MASTER

How can load fill be optimized in the non-food transport sector

a case study at Van Der Wal on the definition, improvement mechanisms and impact of those mechanisms

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Master Thesis

How can load fill be optimized in the non-food transport sector: a case study at Van Der Wal on the definition, improvement mechanisms and impact of those mechanisms.

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Management summary

This thesis focuses on increasing load fill. Load fill maximization is important for the logistic sector since regulations are coming and hydrogen and electric fuel cells will probably be too late before the start of those regulations, hence the logistic sector has to find other mechanisms to reduce carbon emission. One of them is increasing load fill. A causation for the load factor being low is just-in-time transportation, this leads to storage being on roads instead of in warehouses which makes storage cheaper, however, it makes transportation costlier and more carbon intensive. One key component in the entire process is the human actor. Several human decision makers (actors) are present throughout the process, and thus an optimization algorithm is not the required solution since there are too many factors why the human actor would change the decision provided by an algorithm. Therefore, awareness is a much stronger mechanism to improve the load factor. The main research question asked throughout the thesis is:
How can non-food transport companies reduce their CO2 emissions by increasing the load factor on their 4PL shipments, while minimizing the negative effects for the end customers?

Research Methodology

The main methodology in this thesis is based on the design science approach explained by Keskin and Romme (2020). The design science approach consists of four phases, exploration, synthesis, creation and evaluation. Central in this process are the design principles, and this in total forms the design cycle. The exploration phase existed out of observations, interviews and an initial literature review. An additional literature review was conducted since there were still issues from the empirical analysis unaddressed. During both exploration cycles interviews were held with different stakeholders in the 4PL supply chain. Within the empirical analysis first a thematic framework was developed based on the transcripts of the interviews. In the synthesis, design requirements and principles were developed. These design principles were based on CAMO logic, where the Context, Agency, Mechanism(s) and Outcome(s) of the principles are explained. In the creation phase potential solution direction were developed based on the requirements and design principles. Finally, the potential solution directions and underlying design principles were evaluated using an alpha test.

Results

Within the systematic literature review firstly the definition of load fill was found. Here it is visible that load fill is measured on different levels, which makes it possible to identify on which level problems occur. In the second part of the systematic literature review the mechanisms increasing load fill are addressed. In the first place load fill can currently be increased optimizing routes. This can be done by limiting the number of warehouses and increasing them in size, this centralizes the flow of goods. Secondly, algorithms such as the Ant Colony algorithm can be used to minimize the distance traveled. Furthermore the truck space can be used more optimally. This can be done in four ways, and the first one being consolidating multiple orders into the the same truck. Secondly, customers should order full truck loads. Thirdly, the manufacturer should package products more optimally for a load unit. Finally, standard vehicles and load carrying units should be used to make consolidation easier.
The observations showed that the capacity of the vehicles was not always optimally used. There was space left in either the height and/or on the floor surface of the truck. In the thematic framework based on the interviews several themes were found. The first theme explained the load fill improvement mechanisms, these are divided into sub themes and the first being warehousing, which is already in place at Kimberly-Clark. Secondly order and delivery, which was at the time of interviewing not dealt with. Within this part of the framework, it became clear that Kimberly-Clark does not always have the required information to educate customers on the consequences of their ordering pattern, and customers themselves have no insights in the impact of their order pattern. Thirdly, the loading

principle, which is already in use, but not that much. In the first place, in some occasions 34 pallets are loaded instead of 33. This is an advanced method of loading and not all customers and warehouses are familiar with this way of loading. Additionally, loads can be double stacked, where the maximum height of a single pallet is 1.35 meter. These two mechanisms have limitations, since load can get damaged. Finally, loads can be consolidated, however there are multiple aspects that limit the ability to consolidate. These can all be explained by the fact that the number of orders is too low, or that performance is negatively impacted. The second theme explains the communication network between all stakeholders. The network is in form of a chain and no links can be skipped, only for operational communication. The chain from left to right consist of the customers, the manufacturer (Kimberly-Clark), the planner (Van der Wal) and the carriers. The third frequently occurring theme was the desired results. The results are desired on a monthly basis per unique delivery address. Furthermore, the results should explain where cost and carbon emission can be saved and finally it should also be shared with customers as well. The final theme explains the inaccuracies in the data. Firstly, the height data is not always correct. Furthermore, both promotions and stock issues decrease the accuracy of the data.

Additionally from the interviews a cause effect diagram can be made. In the first place both loading procedures and order patterns are not improved, since customers are not informed by the manufacturer. Eventually this can be explained by the fact that there is no standard procedure to inform the manufacturer and that transportation is merely a small factor in the total cost. Another cause for not improving load fill is that there is no ability to consolidate. This eventually can be explained by the fact that consolidation is not allowed since it decreases performance, or the fact that there are not enough orders to apply consolidation due to the fact that demand is too low and the customer base to small. From this insight a second literature review was done. Demand can be increased by using dynamic pricing. Additionally, supply can be increased, by using a carrier pooling network. Increasing supply helps since the chance increases for one of the carriers already having a load which can be consolidated with a load of Kimberly-Clark. Eventually this yields the following 17 design principles:

1. In order to increase load fill in the supply chain The planner and/or carrier should improve the loading procedure By using standardized vehicles Which in turn allows for an optimal use of space.
2. In order to increase load fill in the supply chain The manufacturer should improve the loading procedure By using standard load units Which in turn allows for an optimal use of space.
3. In order to increase load fill in the supply chain The manufacturer and/or customer should improve the loading procedure By using/allowing for double stacking Which in turn allows for an optimal use of space.
4. In order to increase load fill in the supply chain The manufacturer should consolidate orders By centralizing and increasing warehouses Which in turn decreases the number of lanes and thus increases the opportunity for consolidation of orders.
5. In order to increase load fill in the supply chain The planner should consolidate orders By using optimization algorithms such as the ACO algorithm Which in turn decreases the number of lanes and thus increases the opportunity for consolidation of orders.
6. In order to increase load fill in the supply chain The planner should consolidate orders By consolidating similar lanes Which in turn decreases the number of lanes and thus increases the opportunity for consolidation of orders.
7. In order to increase load fill in the supply chain The planner, carrier and/or manufacturer should increase the average order size By limiting the order options Which in turn increases the number of products per truck.
8. In order to increase load fill in the supply chain The planner and/or carrier should increase the average order size By leaving empty load units until they match a full truck Which in turn increases the number of load units per truck.
9. In order to increase load fill in the supply chain Van der Wal should analyze the impact of order patterns and loading procedures by calculating the potential cost and carbon emission saving per configuration and for double stacking which in turn yields a clear overview of potential gains and a summary of the entire customer base.

10. In order to increase load fill in the supply chain Van der Wal should aid sales department of the manufacturer in negotiations for increasing the average order volume by providing an analysis per improvement mechanism (loading and ordering in the different configurations) which in turn allows the manufacturer to incentivize (offer a discount to) customers who order in higher configurations.
11. In order to increase load fill in the supply chain Van der Wal should schedule loads based on the lowest price by tendering the load to different carriers which in turn increases the number of loads booked via a dynamic price.
12. In order to increase load fill in the supply chain Kimberly-Clark should separate transport costs from product prices by making the cost for transportation variable which in turn allows for the use of dynamic pricing.
13. In order to increase load fill in the supply chain Van der Wal should educate the manufacturer on potential savings in loading procedures and ordering patterns by summarizing the entire cost and carbon emission per region which in turn increases the utility of the analysis.
14. In order to increase load fill in the supply chain Van der Wal should provoke detection behavior by using a negative frame which in turn increases the chance of target setting by the manufacturer.
15. In order to increase load fill in the supply chain Van der Wal should determine the most impactful customers on cost and carbon emission by providing the analysis in a two-by-two matrix with data points per lane with cost and carbon emission savings on the axis which in turn makes negotiations for the manufacturer with customers more effective.
16. In order to increase load fill in the supply chain Van der Wal should make use of dynamic pricing by adding a surge multiplier to the costs for transportation which in turn increases demand for shipments that are possible to consolidate.
17. In order to increase load fill in the supply chain the carrier should should make use of dynamic pricing by adding a surge multiplier to the cost for transportation which in turn increases demand for shipments that are possible to consolidate.
18. In order to increase load fill in the supply chain Van der Wal should make use of a carrier pooling network by adding more carriers to their current network of carriers which in turn allows a cheaper price for transportation and a higher load factor when this cheaper carrier is chosen.

From these principles potential solution directions were made. Afterwards the potential solution directions and design principles were evaluated by an expert panel during an alpha test. From this alpha test the final solution has been developed.

Conclusion

In the first place load fill should be measured on the different load levels provided by Santén and Rogerson (2018). However, this framework only explains the problematic level, but not which stakeholder should act on the problematic level. Therefore, load fill should be measured by stakeholder as well.

Based on the evaluation of the final design principles and the potential solution direction the final design is developed. In this final design the planner provides an overview based on order patterns and loading procedures. First customer logistic managers need to be convinced after which they can set targets for the sales department. They can be convinced by applying a negative frame and a summary of the entire region in their account. Additionally the analysis should consist of a two-by-two matrix, from this matrix sales can easily select the customer withe the greatest impact on both cost and carbon emission. Finally, the analysis should show the impact per improvement mechanism, since not all mechanisms are applicable and now the human decision maker can decide which to apply. Finally, as recommendation for implementation, the solution should be digitally. Furthermore, to calculate the impact of the improvement measure, the profit per load unit should be measured and multiplied by the number of load units shipped in the after the improvement measure is in place.

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1 Introduction

In the introduction first the context will be explained, thereafter the problem statement for Van der Wal will be explained. From both the context and the problem statement from Van der Wal, the research question will emerge. To support answering the research question subquestions will be defined. Finally, the relevance of the thesis will be explained followed by an outline of the thesis.

1.1 The Context

One of the biggest challenges we as humans are currently facing is the climate change. The planet is getting hotter, due to the CO_2 emissions we produce. This is happening because the CO_2 works as a blanket around our planet. Due to the increasing temperature the poles melt. The melted water ends up in our oceans and causes sea levels to rise (Kalnay et al., 1996). The higher sea levels threaten our existence around coastal areas (Neumann et al., 2015). Additionally, the heating of the planet causes more extreme weather, which threatens the water supplies and the crop yields (Barnett et al., 2005; Ciais et al., 2005; McMichael et al., 2006). All in all, the climate change could threaten our existence, which is why nearly all countries collectively made a deal to stop the rise of the temperature and go fully carbon neutral by 2050 (Beleidsnota Rijksoverheid, 2020).

To go fully carbon neutral a strict legislation was made. For the transport sector this implies that by 2030 the sector needs to reduce their carbon emission by 55% (European Commission, 2020). One proposed solution is changing the fuel to hydrogen or electricity (Cullen et al., 2021). However, driving on hydrogen or electricity alone is not a feasible solution yet. The transition to other fuel cells will take longer than ten years. This can be explained by the fact that the energy density of batteries is currently too low. Hydrogen is closer to competitiveness, however, this still has some major obstacles regarding infrastructure, since it is only available at very few places (Gray et al., 2021).

Rogerson (2017) proposed several, more feasible, solutions for both the reduction of carbon emission as well as the growing demand. The author argued for more efficient use of transportation vehicles. She does this by introducing seven logistical variables. Optimizing for these logistical variables should reduce carbon emissions. The seven logistical variables are showed in Table 1.1. The first logistical variable is mode used, this refers to the mode of transportation. Not all means of transportation are equally as polluting, hence, an optimal distribution between train, ship, and truck needs to be made. Another one is handling factor, this is the number of times a product is loaded onto a vehicle. A higher handling factor most likely hints to a suboptimal route. Average length of haul is the mean distance of each link in the supply chain, these should obviously be as short as possible to reduce carbon emission. Load factor (or load fill or fill rate) refers to the actual shipment size or weight in relation to the maximum possible carrying capacity. When the load factor is higher, the amount of carbon emission per product becomes less, since the transportation is more efficient. Empty running refers to the vehicle movement without load, this needs to be as low as possible. Fuel efficiency refers to the distance travelled per fuel consumed, variables of influence here are the driving behavior and traffic conditions to name a few. When more distance is covered per fuel consumed, the emissions become lower. Carbon in fuel refers to the type of fuel that is being used. For example diesel is more polluting than bio-fuel.

Instinctively one would say that improving all logistical variables is important, however the scope for this study would be too massive to focus on all of them. According to Fedoskin et al. (2020), between 2014 and 2018 the average load factor deteriorated with 6.4 percent, this is the second greatest factor for a decrease in annual productivity of a truck. Moreover, Blinge (2014) rates the load factor increases as one of the most important success factors for a Green Corridor which supports a more sustainable logistic sector. Additionally, as one will read from the following sections there is still an enormous opportunity to improve the load factor, in the first place there are different definitions for the load

Table 1.1: Logistical variables (Rogerson, 2017)

Logistical variable	Description
Mode used	Mode of transport used (e.g. road). Shifting from modes with relatively high carbon intensity to ones with lower carbon intensity can decrease CO2 emissions from transport.
Handling factor	A measure of the number of times products are loaded onto vehicles, reflecting the number of links in the supply chain.
Average length of haul	The mean distance of each link in the supply chain.
Load factor	evaluated against maximum carrying capacity.
Empty running	Vehicle movement without a load.
Fuel efficiency	Distance travelled per fuel consumed. Depends on vehicle characteristics, driving behavior, and traffic conditions (e.g. congestion)
Carbon in fuel	Type of fuel used and amount of CO_2 emitted for that specific type.

factor. Furthermore, the load factor is measured inaccurately (Santén and Rogerson, 2018). Finally, there are several ways to increase the load factor and a lot of studies have tried to solve this problem. Santén (2017) first tried to map all solutions, and she found five main categories in which the solutions can be placed. These are: warehousing, order & delivery, packaging, loading and consolidation. However, no one has yet compared these solutions against one another. This is important since not all these solutions are effective when used together, and one solution can deteriorate the effect of the other. One example is that greater order sizes, could reduce the opportunity to consolidate orders, since smaller orders are easier to consolidate. Hence, the net effect on the load factor is uncertain.

Additionally, there are different types of transportation. First of all, FTL which means full truck load. In this case the customer pays for the entire truck capacity a fixed price. The second type of transportation is LTL, which means less than truckload. Less than truckload orders are mostly shipped with groupage carriers. The objective of groupage carriers is to consolidate multiple orders into the same truck. Therefore, they can offer a lower price for transportation. Groupage carriers operate similar as parcels, with a hub-and-spoke network. Optimizing load fill for either type of transportation brings its own difficulty.

Furthermore, in transportation the major stakeholders are manufacturers, planners, carriers and customers. Often planners and carriers are the same stakeholder, then they can be seen as the transport company. All stakeholders have different responsibilities and have there own (conflicting) values. One of these conflicting values is between the needs of customers and transport companies. Customers want to minimize their inventory since this saves money. Minimizing inventory comes from 'just in time' (JIT) transport (Kamakaté and Schipper, 2009). This JIT transport is closely related to JIT manufacturing which emerged in Japan in the early 1970s since it was developed envisioning the same goal, which is minimizing the cost for storage (White et al., 1999). This JIT behavior leads to order quantities which are less than a full truck load (LTL). This deteriorates the load factor tremendously. Transport companies have a hard time allocating this wasted space to other customers or different orders, hence more road transport is required. Additionally, to support the JIT focus, customers demand deliveries every day and make use of time windows which need to be booked days prior before delivery (Figliozzi, 2011; Rogerson, 2017). This again leads to an increase in road transport. On the contrary, an increment in road transport conflicts with the customer's demands for environmental friendlier transport (Lammgård and Andersson, 2014). A balance is required between both flexibility and the load factor to minimize carbon emissions and costs. This problem leads to the following off-setting effect: when increasing the load factor, the warehouse size increases and thus the costs for customers increases. On the other hand, when the load factor is increased, less trucks are required and thus the cost for the customer will decrease.

Throughout the decision making process for ordering, which is a key component for transport, human

decision makers are involved. This decision making process can be explained as following, a predictive algorithm generates a forecast for the human decision maker and this human decision maker has a monitoring role on the forecast. This is similar as a 'human-in-the-loop' structure described by Pardo et al. (2022). This human decision maker often makes changes to a forecast based on rational factors, such as transient factors, transferred impact factors, new seasonal factors, quantum jump factors and trend change factors (Jae Kyu Lee et al., 1990). Furthermore, there are some non-rational judgemental factors which consists out of two categories; decision biases and utility functions. Some decision biases are: pull-to-center, mean anchoring, demand chasing (Hoskin, 1983; Schweitzer and Cachon, 2000). Utility functions refer to preferences of the planner that impacts their decision, such as: risk preferences, loss aversion and mental accounting (Eeckhoudt et al., 1995; Katok and Wu, 2009). Other factors that could encourage decision makers to change a forecast are: the inability to distinguish statistical patterns from noise and the display of attending to the task of reviewing (Fildes et al., 2009; Lawrence et al., 2006). Eventually, it is likely that human decision makers will change an optimal provided solution by adjusting the forecast, due to all aforementioned factors. This is especially true when the optimization is done based on the manufacturer's cost for transportation, and likely to be far from optimal for customers. Hence, the human decision maker (at the customer's side) is likely to change the order size which deteriorates the load factor due to the fact that customers are likely to change a recommendation provided by the manufacturer for a given quantity.
To conclude the introduction, there are three off-setting effects at play while improving the load factor. The first off-setting effect explains the cost component: for a higher load factor, larger warehouses are required. This is argued by the work of Santén (2017) as one of the main points to improve the load factor. Memari et al. (2016) also explains the occurrence of this effect briefly. However, this comes with a negative effect, this namely drives up the costs. The second off-setting effect is when load fill is increased less trucks are required and thus costs decrease. To optimize this net effect it is important to minimize the first effect and maximize the second effect. In order to reach this optimization, consolidation efforts should always be discussed with the customer to see what is possible for them without needing to increase their warehouse size. Additionally, the first part of the effect decreases the willingness for customers to cooperate, while the second part of the effect increases the willingness for cooperation since the first effect is beneficial for them and the second is actually disadvantageous. This off-setting effect is represented in Figure 1.1.

Another off-setting effect is: when the JIT principle is relaxed, the time for consolidation increases

Figure 1.1: Off-setting effects on costs for customers

and the load factor will increase, however this relaxing effect consequently slows the delivery speed and thus leads to lower customer satisfaction. This principle is introduced by McKinnon (2016). In his work he studied the exact effect of de-speeding the logistics industry in order to achieve a decrease in carbon emission. This is done by relaxation of the JIT mindset. One of the effects of this relaxation is that there would be more time for consolidation, and this will eventually increase the load factor. On the other hand, this leads to a longer delivery time and thus to a longer overall cycle time. This off-setting effect can be found in Figure 1.2 One of the most important aspects of a well-performing service provider in the supply chain is speed (Lim et al., 2021), thus this decreases the overall service quality. This time a good balance must be struck, since maximizing the first effect increases the load factor, however when the first effect is too strong, customers will become dissatisfied, due to the lack of service speed.

Figure 1.2: Off-setting effects from relaxation of JIT

The third and final off-setting effect explains the effect that an emission cap can have on the actual emissions. Strict carbon caps increase the yearly orders, which increases the actual emission. On the other hand, moderate caps reduce the yearly orders and thus reduces the actual emission. When an emission cap is very strict the chances for retailers of being out of stock increase, since they reached the cap for carbon emission. To fulfill demand the system requires shipping levels at the maximum possible level. These tighter caps can remove a company's opportunity to emit more in one period if this implies a significantly smaller total emission in other periods. On the other hand moderately strict emission caps could actually help in reducing the total amount of CO_2 emission (Memari et al., 2016). This effect is also visible in Figure 1.3

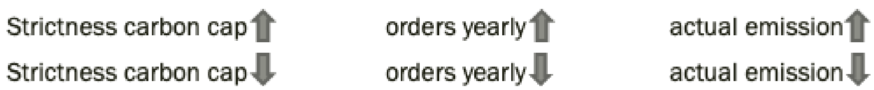

Figure 1.3: Off-setting effect emission cap

1.2 Problem statement Van der Wal

Van der Wal conducted a research on the load factor with one of their own fourth party logistics (4PL) customers (Kimberly-Clark). 4PL here means that Van der Wal is completely responsible for the transport of their customer. In this role Van der Wal links transport companies to their customer and can thus be seen as the planner. Hence, customers order goods directly from Kimberly-Clark. Van der Wal has a direct link with the information system from Kimberly-Clark to receive the orders placed by customers. Van der Wal then plans transportation for these orders at different carriers depending on the cheapest price. The carrier has half an hour to accept the tender before it is tendered to the second cheapest carrier. Van der Wal found that a lot of space is left in their trucks. Some trucks have floor space left, others have space left on top, but the vast majority of orders have both. The process of receiving the orders and tendering the orders out to carriers (who ship the order) is mostly automated, thus Van der Wal has very little insight over what is actually happening other than seeing the number of pallets which are transported by the transport company. The only ones that really see what is happening are warehouse personnel and truck drivers, however they are not (or less) concerned with the load factor than Van der Wal. To explain the problem in more detail the following example occurred at one of Kimberly-Clark's customers. An employee at Van der Wal noticed that pallets were only 1.6 meter high, while the truck is approximately 2.7 meters high. 1.1 meter is thus empty space within the truck. This means that approximately 41% of the space is wasted. This employee found three probable causes for the low load factor. In short they are automation, just-in-time manufacturing, and customized packaging. These causes will be explained in more detail below.

In the first place, automation can deteriorate the load factor. With this automation load was automatically transformed in a full-truck load (FTL), while the actual shipment existed out of 20 to 25 pallets. This comes short to the actual FTL of 33 euro pallets (Lusby et al., 2010). This thus creates empty space. Rogerson and Sallnäs (2017) show that this problem does not only appear at Van der

Wal, but in more contexts as well. In their study smaller orders are placed several times a week. This could be caused by a lack of cooperation and communication between customer and manufacturer.
Another cause for the problem is JIT transport as explained in the previous section. Van der Wal encountered multiple problems with JIT transport on the load factor. First of all, it is much harder to make a planning. JIT manufacturing causes a lot of irregularities in shipments and thus it is much harder to consolidate orders. Furthermore, some orders from the manufacturer come through late and cause a lot of delays, which further deteriorates the planning. This became visible for them since domestic shipments perform worse than international shipments, which need to be booked more in advance. Timeslots make these domestic shipments even more complex. Customers of Kimberly-Clark book a shipment for a specific day and loads are confirmed by Van der Wal quite early, since this reserves a timeslot at the customer. However, this order is far from optimal since in most cases less than 33 pallets are ordered. Quite often an additional shipment is ordered for the same day, however since the order has already been booked it is moved to another day or the same day and a different carrier delivers the shipment. In an ideal situation the same carrier consolidates the two shipments into one shipment, however this is not always possible. When this is possible the two shipments are settled separately, thus one load is purchased twice. This increases the price significantly for the same shipment compared to when the two orders are consolidated by Van der Wal before booking the time slot. These time slots also complicate the consolidation process to the point that far from ideal orders are booked as FTL. Rogerson and Santén (2017) found this in their work as well.
Finally, Van der Wal found that the use of customized pallets is detrimental for the load factor as well. In the first place, an effective lay out must be made manually, which takes significantly more time, compared to when the load is standardized, because it is generally accepted that a truck can ship 33 pallets (and 66 when double stacked) (Lusby et al., 2010). Furthermore, there is the risk that customized pallets could damage other pallets. Due to its irregular shape, it is more difficult to handle for warehouse employees, and thus chances are higher for damaging other orders. A solution for this effect is that customized pallets are given more space than required, which reduces the load factor.

