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Optimization of Outbound Handling and Freight to Customer Operations (Tier 2) by adjusting the Customer Order Frequency and the Minimum Order Quantity

A case study of The Kraft Heinz Company

TUDelft

Optimization of Outbound Handling and Freight to Customer Operations (Tier 2) by adjusting the Customer Order Frequency and the Minimum Order Quantity

A case study of The Kraft Heinz Company

By

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Preface

This thesis has been written as the last step towards the culmination of my studies at the Delft University of Technology and the acquisition of my second Master of Science degree in Mechanical Engineering. Being part of my specialization in the track of Transport Engineering and Logistics, this thesis covers the topic of optimization in outbound handling and freight to customer operations with a case study being conducted at The Kraft Heinz Company. The substantial help I received from certain individuals while researching the topic should not remain unnoticed.

First of all, I would like to thank my graduation committee members and specifically my supervisor Ir. Mark B. Duinkerken for his guidance and support that helped me to stir the direction of the project towards gaining scientific insights and increasing the level of abstraction. I would like also like to thank the committee chair Prof. dr. ir. R.R. Negenborn for his critical feedback in all the meetings that helped me second-guess my progress, revise and improve my work.

Moreover, I would like the staff of The Kraft Heinz Company and especially my company supervisor and manager of the Logistics Benelux Team A. Papakonstantinou for the numerous times that he reviewed my model providing feedback on potential improvements as well as for providing me with opportunities to improve both my analytical and presentation skills. I would also like to thank M. Batalha and L. Mulder for their interest in my project and for their support throughout my internship and all the members of the S&OP and Logistics team for the welcoming environment that they created. It has been a pleasure working with all of you in the otherwise gloomy times of the pandemic.

Finally, the completion of this thesis would not have been possible without the support of my friends and family. I am thankful beyond words to my parents Iraklis and Anastasia who have been next to me throughout the duration of my studies, constantly supporting me both emotionally and financially. Their patience, active listening and care got me through all the difficulties I had to face. I would also like to express my gratitude to my friends Jelmer, Catrijne, Matt, Marina, Ashutosh, Miriam, Jelle, Ventsislav, and Ana whom I have been fortunate enough to meet during my studies, and the great times we had together boosted my motivation to proceed with the task.

Dimitrios Logothetis Delft, April 11, 2022

Abstract

Today's supply chains have to function in a ever-changing global business environment, defined by strong competition, shifting consumer habits and short-time deliveries. As a result, companies strive to sufficiently meet the customers' demand while being cost-effective. In addition, supply chain complexity has vastly increased due to the remarkable levels of outsourcing leading to an inflated the degree of uncertainty and risks that companies have to face. In this context, the optimal design and coordination of all the activities of the supply chain entities is essential. On the grounds of that need for optimal activity coordination the Optimization of Outbound Handling and Freight to Customer Operations has been the focus of this research. More specifically,

The main research question of this thesis is the following:

- **How can the outbound handling and freight to customer operations efficiency be maximized ?**

In order to achieve the optimal coordination of activities companies have to utilize their data to measure their efficiency and support their decision-making process. However, there is literature gap in the use of real data when it comes to Outbound Handling and Freight to Customer Operations Optimization problems. This research will use the real data of a company as a case study and a data-driven model will be developed. Attention has not either been placed on the suppliers perspective, with the existing models focusing mainly on the retailer. This is why a case study focusing on a supplier a supply chain like The Kraft Heinz Company is such an interesting subject and is going to expand the knowledge in the field. It is also interesting that, with respect to the time span of the decisions to be made, research has tended to focus on Long-term models like strategic network design and Short-term models like vehicle routing problems, rather than Medium-term models like ordering policies decisions that affect the truck space utilization and warehouse handling efficiency. Therefore, this research will focus in deepening the knowledge in this field. Furthermore, despite the width of literature, there is a lack of research regarding the effect of the supplier's influence elements such as order size and frequency has to truckload operations. For this reason, this research focuses on adjusting the Customer Order Frequency and the Minimum Order Quantity. In the existing literature Activity Based Costing and more specifically, cost to serve models have been identified to be the ideal way to approach the problem since they are meant not only to compare customer order patterns but also to analyze the strategic decisions to be applied per customer when efficiency has to be enhanced and costs to decrease.

Before the cost to serve model development, the logistic system has been described and a data analysis of the current performance in outbound handling and freight to customer operations of the case study company has been conducted leading to the identification of the design alternatives. The activities performed and their associated costs have been identified. Outbound handling includes full pallet picking, layer picking and case picking activities while freight to customer operations only the shipping from warehouse to customers activity. The costs vary per third party logistics provider (3pl) and each delivery location is being served by a specific 3pl. Underlying performance indicators identified from the literature and industrial practices such as the Loading Factor, the Full Pallet Picking Percentage and the Order Frequency have been used to analyse the data and evaluate the current performance.The data indicate that the current performance is not optimal with a lot of inefficiencies being spotted both in the general statistics and the in the detailed analysis of the order patterns of each customer. The retail Chanel in the Netherlands seems to have the combination of inefficiencies and shipped volume that makes it more prosperous for potential efficiency improvements. While the order patterns of the customers verify that a "one size fits all" approach should be avoided indicating different types of inefficiencies for each customer. The analysis also suggests that the design alternatives to be examined are Minimum order quantities strategies, with a focus on either the number of pallet places in a truck shipped or on Number of cases per product ordered, and Order frequency reduction strategies. The KPI of Costs has been selected for the evaluating the performance of the design alternatives.

After the data analysis, a conceptual model has been created representing the real-life system and a mathematical model transforming it into mathematical language with the required assumptions being made. The model is using the demand for each product in each order at all the ship-to locations throughout the year 2019, the list with the information regarding which 3pl is serving which ship-to location and the tariffs applied by each 3pl for each activity to calculate the numbers of full pallets, cases on full layers,cases case-picked and pallet places and finally the cost to serve each customer. The model has been implemented in Microsoft Excel and the implementation has been described. Finally, verification has been provided to the model through continuity tests, degeneracy tests, consistency tests and fault injection and it has been proven that the model is implemented according to the described specifications and that the implementation accurately represents the conceptual description.

After the model having been conceptualised, mathematically described, implemented and verified the design

alternatives have been transformed into eleven alternatives that have been evaluated for each of the case study company's customers, through the experiments conducted namely:

1. MOQ=full layers alternative
2. MOQ=full pallets alternative
3. MOQ=The first quartile (Q1) of the number of pallet places of all the orders for each customer alternative
4. MOQ=The median (Q2) of the number of pallet places of all the orders for each customer alternative
5. MOQ=The third quartile (Q3) of the number of pallet places of all the orders for each customer alternative
6. MOQ=Full Truck loads (26 pallet places) alternative
7. Order Frequency= 1 day per week alternative
8. Order Frequency= 2 days per week alternative
9. Order Frequency= 3 days per week alternative
10. Order Frequency= 4 days per week alternative
11. Order Frequency= 5 days per week alternative

The alternatives have been compared with the base case experiment representing the alternative where no policy is applied and have all been found to lead efficiency improvements for all customers. An exception is the alternative-delivery location combination in which the demand could not have been satisfied if an MOQ or a frequency reduction was applied. This is because, for the case study company, demand satisfaction is non-negotiable and consequently the model assumes that when the demand cannot be satisfied then the alternative is non applicable and the costs are the same as in the no MOQ implementation. Through an analysis of the model's results, the design alternatives have been compared and the ones leading to the lower costs have been selected for each customer. In that way the model's selected design alternatives are the ones that lead to the highest cost savings. However, in reality the actual selection of the alternative to be implemented is the outcome of the negotiation of the supplier with the retailers. For that reason, the design alternatives leading to cost savings has also been sorted from the one leading to the highest savings to the ones to leading to the lowest in order for the supplier to be able to use these alternatives in case of negotiations with the retailer regarding the changes in the order pattern. In addition, the combination of customers with design alternatives have been sorted with respect to cost saving opportunity in order for the supplier to prioritise the strategies to be implemented. In that sense the model both suggest the optimal design alternative and supports the real-life decision making. Finally, the performance of the design alternatives has been evaluated for clusters of customers that share specific characteristics regarding the country and the sector they operate in, their yearly demand, their average order size, their order size variability and their order frequency leading to insights that raise the level of abstraction.

In the real world the proposed design alternatives were not followed to the letter since the implementation is dependent on the willingness of the customers to change their order patterns. However, the alternatives that have been applied could be described as a combination of the ones suggested by the model in some cases, while in others as not strictly enforced MOQs. The implementation that took place only in the Netherlands retail channel despite not being the exact model's suggestion has led to the astonishing efficiency improvements and cost savings validating the model. It should be highlighted here, as a quantification of the achieved improvements, that the cost per case for the first and second biggest retailers in the Netherlands has been reduced by 7% and 19% respectively.

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1 Introduction

1.1 Supply chains

Supply chains are traditionally defined as networks of manufacturers, their suppliers, distributors, retailers and customers.(Soni et al., 2019) Through these networks the acquisition of raw materials ,their transformation into products and their delivery to the end customers takes place. A supply chain includes all the activities related to the flow of goods and information(de Souza Henriques, 2019) and aims at the optimal allocation of the produced goods promoting a competitive strategy.(Soni et al., 2019) This competitive strategy is achieved by the creation of synergies among the collaborating companies. These synergies make the supply chain as a system superior to the sum of the companies that compose it.(Vassiliadis and Dounias, 2011)

Today's supply chains have to function in a ever-changing global business environment, defined by strong competition, increasing demand for customized products and short-time deliveries. As a result, companies strive to sufficiently meet the customers' demand while being cost-effective.(Kuppers et al., 2015) The steep increase in the demand of tailor-made products and the remarkable levels of outsourcing have induced an all-time high in supply chain complexity and consequently inflated the degree of uncertainty and risks that companies have to face(Giannakis and Louis, 2011). In this context, the optimal design and coordination of all the activities of the supply chain entities is essential.(Garcia and You, 2015)

1.2 Supply Chain Management

In this context, "a supply chain can be defined as a network of autonomous or semi-autonomous business entities collectively responsible for customer satisfaction with procurement, manufacturing and distribution activities." (Lu et al., 2012) The cooperation of these entities can be managed by a supply chain management system while their roles can be modeled as distinct agents.(Plinere and Borisov, 2012) In supply chain management, the various entities of the supply chain tend to work closer to each other and depend to each other, achieving an improved coordination of the whole network, creating synergies by coordinating their activities together and consequently achieving an improved global performance.(Lam, 2019).

1.3 Kraft Heinz -The case study Company

The Kraft Heinz Company will be the source of information and the company where any developed applications will be implemented. The Kraft Heinz Company (KH) manufactures and makes food and beverage products including condiments and sauces, cheese and dairy, meals, meats, refreshment beverages, coffee and other grocery products. KH controls the entire supply chain of their branded products and their main business driver is sustainability. As presented in the figure below, KH is a multinational company with presence in all continents and is one of the leading fast moving consumer goods (FMCG) companies in the world. The regional division of the company includes the United States, Europe-Middle East-Africa, Canada, Asia-Pacific and Latin America.

Figure 1: Kraft Heinz's presence in all continents (kraftheinzcompany.com, 2021)

KH provides products for all occasions and its most iconic brands in the Netherlands include Heinz, Kraft, Honig, Karvan Cevitam, Brinta, De Ruijter, Venz, Wijko, Roosvicee, and Amoy. KH's products are sold in relatively low cost to big consumer groups daily, are produced large volumes and commercialized in small quantities.

1.4 Kraft Heinz Supply chain

KH has a complicated supply network in the Netherlands consisting of 2 factories 4 warehouses and more than 570 delivery locations of Retailers and Food Service providers making the prevention of losses complicated and challenging. With each product available in various formats, as presented in the figure below, more than 700 different stock keeping units are being sold in the Benelux, increasing the complexity even more.

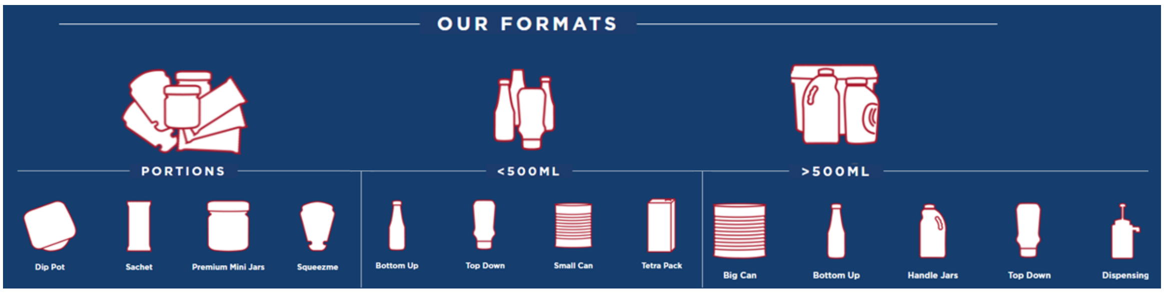


Figure 2: Kraft Heinz sauces' 13 formats (kraftheinzcompany.com, 2021)

In order to ensure minimum costs and sustainability under this complexity the company's logistics operations have to be based on the appropriate models and algorithms. The Benelux Headquarters of KHC is located in the Netherlands, and more specifically in Zeist (KHC, 2016). Two of the largest European manufacturing sites are located in the Netherlands namely plant Elst and plant Utrecht. Elst is a factory located in Gelderland, which is the primary production facility of Heinz sauces for Western Europe. The other KHC manufacturing site is in Utrecht, where the production of the various Dutch brands takes place. The most important and successful Dutch brands are the cordials Karvan Cévitam, Roosvicee, the bread toppings Venz, De Ruijter and the cereals Brinta.

The product flow, presented in the picture below, is distinguished between Tier-1 movements moving products from production facilities (factories & co-packers) to warehouses and Tier-2 movements moving products from warehouses in the logistics network to the customers. The products sourced by plants either owned by KraftHeinz or by third parties both from inside and outside the Benelux region. The company utilizes mainly road but also intermodal, rail, sea and air transportation for the Tier-1 movements while almost only road transportation is used for the Tier-2 movements due to the shorter lead times it can achieve when shipping to customers. This report will be focusing only on Tier-2 movements.

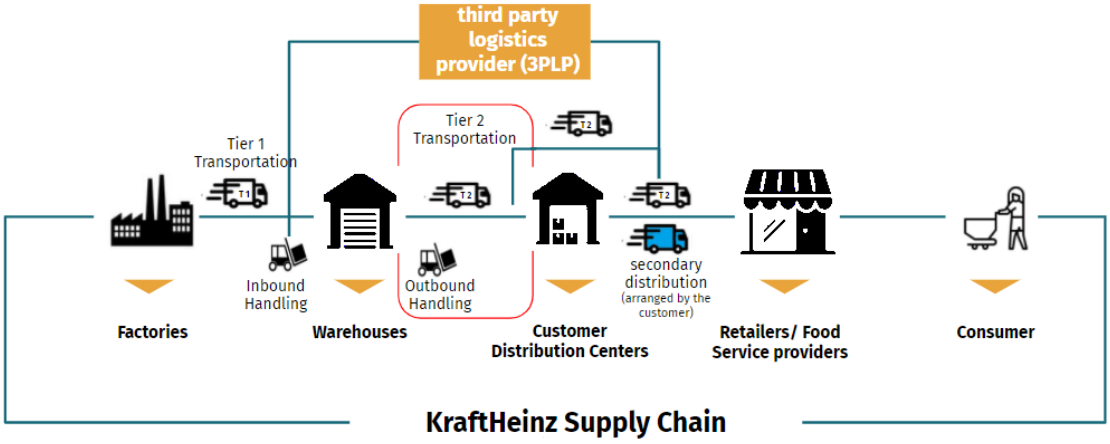


Figure 3: Kraft Heinz Supply chain

The storage takes place in KraftHeinz owned and operated warehouses, third party logistics dedicated warehouses and third party logistics multi-user warehouses in which KraftHeinz shares capacity with other customers. Warehousing consists of inbound handling, dock-to-stock, storage, replenishment, order picking and outbound handling of which only outbound handling is of interest to this assignment. Finally, the customers either receive their orders at their stores or at distribution centers from where they arrange a secondary distribution to the store themselves. In that way the products reach their consumer. The Tier-2 transportation from the warehouses to the retailer is also handled by third party logistics providers (3PL's) and alongside with the warehouse services are associated with certain costs.

1.5 Kraft Heinz Supply Chain Management

Since various nodes and links of the supply chain network are outsourced, KraftHeinz Supply Chain Management focuses on coordination the network via managing the flow of its products from the production facilities to the customers while ensuring the delivery of the right quantities at the right time. The transportation management and warehouse management, which are of interest for this report, are the main tools for the aforementioned coordination. Creating efficient transportation plans for tier-1 and 2 allows to reduce costs, improve service and increase overall reliability studying how the flow of products could be best organized across the network while order management and scheduling can further increase the cost savings. The logistics department of Kraft Heinz apart from increasing the fraction of customer demand that is met through immediate stock availability, without back-orders or lost sales also focuses on finding logistical supply companies and using them to spin the web that is the logistical transport network of Kraft Heinz. They have the chief responsibility of keeping logistics costs as low as possible.

1.6 Third party logistics providers

Nowadays, companies are able to trade internationally, relocate their business processes from one country to another and have large and complex supply chain networks. This trend has lead the sector of transport and logistics services to flourish. Many medium or large businesses outsource their logistics services in order to reduce their operating costs and investment in storage and transportation, mitigate risk, save time and allow them to focus on their own field of expertise. Companies consisting of professional logisticians that provide services of inventory management, warehousing, and order fulfillment are called third-party logistics providers (3PL).(Akter, 2019) Truck volume utilisation affects the 3PL's operational costs and via their costing system it affects the logistics costs of the outsourcing company. (Ceia, 2014) Apart from costs truck volume utilisation also affects the environmental impact of transportation as the number of trucks needed to satisfy demand increases with inefficient deliveries.(Daudi and Thoben, 2020) The connection of truck utilization on the one hand with operational costs affecting the supplier and on the other hand with hazardous gassesWehner (2017) has lead 3PLs to look out for optimization in the field. However, there are some elements that are out of the 3PL's reach, such as the customers order quantity and order frequency, that a supplier like KraftHeinz could influence via its policies.

1.7 KH's Opportunity & Problem formulation

A large proportion of the supply chain costs is depending on logistics Performance indicators such as the Drop Size, the Full Pallet Picking Percentage and the Order Frequency of the customers. In the context of continuous improvement in the Supply Chain Management, KraftHeinz desires to close the gap between the optimal and actual performance of its customer's order pattern. The opportunity apart from cost saving can expand to sustainability since optimized logistics lead to fewer trucks on the roads and consequently to less CO_2 emissions. Furthermore there is an opportunity of improving KraftHeinz relations with its customers via improved customer service since optimized order patterns can yield benefits to the customers such as fewer out of stocks, fewer dock scheduling appointments, less inbound workforce etc. The Opportunity can be summarised as Cost Saving, Sustainability and improved customer relations. Consequently, the Key Performance indicator is Costs while other KPIs could be the Emissions and the Service Level with the underlying performance indicators being the drop size, the order frequency and the fill rates.

In order to achieve KraftHeinz's goal of improving the efficiency of its operations, minimizing the logistic costs and the CO_2 footprint while improving the relations with its customers, KH trucks' volume has to be fully utilized. Transportation from the factories to the warehouses is already optimised in Full Truck Loads and Full pallets leading to substantial cost savings. This observation from practice in KraftHeinz makes the optimization of the transportation from the warehouse to the retailers distribution centers and intriguing challenge and in combination with the inspirations from the related literature on the topic it becomes an attractive subject for this research to focus on.

Consequently, the problem can be stated as follows: The optimal Outbound Handling and Freight to Customer Operations require the maximum utilisation of KH trucks' volume. An optimal Outbound Handling process would require the elimination of case and layer picking and an optimal Freight to Customer Operation process would require only Full Truck Loads. The optimization is constrained by the ability of each customer to order up to a specific volume or monetary value. However the customer's warehouse capacity and purchasing power are not the only causes of inefficiencies since the customer's order performance is frequently way lower than their own best practice.

1.8 Main research question and sub-questions

Summarizing the problem description, the main research question can now be formulated.

The main research question is the following:

- **How can the outbound handling and freight to customer operations efficiency be maximized ?**

This will be the main focus of this research. The research question can be sub-divided into the following sub questions that will help in answering it:

1. How are outbound handling and freight to customer operations problems being addressed and how their performance is compared in the existing literature?

2. How can the logistic system of outbound handling and freight to customer operations be described, what is its current performance and what are the identified design alternatives?

3. What should the structure of a model be, in order to compare the outcome of the design alternatives?

4. What are the selected design alternatives of this model?

5. How do the selected design alternatives perform in a real world experiment?

1.9 Research Methodology and Structure

The approach taken in order to address the aforementioned research questions is presented below.

Initially the problem and objectives have to be defined leading to the formulation of the research question. Afterwards, a literature study will be conducted on the related warehouse efficiency and truck volume utilization problems, in order to develop a foundation of knowledge. The next step will be to utilize that knowledge in order to analyse and describe the problem and its specifications. Subsequently, the various methods to address the problem will have to be identified in the literature. The research gap will be identified and the methods and solutions that are aligned with the problem specifications will be selected. Then the current status will have to be analysed in order for a clear depiction of reality to occur and the current efficiency will have to be evaluated in order for the opportunities to be spotted. Based on the literature and the current status analysis, a conceptual model tailored to the problem specifications will be designed and its mathematical counterpart will be developed and via programming lead to results. The model will be verified, the experiments will be conducted and the results will then be discussed. For the validation of the results some of the design alternatives will be applied in the real world and their implementation of the solution will be ensured via the development of an order management tool and then compared with the model's results. Finally, the results will be discussed and conclusions will be drawn.

The report is structured as presented in the table below:

Chapter	**Contents**	**Questions Addressed**
1 Introduction	Problem Statement and Research Questions	-
2 Literature review	Background analysis, problem specifications and method selection	1
3 Data analysis	Current performance and opportunities	2
4 Cost to serve model	Conceptual and mathematical model, model implementation and model verification	3
5 Experiments and Results	Experimental plan and presentation of results	4
6 Real-world implementation performance	Real-world experiment and model validation	5
7 Conclusions & Recommendations for future work	Discussion of results and recommendations for future research	-

Table 1: Report Structure

The first chapter gives an introduction to the subject, and presents the research questions to be answered. The second Chapter focuses on related literature and how it can be utilized to understand the logistic operations, the activities that they include and the costs they generate. Furthermore the existing methodologies to address the problem are examined and the ones most suitable for answering the main research question are selected, answering, in that way, research question one. Hereafter, the focus of the report shifts from enhancing the knowledge on the subject, to presenting the findings of the research. Chapter three provides an analysis of the current performance in outbound handling and freight to customer operations while identifying the design alternatives, with that research question two is being answered. Chapter four provides the answer to research question three by presenting a conceptual model and its mathematical translation that can be used to compare the outcome of the possible actions taken from KraftHeinz. In addition, chapter four includes a brief description of the model implementation in Microsoft excel and the model verification. The experiments conducted and the recommendations of the model regarding the optimal ordering schedule for each customer,and the design alternatives evaluation for groups of customers sharing similar characteristics are presented in detail in Chapter five. The last research question is being addressed in Chapter six, where an order management tool is used to identify the inefficiencies of the orders in real time and recommending the changes according to the implemented strategy. The results of the real-world implementation of the alternatives, that the case study company has decided to proceed with, are presented and compared with the expected outcome to provide validation to the model. Finally, in Chapter seven the deducted conclusions are displayed alongside with the recommendations for future research.

2 Literature review

In this section the related literature will be reviewed, the concepts that can be utilized will be identified and the methodology to approach the problem will be selected.

2.1 Processes

In his investigation of ways to increase warehouse efficiency, Karasek (2013) documented an analysis of all the activities that take place in a warehouse. A similar classification of warehouse activities can be found in Abdoli and Kara (2016)'s work. These activities, also characterised as "basic processes" by the authors, are:

1. the inbound of products
2. their storage,
3. the retrieval of products
4. shipping products

This master thesis focuses on the optimization of the last 2 processes, picking / retrieval / outbound handling and the shipping of products or Freight to customer operations.

2.1.1 Outbound Handling

Outbound Handling is the process of handover of shipments between warehousing and Tier 2 transportation. Zuniga et al. (2015) describes the process of outbound handling as the retrieval of SKUs from their unique location in the warehouse due to the placement of a customer order. The importance of outbound handling is highlighted in Liu (2007) and Karasek (2013)'s work, where it stated that 55% of the running expenses in a warehouse derive from picking related activities. Going further into detail, the costs are split among the aforementioned activities as follows: transporting products(55%), seeking the product (15%), obtaining the product from the racks (10%), and administrative formalities (20%). A similar classification can be found in de Koster et al. (2007)'s research regarding order picking. In Bartholdi and Hackman (2011) work picking activities are further distinguished with respect to the handled entity's nature into :

1. Full pallet picking
2. Layer picking
3. Case picking
4. Broken-case (unit) picking

In Karasek (2013)'s article one can also find a distinction of picking into homogeneous and heterogeneous, with homogeneous referring to picking only Full Pallets and heterogeneous referring to picking specific quantities and units of various products to create one pallet.This distinction is based on the fact that when the customer places an order the 3PL picks the full pallets and generates new pallets from the products that are not ordered in full pallet quantities. In that way it is possible that a pallet can consist of multiple layers of various products or even of multiple cases of various products. It is also stated that, heterogeneous picking is more common due to client requirements but also more costly due to the fact that picking smaller units requires more time and effort from the warehouse personnel. In the case of 3PL's this results into higher prices when the order requires heterogeneous picking and in the case of Kraft Heinz this results into higher logistics costs. The labour intensity of manual order picking is also highlighted by Gebennini et al. (2013) and is also identified as the reason why these activities have always been moved as downstream in the supply network as possible. In their article they argue that picking activities can be moved upstream by automating the process.

2.1.2 Freight to Customer Operations

All shipments related to bringing the products from the warehouses to the customers, which could be distribution centers for retailer or food service customers or even direct-store shipments, are registered under the term "Freight to Customer Operations". This part of the transportation network is of vital importance to the business, as its performance in terms of service impacts the customer directly and accounts for the majority of transportation spend.Karasek (2013) defines "shipping" or Freight to Customer Operations as the activities to ensure that the packed consignments will be transported at the correct destination with the correct truck and will be optimally loaded on it.

The efficiency of the loading of the truck can be measured by the usage of its carrying capacity via a loading factor/vehicle fill rate/filling rate. This can be translated in percentages of area occupied over area of the deck or volume occupied over volume of the truck (Akyelken, 2011),(Ni and Wang, 2021) or even weight of the load over the maximum legal weight(McKinnom.A, 2010). Akyelken (2011) further explains that when the product is in unitized loads like pallets, the number of units carried over the maximum number of units can be carried.

Kraft Heinz uses two types of pallets namely Euro and Block. Euro pallets have 800mm width and Block pallets have 1000mm width while both pallets have the same length of 1000mm and height of 144mm.

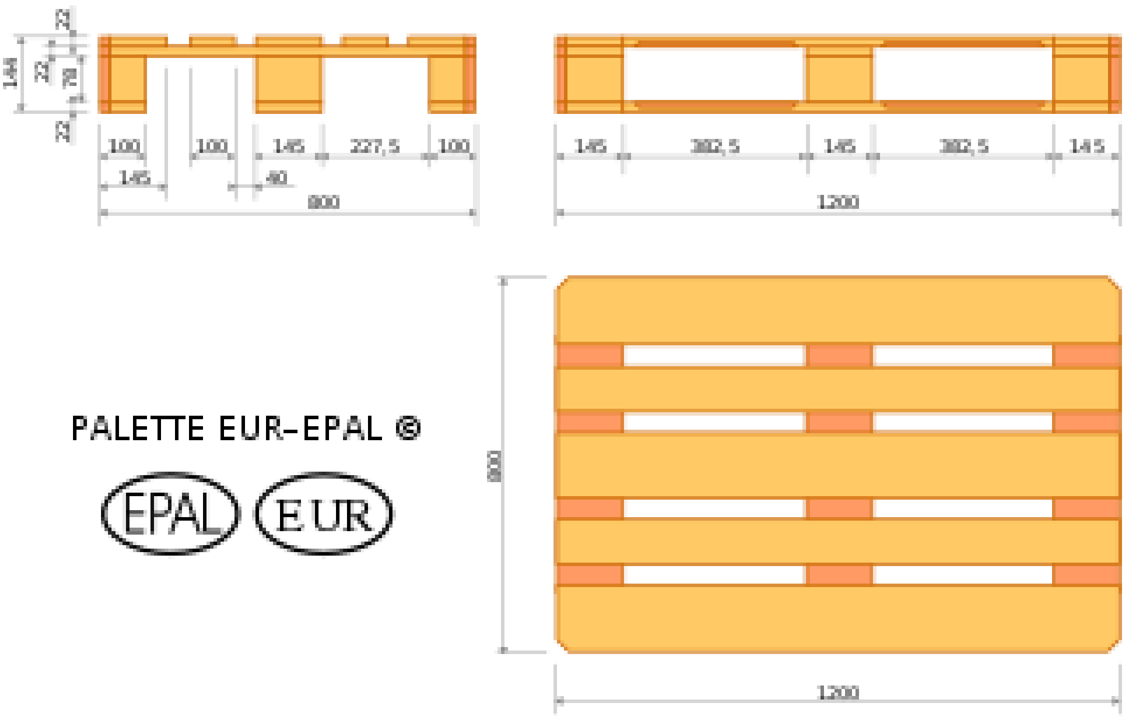


Figure 4: EUR-pallet 1200mm x 800mm x 144mm (hellaspal.gr, 2021)

While Kraft Heinz's fleet in continental Europe consists of semi-trailers with 13600mm length, 2450mm width and 2450mm height. The dimensions of the semi-trailers are presented in figure 5.

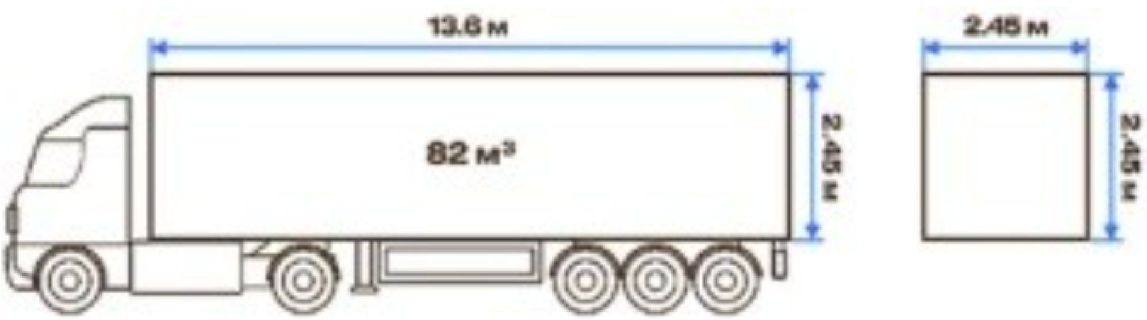


Figure 5: Semi-trailer 2450 mm x 13600 mm x 2450 mm (constanta sp.com, 2021)

Furthermore, as depicted in the figure 6 the truck can fit up to two pallets width-wise independently of the pallet type but the number of pallets it can fit length-wise depends on the pallet type.

Figure 6: A full truck

When incorporating (Akyelken, 2011)'s observation for unitized loads in KraftHeinz's case study, the trucks capacity in terms of number of pallets varies per pallet type between 26 and 33 for Block and Euro pallets respectively.

Moreover, a combination of the density of the loaded product the height of the loaded cases and the regulations regarding the safe working load for a pallet define if a pallet can be stacked or not. That means that for specific products 2 full pallets can on top of each other can be occupying only one pallet place in the truck as presented in the picture below.

Figure 7: Two full block pallets stacked occupying one pallet place

Since the products vary in each order with all possible combinations available, a Euro to Block coefficient has to be established per product with 1 Euro pallet = 0,8 Block pallet as well as a stack-ability coefficient with a stack-able pallet = 0,5 non-stack-able. Similarly a coefficient has to be established for the pallets that are not full but contain only layers or cases this height coefficient can be the percentage of the height of the current layers or cases over the height of a full pallet.

Based on Gudehus and Kotzab (2012) Chapter "Logistic Units and Master Data" and having the specifications of Akyelken (2011) in mind, the loading factor of trucks can be defined as:

$$\eta = \frac{number\ of\ logistic\ units\ contained\ in\ an\ order}{number\ of\ filling\ units\ maximally\ achievable}$$

or

$$\eta = \frac{\sum_i m_{FO_i}}{C}$$

where $m_{FO_i} = c_{b_i}\, c_{s_i}\, c_{h_i}$
with
m_{FO_i} being the number of filling units equivalent,
c_b the Euro to Block coefficient,
c_s the stack-ability coefficient,
c_h the height coefficient and
C the load unit capacity

The loading factor values vary between 0 and 1 with 1 being for ordered quantities that are equal to an integer multiple of a full truck's capacity. If the order is not equivalent to a full truck then the loading factor's value is below 1.

3PL's have pricing policies, based on truck capacity usage and aimed at providing in order to improve their truck capacity utilization.(Ilie-Zudor et al., 2014). Motivated by this cost efficiency, suppliers/manufacturers can deploy policies that will increase truck capacity utilization (Lee and Lee, 2002) (Tsao, 2015).

Gudehus and Kotzab (2012), at the same Chapter of the book that helped in the loading factor definition, proposes two alternative policies for maximizing the loading factor namely : "Quantity Adjustment" and "Capacity Adjustment".

"Quantity Adjustment" refers to changing the order quantities into full pallet multiples by either rounding up or down to the closest full pallet number. This policy is usually applied in Tier-1 transportation between the sourcing factory and the warehouse. (Gudehus and Kotzab, 2012)In that case full pallets are stored until a full truck can be loaded and shipped to the warehouse. This is common practice in KraftHeinz. On the other hand, when referring to Tier-2 transportation this could be translated into applying a Minimum Order Quantity policy. In that case the retailers are allowed to order only full truck multiples or their orders are automatically adjusted by adding pallets to be rounded to full truck multiples or orders that do not correspond to a full truck are delayed until the customer places another order that aggregate to a full truck.(Aliabadi et al., 2019)(Zhu et al., 2015)(Shen et al., 2019)(Tuncel et al., 2018) This is the area from where potential design alternatives can arise, the various ways to achieve "Quantity Adjustment" like minimum order quantity and order frequency limitations and their specifications will be the design alternatives.

"Capacity Adjustment" refers to changing the trucks capacity to be slightly smaller than the average order quantity. This policy requires a high investment since the entire fleet of transporting vehicles has to change.(Gudehus and Kotzab, 2012) Furthermore, this choice is for the third-party logistics provider to make and not for KraftHeinz, consequently it is of no interest for this research and will not be used in the search of design alternative.

2.2 Modeling approach

There is a wide range of models aiming at truckload utilization in the logistics literature.

Mehmann and Teuteberg (2016) investigated the introduction of a "neutral provider of services" in the supply chain. This provider has a sole purpose the efficiency and sustainability improvements of the entire network while integrating all involved actors. In other words they propose a Centralized optimization model. These types of models are unrealistic from a pragmatic point-of-view in the case of supply chains with numerous companies, since they completely disregard the existence of self-interest of the supply chain parties and their local objectives while the required information sharing of all the entities is almost impossible to attain in practice.(Maxim et al., 2019)(Gao and You, 2019)(Prasad et al., 2019)(Giannoccaro, 2018).

Van De Klundert and Otten (2011) have studied the concept of on line freight exchanges among transportation companies that can accept or reject orders when they have partially filled trucks or empty trucks that travel after making a delivery.The main limitation of this proposal is that it requires a internet market place for various 3PLs and a mobile communication technology installed in all their trucks. Consequently, this solution is not applicable in the current research.

Petersen and Aase (2004), de Koster et al. (2007) and (Baykasollu and Kaplanollu, 2015) have examined the vehicle routing perspective of picking considering the strategies a picker should follow to minimize its travel time when picking an order. The problem they are trying to address is described from a 3PL's perspective and only the 3PL is able to apply the solutions they provide.

Abate (2014) has examined how the ratio of the average load to the total vehicle freight capacity is affected by the traveled distance, the existence of multiple 3PLs, the space capacity of the truck itself. In spite of the interesting results, the variables that this research examines are either not in the direct influence of the supplier or determined at design phase of the network.

Üster and Kewcharoenwong (2011) studied the effect of strategic network design in the truck load utilization, while Thomas and Meller (2015) investigated the impact of a strategic warehouse design configuration on case-picking activities. Their researches, despite presenting interesting results, falls into a different classification than this one, with respect to the time span of the decisions to be made. In the current study the network and warehouses are determined beforehand and it's design falls out of the scope.

The study conducted by Hubbard (2001) suggests the combination of various orders from various customers in order to utilize the truck space. In that way, many inefficient orders are combined into an efficient one. This approach is regarding truck volume utilization from the third party logistics provider's perspective, in the sense that the combination of orders with different destinations is in the 3PL's discretion.

Ab Rahman et al. (2016) developed a vendor-buyer model where the buyer's order quantity and delivery frequency are considered via a cost function in the joint, optimal, inventory replenishment decision making under symmetric information. However real supply chain entities want to maintain their competitive advantage and their bargaining power or even aiming to better prices and in order to do so they are made reluctant to make their information equally available to all parties leading to a lower global supply chain performance. In that way scarcely any supply chain is functioning under information symmetry and consequently only the asymmetric models are accurately representing reality.(Shen et al., 2019)(Egri and Váncza, 2012).

Another supplier-buyer model was developed byAltintas et al. (2008). In this model a quantity-discount scheme is offered from the supplier in order to increase the average order size of the buyer increasing the utilization of the trucks space and thus reducing their transportation costs. This model is examining the problem from the suppliers perspective but only considers one buyer and one product. Models considering one-buyer-one supplier are oversimplifying, regarding only the interactions between two entities and focusing on the "micro-level" of the supply chain, consequently they are not realistic.(Reiß and Buer, 2014)(Montoya-Torres and Ortiz-Vargas, 2014).Furthermore, multi-product models can capture the essence of real supply chains while single-product models fail in this aspect. (Stadtler, 2009)(Egri and Váncza, 2012).

2.3 Costs and decision making in logistics

Awareness and manipulation of costs is fundamental in supply chain management.(Kumar and Zander, 2007) Costs are usually associated with inefficiencies such as not utilized resources and consequently when the efficiency goals are reached costs decrease (Seuring and Goldbach, 2002).Lee and Lee (2002) also highlights the connection between capacity utilization in distribution and cost efficiency. The same can be said for outbound handling, since as Coelli, T.J, Rao, D.S.P., Prasada Rao and Battese (2005) highlight, economic efficiency is the combination of allocative (pricing) and operational efficiency. Furthermore, logistics costs can affect the total costs of an enterprise in a great degree they should be understood and considered in the decision making.(Christopher, 2011) This need for understanding and consideration of costs has lead to the development of cost accounting tools like Activity Based Costing and Cost to serve models.

2.3.1 Activity Based Costing

Activity Based Costing (ABC) introduced by Kaplan and Cooper, R (1998) is a tool designed initially for achieving “effective efficiency" in commercial functions. It aims at determining the costs per product based on all the activities each product requires to be produced and commercialized. However, it has entered the sphere of logistics as a cost-determination tool providing the costs for each logistical process.(Guerreiro et al., 2008)(Swanson, 2020) Before ABC, costs per unit were allocated by dividing the total expenses by the total produced volume. ABC has changed radically the way costs are allocated to products(van Raaij, 2005). Apart from determining which products have the highest costs ABC improves the understanding of processes (Stapleton et al., 2004),(Özbayrak et al., 2004) and thus improves the overall decision making and opening the way to customer cost allocation.(van Raaij, 2005)

2.3.2 Cost to serve models

This customer cost allocation described in the previous paragraph is the focus of Cost to serve models. Activity Based Costing is based on the principle that each product has certain types and levels of activities related to them. Expanding the same observation to customers lead to Cost to serve models(van Raaij, 2005).As Lau (2012) has observed, companies should not follow "one-size-fits-all" strategies in their distribution but they should differentiate their supply chain solutions to meet different customer specifications. These unique specifications are often identified in logistics requirements Collins et al. (2001) and Cost to serve, has the important asset of identifying the singularities of each customer concerning their order patterns(Christopher, 2011). Cost to serve is a customer driven Activity Based Costing. Specifically, the main idea behind these models is that information regarding the order pattern of the customer such as order quantities, order frequencies, specific dates and specific locations has to be interpreted into costs and then be taken into consideration when decisions have to be made.(Guerreiro et al., 2008)(Lau, 2012) What makes the cost to serve models ideal for the problem this thesis comes to answer is, that cost to serve models are meant not only to compare customer order patterns but also to analyze the strategies to be applied per customer when efficiency has to be enhanced and costs to decrease.Guerreiro et al. (2008) Furthermore, Cost to serve is ideal for costs deriving from outsourcing activities(**?**) like the ones that are handled by third party logistic providers. Finally, Activity Based Costing and Cost to serve models have been used to drive improvements both in outbound handling (Thomas and Meller, 2015)(Gebennini et al., 2013) and in freight to customer operations(Lau, 2012).

2.4 Conclusion of the review

Answering research question 1, research has tended to focus on Long-term like strategic network design (with respect to the time span of the decisions to be made) and Short-term models like vehicle routing problems, rather than Medium-term models like ordering policies decisions that affect the truck space utilization and warehouse handling efficiency. Furthermore, many experts have used either on centralized optimization models or on joint decision making with shared information which is unrealistic. As discussed, in reality information sharing is partial at the very best with the order quantities being the only exchanged information between the parties, the 3PL's price list known only by the supplier and the retailers order frequency deducted from historical data. Moreover, despite the width of literature, there is a lack of research regarding the effect of the supplier's influence elements such as order size and frequency has to truckload operations. These elements can be manipulated before the engagement of third party logistics providers via order management. The only paper that addressed this issue considered one supplier and one customer and also one product oversimplifying the problem. It can also be mentioned here, that the literature also thrives in inventory/replenishment (EOQ) models that have not been analysed here because they are by principle regarding the problem from the retailers perspective by trying to minimize the retailers inventory costs. Not only the retailers perspective is already well studied but it can be argued that the inefficiencies in handling and transportation are playing a much more important role in the formation of costs than the inefficiencies in inventory especially with regards to fast moving goods supply chains(Vlist and Broekmeulen, 2006). Furthermore, with respect to the provided proof of consistency to the intended application, most of the studies use Numerical examples as a demonstration of the function of model solving some computational experiments, while very few provide case studies where real data-sets are used leading to a comparison with the "real world". In addition no model has been designed to address both outbound handling and freight to customer operations problems. The current research will try to cover the research gap described above by addressing the truck utilization and warehouse handling efficiency problems from a suppliers perspective. The supplier can lead quantity adjustments by applying policies to the orders of the retailers. The supplier has knowledge of the retailer's order patterns and the tariffs applied from the third party logistics provider. The objective of this research, to utilize the volume capacity of trucks, is aligned with the loading factor literature and could potentially be described as a maximization of the loading factor. However, regarding it as a volume-metric problem does not reflect reality because the problem is constrained by the customer requirements. Consequently, the understanding of the order pattern of KraftHeinz's customers is a necessity when answering the research question and providing solutions. Additionally, minimizing the costs is one of the goals of KraftHeinz that led to the formulation of the business problem this research is trying to address and a loading factor approach would de-prioritize inefficiencies in picking since they have less impact in the truck volume than the number of pallets. All things considered, when reviewing the existing literature, the loading factor is standing out as a concept but in order to be applied to this problem's specifications it has to be enhanced by a customer understanding perspective which is the key aspect of cost to serve analysis.

