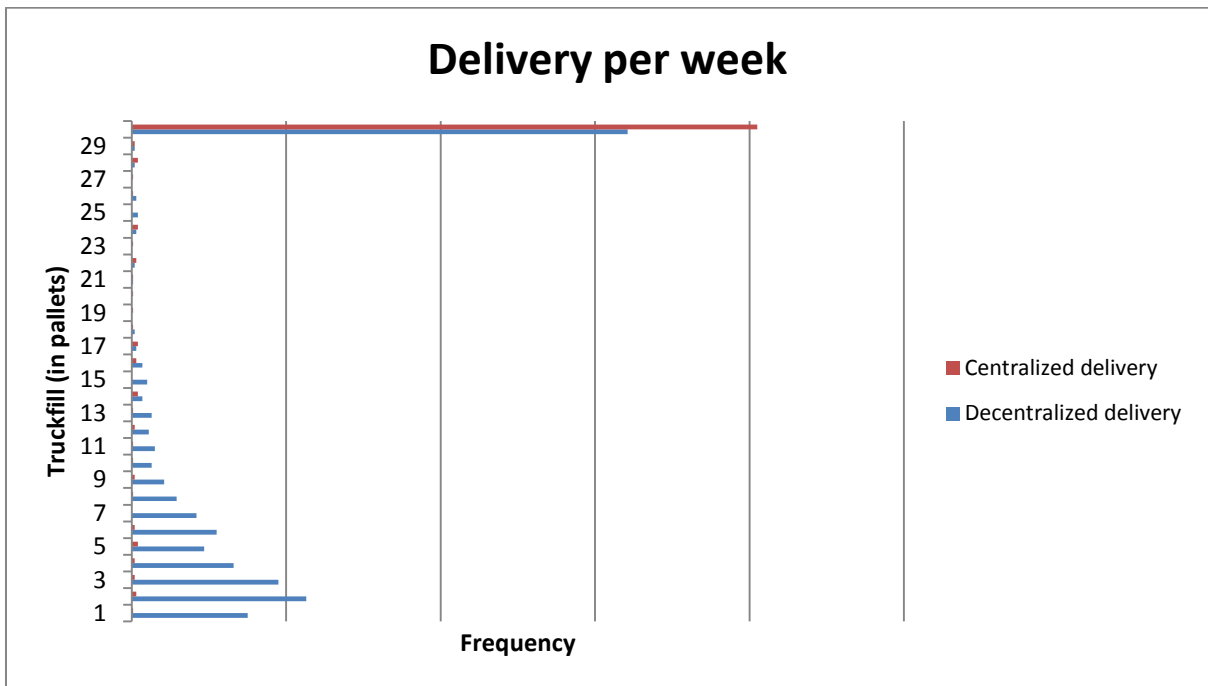


Figure F.11: Truck fill frequencies in a weekly (de)centralized delivery system at Customer B