1.3 Research Questions

From both the problem statement and literature it is clear that there is a problem regarding load factor. All improvement mechanisms eventually have some negative effects for the end customers, since they need to give up some flexibility in order to increase the load factor. This leads to the following research question:

How can non-food transport companies reduce their CO_2 emissions by increasing the load factor on their fourth party logistics (4PL) shipments?

From literature it is obvious that fill rates are not measured universally the same. First of all, there are multiple means to calculate the fill rate. The second problem is how data is collected, the literature shows that volumetric fill rates are only guessed, and the weight is measured very poorly. Furthermore, In the problem statement it becomes clear that the right information is often missing, since Van der Wal only plans transportation for orders booked by Kimberly-Clark's customers. Moreover, when problem causes are found, which deteriorate the load factor, it is hard to find the best solution. This leads to the following sub question:

How should the fill rate be defined, what information should be collected and how should this information be collected?

Within the literature numerous improvement mechanisms are proposed and these exist in four main categories, namely order & delivery, packaging, loading and consolidation. these main categories have never been compared against each other and how they relate to the different load levels. This is important since using multiple mechanisms at the same time can actually deteriorate load fill instead of improving it. This leads to the following sub question:

How do the different load fill improvement mechanisms relate to each other and to the load factor levels?

Currently, the effect of different load fill improvement mechanisms has not been calculated therefore, it is hard to decide whether applying a mechanism is worth the effort. Hence, this yields the following sub question:

How can the impact of the different means for load fill improvement be calculated?

1.4 Academic and practical relevance

Several academics already tried to increase load fill, however since 1990 to 2020 the load factor is rather stable, despite all recommendations present in current literature (Cruijssen, 2012; European Environment Agency, 2009; van der Meulen et al., 2020). This can be explained by the fact that JIT is the main principle for business operations, since this reduces cost for inventory. On the other hand, customers lack the appropriate information to balance the the first off-setting effect presented in the introduction, between inventory cost and transportation cost, since transportation costs are included in the price for the product. New approaches are thus required to inform the customers with the correct information, so that they can balance the inventory costs with the transportation costs. Hence, in this thesis a foundation will be build to make a fair comparison between the off-setting effect presented in Figure 1.1. This eventually will help managers of companies within the supply chain to make a fairer

Table 1.2: Overview of the current literature on the load fill improvement mechanisms

Study	Packaging	Loading	Consolidation	Ordering
Abate (2014)			✓	
Ahmad et al. (2022)	✓			
Allcock et al. (1997)		✓	✓	
Aronsson and Huge Brodin (2006)		✓	✓	
Biswas and Anand (2022)		✓		
Bø and Mjøsund (2022)				✓
Calabrò et al. (2020)			✓	
Cruijssen (2012)			✓	
Gattuso and Cassone (2011)			✓	
Hellström and Nilsson (2011)	✓			
Liljestrand et al. (2015)			✓	
Liljestrand (2016)		✓		
Mckinnon (2000)		✓		
Özen et al. (2020)		✓		
Rogerson (2017)				✓
Rogerson and Sallnäs (2017)	✓		✓	✓
Rogerson and Santén (2017)	✓			
Santén and Rogerson (2018)	✓	✓	✓	✓
Triantafyllou et al. (2014)			✓	
Turkensteen and Hasle (2017)			✓	
Twede et al. (2000)	✓			
Wever (2011)	✓			

comparison between inventory and transportation cost. This fairer comparison supports optimization algorithms with exhaustive information on all cost components, and move from a sub-optimal solution to an optimal solution.

Secondly, in current literature several mechanisms exist which try to increase load fill. These mechanisms are improving packaging, standardizing and improving loading procedures, consolidating multiple orders, and increase order sizes. These will be further explained in section 3.2. Some of these mechanisms to improve load fill can actually deteriorate load fill when utilized at the same time. This can be explained by the fact that consolidation is easier to apply on smaller loads, however this contradicts with the measure of increasing order sizes, to better fill trucks. Eventually, this can lead to medium sized loads which are both harder to consolidate and do not fill a complete truck. Hence, this thesis will provide an outline on what mechanisms can be utilized simultaneously and the how and when what mechanism should be applied. This is currently not present within the literature. An overview of the literature and which improvement mechanism is discussed is presented in Table 1.2. Remarkable in Table 1.2 is that only in the study conducted by Santén and Rogerson (2018) all four main improvement mechanisms are presented, however these solely presented and not compared.

Finally, in current literature there is not a concise view on load fill. Santén (2017) recognized this problem and tried to introduce a clear definition for load fill. In this study the author named five different definitions for load fill and eventually concluded that multiple should be used to present a complete picture on load fill. On the other hand, this definition lacks a stakeholder. Not all stakeholders in the supply chain can actually improve load fill on all different levels. A clear example would be packaging, mostly the manufacturer is able to influence how the product is packaged, and how much air is shipped within the product. Therefore, other stakeholders in the supply chain cannot be held responsible for the actions of one. Another problem that emerges with the current definition of load fill is that on some levels multiple stakeholders are responsible to increase load fill. This is actually a harmful development, since, in psychology, this is explained as the diffusion of responsibility. A clearer example in this case would be the bystander intervention. The more bystanders there are, the less likely it is that one will intervene, since they see the others as responsible (Darley and Latane, 1968). Within this thesis the responsibility per stakeholder will thus be addressed and in case of shared responsibility the actions per stakeholders will be discussed.

1.5 Thesis outline

This thesis consists of eight chapters, and each chapter has its own purpose. The first chapter introduces the subject of the thesis and explains the context at which the subject was researched. Moreover, the first chapter introduces the research question and supporting sub questions. Finally, the academic and practical relevance is explained. In the second chapter the methodology is explained, first why this methodology was applied for this thesis, thereafter how it was applied. Later in this chapter the methodology for the systematic literature review and empirical analysis are explained. Finally, an overview of the complete structure of the thesis is provided. The third chapter describes the systematic literature review that was conducted consisting of three sections, which are the definition of load factor, the mechanisms to increase load fill and the design principles. The fourth chapter focuses on the results of the empirical analysis that have been found within the observations and interviews. In chapter five first an additional literature review is conducted based on the results, thereafter chapter five tries to synthesize the results of the empirical analysis and the systematic literature review, finally in this chapter the final list of design principles are presented. Chapter six presents three different potential solution directions which are afterwards evaluated together with the final list of design principles. In chapter the final solution is presented, together with the design requirements and underlying calculations. Finally, in chapter eight the (sub) research question(s) is/are answered. Thereafter, the limitations of this thesis are addressed and future research directions are presented, followed by the overall contribution to the literature and managerial implications.

2 Methodology

Within this section of the thesis first the arguments for the method of choice will be explained, followed by an outline of how the design science methodology will be applied to this thesis. Thereafter the different phases of the design science methodology cycle will be addressed. Finally, the overall structure will be presented in an overview of all steps which were taken.

2.1 Design Science

At first sight the most appropriate method would appear to be using an optimization algorithm. However, there are human decision makers present in the process who have a monitoring and correcting role. These human decision makers will correct forecasts based on aforementioned arguments in the introduction. For this reason a more human-centric approach; "human-in-the-loop" was favored. In general "human-in-the-loop" entails that a human always need to look over the outcome of an algorithm or simulation (Ketcham et al., 1992). Therefore, one can see that this problem cannot be solved with understanding alone and solutions need to be evaluated with this human decision maker. One method that compares practice with theory is design science (Keskin and Romme, 2020). In their work the authors explain how design science can help in managerial and organizational challenges. Design is described by Simon (1996) as the activity of changing existing situations into desired situations. More recently it became more popular to use design in the field of management, here for example Brown (2009) argued that design can be applied as attitude as well (design thinking). This method is about learning by doing and involves a lot of stakeholders. Important design activities are understanding the user needs, define the problem, conceptualize the solution, conducting an analysis to optimize the solution and evaluating the resulting design solution (Suh, 2001). The result of a design process will always be an artifact, and thus the outcome will be referred to as artifact. This artifact can range from a physical product to an intangible project (Bolland and Collopy, 2004; Dresch et al., 2015). Especially the aspect of including stakeholders in the process made this method the most appropriate one. Developing a potential solution can be a political process, where different stakeholders have different benefits from the solution. Most importantly when the human actor is involved in the process, which occurs frequently in design science, the artifact will be implemented more effectively (Holmström et al., 2009).

To include design activities in the methodology, the methodology developed by Keskin and Romme (2020) is used. In their work, the authors explain that a solution can be found while combining both literature and practical research. This is done by using the generic design science (DS) cycle, a visualization of this cycle is visible in Figure 2.1. Central in this framework are the design principles. Design principles are proven theories which help to reach the desired outcome (Romme and Endenburg, 2006). In the generic DS cycle four steps are described; explore, synthesize, create and evaluate. These will be explained in more detail in their respective section.

Furthermore, to get a better understanding of the problem a theoretical and empirical analysis are conducted, within the exploration phase (explore in Figure 2.1). In the synthesis phase (synthesize in Figure 2.1) the results of both analyses are synthesized into design principles and design requirements. Both the requirements and principles are the building blocks which shape the solution designs and determine the boundaries (Keskin and Romme, 2020). The first step of the creation phase (create in Figure 2.1) exists of a diverging process where multiple proposed solution designs will be generated. The second step is the converging process of these multiple proposed solutions into one final solution. In the evaluation phase (evaluate in Figrue 2.1) the final solution is evaluated.

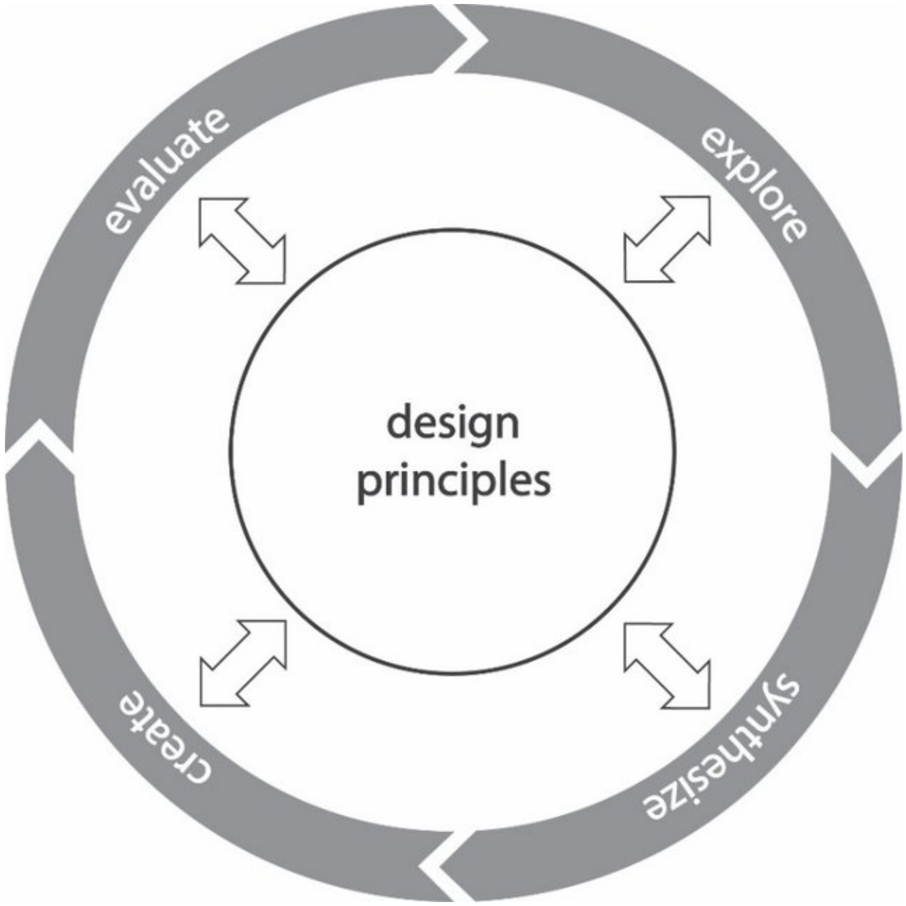

Figure 2.1: Generic Design-Cycle (Keskin and Romme, 2020)

2.2 Exploration

For the exploration phase of the project, both a theoretical analysis and empirical analysis have been conducted. These are more elaborately explained in their respective subsection. The theoretical analysis existed of a systematic literature review and the empirical analysis consisted of semi-structured interviews analysed by grounded theory building, systematic observations and informal interviews.

2.2.1 Systematic literature review

The methodology of the systematic literature review is mostly based on the work by Kitchenham and Charters (2007). The review was conducted to understand the full context of the problem. For this search Scopus was used as article database, since Scopus allows for longer Boolean operates. Boolean operators were used to search for articles. From the research questions a search query has been established by making a list of synonyms, abbreviations, and alternative spellings of the individual facets within the research questions (Kitchenham and Charters, 2007). After a few iterations and a trial-and-error process the following two queries have been established:

"(("fill rate" OR "fill-rate" OR "load factor" OR "load-factor") AND ("transport" OR logistic) AND ("truck" OR "road"))"*

The second search query was:

Table 2.1: Search strategies and results

Library	Scopus	Scopus
Search query	"(("fill rate" OR "fill-rate" OR "load factor" OR "load-factor") AND ("transport" OR logistic*) AND ("truck" OR "road"))"	"vehicle fill rate" OR "vehicle fill-rate" OR "load factor") AND logistic*)"
Search in	Abstract	Abstract
Filter	Journal Article	Journal Article
Filter	English	English
Filter	No author	No author
Filter	Wrong means of transportation	Wrong means of transportation
Results before filter	109	95
Results after filter	14	12
Unique results	22	

"(("vehicle fill rate" OR "vehicle fill-rate" OR "load factor") AND logistic)"*

This search query was used on abstracts of papers because this has the highest probability of yielding results about the load factor of trucks. Additionally, search filters were applied to increase the percentage of relevant articles. Search filters were: All articles should be journal articles, since these are peer-reviewed before publication, which increases the validity of the study. Furthermore, all articles should be written in English, since this is the language for research worldwide. The first exclusion filter was when no author has been mentioned, since this worsens the credibility and validity of the work (Kitchenham and Charters, 2007). Another exclusion filter was the wrong means of transportation. The search still yielded numerous results in the sea, train and air industry, so these were excluded as well. This since the context of the problem is solely road transportation. Eventually, this yielded 22 unique journal articles which were used as a basis for writing the literature review. Additionally, some cross references were used to elaborate further on some parts of the text. In Table 2.1 the final results of the literature review can be found.
ProQuest has also been considered as database, here 63 articles have been found and 7 of those 63 were duplicates. All other 56 articles were deemed irrelevant, based on criteria described in Table 2.1.

2.2.2 Empirical analysis

For the empirical analysis, multiple different approaches were used to gain information about the context of the problem and to create the design requirements and principles. These were semi-structured interviews, observations and some additional informal interviews. The research can be seen as a single-case study since the case investigated is load fill improvement (Bryman and Bell, 2011).
For this thesis the interviews were conducted in a time period of around four weeks. Within this period the interviews were also transcribed. The group of interviewees consists of three logistic engineers, two 4PL planners, a 2PL planner from Van der Wal, four customer logistic managers and a transport and sustainability leader from Kimberly-Clark, a transport manager from Kimberly-Clark, two planners from Van der Wal, two customers from Kimberly-Clark, one planner from the 2PL division from Van der Wal (which acts as a carrier) and one truck driver from MKG. This totals to twelve interviewees and according to Galvin (2015) this is the saturation point and from additional interviews hardly any new insights arise. Furthermore, barely any new insights were gained from the latter interviews which was additional proof that saturation had been achieved. A full list of the interviewees can be found in

Interviewee number	Job description	Firm
1	Logistic engineer	Van der Wal
2	Transport and sustainability leader	Kimberly-Clark
3	Planner Iberian domestic region	Van der Wal
4	Business unit manager	Van der Wal
5	Planner German domestic market	Van der Wal
6	Logistic engineer	Van der Wal
7	Customer logistic manager	Kimberly-Clark
8.1	Customer Business Manager Brand & Retailer Brand	Kimberly-Clark
8.2	Customer Business Manager Brand & Retailer Brand	Kimberly-Clark
9	Truck driver	MKG
10	Planner 2PL (can be seen as carrier)	Van der Wal
11	UK Customer Logistics Manager	Kimberly-Clark
12	Logistic engineer	Van der Wal

Table 2.2: List of interviewees

Table 2.2.
The interviews had three main themes, first the interviewee was asked about their function and responsibilities. The second theme entailed their role in increasing load fill, or how they increase the number of products per truck. During the final theme, the required data to increase load fill was discussed. Questions supporting the themes varied between the different functions of the interviewee. The duration varied between the different interviewees depending on when saturation for that specific interview was achieved. Afterwards the interviews were transcribed as soon as possible.

To further gain an understanding about the context of the problem, non-participant observations were made as well. These were done in a systematic way as is described by Bryman and Bell (2011). During the observations information about loads was collected visually and within the information system of Van der Wal. These different sources of information were compared to check if there were any deviations. The observations were made in Dormagen, Germany at a Kimberly-Clark warehouse on the 2nd of November, from 7.30 AM to 2.00 PM, which was a regular day at the warehouse. The warehouse in Dormagen is rented by Kimberly-Clark and is mainly used for shipments to the German domestic market. This warehouse has two docks, however in some cases three trucks can be (un)loaded at the same time. Both groupage and FTL carriers ship orders from this warehouse, however only the FTL orders were recorded the day the observations took place. This is due to the fact groupage carriers coincidentally came when other shipments were being observed.

Finally, some informal interviews were held during breaks to get a better understanding of the context of the problem.

For analyzing the semi-structured interviews the method by Dougherty (2002) was followed. In her work she explains how a qualitative analysis based on GTB (grounded theory building) should be conducted. With GTB the inherent complexity of social life is captured, which helps to explain the context of the problem. GTB aims to name and explain the complexity of organizations. This method is especially helpful in this context due to the complex collaboration between Kimberly-Clark and Van der Wal. Furthermore, GTB is the most commonly used method for analysis in single-case studies and for answering the "*how*" a phenomenon exists (Bryman and Bell, 2011). From this method a practice for qualitative interview data analysis is developed and this data analysis practice exists in three steps which must be conducted simultaneously and iteratively, however the first step should be conducted more towards the beginning and the last step more towards the end. The first step is open coding. With open coding data is labeled and categorized. In the early stages the intention is to create

as many themes as possible. The second step is axial coding, this step is an intense analysis around one category at a time across the data and to find as much data as possible around one theme. The final step is selective coding. With selective coding the core themes that connect all other themes are found. This process had been repeated three times to improve reliability and thus to check whether the outcomes hold after repetition.
Eventually, the different type of data sources (interviews, observations and systematic literature review) triangulate the data and finally data triangulation leads to improved validity of this research (Flick, 2004).

2.3 Synthesis

The synthesis phase was about sense making and forging connections between the different works of others (Keskin and Romme, 2020). Within this phase design principles and design requirements were developed.

2.3.1 Design Principles

From the systematic literature review, design principles were formulated. Santén (2017) provided different solution directions to increase load factor and these directions were used as a starting point for the design principles. While conducting the systematic literature review other solutions were distributed over the directions Santén (2017) provided. These solution directions were then synthesized into design principles within a CAMO (Context, Agency, Mechanism and Outcome) framework. The CAMO framework is based on the CIMO framework described by Denyer et al. (2008). CIMO stands for context, intervention, mechanism and outcome. They describe these components as following: context are the surrounding factors and the nature of human actors. Interventions are the interventions managers have at their disposal to influence behavior. Mechanism is the mechanism that in a certain context is triggered by the intervention. Outcome is the outcome of the intervention in its various aspects. The CAMO framework developed by Romme and Dimov (2021) varies on one point with CIMO, namely the intervention has been replaced by agency. This has been done since the intervention merely describes the action where the agency describes the actor as well. All in all, these design principles helped by creating solution designs as these are the interventions and mechanisms at play to yield the desired state.

2.3.2 Design requirements

To create boundaries for the desired state, requirements are set. Keskin and Romme (2020) describe that these can both be grounded from literature and field research. Within this thesis the requirements were mostly based on the empirical analysis and then especially the formal interviews. These interviews were merely focused on gaining information on the current state for improving load fill, the desired state for improving load fill and defining the solution space. With the help of several types of design requirements the solution space is defined. These different types are functional requirements, user requirements, boundary conditions and design restrictions. Functional requirements describe the core of the specification in the form of performance demands on the artifact to be designed. User requirements take the point of view of the user. Boundary conditions must be met unconditionally and finally the design restrictions define the preferred solution space (van Aken et al., 2007).

2.4 Creation

Creation was done two times this thesis. In the first phase a sprint prototype was build on the systematic literature review, half the interviews and all observations. The design of the sprint prototype

was developed with the help of informal interviews with employees from Van der Wal based on load fill. This helped gaining an understanding of both the context and the problem. This sprint prototype is based on an agile project management approach, which originates from the field of software development. Benefits of this approach are that the prototype is more adaptive for changes required by the customer and improved development productivity (Cooper and Sommer, 2016). Eventually, the first sprint design was made under the supervision of an engineer from Van der Wal, and when finished, the supervisor tested the initial sprint design at Kimberly-Clark. Additionally, the first sprint prototype served as a foundation for for one of the potential solution directions.
The second creation phase mainly consists out of a diverging phase. Here the different potential solution directions were developed. The first two potential solution directions were developed during a brainstorm session, and the third potential solution direction is based on the sprint prototype. The potential solution directions are based on the design principles, systematic literature review, ideas from Van der Wal and my own creativity. The objective of this phase was to create as many ideas as possible. The second part of this process aimed at converging ideas into a few potential solution directions.

