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Optimizing delivery scheduling with multiple storage locations

A case study for replenishing the factory outlet store of L'Oreal

TU Delft

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A case study for replenishing the factory outlet store of L'Oreal

By

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TU Delft

Preface

This report has been written to complete the master assignment for second year TEL students. The content of this report is focused on optimizing the transport process for replenishing outlet stores. A case study has been performed at the factory outlet store of L'Oreal, which is based in Roermond. During the research on the mentioned topic, I got great help from my supervisor ir. M. Duinkerken, great feedback during progress meetings from prof. dr. R.R. Negenborn and great help on the case study of P. Groot and B. Wagter, which I would like to thank all for sharing her knowledge.

Summary

In this report, supply chains of factory outlet stores are analyzed. Here, the concept of factory outlet stores have been investigated in literature to be able to understand which goal these stores serves. Based on a pull based supply chain perspective, replenishment has been investigated. Here, demand forecast, inventory, order fulfillment and transport have been considered. Here, transport models from literature are introduced to see which factors are considered and for which purpose these models can be used. Also, the performance of supply chain has been discussed, which consists of financial as non financial aspects.

A case study will be done at the factory outlet store of L'Oreal. Here, the supply chain has been analyzed, as the catalogue and type of products they offer. The replenishment policy has been analyzed, in which the transport process from the CPD warehouse to the store will be investigated. Here, a model will be designed to be able to schedule the deliveries to the store in a more cost efficient way.

An analytical modelling method is selected to develop a model which captures the mentioned transport process. Here, aspects of models in literature are evaluated to be used in the transport model for scheduling deliveries. The model is developed as an integer mixed linear programming model and will schedule the amount of pallets per delivery to a storage location, in which two storage location are presented. This model is described as the delivery scheduling transport model (DSTM) and is checked on implementation in MATLAB in a verification step.

The DSTM has been configured for the case study at L'Oreal, which is checked by a validation step to see if the model meets the system requirements. Then, experiments with different inputs are executed to see if savings can be realized by scheduling the transport via this model. This is realized in all the inputs scenarios. To see if more savings can be realized, sensitivity analysis have been performed to investigate how parameters can be tuned to realize lower cost. A conclusion will finalize this research to conclude that replenishment orders can be scheduled in a more cost efficient way by the DSTM, which is the result of a case study of L'Oreal.

List of symbols

SS_j	Deisred safety stock level for product j
$D_{avg,j}$	Average demand during the last 10 weeks of product j
$SF_j(D_{LW,j})$	Safety factor based on the demand of product j in the last week
i	product type
j	delivery day
k	numbered pallet of a delivery
l	delivery location
N	amount of distinct products
J	amount of allowed delivery days
MP	maximum amount of pallets per delivery
$X_{i,j,l}$	scheduled delivery of product i on day j on location l
$D_{j,l}$	cumulative size of the delivery on day j on location j in pallets
$PU_{j,k,l}$	scheduled use of k-th pallet on delivery day j on location l
PC_k	Transport cost of the *k-th* pallet of a delivery
W_k	Expected waiting cost of a delivery of size k pallets
F	Receiving cost for external storage location in €/box
O_i	Ordered amount of boxes of product i
LD_i	Latest numbered delivery day of product i
P_i	Pallet volume of a box of product i
M	Big positive number
$u_{max,l}$	Maximum delivery size at storage location l

List of abbreviations

ERP	Enterprise resource planning
3PL	Third party logistics
FMCG	Fast moving consumer goods
DSTM	Delivery scheduling transport model
KPI	Key performance indicator
CPD	Consumer products division
ACD	Active cosmetics division
PPD	Professional product division
LPD	luxurious product division
EOQ	Economic order quantity
KOQ	Kanban order quantity
VMI	Vendor managed inventory
EOI	Economic order interval
JRP	Joint replenishment problem
MHLP	Modular hub location problem
SLOB	Slow movers and obsoletes
DC	Distribution centre
OD	Outbound delivery
PO	Purchase order
GI	Goods issue
SKU	Stock keeping unit
MPC	Model predictive control

Contents

1 Introduction

In the first chapter of the report, the subject of this master assignment will be introduced. In general, this research focuses on an analysis of a factory outlet supply chain. A general approach can be applied in the analysis of this type of supply chain. The gained knowledge will be applied in a case study on the factory outlet of the consumer product division (CPD) of L'Oreal. A brief introduction will be given of this company and the related division within L'Oreal. From this introduction, a problem statement at the current factory outlet of L'Oreal will be described. Afterwards, the research questions, research approach and flow diagram of this research are explained. Finally, a timeline of the research will be presented.

In the remaining of this report, the terms factory outlet and outlet will be interchanged, but they point to the same type of outlet store. A further introduction on the concept of a factory outlet store will follow in this section.

1.1 General description

In the transport and logistic section, "supply chain" is a very popular term. According to the definition of Kenton (2020), a supply chain can be described by the network between a customer and its supplier to distribute a certain product. Here, certain activities, people, resources and information are included, as well as process of getting the product or service to the customer. By managing a supply chain, the process can be streamlined to increase efficiency and make it as economical as possible.

In this research, supply chains of goods are considered. Especially, fast moving consumer goods are considered. These goods are being sold at the end of a supply chain to the consumer of the product. Fast moving consumer goods can be identified as goods which are purchased for consumption. These goods have a lifetime which is less than several years. These goods are sold quickly, at low cost and in high quantities. Examples of these goods are food, toilet paper, drink, medicines, cleaning products, cosmetics etc.

1.1.1 L'Oreal

The world leader in selling cosmetics and beauty fast moving consumer goods is L'Oreal, according to Parker et al. (2020). The company has been raised in 1919, by a French chemist called Eugene Paul Louis Scheuller. Over the years, the company was able to grow to almost 86.000 employees. Besides, the variety of field in which L'Oreal is active increased, since it is active in dermatology, toxicology, tissue engineering and bio-pharmaceutics nowadays. The headquarter of L'Oreal is located in France near Paris, where it leads the different departments in over 130 countries and five continents. Among these different departments in different countries, no concurrence may be created. Therefore, each department has to focus on the market of the country in which it is located. The department located in the Netherlands is partly integrated with the department in Belgium, since they share the same warehouse.

1.1.2 Divisions

The brand L'Oreal is mostly known for its beauty and cosmetics products. The company owns multiple brands, which are managed over several divisions. An overview of the brands of L'Oreal can be found in figure 1.1.

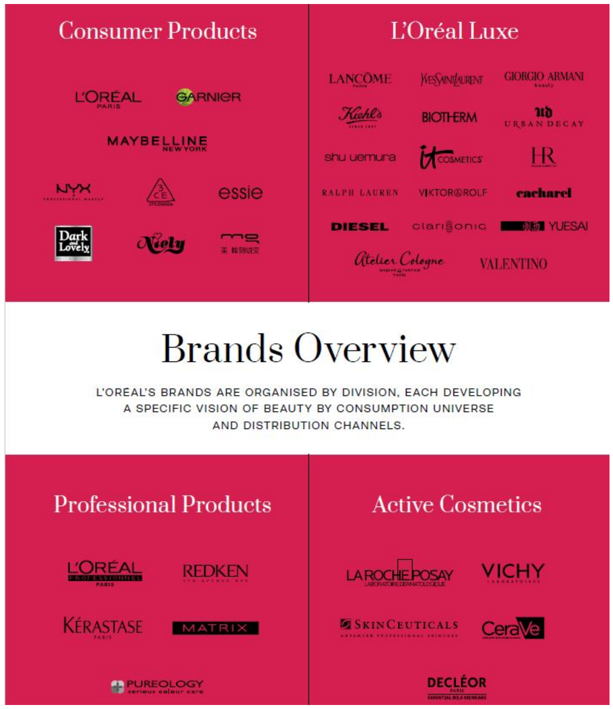

Figure 1.1: Brands of L'Oreal (Parker et al., 2020)

The shown brands are being managed by different divisions within L'Oreal. Based on the annual report of 2019 (Parker et al., 2020), these divisions are introduced. These divisions are the following four:

- The active cosmetics division (ACD) is focusing on pharmaceutical products which can be bought at drugstores, pharmacies and other medical centres. Brands in this segment are Vichy, La Roce-Posay and SkinCeuticals. The products which are being sold should have a calming layout and include medical advice, which is considered more important in this sector. The products of the mentioned brands are focusing on better health for the customer's skin and hair. In terms of sales, this division is the smallest of all the four divisions since it contains only 8.9% of the sales of L'Oreal in 2019.
- The professional product division (PPD) is focusing on products for beauty salons and hairdressers. It is focusing on the products which are being used by these beauty professionals and are being sold by these beauty professionals. Due to the fact that there are a lot of hairdressers working as freelancers, the orders in this division are of small size and ordered at short intervals. However, the quantity of the amount of orders is high, which is different compared to the order amount in other divisions. Brands in this division are L'Oreal professional, Redken, Kérestase, Matrix and Pureology. In 2019, the sales of this division was 11.5 % of the grand total of L'Oreal.
- The L'Oreal luxurious product division (LPD) is focusing on quality and having a premium layout for the customer. It is focusing on skin care, make-up and perfume, which are being sold at cosmetic stores, travel retailers and department stores. The products of this divisions should be seen through the eyes of the customer as luxurious and desirable. Therefore, it is only sold at a couple of customers and in small quantities. During the holiday period, the largest amount of products are being sold, which challenges retails to have products on stock during this period. Compared to the other divisions, this division contains by far the most brands (16), of which the most known are Lancôme, Yves Saint Laurent, Ralph Lauren, Giorgio Armani and Diesel. In 2019, this division was responsible for 36.9% of the sales of

L'Oreal.