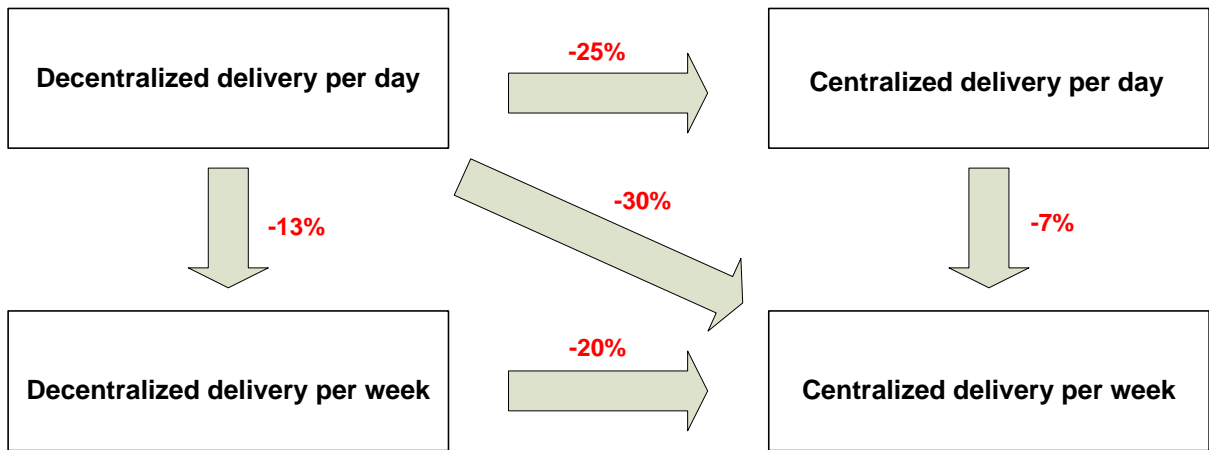


Figure F.12: Estimated transportation cost reductions at Customer B due to centralization