2.5 Evaluation

Eventually all potential solution directions and underlying design principles were evaluated against one another. For the selection process weighted scoring will be used. The weighted scoring method consists of evaluating multiple criteria and their respective weight. Weights and evaluation criteria were developed together with two engineers form Van der Wal. Additionally, to further evaluate the multiple solution directions, an expert interview (or Alpha test) was conducted. During the interview the artifact is submitted to a panel of experts. The experts imagine how the artifact will interact with problem contexts imagined by them. Then they predict the effect the artifact has in the context. When the artifact does not have the desired effect the artifact should be redesigned (Wieringa, 2014). This expert panel consists of the same two engineers from Van der Wal who also helped in developing weights and evaluation criteria.
To evaluate the potential solution directions a weighted scoring table was used. First, a brainstorm was conducted on the criteria together with the expert panel. Thereafter, the weight per criterion was determined and eventually the solution direction would receive scores from 0 to 5, where 0 is the worst possible and 5 the best possible. Again both weights and scores were applied together with the expert panel.

2.6 Overall structure

Eventually, from the entire methodology a structure could be build. This is shown in Figure 2.2. Note the presence of an additional literature review, this was not planned beforehand, however after the construction of a cause-effect diagram a gap in the systematic literature review existed, since the increase in demand for consolidated orders was not yet addressed in the current literature review. Additionally, from the findings one could also find that the potential yields are too low to intervene, hence additional literature was found to increase the expected utility of the potential yield.

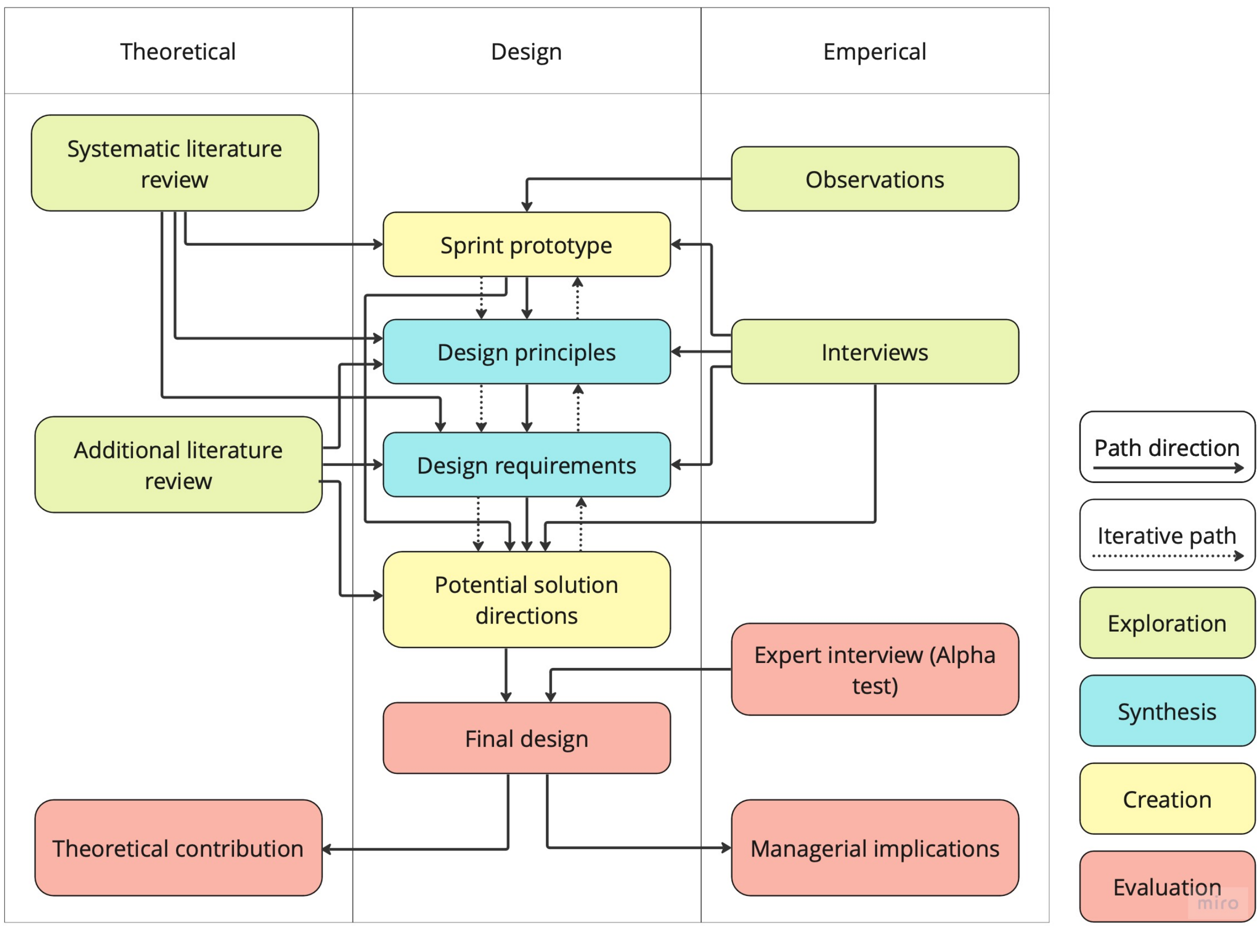

Figure 2.2: Complete overview of the methodology

3 Systematic Literature Review

Within this section of the report the problem is further explored. The paragraph exists of four main parts, within the first part the definition of load factor is further explored, within the second part measures which increase load fill are explained which currently exist in the literature. This chapter will be ended by a section on the design principles. The method used for the systematic literature review is explained in section 2.2.1.

3.1 Definition of load factor

As mentioned before, to reduce carbon emission one of the key logistical variables is load factor (Rogerson, 2017). Another common terminology of load factor would be fill rate or load fill. Fill rate is the load carried divided by the maximum load which can be carried by a specific vehicle (Ahmad et al., 2022). The load factor is used to measure the performance for strategic, tactical, or operational purposes. This performance effects several dimensions such as management, cost, customer service, productivity, and quality (Santén, 2017). A higher load factor has beneficial effects on carbon emission, costs for deliveries and traffic congestion (Ahmad et al., 2022; Aronsson and Huge Brodin, 2006; Mckinnon, 2000; Rogerson, 2017; Santén, 2017).

The first problem described in the literature is: how can the load factor be defined. Santén (2017) found five definitions for the load factor. First the proportion of truck-km that run empty. Secondly, the weight of the actual goods carried to the maximum weight which could have been carried. Thirdly, the ratio of the actual tonne-kilometer moved to the maximum tonne-km that could have been moved. Fourthly, the proportion of the cubic space occupied by the load. Finally, the proportion of vehicle floor utilized by the load. Santén (2017) recommends using more than one of these definitions, since only one of the five cannot provide a full picture of the load factor. For instance, the floor can be covered by single stacked pallets, in this obvious case pallets should be stacked to create more room for additional load when stacking is possible. From the five definitions the author developed a formula to describe the load factor. The formula is denoted as following: the load factor is the product of packaging efficiency, loading efficiency, and booking efficiency. Here packaging efficiency refers to load factor in the packaging (in the load unit, e.g. EURO pallet), loading efficiency refers to the load factor in the share of the vehicle used after loading (e.g. EURO pallet in vehicle), and booking efficiency refers to the share of the vehicle used after booking (load meters booked). Furthermore, Santén and Rogerson (2018) recommend to collect data on both mass and volume, and check what the limiting factor would be and use that for load factor calculations.

The aforementioned definitions all refer to the higher levels of load fill, however within packages empty space is present as well. Three different packaging levels exist, namely primary, secondary and tertiary packaging. Here primary packaging refers to the packaging of the goods, secondary refers to the packaging of multiple goods together (mostly in cardboard boxes), finally, tertiary refers to the packaging of multiple secondary packaged goods (mostly on roll cages or pallets) (Allcock et al., 1997). Svanes et al. (2010) argued that the load factor in primary and secondary packaging levels should be calculated using the volume rate.

The final problem the load factor is facing, is the manner in which data is collected. According to Santén (2017) most weight-based data is incorrect or entirely missing. Additionally, the author claims that volume-based data is gathered by only using visual observations and, in another study, she states that it is also based on assumptions rather than objective measures (Santén and Rogerson, 2018). Santén and Rogerson (2018) are critical towards the use of load factor data, since it lacks transparency of how it is measured throughout the entire literature. Thus, using load factor as input for a total cost tool is impossible since the data is too unreliable, and it is too resource intensive to measure. Finally, statistics about the weight-based data is only available in some countries and volume-based data is

not available at all (Santén, 2017).
Despite all difficulties, Santén and Rogerson (2018) try to solve this problem by setting requirements for measuring the load factor, these are: enable shippers to measure the load factor, provide a transparent method for measuring, allow historical comparisons to be made between transport flows and between companies, be comprehensive (address load factor at several system levels), be able to handle both volume and weight, clarify what "100 percent capacity" means and finally allow applications that are independent of the characteristics of the goods flow. These requirements must first be met before load fill can be calculated. Thereafter, they proposed a framework on how to calculate the required capacity and available capacity. For the required capacity, in the first place the total weight or volume of one load unit should be derived from individual items. When this is not possible the volume or weight after items have been combined should be measured. This can be done by subtracting the empty space after items have been loaded. This first method is preferred since it says more about different packaging levels. Now the load fill can be defined at six levels. These levels are primary, secondary and tertiary packaging, load to shipment, load to vehicle and load to fleet of vehicles. The volume of the product divided by the total available capacity is the actual load fill. To improve the entire load fill all six levels should be improved, however the poorest performing level could be a good starting point to effectively increase the load fill. At the end of their study, Santén and Rogerson (2018) recommend that their proposed solution should be tested in different contexts to test its applicability. Eventually, these different levels are important to divide the responsibility over the different stakeholders, since not all stakeholders are able to influence all levels, for example a planner cannot determine how individual products are packaged. Hence, the requirements at the start of this paragraph must be met to deduce the levels and thus the stakeholders.

3.2 Mechanisms for increasing load fill

A study conducted by Santén (2017) provided a list of mechanisms currently existing in literature to increase the load factor, when this load factor is deemed reliable. This list contains five mechanisms, which are the following: warehousing, order & delivery, packaging, loading and consolidation. This list is considered as starting point for measures to increase load fill, however warehousing is considered as a mechanism to ease the effort of consolidation, since the goal of warehousing is to make consolidation easier.
The first manner to improve the load factor is order & delivery. Rogerson (2017) found multiple components within the purchasing process that could improve the load factor. In the specification phase of the purchase process, time, shipment size, and customization options should be limited and standardized. Moreover, specifying a requirement for delivery precision reduces the load factor as well. Rogerson and Sallnäs (2017) conducted three case studies to improve the load factor in different contexts. In their case study they found that the order size should match a full vehicle. Additionally, there should be an option that pallets can be sent at earlier occasions and left for later occasions when possible. This is confirmed by Bø and Mjøsund (2022), they found that it would be ideal to set a minimum number of pallets for backloading, since returning only one pallet would be less efficient and less environmentally friendly, although that comes at the cost of a lower customer service level. Finally, Rogerson and Sallnäs (2017) found that the frequency of shipments should be adjusted. They imply that lanes to the same customer should be driven less frequent since it will increase the load size significantly and it probably has no negative implications for the end customer.
The second mechanism to improve the load factor is packaging. Rogerson and Santén (2017) conducted three case studies at three different logistic companies to consider changes in order to increase the load factor by improving packaging. Three main solutions were proposed by the authors. In the first place, plastic boxes should be stacked with a pallet on top, parcel cages should be used for long, or unevenly

sized goods, and steel racks for long items stacked on top of one another. Furthermore Ahmad et al. (2022) conducted a synthesis on packaging in different sectors. The most applicable sector for this research is the non-food retail sector, thus this section of the work from Ahmad et al. (2022) will be used to find solutions to increase the fill rate. First the authors refer to improve secondary packaging. Wever (2011) conducted a study on secondary packaging and suggests, better product placement in a package, use of volume efficient cushioning, product redesign to reduce fragility and incorporate cube utilization as the leading principle in product design. Tertiary packaging can be improved by using custom pallet sizes (Hellström and Nilsson, 2011). However, this comes with downsides as well. In the paper the authors state that warehouse handling will be more difficult. Additionally, one can imagine that making custom pallets is more resource intensive compared to only using the standard EURO pallets. This since they need to be handmade in the first place which will cost time. Moreover, now pallets need to be made at the manufacturing plant as well, which will increase the material costs on wood and nails. Finally, Aronsson and Huge Brodin (2006) state that this could deteriorate the load to shipment ratio. The final mechanism for improving secondary and tertiary packaging mentioned in the research conducted by Ahmad et al. (2022), the authors cite the work done by Twede et al. (2000) as example, who conducted a case study at HP. At HP the authors tested whether delaying shipments would benefit the secondary and tertiary packaging. As a result of delaying the transport, the shipment could be sent in bulk, which eliminates the need of secondary packaging. To improve tertiary packaging, the EURO pallets were replaced by slip sheets. All in all, the most attractive option is a tactical intervention followed by a new box design at second level packaging. Rogerson and Sallnäs (2017) claim that pallets could be packed more efficiently, by using more accurate loading plans.
The third mechanism to increase the load fill is in the loading procedure. Biswas and Anand (2022) found that non-standardization of vehicles deteriorates the fill rate in India, since they are not optimal for standard load configurations. Aronsson and Huge Brodin (2006) found that the same holds for the load carrying units (e.g. pallets). If these are standardized it will be easier to fill (different) vehicles. Mckinnon (2000) saw opportunities in stacking load within the vehicle. The author's argument is that most pallets are only 1.5 meters high, and thus another meter is filled with air. This is in line with the work of Allcock et al. (1997), they argue that pallet height should be derived from the inner truck height to increase load fill. One measure to utilize the maximum height of a truck is double-stacking. With double stacking the cost for transportation is similar, however the number of products per shipment is increased. This allows for cheaper transportation since less trucks are required and a higher load factor since the capacity of the truck is more optimally used (Liljestrand, 2016). Additionally, multiple studies showed that larger trucks negatively correlate with the load factor and that longer routes positively correlate with the load factor, meaning that the larger the truck the lower the load factor and the longer the route the higher the load factor (Abate, 2014; Özen et al., 2020). A possible explanation that longer trucks correlate with a lower load factor would be that there is more space in the truck and thus there is simply a higher possibility for a lower load factor. Additionally, when longer routes are present, load factor becomes increasingly more important, since transportation becomes more expensive in relation to the production cost.
The fourth and final mechanism is consolidation. This mechanism includes both internal and external consolidation efforts. To start with an internal effort, Liljestrand et al. (2015) developed a portfolio which can be used as a decision tool for planning. With this portfolio different shipments are classified using two classifiers in a list of three. These two classifiers act as axis for a two-by-two matrix with either high or low characteristics for these classifiers. These high or low characteristics can be defined as barrier or as enabler to improve the load factor. Shipments that need attention are mostly classified with at least one barrier and these shipments probably need rescheduling. The complete list of classifiers is distance, shipment characteristics and product-specific characteristics. Shipment characteristics refer to size, frequency, total volume, and variance of shipment sizes. Finally, product-specific char-

acteristics refer to unique attributes of a transported good (e.g. temperature-controlled settings). All in all, this portfolio should help in prioritizing which shipments need adjustments in order to improve load factor. Furthermore, it should present the level of difficulty for improving the load factor in a specific shipment. External efforts for consolidation could refer to the vehicle routing problem. This problem is hard to solve since it is a computational time expensive problem. Several heuristics and metaheuristic algorithms were developed that generate solutions which are very close to the optimal one. One of the algorithms is described by Calabrò et al. (2020), in their work they use the Ant Colony Optimization (ACO) algorithm. Their objective function was to minimize the total distance travelled. Inherently, while reducing the total distance travelled and keeping the same amount of load, fill rates will increase. At the start of their simulation the load factor only increased marginally compared to the scheduled deliveries. However, when the simulation reaches the maximum number of vehicles, the algorithm optimizes the load factor in order to reduce kilometers. Thus, a near optimal solution for routing should help in increasing the load factor. Another effort that could help for consolidation is centralizing the flow of goods. This can be achieved by changing the location and size of warehouses (Santén, 2017). In the study conducted by Aronsson and Huge Brodin (2006), the authors studied what changes would impact the environment positively. One option which helped to improve the load factor is the centralization of warehouses. With this centralization of warehouses fewer of them are required, and the ones which are centralized need to grow. This helps to centralize the flow, and thus more vehicles will eventually follow the same route, which eases the efforts for consolidating multiple orders. Triantafyllou et al. (2014) even proposed an urban consolidation center (UCC) close to city centers to serve the entire city center. The result would be much higher load factors for last mile delivery. This is similar to the urban distribution center (UDC) proposed by Gattuso and Cassone (2011). Finally, Rogerson and Sallnäs (2017) argue that similar lanes should be combined into one. On the other hand, Turkensteen and Hasle (2017) are wary that not all lanes should be mixed and set four conditions when mixing should not be applied, namely when many locations are evenly distributed between supply and demand location, when the distance from depot to nearest location is small, and when the payload causes a large share of carbon emissions.
To conclude this part of the literature review, Allcock et al. (1997) found that poor load factors are widely accepted among transport companies. Nowadays a lot has changed and a shift in mindset is happening, since more regulations are coming, and transport needs to be greener. Customers will thus probably be less reluctant in giving-in some flexibility for efforts to increase the load fill. However, all aforementioned solutions are not applicable in every level of the load factor and for every type of road transportation, thus it can be hard for a company to find the best solution for a particular situation. A summary of the four main mechanisms to improve load fill according to the literature can be found in Table 3.1

3.3 Design Principles

All in all, four main mechanisms provided by literature exist to increase load fill. In the first place the capacity in a truck should be used more optimally. This can be done by optimizing the packaging of a single product, package and load unit. Furthermore, multiple orders can be loaded per shipment, which is called consolidation. Mechanisms that support consolidation of orders are optimization algorithms, such as the ACO algorithm, centralizing the flow of goods by increasing warehouse sizes and place those in central locations and by consolidating similar lanes into one route. Additionally, the order size per customer should be higher, this can be done by customers ordering less frequently, this basically consolidates orders internally at the customer's side. Finally, loading procedures should be improved, this can be done by standardizing load carrying units and trucks and by double stacking orders. A full overview of all design principles found in the literature is visible in Table 3.2

Table 3.1: Four main mechanisms to increase load fill provided by literature

Main improvement mechanism	How to apply the mechanism	Sources
Packaging	1. Using plastic boxes 2. Using parcel cages (for long unevenly sized goods) 3. Improving secondary packaging by: volume efficient cushioning, product redesign, and incorporate cubes in the design as much as possible 4. Improve tertiary packaging by: custom sized pallets, using slip sheets 5. Send items in bulk (can eliminate the need of secondary packaging)	Ahmad et al. (2022); Hellström and Nilsson (2011); Rogerson and Sallnäs (2017); Rogerson and Santén (2017); Twede et al. (2000); Wever (2011)
Loading	1. Standardize vehicles 2. Standardize load units 3. Make use of double stacking	Abate (2014); Allcock et al. (1997); Aronsson and Huge Brodin (2006); Biswas and Anand (2022); Liljestrand (2016); Mckinnon (2000); Özen et al. (2020)
Consolidation	1. Centralization and increased size of warehouses (centralizes the flow of goods) 2. ACO algorithm (or other optimization algorithms) 3. Consolidating similar lanes	Allcock et al. (1997); Aronsson and Huge Brodin (2006); Calabrò et al. (2020); Gattuso and Cassone (2011); Liljestrand et al. (2015); Rogerson and Sallnäs (2017); Santén (2017); Triantafyllou et al. (2014); Turkensteen and Hasle (2017)
Ordering	1. Limit order options (for example with a minimum order quantity 2. Consolidate pallets at the customer until it matches a full vehicle	Bø and Mjøsund (2022); Rogerson (2017); Rogerson and Sallnäs (2017)

Table 3.2: Design principles from the systematic literature review

Nr	Context	Agency	Mechanism	Outcome
		1. Packaging		
1a.	In order to increase load fill in the supply chain	The manufacturer should package products more efficiently	By using plastic boxes	Which in turn decreases the volume required for and thus allows for more products per truck.
1b.	In order to increase load fill in the supply chain	The manufacturer should package products more efficiently	By using parcel cages	Which in turn decreases the volume required for and thus allows for more products per truck.
1c.	In order to increase load fill in the supply chain	The manufacturer should package products more efficiently	By incorporating cubic design as much as possible, redesign products such that cushioning is not required and by volume efficient cushioning	Which in turn decreases the volume required for and thus allows for more products per truck.
1d.	In order to increase load fill in the supply chain	The manufacturer should package products more efficiently	By using customized pallets and by using slip sheets	Which in turn decreases the volume required for and thus allows for more products per truck.
1e.	In order to increase load fill in the supply chain	The manufacturer should package products more efficiently	By sending items in bulk	Which in turn decreases the volume required for and thus allows for more products per truck.
		2. Loading		
2a.	In order to increase load fill in the supply chain	The planner and/or carrier should improve the loading procedure	By using standardized vehicles	Which in turn allows for an optimal use of space.
2b.	In order to increase load fill in the supply chain	The manufacturer should improve the loading procedure	By using standard load units	Which in turn allows for an optimal use of space.
2c.	In order to increase load fill in the supply chain	The manufacturer and/or customer should improve the loading procedure	By using/allowing for double stacking	Which in turn allows for an optimal use of space.
		3. Consolidation		
3a.	In order to increase load fill in the supply chain	The manufacturer should consolidate orders	By centralizing and increasing warehouses	Which in turn decreases the number of lanes and thus increases the opportunity for consolidation of orders.
3b.	In order to increase load fill in the supply chain	The planner should consolidate orders	By using optimization algorithms such as the ACO algorithm	Which in turn decreases the number of lanes and thus increases the opportunity for consolidation of orders.
3c.	In order to increase load fill in the supply chain	The planner should consolidate orders	By consolidating similar lanes	Which in turn decreases the number of lanes and thus increases the opportunity for consolidation of orders.
		4. Ordering		
4a.	In order to increase load fill in the supply chain	The planner, carrier and/or manufacturer should increase the average order size	By limiting the order options	Which in turn increases the number of products per truck.
4b.	In order to increase load fill in the supply chain	The planner and/or carrier should increase the average order size	By leaving empty load units until they match a full truck	Which in turn increases the number of load units per truck.

4 Results from empirical analysis

Within this chapter of the report the results of the empirical analysis will be discussed. For the empirical analysis both observations were made and interviews were held with different stakeholders in the value network of the 4PL supply chain. stakeholders here are employees from Van der Wal, Kimberly-Clark, carriers and drivers. This framework is the third iteration of the thematic framework. Additional subsections of the results are a cause-effect diagram based on the interviews and finally, the design principles from the empirical analysis are defined and evaluated.