In a nutshell this research will focus on:

1. mid-term level decision making
2. the supplier's perspective
3. combining outbound handling and freight to customer operations problems

4. differentiated solutions per customer
5. cost to serve models

Finally, design alternatives can arise from the area of "Quantity Adjustment" strategies. Analysing the data will help in the specification of these alternatives.

3 Data analysis

In this section the system will be described and the case study data will be analysed in order for a general understanding of the current situation in the company to be established. The data that will be analysed have been extracted by the Enterprise resource planning (ERP) program and regard some specifications about the customers and their order pattern in 2019. The reason that 2019 data have been selected instead of 2020 data is for the effects of the covid-19 pandemic effects to be disregarded as they don't fall in the scope of this research. The customer specifications regard the name of the customer the country where the customer is located, the distribution channel the customer belongs to, the various distribution centers that the customer uses and their address. The order pattern regards the order quantities per product and order dates of each distribution center. The order quantities with the help of data regarding the number of cases per pallet/per layer can be translated in to Full Pallet Picking, Layer Picking and Case Picking percentages per order as well as in to Loading Factor per order. Furthermore, the order dates can be transformed into number of orders per week (order frequency) and the specific weekdays that the customer usually orders can also be extracted. Finally, the customer specifications data can help in order to create averages per customer.

3.1 System Description

The activities related with Outbound Handling and Freight to Customer operations have already been discussed in the literature review. What is of interest here is how these activities are taking place in KraftHeinz's network and what are the associated tariffs that come with those activities.

With respect to Outbound Handling, in KraftHeinz's warehouses, only the first 3 types of Bartholdi and Hackman (2011)'s classification, discussed in the literature, are present with the 3PL's the picking activities being partially automated. Full Pallet picking requires the less time and effort from the warehouse personnel, employees driving their forklift trucks to the storage locations and picking the ordered products. Layer picking requires the full pallet of the products that are ordered on a layer level to be brought to the Automated layer picker, there layers of various products are placed on a collection pallet with intermediate pallets in between and are wrapped with sealing foam to ensure stability. Finally, Case picking is a completely manual process with the warehouse employees picking the cases with their bare hands placing them on an empty pallet and stacking the various cases in way that stability is ensured. The labour intensity of each process can also be observed in the 3PL's price table.

Tariffs	**Price**	**unit of measurement**
Full Pallet Picking	2,02 €	pallet
Layer Picking	0,15 €	case
Case Picking	0,2 €	case

Table 2: Picking tariffs of a third party logistics provider

With respect to Freight to Customer Operations, as discussed in the literature review these activities focus on bringing the products from the warehouses to the customers and include all the kinds of shipments to customers. The activities required are also handled by various 3pls and the tariffs applied to KraftHeinz for the shipments of its goods to customers is presented in the table below.

pallet places	cost per block pallet place
1	22,94 €
2	18,06 €
3	16,13 €
4	14,69 €
5	14 €
6	13,36 €
7	12,9 €
8	12,33 €
9	12,02 €
10	11,66 €
11	11,35 €
12	11,04 €
13	10,72 €
14	10,41 €
15	10,2 €
16	9,92 €
17	9,73 €
18	9,44 €
19	9,23 €
20	8,93 €
21	8,73 €
22	8,5 €
23	8,28 €
24	8,05 €
25	7,85 €
26	7,71 €

Table 3: Transportation tariffs of a third party logistics provider

Finally, it can be noted here that the connection of the underlying performance indicators and the Key Performance Indicator has been briefly discussed in the previous chapter. Regarding the loading factor the price list presented in Table 3 clarifies that the higher the loading factor is the lower the costs are per shipped pallet and consequently provides a strong motivation for KraftHeinz to increase it. However, with respect to the Full Pallet Picking, Layer Picking and Case Picking percentages, the price table presented in Table 2 reveals that the unit of measurement used for the picking activities varies per type of activity. Consequently,in order to understand the price table, one needs to understand that the configuration of number of cases per pallet depends on the products specifications, packaging and customer requirements and varies widely within KraftHeinz portfolio. KraftHeinz's products are packaged into cases and those cases are placed on pallets next to and on top of each other forming layers up to the point that the stack is still stable and safe for transportation or up to the point that it can fit the customer storage height limitations. This stack is called a Full Pallet. From the graph presented below, the aforementioned variety becomes apparent. Among the 708 stock keeping units sold in the Benelux the cases per pallet are varying between 24 and 600, while the cases per layer are varying between 4 and 160.The number of products sharing the same configuration is presented in the graph below.

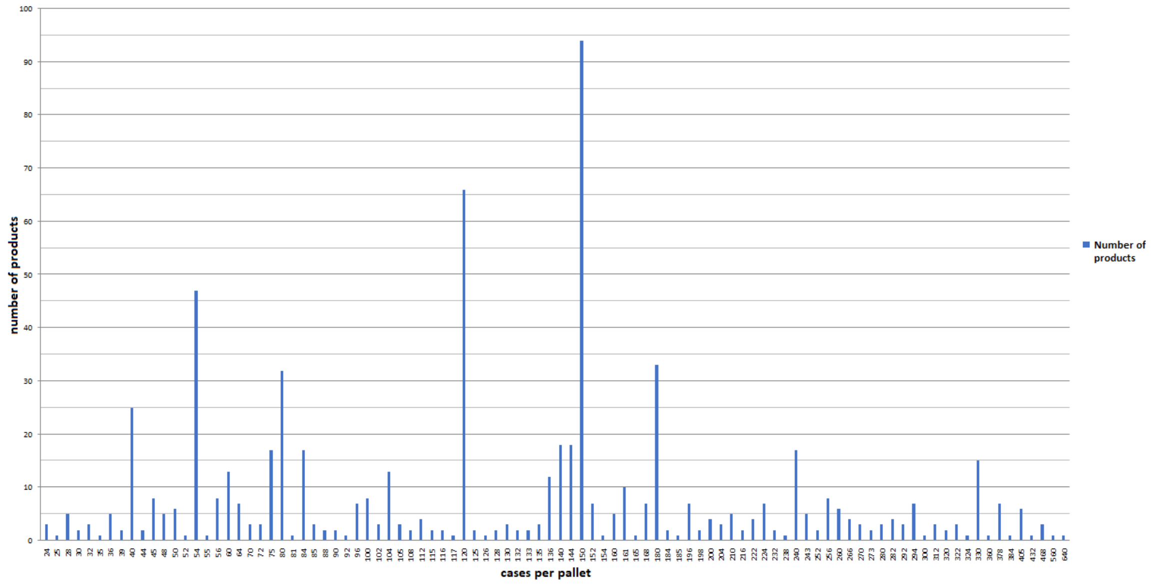
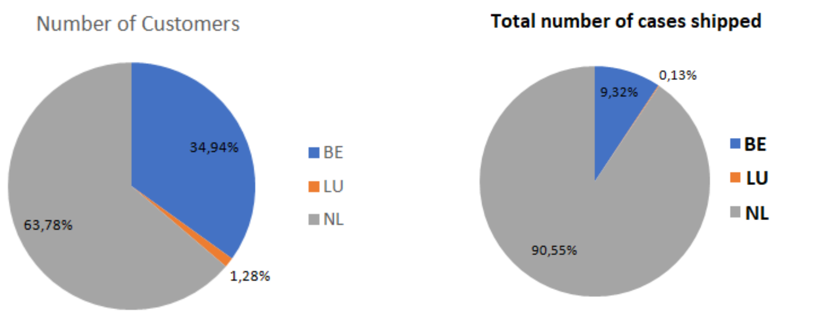


Figure 8: Number of products sharing the same number of cases per pallet

The price list in combination with the number of cases per pallet provide a strong financial motivation to KraftHeinz to utilize the volume one pallet can potentially carry. Specifically, KraftHeinz should ship products on Full Pallets or at least Full Layer multiples whenever shipping FP is not possible while shipping cases should be avoided.

3.2 General Customer Statistics

Kraft Heinz's customers can be classified, with respect to the country they are located, into Netherlands, Belgium and Luxembourg - customers. The graphs presented in figure 9 depict that Kraft Heinz's presence is not equal in all three countries with the vast majority of Kraft Heinz's customers (63,8%) being located in the Netherlands and the bulk of the shipped volume (90,6%) belonging to Dutch customers. This means that potential improvements in the Dutch truck utilization correspond to a higher number of cases being shipped on a full pallet and more trucks being full. The graphs also reveal that both the number of Luxembourgian customers and the volume delivered to them is negligible in comparison to Netherlands and Belgium.



(a) Number of customers per country

(b) Cases delivered per country

Figure 9: Regional classification

The company's customers can further be classified into channels like Retail, Food Service and Export. The retail channel includes all the supper-markets like Albert Heijn, Jumbo, Plus, Coop, Lidl Detail Result Group and many more. Food Service channel consists of customers like Burger King,Bidfood, Metro Cash & Carry, Sligro Food Group etc. while the export channel includes customers like B&S Purchase, Unidex, Groothandel in Lev. Middel van Tol etc.

The information illustrated in figures 10 and 13 indicates that while the majority of Kraft Heinz's customers belong to the Food Service Channel the bulk of the cases are shipped to Supper-markets. As depicted in figures

10,11,13 and 14, this behaviour is observed both in the Netherlands and in Belgium. This indicates that the same improvement of in efficiency (loading factor) would have a different impact on absolute values for different channels.

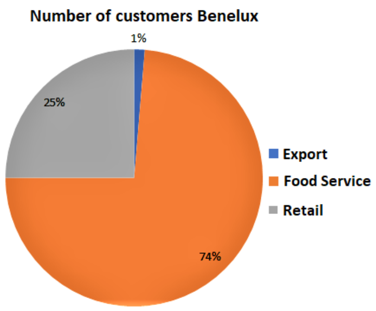


Figure 10: Number of customers per channel in Benelux

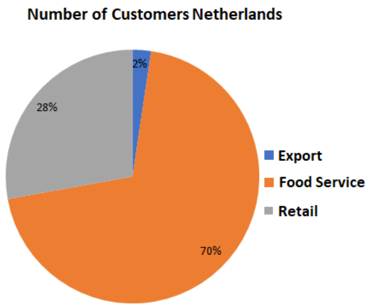


Figure 11: Number of customers per channel in the Netherlands

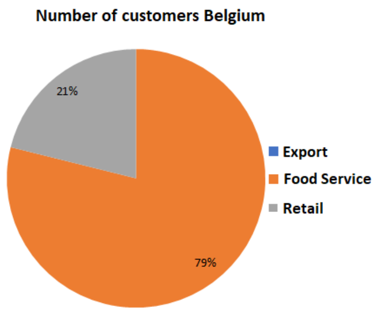


Figure 12: Number of customers per channel in Belgium

Diving into details, in the Netherlands almost 91% of the volume is shipped to a third of the customers that belong to the Retail Channel while in Belgium only one fifth of the customers are supper-markets but more than half of the volume is shipped to them.

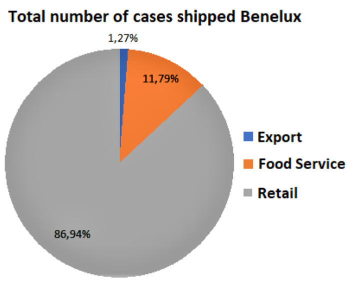


Figure 13: Cases delivered per channel in Benelux

Figure 14: Cases delivered per channel in the Netherlands

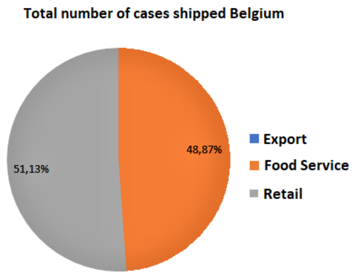


Figure 15: Cases delivered per channel in Belgium

It can also be deduced from the graphs that both the number of customers and the shipped volume to the Export Channel is negligible in comparison to Retail and Food Service. With Luxembourg and Export Netherlands being considered as negligible there only four Country-Channel combinations to examine as depicted in figure 16.

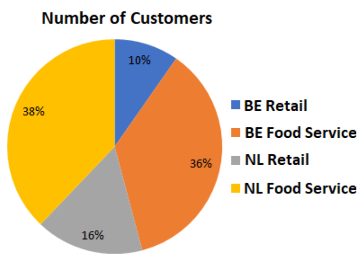


Figure 16: Customers per Country-Channel

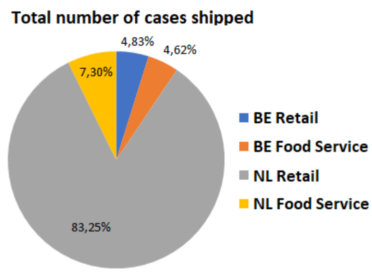


Figure 17: Cases per Country-Channel

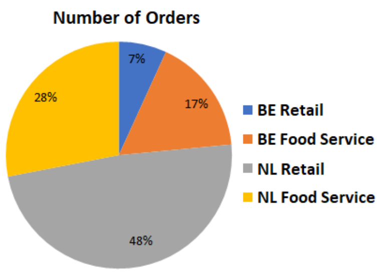


Figure 18: Number of orders per Country-Channel

When comparing figure 16 with figure 17, it becomes apparent that there is a high concentration of the total delivered volume into a small percentage of the customers. More specifically the vast majority (83%)of the delivered cases are delivered to a small percentage (16%) of customers identified as "NL-Retail". The Following "NL-Retail", the second highest ratio of delivered volume over number of customers is the one of "BE-Retail" while "NL-Food service" is third and "BE-Food service" is at the bottom of the list.

Interestingly the same pattern is not observed in customer orders. When comparing figure 17 with figure 18, it can be observed that despite the NL-Retail customers being responsible for 83% of the delivered cases, the relative number of deliveries to them is way less (48%). On the other hand, the Number of deliveries to the rest is considerably higher than their delivered volume. This indicates that a bigger quantity is delivered to NL-Retail customers with less deliveries. Consequently the deliveries to those customers are probably more efficient than the rest. The second most efficient order seem to be deriving from the Belgian Retail while Food Service customers in both countries seem to be having the most inefficient orders.

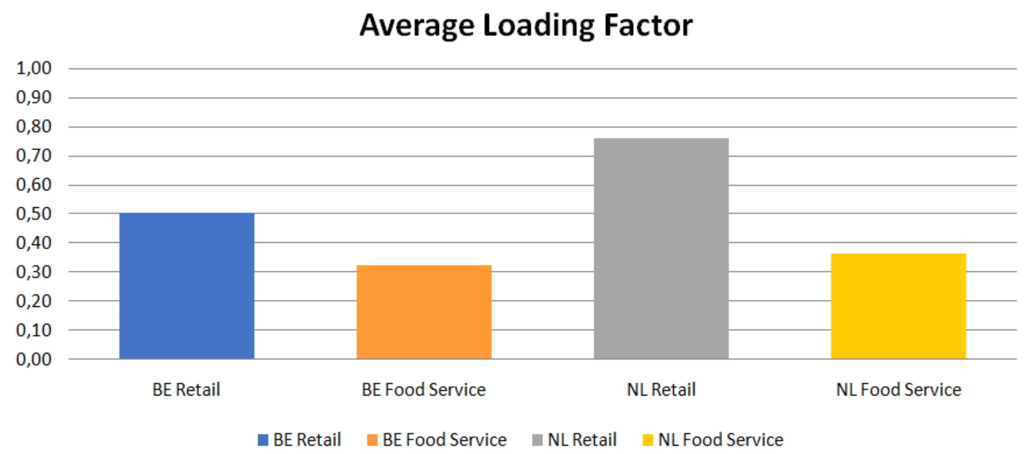


Figure 19: Average loading factor per Country-Channel

Figure 19 illustrating the average number of pallet places per delivery divided by the trucks capacity also called average loading factor, verifies the fact that NL-Retail customers have shipments of bigger quantities being delivered to them and the general pattern observed in figures 17 and 18.

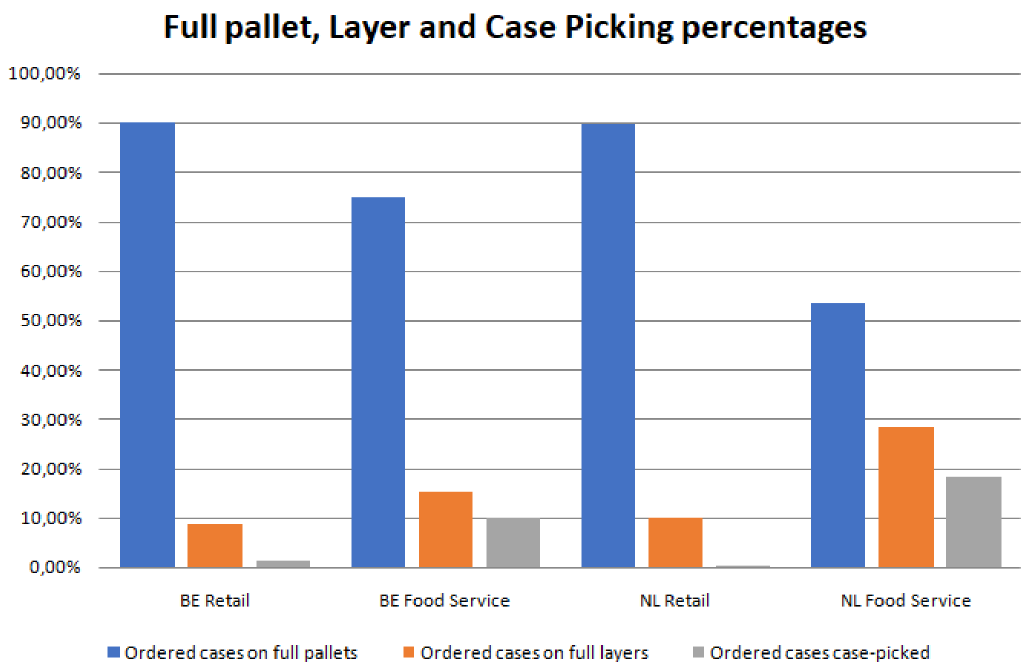


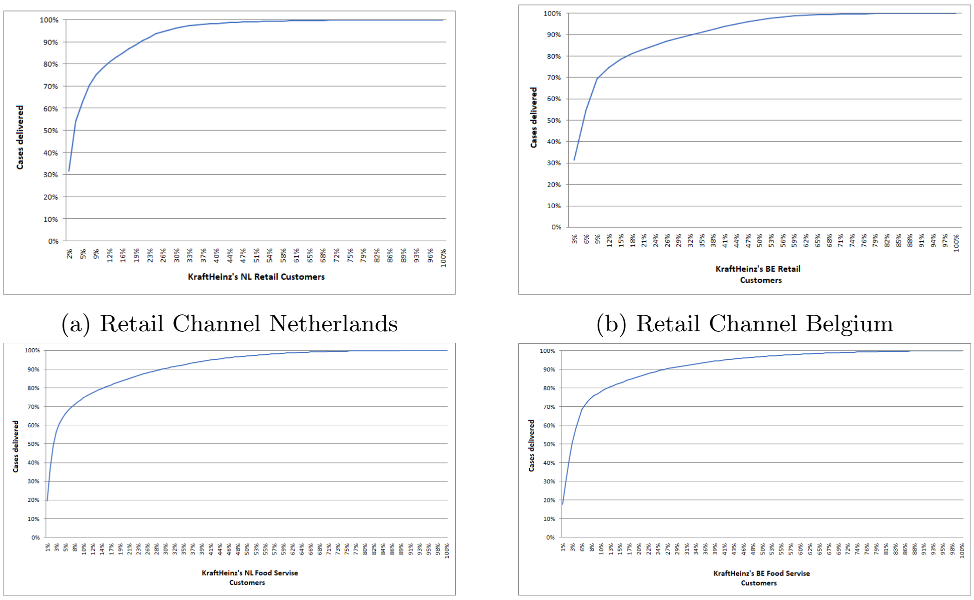
Figure 20: Full pallet Layer and Case Picking percentages per Country-Channel

Figure 20 demonstrates the distribution of the cases that have been ordered on full pallet multiples, on layer multiples or on nothing of the above per Country and Channel. The graph is revealing that retail customers tend to order a higher percentage of their quantities in full pallet multiples in comparison to food service customers. Regarding retailers, the full pallet picking percentages are almost identical for both countries while retailers in the Netherlands seem to have a slightly better performance in terms of layer picking. On the other hand food service customers in the Netherlands are ordering less on full pallet and layer multiples than their Belgian counterparts.

3.2.1 Pareto Principle

As depicted in figure 21, this concentration of the delivered volume, observed earlier, can also be observed within the Channels for both countries. As a matter of fact, this concentration is also described in the literature (Hofmann et al., 2013),(Sabath and Whipple, 2004) as the Pareto principle. This law, also mentioned as eighty-twenty rule, states that "80% of the dependent variable can be assigned to 20% of the independent variable"(Hofmann et al., 2013). In this case, the dependent variable corresponds to the cases delivered and the independent variable corresponds to the customers.

From the graphs presented in figure 21 it becomes apparent that, despite the differences between countries and channels, in Kraft Heinz's case, the distribution is even more concentrated than the Pareto principle. More precisely, for the Retail Channel in the Netherlands the 80% of the volume is delivered to 12% of the customers, for the Retail Channel in Belgium the same percentage is delivered to 17,5% of the customers, for the Food Service Channel in the Netherlands it is delivered to 14,3% and for Food Service Channel in Belgium to 11,8%.



(a) Retail Channel Netherlands (b) Retail Channel Belgium

(c) Food Service Channel Netherlands (d) Food Service Channel Belgium

Figure 21: Pareto principle for cases delivered to KraftHeinz customers

The aforementioned concentration indicates that a small improvement in the loading factor of the deliveries to some customers can have the same impact to the average efficiency as a big improvement in other customers. Consequently it verifies the selection of a cost to serve approach as well as the need for a more detailed analysis on a customer level. This analysis is presented in the next subsection and complements the general statistics of Countries and Channels, that is not enough to describe the current situation.

3.3 Order patterns

This more detailed analysis required is presented below. The top customer's responsible for 80% of the shipped volume have been selected from each customer group and the average loading factor for the shipments to them in 2019 has been calculated. Furthermore again from their order's data the number of cases that have been delivered to them on a full pallet over their total delivered cases has lead to their Full Pallet picking percentage. The analysis of the order patterns of the top customers of each group has been presented here as an example of the variety of inefficiencies between and even inside the groups, however the analysis is more extensive and has been done for each individual customer that can be found in the appendix.

3.3.1 Retail Netherlands

The bubble graph presented below indicates the efficiency of the deliveries to each customer as well as the effect an improvement can have on the average of the customer group. The average loading factor is represented by the x-axis, the full pallet picking percentage is represented by the y-axis and the number of cases delivered to each customer is represented by the size of the bubbles. In that sense the further to the top and right the center of the customer's bubble is the higher the efficiency of the deliveries to them is and the bigger the size of the bubble is the higher the influence of the deliveries to that customer is to the overall efficiency of the customer group. The overall efficiency can be considered as a weighted average of the efficiency of each customer with the weight being the size of the bubble. As an analogy one could consider the average efficiency of the customer group to be the center of gravity with the weight of each bubble being proportional to its size.

From figure 22 one can deduce that both the truck load utilization and the outbound handling efficiency are quite high in the Dutch Retail channel with all the customers representing the 80% of the shipped volume having loading factors above 0,64 and their percentage of the cases being shipped on full pallets being above 74%. This is also verified by the fact that, the customer with the highest volume delivered has an average loading factor of 0,9 and 98,6% of the cases shipped to them are on a full pallet. The second biggest customer in terms of delivered cases has an even better full pallet picking percentage of 99,36% but a considerably smaller loading factor (0,71). It can also be noted from the graph that despite the good performance there is still room for improvement since the optimal performance would require all the customers' "bubbles" being located at the upper right corner of the graph. Another good indicator of the improvement potential is the fact that the proximity of the bubble's location to the upper right corner does not seem to be proportional to the bubble's size. This means that there are customers that despite their delivered volume being higher than other's, their loading factor and/or full pallet picking percentage is not. In other words, despite the customer's delivered cases being able to justify full truck loads and/or full pallets this is not happening.

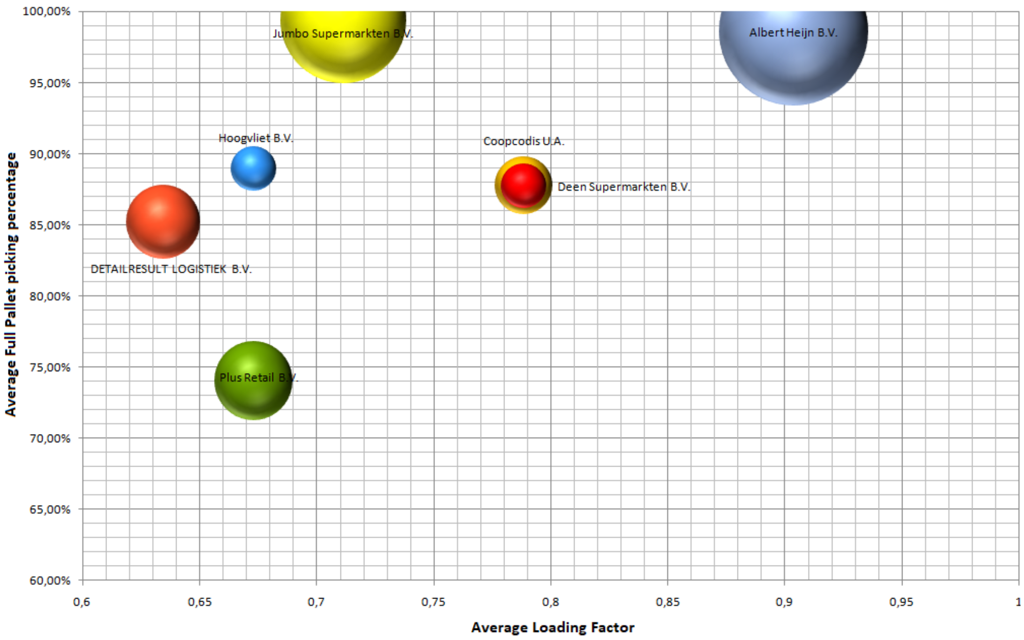


Figure 22: Efficiency in Retail Netherlands

Diving into further detail, in figure 23 one can observe that this group of customers has a high percentage of shipments with loading factors that are between 0,8 and 1. However it can also be observed that most of the dutch retailers receive a significant percentage of their shipments 80% to 98% full. These shipments are probably considered to be full truck loads by the customer because of the customer not considering that pallets can be stacked on top of each other or because the customer did not consider the pallet type of the products they ordered. These shipments with loading factors between 0,8 and 0,98 show that even for the customers with the most efficient deliveries there is still room for improvement.

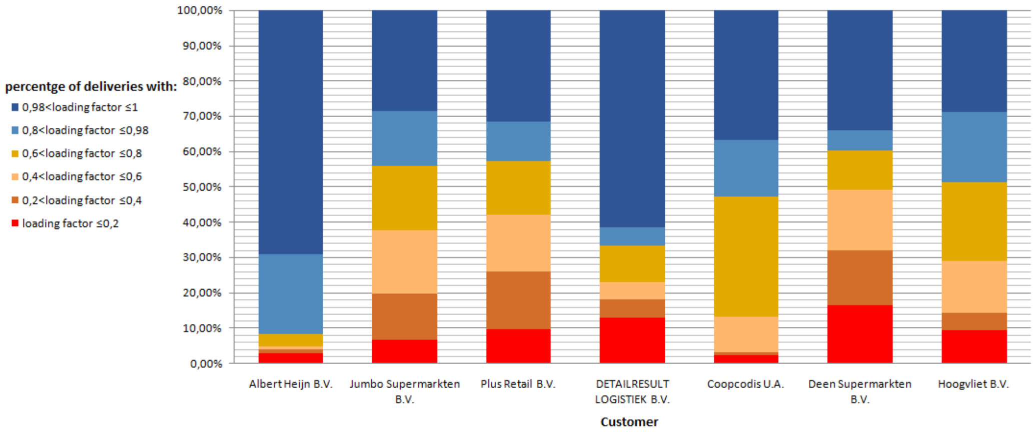


Figure 23: Loading factor in Retail Netherlands

Turning now to shipment frequency, from the graph presented in figure 24, it can be noted that the number of shipments per week is high for the Retail Netherlands customer group with the customers receiving shipments from more than twice a week to almost 7 times a week on average. When comparing figure 24 with the shipped volume presented in the bubble graph in figure 22 it can be highlighted that the number of shipments is in some cases are disproportional to the shipped volume indicating inefficient shipments. For example Coopcodis U.A. is the fifth customer in terms of shipped volume but at the same time it has the highest average of shipments per week. This fact reveals a potential in frequency reduction that can lead to an improvement in the loading factor.

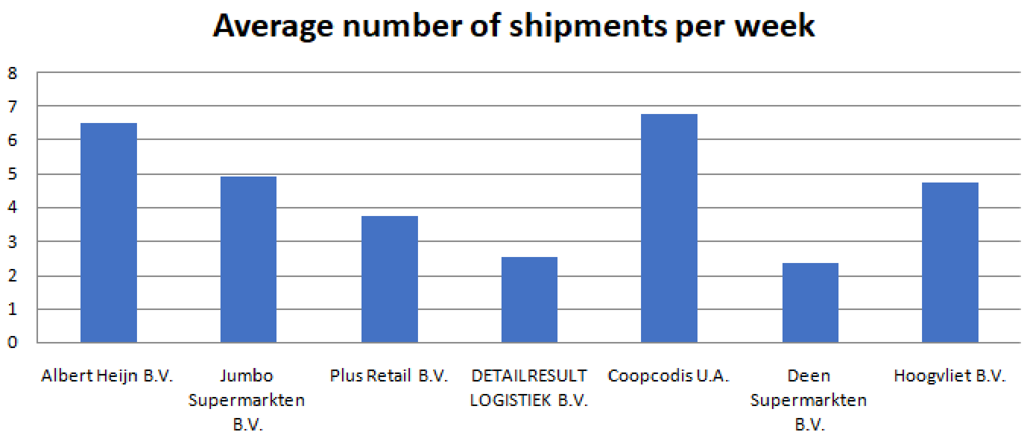


Figure 24: Order frequency in Retail Netherlands

Regarding the number of cases that are shipped on Full Pallets, Layers and as individual cases, figure 25 illustrates a good performance in Retail Netherlands with the highest case picking percentage being 0,24% and the highest layer picking percentage being 25,74%. An interesting fact is that the highest layer picking percentage is observed in the third customer in terms of shipped volume and not the last one, indicating a clear potential for improvement of the orders of that customer in that aspect. Furthermore, it is clear from the graph that for Dutch Retailers whenever a case is not on a full pallet it is usually at least shipped on a layer level. The percentages of case and layer picking for the two biggest customers are significantly low indicating that ordering on layer or case level is not important for these customers and consequently they can be eliminated completely with the appropriate actions are taken from KraftHeinz.

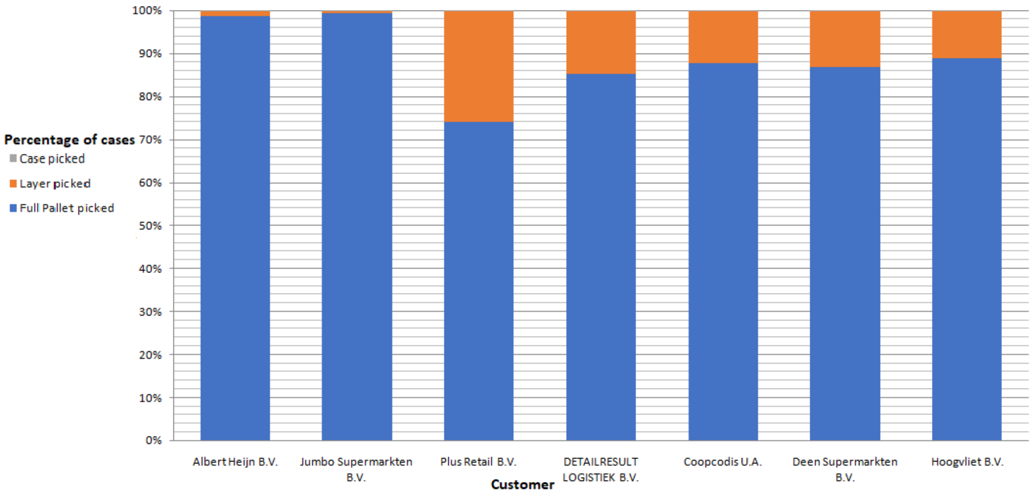


Figure 25: Picking percentages in Retail Netherlands

3.3.2 Food Service Netherlands

The high number of customers representing the 80% of the delivered volume in the dutch food service channel is clearly illustrated in figure 26. Apart from that, figure 26 also illustrates a high potential for improvement with a lot of small size customers that are justifiably located in the bottom left corner of the graph but also some medium and big size customers that do not seem to belong there. Specifically, the second biggest customer of the group in terms of delivered cases has only 36% their cases being on full pallets and an average loading factor of 0,23. Furthermore, the average shipment to the biggest customer of the group is half a truck load with 80% of the cases being delivered on full pallets. There are however some smaller customers that seem to be ordering in a more efficient way like the W. Franken Horecagroothandel B.V. in terms of delivered cases that seems to be ordering only on full pallet multiples and occupies 83% of thee trucks capacity on average. Finally, third biggest customer has the best average loading factor (0,92) but still their full pallet picking percentage is 64%.

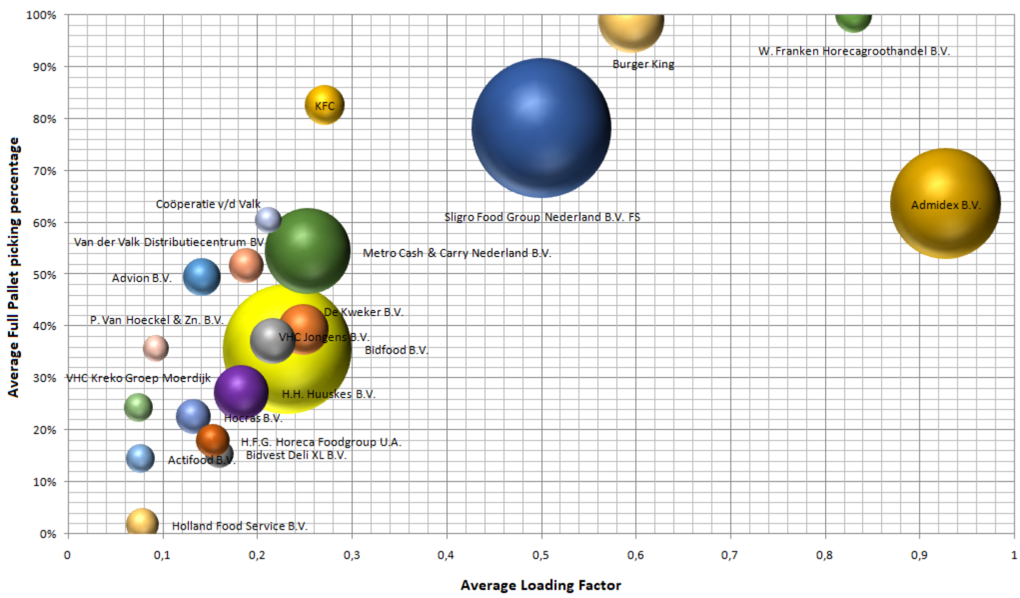


Figure 26: Efficiency in Food Service Netherlands

As illustrated in figure 27 the Food Service channel in the Netherlands has way more inefficient shipments than its Retail counterpart with most of the customers having the majority of their shipments in trucks that are up to 20% full. However, there are also some customers like Sligro Food Group Nederland B.V., Admidex B.V., Burger King and W. Franken Horecagroothandel B.V. that have shipments with loading factors between 0,8 and 0,98 that can easily be transformed into Full truck load shipments with actions take by KraftHeinz.

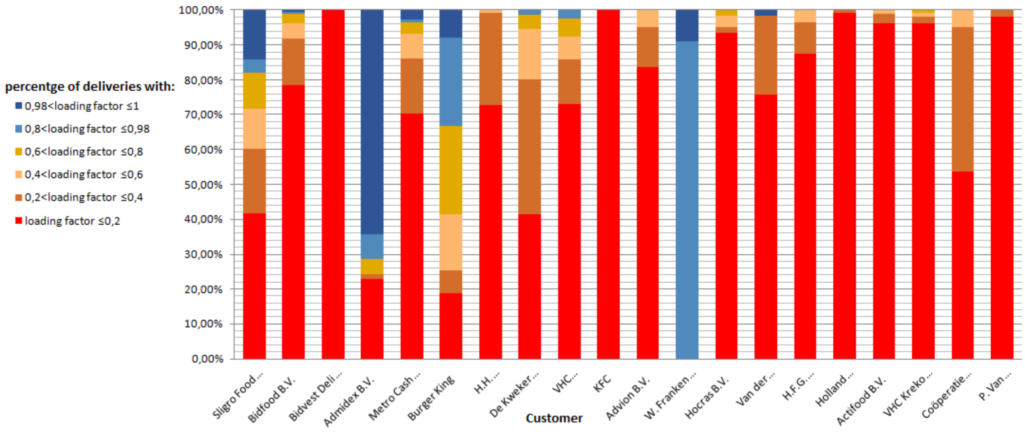


Figure 27: Loading factor in Food Service Netherlands

Regarding the rest of the customers that have most of their shipments in trucks that are up to 40% full, there is great potential of improvement if these customers consolidate some of their deliveries. As depicted in figure 28 there are customers like Metro Cash & Carry Nederland B.V., Holland Food Service B.V. and Actifood B.V. that despite not having the highest number of cases delivered to them have the highest order frequency.

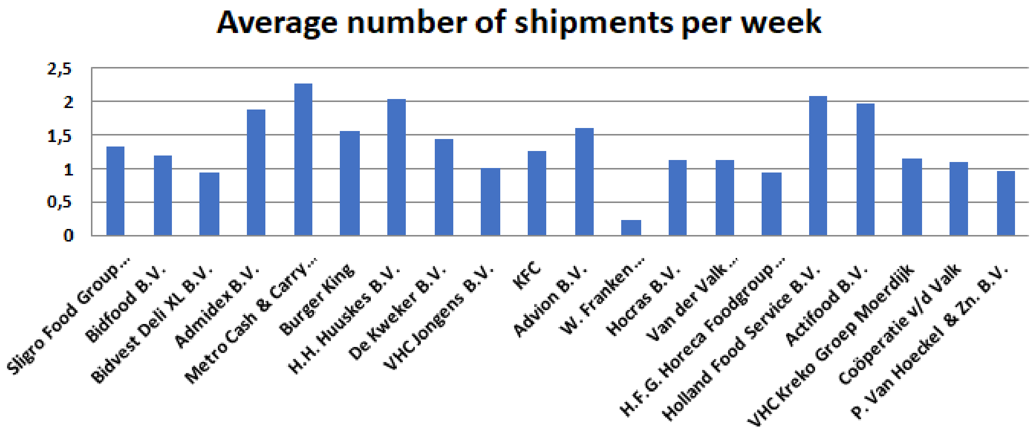


Figure 28: Order frequency in Food Service Netherlands

With respect to the number of cases that are shipped on Full Pallets, Layers and as individual cases, figure 29 shows high case picking percentages for most of the customers in the Dutch Food Service channel, with the third biggest customer having almost half of their cases being case picked. Figure 29 is also revealing that certain customers despite not being the biggest in the group have really high full pallet picking percentages. This indicates that there is potential for the bigger customers to imitate their performance.

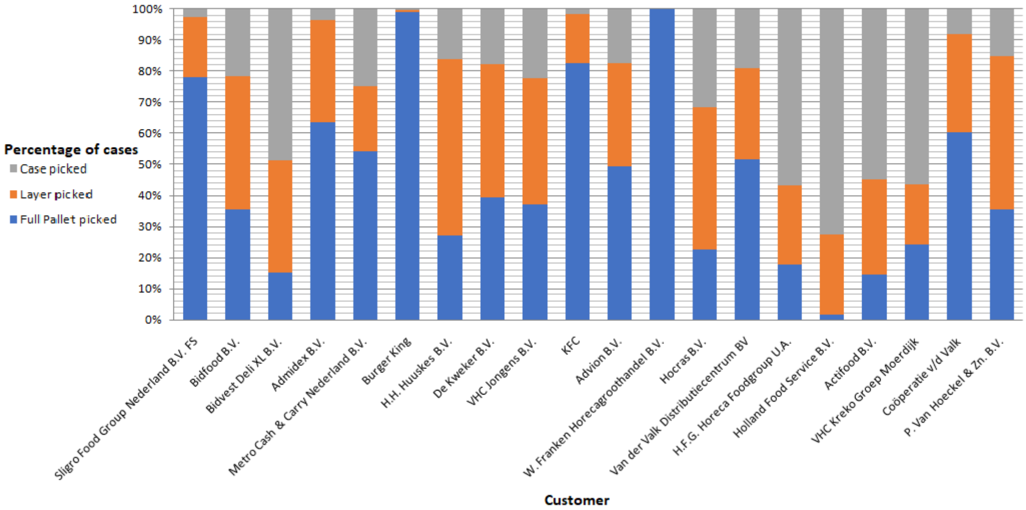


Figure 29: Picking percentages in Food Service Netherlands

3.3.3 Retail Belgium

In the retail channel of Belgium there are only 6 customers responsible for the 80% of the shipped volume. The customer with the highest shipped volume has an average loading factor of 0,62 and a full pallet picking percentage of 98% while the customer with the second highest shipped volume seems to have a better pattern with a loading factor of 0,8 and a full pallet picking percentage of 90%. The percentage of cases being shipped on a full pallet seem to be high even for the smaller customers while the same cannot be said for the loading factor.

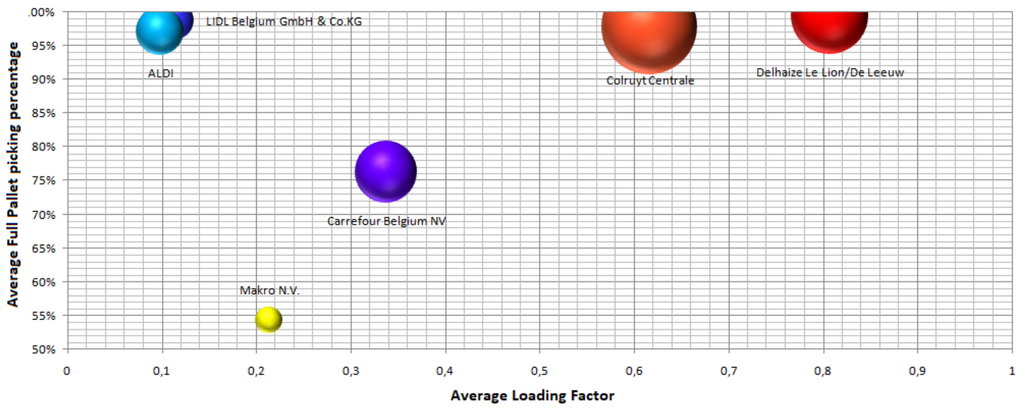


Figure 30: Efficiency in Retail Belgium

Figure 23 outlines the potential of improvement in the Retail Belgium customer group, with the top 3 customers, in terms of delivered cases, having significant percentages of their deliveries being on trucks with loading factors that are between 0,8 and 0,98.