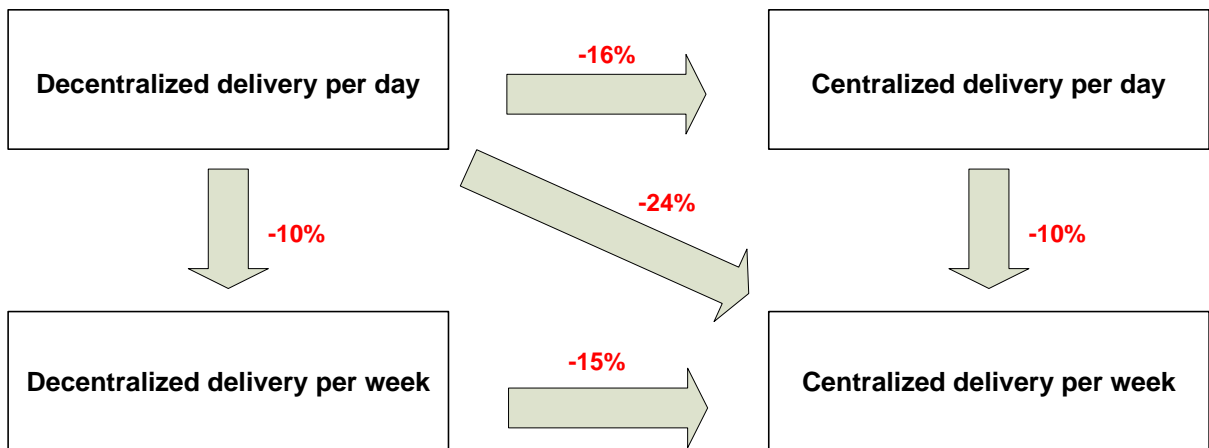


Figure F.13: Estimated total cost reductions at Customer B due to centralization

CUSTOMER C

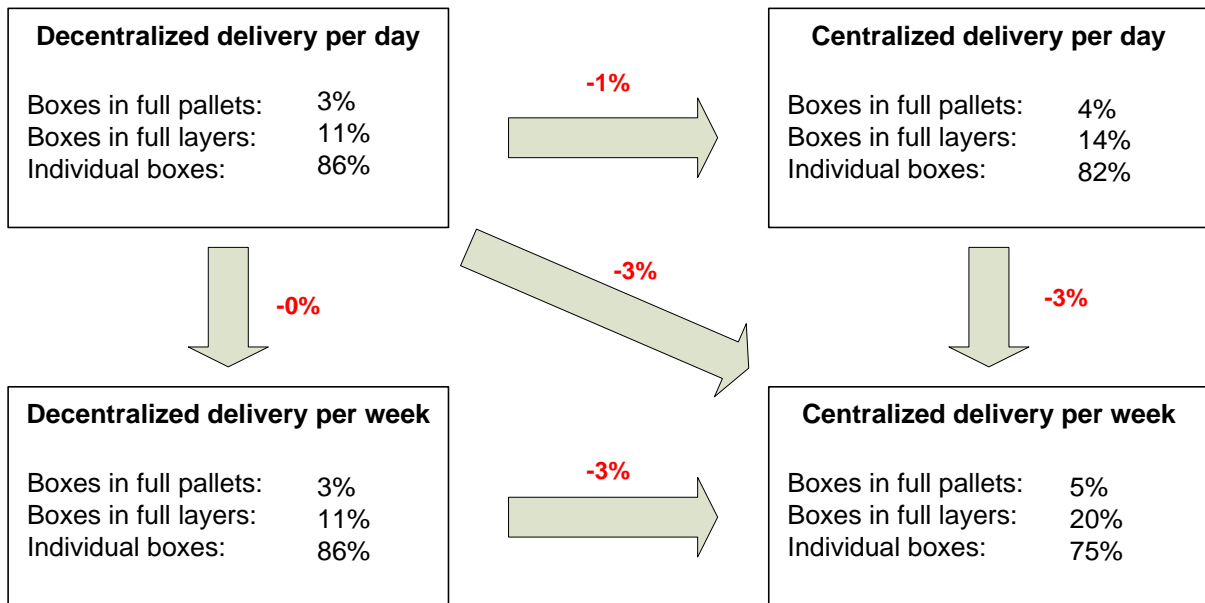


Figure F.14: Estimated handling cost reductions due to centralization at Customer C

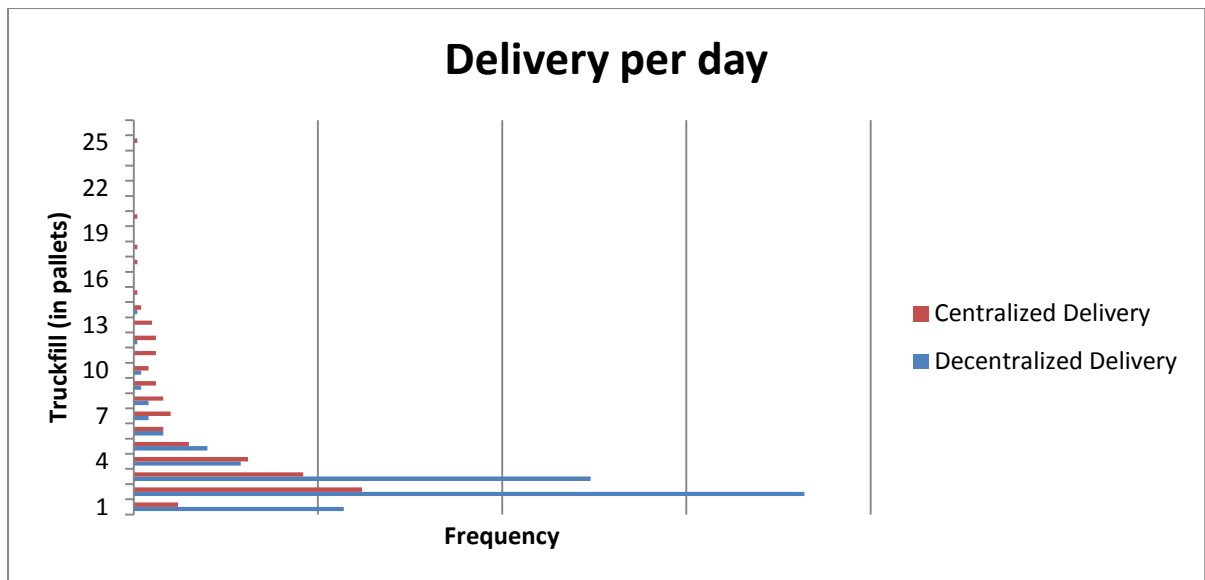


Figure F.15: Truck fill frequencies in a daily (de)centralized delivery system at Customer C