4.1 Observations

Table 4.1: Observations complemented with data from Van der Wal's information system

OBS	L-number	O-number	Vehicle	nr of pallets	height	load type	nr of loads	outbound	image nr	3G Height	3G Pallets per order	3G weight load level	remarks
1	L-1857130	O-2042007	ST	34	1,75	FTL	1	Yes	1, 2, 3	1,95	34	5312,87	1 to 2 additional product layers would have fitted
2	L-1856985	O-2038180	ST	15	1,5	FTL	2	Yes	4	1,8	15	2272,87	There were pallets that were only 1.5 m, could have been stacked higher
2	L-1856985	O-2038178	ST	1	1,7	FTL	2	Yes	4	1,8	1	2272,87	There were pallets that were only 1.5 m, could have been stacked higher
3	L-1861781	O-2046908	ST	33	1,7	FTL	1	No	5, 6	2,7	38	8087,31	Employees think 33 pallets in this case is too much, load shits over other pallets
4	-	-	ST	33	2,5	FTL	1	No	7, 8	-	-		Clamp must be used to unload truck, very time consuming
5	L-1850565	O-2035066	ST	20	1,7	FTL	3	Yes		1,95	5	3557,12	Space for 2 additional layers of products, total nr of pallets: 20
5	L-1850565	O-2035065	ST	20	1,7	FTL	3	Yes		1,95	12	3557,12	Space for 2 additional layers of products, total nr of pallets: 20
5	L-1850565	O-2035064	ST	20	1,7	FTL	3	Yes		1,95	3	3557,12	Space for 2 additional layers of products, total nr of pallets: 20
6	L-1826039	O-2009213	ST	28	1,8	FTL	2	Yes	9, 10	1,8	17	8959,17	highest pallet 1.8m, but there are smaller pallets
6	L-1826039	O-2009214	ST	28	1,8	FTL	2	Yes	9, 10	1,8	11	8959,17	highest pallet 1.8m, but there are smaller pallets
7	L-1865829	O-2050991	ST	34	1,9	FTL	1	Yes		1,95	34	6618,23	many different products, in general an additional layer is possible
8	L-1865828	O-2050989	ST	22	1,9	FTL	1	Yes		1,95	22	6237,75	Takes about 20 empty pallets (3 piles)
9	L-1860386	O-2045285	ST	18	1,5	FTL	1	Yes		7,8	16,5	1355,31	Pallets are really low
10	L-1865951	O-2051148	ST	34	1,7	FTL	1	Yes		1,95	34	4745,43	Additional layer would have fitted

In this section the observations made at a warehouse in Dormagen, Germany are described. The method applied for the observations can be found in Section 2.2.2. The systematic notation of the observations can be found in Table 4.1. Conclusions from these observations are similar as in the overall data. Loads that are shipped from warehouses to customers are overall smaller than a truck load, however are booked as FTL, hence there is a lot of space left in the truck. Additionally, the height of the truck is never optimally utilized. Warehouse employees explained that additional layers could not be the solution, since it would make the load unit unstable, however double stacking would have been an option in most cases.

4.2 Thematic Framework

To derive insights from the interviews GTB was used as explained in section 2.2.2. The main themes that were found are: the load fill improvement mechanisms, communication & responsibilities, desired results and inaccuracies in the data. These themes will be addressed respectively in the next subsections.

4.2.1 Load fill improvement mechanisms

In this section of the thematic framework, improvement measures are compared to the design principles defined within the literature review section. In general, the design principles are similar to the load fill improvement mechanisms, however interviewees better explained the context and agency of those design principles. The frequency count of each theme can be found in Table 4.2. The interviewees' numbers in Table 4.2 correspond with the list of interviewees in Table 2.2, and for the sake of comparability the employees of Van der Wal are in bold, and the driver is in italic. Interviewees who are not bold or italic are Kimberly-Clark employees. The bottom row represents the overall averages and the two rows above the bottom row represent company averages of both Van der Wal and Kimberly-Clark.

Table 4.2: Frequency table of the thematic framework

I-nr.	Improvement Mechanisms					Commun.	Desired results			Inaccuracies in data		
	W-house	Loading	Ordering	Pack	Consol		Analysis	Cost	Emission	Height	Promo	Stock
1	**1**	**6**	**3**	**0**	**4**	**7**	**5**	**8**	**8**	**2**	**0**	**0**
2	0	1	3	1	2	2	3	3	2	1	0	1
3	**0**	**2**	**2**	**0**	**6**	**1**	**0**	**0**	**0**	**0**	**0**	**0**
4	**0**	**8**	**5**	**0**	**6**	**11**	**0**	**1**	**1**	**8**	**0**	**0**
5	**0**	**1**	**1**	**0**	**12**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
6	**0**	**2**	**2**	**1**	**2**	**2**	**0**	**0**	**1**	**3**	**0**	**0**
7	3	2	6	0	0	4	1	0	1	0	2	0
8	1	11	5	0	1	4	0	4	8	0	0	1
9	*0*	*2*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
10	**0**	**0**	**0**	**0**	**10**	**0**	**0**	**0**	**2**	**0**	**0**	**0**
11	0	2	6	0	5	8	0	1	0	0	0	0
12	**2**	**1**	**1**	**0**	**3**	**12**	**0**	**0**	**2**	**0**	**0**	**3**
VdW	0.42	2.85	2.85	0.14	6.14	4.71	0.71	1.28	2.00	1.85	0.00	0.42
KC	1.00	4.00	5.00	0.25	2.00	4.5	1.00	2.00	2.75	0.25	0.50	0.50
Ovr	0.58	3.16	2.83	0.16	4.25	4.25	1.28	1.41	2.08	1.16	0.28	0.71

I-nr. = interviewee number, Commun. = Communication, W-house = warehousing, , Pack = packaging, Consol = consolidation, Analysis = cohesive analysis per lane per month, Cost = cost reduction, Emission = CO_2 reduction, Promo = promotion, Stock = stock issues, VdW = Van der Wal, KC = Kimberly-Clark, Ovr = Overall

To start with the warehouse design principle, this is already applied at the Kimberly-Clark. They try to centralize the flow of goods as much as possible by transporting goods directly from the mill to the end customer. This is stated by interviewee 7 as well: *"Preferably we deliver directly from the mill, resulting in shorter routes."* For this optimization, end customers receive discounts for ordering directly from a mill. To further encourage end customers to optimize their order pattern, a higher discount is given when customers order half- or full truckloads, which makes consolidation a lot easier. This is confirmed by interviewee 8: *"our prices are sharply calculated and keeping in account what kind of price we can make if we deliver full trucks or if we only deliver half trucks or only by pallet.*

So, to offer the lowest price, we always offer full truck or half truck deliveries because these retailer brand products are faster rotating on shelf than our own branded products." Half truckloads are easy to consolidate with other half truckloads to make a full truckload, in this instance the floor surface is nearly optimally utilized. However not all customers can process a full truckload, thus these customers are served via warehouses from Kimberly-Clark. These warehouses are replenished with full truckloads only. This thus further centralizes the flow of goods.
The order & delivery design principle is mainly driven by a customer change in order size. An optimal order configuration exists of either 33 or 34 pallet footprints depending on the product, but this will be further explained at the loading design principle. Furthermore, not all warehouse personnel or truck drivers (who load the truck) are aware of the loading procedure it requires. End customers can be convinced to increase their order sizes by three main principles. First of all, the performance of the service will increase, which is confirmed by interviewee 7 as well: *"The more different loads you put in a truck, the bigger the chance of delays and consequently the on-time performance decreases."* Especially when the load is small enough to be shipped with a groupage service provider this problem becomes bigger. Germany here has a special case, due to the presence of time slots. Groupage service providers must book time slots, and when no (or a sub) optimal slot is available at the end customer, the order will be delayed, which occurs frequently. Secondly, when trucks are full, transportation is more durable since less trucks in total are required. Interviewee 6 explained this as following: *"When customers have a set order quantity of 30 pallets, they miss out on 3 or 4. These are spaces which can be filled. For example when you have 10 loads for this customer this could for example be decreased to 7."* Visible in this statement is the decrease in the number of trucks which leads to a decrease in the costs for transportation and carbon emission. Van der Wal is able to calculate those numbers and present them to logistic managers from Kimberly-Clark. These logistic managers can address the issues to account managers, and account managers to the sales team who have direct contact with the customer. The sales team have the ability to negotiate discounts with customers for ordering a full truck load, instead of the 30 pallets, however they do not have the exact numbers on how much discount they can offer. Van der Wal is thus not directly able to improve load fill via this principle, however they have a key role in providing the right information to the customer. The final manner to improve the ordering pattern of the customer is to include a MOQ (minimum order quantity). For example, interviewee 7 said that the MOQ for the Dutch market it no lower than 5 pallets.
The next design principle is about loading. The loading design principle is already used in two entirely different manners. First of all, the loading procedure had been changed at some warehouses. This made it possible to load 34 euro pallets instead of 33. However, some customers do not accept 34 pallets per truck as these products could potentially be damaged while loading or unloading. Interviewee 8.2 had this already in place with one customer and said the following about it: *"We used to have trucks with 34 pallets in the past and then we got the information that we should only have 33 pallets. I'm not a 100% sure why, I think it was because the last two pallets were damaged when they were loaded in the long way and therefore they decided to have it the other way around."* The other mechanism at play is double stacking. The height of a load unit can be changed to either 1.15 or 1.35 meter and later double stacked to maximize the operational space of a standard or mega trailer respectively. Interviewee 7 said that this is already applied on some lanes from Spain to a customer, and with this mechanism the truck's volume is utilized more efficiently and less orders are required. On the other hand, this cannot be applied to all loads since some products are too fragile. Interviewee 9 said this about double stacking: *"Load cannot always be infinitely stacked, the type of load is very important. Tempex for example can be stacked."* Since the products on the load unit will be stacked differently at the mill already, Van der Wal has a limited role in changing the loading procedure. Furthermore, both changing the loading procedure from 33 to 34 pallets and applying double stacking, is also a form of increasing the total order volume, since more volume will be shipped per shipment. Negotiations with

customers are thus vital to apply the different loading procedures and improve load fill. The sales team again requires information on both cost and carbon emission to know what discounts they can offer to the customer. This again is where Van der Wal comes into play to provide these calculations, which they currently do not yet have the capacity to provide.

The final design principle which was discussed during the interviews is consolidation. Consolidation leads to less overall trucks used by a carrier, while having the same number of orders, and thus increasing load fill. However, using consolidation as mechanism to increase load fill is not that simple. During interviews with both carriers and planners, the interviewees provided different limitations that restrict the number of possibilities to consolidate loads. First of all, it is hardly ever allowed by the customer or Kimberly-Clark. This can be explained by the fact that consolidation probably leads to a lower performance since issues could occur more frequently. For example, at the first unloading location the truck cannot be unloaded immediately because all logistical employees are occupied, and consequently the truck is late at the second address. This lowers the on-time performance and moreover in some contracts a penalty for low on-time performance is included. According to interviewee 8 it is impossible to change such contracts. Another reason why consolidation is complicated is the presence of time slots, according to interviewee 1: *"This is one of the hardest restrictions to work with. In some markets time slots are present and when these are missed it can be difficult to reschedule a load for the same day."* Additionally, the load cannot arrive whenever the planner wants. For example, when two addresses are in proximity from one another, but one has only an available timeslot late in the afternoon and one early in the morning those loads cannot be consolidated, because the driver must wait for an entire day to unload a single truck. Furthermore, distances between two potential locations could be too far from each other to make it a favorable economic option, interviewee 6 said that this is one of the parameters which can be applied while looking for consolidation. Another limitation is, quite obviously, different dates for unloading. According to interviewee 11 there is a possibility to change the date of a certain order to make consolidation somewhat more feasible, however this needs to be communicated to the customer and this is a labour intensive process since this needs to be done manually. Additionally, the type of material could play a role. For example, some customers do not have the capabilities to unload a tautliner (this is a type of truck which is loaded from the side, and this must be done with a forklift), where the neighboring customer requires a tautliner. According to interviewee 10 this is one of the most painful limitations he faces during his work, and he says the following about it: *"The biggest problem is the type of equipment. ... We only know when a driver gets to the trailer, what products could be loaded. We get a list of trailers, and what product is loaded in which trailer, however this is only in the morning and they cannot load it in the trailer which is beneficial for your planning."* The final reason is human factors. Human factors can vary widely, an example provided by interviewee 10 is that a truck driver has an appointment with the dentist in the afternoon and therefore has no time left to deliver additional loads to other customers. Other drivers have physical limitations and therefore cannot unload heavy loads. These are just two of the endlessly different examples possible which can fall under the category of human factors. However, despite all these limiting factors it does not make consolidation impossible. There is a sandbox model present which helps for planning such consolidation loads and it contains approximately 150 parameters. Ranging from the distance a driver yields from the ideal route to the angle between loading location and the second unloading location. Interviewee 7 explained the way it is currently set up. Customers can be divided in clusters, for example per region. For customers who order quite small an order day can be set, and those customers can only order on that day. In this way these smaller customers can be served together. Most of the consolidation however happens at the groupage carrier's side, interviewee 12 said the following about it: *"The carriers do not always consolidate KC stuff, carriers have their own consolidation center. So they pick it up, bring it to their own consolidation centers, and they consolidate it to different areas and different customers. They may have somebody down there to the same place. There is no point* *for us to bring up a truck, because the carrier is going to send two trucks to the same location anyway. In my mind that is what they get paid to do. That's their efficiency rather than us. If we would do it we've got time, how long between each drop, no driving hours, delays, there is too many factors that could effect performance."*

4.2.2 Communication & Responsibilities

The second section of the results is about the communication and responsibilities within the value network of the 4PL supply chain. Communication and responsibilities are key in improving load fill, since no stakeholder can improve load fill on their own. In Figure 4.1 the value network of the 4PL supply chain is visible. Communication is between all parties is according the value network of the 4PL supply chain because of the presence of contractual agreements. Therefore, agreements between different links in the chain can be disrupted when links are skipped. Interviewee 4 explains this as following: *"Realistically, the customer from Kimberly-Clark generates turnover for Kimberly-Clark, and there are commercial agreements, or agreements about tariffs and quantities. There could emerge conflicts, at the moment when we negotiate with those customers."* For the link between end customers and Kimberly-Clark different agreements exist. The main value exchange here is money for goods. Transportation costs are directly processed in the costs for the goods. Customers order these goods directly from Kimberly-Clark. Kimberly-Clark sends those orders directly to Van der Wal. Van der Wal then plans transportation for these orders at the different carriers. First the cheapest carrier is offered the order and this carrier has half an hour to respond before it goes to the second carrier in line. Prices are predetermined and settled during contract discussions with carriers. All price scales are settled based on either a full truck, which has a direct lane from mill or warehouse to customer, or on a per footprint basis when it is transported with a groupage or LTL carrier. Only in very few cases are prices based on volume. The carrier transports goods for Kimberly-Clark in name of Van der Wal. As can be seen in the previous the section, in most cases Kimberly-Clark is the main stakeholder in the value chain of 4PL logistics for the load fill improvement mechanisms. However, this is where the role of Van der Wal comes into play. Nearly all interviewees confirmed that it is Van der Wal's role to provide information on where improvements can be made. Additionally, Kimberly-Clark does not have access to the full overview of costs that are made for transportation, and therefore it is impossible for them to use the ordering and loading mechanism to increase load fill, since they do not know how much they can incentivize (offer discounts to) their customers to agree to a change in loading procedure or order pattern. An example of this was clearly visible during the interview with interviewees 8.1 and 8.2, the interviewer asked whether they possess the knowledge to make calculations for double stacking the loads in their account and she answered as follows: *"Yeah, maybe yes. So if it fits into the truck and the tissues are strong enough and won't be broken on their way, so maybe it's an option if it's possible, let's calculate. Let's see."* Finally, there is a contractual obligation for Van der Wal to improve transportation, and one improvement factor is lower costs for transportation, which is possible when increasing load fill. On the other hand according to interviewee 12 there is a conflict here at play, he explains it as following: *"If we see something that is not right, my team leader or myself will tell it. For example it is gonna cost you 550 pounds if you send it like that, but if you increase the truck fill the cost per pallet is going down. It isn't listened to too much though. Because on the one hand there is interviewee 11's team who delivers it how the customer wants it to keep the customer happy. On the other hand there is interviewee 2's team who wants to keep the costs down. So sometimes they take it out of our hands. So it's a balance between interviewee 11 and 2. In the end interviewee 2 will probably go with interviewee 11, because the sales are more important."* All in all, Van der Wal should provide the required information to Kimberly-Clark to make it possible for Kimberly-Clark to improve load fill. On the other hand, Van der Wal is dependent on Kimberly-Clark to start negotiations with the customer in order to make these improvements. Interviewee 12 said this about this part of the collaboration: *"That's out of our control at the moment. When we see something we address it, but the majority of the time it is getting authorized, because that's for sales."*

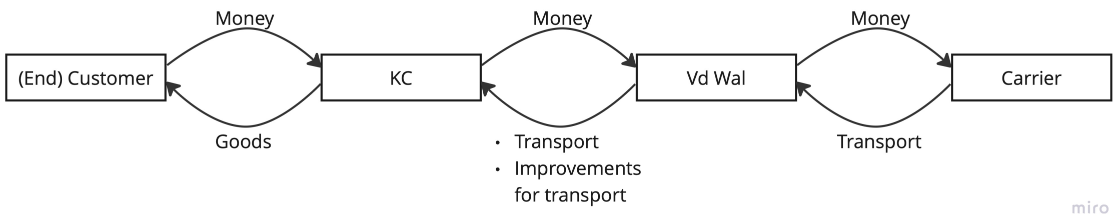

Figure 4.1: Value network of the 4PL supply chain based on the interviews

4.2.3 Desired results

Another theme occurring within the interviews was about the desired results. The first desired result which came forward during the interviews was that the solution must be a cohesive robust conclusion per unique delivery address on a monthly basis. This is partly supported by interviewee 11: *"The key is making sure your data analysis is quite strong and robust."* This is important since these numbers are directly used by the sales team to negotiate price reductions with the customer. This directly explains the fact that the conclusion should be based on a per unique delivery address basis, since the sales team knows who to negotiate with. Additionally the conclusion rapport should be monthly since this is the frequency of feedback meetings between Van der Wal and Kimberly-Clark. Furthermore, the solution should show the amount of possible carbon emission savings. According to multiple interviewees both Kimberly-Clark and Van der Wal have shared goals to decrease carbon emissions. Interviewee 2 (from Kimberly-Clark) said this about carbon emission: *"If we looked at our target for 2023 I think a 5% reduction in our emissions would be a fantastic target for us to achieve. 2% or below I think would be seen as we'd missed a lot of opportunities."* Additionally, this is also a goal for Van der Wal, this is confirmed by interviewee 4: *"Internally we aim to reduce CO2 emissions."* Finally, interviewee 8.1 added this could be potentially interesting to present to customers as well, they said: *"I think customers are also very keen on having as much as possible on the truck as it's more sustainable."* The final desired result of the solution is that it should contain a cost component. This is confirmed by 8 interviewees. In the first place it can support Kimberly-Clark in actually start the conversation with customers since it decreases cost for transportation. Furthermore customers could be supported to adjust their order behavior by a share of the potential benefits the order pattern improvement yields.

4.2.4 Inaccuracies in data

Finally, three inaccuracies in the master data exist, which could potentially disrupt the quality of the final solution. The master data are both, the historic and future orders. The first inaccuracy is inaccuracy in the height data. Height data which is provided by Kimberly-Clark often deviates from reality. This could make potential solutions to change the loading procedure inaccurate. Interviewee 4 explained this by the fact that the master data is inaccurately built. Interviewee 6 added to this that Van der Wal needs to make some assumptions in the height. In most cases the height is marked higher than reality. Another inaccuracy is a promotion. Promotions can disrupt the regular stream of orders, which is not directly visible in the data. Therefore, false assumptions about order patterns can be made. This is also confirmed by interviewee 7: *"You have to differentiate the regular and promotional* *streams, if you want to give a deliberate advise."* The final inaccuracy is a stock issue. Sometimes orders from customers deviate from what is delivered in reality. This deviation is explained by stock issues at Kimberly-Clark's side. The solution could provide information on possible savings where in reality due to stock issues substandard orders are delivered as is confirmed by interviewee 2: *"The only internal checks we need to do is, have we not filled a truck because we did not have enough stock to fill the truck."* This could make customers seem to order in a worse configuration than they actually do.

4.3 Cause-effect diagram

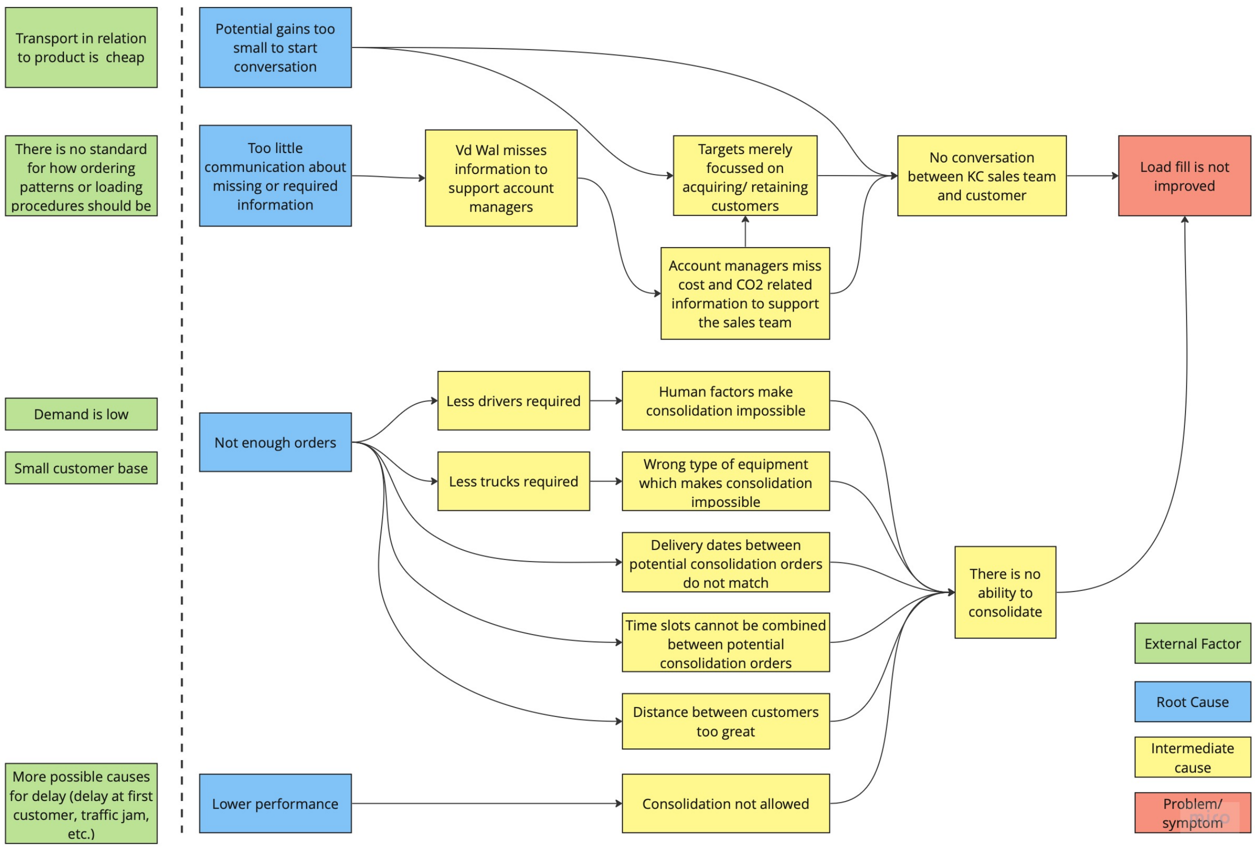

Figure 4.2: Cause-effect diagram from Van der Wal's viewpoint

Based on the interviews, a cause-effect diagram could be developed. From these interviews it became clear that both Van der Wal and Kimberly-Clark have a key role in improving load fill. The sales team of Kimberly-Clark mostly discusses order patterns and loading procedures with customers. Van der Wal here has the contractual obligation with Kimberly-Clark to provide insights in what potential yields are in improving order patterns and loading procedures. However these insights are not directly communicated to the sales team, and first need to pass the logistic team of Kimberly-Clark and the account managers. Information is thus filtered from the sales team or when the information is passed onto the salesperson, he/she themselve decides that the potential yield is too low to start negotiations with customers. This can be explained by the fact that transportation only marginally increases the total price for a product and potential gains are easier to find from the product point of view. Another reason for the sales team to not start negotiations is that the correct information is not always available to them. For example only in some markets a full truck tariff is known beforehand, but this is highly dependent on the type of product. This information is not provided by the account managers and logistic managers from Kimberly-Clark since they do not have access to such information, due to the fact that Van der Wal has price agreements with the different carriers and these are not available for Kimberly-Clark. Van der Wal has not provided such information yet since they do not know what the sales team require. This can be explained by the fact that such procedures are not commonly known (in literature).