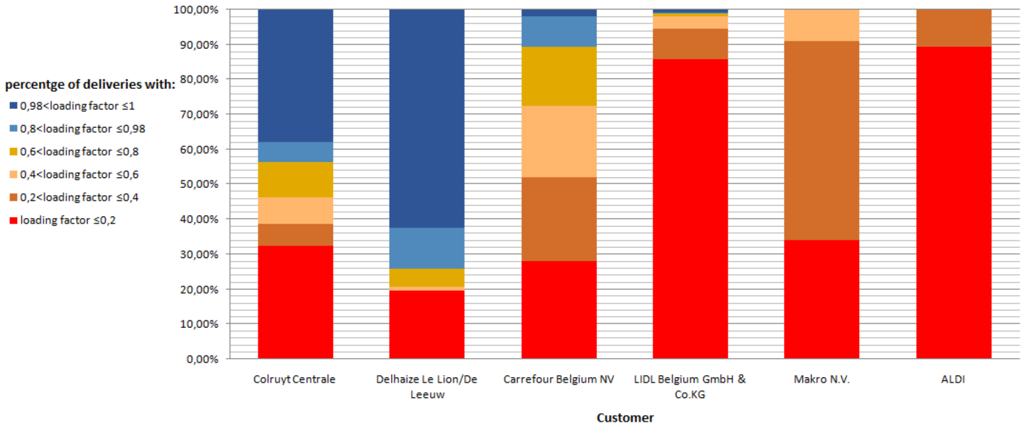


Figure 31: Loading factor in Retail Belgium

The rest of the customers seem to have way less efficient deliveries with a high percentage of their deliveries being on trucks that are up to 20% full. This fact can also be verified by the frequency of deliveries presented in figure 32 where one can observe that the first and the last customer of the group in terms of shipped volume seem to be having a similar number of shipments per week.

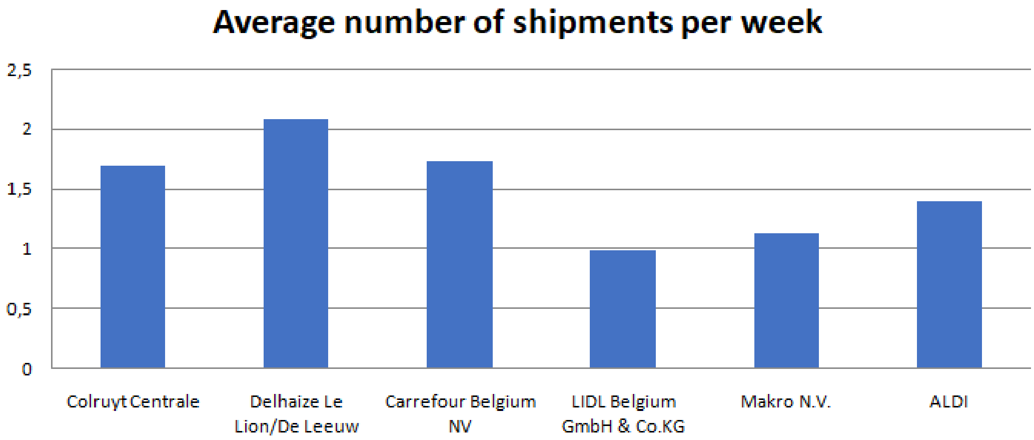


Figure 32: Order frequency in Retail Belgium

Regarding the percentages of case picking layer picking and full pallet picking illustrated in figure 25 it can be observed that the majority of the group has a really good performance in that aspect. Most of the customers have considerably low case picking percentages below 0,2% with the exeption of Carrefour Belgium NV 2,1% and Makro N.V. 7%. The vast majority of the group also has relatively low percentages of layer picking with the same two customers being the exceptions of the group. It is clear that the small percentages of layer picking in the rest of the customers can be eliminated with a small effort while for the 2 exceptions the same could be said about case picking.

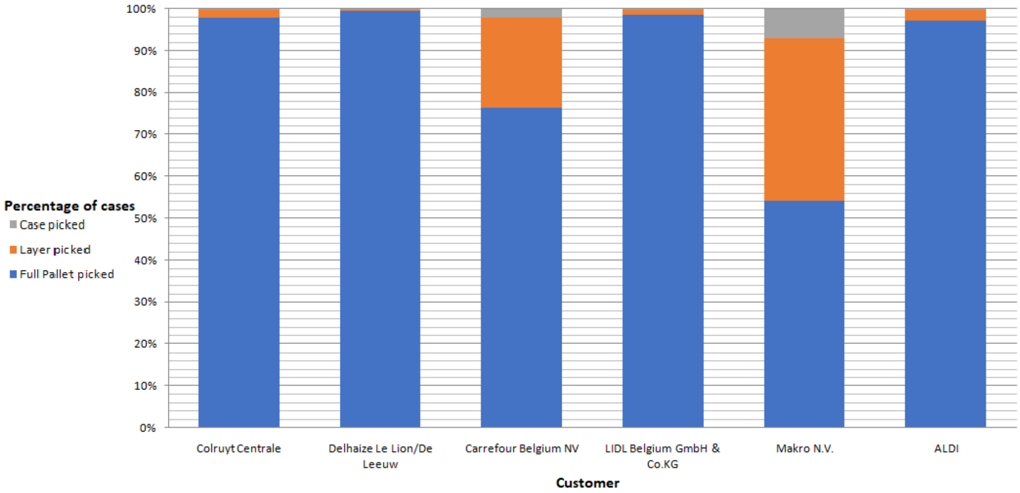


Figure 33: Picking percentages in Retail Belgium

3.3.4 Food Service Belgium

Food Service Belgium similarly to Food Service Netherlands has many more customers representing the 80% of the shipped volume than Retail Belgium. What differs here is that a lot of the customers despite their size have high full pallet picking percentages unlike their dutch counterparts. Moreover, the room for improvement is clear also for this group of customers with the biggest customer having almost half truck shipments as their average and the second biggest having an average loading factor of 0,22.

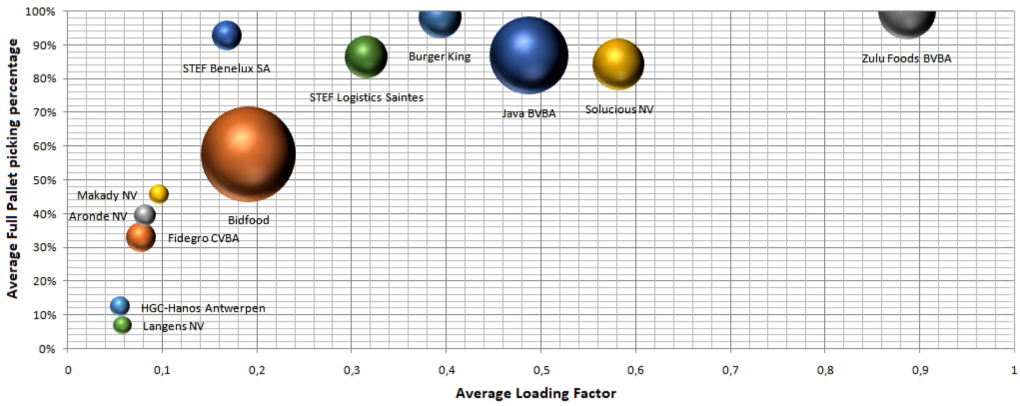


Figure 34: Efficiency in Food Service Belgium

From a more detailed perspective, figure 35 highlights that also in this group there is a high potential for more efficient shipments. More specifically, three customers of the group have a relatively high percentage of shipments with loading factors that are between 0,8 and 0,98 that could be rounded up to full truck shipments. In addition a high number of inefficient shipments is observed in the customer with the second highest shipped volume. These shipments seem to be unjustifiable when compared to the loading factor performance of the third and fourth customer.

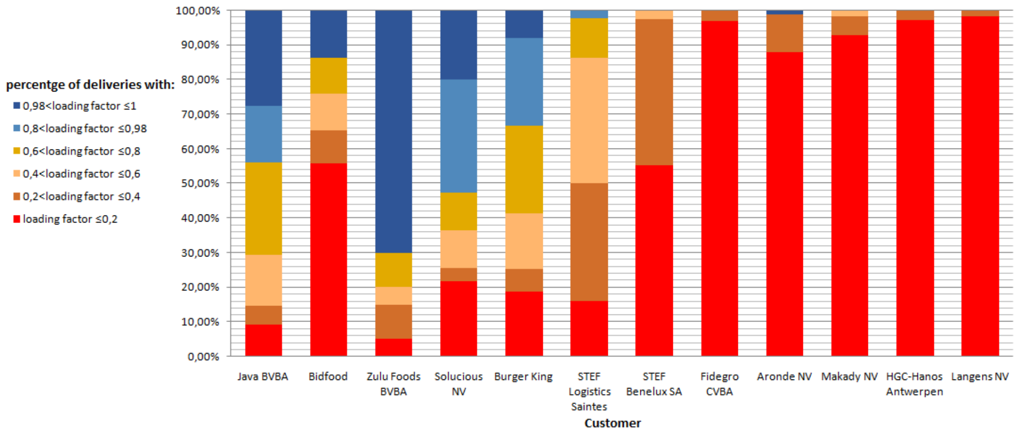


Figure 35: Loading factor in Food Service Belgium

With regards to shipment frequency, a glance in figure 36 reveals that some customers, like Aronde NV, Makady NV, HGC-Hanos Antwerpen and Langens NV, order frequently regardless their low shipped volume. These frequent orders are usually also small in volume leading to loading factors below 0,2 as depicted in figure 35. An order frequency redaction for these customers could result in more efficient deliveries. Furthermore the order frequency of the two biggest customers seems to be way higher than the one of the third one indicating a potential of frequency reduction and consequent loading factor improvement for these customers as well.

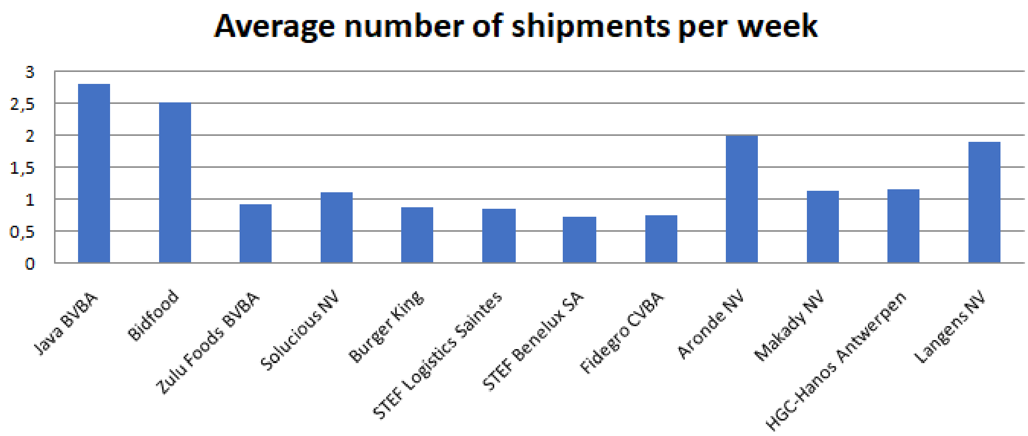


Figure 36: Order frequency in Food Service Belgium

Considering the number of cases that are Full Pallet picked, Layer picked and Case picked presented in figure 37, it is clear that despite the good performance of the majority of the customers in this group there is high potential of improvement. Particularly the customer with the customer with the highest shipped volume has more than a quarter of its shipped cases being picked while the second highest has only 3%. Smaller customers show a deteriorated performance in that aspect which seems to be reasonable with respect to their shipped volume.

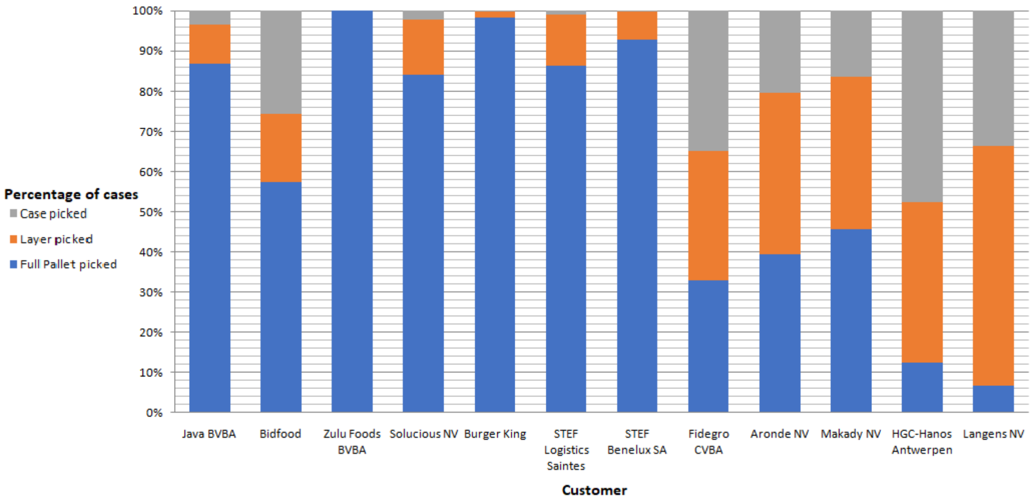


Figure 37: Picking percentages in Food Service Belgium

3.4 Data analysis summary and Opportunity identification

The system has been described with the activities and connection between the underlying and Key Performance Indicator identified. Furthermore, the current performance of the logistic system can be summarized by the general customer statistics and the specific order patterns of the customers.

Summarising the general customer statistics, there is clear evidence (fig. 9) to suggest that the biggest opportunity for KraftHeinz lies in optimizing its outbound handling and freight to customer operations of the customers that are located in the Netherlands and more specifically in the Retail channel (fig. 17). However, this customer group seems to be the one with the most efficient shipments and with the highest full pallet picking percentages. On the other hand a small improvement in this customer group could significantly affect the overall efficiency of KraftHeinz's operations. Moreover, the Pareto principle presented in figure 21 improvements in certain customers could result in higher overall efficiency than in other customers due to the volume that is shipped to them. Consequently, the biggest opportunity seems to be located in the customers with the highest shipped volume.

Summarising the order patterns of the customers, each customer pattern seems to be having certain aspects that can be improved as well as its own limitations verifying the fact that a "one size fits all" approach should be avoided in determining the policy to be implemented. It is clear from the bubble graphs presented above, that in general the way to improve the efficiency of the outbound handling and freight to customer operations is for the "bubbles"/customers to be moved as close to the upper right corner of the graph as possible. For some customers this would mean to order only in full truck loads while for others to order a higher number of pallets in each shipment or reduce their order frequency. For other customers the solution could be to only order on a full pallet level while for others to order at least on a layer level.

The underlying indicators suggest that, for the change in the order pattern of the customers, KraftHeinz can select among the following identified design alternatives:

1. Minimum order quantities strategy, in terms of:
   (a) Number of pallet places in a truck (loading factor)
   (b) Number of cases per product (full pallets/ full layers)
2. Order frequency reduction strategy

In order to support with evidence the decision upon which strategy has to be followed per customer in order to increase efficiency and reduce costs the resulting KPI's have to be used. More specifically the Costs have been selected for the performance validation of the model and the comparison of the current performance with the performance of the design alternatives. Consequently, a cost to serve model has been developed and is presented in the next chapter. In this model strategies will be transformed into the design alternatives to be compared. The model will compare the actual costs with the costs for a alternatives of various minimum order quantities and various maximum order frequencies per customer.

4 Cost to serve model

In this section, after acquiring a general understanding of the current situation via the data analysis done in the previous chapter, a conceptual model will be designed. The conceptual model will help to describe the system, identify the inputs and outputs of the model and define how its composition should look like for the designed alternatives to be tested. With the help of the conceptual model the required assumptions and simplifications can also be identified. After that, a mathematical description will be given to the conceptual model. Furthermore, the developed mathematical model will be build in Microsoft Excel. Finally, after building the model, some tests will be run in order tho ensure that the model is correct, providing verification to the model.

4.1 Conceptual model

The concept of this model is simulating the supply chain by capturing the effect that a strategy can have on the cost to serve a customer. The model has to reflect the changes in the costs associated with the activities involved in the outbound handling and freight to customer operations processes, upon the implementation of a strategy. Consequently, the aim of the model is to allocate supply chain activities and costs to the customers in order to identify the opportunities for each specific customer and test possible outcomes of changing the service strategies of these customers in terms of efficiency improvements and cost reduction. For this to happen, initially the activities and their associated costs have to be identified, then the cost of one order for one customer analysis has to be carried out and finally the influence of the service strategies has to be identified and introduced in the cost analysis creating a model.

As discussed earlier, this study focuses on the two main processes of warehousing that are being outsourced, namely outbound handling and freight to customer operations. The outbound handling process includes the activities of Full Pallet Picking, Layer Picking and Case Picking, while the freight to customer operations process only includes the ship;ping activity. Various 3pl providers are involved in these activities leading to various tariffs being applied. However, the units of measurement associated with the tariffs are the same for all the involved parties creating an identical cost structure presented in the table below.

Activity	**unit of measurement**	**Variable**	**Tariff**
Full Pallet Picking	pallet	fp	C_{Pallet}
Layer Picking	case	clp	C_{Layer}
Case Picking	case	ccp	C_{Case}
Shipping	pallet places	pp	$C_{Shipment}(pp)$

Table 4: Cost structure

There is one-to-one relationship between the location of customers facilities and the 3pl that will satisfy the demand in that way when an order is being placed by a customer the Enterprise Resource Planning program automatically assigns this order to the 3pl that will handle that order. This means that the ship-to location is defining which 3pl's tariffs will be applied for all the activities related with orders from that location. In addition, it can be noted here that the tariff of the Shipping activity does not only depend on the location of the customers facilities but also depends on the number of pallet places ordered.

With the activities and costs identified and the analysis of costs carried out the next step is to introduce the strategies that are expected to influence the costs. As discussed in the previous section the strategies are:

1. the customers being able to order only on full pallets (no layer/ case picking)

2. the customers being able to order at least on full layers (no case picking)

3. the customers being able to order above a specific number of pallet places per order

4. the customers being able to order less than a specific number of times per week

It is clear that design alternative 1.b) has already been analysed into 2 separate strategies one for full layers and one for full pallets. Furthermore, with respect to the design alternative 1.a) regarding the strategy of customers being able to order above a specific number of pallet places per order, this specific number has to be defined per customer. For this purpose 4 sub- alternatives regarding the value of the minimum order quantity have been created based on the customer's current performance. These sub- alternative are that the value of minimum order quantity will be equal to:

1. The first quartile (Q1) of the number of pallet places of all the orders for each customer
2. The median (Q2) of the number of pallet places of all the orders for each customer
3. The third quartile (Q3) of the number of pallet places of all the orders for each customer
4. Full Truck loads (26 pallet places)

The values of the number of pallets for the three first sub- alternatives reflect benchmarking which is a common practice in the industry. the first, or lower, quartile. The first quartile (Q1) represents the value at which 25% of the deliveries lie below that value in terms of pallet places, while 75% of the deliveries lie above that value. This means that setting the minimum order quantity at the first quartile would have the minor impact of influencing 25% of the orders of that customer that happen to have a lower number of pallet places. This sub- alternative could be ideal for customers that have a low number of pallets ordered but still have inefficiencies that could be avoided. The median could have a bigger influence in the efficiency of deliveries influencing half of the orders of that customer. This alternative could be ideal for customers that have a medium number of pallets delivered to them with some of their deliveries being efficient enough with respect to their size but also some deliveries being lower in terms of efficiency than their capacity would allow them. The third quartile as a minimum order quantity can radically change the order pattern of the customer and could be considered as ideal for customers that have frequent deliveries with low truckload utilization and relatively high total number of pallets delivered in one year. Finally, the Full Truck load is taken into consideration only for the customers that already have an exceptional efficiency performance but still have some inefficiencies that could have been avoided.

Moreover, regarding design alternative 2, where customers are able to order less than a specific number of times per week, this specific number does also have to be defined per customer. For this purpose 5 alternative sub- alternatives regarding the value of the minimum order quantity have been created. These sub- alternatives are that the customer will be able to order less or equal to once/twice/thrice/four times/ five times per week.

The purpose of the model is to compare the possible results of those strategies with the actual costs-to-serve in one year. This means that one of the compared alternatives will be the actual calculation of the costs for the orders placed in 2019 when no strategy has been applied. Consequently the alternatives that will be compared by the model are the following:

1. no MOQ design alternative
2. MOQ=full layers design alternative
3. MOQ=full pallets design alternative
4. MOQ= specific number of pallet places (=Q1/Q2/Q3/FTL) design alternative
5. Order Frequency= specific number of days per week (=1/2/3/4/5) design alternative

With all the steps being carried out the conceptual model can now be designed, the system can be modeled as a black box as presented in figure 38. This description allows for the fundamentals to be illustrated without focusing on the inner complexities of the system itself. The representation merely depicts the inputs and outputs of the system, along with the key influences to functional operation and the manners in which the system efficiency can be monitored.

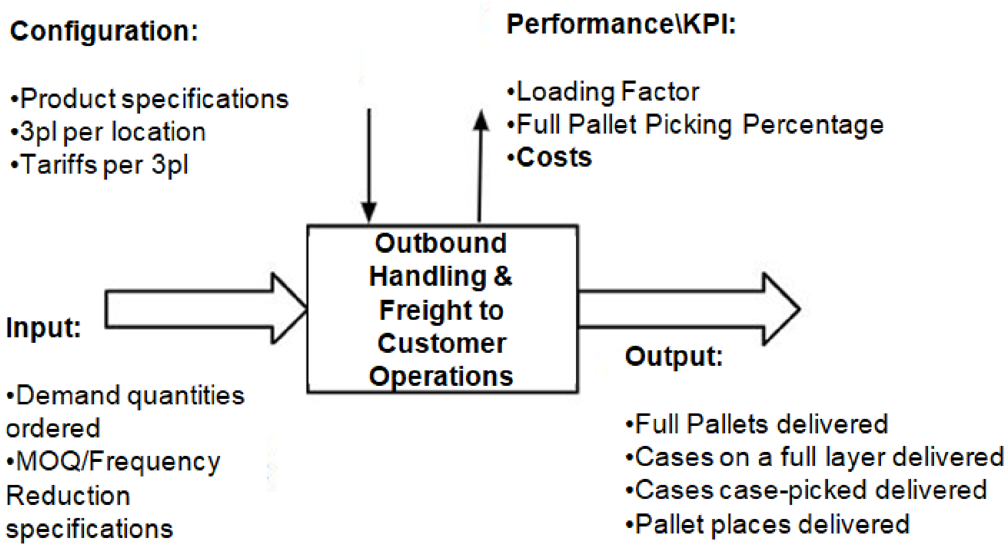


Figure 38: Black box representation of the system

The models function can also be described as presented in figure 39.The initial input to the model is the demand for each product in each order at all the ship-to locations throughout the year 2019. With the help of the one-to-one relation between 3pl and location, the tariffs applied by each 3pl provider and the master data of the products, the cost to serve each customer for the no MOQ alternative can be calculated. At the same time the information regarding the number of full pallets,number of cases on full layers, cases case-picked and pallet places in each order at all the ship-to locations throughout the year 2019 can be extracted and used for the formulation of the alternatives. The alternatives are fed back to the system and the cost to serve each customer is recalculated for every alternative.

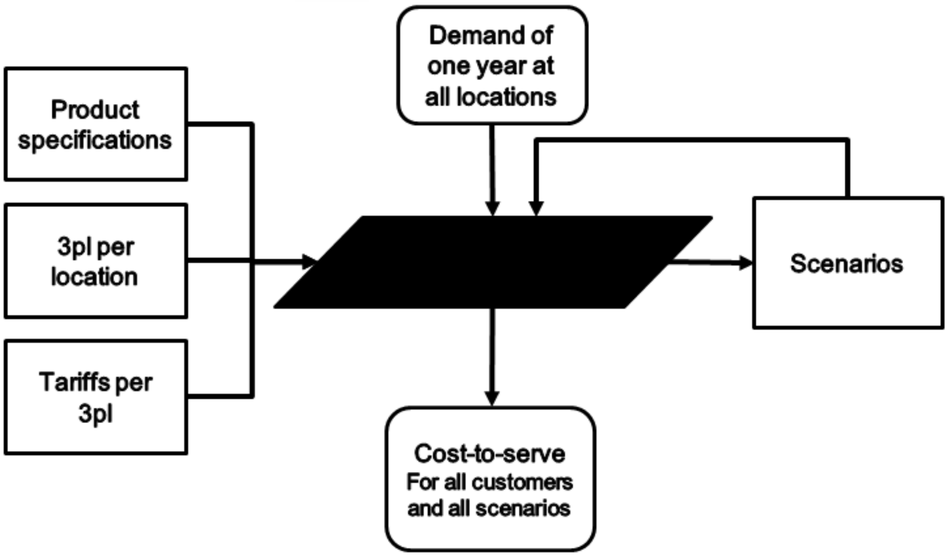


Figure 39: Model representation

A better understanding of the model can be acquired looking into the calculation of the total logistic costs deriving from outbound handling and freight to customer operations related activities for one order of one customer. The input of the analysis is the demand for each product in the order together with the tariffs applied by the 3pl parties at each warehouse location as well as the products' master data like the number of cases that fit in one pallet for each product. The output of the model is the total cost of outbound handling and freight to customer operations. In a nutshell, the model transforms the ordered quantities into the number of full pallets, the number of cases on full layers, the number of cases to be case-picked and the number of pallet places they occupy in a truck. After this transformation is conducted the aforementioned numbers are multiplied by the tariffs associated with each activity to calculate the costs of each order. Finally, the summation of the costs for all the orders is the final output.

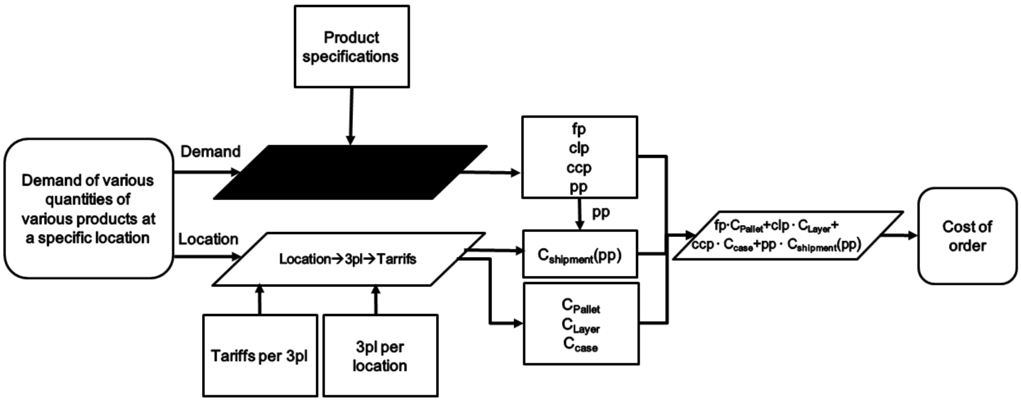


Figure 40: Cost of one order

This analysis will be repeated by the model for every order and every location of the customer's facilities in order for the cost to serve of each customer to be calculated.

4.1.1 Assumptions

It is also important here to clarify the assumptions that will have to be made in the formulation of the mathematical model. The assumptions both regard the model it self and the various alternatives that have been created.

Respecting the model:

1. The total demand of one year is considered to be the same for all alternatives.In reality, strategy implementations can alter the demand of a customer. These changes however are out of the scope of this research.

2. Demand can always be satisfied. The inefficient deliveries due to products being out-of-stock in KraftHeinz's warehouse are left out of scope.

3. Returns and delays are not taken into account for the shipment costs calculation. In reality returns and delays do affect the cost to serve a customer. However returns and delays are not correlated to changes in ordering policies.

4. There is no combination of deliveries. In reality the 3pl is delivering the inefficient orders of different customers that are located in the same region ripping the benefits order consolidation. However the model is regarding the issue from the suppliers perspective so it is assumed that multi-drop routing is not taking place and consequently orders cannot be combined.

5. The tariffs are represented in this model by constant values. However, the 3pls can negotiate new tariffs after a certain period of time. This might have significant effects in future cost savings. For example if the 3pl's realize that the number of inefficiencies is decreasing they might decide to penalize the remaining inefficiencies with a higher tariff reducing the cost savings of the supplier.

6. The number of pallet places (pp_{jl}) is rounded up to the closest integer since the associated tariffs are given per integer number of pallet place occupied in the truck.

Regarding the alternatives:

1. Regarding the MOQ=full pallets alternative, in the number of full pallets calculation, the number of layered-picked cases is divided by the average number of cases per pallet. In reality, this division is done separately for each product with the denominator being the specific number of cases per pallet of that product and not the average. In other words it is assumed that the various layer picked and case picked cases can be combined onto pallets as if they were one "average" product.

2. With respect to the MOQ=full layers alternative, in the number of cases layered picked calculation, the cases that would have been case picked are now assumed to be on full layers. In real life, the customer would have to increase or reduce the number of cases for these products in each order leading to a slightly different total number of cases.

3. With regards to the MOQ= pp_l^* alternative, an equivalent number of shipments is assumed. In reality the number of shipments is always an integer and the customer would have ordered either more or less pallets to meet an MOQ policy in integer number of shipments multiples. However, this would mean a slightly different demand and since the intention is to compare costs for the same demand and various policies the equivalent number of shipments is assumed to be a real number.

4. As regards the Order Frequency= $1/n^*$ alternative, an equivalent average number of pallet places per shipment is assumed. This number is assumed to be a real number for maintaining the same demand in all alternatives. While, in order for the tariff function $C_{Shipment_l}(\overline{pp}_l)$ to be calculated the equivalent average number of pallet places has to be rounded (up or down) to the closest integer.

5. Again respecting the Order Frequency= $1/n^*$ alternative, when the total number of pallets cannot be delivered with the number of shipments allowed by the policy then it is assumed that the alternative cannot be implemented on this customer and the costs stay the same as in the no MOQ alternative. In reality if such a policy was to be implemented upon these customers, they would violate the agreement in periods that the demand would exceed the number of shipments per week allowed with/without a penalty.

6. For all the alternatives the cascading effects are not taken into consideration. For example, in real life, an implementation of a full pallets minimum order quantity could result in small improvements in the number of pallet places per order and vise versa. These improvements are not considered by the model due to the complexity of the required calculations and the limited extend of the cascading effects.

4.2 Mathematical model

The mathematical model presented below intends to specify the conceptual model discussed in the previous section and consequently illuminate the black box of figure 39.

4.2.1 Indices and Sets

From the conceptual model it is clear that the calculations have to be conducted for all products, all orders and all the ship-to locations. Consequently, the sets that are of interest are the following:

$$i \quad for \quad product \qquad I = [product_1, ..., product_m] \tag{1}$$

$$j \quad for \quad orders \quad J = [ordernumber_1, ..., ordernumber_n] \tag{2}$$

$$l \quad for \quad ship-to \quad location \quad L = [ship-to_1, ..., ship-to_p] \tag{3}$$

In the data base of KraftHeinz these sets are represented by identification numbers namely:

1. EPN code for the set of all products

2. ship-to code for the set of all ship-to locations

3. order number for the set of all orders

4.2.2 Parameters

Again from the conceptual model, one can identify the values on which the costs are dependent but are also considered to be known and constant in the model. These values regard the ordered quantities of the products, the products' master data as well as the tariffs applied by the 3pl providers. Consequently, the parameters can be classified as follows:

1. ordered quantities
   d_{ij} ordered quantity of product i in order j

2. product specifications
   x_i number of cases per pallet for product i
   y_i number of cases per layer for product i
   z_i number of layers per pallet for product i
   h_i full pallet height for product i
   $C_{stackability_i}$ stack-ability coefficient for product i
   $C_{pallettype_i}$ pallet type coefficient for product i
   $h_{maxlayer} = 1800mm$ maximum height for a layer-picked pallet
   $h_{maxcase} = 1050mm$ maximum height for a case-picked pallet

3. tariffs
   C_{Case_l} tariff of 3pl serving ship-to location l for the case picking activity of one case
   C_{Layer_l} tariff of 3pl serving ship-to location l for the layer picking activity of one case
   C_{Pallet_l} tariff of 3pl serving ship-to location l for the pallet picking activity of one pallet
   $C_{Shipment_l}(p)$ tariff of 3pl serving ship-to location l for the transportation activity of one pallet depending on the number of pallet places pp in the order

1. ordered quantities
   d_{ij} ordered quantity of product i in order j

2. product specifications
   x_i number of cases per pallet for product i
   y_i number of cases per layer for product i
   z_i number of layers per pallet for product i
   h_i full pallet height for product i
   $C_{stackability_i}$ stackability coefficient for product i
   $C_{pallettype_i}$ pallet type coefficient for product i
   $h_{maxlayer} = 1800mm$ maximum height for a layer-picked pallet
   $h_{maxcase} = 1050mm$ maximum height for a case-picked pallet

3. tariffs
   C_{Case_l} tariff of 3pl serving ship-to location l for the case picking activity of one case
   C_{Layer_l} tariff of 3pl serving ship-to location l for the layer picking activity of one case
   C_{Pallet_l} tariff of 3pl serving ship-to location l for the pallet picking activity of one pallet
   $C_{Shipment_l}(p)$ tariff of 3pl serving ship-to location l for the transportation activity of one pallet depending on the number of pallet places pp in the order

4.2.3 Decision variables identification and Cost Function definition

definitions of variables and the functional relationships

The approach followed to identify the decision variables and define the cost function is analysing the actual costs, defining the variables they depend on and defining the functional relationships between them. Following the same logic as in the conceptual model, this can be split into three steps. The first step is the clarification of the black box presented in figure 40 by expressing the way the various activities induce costs for just one order in mathematical terms.The second step is to mathematically express how these costs are affected by the possible changes and identify the decision variables. Finally the cost function can be defined based on the actual costs calculation and the effect the decision variables have on them.

The three steps for the calculation of the actual cost to serve are presented below.

STEP ONE

Initially the number of full pallets in the order is calculated as the quotient of the Euclidean division between the ordered quantity (numerator) and the number of cases per pallet for product i (denominator).

$$fp_{jl} = \sum_{i=1}^{m} (d_{ij} \text{ div } x_i) \tag{4}$$

The remainder of the division are the cases that are going to be layer picked or case picked. The quotient of the Euclidean division between remainder of the the first division (numerator) and the number of cases per layer for product i (denominator) gives the number of layers to be picked and when multiplied by cases per layer for product i it produces the number of cases that will be layer-picked.

$$clp_{jl} = \sum_{i=1}^{m}(((d_{ij} \bmod x_i) \text{ div } y_i) * y_i \tag{5}$$

While the remainder of the Euclidean division between remainder of the the first division (numerator) and the number of cases per layer for product i (denominator) gives the number of cases that will be case-picked.

$$ccp_{jl} = \sum_{i=1}^{m}((d_{ij} \bmod x_i) \bmod y_i) \tag{6}$$

The calculation of the number of pallet places one order occupies in a truck can be split into 3 terms. The first term regards full pallets and it includes a Euclidean division giving the number of full pallets multiplied by the stack-ability coefficient, in that way a full pallet of a stackable product is calculated as 0,5 pallet places. The second term regards full layers the number of full layers per product are calculated by the numerator of the first fraction and then it is divided by the number of layers this product can have on one full pallet. This percentage of actual layers over maximum layers is then multiplied by the maximum height this product can have when in full pallet giving the height of the full layers. Then this height is divided by the maximum height a layer-picked pallet can have ($h_{maxlayer} = 1800mm$), giving the pallet places occupied by full layers for that product. The same rational is followed in the third term calculating the pallet places due to case-picked pallets. The number of case-picked cases is initially divided by the number of case this product can have on a full pallet and then is multiplied by the height of a full pallet giving the height these cases occupy. Then this height is divided by the maximum height a case-picked pallet can have ($h_{maxcase} = 1050mm$) giving the pallet places occupied by case-picked pallets for that product. Finally all the terms are multiplied by the pallet type coefficient, in that way if product is on a euro pallet then all the terms are multiplied by 0,8. The process is repeated for all products in that order.

$$pp_{jl} = \sum_{i=1}^{m}((d_{ij} \text{ div } x_i)C_{stackability_i} + \frac{((d_{ij} \bmod x_i) \text{ div } y_i)}{z_i}\frac{h_i}{h_{maxlayer}} + \frac{((d_{ij} \bmod x_i) \bmod y_i)}{x_i}\frac{h_i}{h_{maxcase}})C_{pallettype_i} \tag{7}$$

Finally the cost to serve can be calculated by multiplying the costing units of full pallets, cases on full layers, cases case-picked and pallet places with their associated tariffs provided by the warehouse that is serving the ship-to location

$$cts = \sum_{l=1}^{p}\sum_{j=1}^{n} fp_{jl}C_{Pallet_l} + clp_{jl}C_{Layer_l} + ccp_{jl}C_{Case_k} + pp_{jl}C_{Shipment_l}(pp_{jl}) \tag{8}$$

This cost to serve function reflects perfectly the actual costs and is the most accurate calculation of them. However, it does not consider the various alternatives that have to be considered. In order for the decision variables to reflect whether a policy has been applied and which one specifically they have to be reformulated as follows.

STEP TWO

Firstly the number of full pallets has to be calculated per location and not per order since the alternatives do not include information about the demand per order. Consequently fp_{jl} has to be substituted with FP_l the total number of full pallets at location l in a year. The new decision variable is equal to the summation of fp_{jl} for all the orders in the case of no MOQ policy being applied and for the policy of ordering only on full layers. However in the case of the MOQ being ordering only full pallets the new variable changes in order to include the additional pallets that would have been either layer-picked or case-picked if that policy had not been applied. This is reflected by the two additional terms in the equation namely $\frac{\sum_{j=1}^{n} clp_{jl}}{\overline{x_l}}$ and $\frac{\sum_{j=1}^{n} ccp_{jl}}{\overline{x_l}}$. The first term corresponds to the number of pallets that arise due to the previously layer-picked cases and is calculated by dividing the number of layered-picked cases with the average number of cases per pallet in that specific ship-to location. Similarly the second term corresponds to the number of pallets that arise due to the previously case-picked cases and its calculation is a fraction with the case-picked cases in the numerator and the average number of cases per pallet in the denominator

$$FP_l = \begin{cases} \sum_{j=1}^{n} fp_{jl} & \text{for the no MOQ alternative} \\ \sum_{j=1}^{n} fp_{jl} & \text{for the MOQ=full layers alternative} \\ \sum_{j=1}^{n} fp_{jl} + \frac{\sum_{j=1}^{n} clp_{jl}}{\overline{x_l}} + \frac{\sum_{j=1}^{n} ccp_{jl}}{\overline{x_l}} & \text{for the MOQ=full pallets alternative} \end{cases} \tag{9}$$

Secondly, the number of cases layer picked per order clp_{jl} has to be substituted withCLP_l the total number of cases layer-picked in a year. The new decision variable is equal to the summation of clp_{jl} for all the orders in the case of no MOQ policy. However, regarding the policy of ordering only on full layers, a new term has to be introduced. This new term describes the additional layer picked cases that derive from the the cases that will not be case-picked. While for the alternative of the MOQ being ordering only full pallets it is clear that CLP_l has to be 0 since no cases will be layer picked.

$$CLP_l = \begin{cases} \sum_{j=1}^{n} clp_{jl} & \text{for the no MOQ alternative} \\ \sum_{j=1}^{n} clp_{jl} + \sum_{j=1}^{n} ccp_{jl} & \text{for the MOQ=full layers alternative} \\ 0 & \text{for the MOQ=full pallets alternative} \end{cases} \tag{10}$$

Furthermore, the number of cases that will be case-picked per order has to be substituted withCLP_l the total number of cases layer-picked in a year. This new variable is equal to the summation of clp_{jl} for all the orders in the case of no MOQ policy but is equal to zero for the other MOQ alternatives that intend to eliminate the case-picking activity.

$$CCP_l = \begin{cases} \sum_{j=1}^{n} ccp_{jl} & \text{for the no MOQ alternative} \\ 0 & \text{for the MOQ=full layers alternative} \\ 0 & \text{for the MOQ=full pallets alternative} \end{cases} \tag{11}$$

Finally, with respect to the calculation of the number of pallet places the reformulation of the variable in order to include the various strategies is more complicated since the associated costs $C_{Shipment_l}(pp_{jl})$ are correlated with the variable it self pp_{jl}. In order to achieve the reformulation the correlated term has to be included in a new decision variable. This new variable, namely (Shipment Costs) SC_l, in the no MOQ alternative, is equal to the summation of the number of pallet places per order multiplied by their associated costs for every order in location l. However, in the case an MOQ is applied, this variable is equal to the aforementioned value only in the case that the order placed exceeded the MOQ value defined as pp_l^*, for the orders that have less pallet places than pp_l^* a new term is introduced. This term is equal to the MOQ defined as pp_l^* multiplied by the associated costs with that MOQ $C_{Shipment_l}(pp_l^*)$ and the equivalent number of shipments that will be required to satisfy the demand of the remaining orders $\overline{n}$. This number derives from diving the summation of pallet places that are in orders that do not exceed the MOQ with the MOQ value itself as described in $\overline{n} = \frac{\sum_{j=1}^{n} pp_{jl}(1-a)}{pp_l^*}$. In the case of a Order Frequency Reduction policy being applied, the new variable takes the form of a multiplication among number of shipments allowed in one year n^*, the equivalent average number of pallet places per shipment for this frequency reduction $\overline{pp_l}$ and the associated costs this average number of pallet places corresponds to. The equivalent average number of pallet places is calculated by diving the summation of pallet places to be delivered due to the demand with the number of shipments allowed in one year n^* as described in $\overline{pp_l} = \frac{\sum_{j=1}^{n} pp_{jl}}{n^*}$.

$$SC_l = \begin{cases} \sum_{j=1}^{n} pp_{jl} C_{Shipment_l}(pp_{jl}) & \text{for the no MOQ alternative} \\ \sum_{j=1}^{n} pp_{jl} C_{Shipment_l}(pp_{jl}) a + pp_l^* \overline{n} C_{Shipment_l}(pp_l^*) & \text{for the MOQ} = pp_l^* \text{ alternative} \\ \sum_{j=1}^{n} pp_{jl} C_{Shipment_l}(pp_{jl}) b + (1-b) \overline{pp_l} n^* C_{Shipment_l}(\overline{pp_l}) & \text{for the Order Frequency} = \dfrac{1}{n^*} \text{ alternative} \end{cases} \tag{12}$$

Where:

$$\overline{n} = \frac{\sum_{j=1}^{n} pp_{jl}(1-a)}{pp_l^*}$$

$$\overline{pp_l} = \frac{\sum_{j=1}^{n} pp_{jl}}{n^*}$$

$$a = \begin{cases} 1 & pp_l^* \geq pp_{jl} \\ 0 & pp_l^* < pp_{jl} \end{cases}$$

$$b = \begin{cases} 1 & n^* \geq n \\ 0 & n^* < n \end{cases}$$

STEP THREE
The cost to serve function can now be reformulated to:

$$cts = \sum_{l=1}^{p} FP_l C_{Pallet_l} + CLP_l C_{Layer_l} + CCP_l C_{Case_k} + SC_l \tag{13}$$

4.2.4 Decision variables

$$alternative = \begin{cases} \text{no MOQ alternative} \\ \text{MOQ=full layers alternative} \\ \text{MOQ=full pallets alternative} \\ \text{MOQ= } pp_l^* \\ \text{Order Frequency= } 1/n^* \text{ alternative} \end{cases} \tag{14}$$

$$pp_l^*$$

$$n^*$$

4.2.5 Cost Function

$$cts = \sum_{l=1}^{p} FP_l(alternative) C_{Pallet_l} + CLP_l(alternative) C_{Layer_l} + CCP_l(alternative) C_{Case_k} + Shipmentcocsts_l(alternative) \tag{15}$$

It can be noted here that the first three terms of the cost to serve function 15 are related to Outbound Handling Costs while only the last term is related to Freight to Customer Costs. In addition one can observe that the cost to serve is calculated per customer, thus in order for the total costs (function 17) to be calculated an additional set will have to be introduced.

$$k \quad for \quad customer \qquad K = [customer_1, ..., customer_q] \tag{16}$$

$$tc = \sum_{l=1}^{q} cts_k \tag{17}$$

4.3 Implementation

In this subsection a brief description of the model implementation in Microsoft Excel is given, a more detailed description of the programming can be found in Appendix B (7.2). The implementation takes place in two excel files with the first one focusing on the transformation of the demand information into the level of activities to be monitored and the second one focusing on the calculation of the costs for these activities. Consequently, the first file transforms the ordered quantities into a number of full pallets, cases on full layers, cases case-picked and number of pallet places in each order, and the second transforms these numbers into costs for every alternative.