- The consumer products division (CPD) is the largest division of all and was responsible for 42.9% of the sales in 2019. This division is focusing on drugstores and supermarkets, at which the quantity of sales is high compared to other divisions. Brands of this division are L'Oreal Paris, Garnier, Essie, Maybelline and NYX. This market is also focusing on e-commerce, since the retailers in these brands offer the products in their webshops.

This relevant department for this research is the CPD division. Within the CPD department of L'Oreal, a factory outlet store is presented. This research will focus on the supply chain of this factory outlet store. Therefore, a case study on the supply chain of this outlet store of L'Oreal is one of the main topics of this report. This outlet store only sells products of the CPD division and has a different supply chain than those of the regular customers. The products offered at this outlet store are in general not the same as the assortment offered to regular customers, but the product types and brands are the same. The assortment offered by L'Oreal in the outlet store is going to be discussed in subsection 1.1.3.

1.1.3 Assortment

The assortment of beauty and cosmetic products of the CPD of L'Oreal can be divided in certain categories. These categories, including brand names and product types per category, are:

- Fragrance. The fragrance product have different smells and designs for perfume for men and women. These two types of product can be recognized as the only types of products in this category. Brands which belong to this category are Daniel Hechter, Eau Jeune and G.Vanderbilt.
- Hair. The hair product category contains products for hair care, hair colouring and hair styling. There are several product types in these category, which are explained one by one. The first product type in this category is hair care, which includes products like shampoo, conditioner, other rinse products or no rinse products. The second product type in this category is hair colouration. Products can be identified on colour level or the principle of colouring (tone on tone, bleaching or others). The third and last category of products in the CPD assortment are hair styling products, like wax, clay, gel, hair spray or foam. Several brands like Garnier, L'Oreal Paris, Studio Line and Elnett can be found in this assortment category.
- Hygiene. Hygiene products are focused on cleaning and taking care of body. Here, product types are shaving, bath + shower and deodorant. These products are a part of the brand of Garnier and L'Oreal Paris, but also brands like MIXA and Ushuaia.
- Skin care. Skin care products are focused on taking care of the skin of body and face. They focus on the nutrition of the skin, which results in a more elegant and smooth skin. The amount of product types in this category are significant more than in the mentioned product categories, which is the reason why not all these product types are discussed. Several types of these products are the product types self tanning, body protection, anti-ageing, face cleansing, face protection and hydrating products. Brands in this category are Garnier, L'Oreal Paris, Maybelline and MIXA.
- Make-up. All the beauty and cosmetics products belong to this category. Product types are nail, face, eye, lipe and other type of make-up. A wide variety of product type are available in this category like lipstick, foundation, eye shadow and blush. These products are part of brands like Essie, NYX, Maybelline and L'Oreal Paris.

These mentioned product types are offered to consumers in the outlet store of L'Oreal. In the following subsection 1.1.4, an introduction is given on this factory outlet store.

1.1.4 L'Oreal outlet

The outlet store of L'Oreal is located in the outlet shopping centre of Roermond. According to the article of Kenton (2020), over 7.5 million visitors are recorded in 2017, which brings a challenge for the stores to find sufficient workforce (Roosblad, 2018). In the outlet centre of Roermond, different big brands are located, like Nike, Adidas, Puma and Gucci. Also, several beauty stores are presented in this outlet centre. The L'Oreal outlet offers different kind of products are being sold, like hair care, hair colouring, face care, fragrances and make-up. In this store, products are being sold with high discount, which is not temporary as in drugstores. Therefore, it can be called as an outlet, which sounds very attractive for customers. The layout of the L'Oreal outlet store is shown in figure 1.2

Figure 1.2: L'Oreal outlet store (Vrouw, 2015)

The products being sold at the outlet are not the same as in the assortment of the drugstores. In the outlet store, 'excess stock' is being sold. These products are being gathered at the CPD warehouse in Mollem (Belgium). From this warehouse, overstock presented at the warehouse and returned products are shipped to the outlet store. With the term excess stock, two kind of product classifications are meant. These product classifications are obsoletes and slow movers, which are going to be discussed one by one in the next part of this subsection.

Overstock can be presented when too much products have been ordered at the factory. This can have many causes, of which is one is too few sales. These products can be identified as slow movers. The reason for creation of slow movers can be changing trends or other market changes. Certain products can have a high sell out during a promotion, but do not sell that well in regular shelves. Here, the mismatch between inventory and demand is the main reason slow movers are created. Therefore, forecasting the demand and adjusting the inventory level based on thee demand forecast is crucial in a supply chain. Within L'Oreal, overstock is defined as the stock that is presented when 6 month of the demand forecast is being subtracted from the stock level. Due to market changes, overstock can be presented due to having a high stock level and lowered demand forecast. Then, the overstock of this products can be sold at the outlet store.

Next to too few sales, another main cause can be identified for creating overstock. If products are being replaced by a new type of product, the 'new' product can be sold to regular customers. Then, the 'old' product can be sold in the outlet store and can be identified as obsoletes. These obsoletes are also presented since L'Oreal includes a returning program for some of its customers. If new products or slightly changed product are being launched, the 'old' products can be returned to L'Oreal. In return for these products, L'Oreal compensates these customers by a financial refund. The returned products from the customers can be send to the warehouse in Mollem, from where the outlet store can order them to sell them.

The other classification of products which are being offered at the outlet are obsoletes. Within L'Oreal, obsoletes can be defined as products of which stock is presented, while the demand forecast is zero. Causes like replacements, changing markets or changing market plans can be recognized as the cause of having stock on this classifcaiton of products. The demand forecast is being updated by the demand planning team, which tries to keep the forecast as good as possible.

In this research, 'regular' customers of the CPD division of L'Oreal are retailers, of which AS Waton (Trekpleister and Kruidvat), Etos,Jumbo, AH and Action are well known in the Netherlands. Also, e-commerce parties like Bol.com and Wehkamp sell the products of the CPD division. These retailers are a different kind of customers than the customers of the outlet store, which are in fact the consumers of the product. Therefore, attention should be paid when reading the term 'customers', which can be retailers or consumers in this report.

The goal of the outlet store is to sell these slow movers and obsoletes. After a certain amount of time, trends might be totally changed, such that these products cannot be sold anymore to retailers. If this is the case, there can be chosen to destroy these product, which also includes cost. Another option to sell slow movers and obsoletes, is making deal with partners which are located at other countries in which no other L'Oreal department is active. However, by selling the products in the outlet, destruction is being avoided and also a financial benefit is presented. Therefore, it is desired for the business of L'Oreal to sell the products in the outlet.

To have sufficient turnover in the outlet store, a large amount of products has to be sold since these products are being sold against a lower price. Therefore, a large quantity of products has to be shipped to the outlet store to make sure that a sufficient amount of stock is presented. A sufficient amount of stock is required to be able to keep up with the demand of customers, who want to buy their product directly at the store. If products are out of stock, turnover is being missed, which should be avoided. Since transporting is done by an external carrier from the warehouse to the outlet store, transportation cost have been suppressed by lowering the amount of delivering moments per week. Twice a week, several pallets are shipped to the outlet store. Due to the high quantity per delivery, a lot of products have to be stocked at an external location before they can be sold in the store.

In the store, a small stock room is presented. Due to the limited capacity over here, an external location is hired to be able to save the stock. This location can be reached by foot from the store. Transshipment from these external location to the store can be done by cages, since no trucks or other equipment are allowed during the day to transport to the store. Only before 11 o'clock in the morning during working days, trucks are allowed around the store, which limits the possibilities of scheduling deliveries.

1.2 Problem statement

During the transport of the products from the warehouse of L'Oreal to the consumer in the store of the outlet, certain problems can be identified. Two main problems can be recognized, which are going to be discussed in detail in this section. The first one is the transport cost for replenishing the outlet store, which is due to the large delivery sizes. The mentioned delivery scheduling is a topic in which the business of L'Oreal has challenged the supply chain team to lower the cost. Compared to deliveries to other customers, extra cost are mode for the transport of the goods to the outlet store, which is caused by multiple extra tariffs of the transporting company. Since this cost is relatively high, a problem can be identified to be explored what the cause is. Besides, there can be explored if it is possible to reduce the cost related to transporting the goods to the outlet. Due to the high quantity per delivery and limited storage capacity at the outlet store, the store personnel does not really know how to manage the large amount of incoming goods. Therefore, the store personnel cannot unload the pallets that quickly, which results in the fact that the truck is not able to leave in the reserved time slot of the transport company, which results in extra cost. Therefore, the cost for transporting goods to the outlet are higher compared to the cost for transporting goods to other retailers, so improvements could be possible on this topic.