The other main reason why load fill is not always improved, can be explained by the fact that there is no ability by the planners (or carriers) to consolidate orders. A factor which solely plays a role for the planners is that consolidation is not always allowed by the customer or Kimberly-Clark. This can be explained by the performance decrease consolidation brings. The performance is lower due to the fact that there is a higher possibility for delays. Other factors which play a role at both carriers and planners are human factors, wrong type of equipment, no matching delivery dates, no matching time slots or distances which are too great between customers. This is all further described in section 4.2.1, specifically where consolidation is compared with its design principle from the literature. All these limiting factors which distort the ability to consolidate, can ultimately be explained by the fact that the order quantities are too low. Potential external factors for the low order quantity could be that the demand is low or the customer base is too small. A full overview of the cause-effect diagram can be found in Figure 4.2.

4.4 Design Principles from empirical analysis

From the observations it became clear that there is plenty of space left in a truck to add more products per truck, both on the floor area and above the current pallets. To utilize this space better Van der Wal should provide the impact of the improvement mechanisms, since Van der Wal has the innovating role within the value network of the 4PL supply chain according to the interviews. The role of the planner (Van der Wal) is to educate the manufacturer of the goods on the role order patterns and loading procedures have on transportation. Furthermore, from the interviews it became clear that employees of Kimberly-Clark are not always triggered by small yields per customer. Moreover, the manufacturer does not always possess the correct knowledge about which mechanism could achieve what cost and carbon emission reduction for what customer. Hence, incentivizing customers based on improved order patterns could be difficult, so Van der Wal should support the manufacturer with an analysis per load fill improvement mechanism per customer. Furthermore, according to interviewee 12, it is in a groupage carrier's best interest to consolidate orders as much as possible, since that is where they earn their profit. When Van der Wal tenders a load to the cheapest carrier it is probably the easiest for them to consolidate the load, otherwise the price would not be economically viable. Finally, currently prices are total prices, so cost for transportation is included in the final price. However, this does not trigger customers to save prices on transportation, since it is not transparent for them how order patterns or delivery days influences the cost for transportation. Eventually this yields the design principles presented in Table 4.3.

Table 4.3: Design principles based on the empirical analysis

Nr.	Context	Agency	Mechanism	Outcome
1.	In order to increase load fill in the supply chain	Van der Wal should analyze the impact of order patterns and loading procedures	by calculating the potential cost and carbon emission saving per configuration and for double stacking	which in turn yields a clear overview of potential gains and a summary of the entire customer base.
2.	In order to increase load fill in the supply chain	Van der Wal should aid sales department of the manufacturer in negotiations for increasing the average order volume	by providing an analysis per improvement mechanism (loading and ordering in the different configurations)	which in turn allows the manufacturer to incentivize (offer a discount to) customers who order in higher configurations.
3.	In order to increase load fill in the supply chain	Van der Wal should schedule loads based on the lowest price	by tendering the load to different carriers	which in turn increases the number of loads booked via a dynamic price.
4.	In order to increase load fill in the supply chain	Kimberly-Clark should separate transport costs from product prices	by making the cost for transportation variable	which in turn allows for the use of dynamic pricing.

5 Synthesis

Within this section an additional literature review was conducted, later the different sources of data (literature, observations and interviews) are triangulated.

In the first place, as is visible in the systematic literature review (section 3.2), packaging is a large topic in the load fill literature and many authors tried to improve load fill via this mechanism. However, little data about packaging was acquired during the empirical analysis, since Van der Wal and the employees interviewed at Kimberly-Clark have only marginal knowledge about packaging. Hence, from this point packaging will no longer be addressed in this thesis, since reliability and validity of research on packaging will be low, due to the limited empirical evidence. Moreover, from the cause-effect diagram presented in Figure 4.3 it became clear that an additional literature review was required to create a better understanding on how demand for consolidated orders can be increased. Hence, the secondary literature review was conducted while searching for dynamic pricing. Here the course material of Infonomics on dynamic and surge pricing was consulted (Sadowski, 2021). Additionally, cross-references from the course material were used to find additional papers on dynamic pricing. Furthermore, work based on carrier networks were found in the initial literature review, however suited better in this part of the literature section, which is about increasing demand for consolidated orders and increasing supply (or competition). Finally, from the empirical analysis it became clear that employees of Kimberly-Clark are not always triggered by small yields per customer, hence an additional literature review was conducted to increase the expected utility of the yield. For this paragraph the course material of Behavioral operations management was consulted (van de Calseyde et al., 2022).

5.1 Additional literature review

Within this section the effect of differential pricing and carrier collaboration will be discussed more elaborately, since these could alleviate the the problem causes for the decreased ability to consolidate orders. Finally, a potential solution to increase the expected utility will be provided.

Price differentiation or personal pricing is a pricing strategy used by firms to offer different prices to different segments of customers based on various factors such as customer willingness to pay, geographic location, time of purchase, supply or demand (Amrouche et al., 2020). An example of how the price is based on supply and demand is visible in the work conducted by Qiao et al. (2019). In their work the authors researched the effect of dynamic pricing decision-making problem for LTL shipments. The authors recommend that groupage carriers should either use a unique price strategy (one similar price for all requests) or variable price strategy (different price for each request) to determine the optimal price for a load and optimize the carrier's profit. A variable price strategy outperforms the unique price strategy in every aspect, however it is much more resource intensive to apply, so in some situations it would be better to use the unique price strategy. So, this implies that a groupage carrier should bid a different price on every incoming order, but only when they have the resources to do so. To use dynamic pricing three conditions need to be met. First of all, the firm must have market power. Secondly, the firm must prevent the customer from reselling the goods. Finally, the firm must be able to differentiate the customers who are willing to pay more from the customers who are not. There are three ways in which this can be done and are referred to as degrees of price differentiation. In the first degree of price differentiation, the firm collects information from every single buyer and charges the maximum amount a buyer is willing to pay. In second degree price differentiation the seller is not informed about how much a buyer is willing to pay, thus offers their products by versioning. An example of versioning is a hardcover versus a paperback or e-book version of a book. In third degree price differentiation the seller does not know the purchasing power of individual buyers, but separates different buyers into clusters. These clusters are then evaluated on the wealth or eagerness to purchase the product. An example would be student or senior discounts (Varian, 1989).

The aim of price differentiation is to capture more value from customers who are willing to pay a higher price, while still attracting price-sensitive customers with lower prices (Varian, 1992). This strategy has been widely studied in various industries, including retail, hospitality, and transportation. Good examples of personal pricing in the transportation sector is the price differentiation at Uber. For the same ride on a different location prices vary based on a surge multiplier (Battifarano and Qian, 2019). The surge multiplier is mainly introduced to balance supply and demand. Areas with a higher surge multiplier are visible on their map for drivers, so more drivers move to the surge area to balance supply and demand.

On the other hand, dynamic pricing or sometimes referred to as price discrimination is prohibited when the intent of the price discrimination is to harm competitors (Cornell law school, 2023). Furthermore, it can confuse customers, since it is not always clear how a price is determined. For example, in the airline industry this can be explained by the fact that the airlines use a network revenue model. This leads to behavior of customers to book tickets with additional stops to make the trip cheaper. Another trick customers use is purchasing a roundtrip while they only require a single trip, since in some cases this makes the flight cheaper Aslani et al. (2014). Eventually, this can make price discrimination less effective, since customers try to find loopholes in the system. Another negative aspect of price discrimination is that it can create mistrust and dissatisfaction. This is especially true when the process for the price determination is not transparent (Huang et al., 2022). This could harm the overall revenue, due to the fact that customers are more likely to switch when they are dissatisfied.

Another commonly used mechanism within the literature to increase the ability to consolidate orders is carrier pooling. In the work conducted by Hajdul (2011), the author argues that the load factor problem can be solved by an overarching network (carrier pooling network) to which distributors are connected, because currently orders are offered to a very small network of carriers. An overarching network could solve the complete vehicle routing problem much more efficiently, since more data will be available, thus shorter distances between loading and unloading can be scheduled (Danloup et al., 2015a; Hajdul, 2011). In the first place it will reduce empty running, but it will also increase the load factor. Additionally, this increases competition and the carrier with the cheapest rate will be chosen. A carrier can become the cheapest due to the fact that the carrier can easily combine or consolidate the order with another order. However, currently smaller networks are used and for a carrier to gain access, contracts are discussed and in those contracts prices are fixed and a performance is discussed. Due to the intensive labor this takes, the network stays small. An overarching network could solve the problem, by more efficient allocation of loads. However, performance of the carriers cannot be tracked as efficiently as it currently is. Additionally, Danloup et al. (2015b) found that cultural issues like issues of trust between competitors are one of the main barriers for collaboration in an overarching network.

To conclude this additional literature section a mechanism to increase expected utility will be ex-

Table 5.1: Design principles based on the additional literature review

Nr.	Context	Agency	Mechanism	Outcome
1.	In order to increase load fill in the supply chain	Van der Wal should educate the manufacturer on potential savings in loading procedures and ordering patterns	by summarizing the entire cost and carbon emission per region	which in turn increases the utility of the analysis.
2.	In order to increase load fill in the supply chain	Van der Wal should provoke detection behavior	by using a negative frame	which in turn increases the chance of target setting by the manufacturer.
3.	In order to increase load fill in the supply chain	Van der Wal should determine the most impactful customers on cost and carbon emission	by providing the analysis in a two-by-two matrix with data points per lane with cost and carbon emission savings on the axis	which in turn makes negotiations for the manufacturer with customers more effective.
4.	In order to increase load fill in the supply chain	Van der Wal should make use of dynamic pricing	by adding a surge multiplier to the costs for transportation	which in turn increases demand for shipments that are possible to consolidate.
5.	In order to increase load fill in the supply chain	the carrier should should make use of dynamic pricing	by adding a surge multiplier to the cost for transportation	which in turn increases demand for shipments that are possible to consolidate.
6.	In order to increase load fill in the supply chain	Van der Wal should make use of a carrier pooling network	by adding more carriers to their current network of carriers	which in turn allows a cheaper price for transportation and a higher load factor when this cheaper carrier is chosen.

plained. Customer logistic managers consider the individual yields to be insignificant. This can be explained by the fact that individual yields are very low since transportation cost are merely a fraction of the total cost of a product. One mechanism to increase the expected utility would be to summarize all customers from the account of a customer logistic manager, since more money implies a higher expected utility according to the prospect theory, despite the fact that the function is logarithmic (Kahneman and Tversky, 1979). Furthermore, a valence frame should be applied to the message since this could increase the expected utility as well. One mechanism to do this is by framing the message as a loss, since humans are risk seeking in the loss domain and risk averse in the gain domain (Levin et al., 1998). Furthermore, the message appeals differently to the reader when framed differently. Gain frames promote prevention behavior and loss frames promote detection behavior. In this instance a negative frame is more favorable, since detection behavior is required due to the fact that the problem of less than ideal order sizes is already occurring and thus requires a solution. Additionally, to support the account managers and sales department in targeting the most problematic cases a two-by-two matrix could be used to cluster the customers in different categories. The axis on this cluster are carbon emission and potential cost savings. Hence, one category of customers will consist of customers who perform most problematic on both cost and carbon emission. This two-by-two matrix is based on work done Liljestrand et al. (2015), explained in section 3.2. This leads to the following design principles presented in Table 5.1

5.2 Triangulation

Both from interviews and observations it became clear that trucks are not always fully filled. One obvious reason is that the floor area is not fully used. Both in literature and in interviews two possible solutions are consolidation and greater order quantities. On the other hand, increasing order patterns is currently not an option for customers since cost for transportation is included in the overall cost for the product. The cost for transportation should thus either be separated or improvements on order patterns should be incentivized. Furthermore, consolidation is not as easy as it seems to apply for Van der Wal, since the number of orders is currently too low to apply consolidation internally as is explained in the interviews. Another factor which makes consolidation hard is the fact that Van der Wal is not allowed to consolidate one 4PL customer with another customer from, either their 2PL or 4PL department. Additionally, both from the observations and interviews it became clear that a lot more can be done on the height of the load units. Literature shows that double stacking could help in utilizing the maximum height of a truck. Currently there are hardly any initiatives for utilizing the maximum height of a truck. From the interviews it became clear that the manufacturer is not fully aware of the impact utilizing the maximum height has. They are open to start the conversation with the customer when they know the possible benefits on cost and carbon emission. Literature showed that increasing the size of warehouses and centralizing them could centralize the flow of goods and eventually make consolidation more feasible. Additionally, literature showed that using the ant-colony algorithm would increase load fill. Van der Wal already uses this algorithm as much as possible, however is again limited by the number of orders. A possibility to counter the low number of orders is to increase specific demand. One way of doing this is using dynamic pricing as it is explained in section 5.1. Another possibility is to counter the low number of consolidation options by increasing supply. This can be done by using a carrier pooling network. Eventually, this will lead to the design principles presented in Table 5.2.

Table 5.2: Final list of design principles based on the observations, interviews and literature

Nr.	Context	Agency	Mechanism	Outcome
1.	In order to increase load fill in the supply chain	The planner and/or carrier should improve the loading procedure	By using standardized vehicles	Which in turn allows for an optimal use of space.
2.	In order to increase load fill in the supply chain	The manufacturer should improve the loading procedure	By using standard load units	Which in turn allows for an optimal use of space.
3.	In order to increase load fill in the supply chain	The manufacturer and/or customer should improve the loading procedure	By using/allowing for double stacking	Which in turn allows for an optimal use of space.

Table 5.2: Final list of design principles based on the observations, interviews and literature

Nr.	Context	Agency	Mechanism	Outcome
4.	In order to increase load fill in the supply chain	The manufacturer should consolidate orders	By centralizing and increasing warehouses	Which in turn decreases the number of lanes and thus increases the opportunity for consolidation of orders.
5.	In order to increase load fill in the supply chain	The planner should consolidate orders	By using optimization algorithms such as the ACO algorithm	Which in turn decreases the number of lanes and thus increases the opportunity for consolidation of orders.
6.	In order to increase load fill in the supply chain	The planner should consolidate orders	By consolidating similar lanes	Which in turn decreases the number of lanes and thus increases the opportunity for consolidation of orders.
7.	In order to increase load fill in the supply chain	The planner, carrier and/or manufacturer should increase the average order size	By limiting the order options	Which in turn increases the number of products per truck.
8.	In order to increase load fill in the supply chain	The planner and/or carrier should increase the average order size	By leaving empty load units until they match a full truck	Which in turn increases the number of load units per truck.
9.	In order to increase load fill in the supply chain	Van der Wal should analyze the impact of order patterns and loading procedures	by calculating the potential cost and carbon emission saving per configuration and for double stacking	which in turn yields a clear overview of potential gains and a summary of the entire customer base.
10.	In order to increase load fill in the supply chain	Van der Wal should aid sales department of the manufacturer in negotiations for increasing the average order volume	by providing an analysis per improvement mechanism (loading and ordering in the different configurations)	which in turn allows the manufacturer to incentivize (offer a discount to) customers who order in higher configurations.
11.	In order to increase load fill in the supply chain	Van der Wal should schedule loads based on the lowest price	by tendering the load to different carriers	which in turn increases the number of loads booked via a dynamic price.
12.	In order to increase load fill in the supply chain	Kimberly-Clark should separate transport costs from product prices	by making the cost for transportation variable	which in turn allows for the use of dynamic pricing.

Table 5.2: Final list of design principles based on the observations, interviews and literature

Nr.	Context	Agency	Mechanism	Outcome
13.	In order to increase load fill in the supply chain	Van der Wal should educate the manufacturer on potential savings in loading procedures and ordering patterns	by summarizing the entire cost and carbon emission per region	which in turn increases the utility of the analysis.
14.	In order to increase load fill in the supply chain	Van der Wal should provoke detection behavior	by using a negative frame	which in turn increases the chance of target setting by the manufacturer.
15.	In order to increase load fill in the supply chain	Van der Wal should determine the most impactful customers on cost and carbon emission	by providing the analysis in a two-by-two matrix with data points per lane with cost and carbon emission savings on the axis	which in turn makes negotiations for the manufacturer with customers more effective.
16.	In order to increase load fill in the supply chain	Van der Wal should make use of dynamic pricing	by adding a surge multiplier to the costs for transportation	which in turn increases demand for shipments that are possible to consolidate.
17.	In order to increase load fill in the supply chain	the carrier should should make use of dynamic pricing	by adding a surge multiplier to the cost for transportation	which in turn increases demand for shipments that are possible to consolidate.
18.	In order to increase load fill in the supply chain	Van der Wal should make use of a carrier pooling network	by adding more carriers to their current network of carriers	which in turn allows a cheaper price for transportation and a higher load factor when this cheaper carrier is chosen.

6 Potential solution directions

In this chapter first three potential solution directions will be discussed, followed by an evaluation of those solution directions and on the design principles. From both literature and empirical evidence different design principles have emerged. These design principles mainly fit in three different categories being: (end) customer education, increasing supply & demand and finally route optimization. However, there is already a route optimization algorithm in place, and no problem currently exist on the effectiveness of it. These principles will thus be neglected for the final list of design principles.

6.1 Potential solution direction 1: Surge pricing for transport

Table 6.1: Design principles for potential solution direction 1 described in section 6.1

Context	Agency	Mechanism	Outcome
In order to increase load fill in the supply chain	The planner should consolidate orders	By consolidating similar lanes	Which in turn decreases the number of lanes and thus increases the opportunity for consolidation of orders.
In order to increase load fill in the supply chain	Van der Wal should schedule loads based on the lowest price	by tendering the load to different carriers	which in turn increases the number of loads booked via a dynamic price.
In order to increase load fill in the supply chain	Kimberly-Clark should separate transport costs from product prices	by making the cost for transportation variable	which in turn allows for the use of dynamic pricing.
In order to increase load fill in the supply chain	Van der Wal should make use of dynamic pricing	by adding a surge multiplier to the costs for transportation	which in turn increases demand for shipments that are possible to consolidate.

The first potential solution direction, targets the low demand for orders at Van der Wal. Low demand increases the difficulty for consolidation as is visible in Figure 4.2. The underlying design principles are present in Table 6.1. For this solution a comparison will be made between Uber and 4PL supply chain. Differences between LTL and FTL can be denoted as a single person desiring an Uber ride and a group of friends who exactly fill a car desiring an Uber ride. The group of friends pay an Uber to go exactly to the desired location, where for the single person there is an option to share the Uber or to pay 'a premium' and go immediately to the right location. This possibility currently exists for transportation as well. Here the share option is the groupage carrier. Loads do not take the direct route to the desired destination but travel via hubs. An additional functionality on the Uber app, which currently does not exist yet in the transportation of goods for Kimberly-Clark is surge pricing. Surge pricing is "the dynamic pricing mechanism employed to ensure sufficient vehicle supply during periods of high rider demand" (Battifarano and Qian, 2019). This mechanism can be translated to the 4PL supply chain, but in a reversed fashion. For Van der Wal finding a carrier for transportation is a smaller issue than the low amount of LTL orders that makes consolidation internally at Van der Wal impossible. This is more interesting for smaller customers, since those customers order in smaller volumes, because they have smaller warehouses. Additionally, these customers are probably more attracted to those cheaper prices since it makes, in terms of percentage, more impact on their total expenditures.
On the other hand, a large change in contracts is required. Now prices per products are predetermined in contracts. In those prices, costs for transport are included as well. Part of this solution direction implies that Kimberly-Clark should form a new contract with their customer. The old contract is an

optimal performance contract, where goods will always be on-time, and when ordered in FTL configuration as cheap as possible. The new contract will only contain a price for the goods and a variable price for transportation. This variable price is determined on a few factors, like order size, location, supply, demand, date, and time. These factors can all play a role in the difficulty for consolidation. Factors, location, date, and time all follow directly as intermediate cause from Figure 4.2, supply and demand are always crucial in determining the right price, as is explained in section 5.1. Order size can play a role here as well, for example when a customer orders 22 pallets, consolidation can become harder, because now only 11 additional pallets fit into the truck. Eventually, this contract optimizes for cheaper cost in contrary to the old contract which optimizes for performance.
The solution for customers on this new contract could be in a form of live prices. This is related to airline prices. For example, when the desired location is London Heathrow, and the date should be somewhere in week 34, then there are multiple prices based on time (when there are multiple flights a day) and weekday, these prices differ due to the demand of customers as well. A similar pricing table for customers will be developed in this potential solution direction, with on one axis desired date and the other axis the desired time. Before the customer reaches this table, the customer should enter the desired order in their order menu, for example 10 pallets of product X and 2 pallets of product Y. A lot of customers do have automatic order systems, here customers should program their system in the preferred state. One state for example could be that the system should choose the cheapest available slot for the next week when the order is placed.