Specifically, with respect to the first file, initially, the master data of the products, regarding the EPN number of the product, the number of cases per pallet/layer, the number of layers per pallet, the stackablility and the pallet type are extracted from SAP's display material report and inserted in a spreadsheet. Another set of data, regarding the demand for each product in each order at all the ship-to locations, are inserted in a separate spreadsheet of the same book. These data are also extracted from SAP but this time by executing the sales order report selecting a specific layout in order for the information to be displayed as desired. This report contains the information, regarding the order number, the customer, the ship-to location, the ordered product (EPN number) and the ordered quantity, that is needed for the first step of the calculation.

A vertical lookup function is used searching the ordered products' EPN number in the master data and returning their full pallet height (h_i) , cases per pallet (x_i), cases per layer (y_i), stackability ($C_{stackability_i}$) and pallet type coefficient ($C_{pallettype_i}$) in the columns next to the extracted information. The looked up information is used to transform the ordered quantity of each product to the exact number of pallets, layers, cases layer picked and cases picked respectively. Right after that, the calculation of the pallet places of the order takes place. This calculation is broken up to multiple columns. Initially, the number of full pallets of the product are transformed into a number of pallet places multiplying by the stackability and pallet type coefficients. Then, the number of layers is transformed into a percentage of a full pallet. After that, the product's Full Pallet Height is divided by the maximum height a layer-picked pallet can have. The two numbers are then multiplied giving the layers' equivalent in pallet places. Afterwards, the number of pallet places the product occupies is calculated by multiplying the summation of the conversions with the pallet type coefficient. The cases' equivalent in pallet places is calculated in a similar way. With all the conversions calculated and summed up it is now clear how many pallet places a product of an order occupies. The number of pallet places is required for the entire order so a cumulative is calculated by adding the value of the previous row only if the order number is the same as in the previous line. Finally, since only the final number of the cumulative is needed this number is singled out with a help of an if function that recognises if the order number is the same with the one of the next line.

With the fp, clp, ccp , and pp numbers calculated, using the equations eq.4 eq.5 eq.6 and eq.7 respectively, for every order of every ship-to location of every customer the data are reformulated via pivot tables and extracted in a different excel book. In this book the calculations of costs are going to take place initially for the no MOQ alternative but for the other alternatives as well. In the second file the data, regarding the tariffs applied by the 3pl parties (C_{Case_l},C_{Layer_l},C_{Pallet_l},$C_{Shipment_l}(p)$) at each warehouse location as well as the one-to-one relation between location and 3pl serving this location, are inserted in three spreadsheets.

With respect to the outbound handling costs of the calculation, the summarized data of the first file are copied as a link in one of the spreadsheets. The linked information is used for the calculations that are a simple multiplication of the cases picked, the layer-picked case and the full pallets with their associated tariffs. Finally, the costs associated with the Outbound Handling activities are summed up.

For the Full Layers MOQ alternative the costs are recalculated with the Cases on full layers and Cases picked being multiplied with the layer picking tariff but the full pallet picking costs staying the same. For the Full Pallets MOQ alternative the costs are reformulated with the previously picked and layer picked cases are added and divided by the average number of cases per pallet for each ship-to location found by a vertical lookup function and then multiplied by the full pallet associated tariff. The costs of the previously picked cases now calculated as full pallets are added to the costs of the Full Pallets that were there before the policy implementation.

Moving on to the Freight to customer costs calculation, the summarized data of the first file are pasted in another separate spreadsheet.Then with the help of a vertical lookup function the 3pl serving each location is identified and returned in alongside the pallet places information. Having that information the costs for each day can now be looked up in the associated tariff table. The formula doing that is extended for the equivalent of the number of days of the year. Finally, the costs of all the days are summed.

For the MOQ alternatives initially the quartile values are calculated. Then, the total number of pallet places shipped in shipments that had less pallet places than the MOQ value are calculated. These pallet places are divided by the applied MOQ leading to the calculation of the number of shipments needed for the previously inefficient orders to be shipped with the value of the MOQ. After that the costs for the changed shipments due to the MOQ can be calculated with a multiplication of the number of changed shipments with the tariff of the 3pl serving the specific location found by a vertical lookup. While the costs of the not changed shipment can be found with the help of a sumif function summing the costs only if the shipment has a number of pallet places below the MOQ.

With respect to the frequency reduction alternatives, for the costs to be calculated initially the total number of pallet places shipped has to be found. The total number of pallet places shipped is found by adding up the pallet places of the entire year. After that the number of shipments is counted by a countif function neglecting the empty cells. Finally, the costs are calculated. Only in the case that the number of shipments is above the one allowed by the frequency policy the calculation proceeds. In the case it is below the allowed number then the Freight to Customer Costs of the no moq alternative are used. The same goes for the situation that the volume cannot be shipped by with the allowed number of shipment. For example, for the 1 shipment per week, this condition is being met if the total pallet places divided by the total number of shipments allowed ,which is 52(as the number of weeks in a year), is not exceeding the maximum number of pallet places in a truck which is 26. In the case that both conditions are being met then the number of pallet places are divided by the number of allowed shipments calculating the new average pallet places number and the associated tariff depending on the 3pl is found with the help of a lookup function and multiplied by the number of shipments that will occur.

Finally, in the results tab of the second file the design alternatives with the lowest cost to serve(14) are presented as the models proposed solution. In addition the other alternative's results are summarised in various pivots containing the information in terms of cost to serve (eq.15) and total costs (eq.17).

4.4 Verification

In this subsection the correctness of the implementation of the mathematical model in Microsoft Excel is tested providing verification to the model. This requires, apart from debugging the code, examining whether the output values of the model's implementation are equal to the ones anticipated. Some of the most common test runs used for model verification are input checks, seed independence, continuity tests, degeneracy tests, consistency tests and fault injection, while models can also be verified by comparing some simple test cases with analytical results.

The verification tests held to verify the model of this report are presented below. It is important to note here that the data set used is identical for all the tests with apart from the critical parameters that are modified in each test.

- **Continuity test:** runs with insignificantly different parameters expecting a insignificant difference in the output.

  1. Initial run to test if the result is logic
  2. Increase demand by the equivalent number of cases of one pallet for one random product in one order of every ship-to location
  3. Decrease demand by the equivalent number of cases of one pallet for one random product in one order of every ship-to location

- **Degeneracy test:** examining if the model works as expected for extreme cases.

  4. Set all ordered quantities at 0
  5. Set all tariffs at 0
  6. Set outbound handling tariffs at 0
  7. Set freight to customer tariffs at 0
  8. Set all locations to be served by the 3pl with the highest tariffs

- **Consistency checks:** evaluating if the model generates similar results for various input values that have approximately the same effects.

  9. mix the shipments of two locations of the same customer(cost to serve the customer should remain the same)

- **Fault injection:** investigating if input values that are faulty can be detected by the model.

  10. Set demand exceeding 26 pallet places
  11. Set cases per pallet of all products to 0
  12. Set cases per layer of all products to 0
  13. Set layers per pallet of all products to 0

The results of the verification tests can be found in the table presented below. In this table one can find a description of the tested situation, the anticipated result, the actual result of the model and the outcome of the test in that order. The outcome of the verification test is considered to be positive when the actual results match the anticipated ones. The results presented in the table represent the test for only one customer since the cost to serve is calculated per customer. However the test runs have been repeated for multiple customers and all of them have been successful.

Description	Anticipated result			Model's Result			Test Outcome
	Freight to Customer Costs	Outbound Handling Costs	Cost to Serve	Freight to Customer Costs	Outbound Handling Costs	Cost to serve no moq	
1. Initial run	>0	>0	>0	399.258 €	131.284 €	530.542 €	Pass
2. dj new=dj old+d(1ppeqv)	>399.258€	>131.284€	>530.542€	399.265 €	131.294 €	530.559 €	Pass
3. dj new=dj old-d(1ppeqv)	<399.258€	<131.284€	<530.542€	399.250 €	131.274 €	530.524 €	Pass
4.dij=0	- €	- €	- €	- €	- €	- €	Pass
5.Ccasel=Clayerl=Cpalletl=Cshipmentl(p)=0	- €	- €	- €	- €	- €	- €	Pass
6.Ccasel=Clayerl=Cpalletl=0	=399.258€	- €	=399.258€	399.258 €	- €	399.258 €	Pass
7. Cshipmentl(p)=0	- €	=131.284€	=131.284€	- €	131.284 €	131.284 €	Pass
8.Cshipmentl(p)=CshipmentVR(p)	>>399.258€	=131.284€	>>530.542€	467.765 €	131.284 €	599.049 €	Pass
9. (dj+dj+1)old=(dj+dj+1)new	=399.258€	=131.284€	=530542€	399.258 €	131.284 €	530.542 €	Pass
10.dj–>ppj>26	Error detected	Error detected	Error detected	Error	Error	Error	Pass
11. xi=0	Error detected	Error detected	Error detected	Error	Error	Error	Pass
12. yi=0	Error detected	Error detected	Error detected	Error	Error	Error	Pass
13. zi=0	Error detected	Error detected	Error detected	Error	Error	Error	Pass

Table 5: Verification tests' results

4.5 Cost to serve Model summary

Research question three has been answered in this chapter. Specifically, the structure of the model that is able to evaluate the outcome of the design alternatives has been described both by a conceptual model and a mathematical model with the required assumptions, the model was implemented and verified. The conceptual model serves as a precise illustration of the real-life system while the mathematical model serves as a specification of the concept into mathematical language. The indices and sets, parameters, decision variables and cost function have been defined. The sets include the products, the ship-to locations and orders while an addition set of customers is required for the total costs calculation. The parameters include the quantities, the product specifications and the tariffs while the decision variables are the alternatives to be tested and their specifications. The cost function is a multiplication of the calculated costing units of full pallets, cases on full layers,cases case-picked and pallet places depending on the alternative with their associated tariffs. The cost to serve function (cts) consists of four terms three related with outbound handling activities and one with freight to customer activities and is calculated separately for each customer. For a total cost calculation all one needs to do is to add the cost to serve of every customer. Furthermore, the structure of the model has also been described in the software environment where it has been implemented. Finally, it has been verified that the model is implemented according to the described specifications and that the implementation accurately represents the conceptual description.

5 Experiments and Results

In this section, having verified that the introduced cost-to-serve model has been implemented correctly, the research can now proceed to the model experimenting step. A summary of all the planned experiments will be presented defining the experimental plan to be followed and the specifics of each experiment. After that the results of the experiments are going to be presented and analysed, leading to the evaluation of the design alternatives, the selection of the design alternatives and consequently to the answer of research question 4.

5.1 Experimental plan

Keeping in mind that the experiments to be executed will have to lead to the answer of research question 4, the experiments will have to be evaluating each of the design alternatives.

Goal The goal of each experiment is to determine the performance of each design alternative with respect to the KPI which is costs. The experiments consist of model runs and the runs' output. The output is quantifying the performance of the alternative and after conducting a comparative analysis the selection of the design alternatives per customer can take place. Furthermore, the performance of each design alternative can be evaluated in various customer groups sharing similar characteristics regarding the country and sector they operate in, the size of their demand, the frequency and the size of their orders as well as the variability of the size of their orders.

Input The input for all the experiments is the demand data for each product in each order at all the ship-to locations throughout the year 2019 with the MOQ or frequency reduction specifications varying per experiment.

The customers are classified as follows and experiments will be held per customer type.

1. Country
   (a) Netherlands
   (b) Belgium
   (c) Luxembourg
2. Channel
   (a) Retail
   (b) Food Service
   (c) Export
3. Demand with respect to the number of cases shipped in a year
   (a) Insignificant (≤1000)
   (b) Low (≤10000)
   (c) Medium (≤100000)
   (d) High (≤1000000)
   (e) Significantly High (>1000001)
4. Order Frequency with respect to the year's average number of shipments per week
   (a) Very Low (0-1,4)
   (b) Low (1,4-2,8)
   (c) Medium (2,8-4,2)
   (d) High (4,2-5,6)
   (e) Significantly High (>5,6)
5. Order Size with respect to the year's average number of pallet places per shipment
   (a) Very Small (0-5,2)
   (b) Small (5,2-10,4)
   (c) Medium (10,4-15,6)

(d) High (15,6-20,8)

(e) Significantly High (20,8-26)

6. Order Size Variability with respect to the year's standard deviation of the number of pallet places per shipment

   (a) Low (≤1)

   (b) Medium (≤2)

   (c) High (≤4)

   (d) Extremely High(>4)

Configuration The configuration regarding the one-to-one relation between 3pl and location, the tariffs applied by each 3pl provider and the same master data of the products, is fixed for all the experiments. 12 alternative configurations have been used with respect to the strategy applied:

1. no MOQ alternative

2. MOQ=full layers alternative

3. MOQ=full pallets alternative

4. MOQ=

   (a) The first quartile (Q1) of the number of pallet places of all the orders for each customer alternative

   (b) The median (Q2) of the number of pallet places of all the orders for each customer alternative

   (c) The third quartile (Q3) of the number of pallet places of all the orders for each customer alternative

   (d) Full Truck loads (26 pallet places) alternative

5. Order Frequency=

   (a) 1 day per week alternative

   (b) 2 days per week alternative

   (c) 3 days per week alternative

   (d) 4 days per week alternative

   (e) 5 days per week alternative

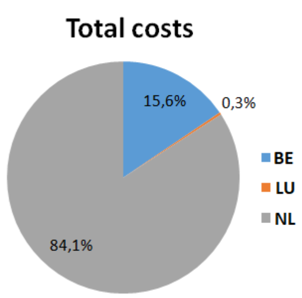
Consequently 12 experiments 1 base and 11 alternatives have been scheduled per customer and per customer type.

5.2 Analysis of the model's results

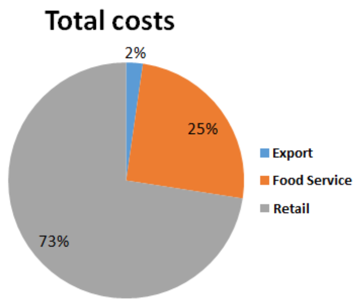
Initially, the investigation will focus on the "no moq alternative", verifying and improving the understanding of the current situation acquired in the third chapter. With the help of the model the performance can now be measured by the introduced KPI of costs. In that way, the data analysis of chapter 3 that used the underlying indicators of loading factors, shipments per week and picking percentages will be verified and expanded by the resulting KPI. The costs of the "no moq alternative" will establish the base of comparison with the possible design alternatives. In order for an improved understanding of the current situation the total costs (eq.17) will be used and general insights regarding how costs are spread among the countries and the channels, which activities are inducing more costs for each country and channel and how are the total costs concentrated among the customers. However, the main focus will be on the cost-to-serve gaining insights 15 regarding the current performance of for each customer in every group. Then again via the total costs (eq.17) it will be investigated whether the design alternatives can result in cost reduction for every customer group and whether the stricter alternatives result in lower costs. Afterwards, each design alternative will be investigated in depth using the cost-to-serve 15 for each customer in every customer group. Finally, the design alternatives will be evaluated upon their performance in the resulting KPI. The design alternatives will be sorted from the one resulting to the lowest costs to the one resulting to the highest costs for every customer and the one with the lowest costs will be considered to be the model's selected design alternative. Also, the combinations of customers and design alternative will further be sorted from the ones resulting to the highest savings to the lowest savings for the strategy prioritisation of the case study company. Finally, it is important to note here that the analysis has been done for each and every customer of the case study company. However, in order to be as concise as possible the cost-to-serve per customer results are presented only for the customers responsible for the 80% of the shipped volume in the retail channel of the Netherlands. The results regarding the customers responsible for the 80% of the shipped volume of the other customer groups can be found in the appendix, while the results regarding the plethora of smaller customers responsible for 20% of the shipped volume have not been included in the report.

5.2.1 General Insights (current situation)

The base case 1. experiment results are presented here in terms of total costs. The first figure in 41 when compared with 9 from the third chapter indicates that the percentage of costs related to serving Belgian customers are higher than the corresponding percentage of number of cases shipped to the same customers.The opposite is true for the Netherlands.



(a) per country



(b) per channel

Figure 41: Total costs

When comparing figure 16 with figure 41, One can see that while NL-Retail customers are responsible for 83% of the delivered cases, the costs induced from handling and transferring those cases amounts only up to 68% of the total. The Belgian Retail customers being responsible for 7,3% of the volume have an almost equal percentage of the total costs 7%. On the other hand, the Food Service channel while responsible for 9,45% of the volume shipped they amass a quarter of the costs' pie. The results presented in 41 and 16, essentially, provide additional evidence that the most inefficient orders derive from Food Service and the most efficient ones from NL-Retail. Figure 41 also verifies the observation made in chapter 3 regarding the opportunity being located at NL-Retail since the majority of the costs are deriving from this Country-Channel.

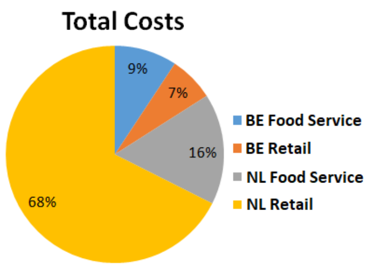


Figure 42: Total costs

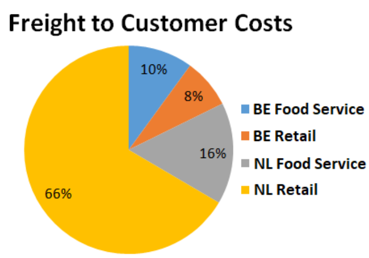


Figure 43: Freight to Customer costs

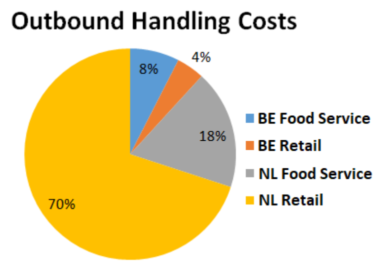


Figure 44: Outbound Handling Costs

More interesting insights can be found in figure 45, where it becomes apparent that the freight to customer costs outweigh the outbound handling costs in every customer group with the former being higher in Belgium and the later in the Netherlands. This means that MOQ policies regarding pallet places and the order frequency policies have a potential to affect a bigger percentage of the costs while the full pallets/full layers MOQ polices can only affect a smaller percentage of the costs. The potential pallet places and order frequency policies is higher in both countries but seems to be even higher in Belgium when comparing countries and in Retail when comparing Chanels.

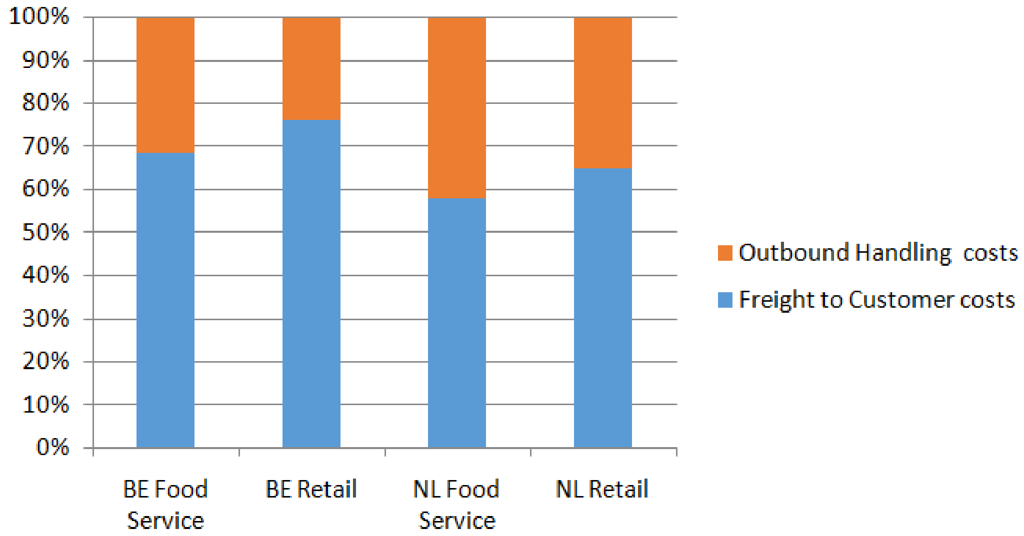
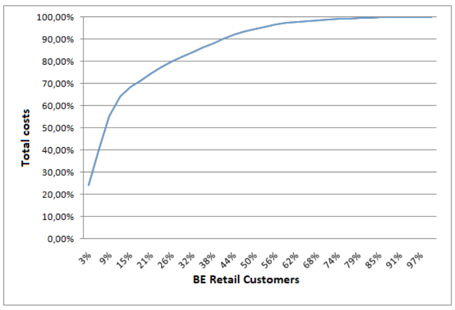


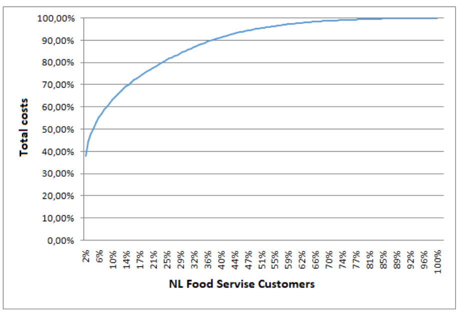
Figure 45: Outbound Handling vs Freight to Customer Costs

The pareto principle observed in the delivered cases (fig. 21), can also be observed in figure 46 where the dependent variable is costs. More precisely, for the Retail Channel in the Netherlands the 80% of the costs derive from 16% of the customers, for the Retail Channel in Belgium the same percentage is delivered to 26% of the customers, for the Food Service Channel in the Netherlands it is delivered to 24% and for Food Service Channel in Belgium to 28%. When compared with figure 21 the graphs reveal that the concentration of the volume delivered is higher than the concentration of costs indicating a higher a efficiency in the customers with the highest volume.

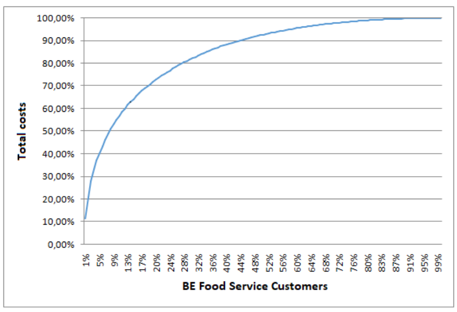
(a) Retail Channel Netherlands



(b) Retail Channel Belgium



(c) Food Service Channel Netherlands



(d) Food Service Channel Belgium

Figure 46: Pareto principle for costs of KraftHeinz customers

5.2.2 No MOQ alternative

The base case 1. experiment results are presented here in terms of cost-to-serve per customer. The graph presented in figure 47 illustrates information regarding the cost-to-serve per customer for the top customers representing the 80% of the shipped volume in the Retail Chanel of the Netherlands. It can be seen that the values of the cost to serve span between more half a million and 60 thousands. In addition, one can note that among those customers the top 2 are responsible for more than half of their costs with a substantial difference in the cost to serve those two and the cost to serve of any other customer in the group. Moreover, it is clear from the graph that the majority of the costs are induced from the freight to customer activities for all the customers and in that sense the higher cost savings are expected in the alternatives that influence them. It is further interesting that the customers with the highest volume delivered are the ones with the highest costs in this customer group. This however is not true for every customer group as depicted in figures 75, 76 and 77 in the appendix.

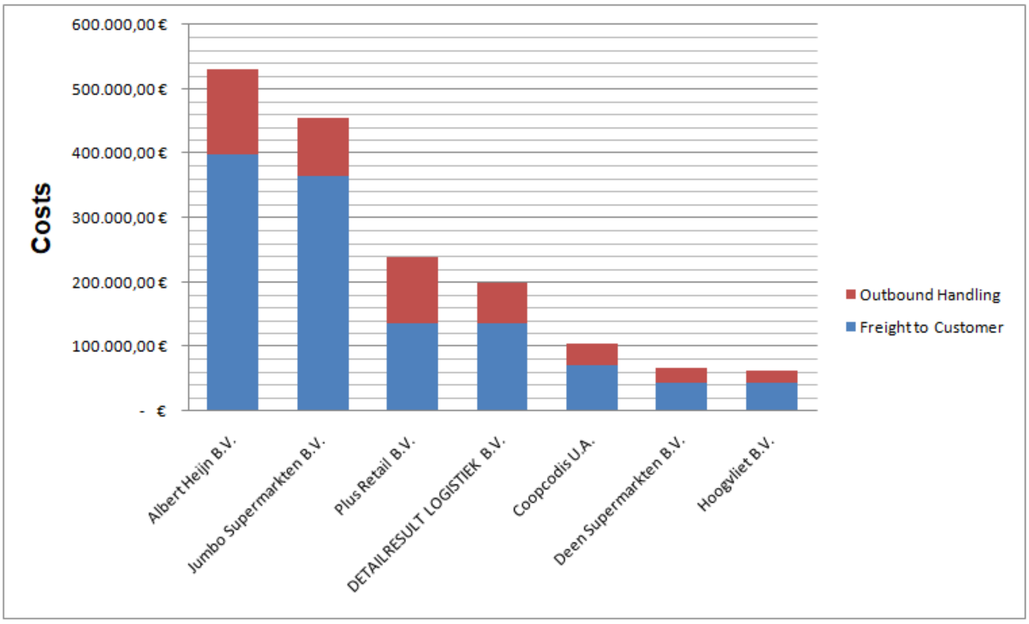


Figure 47: Cost to serve in Retail Netherlands

Actually, as highlighted in figure 48, the relationship between volume delivered and costs induced is not proportional. The costs per case, by taking into account the volume delivered, is a better indicator of the efficiency of each customer than the total costs. In that sense the biggest customer might be having the highest total costs but is also the most efficient with the lowest costs per case. Furthermore, this graph indicates in which activity the inefficiencies are lying. For example it is clear that the second biggest customer could improve its order pattern in terms of order quantity/frequency since the freight to customer induced costs per case are higher than the ones of the biggest customer. In addition, the freight to customer costs per case vary between 0,055€ for the most and 0,078€ for the least efficient while the Outbound Handling costs per case vary between 0,017€ for the most and 0,051€ for the least efficient among the customers representing the 80% of the shipped volume in the customer group. The low costs per case observed verify the high the truck load utilization and the outbound handling efficiency in the group. Consistently this graphs are verifying the observations made in the bubble graph presented in figure 22 in chapter 3.

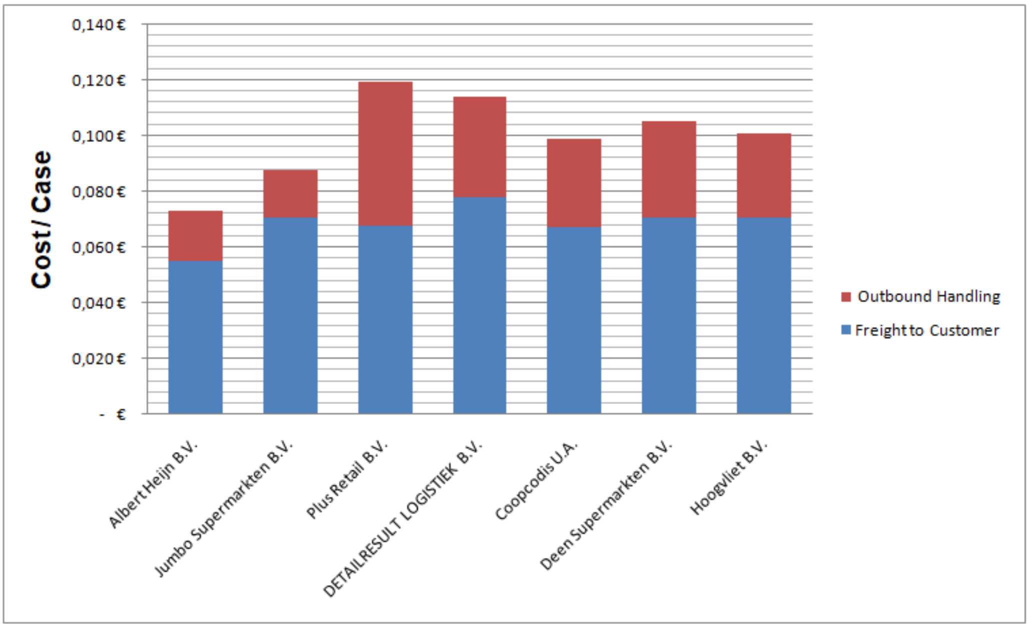


Figure 48: Cost per case in Retail Netherlands

5.2.3 General Insights (Alternatives)

The base case 1. experiment results are compared with the experiment results of the design alternatives tested in experiments 2,3,4 and 5 here in terms of total costs. From figure 49 it becomes apparent that the implementation of an MOQ policy has a positive effect on costs. Furthermore, it is clear from the graph that, as expected, the stricter the MOQ policy gets (higher number of pallets required) the lower the freight to customer costs get. Another observation that can be made from this graph is that the decrease of costs is incremental for the three "quartile" MOQ alternatives while for the full truck loads MOQ the decrease in costs is significantly bigger for all the groups apart from NL-Retail where the decrease is incremental. The reasoning behind this fact is that the "quartile" alternatives are by definition related to an incremental change (setting the bar at the top 25%, 50% and 75% of no MOQ performance) while the "full truck load" alternative's target is not related to the no MOQ performance . In the case of NL-Retail the costs incrementally converge to the costs of a "full truck load" alternative because the efficiency of this group is already high and consequently the costs are closer to minimum while for the other groups a "full truck load" alternative is so far from reality that even changing to the top 75% performance would induce way more costs than switching to full truck loads. This also indicates that the Full Truck Load alternative is probably unrealistic for all customer groups apart from Retail Netherlands.

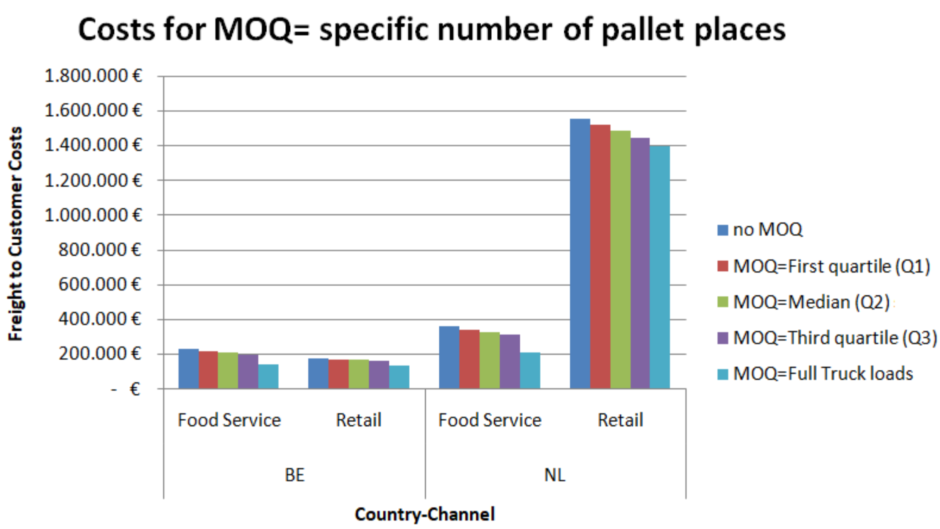


Figure 49: Costs for the MOQ=pp_l^* alternatives

It is also clear from the graph and even more from table 6 that the highest cost saving potential can be found in the NL-Retail group for any MOQ while the second highest potential can be found in NL-Food Service with BE-Food Service and BE-Retail following again for every MOQ.

cost savings for	MOQ=Q1	MOQ=Q2	MOQ=Q3	MOQ=FTL
BE-Food Service	17.240 €	22.680 €	34.144 €	91.771 €
BE-Retail	5.406 €	8.729 €	12.319 €	44.800 €
NL-Food Service	25.184 €	34.871 €	53.632 €	155.456 €
NL-Retail	30.807 €	69.787 €	109.073 €	156.965 €

Table 6: Cost savings for the various MOQ= pp_l^* alternatives

Figure 50, illustrating the costs for the full pallet and full layer MOQ alternatives in comparison with the alternative where no MOQ is implemented, also demonstrates that these MOQ policies are beneficial with respect to costs. Furthermore, a significant difference in the magnitude of cost savings for the two alternatives can be noted in the graph, with the Full Pallets MOQ alternative being the one providing the sharpest decrease in costs for all customer groups.The graph also indicates that the highest potential lies in the implementation of a Full Pallet policy in the Retail Channel of the Netherlands with the savings of all other customer groups being significantly lower. In addition, the cost savings for the full layer MOQ alternative are almost negligible for the retail channels of both countries while the same is not true for the food service channels. This difference between the two channels is the expected outcome of the order pattern observed in figure 20 and demonstrates the potential for improvement in layer picking for the food service channel.

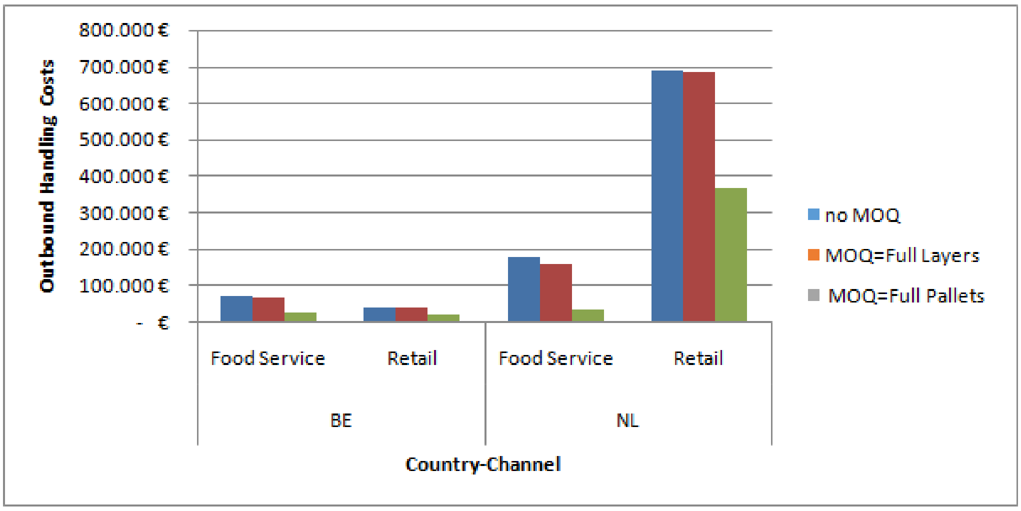


Figure 50: Costs for the MOQ=full layer/pallet alternatives

The results regarding the frequency reduction alternatives presented in figure 51 can only be comprehended when keeping in mind the assumption that "when the volume cannot be delivered with the number of shipments allowed by the policy then the costs stay the same as in the no MOQ alternative for that customer" and that when the number of shipments allowed is higher than the number of shipments for the no MOQ alternative then the order pattern remains the same. In that sense, the number and "size" of customers with an order frequency higher than the allowed by the policy but with a volume that can be delivered if the policy gets implemented is the key factor influencing the results. Regarding the NL-Retail customer group the highest potential seems to be lying in a Order Frequency of 3 shipments per week also being with 5 and 4 shipments per week also having significant benefits. This is because the most inefficient orders occur to customers that have volumes that could be delivered with only 3 shipments per week but their current order pattern is more frequent than that. The cost savings from 5 and 4 shipments per week policies seem to be also high because of the bigger customers being able to reduce their order frequency. While the lower order frequency alternatives seem to affect only a smaller percentage of the groups delivered volume.In the other customer groups it can be observed that the higher order frequency alternatives have no effect because the customers order below that frequencies anyways. For example in Food Service Netherlands it can be observed that the majority of groups delivered volume could be in a frequency of 1 shipment per week with 2 and 3 orders per week also having some potential. Finally, regarding the Belgium customer groups, no order frequency policy seems to have any potential apart from the 1 shipment per week.

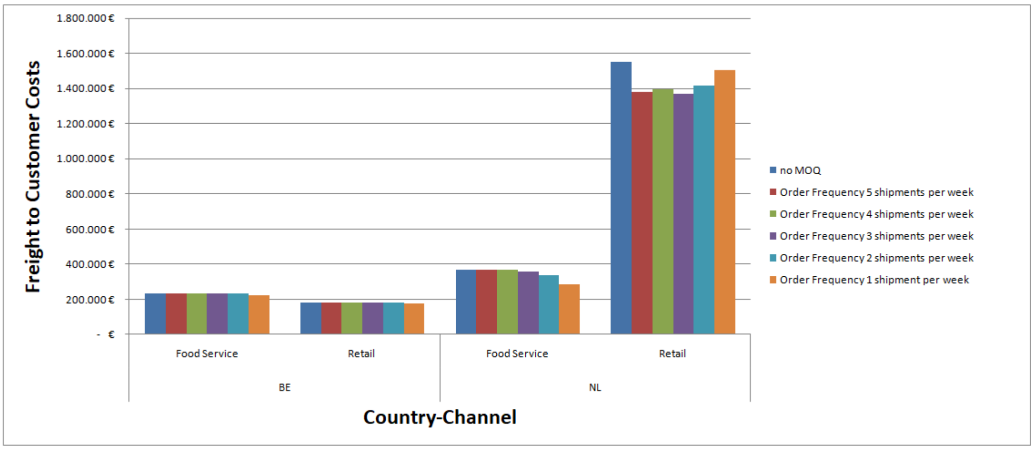


Figure 51: Costs for the frequency reduction alternatives

5.2.4 MOQ equal to a specific number of pallet places alternatives

The base case 1. experiment results are compared with the results of experiments 4.a,4.b,4.c and 4.d in terms of cost-to-serve per customer. The graph presented in figure 52 portrays the results of the "MOQ equal to a specific number of pallet places" alternatives. It becomes apparent from the graph that any MOQ policy would decrease costs and improve the efficiency of the freight to customer activities of every customer in the group. The highest potential in the group is observed at the second biggest customer for every alternative with the third and fourth also showing potentials greater than the one of the first customer for every alternative apart from the one of an MOQ equal to their first quartile. When looking back at figure 22, one can see that the third and fourth customer in size are the ones with the lowest average loading factors in the group explaining their high potential while the combination of size and "relatively low loading factor explains the potential of the second biggest customer. The incremental decrease in costs with the severity of the policy is observed in every customer with the exception of the third and fifth customer where the costs for the third quartile alternative and the full truck loads alternative are almost equal because the third quartile value is almost equal to the one of a full truck load.

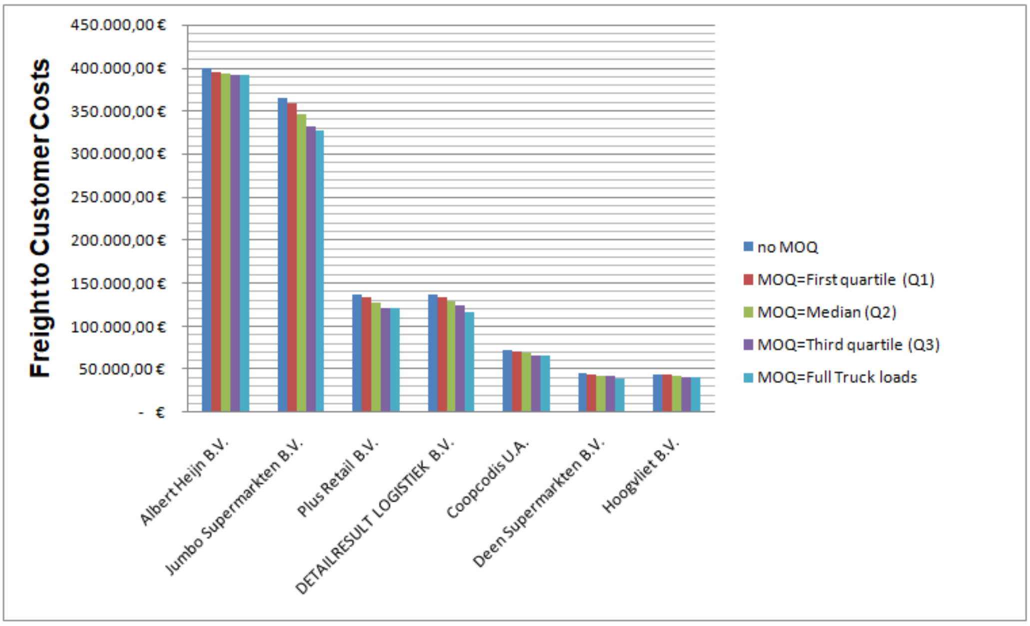


Figure 52: Freight to Customer Costs in Retail Netherlands

5.2.5 Order Frequency equal to a specific number of days per week alternatives

The base case 1. experiment results are compared with the ones of Order Frequency design alternatives tested in experiments 5.a,5.b,5.c,5.d,5.e in terms of cost-to-serve per customer. The results regarding the "Order Frequency reduction to a specific number of days per week" alternatives for the dutch retail channel customer group are depicted in figure 53. A first glance at the graph reveals that not every order frequency alternative has a beneficial effect for every customer. This fact, as well as, the non-incremental and non-proportional decrease of costs with the severity of the policy, can be explained by the two ways the model operates as discussed in the general insights section earlier. When looking at the results one should keep in mind that each ship-to location of every customer has its own order frequency. In that sense, the number and size of locations, with an order frequency higher than the allowed by the policy but with a volume that can be delivered if the policy gets implemented, is forming the results. For example, we can see that for the first customer there are a lot of locations that have volumes that could have been delivered with a policy of a maximum 5 shipments per week and consequently this is the order frequency that yields the most savings. The rest of the alternatives do not yield any cost savings with the exemption of the one shipments per week that is affecting a ship-to location with a small volume. The highest potential in the group is observed at the second biggest customer for the alternative with order frequency equal to 4 shipments per week while the biggest customer has the second highest potential for the 5 shipments per week alternative. A big potential can also be observed for the "Order Frequency 2 shipments per week" alternative of the third customer and the 3 shipments/week one of the fourth customer.