The second problem is that there is no clear overview on what is really on stock per storage location. Here, two storage locations already have been introduced, which are the internal storage location at the store and an external storage location. Boxes are being placed several time at 'wrong' places, in which the place is wrong if products are not grouped at a storage location. If these stock has to be sorted later on, boxes are picked up several time before the products are placed in the shelves of the store. Besides, the management of the stock in the store is not that organized that the products can be placed easily on a single spot, which is also caused by the multiple storage locations which the outlet has. This results in the fact that several products are located on a single spot, which makes it hard to have an overview how many products of a single type are presented. By not having an overview the stock, orders cannot be done based on the right amount of stock. This can results in having too few stock or too many stock. If products are out of stock (OOS), turnover is being missed, which is not desired. During last Christmas, over €15.000 of turnover was missed according to the retail manager. Overstocking results in products that cannot be sold during a certain period, which means that they should be destroyed or sold in an alternative way (more discount or as gift). Therefore, the stock overview can be improved, which should result in better stock management.

1.3 Objective

Of the mentioned problems, the mentioned first problem is the main focus in this research. The first stated problem, having large deliveries and high transport cost related to deliveries to other customer, is going to be investigated in this research to see how deliveries can be scheduled in a more optimal way for the store personnel. By seeing which profits can be made by scheduling more smaller deliveries, the stock management can be improved since less amount of units have to be ordered per day and orders can be adjusted based on the stock level during the wee.

By studying the concept of a general outlet supply chain, the goal of this research is to optimize the transport scheduling for replenishing the L'Oreal CPD outlet. Here, an investigation on the supply chain is the main topic of this research. Here, the focus is on investigating the replenishment strategy and which role this strategy has in the overall performance. Here, transport scheduling is another main focus of this research, since it is connected to the performance of the replenishment strategy of the outlet supply chain.

Based on a general approach on optimizing performance of an outlet supply chain, gained knowledge can be applied to the case study of L'Oreal. The cost involved are of interest for the company, but also several aspects should be investigated to measure the performance of the supply chain and see which replenishment strategy is used. Explicitly, the replenishment process of the factory outlet is going to be investigated, which is an adjustable process in the supply chain. Also, related variables to this replenishment strategy are used to optimize the performance, such as order amount, amount of stock desired and stock management.

1.4 Research questions

Based on the objective of this research, the following main research question will be answered in this research:

"How can the performance of the transport process of replenishing the factory outlet store of L'Oreal be optimized?"

The following sub-research questions will be answered to help to answer the main research question

1. What differs a factory outlet supply chain of a regular supply chain?
2. Which replenishment strategies are used in a push supply chain?
3. What is the current transport process for replenishing the L'Oreal factory outlet store?
4. Which modelling method is suitable for modelling the transport process of replenishing a factory outlet store?
5. How can the transport process of replenishing a factory outlet store be expressed in a model?
6. Which savings can be realized by scheduling transport according to the described transport model for replenishing the factory outlet store of L'Oreal?

The steps to complete to be able to answer these research questions, a research approach is introduced in section 1.5.

1.5 Research approach

In this section, an approach will follow to answer the introduced research questions. The research approach introduction is done by splitting the approach in different steps. Per step in the research, a desired goal will be defined. The steps of the research approach will also be shown in a flow diagram, which is located at the end of this section. The approach of the research contains the following steps:

1. Literature research. The first step of the research is to explore which stakeholders and components are involved in an outlet supply chain. Also, the differences between a 'regular' and outlet supply chain are investigated. The goal of this steps is to identify related components and aspects of an outlet supply chain by literature research.

   Inventing the wheel which already has been done does not add anything to current literature. Therefore, doing literature research can give insight in current supply chain developments. This literature research is done next to the step of analyzing an outlet supply chain. From existing literature, improvements in the context of industry 4.0 are investigated to see what are the current development for optimizing replenishment processes. Also, available models for modelling transport scheduling are discussed to be able to investigate which parts of existing models can be used for modelling the delivery scheduling process in the context of an outlet supply chain. The literature research is discussed in chapter 2.

2. Analyze outlet supply chain. The goal of this step of the research is to dive into the details of a supply chain of the outlet store of L'Oreal and analyze the role of different involved components. Based on literature, an analysis will follow to see how gained knowledge can be applied in the context of the L'Oreal outlet supply chain. Here, the focus is on the case study of the L'Oreal outlet supply chain. Getting clear insight in the pain points of the L'Oreal outlet supply chain is the goal of this step in the research. The analysis on the outlet supply chain of L'Oreal is discussed in chapter 3.

3. Model selection. Based on the found models in literature, a modelling method is selected to model the transport process of replenishing of outlet supply chains in literature. Due to the fact that supply chains are widely reviewed in literature, certain parts of models can be interesting to use in a model of the transport process for replenishment. Combing existing models and applying them in a new situation, can also lead to new insights in new applications. Therefore, the delivery scheduling models found in literature are reviewed to see which parts can be used in the application of delivery scheduling for replenishing an outlet store. The model selection is discussed in chapter 4.

4. Model building. Building a general selected model of the transport process in an outlet supply chain is the next step in this research. Here, known models are discussed to see which parts are used in this new model, which is also introduced by describing its assumptions. Besides, a verification will follow to see if the model has been implemented correctly. This is discussed in chapter 5.

   The general introduced model can be specified for the case study of L'Oreal, which is the next goal in this research. The introduced parameters are validated by checking if the model meets its purposes and captures the assumed reality. This can be done by comparing the outcome of the model to situations in the past in chapter 6.

5. Model experimenting. The introduced model can be used to minimize the related cost of the transport process of replenishing the L'Oreal outlet. Therefore, an experimental plan has to be designed and performed to be able to investigate if savings can be realized in practice. Different scenarios of input and configurations are introduced, to be able to investigate the behaviour of design alternatives of the model.

The key points of the steps and goals of this research are shown in table 1.1.

Steps	Chapter	Goals	Answered research questions
1. Literature research	2	- Identifying supply chain components / aspects - Supply chain improvements in industry 4.0 - Available transport models	1. What differs a factory outlet supply chain of a regular supply chain? 2. Which replenishment strategies are used in a push supply chain?
2. Analyze supply chain	3	Insight into pain points of current supply chain at L'Oreal	3. What is the current transport process for replenishing the L'Oreal factory outlet store
3. Modelling method selection	4	Selecting a suitable model for modelling L'Oreal outlet supply chain	4. Which modelling method is suitable for modelling the transport process of replenishing a factory outlet store?
4. Model development	5	Building a general transport model with multiple storage locations	5. How can the transport process of replenishing a factory outlet store be expressed in a model?
	6	Specifying the introduced transport model for the case study of L'Oreal	
5. Model experimenting	7	Designing and performing an experimental plan to optimize the performance of the L'Oreal outlet supply chain	6. Which savings can be realized by scheduling transport according to the described transport model for replenishing the factory outlet store of L'Oreal?

Table 1.1: Research approach, steps and goals

Setting these steps in a flow diagram, will give the result as shown in figure 1.3. After the introduction, first an outlet supply chain and replenishment processes are explored via a literature research. Next to this, the supply chain of the L'Oreal outlet is analyzed. Afterwards, a possible model is selected to model the transport process for replenishment applications. Afterwards, a general model can be built for the mentioned process. Then, experiments are done with the model to optimize the performance of the transport process for replenishing the factory outlet of L'Oreal. A conclusion will finalize the report.

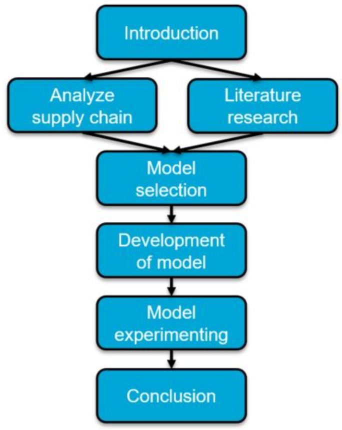

Figure 1.3: Flow diagram

2 Literature

In this section, a literature review on supply chains of a factory outlet is stated. First, the concept of supply chain in general will be reviewed in section 2.1. Then, the concept of a factory outlet will be reviewed in 2.2. According to this concept, the supply chain of a general factory outlet will be formulated in 2.3. Next, the supply chain aspects demand forecast (2.4), stock and replenishment (2.5) and order fulfillment (2.6) will be discussed. These aspects will be important to come up with performance measurement of a supply chain in section 2.8. A conclusion will finalize this chapter.

2.1 General supply chain

In the following section, general supply chain terms and focuses are introduced. The definition of a supply chain has already been discussed in the introduction and contains different aspects. In this section, these aspects are introduced in detail and compared in two distinguishing supply chains. Several aspects can help to classify the supply chain with certain terms like echelon level. These aspects will also be discussed at the end of this section.

2.1.1 Pull vs Push

According to the research of Sharma (2018), supply chain management can be categorized in two different strategies. Both strategies can be useful to use in a certain type of industry, which are going to be explained after the introduction of the strategies. The investigated supply chain strategies are the following two:

- Pull. A pull supply chain is based on supply due to actual demand. Inventory is only required when it is needed for an action. This type of strategy can be very effective for a company of which the demand can be predicted in a very accurate way. Since less inventory is presented, a supply chain of this strategy gets into trouble when unexpected demands appears. It can be compared to an operation at a car garage, in which only 'expensive' parts are ordered when they are required.
- Push. A push supply chain is based on demand in the future, which are based on long-term projections of customers. Planning events in the future gives companies an idea how to be prepared for the future. An example of such a strategy isthe sales of suncare, which have to be presented when the sun is out. Only at this time, consumers want to buy the products to immediately use it to protect their skin.