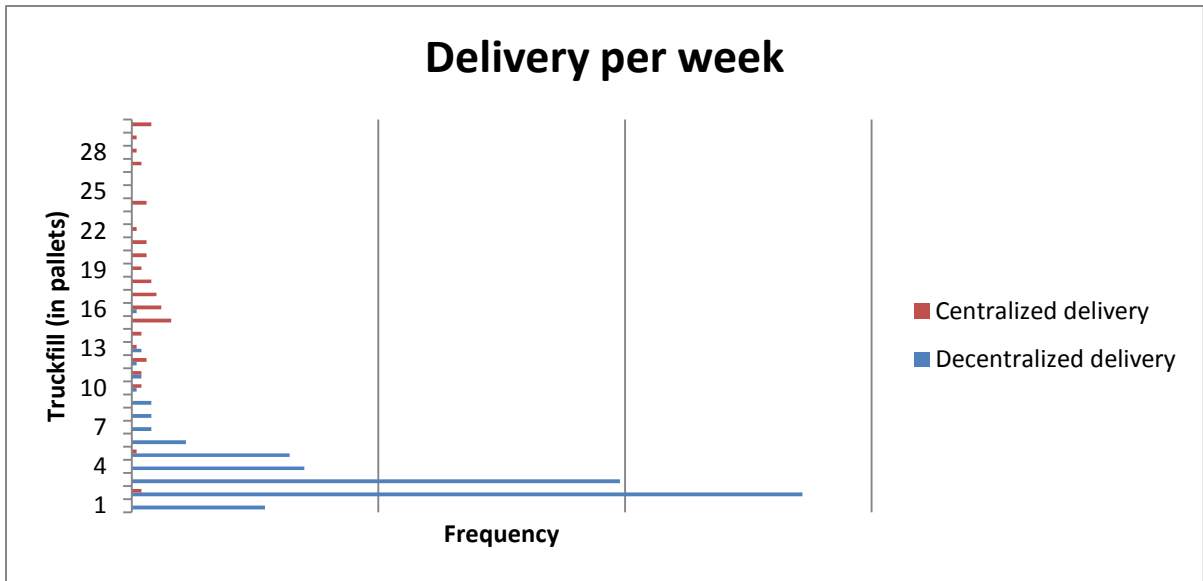


Figure F.16: Truck fill frequencies in a weekly (de)centralized delivery system at Customer C

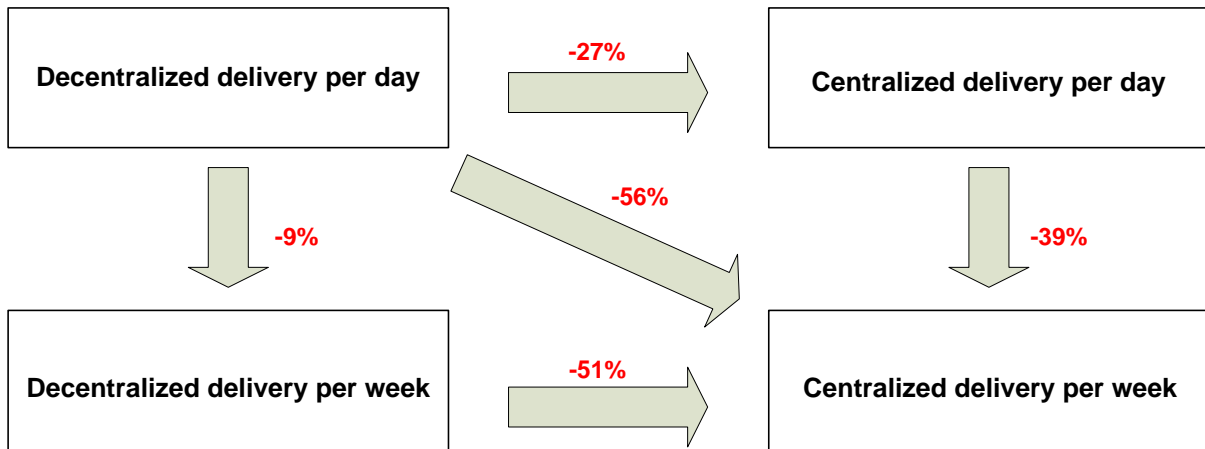


Figure F.17: Estimated transportation cost reductions at Customer C due to centralization