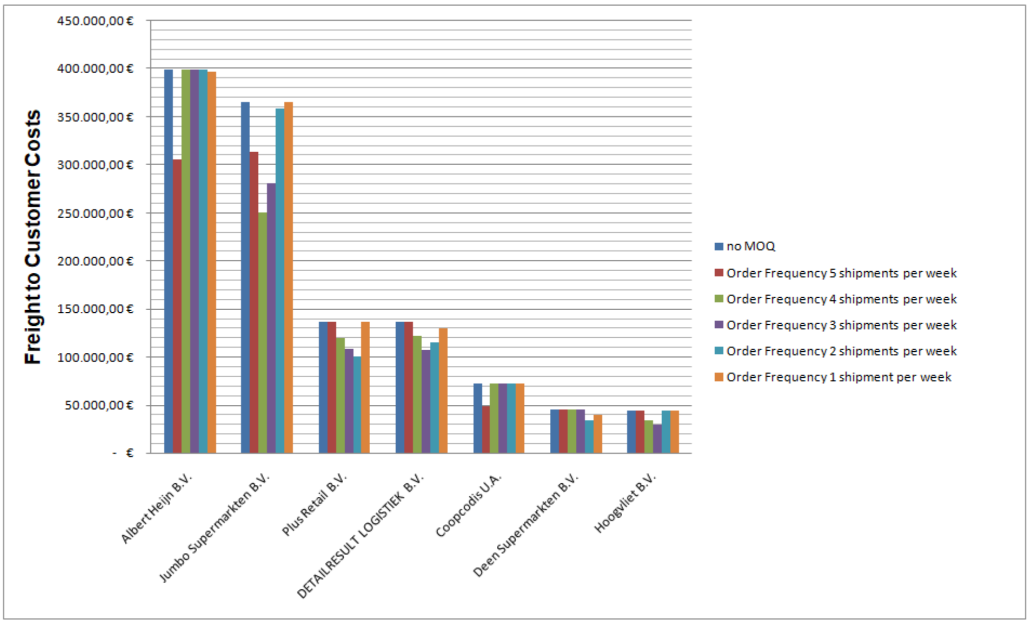


Figure 53: Freight to Customer Costs in Retail Netherlands for the frequency reduction alternatives

5.2.6 MOQ equal to full layers/pallets alternatives

The base case 1. experiment results are compared with the ones regarding the design alternatives of MOQ equal to full layers and MOQ equal to full pallets tested in experiments 2 and 3 in terms of cost to serve per customer. The results regarding the MOQ=full layers alternative and the MOQ=full pallets alternative are presented in figure 54. The really good performance of the group observed in figure 25 with significantly low case picking percentages explains the fact that the full layers alternative is not yielding any significant cost savings. The only alternative with a potential in this customer group is the one of the customers ordering full pallets only. In this alternative the highest cost savings are observed in third customer with the savings outweighing the ones for the implementation of the same alternative on 1st,2nd,4th and 5th customer combined. The second biggest potential is lying in the fourth biggest customer of the group. The implementation of the full pallets MOQ would also have considerable effects on the customer with the highest volume as well as on the one with fifth highest volume.

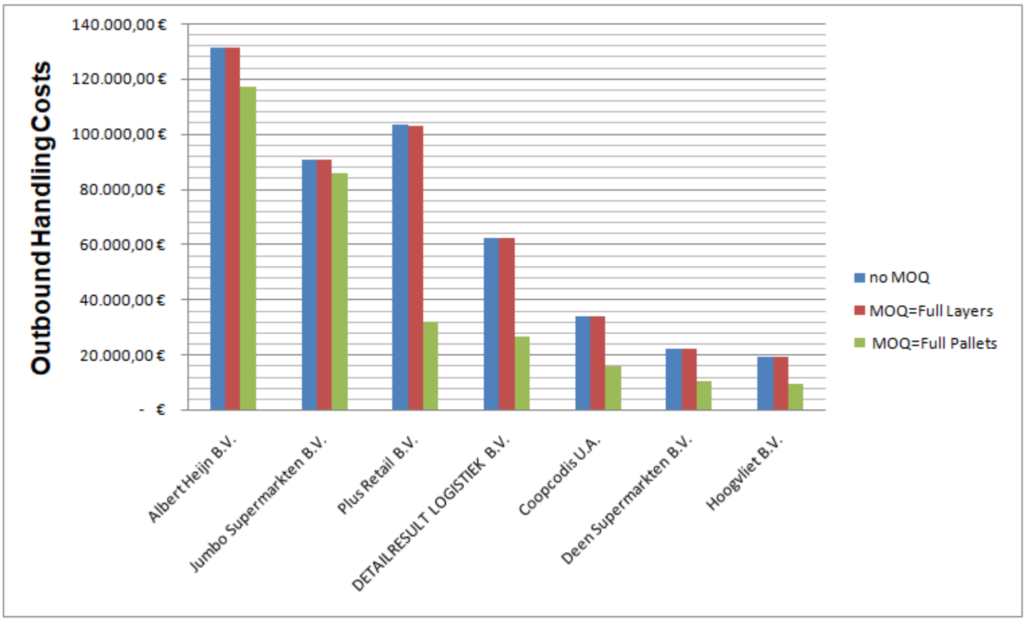


Figure 54: Outbound Handling Costs in Retail Netherlands

5.3 Evaluation of the design alternatives and model's proposal per customer

Following the analysis, the experiments' results for each design alternative can now be evaluated and the proposal of the model can be presented. A summary of the cost to serve for every tested alternative of the customers representing the 80% of the shipped volume in the dutch retail channel customer group can be found in tables 7 and 8. This table can be used as an indication of the performance of each design alternative for each customer. The design alternatives all have better or equal performance with the base case. it should be noted here that the performance is equal only for the alternatives where the total number of pallets could not be delivered with the number of shipments allowed by the policy (see assumption 5 regarding the alternatives). The expected cost saving per alternative can be calculated as the difference between the cost to serve of the alternative and the cost to serve of the base case(no moq).

costs for	no moq	Q1	Q2	Q3	FTL
AH	530.542 €	525.877 €	524.122 €	523.396 €	522.449 €
Jumbo	455.986 €	449.043 €	436.085 €	423.134 €	417.878 €
Plus	239.467 €	236.912 €	231.209 €	224.968 €	224.684 €
DRG	198.299 €	195.620 €	191.780 €	186.483 €	178.711 €
Coop	105.273 €	104.220 €	102.255 €	100.018 €	99.993 €
Deen	66.800 €	65.830 €	64.263 €	63.632 €	61.493 €
Hoogvliet	63.550 €	62.561 €	61.294 €	59.481 €	59.481 €

Table 7: Cost to serve per design alternative

costs for	5/wk	4/wk	3/wk	2/wk	1/wk	FL	FP
AH	432.680 €	530.542 €	530.542 €	530.542 €	528.348 €	530.268 €	516.442 €
Jumbo	389.531 €	339.870 €	392.645 €	449.489 €	455.986 €	455.835 €	451.295 €
Plus	239.467 €	223.473 €	209.609 €	202.719 €	239.467 €	239.235 €	168.046 €
DRG	198.299 €	175.987 €	168.949 €	176.995 €	191.159 €	198.163 €	162.767 €
Coop	81.460 €	105.273 €	105.273 €	105.273 €	105.273 €	105.257 €	87.429 €
Deen	66.800 €	66.800 €	66.800 €	55.270 €	61.536 €	66.761 €	55.135 €
Hoogvliet	63.550 €	52.064 €	48.222 €	63.550 €	63.550 €	63.493 €	53.941 €

Table 8: Cost to serve per design alternative

With the help of the tables presented above, the design alternatives can now be prioritized per customer with the ones resulting to lower costs having higher priority and the one with the lowest cost being the model's selected design alternative. A synopsis of the prioritisation can be found in table 9 presented below. It is clear from the table that for each customer the prioritization of the alternatives is different proving, what was before just indicated, that a "one size fits all" approach is definitely not leading to the overall efficiency optimization.

	Selected(1st)	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th
AH	5/wk	FP	FTL	Q3	Q1	Q2	1/wk	FL	3/wk	4/wk	2/wk
Jumbo	4/wk	5/wk	3/wk	FTL	Q3	Q2	Q1	2/wk	FP	FL	1/wk
Plus	FP	2/wk	3/wk	4/wk	FTL	Q3	Q1	Q2	FL	1/wk	5/wk
DRG	FP	3/wk	4/wk	2/wk	FTL	Q3	1/wk	Q2	Q1	FL	5/wk
Coop	5/wk	FP	FTL	Q3	Q2	Q1	FL	1/wk	2/wk	4/wk	3/wk
Deen	FP	2/wk	FTL	1/wk	Q3	Q1	Q2	FL	3/wk	4/wk	5/wk
Hoogvliet	3/wk	4/wk	FP	Q3	FTL	Q1	Q2	FL	5/wk	1/wk	2/wk

Table 9: Design alternative prioritisation per customer

5.4 Evaluation of the design alternatives per customer type

Following the model's proposal per customer, the results of the experiments per customer type are analyzed and the determination of the best strategy per customer type can be achieved. Using the total costs function per customer group sharing specific characteristics the alternatives effect on the costs can be quantified. In the graphs presented in this section the performance of each alternative is presented as the Percentage Change from the base case that can be achieved. In that sense, the minimum value of costs can be found in the alternative with the highest cost reduction. The selection of this type of representation has been done because some customer groups have costs that are orders of magnitude higher than others and consequently would not be able to be represented on the same graph giving a holistic view if the absolute values were used. The representation with the cost reduction percentage allows for comparisons to be made per group sharing the same characteristics but should not be used for comparisons among different customer groups.

5.4.1 Country-Channel

Figure 55 is interesting in several ways. With respect to the customers located in the Netherlands, it shows that for the retail channel, the minimum value of costs can be found in the alternative of full pallet with costs that are lower by 14% than the no MOQ implementation alternative. The alternative that is leading to the second lowest costs for the same group of customers is the one of an order frequency reduction to 5 days per week with an 8% cost reduction being achieved upon implementation. For the food service channel, on the other hand, the prevailing design alternative is the one of full truck loads with a difference of 29% in costs from no action being taken. The full truck loads alternative is closely followed by the full pallets one leading to a 26% reduction while the order frequency reduction to once per week is also leading to costs significantly lower(15%) than a no MOQ implementation. For the Export Chanel, the order frequency reduction to once per week alternative is the one leading to the highest cost reduction with the full truck loads also leading to similar cost savings. Regarding Belgium, for both retail customers and food service the full truck loads alternative implementation would lead to a cost reduction that cannot be compared with the ones of any of the alternatives. The full pallets and third quartile MOQ alternatives are second and third respectively in terms of cost reduction for both channels. With regards to Luxembourg, both full truck loads and full pallet alternatives seem to share the first position in cost reduction in the retail channel while in the food service channel the full truck loads alternative would lead to significantly higher cost reduction with the full pallets and third quartile MOQ sharing the second position.

An interesting observation that can be made here is that the entirety of the design alternatives leads to a cost reduction only in the retail channel of the Netherlands. The alternatives of order frequency reduction to 5 and 4 shipments per week cannot be implemented in the other customer groups since their customers already have lower order frequencies. The same can be said for the order frequency reduction to 3 and 2 shipments per week that only have some impact on retail and food service customers in the Netherlands. Interestingly the order frequency reduction to 1 shipments per week is the prevailing one for the export channel in the Netherlands while it leads to the least cost savings for both channels in Belgium and to no cost savings in food service Luxembourg. In addition, it should be noted here that the full layers design alternative only has a limited but observable cost reduction in food service of all countries while in the retail channel of Netherlands and Belgium it only leads to negligible and inconsiderable cost reduction.

Furthermore, it can be observed that the cost reduction that can be achieved by implementing a full truck loads, the third quartile, the median and the first quartile MOQ alternatives, is higher for food service customers for all countries. The same could be said for the full pallets alternative but only regarding the Netherlands and Belgium with the situation being the opposite for the customers in Luxembourg.

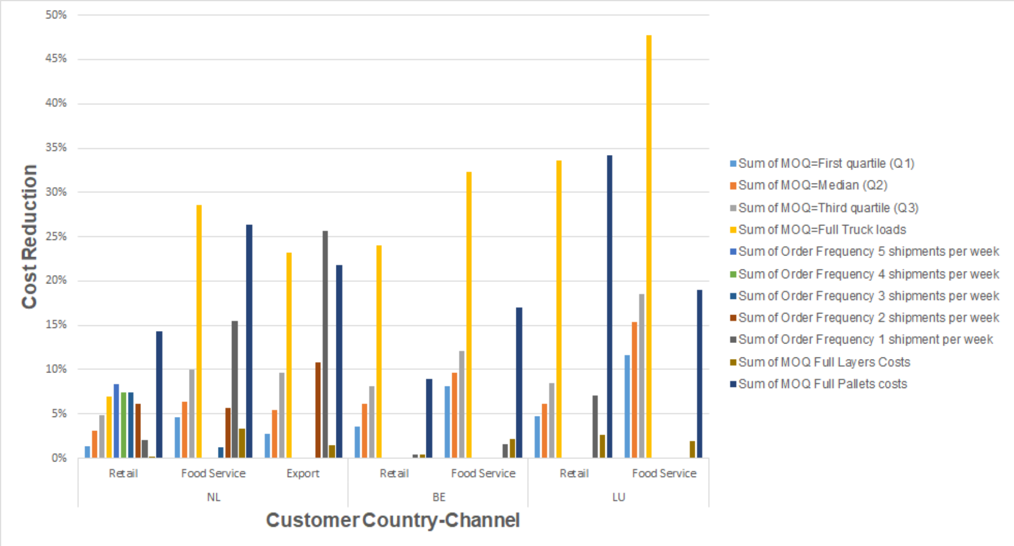


Figure 55: Cost reduction achieved by each design alternative per group of customers operating in a specific country and channel

5.4.2 Demand

Figure 56 illustrates how alternatives would perform upon implementation on customers with specific demand magnitude. It can be seen that for customers with an insignificant, low and medium demand the prevailing alternative is the one full truck loads with the second being the one of full pallets. The order frequency reduction alternative has only some significance for the medium demand size customers capturing the third position in cost reduction. For the high demand customers the full pallets alternative seems to be the prevailing alternative with the second and third alternative of full truck loads and order frequency reduction to 2 shipments per week leading to significantly lower cost reduction. For the customers with significantly high demand the situation differs even more with the Order Frequency reduction to 5 and 4 days per week design alternatives leading to the highest cost reduction followed by the full pallets one and the full truck loads only capturing the 5th position in cost reduction.

Figure 56 also indicates the absence of any impact in cost reduction of the design alternatives of frequency reduction to more than 2 shipments per week for the customers with up to a medium demand. Apart from that, it is highlighted in the graph, that the alternative of order frequency reduction to 1 shipment per week has some impact to customers with a medium and low demand.

Moreover, in this graph it can be observed that the cost reduction percentage for the MOQ alternatives is higher for customers with low demand and becomes lower for customers with higher demands.

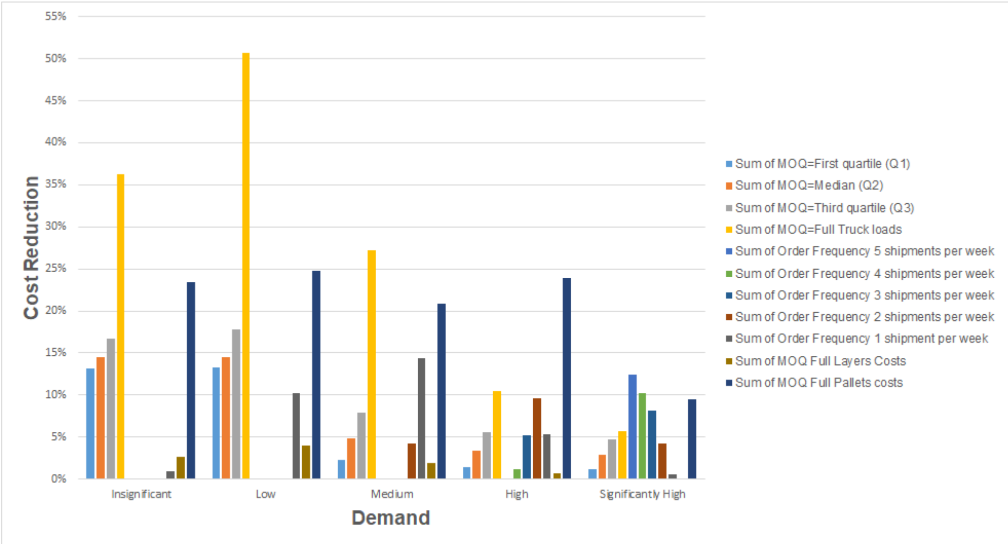


Figure 56: Cost reduction achieved by each design alternative per group of customers with certain Demand magnitude

5.4.3 Frequency

Figure 57 summarizes the data on the effect of order frequency upon the design alternative selection. It is clear from the graph that for customers with very low order frequency the full truck loads design alternative can have a tremendous effect in the reduction of costs while a little lower effects can be achieved with the implementation of a full pallets design alternative. For the customers with low order frequency the prevailing alternative is the one of full pallets being followed by the one of full truck loads and the order frequency reduction to 2 days per week. For the customers with a medium order frequency on the other hand the alternative leading to the highest cost reduction is the one of order frequency reduction to 4 shipments per week followed by the full pallets and the order frequency reduction to 3 shipments per week. Furthermore, for the customers with a high order frequency, the cost reduction of the "order frequency reduction to 5 shipments per week" alternative is outstanding with no other alternative being able to achieve a cost reduction of a similar extend. Finally, for the customers with an significantly high order frequency, it is clear from the graph that the prevailing design alternative is again the one of order frequency reduction to 5 shipments per week with the alternative of 4 shipments per week being in the second place.

It is also demonstrated in the graph that the Full layers alternative has an insignificant cost reduction for customers with medium order frequency and none at all for high and significantly high order frequency customers.For medium and high order frequencies insignificant is also the cost reduction of the order frequency reduction to 1 shipment per week while the 2 shipments per week order frequency reduction causes no cost reduction to customers with high average order frequencies.

Additionally, from graph it becomes apparent that the cost reduction percentage for the MOQ alternatives is higher for customers with low order frequencies than for customers with higher order frequencies. The opposite is true for the best order frequency reduction alternative per customer group. For example, the order frequency reduction alternative that is best suited for low order frequencies has a lower cost reduction percentage than the order frequency reduction alternative that is best suited for medium order frequencies.

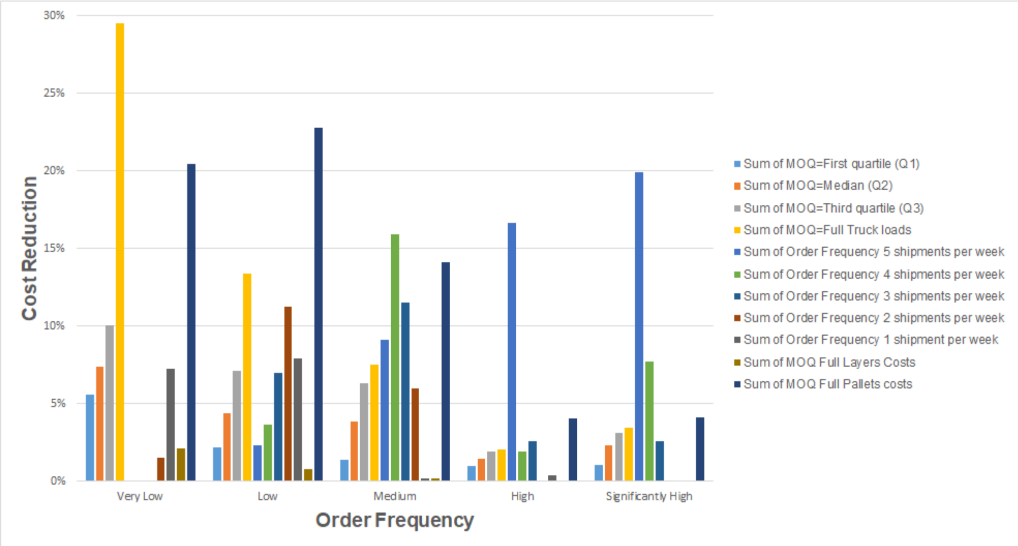


Figure 57: Cost reduction achieved by each design alternative per group of customers with certain Order Frequency

5.4.4 Order Size

The effect of order size upon the design alternative selection can be observed in figure 57. In that figure it is depicted that for customers with very small average order size the full truck load alternative is the one leading to a significantly high cost reduction followed by the full pallet alternative. For the customers with a small average order size it is clear that the alternative leading to the highest cost reduction is the one of full pallets with the second position belonging to the full truck loads design alternative. For medium order size customers the full pallets alternative is again the one with the highest cost saving, but for these customers this alternative is closely followed by the one order frequency reduction to 4 shipments per week, having similar cost reduction effects. The full truck loads alternative is 4th in the cost reduction right after the order frequency reduction to 3 shipments per week. Similarly, for the customers with a high order frequency one can observe that, the full pallet design alternative almost shares the first position of cost reduction with the alternative of frequency reduction to 5 shipments per week, while the full truck loads alternative is again the fourth alternative right after the order frequency reduction to 3 shipments per week. Finally for the customers with a significantly high average order the graph clearly illustrates that the cost reduction of the full pallets alternative cannot be approached by the implementation of any other design alternative. For these customers the order frequency reduction to 2 shipments per week is second with respect to cost reduction followed by order frequency reduction to 3 shipments per week.

Interestingly the impact of the full layers design alternative is more prominent on customers with very small order size and is almost negligible for customers with bigger average order sizes. In addition, the order frequency reduction alternatives to 5,4 and 3 days per week have no effect on the customers with a very low average order size. The same is true for the 4 shipments per week and the small order size customers as well as for the 5,4 and 1 shipments per week for the customers with a significantly high order size.

In addition, the graph reveals that customers with significantly high order sizes have a smaller cost reduction percentage for the MOQ alternatives than the customers with lower order sizes and the percentage incrementally increases with reducing the order size.

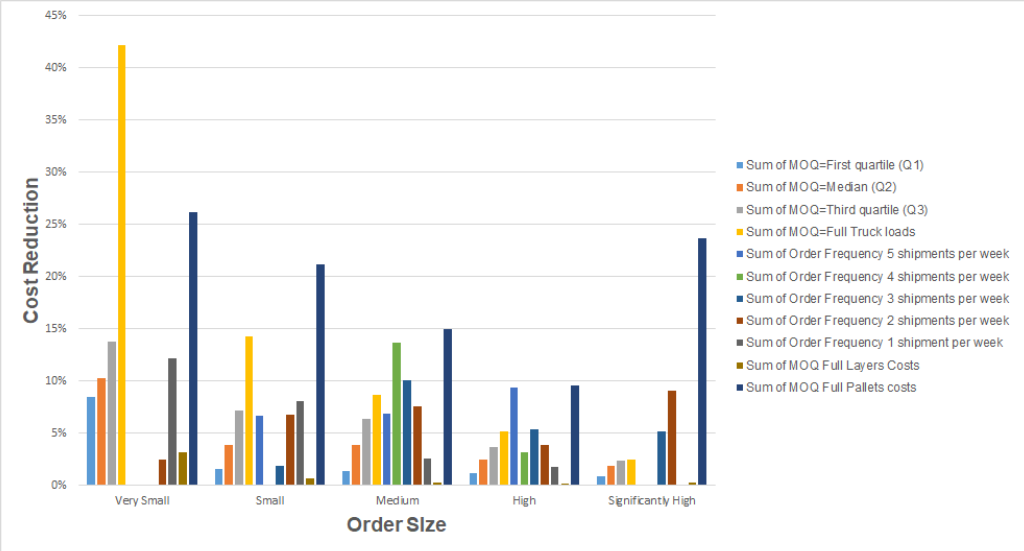


Figure 58: Cost reduction achieved by each design alternative per group of customers with certain Order Size

5.4.5 Order Size Variability

With respect to the effect of Order Size Variability upon the selection of a design alternative the results can be observed in figure 59. The graph indicates that for customers with low order variability the prevailing alternative is the one of full truck loads followed by the full pallet alternative that can however achieve only half of the cost reduction of the prevailing alternative. For the customers with a medium order size variability one can observe in the graph that again the full truck and full pallet alternatives have the first two position in cost reduction respectively. However in this group of customers the difference in the reduction of costs for the two alternatives seems to be relatively narrower and the full truck load alternative despite maintaining the first position having significantly lower effects that the one it has in the low order size variability customers. With respect to the customers with high order size variability the full truck loads alternative is again the first in cost reduction but this time closely followed by the order frequency reduction to 5 shipments per week and the third alternative being the full pallets one. Finally for the customers with an extremely high order size variability it can be noted that the full pallet alternative has the highest reduction in costs with the alternatives of frequency reduction to 5 and 4 shipments per week ass well as the one of full truck loads sharing the second position in cost reduction.

Figure 59 also demonstrates that frequency reduction up to 2 shipments per week have no effect to customers with low order size variability, while frequency reduction to 4 and 3 shipments per week have no effect to customers with medium and high order size variability. In addition it is also illustrated that the cost reduction of the full layers alternative is higher for low order size variability customers while it is almost negligible for customers with an extremely high order size variability.

Also, it could be noted in the graph that the MOQ alternatives lead to higher percentages of cost reduction for lower order size variability than for higher ones.

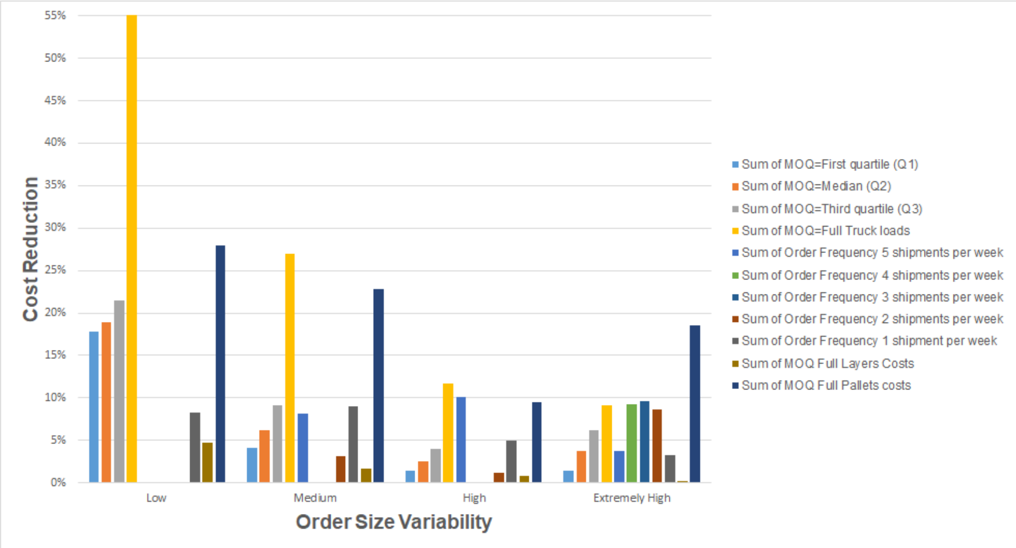


Figure 59: Cost reduction per group of customers with certain Order Size Variability

5.5 Results summary

In this chapter, the performance of the design alternatives has been evaluated by comparing the costs, which is the Key Performance Indicator. The design alternative with the lowest cost is recommended by the model as the optimal strategy per customer. In that way, the design alternatives can be selected providing the answer to research question 4. The developed model not only offers the opportunity for the costs to be compered per activity but also allows a comparison of the design alternatives for every single customer. In that sense, it becomes clear in which customers the biggest efficiency improvement and cost saving opportunities lie and for which design alternative. These results are essentially providing evidence upon which strategy should be followed for which customer and how should these strategies be prioritised from the supplier. An example on how this decision can be prioritised is given in tables 7 and 8. It is clear from the table that priority in this group should be given in the frequency reduction of the second biggest customer to 4 shipments per week and the biggest customer to 5 shipments per week and to the third and fourth customer ordering on full pallets only.

However, the change in the order pattern of a customer is the result of negotiation between the supplier and the customer where the customer's willingness and ability to change play an important role. Keeping that into consideration, the knowledge of the savings each strategy leads to, can be used to provide financial motivation to the customer in order for them to comply to it.

Furthermore, the performance of each of the design alternatives has been evaluated in groups of customers sharing similar characteristics regarding the country and the sector they operate in, their yearly demand, their average order size, their order size variability and their order frequency. A summary of the performance evaluation of all the alternatives can be found below.

1. **MOQ=full layers alternative**
   This alternative is among the ones that offer the lowest cost reduction for every customer type regarding every characteristic. It seems that is should only be considered as an alternative for low and insignificant demand customers operating in the food service of all countries and in the retail of Luxembourg as well as for customers with very small order size low or very low order frequency and low order size variability with the cost reduction ranging from 1% to 4%for customers sharing these characteristics.

2. **MOQ=full pallets alternative**
   This alternative is in the top 2 in terms of cost reduction for almost every type of customer. It is the alternative that leads to the maximum cost reduction for customers with high demand, extremely high variability, order sizes from small to significantly high and low order frequencies as well as for customers that operate in retail of the Netherlands and Luxembourg. It is third in terms of cost reduction only for the customers with significantly high demand where the frequency reduction alternatives prevail and for customers with high order variability.

3. **MOQ=**

(a) **The first quartile (Q1) of the number of pallet places**
This alternative, despite not being among the sharing the top places in cost reduction, can lead to cost reduction if implemented on customers with insignificant or low demand(13% reduction), very small order size(9%) and low order size variability(18%) and very low order frequencies(6%). If implemented upon customers operating in the food service sector of Luxembourg it can lead to 12% cost reduction and 8% upon implementation to their Belgian counterparts.

(b) **The median (Q2) of the number of pallet places**
It should be considered for the same type of customers as the first quartile MOQ alternative but it leads to a bit higher cost reductions for every characteristic.

(c) **The third quartile (Q3) of the number of pallet places**
It should be considered for the same type of customers as the first and second quartile MOQ alternatives leading higher cost reductions than both of them. Apart from those, it can also be considered for customers with medium demand (8% cost reduction), small order size (7%), medium order size variability (9%), low and medium order frequencies (6%).

(d) **Full Truck loads (26 pallet places) alternative**
This alternative is in the top 2 in terms of cost reduction for almost every type of customer. It can lead to tremendous cost reduction if implemented in the customers that the other MOQ design alternatives are just to be considered. For example, it is the one leading to the highest cost reductions when implemented at customers with insignificant(36%) low (51%) and medium (27%) demand. It is also the second most preferable for customers with high demand leading to 10% cost reduction. It can also be considered for high (12%)and extremely high(9%) order size variability. It is the most preferable alternative for food service customers leading to 48% cost reduction in Luxembourg, 32% in Belgium and 29% in the Netherlands.

4. **Order Frequency=**

(a) **1 day per week alternative**
can be considered for customers with low medium and high demand leading to cost reductions of 10%, 14%, and 5% respectively, very small and small order sizes with savings of 12% and 8% respectively low and medium order size variability leading to 8% and 9% cost reduction. While among the customers with very low and low order frequencies it can achieve cost reductions of around 8%. Furthermore, it is the one leading to the highest cost reduction for customers in the export channel of the Netherlands and should also be considered for food service customers of the Netherlands leading to 15% cost reduction.

(b) **2 days per week alternative**
Among customers with high demand this alternative can achieve a 10% cost reduction placing it in the third position of the most preferable alternatives among customers sharing this characteristic. It also occupies the second position of the most preferable alternatives for customers with significantly high order sizes leading to 9% cost reduction in their group. Furthermore it can achieve 9% reduction for customers with extremely high order size variability and can also be considered for small and medium order sizes as well as for customers with low and medium order frequencies. It is applicable in all 3 channels of the Netherlands with cost reduction being at 5% for food service 6% for retail and 10% for export.

(c) **3 days per week alternative**
it should be noted that this alternative can only be implemented upon customers that operate in the Netherlands and is most preferable for those in retail. This alternative is 3rd for medium and low order frequencies leading to a cost reduction around 12% for customers sharing this characteristic. It is also second most preferable for customers with extremely high order size variability and third most preferable for customers with medium order sizes with 10% cost reduction for customers in both groups. Apart from that, it can be considered for customers with high and significantly high order sizes cost reduction 5%. I can also be considered regarding customer with high and significantly high demand as it leads to 5% and 8% cost reduction respectively.

(d) **4 days per week alternative**
This alternative is possible for application only in retail Netherlands. It is the prevailing alternative in terms of cost reduction for customers with medium order frequency leading to a 16% reduction and second most preferable for customers with significantly high order frequency leading to 8% reduction. It is leading to 10% cost reduction when applied to customers with significantly high demand, 14% to customers with medium order size and 9% to customers with extremely high order variability.

(e) **5 days per week alternative**
This alternative is applicable only on customers operating in the retail sector of the Netherlands, Specifically it is the most preferable alternative among customers with significantly high demand as well as among customers with high and significantly high frequency leading to 12% 20% and 17% reduction of costs respectively. Furthermore this alternative is sharing the first position for high order sizes with 9% in cost reduction, while, when applied to customers with high order variability it leads to 8% reduction.

Summarising the results section, the cost to serve model provides the means of evaluation of the design alternatives and leads to proposals for each customer. Furthermore, the cost to serve model leads to an identification of the customer characteristics that each design alternative is more suited for. Consequently, it sufficiently supports the mid-term decision making of the supplier for both outbound handling and freight to customer operations' optimization.

6 Real-world implementation performance

In this section the results deriving from the real-world implementation of the selected design alternatives will be discussed. The performance of the implemented alternatives is going to be compared both with the former situation as well as with expected results deriving from the model suggestions.

6.1 Selected strategies

The models selected design alternatives have been considered and used in the negotiations with the customers in the beginning of the year 2021. The case study company initiated the actions that will lead to efficiency improvements starting from the retail channel of the Netherlands, as the prioritization of the customers-alternatives suggested. In the negotiations it became clear that despite the order frequency reduction being the most favourable design alternative for the supplier is the least desired one from the retailers. The retailers were more open to minimum order quantity alternatives. The two biggest customers of the group have agreed to a combination of both full truck load and a full pallet MOQ implementation. Consequently, regarding these customers, the experiments 3 and 4.d. conducted in the previous chapter are of great interest as the combination of their results could be modeling the real-world implementation. For the implementation of the MOQ a real-time order management tool has been developed. This tool uses the very same calculation of the cases, layers, pallets and total number of pallet places as the model. But instead of leading into a cost calculation it makes suggestions regarding the quantity of each product needed to be added in an order for every product to be on a full pallet (fig. 60) as well as suggestions regarding the products to be added in order for the shipment to have a loading factor of 1 (fig. 61). When the loading factor is below 1 the tool is selecting products that have high demand by the specific retailer and are already in the order and suggests additional pallets of that products to be added.

PO Number	Cases/Layers to be added for FP
0005067273	Add 144 CS of EPN: 76010083. New order quantity: 322 CS
0005100621	Add 18 CS of EPN: 76009506. New order quantity: 104 CS CS
0005112331	Add 4 layers and 25 CS (145CS) of EPN: 76013640. New order quantity: 330 CS
0005135266	Add 1 layer and 4 CS (10CS) of EPN: 76015482. New order quantity: 240 CS
0005152369	Add 1 layer and 7 CS (19CS) of EPN: 76010632. New order quantity: 144 CS

Figure 60: Order management tool suggestions regarding Full Pallets

PO Number	Pallets to be added for Full Truck
0005067192	Add 1 pallets (150CS) of EPN: 76007937. New order quantity: 300 CS and 1 pallets (280CS) of EPN: 76004810. New order quantity: 560 CS
0005067296	Add 1 pallets (120CS) of EPN: 76012886. New order quantity: 360 CS and 1 pallets (120CS) of EPN: 76012938. New order quantity: 240 CS
0005067818	Add 3 pallets (360CS) of EPN: 76012982. New order quantity: 480 CS and 1 pallets (180CS) of EPN: 76007752. New order quantity: 249 CS

Figure 61: Order management tool suggestions regarding Full Trucks

The tool was used from the customer service team of KraftHeinz on a daily basis to automatically correct the orders that were going to cause inefficiencies. The biggest customer of the group had just to be notified of the changes while the second biggest customer had to be notified of and approve the changes. For the fifth and seventh biggest customers of the group a less strict policy has been implemented. These customers were willing to improve their order patterns regarding both full pallets and full truck loads but didn't want an order policy to be implemented. The negotiation lead to an agreement that they would be notified of their inefficient order patterns on a monthly basis. The developed model has been used to analyse their order patterns. The products that were consistently ordered in quantities that were not the ones of a full pallet as well as the number of pallets shipped in subsequent inefficient shipments of one week have been highlighted and communicated to them. With respect to these customers, only experiment 3 conducted in the previous chapter is of interest, and when and if one compares the experiment results with the real-world one should always keep in mind that there was no strict policy implementation. The rest of the customers have just agreed upon trying to improve their full pallet ordering pattern maintaining a complete freedom of ordering, these customers were also notified of their inefficient shipments and products that were not on a full pallet on a monthly basis but their willingness to improve their order patterns was lower.

6.2 New Order patterns

The bubble graph presented below indicates the new efficiency of the deliveries to each customer after the actions taken towards efficiency improvement. Just a glance at the graph presented in figure 62 reveals a significantly improved efficiency in 2021 for some customers when compared to their order pattern efficiency in 2019, presented in figure 22 of the third chapter. The 2019 data of the two biggest customers have been added to the graph for an easier comparison. It is clear that the bubbles representing the 2 biggest customers have moved towards the upper right corner, representing the maximum efficiency. The same could be said for the fifth and seventh customers of the group yet with a small distance from the optimal remaining to be covered. The third biggest customer improved significantly in terms of full pallet picking while they remained stable in terms of loading factor Finally, the fourth and sixth biggest customers improved significantly only in terms of full pallet picking while their order pattern became less efficient in terms of loading factor. Keeping in mind that the overall efficiency can be considered as a weighted average of the efficiency of each customer with the weight being the size of the bubble, one could argue that the overall efficiency of the KraftHeinz's outbound handling and freight to customer operations have significantly improved for this customer group.//

Diving into detail, for the customer with the highest volume delivered the average loading factor has increased to 0,96 from 0,9 in 2019 while the percentage of cases shipped to them on a full pallet has increased to 99,6% from 98,6%. The improvement has been even more substantial for the second biggest customer with the loading factor increasing from 0,71 to 0,94 while the full pallet picking percentage has also slightly increased (0,2%). The lowest percentage for the group of full pallet picking for the group is now at 92% instead of 74% that it was in 2019. On the other hand, the lowest has dropped to 52% from 64% being its initial value. However, a more accurate understanding of the data can be acquired when comparing costs, the Key Performance indicator. Consequently, the cost to serve model has been run with the 2021 actual data being used as an input.

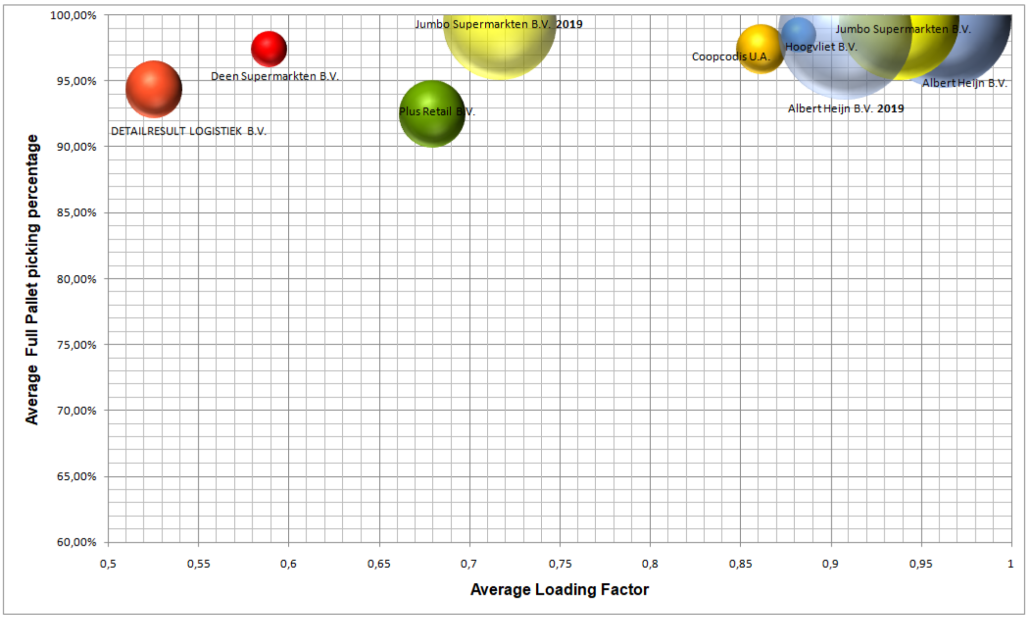


Figure 62: Efficiency in Retail Netherlands 2021

6.3 New Cost to serve

The graph presented in figure 63 illustrates information regarding the cost to serve per customer for the top customers representing the 80% of the shipped volume in the Retail Chanel of the Netherlands for the first half of the year 2021. In order to compare the results from the two years one could double the costs of the first half of the year assuming that there is no seasonality in demand. However, this is not true in consumer goods industries. Another way to compare would be to run the model for the first half of 2019. This would not take into account the difference in demand between the two years. These two approaches have been used as a first rough estimate and they do verify the improvements observed in the bubble graph but they should not taking everything into consideration. In order to have a more precise comparison of the expected and the actual efficiency the costs per case has been used.