6.2 Potential solution direction 2: Surge pricing at carrier with a carrier pooling network

Table 6.2: Design principles for potential solution direction 2 described in section 6.2

Context	Agency	Mechanism	Outcome
In order to increase load fill in the supply chain	The planner should consolidate orders	By consolidating similar lanes	Which in turn decreases the number of lanes and thus increases the opportunity for consolidation of orders.
In order to increase load fill in the supply chain	Van der Wal should schedule loads based on the lowest price	by tendering the load to different carriers	which in turn increases the number of loads booked via a dynamic price.
In order to increase load fill in the supply chain	Kimberly-Clark should separate transport costs from product prices	by making the cost for transportation variable	which in turn allows for the use of dynamic pricing.
In order to increase load fill in the supply chain	the carrier should should make use of dynamic pricing	by adding a surge multiplier to the cost for transportation	which in turn increases demand for shipments that are possible to consolidate.
In order to increase load fill in the supply chain	Van der Wal should make use of a carrier pooling network	by adding more carriers to their current network of carriers	which in turn allows a cheaper price for transportation and a higher load factor when this cheaper carrier is chosen.

To start this potential solution direction a similar approach as the solution proposed in section 6.1 will be pursued. Again the dynamic pricing design principle will be used, however in this instance the agency is different. The agency is changed from Van der Wal to the carrier, since a carrier can have a lot more impact on consolidation, due to the fact that carriers have a larger customer base. All other aspects of the previous proposed solution will be similar in this proposed solution. However this proposed solution will make use of one additional design principle, which is a carrier pooling network that can be used to increase supply and thus create competition. The additional competition here is in the form of additional carriers. To continue with the Uber example in this instance Uber is a carrier and additional competitors are added to the network, like for example Lyft, now Lyft is another carrier. Lyft can offer a lower price for a lane on a specific time when a shipment is already booked on a similar lane (by a different customer). Uber who has not yet received an order in a similar route, thus is not able to consolidate the order and requires a higher fee. The most cost effective option will be chosen, hence the option with the higher load fill. Load fill has been increased compared to the situation where only one carrier was available. Underlying design principles can be found in Table 6.2

6.3 Potential solution direction 3: Customer education

Table 6.3: Design principles for potential solution direction 3 described in section 6.3

Context	Agency	Mechanism	Outcome
In order to increase load fill in the supply chain	The manufacturer and/or customer should improve the loading procedure	By using/allowing for double stacking	Which in turn allows for an optimal use of space.
In order to increase load fill in the supply chain	The planner, carrier and/or manufacturer should increase the average order size	By limiting the order options	Which in turn increases the number of products per truck.
In order to increase load fill in the supply chain	Van der Wal should analyze the impact of order patterns and loading procedures	by calculating the potential cost and carbon emission saving per configuration and for double stacking	which in turn yields a clear overview of potential gains and a summary of the entire customer base.
In order to increase load fill in the supply chain	Van der Wal should aid sales department of the manufacturer in negotiations for increasing the average order volume	by providing an analysis per improvement mechanism (loading and ordering in the different configurations)	which in turn allows the manufacturer to incentivize (offer a discount to) customers who order in higher configurations.
In order to increase load fill in the supply chain	Kimberly-Clark should separate transport costs from product prices	by making the cost for transportation variable	which in turn allows for the use of dynamic pricing.
In order to increase load fill in the supply chain	Van der Wal should educate the manufacturer on potential savings in loading procedures and ordering patterns	by summarizing the entire cost and carbon emission per region	which in turn increases the utility of the analysis.
In order to increase load fill in the supply chain	Van der Wal should provoke detection behavior	by using a negative frame	which in turn increases the chance of target setting by the manufacturer.
In order to increase load fill in the supply chain	Van der Wal should determine the most impactful customers on cost and carbon emission	by providing the analysis in a two-by-two matrix with data points per lane with cost and carbon emission savings on the axis	which in turn makes negotiations for the manufacturer with customers more effective.

The third potential solution direction utilizes the design principles which are based on changing customer behavior. As can be seen in the top part of Figure 4.3, customer logistic managers deem the individual improvements for single customers insignificant, however the total amount of money from an entire region could probably trigger them to set targets for the sales department. Based on the prospect theory people are risk averse in the gain domain and risk seeking in the loss domain. This implies that the utility is greater when both money and carbon emission is expressed as the amount that is wasted (Kahneman and Tversky, 1979). This is also in line with the valence framing theory of Levin et al. (1998), in their work they address three types of valence framing mechanisms, and one being goal framing, which impacts the persuasion of the goal. The message appeals differently depending on whether it stresses the positive consequence of performing an act to achieve a goal (gain frame) versus the negative consequence of not performing an act (loss frame). Detweiler et al. (1999) found that gain frames promote prevention behavior and loss frames promote detection behavior. In this instance detection behavior is more favorable, since there is already a problem which requires a solution.

Furthermore, the total mass of CO_2 probably does not trigger those managers, since those numbers do not represent value for the managers. Hence, the mass of CO_2 can be translated into number of trees, and the number of trees can be visualized into acres of forest. This expresses the urgency of the problem and thus more customer logistic managers address the problem to the sales department and account managers. This leads to the next problem, because the sales department or account managers receive those targets, however they require an insight in which customer to contact to most effectively reach those targets. According to Liljestrand et al. (2015) a two-by-two matrix should work effectively. Where on the x-axis the potential saving in CO_2 is denoted and on the y-axis the potential cost savings. Then the edges of the quadrants consist out of half of the maximum amount of potential CO_2 and cost saving. To aid the sales department and account managers in their negotiations with the customer the data for individual lanes needs to be visible for them as well, and again the number of trees and acres of forest should be expressed instead of CO_2. Now they are able to negotiate an a potential discount for customers on improved behavior and convince customers to change their behavior based on the impact the loading procedure and their order behavior have. The different mechanisms for improving load fill should be visualized in one combined two-by-two matrix, however when required the impact per mechanism should be visible per customer, because some customers do not have the capability to receive double stacked orders, however are able to receive 34 pallets per order. Hence, account managers and the sales department should customize the approach to the ability of every customer. All design principles used can be found in Table 6.3

6.4 Evaluation of the different potential solution directions and design principles

Both the potential solution directions and design principles were tested during an alpha test, which is explained in section 2.5. To start with the design principles those were evaluated per principle. Eventually, most principles are already in place at Van der Wal, however are currently limited in its use.

Additionally, the potential solution directions were evaluated as well. This is done based on a weighted scoring table visible in Table 6.4 Criteria in the table are developed together with the expert panel as well as the applied weights per criteria. Eventually, scores for the different potential solution directions were determined based on the criteria.

Table 6.4: Weighted scores for the three different solution directions

Criteria	Weight	Solution direction 1	Solution direction 2	Solution direction 3
Feasibility	1	1	1	4
Impact on cost	3	1	2	3
Impact on carbon emission	3	1	2	3
Improvement on the different load levels	1	2	2	3
Ability to measure impact	2	1	0	4
Total	-	11	15	33

From the weighted score table (Table 6.4) it is visible that potential solution direction 3 probably is the best solution direction to proceed. Additionally, both the first and second solution direction are very similar and both focus on maximizing the consolidation possibilities. The first solution direction does this by increasing the possibilities for consolidation for the planner. This can be explained by the fact that demand should be increased for possible consolidations. For the second solution direction supply is increased by the carrier pooling network and demand for consolidated orders is increased by lower prices for transportation. In general, for both solutions the average order size will decrease, since customers are more likely to place an order earlier, due to the opportunity for cheaper prices for transportation. Earlier here implies that the replenishment of the stock is sooner than in a normal situation. On the other hand, potential solution direction 3 tries to increase the order sizes of the customers, since the focus lies on increasing order patterns for the customers. For consolidation smaller sized orders are preferred since these increase the probability for consolidation. Eventually, these two directions do not function together, hence coexistence of the two different categories of solution directions is nearly impossible.

Feedback by the expert panel on the design principles presented in Table 5.2 is shown in the following enumeration:

1. Design principle 1 is already in place, we use mostly standard trailers and when the load requires a mega trailer, we will use mega trailers.
2. Design principle 2 is already in use as well, since most loads are shipped with EURO pallets, and in the UK with block pallets
3. Design principle 3 is something we are currently working on. For stock replenishments at warehouses this happens already, however not for loads to customers.
4. Design principle 4 is already in use as well. Warehouses are currently hired so they are not Kimberly-Clark owned. It is hard to reduce the number of warehouses even further since then factors such as driving time could play a role.
5. Design principle 5 is already in use as well, and tenders are made one day before the scheduled arrival of the load.
6. Design principle 6 is already in place, especially at groupage carriers, since it is their core business to consolidate multiple loads. On the other hand we are limited by a lot of factors, and one factor that was not already mentioned during interviews it the fact that customers do not allow it since they do not want their products to be in the same truck as a competitor.
7. Design principle 7 itself is correct, however not very often in use due to a lack of awareness at the customer's side.

8. Design principle 8 itself is correct, however not applicable in our case, since we try to increase the load factor for deliveries specific and not for backloads.
9. Design principle 9 has currently just been started, the manufacturer seems very content with overview provided.
10. Design principle 10, sounds interesting, this makes the problem visible for the people working with it. Furthermore, it provides a selection for the customer, and now they know where the biggest gains are in terms of carbon emission and cost reduction.
11. Design principle 11 is already in place. Van der Wal provides the opportunity for half an hour for the cheapest carrier to accept the tender, before the next carrier is tendered.
12. Design principle 12 sounds interesting. An addition to this should be a CO_2 component. This should raise awareness at the end customer. The factor which makes it more difficult is that transportation is mostly a small fraction of the entire cost and the sales department sees it as a waste of time to address this.
13. Design principle 13 describes the task of a 4PL service provider. It is important that the planner shares its knowledge from the logistic sector. On the other hand, the manufacturer and warehouse owners should evaluate whether the improvements are actually possible, sometimes they are for example limited by the knowledge of the warehouse employees.
14. Design principle 14 is not yet in place, and quite the opposite was the way of providing information. This could actually be very interesting and sales representatives at the manufacturer could receive budget targets, that they for example should reduce 10% of their current budget.
15. Design principle 15, sounds interesting, this makes the problem visible for the people working with it. Furthermore, it provides a selection for the customer, and now they know where the biggest gains are in terms of carbon emission and cost reduction.
16. Design principle 16 could theoretically work and sounds very interesting, however due to the limited number of orders the impact would not be high.
17. Design principle 17 sounds interesting and a lot more doable, however information should be provided on-time. This is a bit unrealistic since the data aspect and the translation takes a lot of work. On the other hand, this happens already low-key. Now there are fixed rates and carriers who preferably ship the load, demand the lowest flat rate. This is probably because consolidation for this carrier is easier than for the other carrier.
18. Design principle 18 is already in use as well, however Van der Wal is limited internally because they do not have enough employees for carrier management to maintain all relationships with carriers and to find new carriers which can be added to the network.

7 Final solution direction

In this chapter of the thesis first the final list of requirements will be presented. Thereafter, underlying calculations for the analysis will be presented, followed by a section how customer logistic managers and eventually the sales department and account managers are triggered to address this problem more frequently to customers.

7.1 Design Requirements

Table 7.1: Design requirements and their origin

Type of requirement	Requirement	Source
Functional	The artifact should measure load fill on the different levels	literature
Functional	The artifact should measure potential cost savings	interview
Functional	The artifact should measure potential carbon emission savings	interview
User	The artifact should be an analysis per lane on a monthly basis	interview
User	The artifact should exist in one place with customer (KC) access	interview
User	The artifact should be easy to understand	expert interview
Boundary	The artifact should be developed without the help of external resources	expert interview
Design	The artifact should be digital	expert interview
Design	The front-end of the artifact cannot contain any code	expert interview

Within this section of the thesis the requirements are discussed and the division of the requirements over the different categories (functional, user, boundary and design) introduced by van Aken et al. (2007). The final list of requirements are visible in Table 7.1.
From the literature it becomes clear that measuring load fill on all levels simultaneously is not insightful, since it does not identify the problem and different types of analyses are thus required. The first functional requirement would therefore be that the artifact should measure load fill on one level simultaneously. Additionally, the interviews showed that the artifact should provide information on potential cost savings. Moreover, the artifact should provide information on potential carbon emission savings. These are two functional requirements, since without these requirements the design will not function since the design principles cannot be activated without this information.
Furthermore, the interviews also provided insights in the user requirements. The first user requirement being that the artifact should be an analysis per lane on a monthly basis. Otherwise analysing the results of the artifact becomes too time intensive and the different lanes can be divided over the different account managers linked to a specific lane. Another user requirement is that the artifact should exist in one place and the customer (Kimberly-Clark) should have access to this artifact. This decreases the need for additional unnecessary communication between Kimberly-Clark and Van der Wal. The final design requirements are developed during the expert interview with an engineer from Van der Wal. Here the first requirement is an additional user requirement. This requirement is: the artifact should be easy to understand, since Van der Wal cannot always contact every single account manager who will be working with the tool.
The second requirement is a boundary restriction being that the artifact should be developed without the help of external resources. This can be explained by the fact that Van der Wal has already the capabilities and resources in-house to make a sufficient final product without requiring additional resources to increase the aesthetics of the artifact.
The final type of design requirements are the design restrictions. Two design restrictions were found during the expert interview and the first being that the design should be digital since this provides the best customer access and overview. Finally, the front-end cannot contain any code, because not

everyone within Van der Wal and Kimberly-Clark do have the knowledge to work with different coding languages.

7.2 Underlying Calculations

The final solution direction should be a cohesive monthly analysis per lane. This analysis is based on the historic order data of the customers and cost of transportation per location. For this analysis calculations are required to show the impact an improvement mechanism such as ordering more pallets per load would have on cost and carbon emission. These will thus be further explained in this section.

7.2.1 Data Cleaning

To be able to calculate the impact of the different improvement mechanisms, several data cleaning steps need to be taken. First of all, within the data the number of footprints is denoted as a float number, however these footprints are purchased as full, thus these are rounded up with a ceil function to nearest integer. The number of footprints per load i in a specific lane L is denoted as V_{Li}. Here lanes express loads with a unique set of loading location and unloading location. Note that the same customer can have multiple lanes, for example when they order from a different mill or when the customer has multiple sites. V_{Li} is the number of footprints for load i in lane L, such that $V_{Li} \in \mathbb{Z}$ and $1 \leq V_{Li} \leq 33$. This filters loads that have a footprint lower than 1 and higher than 33, this since these loads do not fit in a standard trailer, or there was a mistake in tracking the number of pallets for that load (Lusby et al., 2010). Loads that do not fit in standard trailers are filtered from the data since not every lane has a road train tariff. Furthermore, some loads contain multi-stops, these are filtered from the data as well, since here already some improvements took place and improving the order pattern for this specific load could actually worsen the load fill. In the data multi-stops can be recognized by a missing value of the second, third and up to the last stop in the loading location column. Lanes from mill to a warehouse from Kimberly-Clark are removed as well, since these lanes are quite optimal already, because nearly always trucks are fully loaded with 34 pallets double stacked, and only when a stock issue occurs this is not the case. Finally, the distance per lane is different for individual loads, thus to counter the effect of the volatile data the average distance per lane is taken beforehand. This is done according to following formula:

$$\bar{d_L} = \frac{1}{N_L} \sum_{i=1}^{N_L} d_{Li} \tag{1}$$

where

$\bar{d_L}$ is the average distance per lane L.

N_L is the number of loads per lane L

d_{Li} is the distance in lane L per load i

In the rate card some preparation steps are taken as well. First of all, weekend scales and road train tariffs are removed. Furthermore the cheapest cost is chosen per unique identifier of the loading location α, per unique identifier of the unloading location β and per configuration j. This is denoted as $C_{\alpha\beta j}$. Examples of such identifiers are postal codes, unique location numbers and regions. Note that some unique identifiers are not unique per lane, hence the same tariff can be applied to multiple lanes. Finally, the cost per configuration and per unique identifiers for loading and unloading location are merged to all loads based on these identifiers and thus will not be used further since the analysis will be conducted based on lane. This leads to the following notation for the cost C_{Lij} in a specific lane L per load i per configuration j.

7.2.2 Historical Performance per lane

To calculate all potential cost savings on a monthly basis historic data can used. This should be done per region since all regions use different contract strategies, and thus costs deviate between regions. All costs which are impossible due to the footprint configuration of the order should be deleted. For example, when an order has 17 footprints, a carrier cannot be paid for 6 pallets, on the other hand tariffs for 17, 18, etc. pallets are possible, however due to the structure of the pricing scale either the exact number of footprints or an FTL tariff is likely chosen. The cost for the shipment is the cheapest possible option. To calculate the cheapest freight spend possible per delivery address all those costs are summed per customer. This leads to the following calculation:

$$HS_L = \sum_{i=1}^{N_L} \min_{j \geq V_{Li}}^{33} C_{Lij} \tag{2}$$

where

HS_L denotes the historic freight spend per lane L

C_{Lij} is the cost in lane L per load i per configuration j

$\min_{j \geq V_{Li}}^{33} C_{Lij}$ denotes the minimum cost among all configurations greater or equal to the footprints per load up to and including 33 for load i in lane L

V_{Li} is the number of footprints in lane L per load i such that $1 \leq V_{Li} \leq 33 \ \forall \ V_{Li} \in \mathbb{Z}$

To calculate the historic carbon emission per order first the carbon emission per order needs to be determined. The emission per kilometer is not universally the same, the emission for an empty truck is 0.35 kilogram of CO_2 per kilometer and for a full truck this number equals 0.65 (**?**). These figures are both based on data from Van der Wal internally. Hence, the emission per pallet can be determined as following: $\frac{0.65-0.35}{33}$. Thus the emission of kilogram CO_2 per load per kilometer can be determined as following:

$$\frac{0.3}{33} V_{Li} + 0.35 \tag{3}$$

where

The term $\frac{0.3}{33} V_{Li}$ denotes the carbon emission per footprint per kilometer.

V_{Li} denotes the number of footprints in lane L per load i.

The term 0.35 denotes the carbon emission for the truck per kilometer.

To calculate the complete carbon emission per lane, the average distance per lane needs to be multiplied by all carbon emission numbers per lane per load. This can be done according following calculation:

$$HE_L = \bar{d_L}\left(0.35N_L + \frac{0.3}{33}\sum_{i=1}^{N_L} V_{Li}\right) \tag{4}$$

where

HE_L denotes the historic emission of CO_2 per lane.

$\bar{d_L}$ denotes the average distance per lane L.

N_L denotes the number of orders per lane L.

V_{Li} denotes the number of footprints in lane L per load i

The term $0.35N_L$ denotes the emission for all trucks per lane per kilometer.

The term $\frac{0.3}{33}\sum_{i=1}^{N_L} V_{Li}$ denotes the carbon emission for all pallet footprints per lane per kilometer.

7.2.3 Ordering

To analyze the impact of the ordering patterns, simulations are made for different numbers of pallet footprints. This is a simulation to check the impact per lane on an average order pattern, so the cost and emission are calculated over a certain configuration number, and customers in this simulation are not allowed to order any other configuration, only when the residual pallets are lower than the configuration number. To calculate the cost per configuration first the number of whole shipments needs to be calculated for a particular configuration, and for multiplied by the cheapest available cost for that configuration. This can be calculated by the following calculation:

$$\left\lfloor \frac{1}{X}\sum_{i=1}^{N_L} V_{Li} \right\rfloor \min_{j \geq X}^{33} C_{Lij} \tag{5}$$

where

X is the configuration such that $X \in \mathbb{Z}$ and $1 \leq X \leq 33$

$\left\lfloor \frac{1}{X}\sum_{i=1}^{N_L} V_{Li} \right\rfloor$ denotes the floor function of the expression $\frac{1}{X}\sum_{i=1}^{N_L} V_{Li}$, which returns the greatest integer that is less than or equal to the argument.

$\min_{j\geq X}^{33} C_{Lij}$ denotes the minimum cost among all configurations j greater or equal to the given configuration X up to and including 33 for load i in lane L.

Thereafter the cost for the leftover pallets is calculated by applying the cheapest possible cost for the leftover footprints, which can be denoted as following:

$$\min_{j\geq \sum_{i=1}^{N_L} V_{Li} \mod X}^{33} C_{jL} \tag{6}$$

The total cost per configuration per lane can thus be determined by the following equation:

$$CS_L(X) = \left\lfloor \frac{1}{X}\sum_{i=1}^{N_L} V_{Li} \right\rfloor \min_{j\geq X}^{33} C_{jL} + \min_{j\geq \sum_{i=1}^{N_L} V_{Li} \mod X}^{33} C_{jL} \tag{7}$$

Where $CS_L(X)$ denotes the freight spend in lane L per configuration X.

X denotes a given configuration such that $1 \leq X \leq 33 \forall X \in \mathbb{Z}$.

N_L denotes the number of loads per lane L.

V_{Li} denotes the number of footprints in Lane L per load i.

j denotes the configuration which yields the cheapest possible cost for configuration X.

C_{jL} denotes the cost per configuration j in lane L.

To calculate the corresponding CO_2 emission in kilograms per lane per configuration a similar calculation has been used as in calculation 7. Again, first the carbon emission for the full loads per certain configuration is calculated using the following formula:

$$\left\lfloor \frac{1}{X}\sum_{i=1}^{N_L} V_{Li} \right\rfloor \bar{d_L} \left(\frac{0.3X}{33} + 0.35\right) \tag{8}$$

To calculate the carbon emission of the pallets which do not fit in an entire load the following calculation can be used:

$$\bar{d_L}\left(\frac{0.3}{33}\left(\sum_{i=1}^{N_L} V_{Li} \mod X\right) + 0.35\Phi_L\left(V_{Li}, X\right)\right) \tag{9}$$

Where

$$\Phi_L(V_{Li}, X) = \begin{cases} 1, & \text{if } \sum_{i=1}^{N_L} V_{Li} \mod X > 0. \\ 0, & \text{otherwise.} \end{cases}$$

$\Phi_L(V_{Li}, X)$ denotes an activation function in lane L, which equals one when there are leftover pallets present and zero when no leftover pallets are present.

This leads to the total overall calculation for the carbon emission per configuration per lane:

$$CE_L(X) = \bar{d_L}\left(\left\lfloor \frac{1}{33}\sum_{i=1}^{N_L} V_{Li} \right\rfloor \left(\frac{0.3X}{33} + 0.35\right) + \left(\frac{0.3}{33}\left(\sum_{i=1}^{N_L} V_{Li} \mod X\right) + 0.35\Phi_L\left(V_{Li}, X\right)\right)\right) \tag{10}$$

Where

$$\Phi_L(V_{Li}, X) = \begin{cases} 1, & \text{if } \sum_{i=1}^{N_L} V_{Li} \mod X > 0. \\ 0, & \text{otherwise.} \end{cases}$$

$CE_L(X)$ denotes the carbon emission per lane per configuration.