The two mentioned strategies can be visualized in figure 2.1, of where a manufacturer is visualized by a person. The products are visualized by boxes. Here, a push strategy is taking into account that products have to be made just in case they are required. Therefore, the demand is not known exactly, so different scenarios have to be taken into account. Products have to be presented if demand is presented. However, a pull strategy only starts making product when they require it.

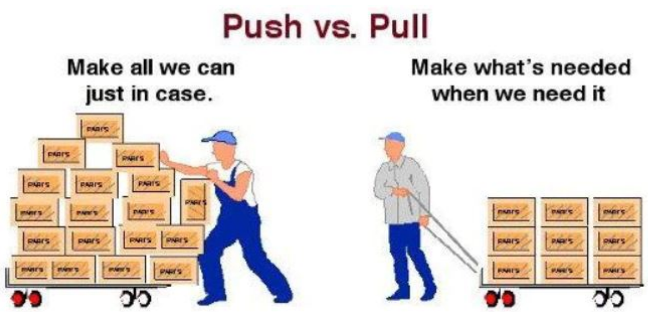

Figure 2.1: Visualized difference of push vs pull strategy (Plex, 2017)

These two principles of supply chains can be compared to the operation principles of manufacturers and retailers. Manufacturers turn raw materials into finished goods, which are being sold. Retailers buy and sell these finished goods to customers, which consume these goods. According to the research of Ge et al. (2019), manufacturer supply chains are totally different than retail supply chains. Manufacturer supply chains have less vendors involved which increases in a more manageable inventory. Besides, manufacturers focus on a limited number of wholesalers, of which the number can be hundreds of millions in case of retailers. This results in a different cost structure, since the focus of manufacturers is on equipment and production lines. Their resources and planning is crucial for their production capacity. Retailers spend most of their cost on understanding their customers and focus on inventory. With growing demands of customers, the supply chain has to be able to fulfill the customers with the right goods.

Therefore, manufacturer supply chain are common to be pull-based and produce on basis of their actual orders. They have some buffers to be able to stay producing, but focus only on producing what they can sell for sure. Common retailers used to have a push based strategy, since their sell-out is more insecure. Therefore, they aim on higher inventory levels than manufacturers do. The demand at retailers can vary a lot, which is due to the fact that they have more customers. All these customers have different demands, which are dependent on external factors. Therefore, forecasts are done, but these are almost always 'wrong' (Pittman, 2015). A forecast can be identified as a "guess" but has a huge influence on cost and profits. However, making accurate or inaccurate guesses on the demand is really important in push based supply chains.

In this research, the focus is on a retail supply chain. Here, inventory management is important and is investigated in more detail in this research. The gained knowledge on retail supply chains can be applied on the supply chain of the outlet of L'Oreal, which can be seen as a retailer. The focus of the outlet is to sell goods in public in small quantities for consumption, not for resale. A traditional retail supply chain flow of products (without manufacturer involved) can be seen in figure 2.2.

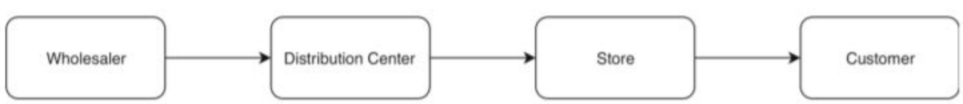

Figure 2.2: Retail (Ge et al., 2019)

2.1.2 Vendors

Vendors, which offer goods for sale, have a lot influence on the process in a retail supply chain. Therefore, they can be defined as the 'chains', who are linked in a supply chain. Multiple vendors on different levels sell the goods until they reach the final customer, which consumes the products. Example of vendors are manufacturers, distribution centers, retailers and stores. The vendors determine who are their customers, which can be within a certain company or external retailers. The product quality and company profits are related to the vendor management.

Information sharing between the different vendors is important for making the vendor management effective Ge et al. (2019). This is important in both of the mentioned supply chain strategies, push and pull. Collaboration and integration between the supply chain partners helps to make jointly decisions about forecasting and planning. Physical flow coordination and the understanding of the role of vendors is also crucial for the related product quality and company profits. Models that are introduced to help the supply chain management of vendors are continuous replenishment programs and vendor managed inventory. These focus on the three categories of vendor management are: information, service and finance.

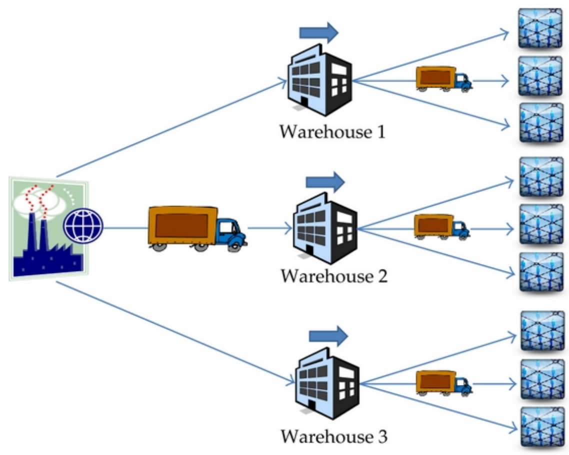

Figure 2.3: Supply chain network with shown vendors (fabric, warehouse, stores in blue) (Cabrera et al., 2012)

Besides, the amount of vendors included in a certain level influences the complexity of a supply chain. This is shown in figure 2.3. Having only one single supplier, can be less complex for a retailer instead of several suppliers. Having an overview on several orders can be easier when less persons are involved, but also depends on the information flow between the vendors. Considering the amount of vendors involved is thus important in selecting a suitable supply chain model. One of the most simple supply chain models focuses only on one supplier and one retailer, but this type of model is too simple for models with multiple suppliers. However, lessons can be learned from these simpler methods to expand for more complex models.

2.1.3 Demand

Forecasting how many products are going to be sold at the end of the supply chain, helps to make the supply chain process more effective. According to the research of Bala and Kumar (2011), changing customer buying patterns are evaluated to come up with a forecast on the demand. However, this forecast cannot be 100% accurate since multiple factors are unpredictable. An example of this is the outbreak of COVID-19, which had huge influence on the demands of the customers. However, due to the growing data availability, machine learning algorithms are introduced in the last years to provide better predictions on the demand (Ge et al., 2019). Matching the supply and demand is crucial to reduce cost and improve competitive advantage.

According to the research of Kumar et al. (2016), demand can be categorized in two different categories. These are static demand and varying demand. In case of a static demand, the demand of a customer follows a specific distribution. In business, these assumption are considered as too simple and not useful. This kind of demand can only be assumed in single-item systems, which is not realistic in many cases. Therefore, varying demand is assumed to be more realistic since it is resulting from a lot of decisions of suppliers, customers and consumers.

The role of demand is different in the mentioned supply chain strategies. In a pull supply chain, the demand is the leading factor of the order which has to be fulfilled. Forecasting demand is not considered as that important, since action only takes place after receiving an order. Forecasting demand is crucial in a push supply chain. By forecasting a demand which is too high, investments on a too high scale are done. This results in a lost of cost on ordering, stocking and 'dumping' the stock. Forecasting a too low demand results in missed turnover and emergency shipments. Both indicate that the optimum of demand forecasting is when forecasting the exact demand, but this is not realistic in the market of this moment due to the raising complexity.

2.1.4 Inventory

Inventory or stock management is all about making decisions on quantity and placement of stocked goods. Information is crucial on monitoring the amount of goods which are moved in and out of the inventory. Here, the balance of the inventory should be sufficient to fulfil the demand before another replenishment will take place. According to the research of Ge et al. (2019), replenishment, transport and placement are the three crucial aspects for inventory management. An introduction will follow in these aspects.

- Replenishment is bringing the stock to a sufficient level. Due to varying demand and lead-times, items may be required than the supplier can provide it. Stock-out results in missed turnover, which is unwanted for retailers. Therefore, a desired stock level can be set, of which safety stock is common used supply chain term. Inventory is mostly presented at all at the vendors of a supply chain and can be evaluated different at various layers. Therefore, information sharing is crucial to come up with a sufficient stock level which can fulfill the demand.

  In case of a push supply chain strategy, inventory levels are in general higher than a pull supply chain strategy. Unknown demand in a push strategy requires goods to be on stock, since customer want it for sure in a certain period. When it is getting cold, there are people who want to buy gloves. So, gloves are an example of such a good, but the quantity which is sold depends on multiple factors. In case of a pull supply chain strategy, inventory levels are lower. This is due to the fact that orders are only being placed to replenish if these goods are required in the near future.

- Transport deals with moving the goods between inventory facilities. Here, movement of the goods differs this process from other processes in the supply chain. This can be done by an external company or by transporting facilities which are owned by the company. By moving goods to the next chain in the supply chain, the overall inventory level can be reduced. Two types of transport can be recognized, which are proactive and reactive. Proactive transport redistributes as a kind of foreseeing in advance of any orders. Reactive transport only distributes based on orders or real demand.

  These two transport types can also be placed in the perspective of the pull and push supply chain strategies. Proactive transport can be observed in supply chains with a push strategy, since the gloves have to be at the retailers when it is getting cold. If they have sufficient stock at a retailer, the retailer can be able to maintain a certain stock level. Then, they can switch to a more reactive way of replenishing, which can be demand based. If they only order what is being sold, they can try to keep their inventory level at a certain point. Proactive transport will not be observed in a supply chain with a pull strategy, since only transport will take place after an order has been placed. Therefore, reactive transport can be observed in a pull supply chain.