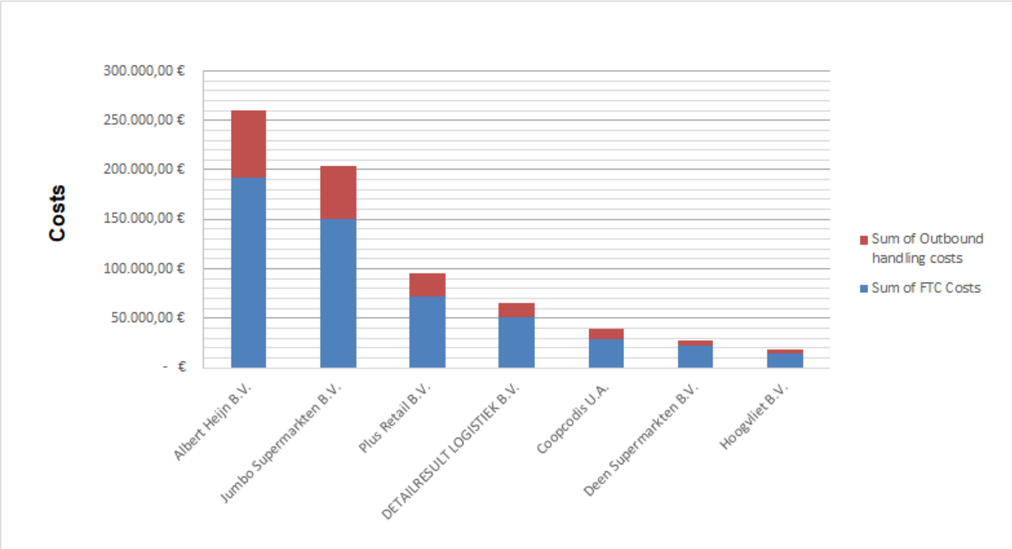


Figure 63: Cost to serve in Retail Netherlands for the period of January-June 2021

Figure 64 illustrates how the cost to serve is transformed when the shipped volume is taken into consideration. In 2021 the shift in the order pattern of the second biggest customer has lead to similar costs per case with the biggest customer which is a desired outcome since their volumes are comparable. Comparing the graph with the one of figure 48 one can notice that, the freight to customer induced cost per case has been reduced by 0,003€ for the biggest customer with similar reduction for the 4th, 5th and 7th customer while a 0,019€ reduction has been observed at the second biggest one. What is interesting here is that the 5th customer despite deteriorating in the loading factor has actually decreased it's cost per case because its total order volume has decreased even more radically. The freight to customer induced cost per case has been increased for the 3rd and 6th biggest customers of the group by 0,018 and 0,014 € respectively. With respect to the outbound handling costs per case there has been a decrease for the 3rd (0,022€) 4th(0,013€) 5th (0,007€) and 6th (0,013€)and 7th (0,03€) customers while for the biggest 2 customers there has been a insignificant increase (0,001€), this small increase occurred due to an increase in the case picked cases.

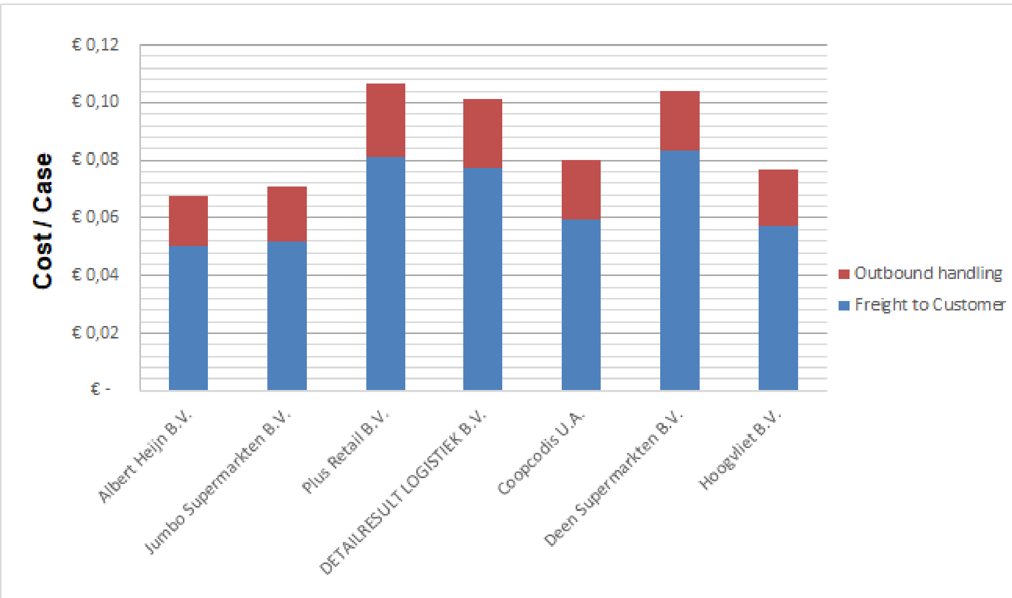


Figure 64: Cost per case Retail Netherlands for the period of January-June 2021

6.4 Comparison with the former situation and with the expected results

Table 10 summarises the results of the two customers that have agreed to an MOQ policy implementation. The significant cost per case reduction is visible when comparing the actual values of 2019 and 2021 while the proximity of the models results to the actual results of the implementation can also be observed. The strategy implementation has lead to a cost per case reduction higher than the one expected by the model. It should be noted here that the selected strategy is actually a combination of two of the design alternatives as both a full truck load MOQ and a full pallet MOQ are applied. Consequently, this is a alternative that has not actually been tested by the model. The Model Expectation Cost/case is an approximation made by combining the outbound handling costs of the full pallet MOQ alternative and the freight to customer costs of the full truck load MOQ. This approximation does not take into consideration the cascading effects the two strategies have upon each-other. Another thing that should be noted here is that the model has used 2019 demand data and consequently is not accurate in terms of the mix of the products ordered by the customer. For example, the customers could be ordering more pallets of products that have more cases per pallet in 2021 leading to a decrease in the cost per case. This effect could only have been avoided if an accurate forecast of the demand per product and per customer had been used. This type of data has not been available for the purposes of this thesis however the model can function if these data are used as an input. These two notes explain why the Model's Expectation regarding the Cost/case for the selected design alternative happens to be a bit higher than the Actual Cost/case deriving from 2021's data. The outbound handling and freight to customer operations efficiency of the two customers has definitely been improved and to an extend that was above the expectations.The models accuracy has been considered more than sufficient by the case study company and in the case that more accurate results are needed in the future it is suggested that the demand forecast is used as input instead of the actual demand of a previous year.

Customer	Alternative	2019	Model Expectation	2021	Reduction
Albert Heijn B.V.	FTL&FP	0,0733 €	0,0696 €	0,0683 €	7%
Jumbo Supermarkten B.V.	FTL&FP	0,0880 €	0,0798 €	0,0713 €	19%

Table 10: Cost per case comparison

6.5 Real-world implementation performance summary

Research question 5 has been answered in this chapter. Specifically, the actions taken by the case study company in order to improve its freight to customer and outbound handling operations efficiency have been presented. The real world implementation differs to an extend from the proposed design alternatives of the model, since in reality these strategies are subject to negotiation with the customer. In some cases a combination of the design alternatives has been selected, while in others the customers have not committed to a specific strategy but agreed to try improve their order patterns while being systematically informed of the inefficiencies they cause. Six months after the initiation of activities towards efficiency improvements, the cost to serve model has been used for assessing the new situation with 2021's data as input. The models results have been presented both as an absolute value and as a ratio of costs to shipped cases in order for a valid comparison to take place. The results indicate that the selected design alternatives perform as expected if not better than expected in the real world and that the models suggestions led to significant efficiency improvements.

7 Conclusions & Recommendations for future work

In this last section, the conclusions will be drawn by providing an answer to the main research question of this thesis composed in the first chapter. The results will be discussed and recommendations will be given for future research on the topic.

7.1 Conclusions

The conclusions will be drawn by answering the research question and the sub questions that were composed to aid in answering it. The main research question of this thesis is the following:

- **How can the outbound handling and freight to customer operations efficiency be maximized ?**

This question can be answered when reviewing the results of this thesis. The answer lies in the order pattern of the customers which has been proven to be a substantial influencing factor for efficiency. Various ways to improve the order pattern have been examined as the data analysis has indicated and a cost to serve model has been developed to evaluate these design alternatives per customer. The evaluation indicates which alternative should be selected per customer as well as which alternative is the second(/third/fourth/etc.) best in case the customer is not willing to comply with the most efficient alternative. Furthermore, the evaluation of the design alternatives through the cost to serve model results indicates which customer order pattern changes would have the maximum impact in improving the overall outbound handling and freight to customer operations efficiency. In that way, the model helps the supplier prioritize both the strategies to be implemented per customer and the customers that are important for a strategy implementation. Finally, the performance of the design alternatives has been evaluated for clusters of customers that share specific characteristics. The results indicate that the design alternatives of full pallets minimum order quantity, full truck loads, as well as the order frequency reduction alternatives to 5 and 4 shipments per week all lead to the highest cost reduction for different customer groups sharing specific characteristics, while others like the the full layers minimum order quantity, the specific number of pallet places Q1,Q2,Q3 minimum order quantity and the order frequency reduction alternatives to 3,2 and 1 shipments per week are not the most preferable ones for any group of customers with a specific characteristic. The exact process followed to reach this conclusion as well as the specifications of it are explained by answering the following five sub questions:

1. How are outbound handling and freight to customer operations problems being addressed and how their performance is compared in the existing literature?

Outbound handling and freight to customer operations problems are being addressed via Long-term (strategic network design) and Short-term models (vehicle routing) while less focus has been placed in the Medium-term models like the ones of truck space utilization and warehouse handling efficiency perspectives that this research is focusing on. Attention has not either been placed on the suppliers perspective with the existing models focusing mainly on the retailer nor to the combination of solving Outbound handling and freight to customer operations problems. From the existing literature the concepts of "quantity adjustment" and "loading factor" have been proven useful. Finally, in the existing literature the way to compare performance in problems that incorporate multiple activities been identified in activity based costing and more specifically in cost to serve models.

2. How can the logistic system of outbound handling and freight to customer operations be described, what is its current performance and what are the identified design alternatives?

This sub question was answered by performing a data analysis. The activities performed and their associated costs have been identified. Outbound handling includes full pallet picking, layer picking and case picking activities while freight to customer operations only the shipping from warehouse to customers activity. The costs vary per 3pl and each ship-to location is being served by a specific 3pl. The data indicate that the current performance is not optimal with a lot of inefficiencies being spotted both in the general statistics and the in the detailed analysis of the order patterns of each customer. The consecration of the shipped volume to specific countries, channels and to specific customers, within the country-channels, suggests that the overall efficiency has bigger potential to increase if focus is placed to the countries, channels and customers that both have inefficiencies and a high shipped volume. The retail Chanel in the Netherlands seems to have the combination of inefficiencies and shipped volume that makes it more prosperous for potential efficiency improvements. While the order patterns of the customers verify that a "one size fits all" approach should be avoided indicating different types of inefficiencies for each customer. The analysis also suggests that the design alternatives to be examined are Minimum order quantities strategies, with a focus on either the number of pallet places in a truck shipped or on the number of cases per product ordered, and Order frequency reduction strategies. The KPI of Costs has been selected for the evaluating the performance of the design alternatives.

3. What should the structure of a model be, in order to compare the outcome of the design alternatives?

This question has been answered both by creating a conceptual model representing the real-life system and a mathematical model transforming it into mathematical language with the required assumptions being made. The model is using the demand for each product in each order at all the ship-to locations throughout the year 2019, the list with the information regarding which 3pl is serving which ship-to location and the tariffs applied by each 3pl for each activity to calculate the numbers of full pallets, cases on full layers,cases case-picked and pallet places and finally the cost to serve each customer. The model has been implemented in Microsoft Excel and the implementation has been described. Finally, verification to the model has been provided through continuity tests, degeneracy tests, consistency tests and fault injection and it has been proven that the model is implemented according to the described specifications and that the implementation accurately represents the conceptual description.

4. What are the selected design alternatives of this model?

This sub question has been answered by developing an experimental plan and describing the specifics of each experiment. Each of the experiments was evaluating one of the design alternatives. Through an analysis of the model's results, the design alternatives have been compared and the ones leading to the lower costs have been selected for each customer. In that way the model's selected design alternatives are the ones that lead to the highest cost savings. However, in reality the actual selection of the alternative to be implemented is the outcome of the negotiation of the supplier with the retailer. For that reason, the design alternatives leading to cost savings has also been sorted from the one leading to the highest savings to the ones to leading to the lowest in order for the supplier to be able to use these alternatives in case of negotiations with the retailer regarding the changes in the order pattern. In addition, the combination of customers with design alternatives have been sorted with respect to cost saving opportunity in order for the supplier to prioritise the strategies to be implemented. In that sense the model both suggest the optimal design alternative and supports the real-life decision making. Furthermore, the model has been used for the evaluation of each of the design alternatives upon groups of customers sharing similar characteristics. The results indicate that for customers with high demand or extremely high variability or order sizes from small to significantly high or low order frequencies or customers that operate in Netherlands and Luxembourg retail sector, the full pallets minimum order quantity is the one that can save more costs. The full truck loads alternative is the one leading to the most cost savings if implemented in customers with insignificant, low and medium demand or very small order sizes or low, medium, and high order size variability or very low order frequency or customers that operate in food service of all 3 countries. Finally, the order frequency reduction alternative to 5 shipments per week is the one that can lead to the highest savings for customers with significantly high demand or high and significantly high order frequencies or customers operating in the retail sector of the Netherlands, while the order frequency reduction alternative to 4 shipments per week is preferable for customers with medium order frequencies.

5. How do the model's selected design alternatives perform in a real world experiment?

In the real world the proposed design alternatives were not followed to the letter since the implementation is dependent on the willingness of the customers to change their order patterns. However, the alternatives that have been applied could be described as a combination of the ones suggested by the model in some cases, while in others as not strictly enforced MOQs. The implementation that took place only in the Netherlands retail channel despite not being the exact model's suggestion has led to the astonishing efficiency improvements and cost savings validating the proposals of the model. It can be highlighted here, as a quantification of the achieved improvements, that the cost per case for the first and second biggest retailers in the Netherlands has been reduced by 7% and 19% respectively.

7.2 Recommendations for future work

In this research the ways to increase outbound handling and freight to customer operations efficiency have been studied contributing to the expansion of knowledge in the field of medium-term supply chain planning. This has been done from the supplier's perspective. It has been made clear that the order pattern of the customers influences the efficiency of outbound handling and freight to customer operations in a great extend. The study discussed the options of possible Minimum Order Quantity as well as Order Frequency reduction strategies being applied. The outcomes of such a strategy implementation have been evaluated with the help of a cost to serve model and a prioritization of the alternatives has taken place. The models results and prioritization have been proven useful for the case study company in rising awareness regarding the causal factors as well as in assisting in the negotiations with the customers and the decision making. Apart from its own contribution, this study has also helped in identifying fields that require further investigation:

- interesting fields for academia:

    1. The application of the model could be expanded to other case study companies willing to share their data in order for the results to be compared and test if the models suggested design alternatives are universally applicable.
    2. In this research Costs have been selected as the KPI upon which the design alternatives have been evaluated. An interesting future research direction would be to use CO_2 emissions as a KPI and compare the suggested alternatives with the ones proposed by this research.
    3. An interesting research direction could be to incorporate more factors that support the decision making process in the model. Potential of cost savings calculated by the cost to serve model for every alternative and every customer is only one factor amongst those that define the strategy to be selected to be negotiated with the customer. Factors that could be also taken in to consideration are the market share and potential market growth of the customer as well as the state of the business relationship of the supplier with the customer.

- interesting fields for the case study company:

    1. With respect to additional design alternatives to be studied. A future research could evaluate the efficiency improvements of multi-drop routing to various customers. In this alternative the optimal weekdays per region would have to be found and the customers would have to order only on these specific weekdays. This has not been the focus of this research because at the moment the benefits of this alternative could only be ripped off by the 3pl provider and not from the supplier. Another interesting alternative that could be studied in the future is the reduction of ship-to locations per customer.
    2. The developed model is modular allowing also other types of scenarios to be tested for example one could use the very same model developed for the purposes of this thesis to evaluate switching to a different 3pl provider. In that case the scenarios would be the various 3pls and their tariffs while the order pattern of the customers would be constant for every scenario.
    3. This research has considered the product specifications like the number of cases per pallet, the full pallet height, the maximum height for layer-picked and case-picked pallets as well as the types of products that their pallets are able to be stacked, to be unalterable and thus constraining the problem. These specifications are set in order to ensure stability and avoid potential collisions due to sliding or overloading. However, with the appropriate packaging modifications and always taking the related regulations into consideration, the constrictions can be relaxed allowing more space for optimization. Consequently, it would be interesting for the case study company to investigate such solutions. The modularity of the developed model is allowing this type of a scenario to be investigated but in that case it would be wise to include the additional packaging material costs in the analysis of the results.
    4. This research has used the demand data of 2019 to evaluate various alternatives. These results give an exact answer to the question what the effects of a design alternative implementation would have been in 2019. With the assumption of the yearly demand does not fluctuate substantially per year one could use these results to forecast the costs of a design alternative implementation in the following year. For more accuracy however it would be wise for the study to be repeated with the forecasted demand data as an input.
    5. Future research could also focus on examining the ways that the cost savings could be offered to the customer as incentives to ensure the changes in the order pattern. A research in this field could focus on defining which customers require financial motivation in order to conform to an MOQ strategy, what percentage of the savings can be offered as incentive and how this incentive be offered.

References

Ab Rahman, M. N., Leuveano, R. A. C., bin Jafar, F. A., Saleh, C., Deros, B. M., Mahmood, W. M. F. W., and Mahmood, W. H. W. (2016). Incorporating logistic costs into a single vendor–buyer JELS model. *Applied Mathematical Modelling*, 40(23-24):10809–10819.

Abate, M. (2014). Determinants of capacity utilisation in road freight transportation. *Journal of Transport Economics and Policy*, 48(PART 1):137–152.

Abdoli, S. and Kara, S. (2016). Designing Warehouse Logical Architecture by Applying Object Oriented Model Based System Engineering. *Procedia CIRP*, 50:713–718.

Akter, N. (2019). Understanding the usage patterns , practices and decision process of third party logistics outsourcing in Bangladesh. 12(3):329–354.

Akyelken, N. (2011). *Green Logistics: Improving the Environmental Sustainability of Logistics*, volume 31.

Aliabadi, L., Yazdanparast, R., and Nasiri, M. M. (2019). An inventory model for non-instantaneous deteriorating items with credit period and carbon emission sensitive demand: a signomial geometric programming approach. *International Journal of Management Science and Engineering Management*, 14(2):124–136.

Altintas, N., Erhun, F., and Tayur, S. (2008). Quantity Discounts Under Demand Uncertainty. *Management Science*, 54(4):777–792.

Bartholdi, J. J. and Hackman, S. T. (2011). WAREHOUSE & DISTRIBUTION SCIENCE Release 0.94. (January):1–321.

Baykasollu, A. and Kaplanollu, V. (2015). An application oriented multi-agent based approach to dynamic load/truck planning. *Expert Systems with Applications*, 42(15-16):6008–6025.

Ceia, J. P. O. (2014). Cost-to-serve Customers ' Optimization. (1446).

Christopher, M. (2011). *Logistics & Supply chain Management*, volume 7. 4th edition.

Coelli, T.J, Rao, D.S.P., Prasada Rao, C. J. O. and Battese, G. (2005). *Introduction to Efficiency and Productivity Analysis, (Second Edition)*. Springer.

Collins, A., Henchion, M., and O'Reilly, P. (2001). Logistics customer service: Performance of Irish food exporters. *International Journal of Retail & Distribution Management*, 29(1):6–15.

constanta sp.com (2021). Euro Pallet 800x1200.

Daudi, M. and Thoben, K.-d. (2020). ScienceDirect ScienceDirect ScienceDirect Self-organizing Logistics Networks for Less-Than-Truckload Self-organizing Logistics Networks for Less-Than-Truckload. *Procedia Manufacturing*, 52(2019):101–106.

de Koster, R., Le-Duc, T., and Roodbergen, K. J. (2007). Design and control of warehouse order picking: A literature review. *European Journal of Operational Research*, 182(2):481–501.

de Souza Henriques, R. (2019). Multi-agent system approach applied to a manufacturer's supply chain using global objective function and learning concepts. *Journal of Intelligent Manufacturing*, 30(3):1009–1019.

Egri, P. and Váncza, J. (2012). Channel coordination with the newsvendor model using asymmetric information. *International Journal of Production Economics*, 135(1):491–499.

Gao, J. and You, F. (2019). A stochastic game theoretic framework for decentralized optimization of multi-stakeholder supply chains under uncertainty. *Computers and Chemical Engineering*, 122:31–46.

Garcia, D. J. and You, F. (2015). Supply chain design and optimization: Challenges and opportunities. *Computers and Chemical Engineering*, 81:153–170.

Gebennini, E., Grassi, A., Rimini, B., and Depietri, E. (2013). Costs and opportunities of moving picking activities upstream in distribution networks: A case study from the beverage industry. *International Journal of Production Economics*, 143(2):342–348.

Giannakis, M. and Louis, M. (2011). A multi-agent based framework for supply chain risk management. *Journal of Purchasing and Supply Management*, 17(1):23–31.

Giannoccaro, I. (2018). Centralized vs. decentralized supply chains: The importance of decision maker's cognitive ability and resistance to change. *Industrial Marketing Management*, 73(April 2017):59–69.

Gudehus, T. and Kotzab, H. (2012). *Comprehensive Logistics.* Springer Berlin Heidelberg, Berlin, Heidelberg.

Guerreiro, R., Rodrigues Bio, S., and Vazquez Villamor Merschmann, E. (2008). Cost-to-serve measurement and customer profitability analysis. *The International Journal of Logistics Management*, 19(3):389–407.

hellaspal.gr (2021). Euro Pallet 800x1200.

Hofmann, E., Beck, P., and Füger, E. (2013). *The Supply Chain Differentiation Guide.*

Hubbard, T. N. (2001). Contractual Form and Market Thickness in Trucking. *The RAND Journal of Economics*, 32(2):369.

Ilie-Zudor, E., Kemény, Z., Ekárt, A., Buckingham, C. D., and Monostori, L. (2014). A solution for information management in logistics operations of modern manufacturing chains. *Procedia CIRP*, 25:337–344. 8th International Conference on Digital Enterprise Technology - DET 2014 Disruptive Innovation in Manufacturing Engineering towards the 4th Industrial Revolution.

Kaplan, R. and Cooper, R (1998). Cost and Effect: Using integrated cost systems to drive profitability and performance. *Choice Reviews Online.*

Karasek, J. (2013). An Overview of Warehouse Optimization. *International Journal of Advances in Telecommunications, Electrotechnics, Signals and Systems*, 2(3).

kraftheinzcompany.com (2021). The kraft heinz company.

Kumar, S. and Zander, M. (2007). *Supply Chain Cost Control Using Activity Based Management.*

Kuppers, P., Saalmann, P., and Hellingrath, B. (2015). An approach for assessing the applicability of collaborative planning concepts. *Proceedings of the Annual Hawaii International Conference on System Sciences*, 2015-March:1049–1058.

Lam, C. Y. (2019). a Network Modeling Approach With Interdependent Agents for Network Coordination. *International Journal of GEOMATE*, 16(55):99–104.

Lau, K. H. (2012). Demand management in downstream wholesale and retail distribution: A case study. *Supply Chain Management*, 17(6):638–654.

Lee, H. L. and Lee, H. L. (2002). Aligning Supply Chain Strategies with Product Uncertainties.

Liu, J. P. (2007). Case study of picking method selection for cosmetic broken-case picking operation. *IEEM 2007: 2007 IEEE International Conference on Industrial Engineering and Engineering Management*, pages 357–361.

Lu, S. Y., Lau, H. Y., and Yiu, C. K. (2012). A hybrid solution to collaborative decision-making in a decentralized supply-chain. *Journal of Engineering and Technology Management - JET-M*, 29(1):95–111.

Maxim, A., Caruntu, C. F., Lazar, C., Keyser, R. D., and Ionescu, C. M. (2019). Comparative analysis of distributed model predictive control strategies. *2019 23rd International Conference on System Theory, Control and Computing, ICSTCC 2019 - Proceedings*, pages 468–473.

McKinnom.A (2010). European Freight Transport Statistics: Limitations, Misinterpretations and Aspirations. *European Automobile Manufacturers Association Avenue*, (September):24.

Mehmann, J. and Teuteberg, F. (2016). The fourth-party logistics service provider approach to support sustainable development goals in transportation - A case study of the German agricultural bulk logistics sector. *Journal of Cleaner Production*, 126:382–393.

Montoya-Torres, J. R. and Ortiz-Vargas, D. A. (2014). Collaboration and information sharing in dyadic supply chains: A literature review over the period 2000–2012. *Estudios Gerenciales*, 30(133):343–354.

Ni, L. and Wang, X. (2021). Load factors of less-than-truckload delivery tours: An analysis with operation data. *Transportation Research Part E: Logistics and Transportation Review*, 150(February):102296.

Özbayrak, M., Akgün, M., and Türker, A. K. (2004). Activity-based cost estimation in a push/pull advanced manufacturing system. *International Journal of Production Economics*, 87(1):49–65.

Petersen, C. G. and Aase, G. (2004). A comparison of picking, storage, and routing policies in manual order picking. *International Journal of Production Economics*, 92(1):11–19.

Plinere, D. and Borisov, A. (2012). A Negotiation-Based Multi-Agent System for Supply Chain Management. *Scientific Journal of Riga Technical University. Computer Sciences*, 45(1).

Prasad, T. V., Veeraiah, T., Kiran, Y., Srinivas, K., and Srinnivas, C. (2019). Decentralized production-distribution planning in a supply chain: Computer experiments. *Materials Today: Proceedings*, 18:A1–A11.

Reiß, F. and Buer, T. (2014). A coordination mechanism for capacitated lot-sizing in non-hierarchical n-tier supply chains. *IEEE SSCI 2014 - 2014 IEEE Symposium Series on Computational Intelligence - CIPLS 2014: 2014 IEEE Symposium on Computational Intelligence in Production and Logistics Systems, Proceedings*, pages 9–15.

Sabath, R. and Whipple, J. M. (2004). USING THE CUSTOMER / PRODUCT ACTION MATRIX Cost to Provide Customer / Product Action Matrix Cost to Serve. *Journal of Business Logistics*, 25(2):1–19.

Seuring, S. and Goldbach, M. (2002). *Cost Management in Supply Chains*. Physica-Verlag HD, Heidelberg.

Shen, B., Choi, T. M., and Minner, S. (2019). A review on supply chain contracting with information considerations: information updating and information asymmetry. *International Journal of Production Research*, 57(15-16):4898–4936.

Soni, G., Jain, V., Chan, F. T., Niu, B., and Prakash, S. (2019). Swarm intelligence approaches in supply chain management: potentials, challenges and future research directions. *Supply Chain Management*, 24(1):107–123.

Stadtler, H. (2009). A framework for collaborative planning and state-of-the-art. *OR Spectrum*, 31(1):5–30.

Stapleton, D., Pati, S., Beach, E., and Julmanichoti, P. (2004). Activity-based costing for logistics and marketing. *Business Process Management Journal*, 10(5):584–597.

Swanson, L. A. (2020). Logistics, Value Chain Analysis, Activity Base Costing, Supply Chain Activities, Supply Chain Decisions, Operations Management. pages 1–20.

Thomas, L. M. and Meller, R. D. (2015). Developing design guidelines for a case-picking warehouse. *International Journal of Production Economics*, 170:741–762.

Tsao, Y. C. (2015). Design of a carbon-efficient supply-chain network under trade credits. *International Journal of Systems Science: Operations and Logistics*, 2(3):177–186.

Tuncel, O., Hasija, S., and Taneri, N. (2018). Why are Minimum Order Quantity Contracts Popular in Practice? A Behavioral Investigation. *SSRN Electronic Journal*.

Üster, H. and Kewcharoenwong, P. (2011). Strategic Design and Analysis of a Relay Network in Truckload Transportation. *Transportation Science*, 45(4):505–523.

Van De Klundert, J. and Otten, B. (2011). Improving LTL truck load utilization on line. *European Journal of Operational Research*, 210(2):336–343.

van Raaij, E. M. (2005). The strategic value of customer profitability analysis. *Marketing Intelligence and Planning*, 23(4):372–381.

Vassiliadis, V. and Dounias, G. (2011). *Nature-Inspired Intelligence in Supply Chain Management: A Review of Selected Methods and Applications*, pages 1–31. Business Science Reference, Hershey, New York, 701 E. Chocolate Avenue, PA 17033.

Vlist, B. P. V. D. and Broekmeulen, R. (2006). Retail consolidation in synchronized supply chains. pages 165–176.

Wehner, J. (2017). Energy efficiency improvements in logistics as a means to environmental sustainability : The case of capacity utilisation in road freight transportation.

Zhu, H., Liu, X., and Chen, Y. F. (2015). Int . J . Production Economics Effective inventory control policies with a minimum order quantity and batch ordering. *Intern. Journal of Production Economics*, 168:21–30.

Zuniga, C. A., Olivares-Benitez, E., Tenahua, A. M., and Mujica, M. A. (2015). A methodology to solve the Order Batching Problem. *IFAC-PapersOnLine*, 28(3):1380–1386.

Appendices

Appendix A - Scientific Paper

Optimization of Outbound Handling and Freight toCustomer Operations (Tier 2) by adjusting the Customer Order Frequency and the Minimum Order Quantity.

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***Abstract*—This research investigates ways to maximize the outbound handling and freight to customer operations efficiency based on the real data of The Kraft Heinz Company. A cost to serve model has been developed to evaluate the performance of various design alternatives deriving from the field of "quantity adjustment" as the dependence of cost efficiency upon labour intensity at the warehouses and the truck volume utilization indicated. The research concludes upon the selection of the optimal design alternative to be implemented per customer as well as upon which design alternative is more suitable for clusters of customers that share specific characteristics.**

I. Introduction

Today's supply chains have to function in a ever-changing global business environment, defined by strong competition, increasing demand for customized products and short-time deliveries. As a result, companies strive to sufficiently meet the customers' demand while being cost-effective [1]. The steep increase in the demand of tailor-made products and the remarkable levels of outsourcing have induced an all-time high in supply chain complexity and consequently inflated the degree of uncertainty and risks that companies have to face [2]. In this context, the optimal design and coordination of all the activities of the supply chain entities is essential. [3] On the grounds of that need for optimal activity coordination the Optimization of Outbound Handling and Freight to Customer Operations has been the focus of this research.

Companies are able to trade internationally, relocate their business processes from one country to another and have large and complex supply chain networks. This trend has lead the sector of transport and logistics services to flourish. Many medium or large businesses outsource their logistics services in order to reduce their operating costs and investment in storage and transportation, mitigate risk, save time and allow them to focus on their own field of expertise. Companies consisting of professional logisticians that provide services of inventory management, warehousing, and order fulfillment are called third-party logistics providers (3PL). [4]

Truck volume utilisation affects the 3PL's operational costs and via their costing system it affects the logistics costs of the outsourcing company [5], while the same could be said for outbound handling, since economic efficiency is the combination of pricing and operational efficiency [6]. Apart from costs, truck volume utilisation also affects the environmental impact of transportation as the number of trucks needed to satisfy demand increases with inefficient deliveries. [7] The connection of truck utilization on the one hand with operational costs affecting the supplier and on the other hand with hazardous gasses [8] affecting the environment has lead 3PLs to look out for optimization in the field. However, there are some elements that are out of the 3PL's reach, such as the customers order quantity and order frequency, that a supplier could influence via its strategy regarding contractual agreements with the customers.

Since the optimal coordination of activities is dependent on data in terms of measuring the operations' efficiency and supporting the decision-making process, this paper will discuss the topic of outbound handling and freight to customer operations efficiency using the real data of a company as a case study and a data-driven model will be developed. The Kraft Heinz Company will be the source of information and the company where any developed applications will be implemented. The product flow of the case study company, presented in the picture below, is distinguished between Tier-1 movements moving products from production facilities (factories & co-packers) to warehouses and Tier-2 movements moving products from warehouses in the logistics network to the customers. This paper will be focusing only on Tier-2 movements.

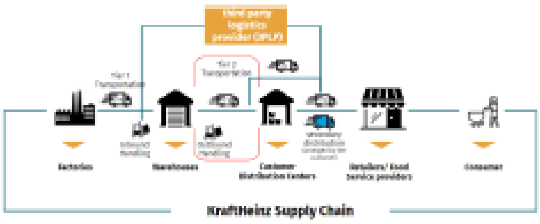


Fig. 1. Kraft Heinz Supply chain

II. Literature review

This research focuses on the optimization of the process of outbound handling that can be described as the retrieval of stock keeping units from their unique location in the warehouse due to the placement of a customer order [9] and the process of "Freight to Customer Operations" that can be described as all shipments related to bringing the products from the warehouses to the customers. Both process are of vital importance to the business, the former due to the high percentage(55%) of the running expenses of the warehouse [10] and the latter due to accounting for the majority of transportation spend and impacting the customer directly.

With respect to outbound handling, the related activities include full pallet picking, layer picking, case picking, broken-case (unit) picking with the time and effort of the warehouse personnel being higher when picking specific quantities and units of various products to create one pallet. [11] [10]

Regarding the efficiency of "Freight to Customer Operations", it depends on the loading of the truck that can be measured via a loading factor(vehicle fill rate/filling rate). These are nothing but ratio's of area occupied over area of the deck or volume occupied over volume of the truck [12], [13] or even weight of the load over the maximum legal weight [14]. For unitized loads like pallets the ratio can also take the form of the number of units carried over the maximum number of units can be carried [12]. Based on [15] Chapter "Logistic Units and Master Data" and having the specifications of [12] in mind, the loading factor of trucks can be defined for the case study as:

$$\eta = \frac{number\ of\ logistic\ units\ contained\ in\ an\ order}{number\ of\ filling\ units\ maximally\ achievable}$$

or

$$\eta = \frac{\sum_i m_{FO_i}}{C}$$

where $m_{FO_i} = c_{b_i}\, c_{s_i}\, c_{h_i}$

with

m_{FO_i} being the number of filling units equivalent,

c_b the Euro to Block coefficient,

c_s the stack-ability coefficient,

c_h the height coefficient and

C the load unit capacity

There are two options to increase the loading factor since it is a fraction these options are either to increase the numerator or to decrease the denominator. This simple observation leads to two policies, namely "Quantity Adjustment" and "Capacity Adjustment" [15]."Quantity Adjustment" refers to changing the order quantities into full pallet multiples by either rounding up or down to the closest full pallet number. "Capacity Adjustment" refers to changing the trucks capacity to be slightly smaller than the average order quantity. However, this choice is for the third-party logistics provider to make consequently it is of no interest for this research.

With respect to the existing methodologies to address the problem, research has tended to focus on Long-term like strategic network design [16] [17] (with respect to the time span of the decisions to be made) and Short-term models like vehicle routing problems [18] [19], rather than Medium-term models like ordering policies decisions that affect the truck space utilization and warehouse handling efficiency. Furthermore, many experts have used either on centralized optimization models [20] or on joint decision making with shared information [21] which are both unrealistic [22] [23] [24] [25] [26]. In reality information sharing is partial at the very best with the order quantities being the only exchanged information between the parties, the 3PL's price list known only by the supplier and the retailers order frequency deducted from historical data. Moreover, despite the width of literature, there is a lack of research regarding the effect of the supplier's influence elements such as order size and frequency has to truckload operations. These elements can be manipulated before the engagement of third party logistics providers via order management. The only paper that addressed this issue considered one supplier and one customer [27] and also one product oversimplifying the problem [28]. It can also be mentioned here, that the literature also thrives in inventory/replenishment (EOQ) models that have not been analysed here because they are by principle regarding the problem from the retailers perspective by trying to minimize the retailers inventory costs. Not only the retailers perspective is already well studied but it can be argued that the inefficiencies in handling and transportation are playing a much more important role in the formation of costs than the inefficiencies in inventory especially with regards to fast moving goods supply chains [29]. Furthermore, with respect to the provided proof of consistency to the intended application, most of the studies use Numerical examples as a demonstration of the function of model solving some computational experiments, while very few provide case studies where real data-sets are used leading to a comparison with the "real world". In addition no model has been designed to address both outbound handling and freight to customer operations problems. The current research will try to cover the research gap described, by addressing truck utilization and warehouse handling efficiency problems that fall into the range of mid-term level decision making from a suppliers perspective.

On the other hand, Activity Based Costing (ABC) introduced by [30], a tool designed for achieving âeffective efficiency" in commercial functions aims at determining costs per product based on all the activities each product requires to be produced and commercialized. ABC has entered the sphere of logistics due to its cost-determination function. [31] [32] Apart from determining which products have the highest costs ABC improves the understanding of processes [33], [34], opening the way to customer cost allocation [35] and Cost-to-serve models. Activity Based Costing is based on the principle that each product has certain types and levels of activities related to them. Expanding the same observation to customers led to Cost-to-serve models [35]. As [36] has observed, companies should differentiate their supply chain solutions to meet different customer specifications like logistics requirements [37]. Cost to serve models help identifying the singularities of each customer concerning their order patterns [38]. These models transform the information of the order pattern of the customer into costs to support decisions. [31] [36]. What makes the cost to serve models ideal for this research is that cost to serve models are meant not only to compare customer order patterns but also to analyze the strategies to be applied per customer when efficiency has to be enhanced and costs to decrease. [31] Furthermore, Cost-to-serve is ideal for costs deriving from outsourcing activitieslike the ones that are handled by third party logistic providers. Finally, Activity Based Costing and Cost-to-serve models have been used to drive improvements both in outbound handling [17] [39] and in freight to customer operations [36].

III. DATA ANALYSIS

In order to acquire a better understanding of the system, the activities discussed in the literature and their associated tariffs have been identified in the case study company's environment. Regarding the loading factor the data retrieved from the price lists clarifies that the higher the loading factor is, the lower the costs are per shipped pallet, and consequently provides a strong motivation for the case study company to increase it. With respect to the Full Pallet Picking, Layer Picking and Case Picking percentages, the data reveal that the unit of measurement used for the picking activities varies per type of activity. Consequently,apart from the price table, one needs also to understand that the configuration of number of cases per pallet depends on the products specifications, packaging and customer requirements and varies widely within KraftHeinz portfolio. KraftHeinz's products are packaged into cases and those cases are placed on pallets next to and on top of each other forming layers up to the point that the stack is still stable and safe for transportation or up to the point that it can fit the customer storage height limitations.

The current performance of the logistic system has been studied and can be summarized by the general customer statistics and the specific order patterns of the customers. There is clear evidence to suggest that the biggest opportunity for KraftHeinz lies in optimizing its outbound handling and freight to customer operations of the customers that are located in the Netherlands and more specifically in the Retail channel.

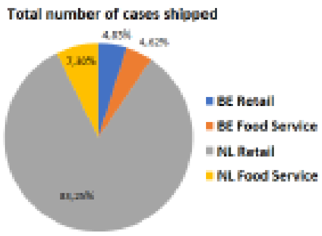


Fig. 2. cases per Country-Channel

However, this customer group seems to be the one with the most efficient shipments and with the highest full pallet picking percentages.

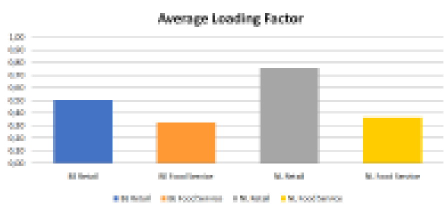


Fig. 3. average loading factor per Country-Channel

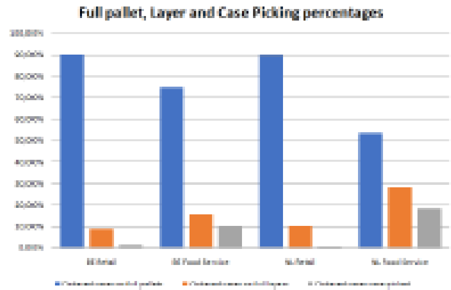
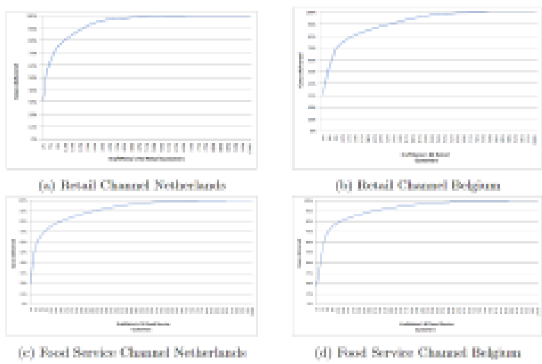


Fig. 4. Full pallet Layer and Case Picking percentages per Country-Channel

On the other hand a small improvement in this customer group could significantly affect the overall efficiency of KraftHeinz's operations. Moreover, the Pareto principle ([40]) presented in figure 5 improvements in certain customers could result in higher overall efficiency than in other customers due to the volume that is shipped to them.



(a) Retail Channel Netherlands (b) Retail Channel Belgium (c) Food Service Channel Netherlands (d) Food Service Channel Belgium

Fig. 5. Pareto principle for cases delivered to KraftHeinz customers

Consequently, the biggest opportunity seems to be located in the customers with the highest shipped volume.

Furthermore, each customer pattern seems to be having certain aspects that can be improved as well as its own limitations verifying the fact that a "one size fits all" approach should be avoided in determining the strategy to be implemented. It is clear from the bubble graphs presented below, that in general the way to improve the efficiency of the outbound handling and freight to customer operations is for the "bubbles"/customers to be moved as close to the upper right corner of the graph as possible.

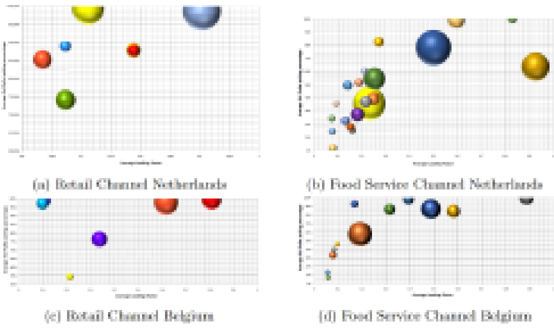


Fig. 6. Efficiency for top customer's responsible for 80% of the shipped volume from each customer group

For some customers this would mean to order only in full truck loads while for others to order a higher number of pallets in each shipment or reduce their order frequency. For other customers the solution could be to only order on a full pallet level while for others to order at least on a layer level. The underlying indicators suggest that, for the change in the order pattern of the customers, KraftHeinz can select among the following identified design alternatives:

1) Minimum order quantities strategy, in terms of:
   a) Number of pallet places in a truck (loading factor)
   b) Number of cases per product (full pallets/ full layers)
2) Order frequency reduction strategy

IV. Model Formulation

The structure of the model that is able to evaluate the outcome of the design alternatives has been described both by a conceptual model and a mathematical model with the required assumptions, the model was implemented and verified. The conceptual model serves as a precise illustration of the real-life system while the mathematical model serves as a specification of the concept into mathematical language.