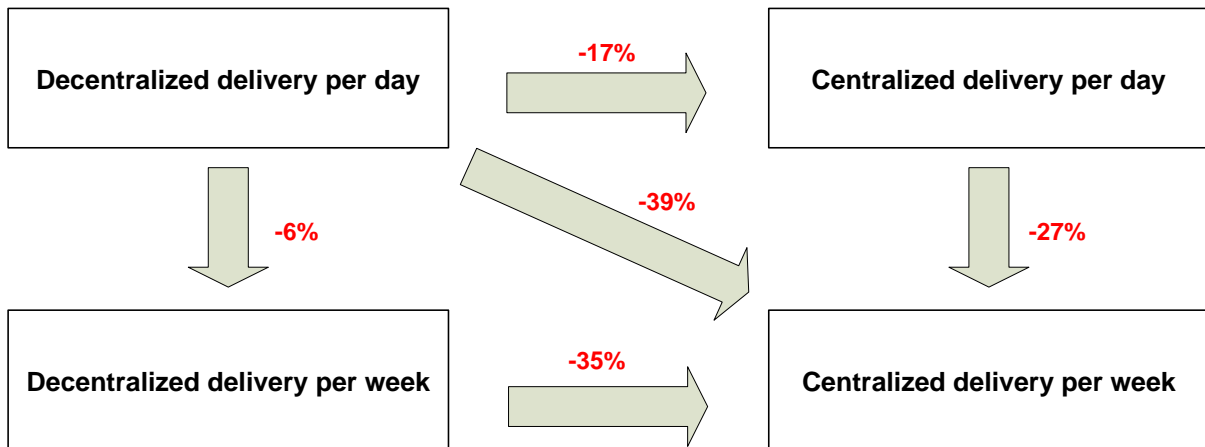


Figure F.18: Estimated total cost reductions at Customer C due to centralization

DISCUSSION

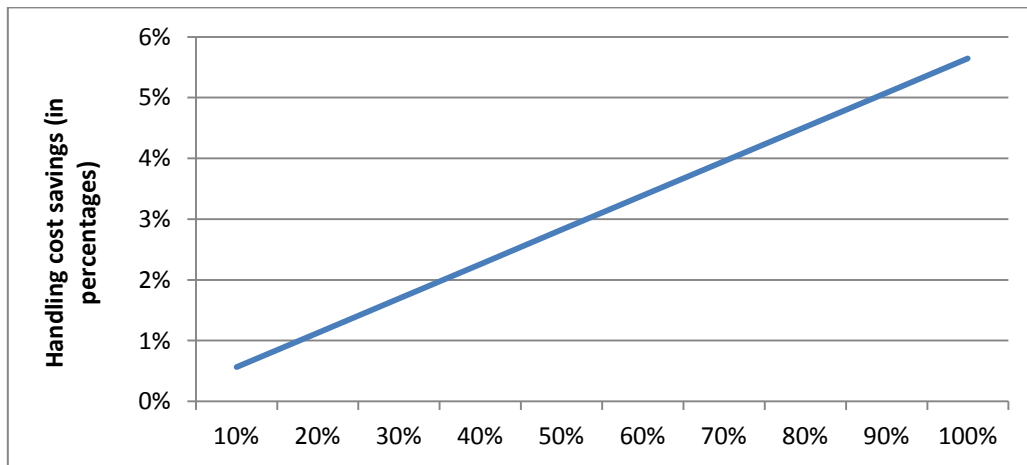


Figure F.19: Yearly handling cost savings per percentage of ind. boxes avoided for Customer B