- Inventory placement is about managing the position of a product in the inventory. In case of a large warehouse, managing the position of products can lead to a reduced amount of distance for the order pickers. In case of e-commerce, inventory placement is specially relevant when picking many order. For a given plan horizon, the total cost can be minimized by looking at demand for each product while fulfilling capacity constraints. Due to the fact that the inventory of a retail store can be the size of a living room, product placement can be of less importance. However, for maintaining overview, this can be important, as already discussed in the problem statement of this research.

From the perspective of push and pull strategy, inventory placement has the same goal. Positioning the goods in the stock rooms to be picked as quick as possible when they are required. In case of a push strategy, the positioning of products can be based on the demand forecast. In cash of a pull strategy, the placement of goods can be organised according to the sequence in which these goods are required.

2.1.5 Order fulfillment

The process from receiving an order to delivery of it is called order fulfillment. Customer experience is influenced by this process and plays an important role in the cost. In case of small orders in an e-commerce warehouse, this process includes lots of decisions due to a wide variety of products and multi-stage steps in the supply chain. Scale and complexity of the supply chain gives rise to a lot of research opportunities. Several steps are included in the order fulfillment process according to Ge et al. (2019), of which the reception of the order is the first step. The retailers needs to select the location from where the product should be shipped. Also, the order should be prioritized (or not) to be able to fulfill the customer demands. From a network point of view, the products should be gathered from multiple locations, of which many routes are possible. At the end, the assembled order should be packed to be able to transport it to the customer. The transportation of the goods to the customer completes the order fulfillment.

Lead time is an important term in order fulfillment. According to Bai et al. (2019), lead time can be defined as the time between order placement and the reception of the order. This includes the time of order fulfillment and transport to its next destination. It is an important term since vendors have to take this time into account when they want to keep their inventory level on point. High inventory levels are required in case of long lead times to be able to keep up with varying demand, which might be unexpected in certain circumstances. This also depends on the cost required per order and transport.

In case of a pull supply chain strategy, short lead times are wished. Based on real demand, orders are being placed. In case of a car garage, certain parts are only ordered in case repairs have to be performed. But, the owner of the car wants that the car is repaired as quick as possible. Therefore, the garage wants to have a short lead time on their orders. Otherwise, the next time the car has to be repaired, the car owner will bring his car to the concurrent.

In case of a push supply chain, inventory have to be built in to be able to react on the demand of the customer. If this is done with sufficient safety stock, long lead times can be handled by this type of supply chain strategy. In case of replenishing, this has to be done while keeping into account the lead time. Therefore, an amount has to be order which keeps the inventory on a certain level before the next order will arrive. Therefore, the concept of safety stock is discussed in more detail in section 2.5.

Under order fulfillment, also product returns can be captured. These have a great influence on the customer experience, according to Ge et al. (2019). Here, no or additional return shipment fees are provided to the customer and the ability to cancel their order within a certain amount of time. Especially in e-commerce, retailers are proving this extra service. Logistic wise, it includes some difficulties if the processed order is cancelled in a later stadium. Therefore, companies are trying to limit the overlap between the cancellation time frame and the time the order is being processed.

2.1.6 Bottlenecks

The research of Kumar et al. (2013) also points out that capacity is an import building block of a supply chain. Unlimited capacity of delivery and stock will not be realistic since physical constraints are presented in industry. Capacity of space and time results in restrictions on different variables at manufacturers, suppliers and customers. This results on restricted demand, order capacity and stock level. In combination with errors and an incomplete information flow, bottlenecks of several supply chains can be recognized. Therefore, capacity is taken into account at replenishing and should defiantly be taken into account in this research.

2.1.7 Supply chain classification

In the following part of the general literature review, general terms about classification of supply chains are going to be discussed. Here, the amount of identical parties involved and the amount of goods in a supply chain are key subjects in this subsection.

2.1.7.1 Echelon

As already presented in the previous chapter, the supply chain is all about the network which distributes goods from suppliers towards its buyer. When the supplier and its buyer are a part of the same company, there can still be spoken of a supply chain between a warehouse and retailing store. Manufacturers, suppliers and customers can all belong to such a network of a supply chain. A term which is often used in the supply chain is echelon, which represent the amount of ranks in a supply chain. The ranks represent grouping of manufacturers, grouping of producers, grouping of suppliers, grouping of distributors and grouping of customers. These can all be sorted at the same rung of a ladder.

The echelon level of a supply chain presents the amount of sorted components in a supply chain. In case of a two echelon supply chain, the supply from a warehouse to a store can be identified. An example of of a three echelon supply chain is the supply of goods from a fabric to a distributor, which transports the goods to customers. When also the suppliers of the fabric are involved in the network mentioned before, the echelon level even raises to four. This gives an idea of how the echelon level of a supply chain is used in practice.

2.1.7.2 Goods

In supply chain networks, goods are transported towards its consumer. Here, certain vendors can sell the product again, in which they are considered as retailer. It is also possible that the retailer consumes the product, in which they are the consumer. Supply chain networks can distribute goods which are identical, which can be considered as a single-item supply chain. In case when there are multiple different goods with different properties, the supply chain can be defined as a multi-item supply chain. The amount of products involved can lead to complexity, since different product properties include restrictions on the introduced capacity on time and space. Therefore, different approaches are used in case of multi-item supply chain.

2.2 Factory outlet

In this section, the concept of a factory outlet is investigated. Here, first the type of shopping facility is evaluated and its purpose. Then, the concept of a factory outlet is going to be evaluated regarding the assortment, target segment of customers, location and pricing.

2.2.1 Shopping facilities

In the last years, the amount of shopping facilities have raised. E-commerce was introduced and is especially popular since everybody with an internet connection is able to buy products. Besides, large shopping malls extended there assortment. Temporary pop-up stores can also be presented at places at which a regular store cannot be located. Also, the outlet or factory outlet store can be seen as a new type of store, different than a regular one. At such a factory outlet, brands sell their product directly to customers to public at substantial discounts (Jones et al., 1997). The products which are being sold at these outlets, can be seen as excess stock. This stock is in fact being disposed at such an outlet centre. Gathering all these brands gives a factory outlet shopping centres, which becomes attractive for the customers to visit.

According to the described development of Jones et al. (1997), the concept is created in the US. The factory outlet centre offered a new experience to the customer due to the connected brand names. An attractive, modern and accessible environment is created as a shopping centre. The outlet shopping centre is owned by an external company of which companies behind brands can hire a location for their store. Therefore, the shopping centre is managed well by an external company, regarding traffic flows and property layout.

In the Netherlands, there are several factory outlet centres. Holland.com (2020) made a list with all the outlet centres, which contains outlet store of many brands. Bataviastad at Lelystad, designer outlet at Roermond and Rosada factory outlet at Roosendaal are the locations in the Netherlands.

An alternative of dumping excess stock is by selling it to second-life retailers Kumar et al. (2016). These second-hand retailers extend the lifetime of products which are not good enough anymore for primary retailers. This results that the products can reach groups of lower levels of the society, which drops the exclusivity of the products. Especially in case of fashion, exclusivity is important for big brands since only the richest can afford it.

Another alternative of dumping excess stock is by giving these products away as a kind of bonus pack. These giveaways can be seen as a rewards for buying the products. However, no turnover is made and in case of a commercial company, maximizing profit is the goal. Therefore, a factory outlet store is preferred above the alternatives.

In this section several aspects of a factory outlet are going to be discussed. The assortment, target segment, location and pricing for factory outlets are the subjects in the following subsections.

2.2.2 Assortment

According to to the research of Ngwe (2017), outlets are offering several product types. The first one is excess stock, which is created due to lower sales. Therefore, these products are categorizes as less desirable and are removed from the assortment of different retailers. The second type are obsoletes, which are products that have been replaced by a newer product. But, outlets are not only selling their less desirable products at the outlets. They also offer exclusive merchandise of their brand to make the outlet assortment more attractive. This is the third and last type or product which is being sold at the outlet. These exclusively products are offered such to make the assortment more attractive. If customers visit the outlet especially for these products, they can be tempted to also pick the discounted products.

In case of fashion outlet stores, collections of previous years are being sold Brun et al. (2017). Besides these products, also must-haves have to be available to be able to offer a complete assortment to the customer. In case of selling make-up products, eye shadow and eyeliner should be offered. Offering only of this products would not make the assortment very attractive for customers.

Due to the fact that these factory outlet are retailers, they tend to have a push focused supply chain strategy. Therefore, their assortment is changing and consists of multiple type of product with all their own properties. Therefore, supply chain analysis including assumptions on a single type of item, are not applicable on these type of supply chains.

Besides, the assortment of factory outlets is changing over time due to stock outs. If the whole stock of products have been sold, no new products can be delivered to outlet store. Therefore, orders should take into account the availability of these items at the warehouse. Alternatives for certain products should be ordered on time to be able to switch to new products in the assortment at the outlet, next to the exclusive factory outlet products. Therefore, a changing assortment should be taken into account in the supply chain of a factory outlet.