$\bar{d_L}$ denotes the average distance per lane L.

N_L denotes the number of orders per lane L.

V_{Li} denotes the number of footprints in lane L per load i.

Alternatively, X can be the configuration such that $X \in \mathbb{Z}$ and $1 \leq X \leq T_L \wedge X = 33$
Here T_L is denoted as the maximum groupage tariff per lane, hence when $X \geq T_L$ the load will automatically shipped by an FTL carrier, since not all groupage carriers offer tariffs for every single configuration. Thus, when using this notation for configuration X only optimal configurations are considered, in other words configurations that yield optimal performance for load fill. This can be explained by the fact that it is in an groupage carrier's best interest to fill a truck as much as possible, since they receive a fee per footprint configuration sold. So, eventually the truck of an groupage carrier

will stay when that is a more economical option. On the other hand, FTL carriers receive a fixed fee no matter the configuration. Hence, to optimally utilize these trucks, they need to be filled as much as possible.

Eventually, to calculate the possible yields in both cost and carbon emission, the difference between the historic freight spend and the freight spend per configuration needs to be calculated. This can be calculated by:

$$S_1L(X) = HS_L - CS_L(X) \tag{11}$$

Where

$S_1L(X)$ denotes the cost savings for freight spend in lane L for configuration X and improvement mechanism number 1 (which is ordering).

HS_L denotes the historic freight spend per lane L.
$CS_L(X)$ denotes the freight spend in lane L per configuration X X denotes configuration such that $X \in \mathbb{Z}$ and $1 \leq X \leq T_L \wedge X = 33$.

Accordingly, a similar calculation returns the total yield of carbon emission per lane, this is denoted by:

$$E_1L(X) = HE_L - CE_L(X) \tag{12}$$

Where

$E_1L(X)$ denotes the carbon emission saving in lane L per configuration X and improvement mechanism number 1 (which is ordering).

HE_L denotes the historic carbon emission in lane L.

$CE_L(X)$ denotes the carbon emission in lane L per configuration X.

X denotes configuration such that $X \in \mathbb{Z}$ and $1 \leq X \leq T_L \wedge X = 33$.

7.2.4 Double Stacking

To calculate the impact of double stacking, the total volume per FTL should be determined. An FTL fits 33 footprints (for 34 pallets another loading procedure is required and this will be addressed separately) and the area per footprint in m^2 is calculated by 0.8×1.2, which are the dimensions of a EURO pallet (Tranpak, 2023). The total usable height in a truck equals $2.7m$, however $5cm$ clearance is required and when pallets are double stacked an additional pallet from $15cm$ is used, hence the total usable height is $2.5m$ (Enpeks, 2023). Thus, the total usable volume per FTL can be calculated by: $33 \times 2.5 \times 0.8 \times 1.2 = \frac{396}{5}$. The volume per load unit can be calculated by: $2.5 \times 0.8 \times 1.2 = 1.4$

To determine the impact of double stacking loads the cost for double stacking should be calculated first. This is done in two parts. First the number of full trucks are calculated. This can be done by taking the sum of the volume per lane and divide it of the total volume shipment times the cost per shipment:

$$\left\lfloor \left(\sum_{i=1}^{N_L} M_{Li} \right) / \frac{396}{5} \right\rfloor C_{33L} \tag{13}$$

Where

M_{Li} denotes the volume M in lane L per order i.

The cost of the leftover volume can be calculated by calculating the leftover pallets and finding the minimum cost for these leftover pallets. Explained by the following formula:

$$\min_{j \geq \left\lceil \frac{1}{1.4} \sum_{i=1}^{N_L} M_{Li} \right\rceil \mod 33}^{33} C_{jL} \tag{14}$$

This yields the minimum for the leftover pallets per lane. The total costs for double stacking can thus be calculated as:

$$DS_L = \left\lfloor \frac{5}{396} \left(\sum_{i=1}^{N_L} M_{Li} \right) \right\rfloor C_{33L} + \min_{j \geq \left\lceil \frac{1}{1.4} \sum_{i=1}^{N_L} \right\rceil \mod 33}^{33} C_{jL} \tag{15}$$

Where

DS_L denotes the freight spend for double stacking in lane L.

N_L denotes the number of orders per lane L.

M_{Li} denotes the volume M in lane L per order i.

C_{33L} denotes the cost in lane L for shipping 33 pallets.

C_{jL} denotes the cost per configuration j in lane L.

To calculate the impact of double stacking, the impact of double stacking should be compared against the situation where all load units are shipped only in a perfect footprint configuration. To calculate the cost of the perfect footprint configuration, Formula 7 can be used where $X = 33$. This is done since this is the fairest comparison between double stacked load and single stacked load. In different comparisons either volume or number of footprints should stay the same, which does not always yield any profit. Hence, the total yield double stacking has, is thus the difference between the cost for transportation when goods are double stacked and the situation where goods are not double stacked, but in the same configuration.

Eventually, the impact of double stacking on the freight spend can be calculated by:

$$S_{2L} = CS_L(33) - DS_L \tag{16}$$

Where

S_{2L} denotes the impact of double stacking in euros in lane L for the second load fill improvement mechanism (which is double stacking).

$CS_L(33)$ denotes the cost in lane L for shipping 33 pallets.

DS_L denotes the freight spend for double stacking in lane L.

To determine the total emission for all full trucks first the total emission per kilometer per lane for all full trucks is calculated according to the following term:

$$0.65 \left\lfloor \frac{5}{396} \sum_{i=1}^{N_L} M_{Li} \right\rfloor \tag{17}$$

The second term calculates the carbon emission of the leftover pallets per kilometer per lane and is denoted by the following formula:

$$0.35\Psi_L\left(M_{Li}\right) + \frac{0.3}{33}\left(\left\lceil \frac{1}{1.4} \sum_{i=1}^{N_L} M_{Li} \right\rceil \mod 33\right) \tag{18}$$

where

$$\Psi_L\left(M_{Li}\right) \begin{cases} 1, \text{if } \left\lceil \frac{1}{1.4} \sum_{i=1}^{N_L} M_{Li} \right\rceil \mod 33 > 0 \\ 0, \text{otherwise} \end{cases}$$

$\Psi_L\left(M_{Li}\right)$ denotes the activation formula in lane L for the number of leftover rides, which is either one or zero.

To calculate the impact of double stacking on CO_2 a calculation similar to Formula 15 will be used. Hence, the full formula will consist out of two terms, again one to calculate the emission of all full trucks and one on calculating the emission of the leftover trucks. Eventually this will be multiplied by the average distance per lane.

This yields the following formula for the total emission per lane:

$$DE_L = \bar{d_L}\left(0.65\left\lfloor\frac{5}{396}\sum_{i=1}^{N_L} M_{Li}\right\rfloor + \left(0.35\Psi_L\left(M_{Li}\right) + \frac{0.3}{33}\left(\left\lceil\frac{1}{1.4}\sum_{i=1}^{N_L} M_{Li}\right\rceil \mod 33\right)\right)\right) \tag{19}$$

Where

$$\Psi_L\left(M_{Li}\right)\begin{cases}1, \text{if } \left\lceil\frac{1}{1.4}\sum_{i=1}^{N_L} M_{Li}\right\rceil \mod 33 > 0\\ 0, \text{otherwise}\end{cases}$$

DE_L denotes the carbon emission per lane for double stacked orders.

$\bar{d_L}$ denotes the average distance per lane L.

N_L denotes the number of orders per lane L.

M_{Li} denotes the volume M in lane L per order i.

Eventually, to calculate the impact from double stacking on the carbon per lane the following equation needs to be used:

$$E_{2L} = CE_L(33) - DE_L \tag{20}$$

Where

E_{2L} denotes the impact of double stacking on carbon emission in lane L for the second load fill improvement mechanism (which is double stacking).

$CE_L(33)$ denotes the carbon emission in lane L for shipping 33 pallets.

DE_L denotes the carbon emission per lane for double stacked orders.

7.2.5 Loading 34 pallets

The final improvement mechanism to improve load fill addressed in this thesis is loading 34 pallets in a single truck. Loading 34 pallets can be done by changing the pallet lay-out to the structure shown in Figure 7.1. Calculating the impact of loading 34 pallets instead of 33 is very similar as Formulas 7 and 10, however now the cost for a configuration is set on 33 and the configuration itself is 34. This yields the following formula for loading 34 pallets per lane:

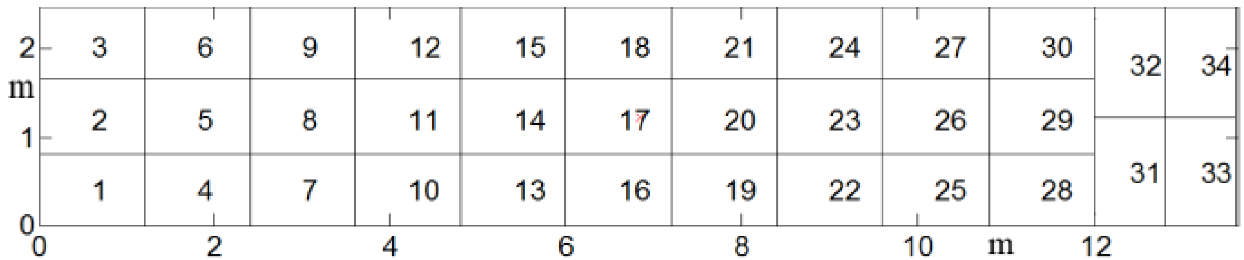

Figure 7.1: Lay-out for 34 pallets per truck, Figure originates from Fries et al. (2015)

$$US_L = \left\lfloor \frac{1}{34} \sum_{i=1}^{N_L} V_{Li} \right\rfloor C_{33L} + \min_{j \geq \sum_{i=1}^{N_L} V_{Li} \mod X}^{33} C_{jL} \tag{21}$$

Where

US_L is the cost for loading 34 pallets for all shipments in lane L.

N_L denotes the number of orders per lane L.

V_{Li} denotes the number of footprints in lane L per load i.

C_{33L} denotes the cost for 33 pallets in lane L.

C_{jL} denotes the cost in lane L per configuration j.

Eventually, to calculate the impact of loading 34 pallets instead of 33 it needs to be compared to the situation where all pallets were loaded in a configuration of 33. This can be calculated as following:

$$S_{3L} = CS_L(33) - US_L \tag{22}$$

Where

S_{3L} denotes the impact of loading 34 pallets instead of 33 has on the freight spend in lane L for the third load fill improvement mechanism (which is loading 34 pallets).

$CS_L(33)$ denotes the cost in lane L for shipping 33 pallets.

US_L is the cost for loading 34 pallets for all shipments in lane L.

Similarly the impact of loading 34 pallets instead of 33 can be calculated. First by calculating the cost of loading 34 pallets for all shipments according:

$$UE_L = \frac{17}{55}\bar{d_L}\left(\left\lfloor \frac{1}{34}\sum_{i=1}^{N_L} V_{Li}\right\rfloor + \left(\frac{0.3}{34}\left(\sum_{i=1}^{N_L} V_{Li} \mod 34\right) + 0.35\Omega_L\left(V_{Li}\right)\right)\right) \tag{23}$$

Where

$$\Omega_L(V_{Li}) = \begin{cases} 1, & \text{if} \sum_{i=1}^{N_L} V_{Li} \mod 34 > 0. \\ 0, & \text{otherwise.} \end{cases}$$

$\Omega_L(V_{Li})$ denotes the activation formula in lane L for the number of leftover rides, which is either one or zero.

UE_L is the carbon emission for loading 34 pallets for all shipments in lane L.

$\bar{d_L}$ denotes the average distance per lane L.

N_L denotes the number of orders per lane L.

V_{Li} denotes the number of footprints in lane L per load i.

Eventually to calculate the impact of loading 34 pallets instead of 33 it needs to be compared to the situation where all pallets were loaded in a configuration of 33. this can be calculated as following:

$$E_{3L} = CE_L(33) - UE_L \tag{24}$$

Where

E_{3L} denotes the impact of loading 34 pallets instead of 33 has on the freight spend in lane L for the third load fill improvement mechanism (which is loading 34 pallets).

CE_L $CE_L(33)$ denotes the carbon emission in lane L for shipping 33 pallets.

UE_L is the carbon emission for loading 34 pallets for all shipments in lane L.

7.2.6 Total impact

Eventually the total effect per lane is required for the sales department and account managers. This helps them to target the right customer lane which is most impactful for them. To calculate the total impact of all three measures on the freight spend, first all measures need to be summed together. Mechanism 1 has the greatest impact when the configuration is set on 33, thus for the first mechanism only $S_{1L}(33)$ will be considered. To calculate the full effect per lane the following formula will be used:

$$S_L = \sum_{p=1}^{3} S_{pL} \tag{25}$$

Where

S_L denotes the total impact on freight spend of all improvement mechanisms per lane.

S_{pL} denotes the impact on freight spend in lane L per improvement mechanism p.

Eventually to show the urgency of the problem to the customer logistic managers the total wasted cost is shown per region. This is calculated by:

$$S = \sum_{L=1}^{R} S_L \tag{26}$$

Where

S denotes the potential cost saving per region.

R denotes the number of lanes per region.

S_L denotes the total impact on freight spend of all improvement mechanisms per lane.

Similarly the total impact of all mechanisms is measured to see the total impact per lane. Again for the first mechanism the configuration is set on 33: $E_{1L}(33)$. The total impact for all mechanisms is calculated according following calculation:

$$E_L = \sum_{p=1}^{3} E_{pL} \tag{27}$$

where

E_L denotes the total impact on carbon emission of all improvement mechanisms per lane.

E_{pL} denotes the impact on carbon emission in lane L per improvement mechanism p Again the impact on carbon emission in an entire region is calculated as well. This is done according following Formula:

$$E = \sum_{L=1}^{R} E_L \tag{28}$$

Where

E denotes the the potential carbon emission saving per region.

R denotes the number of lanes per region.

E_L denotes the total impact on carbon emission of all improvement mechanisms per lane.

7.2.7 Evaluation of the underlying calculations

All calculations have eventually been tested on multiple regions in Python and will be further evaluated in this section. Within the sprint prototype solely the calculations were developed, hence this section can be seen as an evaluation of the sprint prototype.
For all calculations the minimum cost has always been applied. The main reason for this is that carriers are currently selected this way as well. Additionally, this makes the comparison against the simulation fairer. Sometimes a carrier declines a tender and then a more expensive carrier tendered. The process of searching a new carrier cannot be done in the simulation, since it is a hypothetical situation and there is no carrier to accept or reject the offer. Furthermore, there is no data available for how often a carrier accepts or rejects a tender, so developing a simulation with a mean and standard deviation is impossible as well.
For the ordering mechanism two different possible configurations are proposed, the first being $1 \geq X \geq 33 \; \forall \; X \in \mathbb{Z}$ and the second being $1 \geq X \geq T_L \wedge X = 33$, where T_L is denoted as the maximum groupage tariff per lane and configuration $X \in \mathbb{Z}$. The difference here is that for the second notation only existing tariffs are chosen. For example, when for a specific lane only groupage tariffs exist from 1 to 12, only those can be chosen as configuration X. Where in the first notation all configurations are considered from 1 up to and including 33. Eventually, when choosing for the former option load fill can actually deteriorate. For example, when a customer always orders the size of 12 footprints and increases it to 18, in this situation only an FTL truck is available, which can contain 33 pallets, which is far worse than a groupage carrier shipping those 12 footprints and consolidating it with other orders from other customers. Again consolidating for a groupage carrier is far easier than for Van der Wal, due to the network size of the groupage carrier.
The performance of double stacking can be calculated in three different ways. In the first method of calculating the impact of double stacking, the number of loads and the volume per load the same kept the same. This means that only the number of footprints per load decreases, for groupage orders, this decreases the cost, however for FTL there is no cost decrease, hence not interesting to evaluate at a large scale. Second method to calculate the impact of double stacking is only considering loads with 33 pallets. However, this yields an incorrect image on how a lane could actually benefit from using double stacking, since only a fraction of the data will be used in this case. The third method to calculate the impact of double stacking is described in its respective section (using the configuration of 33 for both single stacking and double stacking). One benefit of calculating it this way is that it is robust against stock issues, since now always full trucks are considered. Furthermore, via this method all loads can still be considered. However, the impact is unreliable when customers do not change their ordering behavior to a full truck load. Hence, this option can only be considered when customers already in an FTL configuration.
On the other hand, the double stacking analysis is still unreliable regarding the height. The height in the data is nearly always marked higher than the height in reality. Hence, the double stack analysis turns out less beneficial than the actual yield. To improve the quality of this part of the analysis it is important that Kimberly-Clark sends the right information regarding height to Van der Wal.
For improving the loading procedure to 34 pallets per load, this is again only compared to the situa-

tion where 33 pallets are ordered. This since there is no additional benefit for the sales department or account managers to start negotiations about loading differently when customers do not order already 33 pallets. Hence, this mechanism should only be applied when customers do already order 33 pallets per load. Additionally, for customers who already order FTL loads, this method of analysis makes the data out-of-stock robust, since only the ideal situation of ordering 33 pallets every load is compared to the situation where 34 pallets were ordered.

7.3 How to trigger customer logistic managers

Region: Italy			
When KC does not start negotiations with customers to improve order patterns and double stack orders KC will miss	€ 103.283,00		Per month
	AND		
When KC does not start negotiations with customers to improve order patterns and double stack orders KC will not conserve	64413	kg CO2	Per month
	OR		
	35134	trees	per month
	OR		
	6	Acres of forest	Per month
When not improving the order pattern of 33 pallets per customers for all customers this will be lost:	€ 77.977,08		
	4,53	Acres of forest	
When not applying double stacking to all orders for all customers this will be lost per month:	€ 24.635,00		
	1,43	Acres of forest	
When not loading 34 pallets instead of 33 for all customers this will be lost:	€ 670,92		
	0,04	Acres of forest	
To see which customers are most impactful go to the second sheet.			

Figure 7.2: An example of a summary slide designed to trigger customer logistic managers.

Eventually the calculations yield both results per region and results per lane. However for this section the focus will be shifted to the performance per region since is more likely to trigger logistic managers. One proof for this is the greater the loss the higher the utility and thus the probability increases that an intervention by the cusotmer logistic manager will occur (Kahneman and Tversky, 1979). Furthermore, the data is framed as a loss since a loss frame initiates detection behavior. Where a gain frame triggers prevention behavior. Hence, detection behavior is desired when a problem already exists, and prevention behavior when a problem needs to be prevented (Detweiler et al., 1999). This is part of a valence frame with the aim to improve goal persuasion (Levin et al., 1998). Eventually, the results of this first iteration are presented in an Excel file, as it provides a simple overview.

Additionally, the impact of the mass of CO_2 does not ring a bell for everyone, hence the mass is converted into trees as well. According to Ladrak (2022) one tree sets 22 kg of CO_2 off per year, and thus $\frac{22}{12}$ kg per month. To emphasize the impact even more the number of trees can be transformed in the number of acres forest. According to Hekhuis (2023) 1 acre of forest captures 10,000 kg of CO_2. Hence to set 10,000 kg of CO_2 off, a forest of 1 acre needs to be planted. An example of such overview is visible in Figure 7.2.

7.4 How to trigger the sales department and customer account mangers

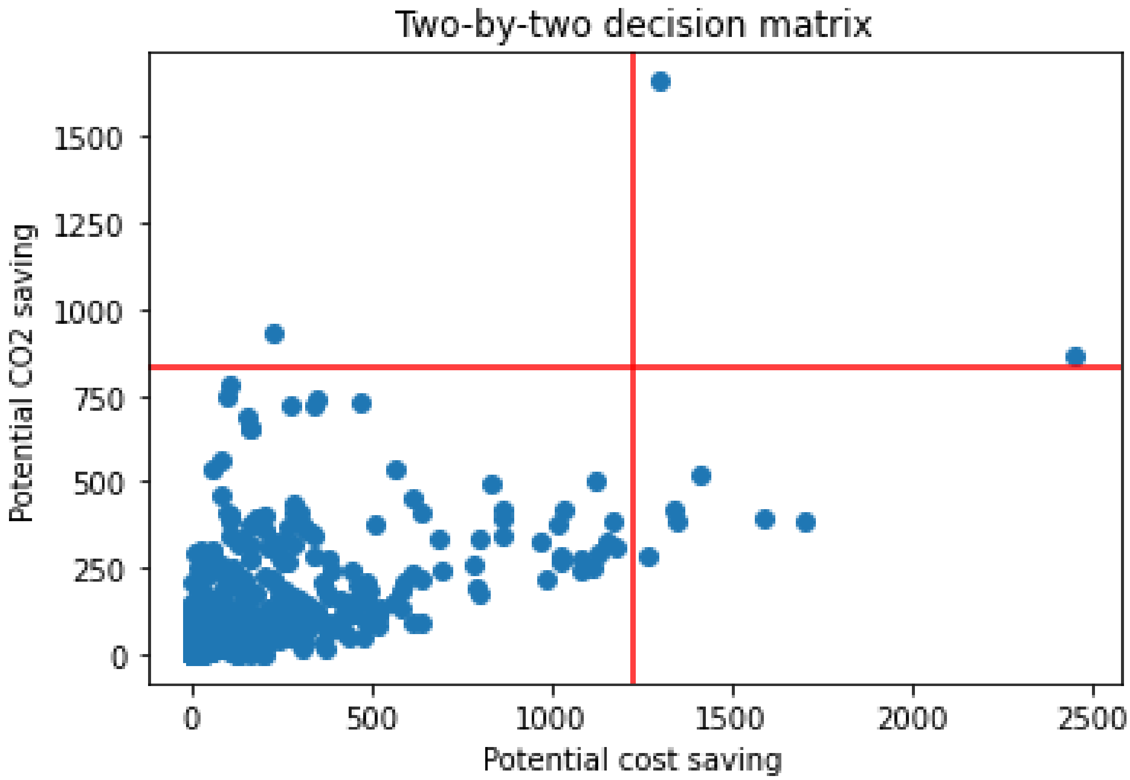

Figure 7.3: An example of a two-by-two matrix to aid the sales department and account managers.

The sales department and account mangers need to be supported to reach their newly set goals by customer account managers. This is firstly done by a two-by-two matrix, similar as visible in Figure 7.3 In this two-by-two matrix they can easily see what customers have to most impact on cost and carbon emission. To support the Kimberly-Clark employee during the negotiations, the another visual is provided. Here the impact per improvement mechanism per lane is visible. The employees can decide for themselves whether it is necessary to immediately address two mechanisms or only one. When addressing the issue the employee can also explain what it would yield in the amount of CO_2, number of trees and acres of forest. Additionally, they can determine with the potential saving figure a much discount they can apply for improved order patterns.