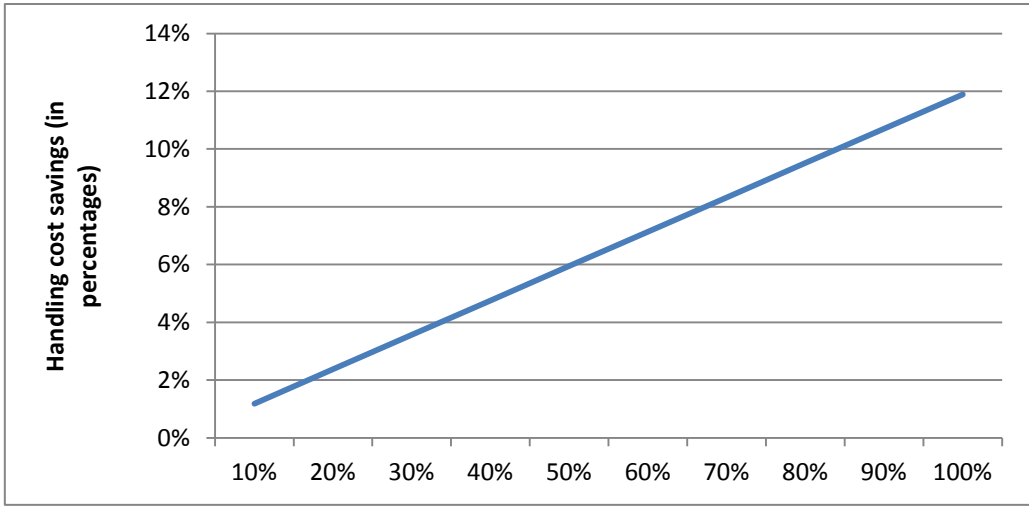


Figure F.20: Yearly handling cost savings per percentage of ind. boxes avoided for Customer C

## APPENDIX G: SUMMARY OF THE DELIVERY FREQUENCY MODEL

Here, the full centralization model is summarized in two parts: the symbol definitions and the calculations of the model.

### SYMBOL DEFINITIONS

$\mathbb{P}$  := The set of all products

$\mathbb{L}$  := The set of all delivery locations (i. e. DC's)

$D_{lp}$  := Average weekly demand of product  $p$  at location  $l$

$C_{fullpallet}$  := Logistic handling cost of one full pallet

$C_{fulllayer}$  := Logistic cost of handling a box in a full layer with the ALP

$C_{indivbox}$  := Logistic handling cost of one individual box

$\bar{x}_l$  := Average number of individual boxes that fit in a full pallet at location  $l$

$\bar{y}_l$  := Average number of individual boxes that fit in a full layer at location  $l$

$\bar{z}_l$  := Average number of full layers that fit in a full pallet at location  $l$

$$\bar{z}_l = \frac{\bar{x}_l}{\bar{y}_l} \quad \forall l \in \mathbb{L} \quad (18)$$

$\bar{D}_l$  := Average weekly demand at location  $l$  (in pallet equivalents)

$F_l$  := Delivery frequency (i. e. the number of drops per week)

$S_l(F)$  := Average dropsize (in pallet equivalents)

$X_l(F)$  :=

Number of full pallets that are delivered at location  $l$  per drop if the delivery frequency is  $F$

$Y_l(F)$  :=

Number of full layers that are delivered at location  $l$  per drop if the delivery frequency is  $F$

$Z_l(F)$  :=

Number of individual boxes that are delivered at location  $l$  per drop if the delivery frequency is  $F$

$HC_l(F)$  := Total yearly handling costs of location  $l$

$TC_l(F)$  := Total yearly transportation costs of location  $l$

$N_l(F_l)$

:= Average number of pallets to be transported after deduction of full trucks to location  $l$  per drop

$$X_p, Y_p, Z_p \in \{0, 1, 2, \dots\} \quad \forall p \in \mathbb{P} \quad (19)$$