2.2.3 Target segment

In the research of Smajovic and Warfvinge (2014), pop-up stores have been compared to outlet stores and regular stores. The goal of such an outlet is to dispose of excess stock. Because the store is owned and operated by the manufacturer, the brand is able to sell at a lower price. However, customers rated the outlet lower in terms of attractiveness, neatness, cleanliness and brightness and felt more comfortable in traditional stores (Smajovic and Warfvinge, 2014). But, these did not weight up against the price aspect, which was the main reason for customers to visit these outlet stores. This is mainly due to a reflection of price of the customer to price of retailers.

Therefore, one target segment of customers in factory outlets are deal-prone shoppers which are brand sensitive. Since they still want certain products of a certain brand, they are willing to seek for cheaper products of these brand. According to the research of Reynolds et al. (2002), two other segments can also be recognized. One of these are the serious economic shoppers, which have less to spend than the previous mentioned segment. Therefore, they cannot offered the primary products of a brand and focus on buying in outlet stores.

A third segment of customers can also be recognized. This segment is the recreational shopper. According to the research of Reynolds et al. (2002), they like to shop with other, spend more time on shopping and continue after making purchases compared to the other segments. Therefore, tourist can also be seen at these shopping centres and recreational or entertainment-type services are also offered for the customers. The location may also be next to tourist sites, to be able to attract these shoppers Reynolds et al. (2002). More information on the choice of location will follow in the next subsection.

2.2.4 Location

The location of outlet centres is focused on the customer segment 'brand and price conscious consumer'. However, locating these outlets in regular shopping streets at prime shopping locations raises a problems. If the same products of the same brand can be bought at the outlet store, less product are sold at other retailers (Sikos et al., 2009). Therefore, the location of outlet centres is set 'near' the city centre. Citizens are required to work at these outlet stores and have to be kept at short distance from their working place (Smajovic and Warfvinge, 2014). So, the distance to travel from a city centre to to an outlet store cannot be too far to make it attractive for employees. Also, a location with high visibility is preferred, which can be easily accessed by car for customers and transport (Jones et al., 1997). So, an urban area near the province capital is selected as most suitable according to Rondan-Cataluña et al. (2019). As already explained, a location near tourist sites is also preferred.

The location of a shopping centre is being managed by an external company, of which brands can hire a store. Therefore, the store locations are not managed by the hiring companies and they have to deal with the available stock room in the stores. Therefore, they have to manage it in an effective way to be able to stock their products, which can be sold in high quantities. However, according to the research of Ngwe (2017), more shelf place is available in an outlet store than in regular store. This also creates opportunities to place more stock in the shelves of the store.

2.2.5 Pricing

At the outlet stores, 'less' desired or replaced products are being sold with high discount. According to Rondan-Cataluña et al. (2019), customers who visit outlet stores are more price sensitive and this is of importance in terms of sales. Knowledge of the product and knowing other offers influences the minimum price which is recommended by this research. Competition and average income of near towns are important, according to (Rondan-Cataluña et al., 2019). In case of a high income in the region, products of retailers the area are probably set higher. In this case, the pricing in outlets centres seems to be more attractive. Also, the amount of tourism of an outlet centre is important for the pricing strategy, since they are willing to pay a bit more.

Pricing is also dependent on activities of the brand Clodfelter and Fowler (2003). Price comparison between those of the competitors at the outlet centre and the price of former products should be taken into account to come up with feasible prices. Besides, prices of exclusive merchandise items can be set without references, since the product is not available at any other retailer. Taking into account the turnover made on these products can be used to set a discounted price for the other products.

Besides, the age of customers can also have influence on a profitable price. According to (Rondan-Cataluña et al., 2019), buyers under the age of 30 suggest lower minimal prices than customers between the age of 30 and 60. The last group of customers is tempted to seek zones where there is competition between retailers to find the lowest price. These groups also have more mobility possibilities and can reach the location of the outlet centres more easily.

Setting the right price can be done in a certain range and is depending on factors like competition, economic capacity of the customers and shopping environment. Setting high discount makes the products attractive for the customers at the outlet centres. More information on pricing and the corresponding demand can be found in the researches of (Bai et al., 2019; Clodfelter and Fowler, 2003; Carlson and Compeau, 2018).

2.3 Factory outlet supply chain

In this section, the supply of products towards factory outlet stores is going to be discussed. According to Ngwe (2017), two types of products are supplied. These can be mentioned as original products, which are taken out of regular stores, and factory outlet products, which are sold only at the outlet stores. Original products are sold at the outlet due to the fact that the demand forecast was not meeting the real demand. Defective or damaged items will not be sold at this outlet, which is a common made misconception. Therefore, the product flow of the supply chain can be modelled as shown in figure 2.4.

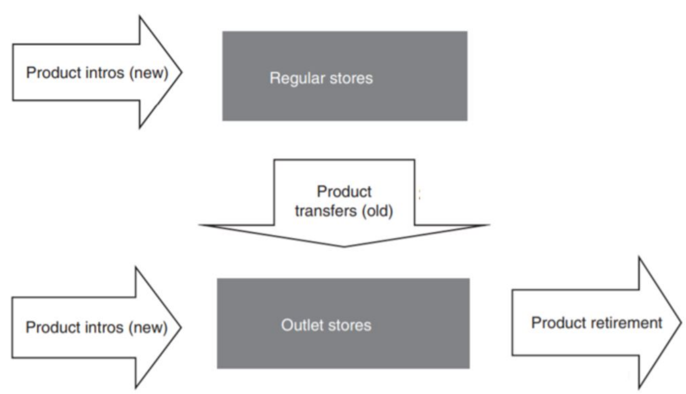

Figure 2.4: Product flow in an outlet supply chain (Ngwe, 2017)

In figure 2.4, the product intros are being transported from the fabric or distribution centre to regular stores. This can be customers or stores which are owned by the same company. If products are being replaced at these customers, the 'old' products are being transported to the outlet store.

This can happen directly or via a warehouse. Exclusive merchandise products from the brand are also transported to the outlet from the fabric or distribution centre.

In the outlet store, the goal is to dump all the excess stock. However, it might be possible that not all products are being sold at the outlet. If this is not the case, product can be transported to external buyers or be destroyed. In these cases, less turnover is being made, so selling more items at the outlet store is desired.

The customer can also be shown in the product flow of a factory outlet supply chain. This gives a more complete overview of the supply chain can give a more complete picture. Besides, the factory outlet can have multiple suppliers since the remaining stock may be transported from a different warehouse than the exclusive merchandise products. Assuming that the products which are being transported to the outlet are sold, only a flow from the factory outlet to the customer is necessary.

The suppliers of the retailers and factory are left out of scope, since it is not investigated how excess stock becomes available for the factory outlet. Therefore, the flow of the warehouse towards the retailers is left out of scope. The transport between different locations can be done by an external company, which can be included in the flows. The placement of the goods in the factory outlet in the stock room or in the shelves is not considered in detail in flow diagram, which is going to be discussed in the next chapter. An overview of a supply chain including, multiple fabric, retailers and warehouses is shown in figure 2.5. In the next chapter, the subsystem of interest of a supply chain is going to be set.

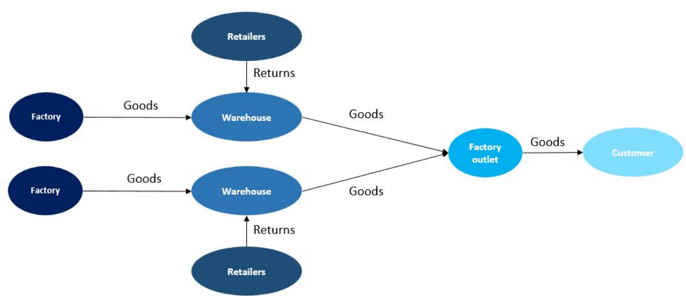

Figure 2.5: Factory outlet supply chain

As already explained, the establishment of excess stock is not investigated in detail. What is of interest, is how the owlet handles the products which have to be sold. Therefore, this part of the supply chain is being discussed on the introduced aspects in section 2.1.

2.4 Demand forecasting

Estimating a certain amount for demand is crucial in a push supply chain to be able to keep up with the actual demand. As already explained, the factory outlet stores are retailers. Therefore, they should aim on applying a push supply chain strategy. In case of a fashion store, a winter collection should be presented at the time it gets cold. Ordering when it is getting cold includes waiting time for the customer, which is not desired from their perspective. Therefore, having a certain amount on stock is crucial for the factory outlet stores.

Stock level, product promotion and profitability are all dependent on the demand forecast (Ongkicyntia and Rahardjo, 2017). An accurate representation of the demand helps to reduce cost and maintain customer satisfaction. Therefore, several models are developed in literature to forecast the demand. These models can be defined in the following categories in the research of (Ge et al., 2019): statistical, machine learning and deep machine learning.

2.4.1 Stochastic

The stochastic time model is the most popular yet under the demand forecasting methods (Ge et al., 2019). This method is model driven and relies on stochastic processes. Based on linear or non-linear approaches, time series model are introduced. Methods which belong to this category are Autoregressive moving average (ARMA) and Seasonal Autoregressive Integrated Moving Average (SARIMA).

All these methods include strong assumptions to reduce demand to such a stochastic process. Therefore, the accuracy of this method can be improved by one of the following methods. Besides, certain stochastic processes assume on of the simpler types of inventory models with only one storage location and a single product (Browne and Zipkin, 1991). However, due to the fact that this method is easy to understand and implement, it is still widely used.