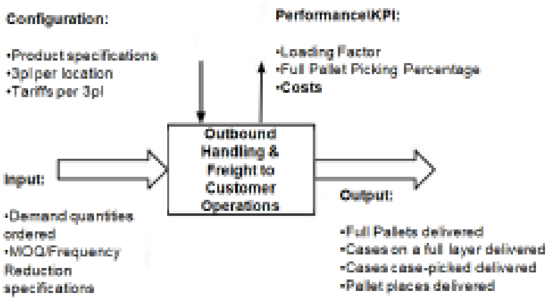


Fig. 7. black box representation of the system

The indices and sets, parameters, decision variables and cost function have been defined as follows:
i for $product$ $I = [product_1, ..., product_m]$
j for $orders$ $J = [ordernumber_1, ..., ordernumber_n]$
l for $ship\text{-}to$ $location$ $L = [ship\text{-}to_1, ..., ship\text{-}to_p]$

The parameters and decision variables have been defined as follows:

1) ordered quantities
   d_{ij} ordered quantity of product i in order j
2) product specifications
   x_i number of cases per pallet for product i
   y_i number of cases per layer for product i
   z_i number of layers per pallet for product i
   h_i full pallet height for product i
   $C_{stackability_i}$ stack-ability coefficient for product i
   $C_{pallettype_i}$ pallet type coefficient for product i
   $h_{maxlayer}$ maximum height for layer-picked pallets
   $h_{maxcase}$ maximum height for case-picked pallets
3) tariffs:
   C_{Case_l} tariff of 3pl serving ship-to location l for the case picking activity of one case
   C_{Layer_l} tariff of 3pl serving ship-to location l for the layer picking activity of one case
   C_{Pallet_l} tariff of 3pl serving ship-to location l for the pallet picking activity of one pallet
   $C_{Shipment_l}(p)$ tariff of 3pl serving ship-to location l for the transportation activity of one pallet depending on the number of pallet places pp in the order

$$alternative = \begin{cases} \text{no MOQ alternative} \\ \text{MOQ=full layers alternative} \\ \text{MOQ=full pallets alternative} \\ \text{MOQ= } pp_l^* \\ \text{Order Frequency= } 1/n^* \text{ alternative} \end{cases} \quad (1)$$

pp_l^* : number of pallet places allowed per shipment
n^* : number of shipments allowed in one year

The cost-to-serve function (cts) consists of four terms three related with outbound handling activities and one with freight to customer activities and is calculated separately for each customer.

$$\begin{aligned} cts = \sum_{l=1}^{P} & FP_l(alternative)C_{Pallet_l} \\ & + CLP_l(alternative)C_{Layer_l} \\ & + CCP_l(alternative)C_{Case_l} \\ & + Shipmentcocsts_l(alternative) \end{aligned} \quad (2)$$

With:

$$FP_l = \begin{cases} \sum_{j=1}^{n} fp_{jl} & \text{for no MOQ} \\ \sum_{j=1}^{n} fp_{jl} & \text{for MOQ=full layers} \\ \sum_{j=1}^{n} fp_{jl} + \frac{\sum_{j=1}^{n} clp_{jl}}{x_l} + \frac{\sum_{j=1}^{n} ccp_{jl}}{x_l} & \text{for MOQ=full pallets} \end{cases} \quad (3)$$

$$CLP_l = \begin{cases} \sum_{j=1}^{n} clp_{jl} & \text{for no MOQ} \\ \sum_{j=1}^{n} clp_{jl} + \sum_{j=1}^{n} ccp_{jl} & \text{for MOQ=full layers} \\ 0 & \text{for MOQ=full pallets} \end{cases} \quad (4)$$

$$CCP_l = \begin{cases} \sum_{j=1}^{n} ccp_{jl} & \text{no MOQ} \\ 0 & \text{for MOQ=full layers} \\ 0 & \text{for MOQ=full pallets} \end{cases} \quad (5)$$

$$SC_l \quad (6)$$

$$= \begin{cases} \sum_{j=1}^{n} pp_{jl} C_{Shipment_l}(pp_{jl}) \\ \qquad \text{for the no MOQ alternative} \\ \sum_{j=1}^{n} pp_{jl} C_{Shipment_l}(pp_{jl}) a + pp_l^* \overline{n} C_{Shipment_l}(pp_l^*) \\ \qquad \text{for the MOQ}= pp_l^* \text{ alternative} \\ \sum_{j=1}^{n} pp_{jl} C_{Shipment_l}(pp_{jl}) b + (1-b) \overline{pp_l} n^* C_{Shipment_l}(\overline{pp_l}) \\ \qquad \text{for the Order Frequency}= \frac{1}{n^*} \text{alternative} \end{cases}$$

Where:

$$\overline{n} = \frac{\sum_{j=1}^{n} pp_{jl}(1-a)}{pp_l^*}$$

$$\overline{pp_l} = \frac{\sum_{j=1}^{n} pp_{jl}}{n^*}$$

$$a = \begin{cases} 1 & pp_l^* \geq pp_{jl} \\ 0 & pp_l^* < pp_{jl} \end{cases}$$

$$b = \begin{cases} 1 & n^* \geq n \\ 0 & n^* < n \end{cases}$$

For a total cost calculation all one needs to do is to add the cost-to-serve of every customer.

$$k \quad for \quad customer \qquad K = [customer_1, ..., customer_q] \quad (7)$$

$$tc = \sum_{l=1}^{q} cts_k \quad (8)$$

It is also important here to clarify the assumptions that had to be made in the formulation of the mathematical model.

Respecting the model: 1) The total demand of one year is considered to be the same for all alternatives. 2) Demand can always be satisfied. 3) Returns and delays are not taken into account. 4) There is no combination of deliveries. 5) The tariffs are represented in this model by constant values. 6) The number of pallet places (pp_{jl}) is rounded up to the closest integer.

Regarding the alternatives: 1) Regarding the MOQ=full pallets alternative, it is assumed that the various layer picked and case picked cases can be combined onto pallets as if they were one "average" product. 2) With respect to the MOQ=full layers alternative, case picked case of the no moq alternative are assumed to be on full layers without any change on the total number of cases. 3) With regards to the MOQ= pp_l^* alternative, an equivalent number of shipments is assumed. 4) As regards the Order Frequency= $1/n^*$ alternative, an equivalent average number of pallet places per shipment is assumed. 5) Again respecting the Order Frequency= $1/n^*$ alternative, when the total number of pallets cannot be delivered with the number of shipments allowed by the policy then it is assumed that the alternative cannot be implemented on this customer and the costs stay the same as in the no MOQ alternative. 6) For all the alternatives the cascading effects are not taken into consideration. Finally, it has been verified that the model is implemented according to the described specifications and that the implementation accurately represents the conceptual description.

Fig. 8. verification results

V. EXPERIMENTS & RESULTS

A. Experimental plan

a) Goal: The goal of each experiment is to determine the performance of each design alternative with respect to the KPI which is costs. The experiments consist of model runs and the runs' output. The output is quantifying the performance of the alternative and after conducting a comparative analysis the selection of the design alternatives per customer can take place. Furthermore, the performance of each design alternative can be evaluated in various customer groups sharing similar characteristics regarding the country and sector they operate in, the size of their demand, the frequency and the size of their orders as well as the variability of the size of their orders.

b) Input: The input for all the experiments is the demand data for each product in each order at all the ship-to locations throughout the year 2019 with the MOQ or frequency reduction specifications varying per experiment.

The customers are classified as follows and experiments will be held per customer type.

1) Country: a) Netherlands b) Belgium c) Luxembourg
2) Channel: a) Retail b) Food Service c) Export
3) Demand with respect to the number of cases shipped in a year: a) Insignificant (1-1000) b) Low (1001-10000) c) Medium (10001-100000) d) High (100001-1000000) e) Significantly High (>1000001)
4) Order Frequency with respect to the year's average number of shipments per week: a) Very Low (0-1,4) b) Low (1,4-2,8) c) Medium (2,8-4,2) d) High (4,2-5,6) e) Significantly High (>5,6)
5) Order Size with respect to the year's average number of pallet places per shipment: a) Very Small (0-5,2) b) Small (5,2-10,4) c) Medium (10,4-15,6) d) High (15,6-20,8) e) Significantly High (20,8-26)
6) Order Size Variability with respect to the year's standard deviation of the number of pallet places per shipment: a) Low ($\leq$ 1) b) Medium ($\leq$ 2) c) High ($\leq$ 4) d) Extremely High(>4)

c) Configuration: The configuration regarding the one-to-one relation between 3pl and location, the tariffs applied by each 3pl provider and the same master data of the products, is fixed for all the experiments. 12 alternative configurations have been used with respect to the strategy applied:

1) no MOQ alternative
2) MOQ=full layers alternative (FL)

3) MOQ=full pallets alternative (FP)
4) MOQ= The first quartile (Q1) of the number of pallet places of all the orders for each customer alternative
5) MOQ= The median (Q2) of the number of pallet places of all the orders for each customer alternative
6) MOQ= The third quartile (Q3) of the number of pallet places of all the orders for each customer alternative
7) MOQ= Full Truck loads (FTL) alternative
8) Order Frequency=1 day per week alternative (1/wk)
9) Order Frequency=2 days per week alternative (2/wk)
10) Order Frequency=3 days per week alternative (3/wk)
11) Order Frequency=4 days per week alternative (4/wk)
12) Order Frequency=5 days per week alternative (5/wk)

Consequently 12 experiments 1 base and 11 alternatives have been scheduled per customer and per customer type.

B. Results

The performance of the design alternatives has been evaluated by comparing the costs, which is the Key Performance Indicator. The design alternative with the lowest cost is recommended by the model as the optimal strategy per customer. The developed model not only offers the opportunity for the costs to be compered per activity but also allows a comparison of the design alternatives for every single customer. In that sense, it becomes clear in which customers the biggest efficiency improvement and cost saving opportunities lie and for which design alternative. The example presented in the table below, illustrates the selected alternative(1st) of the customers(1-7) representing the 80% of the shipped volume in the dutch retail channel customer group as well as the (2nd to 9th) most preferable design alternative sorted with respect to cost to serve from lowest to highest. The customers are also sorted with respect to their shipped volume from highest to lowest. It is clear from the table that priority in this group should be given in the frequency reduction of the second biggest customer to 4 shipments per week and the biggest customer to 5 shipments per week and to the third and fourth customer ordering on full pallets only.

	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
1	5/wk	FP	FTL	Q3	Q1	Q2	1/wk	FL	3/wk
2	4/wk	5/wk	3/wk	FTL	Q3	Q2	Q1	2/wk	FP
3	FP	2/wk	3/wk	4/wk	FTL	Q3	Q1	Q2	FL
4	FP	3/wk	4/wk	2/wk	FTL	Q3	1/wk	Q2	Q1
5	5/wk	FP	FTL	Q3	Q2	Q1	FL	1/wk	2/wk
6	FP	2/wk	FTL	1/wk	Q3	Q1	Q2	FL	3/wk
7	3/wk	4/wk	FP	Q3	FTL	Q1	Q2	FL	5/wk

TABLE I
DESIGN ALTERNATIVE PRIORITISATION PER CUSTOMER
(EXCL.10TH & 11TH)

Furthermore, the performance of each of the design alternatives has been evaluated in groups of customers sharing similar characteristics regarding the country and the sector they operate in, their yearly demand, their average order size, their order size variability and their order frequency. A summary of the performance evaluation of all the alternatives can be found below.

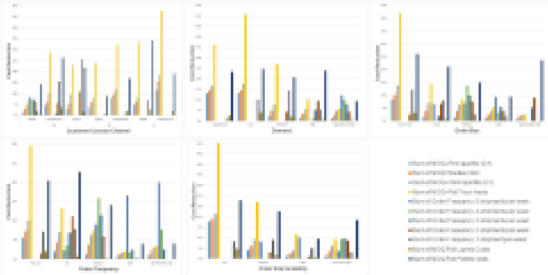


Fig. 9. performance of the design alternatives per characteristic

1) The **MOQ=full layers alternative** is among the ones that offer the lowest cost reduction for every customer type regarding every characteristic. It seems that it can only be considered as an alternative for low and insignificant demand customers operating in the food service of all countries and in the retail of Luxembourg as well as for customers with very small order size low or very low order frequency and low order size variability with the cost reduction ranging in the low levels of 1% to 4% for customers sharing these characteristics.

2) The **MOQ=full pallets alternative** is in the top 2 in terms of cost reduction for almost every type of customer. It is the alternative that leads to the maximum cost reduction for customers with high demand, extremely high variability, order sizes from small to significantly high and low order frequencies as well as for customers that operate in retail of the Netherlands and Luxembourg. It is third in terms of cost reduction only for the customers with significantly high demand where the frequency reduction alternatives prevail and for customers with high order variability.

3) The **MOQ= The first quartile (Q1) of the number of pallet places alternative**, despite not being among the sharing the top places in cost reduction, can lead to cost reduction if implemented on customers with insignificant or low demand(13% reduction), very small order size(9%) and low order size variability(18%) and very low order frequencies(6%). If implemented upon customers operating in the food service sector of Luxembourg it can lead to 12% cost reduction and 8% upon implementation to their Belgian counterparts.

4) The **MOQ= The median (Q2) of the number of pallet places alternative** should be considered for the same type of customers as the first quartile MOQ alternative but it leads to a bit higher cost reductions for every characteristic.

5) The **MOQ= The third quartile (Q3) of the number of pallet places alternative** should be considered for the same type of customers as the first and second quartile MOQ alternatives leading higher cost reductions than both of them. Apart from those, it can also be considered for customers with medium demand (8% cost reduction), small order size (7%), medium order size variability (9%), low and medium order frequencies (6%).

6) The **MOQ= Full Truck loads (26 pallet places) alternative** is in the top 2 in terms of cost reduction for almost every type of customer. It can lead to tremendous cost reduction if implemented in the customers that the other MOQ design

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alternatives are just to be considered. For example, it is the one leading to the highest cost reductions when implemented at customers with insignificant(36%) low (51%) and medium (27%) demand. It is also the second most preferable for customers with high demand leading to 10% cost reduction. It can also be considered for high (12%)and extremely high(9%) order size variability. It is the most preferable alternative for food service customers leading to 48% cost reduction in Luxembourg, 32% in Belgium and 29% in the Netherlands.

7) The **Order Frequency= 1 day per week alternative** can be considered for customers with low medium and high demand leading to cost reductions of 10%, 14%, and 5% respectively, very small and small order sizes with savings of 12% and 8% respectively low and medium order size variability leading to 8% and 9% cost reduction. While among the customers with very low and low order frequencies it can achieve cost reductions of around 8%. Furthermore, it is the one leading to the highest cost reduction for customers in the export channel of the Netherlands and should also be considered for food service customers of the Netherlands leading to 15% cost reduction.

8) The **Order Frequency= 2 days per week alternative**, among customers with high demand, can achieve a 10% cost reduction placing it in the third position of the most preferable alternatives among customers sharing this characteristic. It also occupies the second position of the most preferable alternatives for customers with significantly high order sizes leading to 9% cost reduction in their group. Furthermore it can achieve 9% reduction for customers with extremely high order size variability and can also be considered for small and medium order sizes as well as for customers with low and medium order frequencies. It is applicable in all 3 channels of the Netherlands with cost reduction being at 5% for food service 6% for retail and 10% for export.

9) The **Order Frequency= 3 days per week alternative** can only be implemented upon customers that operate in the Netherlands and is most preferable for those in retail. This alternative is 3rd for customers with medium and low order frequencies leading to a cost reduction around 12%. It is also second most preferable for customers with extremely high order size variability and third most preferable for customers with medium order sizes with 10% cost reduction for customers in both groups. Apart from that, it can be considered for customers with high and significantly high order sizes cost reduction 5% and can be considered regarding customers with high and significantly high demand as it leads to 5% and 8% cost reduction respectively.

10) The **Order Frequency= 4 days per week alternative** is possible for application only in retail Netherlands. It is the prevailing alternative in terms of cost reduction for customers with medium order frequency leading to a 16% reduction and second most preferable for customers with significantly high order frequency leading to 8% reduction. It is leading to 10% cost reduction when applied to customers with significantly high demand, 14% to customers with medium order size and 9% to customers with extremely high order variability.

11) The **Order Frequency= 5 days per week alternative** is applicable only on customers operating in the retail sector of the Netherlands, Specifically it is the most preferable alternative among customers with significantly high demand as well as among customers with high and significantly high frequency leading to 12% 20% and 17% reduction of costs respectively. Furthermore this alternative is sharing the first position for high order sizes with 9% in cost reduction, while, when applied to customers with high order variability it leads to 8% reduction.

VI. Conclusions & Recommendations for Future Work

This research has concluded upon, which customer order pattern changes would have the maximum impact in improving the overall outbound handling and freight to customer operations efficiency. The model has been able to prioritize both the strategies to be implemented per customer and the customers that are important for a strategy implementation. Moreover, groups of customers where specific design alternatives are more preferable have been identified. The research has concluded that for customers with high demand or extremely high variability or order sizes from small to significantly high or low order frequencies or customers that operate in Netherlands and Luxembourg retail sector, the full pallets minimum order quantity is the one that can save more costs. The full truck loads alternative is the one leading to the most cost savings upon implementation to customers with insignificant, low and medium demand or very small order sizes or low, medium, and high order size variability or very low order frequency or customers that operate in food service of all 3 countries. Finally, the order frequency reduction alternative to 5 shipments per week is the one that can lead to the highest savings for customers with significantly high demand or high and significantly high order frequencies or customers operating in the retail sector of the Netherlands, while the order frequency reduction alternative to 4 shipments per week is preferable for customers with medium order frequencies.

In this research the ways to increase outbound handling and freight to customer operations efficiency have been studied contributing to the expansion of knowledge in the field of medium-term supply chain planning. This has been done from the supplier's perspective. The models results and prioritization have been proven useful for the case study company in rising awareness regarding the causal factors, as well as in assisting in the negotiations with the customers and the decision making. Apart from its own contribution, this study has also helped in identifying fields that require further investigation. Firstly, the application of the model could be expanded to other case study companies willing to share their data in order for the results to be compared and test if the models suggested design alternatives are universally applicable. Secondly, in this research the design alternatives have been evaluated costs have been selected as the KPI upon which. An interesting future research direction would be to use CO_2 emissions as a KPI and compare the suggested alternatives with the ones proposed by this research. Finally, an interesting research direction could be to incorporate more factors that support the decision making process in the model. Potential of cost savings calculated by the cost-to-serve model for every alternative and every customer is only one factor amongst those that define the strategy to be selected to be negotiated with the customer. Factors that could be also taken into consideration are the market share and potential market growth of the customer as well as the state of the business relationship of the supplier with the customer.

References

[1] P. Kuppers, P. Saatmann, and B. Hellingrath, "An approach for assessing the applicability of collaborative planning concepts," *Proceedings of the Annual Hawaii International Conference on System Sciences*, vol. 2015-March, pp. 1049–1058, 2015.

[2] M. Giannakis and M. Louis, "A multi-agent based framework for supply chain risk management," *Journal of Purchasing and Supply Management*, vol. 17, no. 1, pp. 23–31, 2011. [Online]. Available: http://dx.doi.org/10.1016/j.pursup.2010.05.001

[3] D. J. Garcia and F. You, "Supply chain design and optimization: Challenges and opportunities," *Computers and Chemical Engineering*, vol. 81, pp. 153–170, 2015. [Online]. Available: http://dx.doi.org/10.1016/j.compchemeng.2015.03.015

[4] N. Akter, "Understanding the usage patterns , practices and decision process of third party logistics outsourcing in Bangladesh," vol. 12, no. 3, pp. 329–354, 2019.

[5] J. P. O. Ceia, "Cost-to-serve Customers ' Optimization," no. 1446, 2014. [Online]. Available: http://hdl.handle.net/10362/15050

[6] C. J. O. Coelli, T.J, Rao, D.S.P., Prasada Rao and G. Battese, *Introduction to Efficiency and Productivity Analysis, (Second Edition)*. Springer, 2005.

[7] M. Daudi and K.-d. Thoben, "ScienceDirect ScienceDirect ScienceDirect Self-organizing Logistics Networks for Less-Than-Truckload Self-organizing Logistics Networks for Less-Than-Truckload," *Procedia Manufacturing*, vol. 52, no. 2019, pp. 101–106, 2020. [Online]. Available: https://doi.org/10.1016/j.promfg.2020.11.019

[8] J. Wehner, "Energy efficiency improvements in logistics as a means to environmental sustainability : The case of capacity utilisation in road freight transportation," 2017. [Online]. Available: http://publications.lib.chalmers.se/records/fulltext/250361/250361.pdf

[9] C. A. Zuniga, E. Olivares-Benitez, A. M. Tenahua, and M. A. Mujica, "A methodology to solve the Order Batching Problem," *IFAC-PapersOnLine*, vol. 28, no. 3, pp. 1380–1386, 2015. [Online]. Available: http://dx.doi.org/10.1016/j.ifacol.2015.06.279

[10] J. Karasek, "An Overview of Warehouse Optimization," *International Journal of Advances in Telecommunications, Electrotechnics, Signals and Systems*, vol. 2, no. 3, 2013.

[11] J. J. Bartholdi and S. T. Hackman, "WAREHOUSE & DISTRIBUTION SCIENCE Release 0.94," no. January, pp. 1–321, 2011. [Online]. Available: papers3://publication/uuid/7F731EF1-7AB3-46A4-BC4A-514E4B78D73B

[12] N. Akyelken, *Green Logistics: Improving the Environmental Sustainability of Logistics*, 2011, vol. 31, no. 4.

[13] L. Ni and X. Wang, "Load factors of less-than-truckload delivery tours: An analysis with operation data," *Transportation Research Part E: Logistics and Transportation Review*, vol. 150, no. February, p. 102296, 2021. [Online]. Available: https://doi.org/10.1016/j.tre.2021.102296

[14] McKinnom.A, "European Freight Transport Statistics: Limitations, Misinterpretations and Aspirations," *European Automobile Manufacturers Association Avenue*, no. September, p. 24, 2010. [Online]. Available: https://www.acea.be/uploads/publications/SAG_15_European_Freight_Transport_Statistics.pdf

[15] T. Gudehus and H. Kotzab, *Comprehensive Logistics*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2012. [Online]. Available: http://link.springer.com/10.1007/978-3-642-24367-7

[16] H. Uster and P. Kewcharoenwong, "Strategic Design and Analysis of a Relay Network in Truckload Transportation," *Transportation Science*, vol. 45, no. 4, pp. 505–523, nov 2011. [Online]. Available: http://pubsonline.informs.org/doi/abs/10.1287/trsc.1100.0355

[17] L. M. Thomas and R. D. Meller, "Developing design guidelines for a case-picking warehouse," *International Journal of Production Economics*, vol. 170, pp. 741–762, 2015. [Online]. Available: http://dx.doi.org/10.1016/j.ijpe.2015.02.011

[18] R. de Koster, T. Le-Duc, and K. J. Roodbergen, "Design and control of warehouse order picking: A literature review," *European Journal of Operational Research*, vol. 182, no. 2, pp. 481–501, 2007.

[19] A. Baykasoflu and V. Kaplanoflu, "An application oriented multi-agent based approach to dynamic load/truck planning," *Expert Systems with Applications*, vol. 42, no. 15-16, pp. 6008–6025, 2015.

[20] J. Mehmann and F. Teuteberg, "The fourth-party logistics service provider approach to support sustainable development goals in transportation - A case study of the German agricultural bulk logistics sector," *Journal of Cleaner Production*, vol. 126, pp. 382–393, 2016. [Online]. Available: http://dx.doi.org/10.1016/j.jclepro.2016.03.095

[21] M. N. Ab Rahman, R. A. C. Leuveano, F. A. bin Jafar, C. Saleh, B. M. Deros, W. M. F. W. Mahmood, and W. H. W. Mahmood, "Incorporating logistic costs into a single vendorâbuyer JELS model," *Applied Mathematical Modelling*, vol. 40, no. 23-24, pp. 10 809–10 819, 2016.

[22] A. Maxim, C. F. Caruntu, C. Lazar, R. D. Keyser, and C. M. Ionescu, "Comparative analysis of distributed model predictive control strategies," *2019 23rd International Conference on System Theory, Control and Computing, ICSTCC 2019 - Proceedings*, pp. 468–473, 2019.

[23] J. Gao and F. You, "A stochastic game theoretic framework for decentralized optimization of multi-stakeholder supply chains under uncertainty," *Computers and Chemical Engineering*, vol. 122, pp. 31–46, 2019. [Online]. Available: https://doi.org/10.1016/j.compchemeng.2018.05.016

[24] T. V. Prasad, T. Veeraiah, Y. Kiran, K. Srinivas, and C. Srinivas, "Decentralized production-distribution planning in a supply chain: Computer experiments." *Materials Today: Proceedings*, vol. 18, pp. A1–A11, 2019.

[25] I. Giannoccaro, "Centralized vs. decentralized supply chains: The importance of decision maker's cognitive ability and resistance to change," *Industrial Marketing Management*, vol. 73, no. April 2017, pp. 59–69, 2018. [Online]. Available: https://doi.org/10.1016/j.indmarman.2018.01.034

[26] B. Shen, T. M. Choi, and S. Minner, "A review on supply chain contracting with information considerations: information updating and information asymmetry," *International Journal of Production Research*, vol. 57, no. 15-16, pp. 4898–4936, 2019.

[27] N. Altintas, F. Erhun, and S. Tayur, "Quantity Discounts Under Demand Uncertainty," *Management Science*, vol. 54, no. 4, pp. 777–792, apr 2008. [Online]. Available: http://pubsonline.informs.org/doi/abs/10.1287/mnsc.1070.0829

[28] J. R. Montoya-Torres and D. A. Ortiz-Vargas, "Collaboration and information sharing in dyadic supply chains: A literature review over the period 2000â2012," *Estudios Gerenciales*, vol. 30, no. 133, pp. 343–354, 2014. [Online]. Available: http://dx.doi.org/10.1016/j.estger.2014.05.006

[29] B. P. V. D. Vlist and R. Broekmeulen, "Retail consolidation in synchronized supply chains," pp. 165–176, 2006.

[30] R. Kaplan and Cooper, R, "Cost and Effect: Using integrated cost systems to drive profitability and performance," *Choice Reviews Online*, 1998.

[31] R. Guerreiro, S. Rodrigues Bio, and E. Vazquez Villamor Merschmann, "Cost-to-serve measurement and customer profitability analysis," *The International Journal of Logistics Management*, vol. 19, no. 3, pp. 389–407, 2008.

[32] L. A. Swanson, "Logistics, Value Chain Analysis, Activity Base Costing, Supply Chain Activities, Supply Chain Decisions, Operations Management," pp. 1–20, 2020.

[33] D. Stapleton, S. Pati, E. Beach, and P. Julmanichoti, "Activity-based costing for logistics and marketing," *Business Process Management Journal*, vol. 10, no. 5, pp. 584–597, 2004.

[34] M. Ozbayrak, M. Akgün, and A. K. Türker, "Activity-based cost estimation in a push/pull advanced manufacturing system," *International Journal of Production Economics*, vol. 87, no. 1, pp. 49–65, 2004.

[35] E. M. van Raaij, "The strategic value of customer profitability analysis," *Marketing Intelligence and Planning*, vol. 23, no. 4, pp. 372–381, 2005.

[36] K. H. Lau, "Demand management in downstream wholesale and retail systems: A case study," *Supply Chain Management*, vol. 17, no. 6, pp. 638–654, 2012.

[37] A. Collins, M. Henchion, and P. O'Reilly, "Logistics customer service: Performance of Irish food exporters," *International Journal of Retail & Distribution Management*, vol. 29, no. 1, pp. 6–15, 2001.

[38] M. Christopher, *Logistics & Supply chain Management*, 4th ed., 2011, vol. 7, no. 2.

[39] E. Gebennini, A. Grassi, B. Rimini, and E. Depietri, "Costs and opportunities of moving picking activities upstream in distribution networks: A case study from the beverage industry," *International Journal of Production Economics*, vol. 143, no. 2, pp. 342–348, 2013. [Online]. Available: http://dx.doi.org/10.1016/j.ijpe.2011.11.016

[40] E. Hofmann, P. Beck, and E. Füger, *The Supply Chain Differentiation Guide*, 2013.

Appendix B - Model implementation in excel

The master data of the products are extracted from SAP and inserted in an excel spreadsheet as presented in figure 65

Material	EPN Description	Height - PAL	Cases per Pallet	Layers per Pallet	Cases per Layer	Pallet type description	Pallet Pace	Stackability
76002180	RVC FD Strawberry (3x10) 200ml	1136	128	8	16	Pallet, Wood, Chep (pool), 1200x1000mm	1	1
76002256	HNZ DPL 1/4 Baked Beans (288) 415gm	1270	4	1	4	Pallet, Chep, 1200x800mm	0,8	1
76002304	HNZ Sweet Chilli Dippot(GB)(400) 25gm	1230	50	5	10	Pallet, Wood, Chep (pool), 1200x1000mm	1	1
76002492	HNZ Tom Ketchup TD(LT/LV/EE)(10) 400ml	1427	133	7	19	Pallet, Chep, 1200x800mm	0,8	1
76002494	HNZ Tom Ketch Sqzy(GR/BG/RO)(10) 300ml	1483	203	7	29	Pallet, Chep, 1200x800mm	0,8	1
76002508	HNZ Tom Ketch Hot(SRB/BG/RO)(10) 400ml	1427	133	7	19	Pallet, Chep, 1200x800mm	0,8	1
76002637	HOP Macaroni Shells KB (1) 3kg	1080	92	4	23	Pallet, Chep, 1200x800mm	0,8	0,5

Figure 65: Master data

In the same book but in a separate spreadsheet, the data regarding the demand are inserted as depicted in the blue headed columns of figure 66.

Document Number	Sold-to	Sold-to Name	Ship-to	Ship-to Name	Material	Description	Requested Delivery Date	Confirmed Qty	Full Pallet Height [mm]	Pallet Coef	Stackability	Cases per pallet	Layers per pallet	cases per layer	Pallets	Layers	Cases	LP % FP	LP to PP using Height	LP to PP Conversion	FP to PP Conversion	CP to PP Conversion	Pallet Places	PP cumulative	Pallet Places OF ORDER
1,103E+09	5000465	Coopcodis U.A.	6E+06	Coop DC Gieten	7,6E+07	KAR Bosvruchten Blik (6) 750ml	04/22/2021	360	1118	1.00	1.0	120	4	30	3	0	0	0	0	0	3	0	3	3	
1,103E+09	5000465	Coopcodis U.A.	6E+06	Coop DC Gieten	7,6E+07	KAR Aardbei Blik (6) 750ml	04/22/2021	720	1118	1.00	1.0	120	4	30	6	0	0	0	0	0	6	0	6	9	
1,103E+09	5000465	Coopcodis U.A.	6E+06	Coop DC Gieten	7,6E+07	Kar Cassis Blik (6) 750ml	04/22/2021	360	1118	1.00	1.0	120	4	30	3	0	0	0	0	0	3	0	3	12	
1,103E+09	5000465	Coopcodis U.A.	6E+06	Coop DC Gieten	7,6E+07	KAR Framboos Blik (6) 750ml	04/22/2021	480	1118	1.00	1.0	120	4	30	4	0	0	0	0	0	4	0	4	16	
1,103E+09	5000465	Coopcodis U.A.	6E+06	Coop DC Gieten	7,6E+07	KAR Citroen (6) 750ml	04/22/2021	240	1118	1.00	1.0	120	4	30	2	0	0	0	0	0	2	0	2	18	
1,103E+09	5000465	Coopcodis U.A.	6E+06	Coop DC Gieten	7,6E+07	KAR Sinaasappel Blik (6) 750ml	04/22/2021	360	1118	1.00	1.0	120	4	30	3	0	0	0	0	0	3	0	3	21	
1,103E+09	5000465	Coopcodis U.A.	6E+06	Coop DC Gieten	7,6E+07	KAR Grenadine Blik (6) 750ml	04/22/2021	360	1118	1.00	1.0	120	4	30	3	0	0	0	0	0	3	0	3	24	
1,103E+09	5000465	Coopcodis U.A.	6E+06	Coop DC Gieten	7,6E+07	KAR Tropisch Blik (6) 750ml	04/22/2021	240	1118	1.00	1.0	120	4	30	2	0	0	0	0	0	2	0	2	26	26

Figure 66: Order data and calculations

The vertical lookup function (=vlookup(EPN;MasterData;3;0)) that was used for searching the ordered products' EPN number in the master data is depicted in the brown headed columns of figure 66

Then the exact number of pallets, layers and cases were calculated with the help of the retrieved information as follows:

number of pallets=IF([@[Confirmed Qty]]=0;0;QUOTIENT([@[Confirmed Qty]];[@[Cases per pallet]]))

number of layers=IF([@[Confirmed Qty]]=0;0;QUOTIENT(MOD([@[Confirmed Qty]];[@[Cases per pallet]]);[@[cases per layer]]))

Layer picked cases=[@Layers]*[@[cases per layer]]

number of cases =IF([@[Confirmed Qty]]=0;0;MOD(MOD([@[Confirmed Qty]];[@[Cases per pallet]]);[@[cases per layer]])) These calculations take place at the green headed columns of figure 66.

The calculation of the pallet places of the order takes place at the purple headed columns presented in the figure 66.

The explicit calculation is presented below step by step as in the multiple excel columns used:

1. transformation of the number of full pallets of the product into a number of pallet places
FP to PP Conversion=[@Pallets]*[@Stackability]

2. transformation of the number of layers into a percentage of a full pallet as presented below
LP % FP=IF([@[Confirmed Qty]]=0;0;[@[Layer picked cases]]/[@[Cases per pallet]])

3. Division of this product's Full Pallet Height by the maximum height a layer-picked pallet can have, giving the:
LP to PP using Height=IF([@[LP % FP]]<>0;[@[Full Pallet Height '[mm']]]/1800;0)

4. multiplication of the two numbers giving the layers' equivalent in pallet places:
LP to PP Conversion=[@[LP to PP using Height]]*[@[LP % FP]]

5. transformation of the number of cases into the cases' equivalent in pallet places as presented below:
CP to PP Conversion=IF([@[Confirmed Qty]]=0;0;[@Cases]/[@[Cases per pallet]]*([@[Full Pallet Height '[mm']]]/1050))

6. calculation of the number of pallet places the product occupies by multiplying the summation of the conversions with the pallet type coefficient:
Pallet Places=([@[FP to PP Conversion]]+[@[LP to PP Conversion]]+[@[CP to PP Conversion]])*[@[Pallet Type Coef]]

7. Calculation of the number of pallet places for the entire order via a cumulative (by adding the value of the previous row only if the order number is the same as in the previous line.):
PP cumulative=IF([@[Document Number]]=A1;[@[Pallet Places]]+AF1;[@[Pallet Places]])

8. Singling out the final number of the cumulative:
   Pallet Places per order=IF([@[Document Number]]=A3;"";ROUNDUP([@[per order2]];0))

The three spreadsheets of the second file containing data, regarding the tariffs applied by the 3pl parties at each warehouse location as well as the one-to-one relation between location and 3pl serving this location are presented in figure 67 68

Pallet Places	per pallet	per shipment
1	28,50 €	28,50 €
2	24,11 €	48,21 €
3	22,53 €	67,60 €
4	21,39 €	85,55 €
5	20,22 €	101,11 €
6	19,41 €	116,48 €
7	18,59 €	130,15 €
8	17,79 €	142,34 €
9	17,04 €	153,37 €
10	16,54 €	165,38 €
11	16,02 €	176,26 €
12	15,58 €	186,95 €
13	15,18 €	197,39 €
14	14,84 €	207,74 €
15	14,54 €	218,03 €
16	14,27 €	228,28 €
17	14,00 €	238,00 €
18	13,69 €	246,48 €
19	13,45 €	255,47 €
20	13,23 €	264,56 €
21	12,97 €	272,38 €
22	12,74 €	280,34 €
23	12,53 €	288,08 €
24	12,31 €	295,38 €
25	12,11 €	302,73 €
26	11,94 €	310,47 €

Figure 67: Tariffs

Ship-To Party	Ship-To Name	Warehouse
5000496	A.S. Watson (H&B Cont Eur) B.V.	NAB
5005307	Abattoir Ettelbruck SA	VR
5523341	AC Loogman	NAB
5000421	Actifood B.V.	NAB
5519832	Action DC Echt	NAB
5519803	Action DC Zwaagdijk	NAB
5521862	Advion B.V.	NAB
5524220	AES Trading International	NAB
5515549	Agape HQ	VR
5000865	Agterberg Vleeswaren B.V.	NAB
5523068	AH Online HSC Eindhoven	NAB
5005166	Albert Heijn	NAB
5002959	Albert Heijn 8514	NAB
5000117	Albert Heijn Geldermalsen	NAB

Figure 68: Location-3pl

Regarding the outbound handling costs of the calculation, the summarized data of the first file is depicted in 69. The linked information can be found under the blue and orange headed columns and the calculations are a presented below:

1. Cost Case Pick =[@[Cases picked]]*'WH costs$G$11

2. Cost Layer Pick =[@[Cases on full layers]]*'WH costs'!H12

3. Cost Full Pallet Pick =[@[Full pallets]]*'WH costs$H$8

4. Summation of costs associated with the Outbound Handling activities:
   Outbound Handling Costs=SUM(Picking_Table[@[Cost Case Pick]:[Cost Full Pallet Pick]])

The outbound handling costs for the various scenarios are presented below

1. For the Full Layers MOQ scenario the Cases on full layers and Cases picked are both multiplied with the layer picking tariff the full pallet picking costs are the same as in the no MOQ scenario:

MOQ Full Layers Costs=([@[Cases on full layers]]+[@[Cases picked]])*'WH costs'!$H12$+[@[Cost Full Pallet Pick]]

2. For the Full Pallets MOQ scenario the average number of cases per pallet is used to find the new number of pallets picked. This number varies per ship-to location so it has to be found by a a vertical lookup function. The costs are calculated as presented below:
   MOQ Full Pallets costs=SUM(Picking_Table[@[Cases picked]:[Cases on full layers]])/VLOOKUP([@[Ship-To Party]];Avg_cases_per_pallet_Table;4;0)*'WH costs'!$H8$+[@[Cost Full Pallet Pick]]

3. For all other scenarios the Outbound Handling Costs are assumed to stay the same as in the no MOQ scenario

The calculations of the outbound handling costs can be found in 69

Country	Distribution Channel	sold-to	sold-to name	Ship-To Party	Ship-to name	Cases picked	Cases on full layers	Full pallets	Cost Case Pick	Cost Layer Pick	Cost Full Pallet Pick	Outbound Handling Costs	MOQ Full Layers Costs	MOQ Full Pallets costs
NL	Retail	5000015	Albert Heijn	5000017	Albert He	344	4514	9124	68,80 €	683,87 €	18.430,48 €	19.182,36 €	19.165,67 €	18.571,29 €
NL	Retail	5000462	Plus Retail B	5000022	Plus Retai	1050	104863	3121	210,00 €	15.886,74 €	6.304,42 €	22.400,30 €	22.349,38 €	8.165,20 €
NL	Retail	5005627	Aldi Zaandar	5000024	Aldi Zaan	1	7	129	0,20 €	1,06 €	260,58 €	260,24 €	260,19 €	270,94 €
NL	Retail	5000030	Hoogvliet B.	5000031	Hoogvliet	1187	68778	4155	237,40 €	10.419,87 €	8.393,10 €	19.050,09 €	18.992,52 €	9.306,35 €
NL	Food Service	5000120	Bidfood B.V.	5000041	Bidvest D	5208	3689	4	1.041,60 €	558,88 €	8,08 €	1.608,38 €	1.355,79 €	153,83 €
NL	Food Service	5000042	Dasselaar B.	5000043	Dasselaar	20	27	114	4,00 €	4,09 €	230,28 €	237,13 €	236,16 €	229,80 €
NL	Retail	5000015	Albert Heijn	5000044	Albert He	260	5780	10001	52,00 €	875,67 €	20.202,02 €	21.128,47 €	21.115,86 €	20.385,17 €
NL	Food Service	5000053	Oriental Gro	5000054	Oriental G	0	0	10	0,00 €	- €	20,20 €	20,20 €	20,20 €	20,20 €
NL	Food Service	5000061	Busser Hore	5000062	Busser Ho	378	0	0	75,60 €	- €	0,00 €	75,60 €	57,27 €	4,74 €
NL	Food Service	5000065	Jansen Food	5000066	Jansen Ho	2513	454	6	502,60 €	68,78 €	12,12 €	581,51 €	459,63 €	55,32 €
NL	Food Service	5000079	Foodpartner	5000080	Foodpartı	2278	434	1	455,60 €	65,75 €	2,02 €	522,88 €	412,39 €	44,66 €
NL	Food Service	5000086	Verhage Fas	5000087	Verhage F	0	60	2	0,00 €	9,09 €	4,04 €	13,13 €	13,13 €	7,07 €
NL	Food Service	5000092	Interfastfoo	5000093	Interfastf	0	0	45	0,00 €	- €	90,90 €	90,36 €	90,36 €	88,88 €
NL	Food Service	5000107	Kreko Pijnac	5000108	Kreko Pijr	2646	732	6	529,20 €	110,90 €	12,12 €	652,07 €	523,74 €	62,85 €
NL	Food Service	5000109	M.L. Lieferin	5000110	M.L. Liefe	4122	444	7	824,40 €	67,27 €	14,14 €	905,42 €	705,51 €	85,64 €
NL	Retail	5000015	Albert Heijn	5000115	Albert He	255	5446	9699	51,00 €	825,07 €	19.591,98 €	20.466,10 €	20.453,74 €	19.763,68 €
NL	Retail	5000015	Albert Heijn	5000116	Albert He	163	4544	8980	32,60 €	688,42 €	18.139,60 €	18.859,24 €	18.851,33 €	18.249,66 €
NL	Retail	5000015	Albert Heijn	5000117	Albert He	4545	72938	18950	909,00 €	11.050,11 €	38.279,00 €	50.236,82 €	50.016,39 €	39.355,63 €
NL	Retail	5000118	Etos B.V.	5000119	Etos B.V.	183	1496	37	36,60 €	226,64 €	74,74 €	337,98 €	329,11 €	99,68 €
NL	Food Service	5000120	Bidfood B.V.	5000121	Bidvest D	4714	49011	346	942,80 €	7.425,17 €	698,92 €	9.064,97 €	8.836,34 €	1.643,16 €
NL	Retail	5005629	Aldi Ommer	5000123	Aldi Omm	5	7	175	1,00 €	1,06 €	353,50 €	355,39 €	355,15 €	381,31 €
NL	Retail	5005630	Aldi Best B.V	5000124	Aldi Best	4	15	158	0,80 €	2,27 €	319,16 €	320,41 €	320,21 €	335,92 €
NL	Retail	5005631	Aldi Drachte	5000125	Aldi Drach	1	17	236	0,20 €	2,58 €	476,72 €	479,37 €	479,32 €	481,05 €

Figure 69: Outbound handling costs calculation

Regarding the Freight to customer costs calculation, the pasted summarized data of the first file in the separate spreadsheet are depicted in 70

