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

D. Logothetis, Ir. M.B. Duinkerken and Prof. Dr. R.R. Negenborn
Department of Maritime and Transport Technology, Delft University of Technology, The Netherlands

***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.

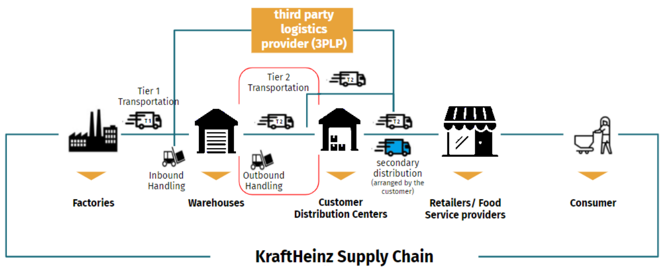


Fig. 1. Kraft Heinz Supply chain

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.

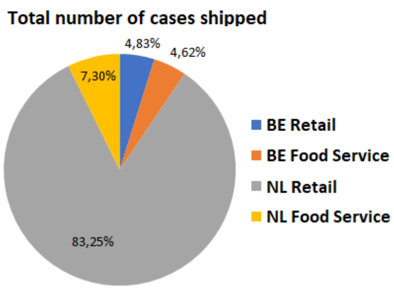


Fig. 2. cases per Country-Channel

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

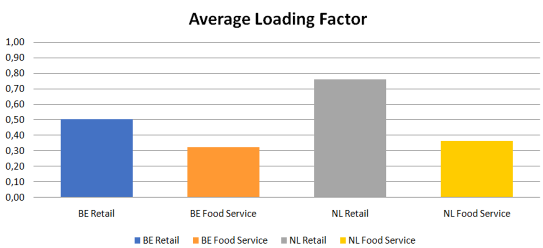


Fig. 3. average loading factor per Country-Channel

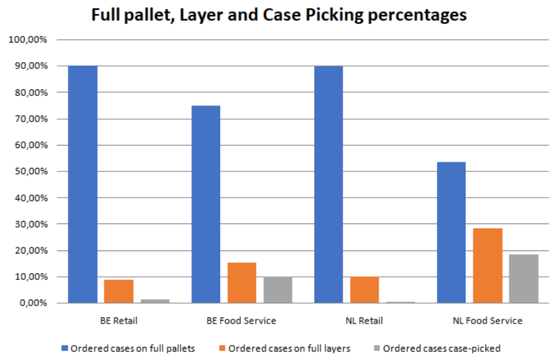
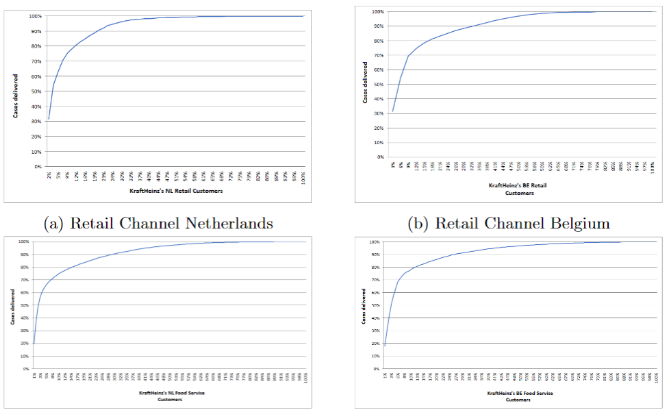


Fig. 4. Full pallet Layer and Case Picking percentages per Country-Channel

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

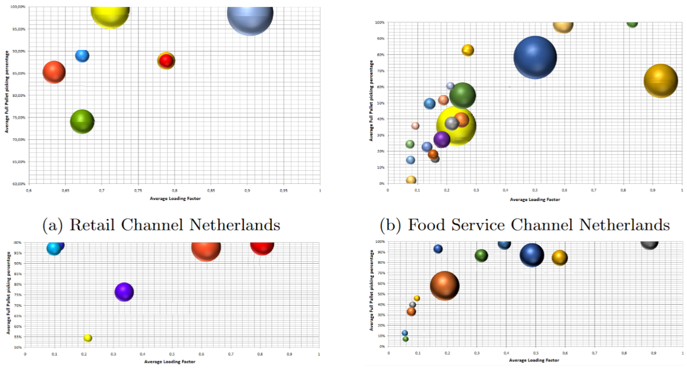
(c) Food Service Channel Netherlands

(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.



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

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.

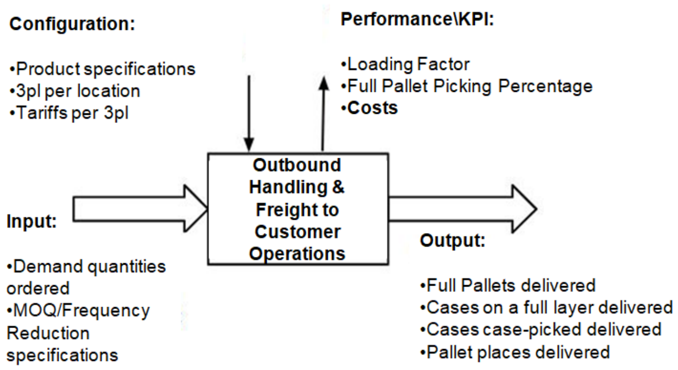


Fig. 7. black box representation of the system

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

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.

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

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.

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

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 (≤ 1) b) Medium (≤ 2) c) High (≤ 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.

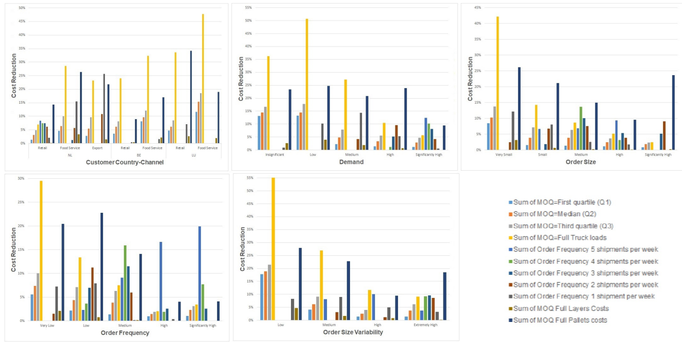


Fig. 9. performance of the design alternatives per characteristic

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

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 3^{rd} 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. Saalmann, 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. Üster 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. Baykasollu and V. Kaplanollu, "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. Srinnivas, "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. Özbayrak, 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 distribution: 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.