---

**CALCULATIONS**

$$\bar{D}_l := \sum_{p \in \mathbb{P}} D_{lp} \quad \forall l \in \mathbb{L} \quad (20)$$

$$S_l(F_l) = \frac{\bar{D}_l}{F_l} \quad \forall l \in \mathbb{L} \quad (21)$$

$$X_l(F_l) = \lfloor S_l(F_l) \rfloor \quad \forall l \in \mathbb{L} \quad (22)$$

$$Y_l(F_l) = [(S_l(F_l) - \lfloor S_l(F_l) \rfloor) * \bar{z}_l] * \bar{y}_l \quad \forall l \in \mathbb{L} \quad (23)$$

$$Z_p(F_l) = (S_l(F_l) - \lfloor S_l(F_l) \rfloor) * \bar{x}_l - [(S_l(F_l) - \lfloor S_l(F_l) \rfloor) * \bar{z}_l] * \bar{y}_l \quad \forall l \in \mathbb{L} \quad (24)$$

$$HC_l(F_l) = \left( C_{fullpallet} * X_l(F_l) + C_{fulllayer} * Y_l(F_l) + C_{indivbox} * Z_l(F_l) \right) * F * 52 \quad \forall l \in \mathbb{L} \quad (25)$$

$$N_l(F_l) = \lfloor S_l(F_l) \rfloor - \left\lfloor \frac{\lfloor S_l(F_l) \rfloor}{29} \right\rfloor * 29 \quad \forall l \in \mathbb{L} \quad (26)$$

$$TC_l(F_l) = \left( \left\lfloor \frac{\lfloor S_l(F_l) \rfloor}{29} \right\rfloor * r_{29} + r_{N_l(F_l)} \right) * F_l * 52 \quad \forall l \in \mathbb{L} \quad (27)$$

$$average\ yearly\ costs\ (F_l) = HC_l(F_l) + TC_l(F_l) \quad \forall l \in \mathbb{L} \quad (28)$$

## APPENDIX H: LOCATION-BASED DELIVERY SCHEDULES

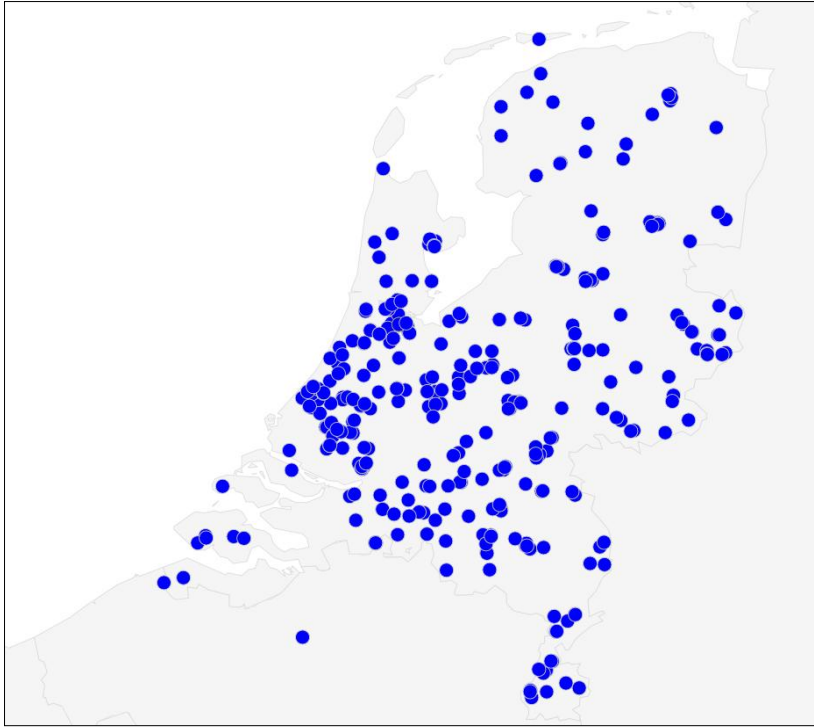


Figure H.1: Locations of all Channel 21 customers