Historical Data																
Total Freight Spend	Total FTP	Total nr of loads	Average FTP / load	1	2	3	4	5	6	7	8	9	10	11	12	13
€ 9.500,12	240	156	1,54	€ -91	€ -91	€ -91	€ -91	€ 1.436	€ 2.269	€ 3.315	€ 3.354	€ 3.354	€ 3.932	€ 4.359	€ 4.736	€ 5.084
€ 20.621,93	543	198	2,74	€ -1.181	€ -1.181	€ -1.181	€ -1.181	€ 2.059	€ 3.179	€ 5.641	€ 5.653	€ 6.581	€ 7.973	€ 9.138	€ 10.061	€ 10.878
€ 28.092,60	418,5	104	4,04	€ -343	€ -343	€ -343	€ -343	€ 7	€ 8	€ 620	€ 633	€ 633	€ 633	€ 619	€ -4.072	€ -1.600
€ 89.958,69	2766	107	25,97	€ -97.980	€ -97.980	€ -97.980	€ -97.980	€ -95.639	€ -95.637	€ -91.540	€ -91.544	€ -91.530	€ -91.544	€ -91.530	€ -122.757	€ -106.431
€ 44.953,41	4515	171	26,40	€ -136.336	€ -136.336	€ -136.336	€ -136.336	€ -109.248	€ -99.932	€ -79.193	€ -79.231	€ -71.520	€ -59.795	€ -50.339	€ -42.395	€ -35.723
€ 45.139,78	3489	129	27,05	€ -133.120	€ -133.120	€ -133.120	€ -133.120	€ -122.621	€ -105.061	€ -83.605	€ -83.618	€ -82.877	€ -70.088	€ -59.666	€ -50.890	€ -43.465
€ 46.261,93	5271	191	27,67	€ -164.378	€ -164.378	€ -164.378	€ -164.378	€ -130.892	€ -111.285	€ -88.726	€ -88.769	€ -76.243	€ -64.016	€ -53.997	€ -45.594	€ -38.623
€ 84.413,05	4597,5	164	28,12	€ -150.482	€ -150.482	€ -150.482	€ -150.482	€ -136.642	€ -113.483	€ -85.235	€ -85.201	€ -85.263	€ -85.263	€ -85.180	€ -113.700	€ -98.383
€ 100.849,31	3204	113	28,48	€ -113.453	€ -113.453	€ -113.453	€ -113.453	€ -111.417	€ -111.416	€ -105.985	€ -105.982	€ -105.992	€ -105.997	€ -105.989	€ -143.456	€ -124.642
€ 115.905,98	6586,5	219	30,08	€ -236.111	€ -236.111	€ -236.111	€ -236.111	€ -214.891	€ -214.886	€ -200.800	€ -200.783	€ -200.783	€ -197.620	€ -169.140	€ -145.418	€ -125.426
€ 68.053,67	8248,5	273	30,21	€ -261.573	€ -261.573	€ -261.573	€ -261.573	€ -209.151	€ -178.439	€ -143.273	€ -143.252	€ -123.495	€ -104.371	€ -88.696	€ -75.709	€ -64.557
€ 136.485,23	4449	147	30,27	€ -165.807	€ -165.807	€ -165.807	€ -165.807	€ -162.035	€ -162.036	€ -155.443	€ -155.445	€ -155.443	€ -155.445	€ -155.431	€ -205.852	€ -179.534
€ 112.538,37	3856,5	126	30,61	€ -149.495	€ -149.495	€ -149.495	€ -149.495	€ -146.226	€ -146.229	€ -140.509	€ -140.513	€ -140.515	€ -140.506	€ -140.502	€ -184.190	€ -161.321
€ 136.015,50	4419	143	31,01	€ -164.238	€ -164.238	€ -164.238	€ -164.238	€ -160.492	€ -160.491	€ -153.946	€ -153.940	€ -153.943	€ -153.946	€ -153.933	€ -222.805	€ -195.208
€ 69.976,50	7848	252	31,14	€ -245.143	€ -245.143	€ -245.143	€ -245.143	€ -198.076	€ -181.781	€ -145.872	€ -145.815	€ -132.392	€ -112.148	€ -95.612	€ -81.752	€ -70.208
€ 48.325,50	3372	108	31,22	€ -124.672	€ -124.672	€ -124.672	€ -124.672	€ -113.820	€ -109.329	€ -86.801	€ -86.784	€ -86.784	€ -76.475	€ -65.202	€ -55.767	€ -47.690
€ 154.913,65	17664	566	31,24	€ -554.345	€ -554.345	€ -554.345	€ -554.345	€ -448.377	€ -411.781	€ -330.821	€ -330.783	€ -300.511	€ -254.971	€ -217.735	€ -186.715	€ -160.374
€ 118.304,93	3961,5	126	31,44	€ -150.863	€ -150.863	€ -150.863	€ -150.863	€ -147.505	€ -147.505	€ -141.632	€ -141.628	€ -141.639	€ -141.628	€ -141.628	€ -186.531	€ -163.085
€ 143.363,44	3852	122	31,70	€ -160.012	€ -160.012	€ -160.012	€ -160.012	€ -156.750	€ -156.746	€ -151.858	€ -151.846	€ -151.856	€ -151.846	€ -151.856	€ -235.399	€ -206.115
€ 29.677,15	3192	101	31,76	€ -98.491	€ -98.491	€ -98.491	€ -98.491	€ -79.367	€ -72.768	€ -58.091	€ -58.091	€ -56.940	€ -48.245	€ -41.217	€ -35.346	€ -30.347
€ 138.164,86	3966	123	32,24	€ -174.189	€ -174.189	€ -174.189	€ -174.189	€ -170.831	€ -170.831	€ -165.791	€ -165.794	€ -165.781	€ -165.794	€ -165.794	€ -234.760	€ -206.092
€ 248.710,50	4401	134	32,97	€ -192.138	€ -192.138	€ -192.138	€ -192.138	€ -188.411	€ -188.406	€ -184.676	€ -184.681	€ -184.674	€ -184.684	€ -184.674	€ -434.041	€ -381.381
€ 206.883,00	26860,5	815	32,98	€ -866.516	€ -866.516	€ -866.516	€ -866.516	€ -695.703	€ -595.697	€ -481.025	€ -481.068	€ -416.937	€ -354.551	€ -303.495	€ -261.039	€ -225.075
€ 27.531,00	3573	108	33,08	€ -115.253	€ -115.253	€ -115.253	€ -115.253	€ -92.548	€ -79.223	€ -64.015	€ -64.011	€ -55.502	€ -47.202	€ -40.454	€ -34.811	€ -30.019
€ 223.218,65	8938,5	252	35,47	€ -374.642	€ -374.642	€ -374.642	€ -374.642	€ -368.961	€ -368.958	€ -353.804	€ -353.797	€ -353.801	€ -353.797	€ -353.797	€ -438.131	€ -387.334

Figure 7.4: The impact per improvement mechanism.

Finally, to exactly know for a sales representative or account manager the amount of discount they can give per improvement mechanism, the cost and carbon emission savings are denoted. For the ordering mechanism this is done per pallet configuration. This should help Kimberly-Clark employees to negotiate for improving the number of pallets ordered per load. An example of such overview is visible in Figure 7.4. In this figure, every row denotes a different lane, furthermore there is some historical information per customer. Finally, the grey and green columns follow. Here the impact of the improvement measure can be found (green when it is an improvement, grey when it is not). Note that here most improvement measures are grey since it is actually a deterioration because the configuration number is lower than the average order size.

8 Discussion

First the conclusion on the sub questions will be presented. Thereafter the limitations of this thesis will be presented, followed by the contribution to the literature and managerial implications. Eventually, the discussion will be ended with a recommendation for implementation for Van der Wal.

8.1 Conclusion

8.1.1 How should load fill be measured, what information should be collected and how should this information be collected

Table 8.1: Definition of load fill based on the load levels described by Santén and Rogerson (2018), and responsibilities per stakeholder

Load levels / Stakeholder	Manufacturer	Planner	Carrier	Customer
Load to primary packaging	the product's volume / volume of the primary package	-	-	-
Load to secondary packaging	the primary packaging's volume / the secondary packaging's volume	-	-	-
Load to tertiary packaging	the secondary packaging's volume / the load unit's volume	-	-	-
Load to shipment	load's actual volume / total volume for the purchased footprints	load's actual volume / total volume for the purchased footprints	-	load's actual volume / total volume for the purchased footprints
Load to vehicle	actual footprints / maximum number of footprints per transport vehicle	actual footprints / maximum number of footprints per transport vehicle	-	actual footprints / maximum number of footprints per transport vehicle
Load to fleet of vehicles	-	the total number of footprints purchased / the fleet's carrying capacity in footprints	the total number of footprints sold / the fleet's carrying capacity	-
Overall definition of load factor	sum of the product's volume / Total volume per 34 load units	load unit's actual volume / the fleet's carrying capacity total volume	the total number of footprints sold / fleet carrying capacity in footprints	load's actual volume / maximum volume per 34 load units

First of all, the load factor should be measured on its limiting factor (Santén and Rogerson, 2018). This implies that either a volumetric or weight maximum per load unit should be used. In this case volume is always the limiting factor and is thus used within this framework. The maximum allowed carrying capacity for a trailer is 40.000 kg and the volume of a trailer is 90 m^3 (Evofenedex, 2022; Rooskens-group, 2022). Hence, when the density of the carried product and the load carrying unit exceeds 440 kg/m^3 the load fill is restricted by mass and when lower than this limit the load fill is restricted by volume. In this case calculations are done a bit differently, since the load unit is an additional limiting factor. Hence the maximum volume is explained by: the footprint area of one load unit ×

the number of load units × the height per load unit. Thus the maximum volume in this case equals: $1.2 \times 0.8 \times 2.65 \times 34 \approx 86.5\text{m}^3$. Secondly, the load factor should be measured based on responsibility, since no stakeholder is fully responsible for all levels of load fill. It would therefore be unfair if responsibilities of other firms are taken into account. The full overview of all definitions can be found in Table 8.1.

The first three levels are all based on packaging. This is solely the responsibility of the manufacturer, since no other stakeholder is able to change the packaging, and the manufacturer is the only stakeholder who has the information on this topic to conduct an analysis to improve load fill on this level. To improve the load to shipment level, the manufacturer, planner and customer are responsible to improve load fill in this category, since these three stakeholders have either the information, or decision power. The planner in this case has the information, hence the planner can support the customer in making the best decision. The customer has the decision power to increase the height per load unit, which increases the load to shipment level. The manufacturer here is the enabler of increasing the height per load unit, by double stacking. They should check whether it is possible to double stack orders together with customers.

For the next level in Table 8.1: load to vehicle, the manufacturer, planner and customer have some responsibility. The customer is able to place orders in greater quantities, the planner should provide the impact these changes in order size have and the manufacturer should negotiate discounts with the customer to support customers to order in greater quantities.

Finally the load to the fleet of vehicles can be improved by either the planner or carrier. They can both consolidate multiple orders into the same vehicle. This improves the load fill over the fleet of vehicles.

The information that should be collected on load level is: the customer information, the number of footprints, the volume and the distance. With this information the calculations in section 7.2 can be conducted. Additionally, the cost information should be collected per lane. This helps the planner to make a financial advise for the manufacturer. This financial advise can be used to incentivize the end customer for improved ordering behavior.

This information should be collected by all stakeholders' information systems and ideally the information should be shared with the planner's information system. This since the planner is the only stakeholder that can improve on all load levels (ignoring the packaging levels). Additionally, the planner is responsible for analyzing the data, since they are a central link in the 4PL supply chain. Finally, they are the stakeholder that posses and negotiate rates with carriers, since they hire the carriers, so they must know the cost scales with the different carriers and they receive the orders and thus know how orders are shipped.

8.1.2 How do the different load fill improvement mechanisms relate to each other and to the load factor levels?

Load fill can be increased by different mechanisms on different levels. First of all, to improve the load per shipment, the height of the truck should be maximized. One mechanism that is currently used a lot already in the context of Kimberly-Clark and Van der Wal is double stacking. To use the double stacking mechanism the height of a single load unit should be decreased to 1.325 meter, this allows for double stacking and leaves 5 centimeter clearance to load the load unit. This cannot be done without negotiations, hence the manufacturer and customer should negotiate how this can be done effectively. The planner should provide the required information to enhance this process.

To improve the load per vehicle, customers should order 34 pallets per shipment. However, they need to be incentivized by the manufacturer since they do not pay for transportation, hence they will order

in configurations which are more optimal for their warehouse. Since manufacturers do not have data readily available on costs they cannot incentivize customers based on good behavior. Therefore, the planner should make an analysis to support the manufacturing party to enhance the negotiations between manufacturer and customer.
Finally, the consolidation of multiple orders can be used to increase load fill. However this mechanism has a lot of limitations, since dates need to be similar, the time slots need to allow for consolidation, the distance between customers cannot be too great, the type of equipment needs to be the same, human factors cannot disrupt consolidation and finally it should fit in a truck. This can make consolidation difficult to apply. A root cause for all these limitations is that the number of orders is not high enough. When the number of orders increases the possibility for consolidation increases as well. Hence, demand for specific orders can be increased by using differential prices. However, this can conflict with improving load fill via more optimal ordering patterns since customers are now stimulated to order earlier than an FTL load. Additionally, the consolidation process can be enhanced by using a carrier pooling network. This increases the supply of trucks and therefore increases the chance of a carrier already having a load planned which can possibly be consolidated with another load. For carriers to help the planner to hire the correct carrier, prices should be decreased where consolidation is possible. This can again be done with a dynamic price.

In general most improvement mechanisms can and should co-exist. However there is one main conflict which is order size. Consolidation requires smaller order sizes, which can in fact deteriorate the load fill. To maximize the load fill from a planner's perspective both can and should be applied. When the manufacturer only allows customers to order in configurations which are directly offered by the carriers to planners, the load fill for planners could theoretically increase to 100%. However, this only applies when all other improvement mechanisms (such as double stacking and loading 34 pallets into a truck) are in place.

8.1.3 How can the impact of the different means for load fill improvement be calculated?

The impact per mechanism can be calculated using historic order data. Important is to collect data on volume, pallets, rates and distances. More importantly this should be collected per unique customer delivery address, since at each unique delivery address another problem (if any) is likely to occur. To start the impact of ordering in different frequencies can be calculated by comparing the current cost for transportation to a situation where a different average order size has been selected. This yields a difference in cost. Additionally, this can be done for carbon emission as well, again the current emission should be compared to a situation where a different average order configuration was chosen. A detailed description of these calculations can be found in section 7.2.3. Secondly, the loading procedure can be changed by applying double stacking loads and loading 34 pallets into a truck instead of 33. The impact of double stacking can be calculated by comparing a situation where only full trucks are ordered to a situation where full trucks are ordered while applying double stacking. Again a more detailed description can be found in its respective section (section 7.2.4). Finally, the impact of loading 34 pallets instead of 33 can be calculated by comparing the situation of loading 33 pallets to a situation of 34 pallets. A detailed description of how this should be conducted can be found in section 7.2.5.

8.1.4 How can non-food transport companies reduce their CO_2 emissions by increasing the load factor on their fourth party logistics (4PL) shipments?

As is already visible in the introduction, increasing the load fill is one of the most important factors to reduce carbon emission. Literature addresses means for increasing load fill for twenty years already, however load fill has hardly been increased in the mean time. Important potential factors for this halt on growth in load fill can be the diffusion of responsibility, the effect different solutions have on each other and the lack of influence customers have on the transport cost. Solutions for these three problems are already addressed in their respective subsection (sections 8.1.1, **??** and **??**) In short, each stakeholder in the 4PL supply chain should try to increase load fill according to their definition for load fill provided in section 8.1.1. Furthermore, the most prohibitive effect exists between consolidation and ordering, consolidation fares better with smaller orders, and ordering tries to increase order sizes as much as possible. To get the best of each improvement mechanism, customers should only be allowed to order in groupage quantities, where orders are shipped via a groupage carrier and network, or order full trucks. This allows for the most optimal consolidation and full trucks. Finally, to allow customers to make a comparison between cost for transportation and storage, transport cost should be decoupled from the product cost. Additionally, the effect of every single order configuration should be shared with the customer. This allows the customer to make the most optimal balance between transportation and storage cost.

8.2 Limitations and future research

The results of this thesis are mainly based on qualitative research. These results showed how load fill can and should be improved by the different stakeholders in the supply chain. Both validity and reliability of the final solution have been proven while evaluating the design principles and the final design during an alpha test. However, this thesis has some limitations as well, which will be discussed in this section, additionally these limitations will serve as a foundation for recommended future research.
First of all, throughout this thesis the customer has never been interviewed, since this was not allowed by the manufacturer. Eventually, this limits the final solution directions in its validity since the final solution has some implications for the customer, which were not tested. Therefore, the implications for the customers are merely hypothesized and should actually be tested in a future research, especially since the final solution can be somewhat disruptive since customers need to change their order patterns. Another argument why in the future the hypothesized solution should be tested with the customer can be explained by the fact that the customer here is the "human-in-the-loop" and thus the decision maker in the process. Furthermore, this thesis serves as a foundation for a fairer balance between transport and storage cost. This because transport cost are considered variable within this thesis and all costs for the different order sizes should be communicated with the customer. This implies that new research about order policies is meaningful to conduct since a new optimum between transport and storage cost can be found.
Additionally, the carbon emission calculation does not fully represent reality. In the first place, the impact of, delaying an order which causes the order to grow in size and move from a groupage carrier to an FTL carrier, on the carbon emission is somewhat questionable, since groupage carriers could still ship the other orders without 'the missing' order. In this case only the weight of the pallets not being shipped conserves the amount of CO_2. Furthermore, solely an estimate for the carbon emission was used and thus the type of equipment, weather and landscape was not considered within the calculations. Therefore, more research needs to be conducted on the impact of groupage orders on carbon emission, and the carbon emission of the logistic sector as a whole.
Finally, Although the theory on valence frames is based on the information of the interviews and has been scientifically supported. The use of valence frames is mostly hypothetical and has only been tested with the planner during the alpha test. However, the manufacturer will face the frames that are being applied, therefore the hypothetical solution should be tested with the manufacturer as well. This can be done by testing how often a customer logistic manager will intervene while using a valence frame, compared to the number of interventions in the situation where no frame has been applied.

8.3 Contribution to literature

This thesis was one of the first works in literature that blended both, the DSM and the 4PL supply chain, hence this provided a new perspective in the vast amount of literature. With the use of DSM potential solutions are communicated via designs, hence solutions can be tested in context instead of only hypothesized (Keskin and Romme, 2020). This helps to test the viability of a potential solution. Something that is currently often missing in the literature about load fill is the human decision maker involved in the process. DSM allows for a user-centered approach to come to a solution (Suh, 2001), and thus involves the human decision maker in the process, which can help for the adoption of the potential solutions (Holmström et al., 2009). Low adoption numbers could well be one of the reasons for a stable load factor over the last decades, which was covered in section 1.4.
Moreover, this thesis contributes to the literature by providing insight on how load fill should be measured. In the work conducted by Santén and Rogerson (2018), an approach was already offered. This thesis extends on that theory by adding the responsibilities of different stakeholders in the value chain. Additionally, this is empirically substantiated by multiple stakeholders during the interviews. This addition is important since not all stakeholders can influence all different levels of load fill. Therefore they cannot be held accountable for the entire definition of the load factor. Eventually, the different definitions of load fill can determine the performance of the different stakeholders, and identify the stakeholder who should intervene. This can become more important when regulations on carbon emission will arise regarding transportation.
Furthermore, this thesis compares the different load fill improvement mechanisms introduced by Santén (2017). Not all mechanisms can be used simultaneously. To be precise, improving the loading procedure by loading double stacked pallets and loading 34 Euro pallets has no conflict with any other mechanism. The same holds for warehousing and packaging. These can and should always be used in order to improve load fill. On the other hand, consolidation and ordering have a conflicting factor, which is the order size. For increasing load fill using the ordering mechanism, customers should order in an FTL configuration and for increasing load fill using the consolidation mechanism the possibility for consolidation increases when order sizes become smaller. Planners can thus improve load fill in this level by providing an analysis on transport cost to their customer (the manufacturer). The manufacturer can improve load fill on this level by allowing customers only to order in groupage or FTL configurations. Finally customers can improve load fill on this level by only ordering in the aforementioned configurations.
Finally, this thesis contributes to the literature by theorizing how an analysis for improving both the loading procedure and order pattern should be conducted by the planner. This is important since only conducting the analysis based on the calculations will not always yield a higher load fill, because the manufacturer is responsible for negotiating with the customer to change behavior and the customer for actually changing their behavior. Hence, this thesis also contributes to the literature by hypothesizing a method how a valence frame should be applied to the analysis to trigger the desired behavior at the manufacturer, which is, increasing load fill (Levin et al., 1998).

8.4 Managerial implications

First of all, decoupling the transportation cost from the product cost allows customers to make a fairer comparison between storage and transportation cost. Important in this process is that transportation cost should be transparent for both customers and manufacturers. For the manufacturer, because then they can communicate the cost seamlessly to the customer, and eventually for the customer so that they can calculate what the best configuration would be for them.
Secondly, only some order flexibility should be allowed by the manufacturer. Most optimal for load fill would be that customers are only able to order in such a configuration that the order will be shipped

with a groupage carrier, or the customer orders an FTL. In this case both consolidation and increased order patterns are optimally used. On the other hand, this comes with a downside, groupage carriers operate in such small margins that only filling a truck half full is not beneficial for them. This implies that loads can stall for a few days in a warehouse until there are enough loads so that it would be economically viable to ship the loads. This leads to delays and decreased performance. Hence, it is important for the manufacturer to communicate the decreased performance smaller shipment sizes cause.

Finally, the planner within the 4PL supply chain should be transparent about the impact order patterns have, to allow for a fairer comparison between storage and transportation cost. In the first place they should do this by calculating the impact of different order configurations on both cost and carbon emission as is explained in section 7.2. Additionally, the impact of double stacking and loading 34 pallets should be calculated, and communicated to the customer as well. To emphasize the impact increasing order sizes has, the planner should translate CO_2 in both number of trees and acres of forest and these should be summarized per month together with the possible cost savings. Additionally, a loss frame should be applied since this triggers a greater response. Since time is not an unlimited resource for account managers, a two-by-two matrix should be used where both CO_2 and cost savings are on the axis. Here four quadrants emerge and now customers are sorted in four categories where an account manager can address the worst performing customers, on both carbon emission and cost for transportation. An additional benefit of transparency is that transparency about costs, signals trust in the firm and eventually leads to an increase in sales (Mohan et al., 2020).

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