2.4.2 Machine learning

Machine learning methods are based on mathematical algorithms to detect patterns, capture demand and spot complicated relationships of large data sets. While stochastic methods are more experience based, machine learning methods are more data based. Therefore, sufficient processing power and a lot of data is required.

This data has to be of high-quality, since the outcome is dependent on the input of data (Taranenko, 2020). Here, accuracy, consistency, relevance and completeness are one of the aspects which should be checked of the data set. Often, checking the data requires preparations before the data is relevant to use. This also includes computations and checks, which increases the complexity of this method.

Benefits of this method can be a more accurate forecast, automatic updates, identifying more patterns and increasing adaptability to changes. Demand models which belong to this category are decisions trees, K-nearest neighbor Regression and Gaussian processes Ge et al. (2019).

2.4.3 Deep machine learning

Deep machine leaning demand forecasting methods go on step further than the introduced machine learning methods. They are based on artificial neural works, which "learn" them self to perform tasks. Even when they are not being programmed with task-specific rules, they are able to recognize patterns. A benefit of these methods is that they do not require any presumption about statistical distributions and are able to handle non-linear models. Here, no need for feature engineering is also a benefit and a resulting better forecast accuracy compared to the previous methods. However, the amount of computations involved increases which also includes a lower interpretability. Therefore, methods based on these networks (like recurrent neural networks and long short-term memory) are not that popular yet.

The difference between deep machine and machine learning methods can be explained in the following way. A machine learning method is focused on 'tree-based' models, which is meant that they can take different aspects (roots of the tree) into account. However, these methods are not able to extrapolate, so they are not able to in cooperate time series trends (Ge et al., 2019). Deep machine learning methods are capable to deal with trends and are able take into account nonlinear behaviour in time. Due to the fact that they are able to extrapolate, these types of models can be seen as network-based and are more advanced and complex than machine learning forecasting methods.

The two last mentioned demand forecasting methods can showing promising results, including early risk warnings and smart decisions makings (Zhao et al., 2020). However, the technologies are also highly dependent on the willing to share data and adjust the format to a standardized one. Since the technology on these aspects is still in an exploratory stage, these methods are still far from perfect and hard to implement.

Based on the demand, the inventory level can be controlled. Inventory, replenishment and stock level are key aspects and are introduced in detail in the following section.

2.5 Replenishment

In a push supply chain, sufficient inventory is important to be able to handle the demand in the future. Here, a buffer is available to be able more unpredictable demand. However, having too much stock also has a downside, according to Roberts (2020). These are the following:

- Storage capacity. Holding more inventory than needed takes more space, which costs more in certain cases. When companies have to hire an external location to stock their product, extra cost are made on extending their storage capacity. Besides, transporting these goods to the store cost money, which should not be left out of scope.

  Besides, overstock of products that will not be sold claim space in the stock rooms. Therefore, no space might be available for products with a high sell-out. Therefore, having overstock has a negative impact on the stock capacity. Also, having overstock can result in less overview for the store personnel.

- Obsoletes. In case of fashion, certain products cannot be sold anymore if they stay at the inventory for too long. Therefore, these products lose their value for the store at that moment. In the perspective of a fashion store, the winter collection should be sold at the winter. It is not valuable for the store to have these products in the inventory during the summer. In the next winter, several products cannot be sold anymore due to changing trends, which decreases the value of these products.

  In case of perishable items, there is a certain data until the product can be used. If the products stay at the inventory for a long, it cannot be sold any more and should be destroyed for the safety of the customer. Overstocking would result in a total loss of the value of these products.

- Discount. Having a lot of overstock, puts stores in positions to sell these products for lower prices to get rid of it. In case of limited storage capacity, products have to be sold to make space for the storage of new products. This results in less turnover, which is not desired.

- Cost. Purchasing goods to be stored in the inventory means that the cash flow might stop. The money that is used for purchasing those goods cannot be invested elsewhere in the business. When the inventory will not be sold at all, an impact on the cash flow will significantly be presented.

Managing the 'right' amount of stock is desirable. Creating an overview has a negative effect on the business, so not creating an overstock would be ideal. Therefore, a balance have to be found between the supply and the demand. According to the research of Chowdhury (2015), inventory is all about managing the right product, at the right time and place, in exactly the right amount at the best possible price.

Due to lead time and varying demand, a buffer can be built in the inventory to have sufficient stock. This level of stock that is desired to have is marked as safety stock. This term is an important term in this research. Based on the demand forecast, the safety stock level can be set higher for products with high sell out than products with a low sell out.

An important classification of a supply chain, is the amount of items involved in a supply chain. If this is only 1, single-item approaches can be applied. If products have different properties, a multi-item approach should be performed. In case of a factory outlet, a multi-item approach should be considered, since an assortment is being offered to the customer. However, this increases complexity of the replenishment models which try to keep the stock at a certain level. Therefore, in the next part of this section, several approaches are discussed for single-item supply chains.

Based on these more simple are approaches, the gained knowledge can be extended and justified for multi-item supply chains.

Replenishing, which focus on maintaining the stock at a certain level, can be done according to several strategies and policies. First, an approach on an optimal order quantity is discussed in subsections 2.1 and 2.2, on which the demand is assumed to be known. Then, different replenishment policies are introduced in subsection 2.5.3, on which intervals and stock level are leading. The desired stock level is investigated section of 2.5.4. Accordingly, an optimal order interval can be discussed in subsection 2.5.5.

2.5.1 EOQ

The amount to order to keep the inventory at a certain level depends on the demand, desired safety stock level, order capacity and lead time. Taking into account all these factor might become hard, since some variables are not always constant. A change in lead time can results in another quantity that should be ordered. Assuming a constant demand and lead time for a single product, an optimal economic order quantity (EOQ) can be calculated Yan et al. (2019). Here, no limit on capital availability and planning are assumed. Also, the holding cost is assumed to be dependent on the stock level and ordering cost dependent on the amount of items ordered. Here, quantity discount is presented when ordering larger quantities. Therefore, an economic order quantity has been developed, which can be calculated by the equation stated in 2.1.

$$EOQ = \sqrt{\frac{2 * A * D}{C}} \tag{2.1}$$

Here, A states the cost per order. D present the demand of product, measured in units per time unit T. T presents a time unit which can be days, weeks, months etc. and is also states in the following variable. C is the inventory carrying cost per time unit T. V present that average cost of one unit of inventory. Orders should be placed every T period. A mathematical proof of this quantity can be found in the article of Çetinkaya and Lee (2000), with corresponding figure 2.6.

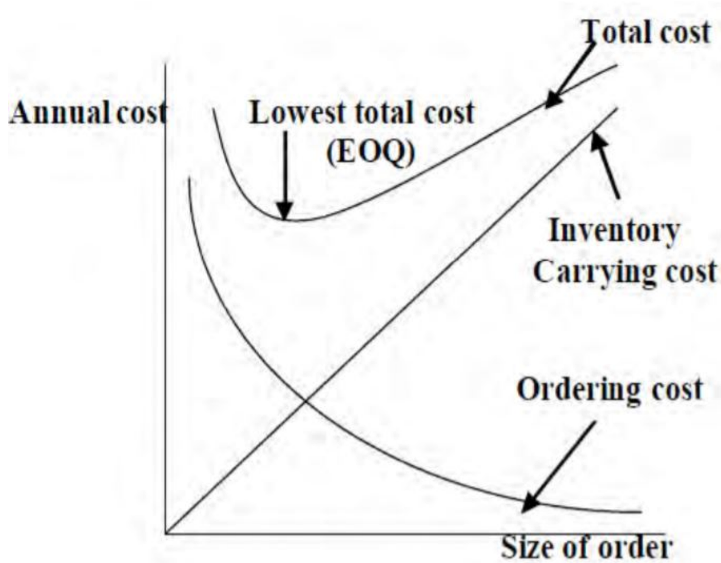

Figure 2.6: Shown EOQ in case of linear inventory cost and inversely proportional to order size Chowdhury (2015)

In case of a factory outlet, inventory cost can be hard to calculate. Due to the fact that the inventory is already owned by the company of the store, related cost may be hard to define. When an external storage location is being hired, these cost can be taken into account as inventory cost. Also, assuming a constant demand is considered as very simple and not realistic. Therefore, the EOQ changes over time and can only be evaluated at a certain point at time.

2.5.2 KOQ

The alternative to EOQ is kanban order quantity (KOQ). This quantity of order is based on the lean just-in-time principle and is focused on shortening the time a product is in a process that is not value adding for the manufacturer of the product (Lyles, 2018). The equation for calculating the KOQ can be observed in equation 2.2.

$$KOQ = \frac{L * D + SS}{2 - 1} \tag{2.2}$$

Here, L presents the actual lead time. D presents the average demand during the presented lead time, which can be calculated by dividing the total demand per time interval T. SS is focused on the target amount of safety stock, measured in units. Here, the denominator is evaluated as presented to maintain the inventory level over time. In case of lowering the inventory level, a denominator of 2 can be set.

The main difference with the EOQ is that that the amount of orders when using KOQ is higher than using EOQ. In case of using the KOQ, cost are not taken into account. This is done since the principles of lean and just-in-time assume that cost are not fixed. It focuses on shrinking these cost, which is also the main goal of EOQ. The KOQ can be used in a pull based supply chain, but this is not applicable for outlet store.