Country	Distribution Channel	Sold-to part	Sold-to name	Ship-To Party	Ship-To Name	2-1-2019	3-1-2019	4-1-2019	5-1-2019	7-1-2019	8-1-2019	9-1-2019	10-1-2019	11-1-2019	12-1-2019	14-1-2019
NL	Retail	5000015	Albert Heijn B.V.	5000017	Albert Heijn Tilburg	26		26		26	26		26	26		26
NL	Retail	5000462	Plus Retail B.V.	5000022	Plus Retail B.V. Zuid (Ittervoort)	13	26				10		19			
NL	Retail	5005627	Aldi Zaandam B.V.	5000024	Aldi Zaandam								2			
NL	Retail	5000030	Hoogvliet B.V.	5000031	Hoogvliet B.V.			23		19		23		12		24
NL	Food Service	5000120	Bidfood B.V.	5000041	Bidfood Groningen					1						
NL	Food Service	5000042	Dasselaar B.V. Nijkerk	5000043	Dasselaar B.V.						4					
NL	Retail	5000015	Albert Heijn B.V.	5000044	Albert Heijn Zaandam	26		26		26	26		26	26		26
NL	Food Service	5000053	Oriental Group Duiven B.V.	5000054	Oriental Group Duiven B.V.											
NL	Food Service	5000061	Busser Horeca Service B.V	5000062	Busser Horeca Service B.V.											
NL	Food Service	5000065	Jansen Foodservice Doetinchem B.V.	5000066	Jansen Horeca Doetinchem	1										
NL	Food Service	5000079	Foodpartners B.V.	5000080	Foodpartners B.V.											1
NL	Food Service	5000086	Verhage Fast Food Groothandel B.V.	5000087	Verhage Fast Food Groothandel B.V.											
NL	Food Service	5000092	Interfastfood Rotterdam B.V.	5000093	Interfastfood B.V.											
NL	Food Service	5000107	Kreko Pijnacker B.V.	5000108	Kreko Pijnacker B.V.									1		
NL	Food Service	5000109	M.L. Lieferink B.V.	5000110	M.L. Lieferink B.V.	1						1				
NL	Retail	5000015	Albert Heijn B.V.	5000115	Albert Heijn Zwolle	25		26		26	26		26	26		26
NL	Retail	5000015	Albert Heijn B.V.	5000116	Albert Heijn Pijnacker	26		26		26	26		26	26		26
NL	Retail	5000015	Albert Heijn B.V.	5000117	Albert Heijn Geldermalsen	26	26	26	26	26	26	26	26	26	26	2
NL	Retail	5000118	Etos B.V.	5000119	Etos B.V.											
NL	Food Service	5000120	Bidfood B.V.	5000121	Bidfood Ede	9		1			4			4		
NL	Retail	5005629	Aldi Ommen B.V.	5000123	Aldi Ommen B.V.											
NL	Retail	5005630	Aldi Best B.V.	5000124	Aldi Best B.V.											
NL	Retail	5005631	Aldi Drachten B.V.	5000125	Aldi Drachten B.V.	1				1		2		1		
NL	Retail	5005632	Aldi Roosendaal B.V.	5000126	Aldi Roosendaal B.V.						2		2			
NL	Retail	5000131	Jan Linders B.V.	5000131	Jan Linders B.V.											
NL	Retail	5000131	Jan Linders B.V.	5000132	Jan Linders B.V.		26				26					
NL	Retail	5000631	B.V. Nettorama Verbruikersmarkten	5000133	B.V. Nettorama Distributie		7			26			18			26
NL	Retail	5000134	Poiesz Supermarkten B.V.	5000135	Poiesz Supermarkten B.V.	26		3		13		1				26
NL	Food Service	5000048	Metro Cash & Carry Nederland B.V.	5000139	Metro Cash & Carry NL B.V.											
NL	Food Service	5000120	Bidfood B.V.	5000145	Bidfood Emmen					3						1
NL	Food Service	5000120	Bidfood B.V.	5000149	Bidfood Hengelo					2						1
NL	Food Service	5000120	Bidfood B.V.	5000150	Bidfood Nieuwegein			2						1		

Figure 70: Pallet places per location and day

The vertical lookup function identifying the 3pl serving each location is the following :
3pl=VLOOKUP([@[Ship-to party]];Ship_To_3pl;3;0) and the returned information is depicted in figure 71

The costs for each day can are looked up in the associated tariff table with the following formula:

costs_of_day=IF(I3="";0;IF(I3>0;IF(LM3="NAB";VLOOKUP(I3;FTC_NAB;3;0);VLOOKUP(I3;FTC_VR[[Pallet Places]:[per shipment]];3;0));0))

A part off the extension of the formula for the equivalent of the number of days of the year can be found in 71

3pl	2-1-20	3-1-20	4-1-20	5-1-20	7-1-20	8-1-20	9-1-20	10-1-20	11-1-20	12-1-20	14-1-20
NAB	200,46 €	- €	310,47 €	- €	310,47 €	310,47 €	- €	310,47 €	310,47 €	- €	310,47 €
NAB	139,36 €	310,47 €	- €	- €	- €	165,38 €	- €	255,47 €	- €	- €	- €
NAB	- €	- €	- €	- €	- €	- €	- €	48,21 €	- €	- €	- €
NAB	- €	- €	288,08 €	- €	255,47 €	- €	288,08 €	- €	186,95 €	- €	295,38 €
NAB	- €	- €	- €	- €	28,50 €	- €	- €	- €	- €	- €	- €
NAB	- €	- €	- €	- €	- €	85,55 €	- €	- €	- €	- €	- €
NAB	200,46 €	- €	310,47 €	- €	310,47 €	310,47 €	- €	310,47 €	310,47 €	- €	310,47 €
NAB	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
NAB	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
NAB	22,94 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
NAB	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	28,50 €
NAB	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
NAB	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
NAB	- €	- €	- €	- €	- €	- €	- €	- €	28,50 €	- €	- €
NAB	22,94 €	- €	- €	- €	- €	- €	28,50 €	- €	- €	- €	- €
NAB	196,25 €	- €	310,47 €	- €	310,47 €	310,47 €	- €	310,47 €	310,47 €	- €	310,47 €
NAB	200,46 €	- €	310,47 €	- €	310,47 €	310,47 €	- €	310,47 €	310,47 €	- €	310,47 €
NAB	200,46 €	310,47 €	310,47 €	310,47 €	310,47 €	310,47 €	310,47 €	310,47 €	310,47 €	310,47 €	48,21 €
NAB	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
NAB	108,18 €	- €	28,50 €	- €	- €	85,55 €	- €	- €	85,55 €	- €	- €
NAB	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
NAB	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
NAB	22,94 €	- €	- €	- €	28,50 €	- €	48,21 €	- €	28,50 €	- €	- €
NAB	- €	- €	- €	- €	- €	48,21 €	- €	48,21 €	- €	- €	- €
NAB	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
NAB	- €	310,47 €	- €	- €	- €	310,47 €	- €	- €	- €	- €	- €
NAB	- €	130,15 €	- €	- €	310,47 €	- €	- €	246,48 €	- €	- €	310,47 €
NAB	200,46 €	- €	67,60 €	- €	197,39 €	- €	28,50 €	- €	- €	- €	310,47 €
NAB	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
NAB	- €	- €	- €	- €	67,60 €	- €	- €	- €	- €	- €	28,50 €
NAB	- €	- €	- €	- €	48,21 €	- €	- €	- €	- €	- €	28,50 €

Figure 71: Freight to customer calculation no moq scenario

The summation of all the costs is done with the following:
FreighttoCustomer costs=SUM(LN3:XQ3)

29-12-2019	30-12-2019	31-12-2019	Freight to Customer Costs
310,47 €	272,38 €	310,47 €	73.276,81 €
- €	- €	165,38 €	32.100,85 €
- €	- €	- €	2.837,56 €
- €	302,73 €	- €	44.292,39 €
- €	- €	- €	2.342,84 €
- €	- €	67,60 €	2.268,27 €
288,08 €	207,74 €	280,34 €	73.512,00 €
- €	- €	- €	219,31 €
- €	- €	- €	142,50 €
- €	- €	- €	1.364,44 €
- €	- €	- €	1.332,52 €
- €	- €	- €	85,50 €
- €	- €	- €	995,25 €
- €	- €	- €	1.832,09 €
- €	- €	- €	1.980,49 €
288,08 €	255,47 €	295,38 €	75.905,85 €
- €	280,34 €	310,47 €	73.987,78 €
310,47 €	310,47 €	310,47 €	94.545,83 €
- €	- €	- €	1.707,33 €
- €	28,50 €	101,11 €	13.280,08 €
- €	- €	- €	3.865,14 €
- €	- €	- €	3.268,15 €
- €	- €	- €	4.845,83 €
- €	85,55 €	- €	3.530,23 €
- €	- €	- €	28,50 €
- €	- €	310,47 €	19.137,77 €
- €	310,47 €	- €	29.957,03 €
- €	280,34 €	- €	22.730,84 €
- €	- €	- €	931,41 €
- €	- €	- €	3.237,50 €
- €	- €	- €	5.032,03 €

Figure 72: Freight to customer summation no moq scenario

For the MOQ scenarios initially the values are selected as follows:
FTL=26
Q1=ROUND(QUARTILE(I3:LL3;1);0)
Q2=ROUND(QUARTILE(I3:LL3;2);0)

Q3=ROUND(QUARTILE(I3:LL3;3);0)

The total number of pallet places shipped in shipments that had less pallet places than the MOQ value are calculated.

PP Under MOQ_FTL=SUMIFS(I3:LL3;I3:LL3;"<"&XS3;I3:LL3;">0")

Then the number of shipments needed for the previously inefficient orders to be shipped with the value of the MOQ.

Shipments when MOQ applied=[@[PP Under MOQ_FTL]]/[@[FTL]]

Cost of changed=IF(LM3="NAB";VLOOKUP([@[FTL]];FTC_NAB;3;0)*[@[Shipments when MOQ applied]];VLOOKUP Places]:[per shipment]];3;0)*[@[Shipments when MOQ applied]])

Cost of not changed=SUMIF(I3:LL3;">="&[@[FTL]];LN3:XR3)

Costs for MOQ_FTL=[@[Cost of changed]]+[@[Cost of not changed]]

The same process is repeated for Q1,Q2 and Q3

31-12-2019	Freight to Customer Costs	FTL	Q1	Q2	Q3	Under MOQ=FTL	Shipments when MOQ ap	Cost of changed	Cost of not changed	Costs for MOQ=FTL
310,47 €	73.276,81 €	26	25,0	26,0	26,0	2389	92	28.526 €	43.666 €	72.193 €
165,38 €	32.100,85 €	26	13,0	23,0	26,0	1303	50	15.561 €	13.661 €	29.221 €
- €	2.837,56 €	26	2	2	3	130	5	1.548 €	- €	1.548 €
- €	44.292,39 €	26	16	21	26	2101	81	25.091 €	15.213 €	40.304 €
- €	2.342,84 €	26	1	1	2	70	3	835 €	- €	835 €
67,60 €	2.268,27 €	26	3	4	6	106	4	1.270 €	- €	1.270 €
280,34 €	73.512,00 €	26	25	26	26	2071	80	24.726 €	47.392 €	72.118 €
- €	219,31 €	26	3	4	4	10	0	119 €	- €	119 €
- €	142,50 €	26	1	1	1	2	0	28 €	- €	28 €
- €	1.364,44 €	26	1	1	1	37	1	447 €	- €	447 €
- €	1.332,52 €	26	1	1	1	24	1	290 €	- €	290 €
- €	85,50 €	26	1	1	1	1	0	15 €	- €	15 €
- €	995,25 €	26	2	3	3	44	2	525 €	- €	525 €
- €	1.832,09 €	26	1	1	1	53	2	637 €	- €	637 €
- €	1.980,49 €	26	1	1	1	56	2	673 €	- €	673 €
295,38 €	75.905,85 €	26	25	26	26	2308	89	27.557 €	47.191 €	74.749 €
310,47 €	73.987,78 €	26	25	26	26	2257	87	26.949 €	45.840 €	72.788 €
310,47 €	94.545,83 €	26	26	26	26	1902	73	22.708 €	70.677 €	93.385 €
- €	1.707,33 €	26	1	1	2	48	2	577 €	- €	577 €
101,11 €	13.280,08 €	26	1	5	13	770	30	9.190 €	310 €	9.501 €
- €	3.865,14 €	26	1	2	3	192	7	2.296 €	- €	2.296 €
- €	3.268,15 €	26	2	2	5	162	6	1.934 €	- €	1.934 €
- €	4.845,83 €	26	1	2	4	209	8	2.500 €	310 €	2.810 €
- €	3.530,23 €	26	2	2	4	176	7	2.105 €	- €	2.105 €
- €	28,50 €	26	1	1	1	0	0	2 €	- €	2 €
310,47 €	19.137,77 €	26	16	26	26	399	15	4.762 €	13.350 €	18.112 €
- €	29.957,03 €	26	9	19	26	969	37	11.569 €	15.524 €	27.093 €
- €	22.730,84 €	26	4	13	26	589	23	7.035 €	12.930 €	19.965 €
- €	931,41 €	26	26	26	26	0	0	- €	931 €	931 €
- €	3.237,50 €	26	1	1	3	131	5	1.564 €	- €	1.564 €
- €	5.032,03 €	26	1	2	3	209	8	2.496 €	621 €	3.117 €

Figure 73: Freight to customer calculation for the moq scenarios

The frequency reduction scenarios calculation takes place in the columns depicted in figure 74.

The total number of pallet places is calculated adding pallet places for all the dates of the year as presented below:
total pallet places=SUM(I3:LL3)

The number of shipments is calculated using the function below
Shipments=COUNTIF(I3:LL3;"<>")

The costs are calculated by the function presented below. FTC 1 shipment per week scenario=IF(52<[@[Shipments]];IF([@ pallet places]]/52<=26;IF($LM3="NAB";VLOOKUP(IF(ROUND([@[total pallet places]]/52;0)<1;1;ROUND([@[total pallet places]]/52;0));FTC_NAB;3;0)*52;VLOOKUP(IF(ROUND([@[total pallet places]]/52;0)<1;1;ROUND([@[total pallet places]]/52;0));FTC_VR[[Pallet Places]:[per shipment]];3;0)*52);[@[Freight to Customer Costs]]);[@[Freight to Customer Costs]])

total pallet places	Shipments	FTC 1 shipment per week scenario	FTC 2 shipments per week scenario	FTC 3 shipment per week scenario	FTC 4 shipment per week scenario	FTC 5 shipment per week scenario
6054,42	313,00	73.276,81 €	73.276,81 €	73.276,81 €	73.276,81 €	49.514,40 €
2407,78	197,00	31.592,99 €	19.805,76 €	23.868,00 €	31.592,99 €	31.592,99 €
129,64	48,00	2.837,56 €	2.837,56 €	2.837,56 €	2.837,56 €	2.837,56 €
3385,82	247,00	44.500,13 €	44.500,13 €	29.172,00 €	33.013,76 €	44.500,13 €
71,66	56,00	1.192,88 €	2.410,44 €	2.410,44 €	2.410,44 €	2.410,44 €
106,33	24,00	2.268,27 €	2.268,27 €	2.268,27 €	2.268,27 €	2.268,27 €
6042,12	367,00	73.466,09 €	73.466,09 €	73.466,09 €	73.466,09 €	49.514,40 €
10,00	3,00	219,31 €	219,31 €	219,31 €	219,31 €	219,31 €
2,33	5,00	142,50 €	142,50 €	142,50 €	142,50 €	142,50 €
37,42	40,00	1.364,44 €	1.364,44 €	1.364,44 €	1.364,44 €	1.364,44 €
24,32	44,00	1.332,52 €	1.332,52 €	1.332,52 €	1.332,52 €	1.332,52 €
1,25	4,00	85,50 €	85,50 €	85,50 €	85,50 €	85,50 €
44,00	16,00	995,25 €	995,25 €	995,25 €	995,25 €	995,25 €
53,33	52,00	1.832,09 €	1.832,09 €	1.832,09 €	1.832,09 €	1.832,09 €
56,36	53,00	1.192,88 €	1.980,49 €	1.980,49 €	1.980,49 €	1.980,49 €
6259,76	336,00	75.905,85 €	75.905,85 €	75.905,85 €	75.905,85 €	50.232,00 €
6104,80	317,00	73.987,78 €	73.987,78 €	73.987,78 €	73.987,78 €	49.514,40 €
7829,68	648,00	94.545,83 €	94.545,83 €	94.545,83 €	94.545,83 €	94.545,83 €
48,35	39,00	1.707,33 €	1.707,33 €	1.707,33 €	1.707,33 €	1.707,33 €
795,64	112,00	7.956,00 €	10.258,56 €	13.280,08 €	13.280,08 €	13.280,08 €
192,24	59,00	3.055,52 €	3.865,14 €	3.865,14 €	3.865,14 €	3.865,14 €
161,95	46,00	3.268,15 €	3.268,15 €	3.268,15 €	3.268,15 €	3.268,15 €
235,34	80,00	3.640,00 €	4.845,83 €	4.845,83 €	4.845,83 €	4.845,83 €
176,25	48,00	3.530,23 €	3.530,23 €	3.530,23 €	3.530,23 €	3.530,23 €
1,00	1,00	28,50 €	28,50 €	28,50 €	28,50 €	28,50 €
1516,78	133,00	19.137,77 €	15.912,00 €	19.137,77 €	19.137,77 €	19.137,77 €
2268,85	196,00	29.957,03 €	19.448,00 €	23.868,00 €	29.957,03 €	29.957,03 €
1681,13	188,00	22.730,84 €	16.506,88 €	19.476,60 €	22.730,84 €	22.730,84 €
78,00	3,00	931,41 €	931,41 €	931,41 €	931,41 €	931,41 €
131,00	54,00	2.516,28 €	3.237,50 €	3.237,50 €	3.237,50 €	3.237,50 €
261,04	60,00	3.640,00 €	5.032,03 €	5.032,03 €	5.032,03 €	5.032,03 €

Figure 74: Freight to customer calculation for the frequency reduction scenarios

Appendix C - Experimental results

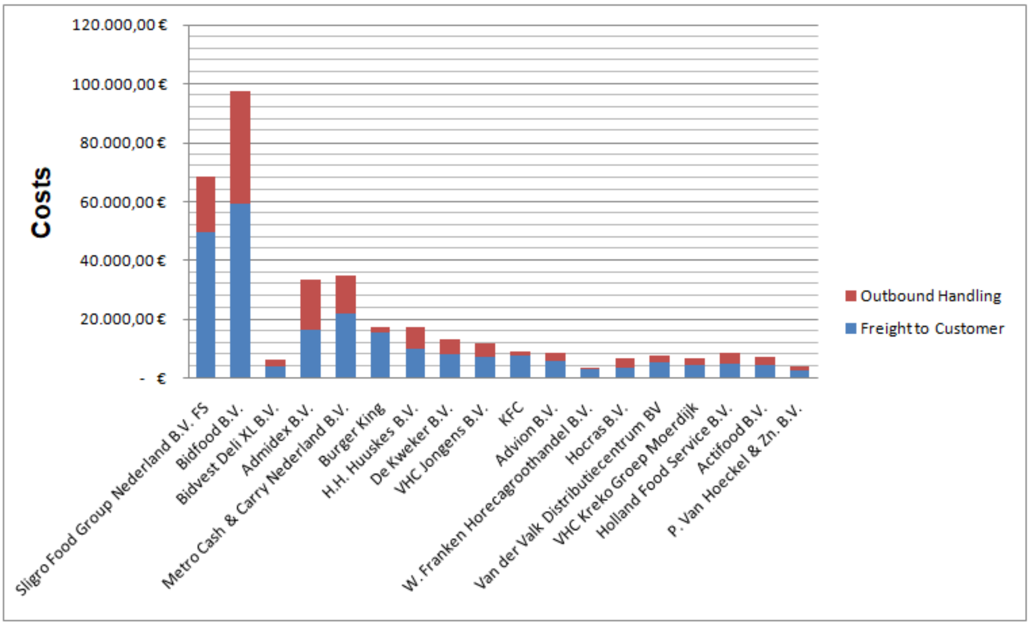

Figure 75: Cost to serve in Food Service Netherlands

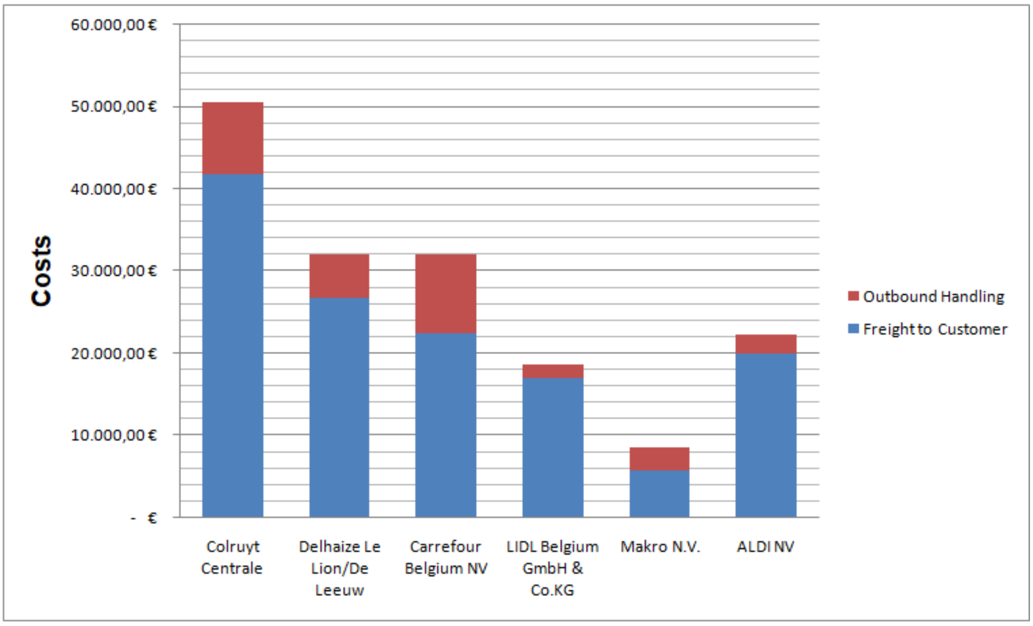

Figure 76: Cost to serve in Retail Belgium

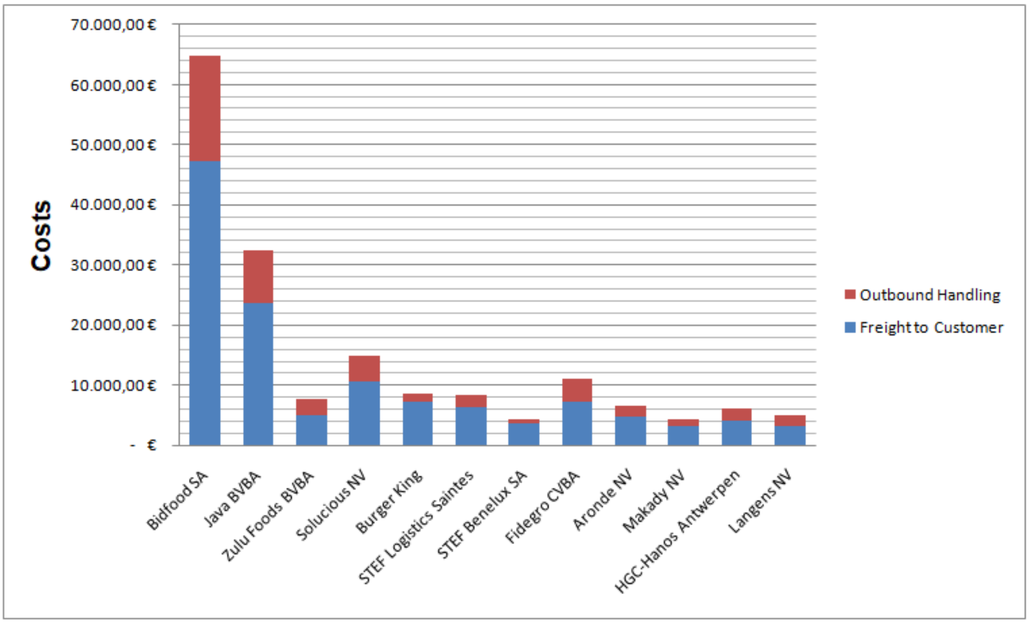

Figure 77: Cost to serve in Food Service Belgium

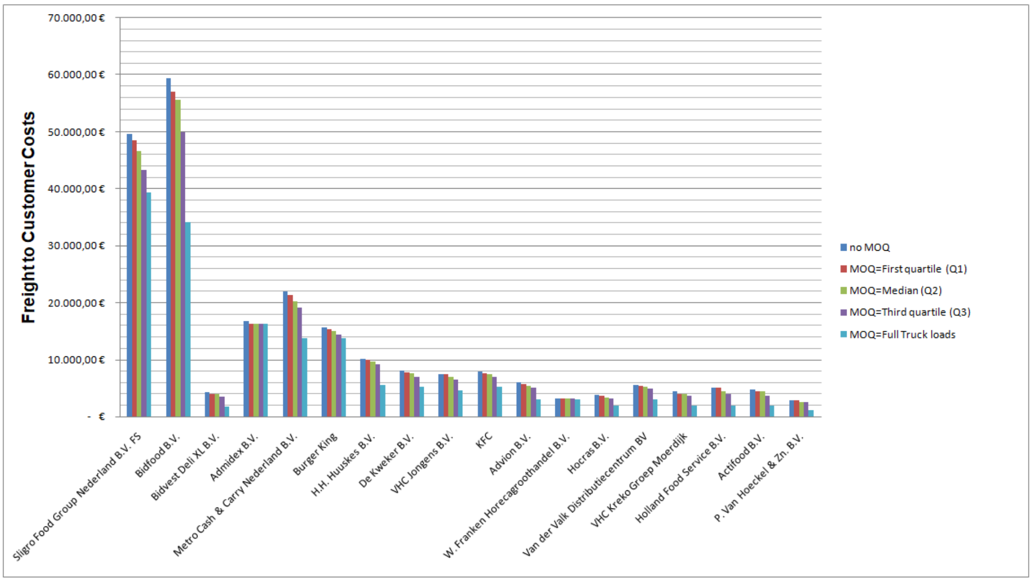

Figure 78: Freight to Customer Costs in Food Service Netherlands

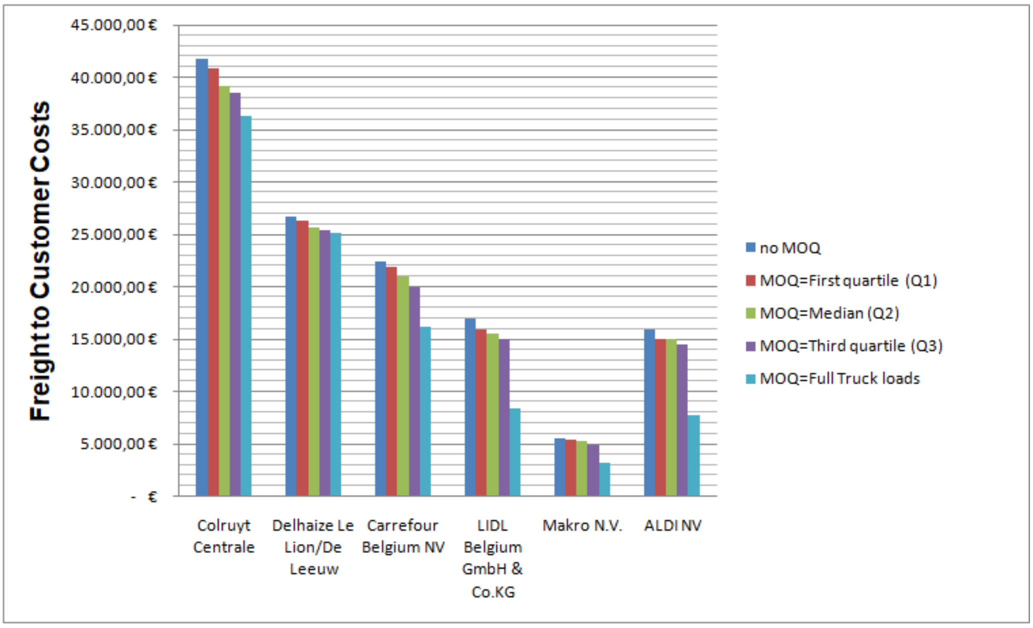

Figure 79: Freight to Customer Costs in Retail Belgium

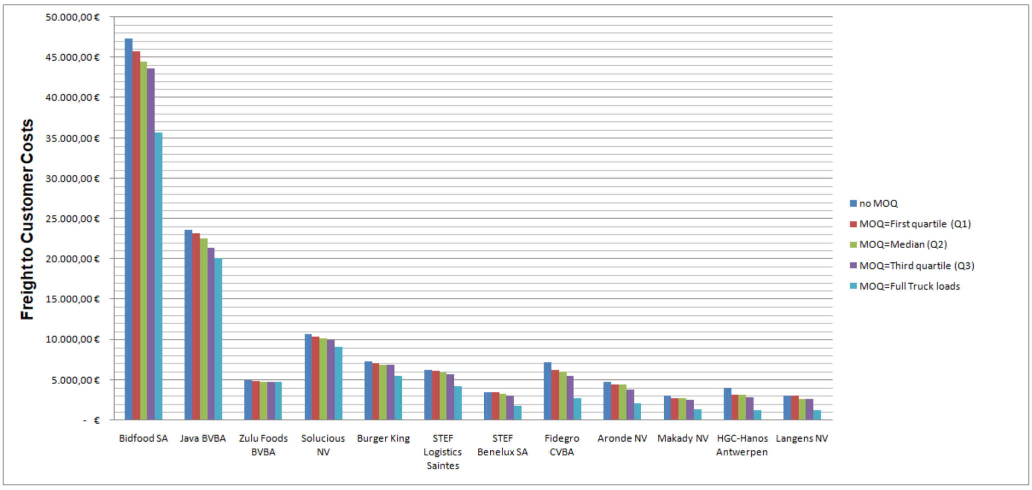

Figure 80: Freight to Customer Costs in Food Service Belgium

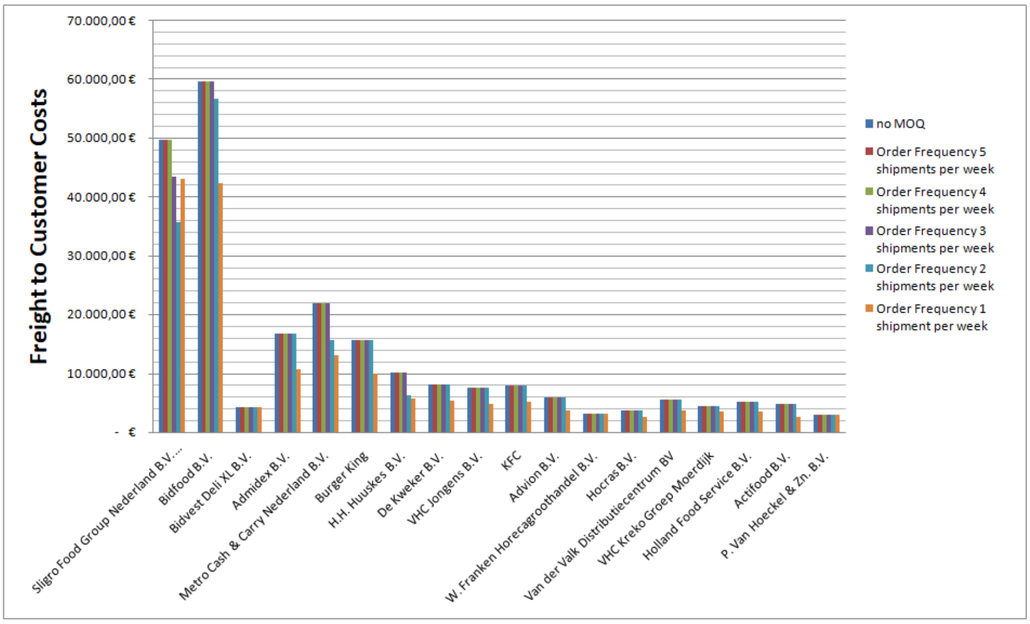

Figure 81: Freight to Customer Costs in Food Service Netherlands with frequency reduction

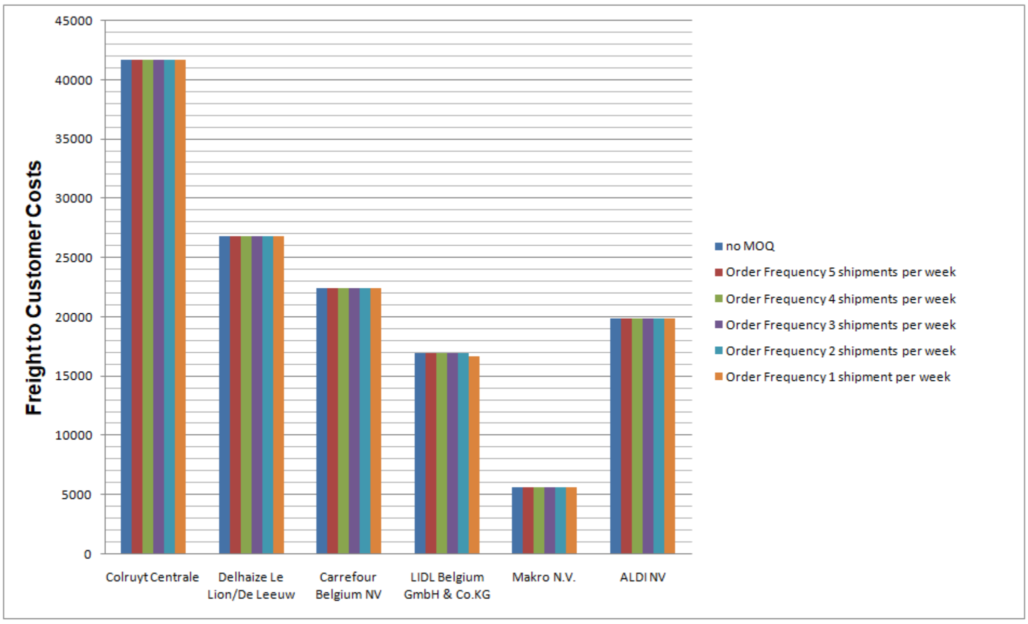

Figure 82: Freight to Customer Costs in Retail Belgium with frequency reduction

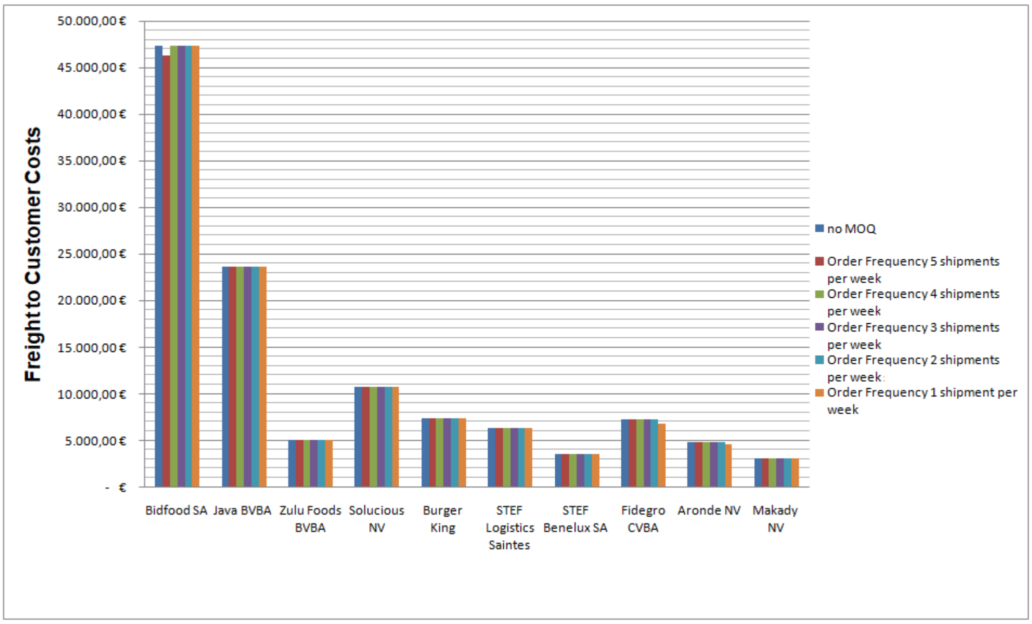

Figure 83: Freight to Customer Costs in Food Service Belgium with frequency reduction

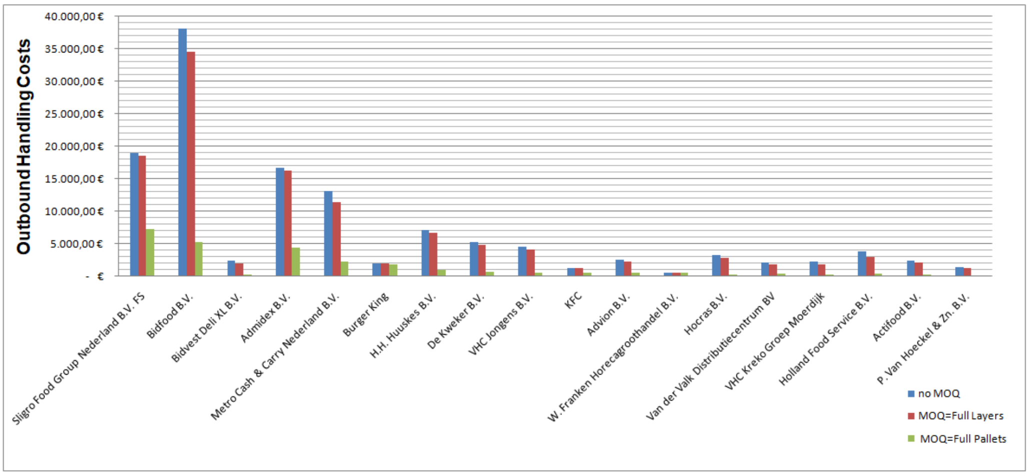

Figure 84: Outbound Handling Costs in Food Service Netherlands

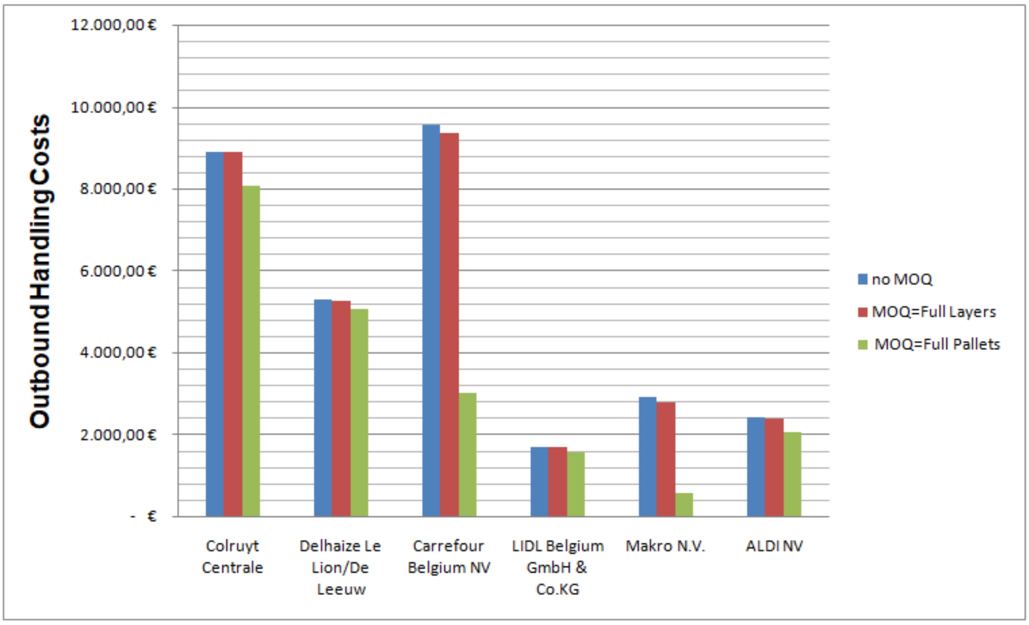

Figure 85: Outbound Handling Costs in Retail Belgium

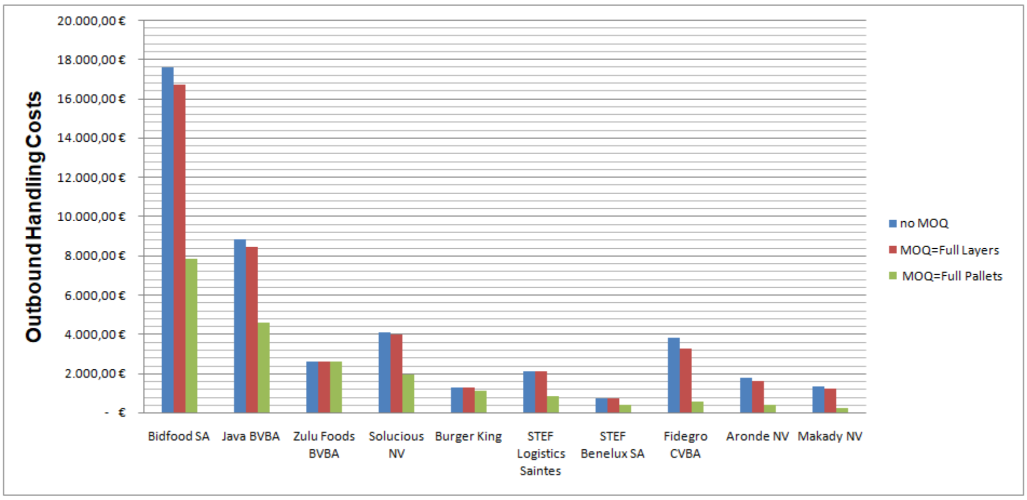

Figure 86: Outbound Handling Costs in Food Service Belgium

Customer - Scenario	**savings**	
Jumbo - 4/wk	116.116 €	
AH - 5/wk	97.861 €	
Plus - FP	71.421 €	
Jumbo - 5/wk	66.455 €	
Jumbo - 3/wk	63.341 €	
Jumbo - FTL	38.108 €	
Plus - 2/wk	36.748 €	
DRG - FP	35.532 €	
Jumbo - Q3	32.853 €	
Plus - 3/wk	29.858 €	
DRG - 3/wk	29.350 €	
Coop - 5/wk	23.813 €	
DRG - 4/wk	22.312 €	
DRG - 2/wk	21.304 €	
DRG - FTL	19.588 €	
Coop - FP	17.844 €	
Plus - 4/wk	15.994 €	
Hoogvliet - 3/wk	15.328 €	
Plus - FTL	14.783 €	
Plus - Q3	14.499 €	
AH - FP	14.100 €	
DRG - Q3	11.816 €	
Deen - FP	11.665 €	
Deen - 2/wk	11.530 €	
Hoogvliet - 4/wk	11.486 €	
Hoogvliet - FP	9.609 €	
AH - FTL	8.092 €	
AH - Q3	7.145 €	
DRG - 1/wk	7.140 €	
Jumbo - Q2	6.943 €	
Jumbo - Q1	6.943 €	
Jumbo - 2/wk	6.498 €	
Deen - FTL	5.307 €	
Coop - FTL	5.280 €	
Deen - 1/wk	5.264 €	
Coop - Q3	5.255 €	
Jumbo - FP	4.691 €	
AH - Q1	4.664 €	
AH - Q2	4.664 €	
Hoogvliet - Q3	4.070 €	
Hoogvliet - FTL	4.070 €	
Deen - Q3	3.168 €	
DRG - Q1	2.679 €	
DRG - Q2	2.679 €	
Plus - Q1	2.555 €	
Plus - Q2	2.555 €	
AH - 1/wk	2.193 €	
Coop - Q2	1.053 €	
Coop - Q1	1.053 €	
Hoogvliet - Q1	989 €	
Hoogvliet - Q2	989 €	
Deen - Q1	970 €	
Deen - Q2	970 €	
AH - FL	274 €	
Plus - FL	232 €	
Jumbo - FL	151 €	
DRG - FL	136 €	
Hoogvliet - FL	58 €	
Deen - FL	39 €	
Coop - FL	16 €	