Besides, both methods focus on single-item replenishment. According to the research of Sitepu et al. (2019), the concept of EOQ can also be adjusted for ordering multiple items jointly, in which the total cost can be reduced. However, this method still assumes on the same relation of inventory and ordering cost to order quantity as the single-item EOQ does.

The focus can be on the order size and order frequency. These aspects have also be evaluated in replenishment policies, which focus on strict guidelines in replenishing. These policies do not include assumptions on the demand, which can be a benefit.

2.5.3 Replenishment policies

According to the researches of Kumar et al. (2013); Sehgal (2008), different policies of replenishment can be applied. These are based on an assumed safety stock level and known lead times. The strategies are discussed in the following paragraphs. First, the approach with a continuous review of the stock level are discussed. Afterwards, the periodic review based policies are introduced.

2.5.3.1 s, Q

The s, Q replenishment strategy is focused on continuous review of the stock level of certain items. When the stock levels of these items drop a certain level, the reorder point of s units is reached. Then, a quantity of Q items is being order to be able to fill the inventory to its desired level.

In case of multiple items, certain levels of items can be combined to see what is a feasible reorder point. This is harder in case of non-identical items, since reorder points have to be aligned to limit the amount of orders.

2.5.3.2 SS

The SS replenishment strategy is focused on placing orders up to level SS. So, to get the stock as quick as possible on the desired stock level. This may lead to multiple small orders of low quantity instead of one large order. The order quantity depends on the inventory level.

Next up, replenishment policies based on a periodic review of the stock are introduced.

2.5.3.3 R, S

The periodic review strategy R, S is focused on ordering based on a fixed time schedule. Here, R is the period of which orders are being placed. The amount of orders which are being placed is the desired safety stock level S minus the actual stock. This strategy is focused on ordering up to S units, which leads to no order if the stock is on level SS

This strategy can be aligned for multiple products by setting different safety stock levels for different items. However, the amount of orders is kept constant due to fixing the periodic review. In case of high demand, the inventory level can get lowered than wished. Therefore, the period of reviewing should be set in accordance with the lead time of the orders to prevent stock outs.

2.5.3.4 R, Q

The R, Q replenishment strategy is focused on periodic review of the stock. After a certain period R, an order of quantity Q is being placed. This strategy can be very effective if the demand is constant. However, in practice this is not assumed to be realistic. Also, the stock level is not taken into account, which can result in high stock levels.

2.5.3.5 R, S, Q_{min}

The R, S, Q replenishment strategy (introduced in Kabadayi and Keskintürk (2012)) is focused on a periodic review of the with period R. Here, the stock level is being refilled to the desired level S, if at least Q_{min} products can be ordered. This can be applicable in situations in which the demand is smaller than the minimal order quantity. If this is not the case, this strategy can give similar results as the R, S strategy.

2.5.3.6 R, s, S

The R, s, S strategy is based on a review period R after which is checked if the stock level of an item is s. If the stock level is below s, the difference of the desired safety stock level S and actual stock is being ordered.

This does not include a fixed order frequency but pins the times at which the stock is being checked. Also, the amount of units ordered depends on the stock level. However, as already explained in the R, s strategy, the amount of units being really on stock can fluctuate due to lead-time and review period.

2.5.4 Safety stock

Ordering up to a desired stock level is mentioned in the previous subsection on replenishment policies. For this safety stock level, the demand and lead time are leading. Here, if no stock is presented while there is demand presented, the desired safety stock level of a presented policy was too low. A name for a related parameter is the service level, which represents which percentage of demand can be fulfilled during a certain period. For an optimal safety stock, different theories have developed considering constant or variable lead time and demand. In this section, the approaches on a variable lead time and demand are discussed.

According to the approach of King (2011), safety stock can be calculated in multiple ways. Here, the lead time and demand are assumed to be distributed according to a normal distribution.The first method (SS_1) is based on the following approach. Over a period of T_1, the demand is being measured. The mean of the demand of these days is noted as D_{avg}. The lead time of the delivery is noted as L, which is also measured over the same period T. Based on the amount of order placed, a set of real lead times in this period can be calculated. Also, an expected lead time should be provided by the supplier. A normalized standard deviation from this expected lead time can be calculated. Adding up this calculated value to the expected lead time, gives a determined value of the real lead time (σ_L). In literature, this term is called 'the standard deviation of the lead time'. This term is misleading, since the standard deviation can be used by only looking at the set of measured lead times. Therefore, this term is not used for σ_L.

Further, the service level can be calculated by assuming a normal distribution with a mean of 0 and a standard deviation SD. This standard deviation is not required, since the probability from minus infinity to a certain level $Z*SD$. The result is independent of SD. Therefore, the mentioned probability equals the service level, of which Z can be determined. Guaranteeing a service level of 100% is unrealistic and the higher the service level is desired, the higher the value for Z should be. According to the article of Bowles (2020), a desired service level in industry can be between 90% up to 99%.

The desired safety stock level can be set up to the concern involved. If the concern of the safety stock is lead time, the safety stock can be calculated via equation 2.3.

$$SS_1 = Z * \sigma_L * D_{avg} \tag{2.3}$$

If the concern is upon variation of the demand, the formula is changed slightly. According to the research of Radasanu et al. (2016), the standard deviation of the demand can be measured over a certain period and is noted by σ_d. The assumed lead time is fixes at L. Then, the safety stock level SS_2 can be calculated by 2.4.

$$SS_2 = Z * \sqrt{\frac{L}{T_1 - 1}} * \sigma_d \tag{2.4}$$

If variability of the demand and lead time is presented, the safety stock SS_3 can be calculated via equation 2.5, which combines the equations of S_1 and S_2.

$$SS_3 = Z * \sqrt{\frac{L}{T_1 - 1} * \sigma_d^2 + (\sigma_L * D_{avg})^2} \tag{2.5}$$

If the demand and lead time variability are independent of each other, the previous introduced equations can be used. Then, the safety stock level SS_4 can be determined by equation 2.6.

$$SS_4 = S_1 + S_2 \tag{2.6}$$

More simple approaches also exist, which have been investigated in the research of Radasanu et al. (2016). These approaches do not assume that demand and lead time are normally distributed. Here, approaches based on the multiplication of average demand, average lead time and safety factor of between 20% and 40% looks the most promising, shown in equation 2.7. Other methods in this research zoom in on the maximum lead time and demand. (Ongkicyntia and Rahardjo, 2017) refers to an equation for calculating the safety stock by using the square root of the average lead time instead of other options.

$$SS_5 = L_{avg} * D_{avg} * SF \tag{2.7}$$

$$SS_6 = Z * \sqrt{L_{avg}} * D_{avg} \tag{2.8}$$

The point to reorder in case of the R, s, s replenishment is also investigated. According to the article of Thieuleux (2020), s can be calculated by equation 2.9.

$$s = SS + D_{avg} * L_{avg} \tag{2.9}$$

These last mentioned strategies all include a review of the stock after a certain period. However, the order interval should be set to prevent stock outs, but should also be set to limit the amount of orders placed to limit the ordering cost. The mentioned strategies can be applied on single-item level, but the effect of placing one total order for multiple orders is not taken into account.

2.5.5 EOI

Setting a certain amount of time before a next order is being placed, is another question that should be answered in periodic review replenishment policies. Therefore, an economic order interval can be introduced, to optimize the inventory cost (Maukar et al., 2013). A constant annual demand per items is assumed to be able to order. Based on a multi item approach, a jointly order optimum can be set up which is given by the equation shown in equation 2.10.

$$EOI = \sqrt{\frac{2(C + n * c)}{F * \sum_{i=1}^{n} P_i * D_i}} \tag{2.10}$$

Here, n is the amount of items considered in the multi-item approach. P_i is the purchasing cost per item and D_i is the considered demand per period T. F is the holding cost as a fraction of the purchasing cost. Here, the holding cost are the cost related to hold the goods, such as cost for damaged items, taxes and insurances and capital involved. C is the cost involved per order and c the order cost associated per item. Here, the assumption is made that the order cost is linear with the amount of items involved. The ordered quantity can be calculated by multiplying the demand per period and the EOI, which makes the quantity to order per item.

In equation 2.10, no regular stock or safety stock has been taken into account. Therefore, this method can be questioned in multiple ways. However, it gives an indication on which level orders can be placed to lower inventory cost.

The replenishment methods assume that orders are being placed at the supplier. This can also be done by the retailer self or by another vendor. Managing the inventory by another vendor is called VMI and is introduced in the next subsection.

2.5.6 VMI

Vendor managed inventory (VMI) is all about the inventory of a retailer, which is being managed by another vendor. This other vendor is responsible for supplying goods and is also full in control of the inventory level of the goods. Therefore, the replenishment decisions are taken by the vendor. Based on these decisions, he can also manage his own stock level to be able to keep up with the demand. According to the research of Mutlu and Çetinkaya (2010), a part of a VMI agreement between vendor and retailer is that retailers are compensated in case of out of stocks or delays in orders. Then, the vendor can choose between the trade-off to wait for more offers before transporting to the retailer. Combining deliveries to multiple retailers can lead to cost reduction, which increases profit for the vendor. In this agreement between vendor and retailer, the wholesale price can also be fixed Kadiyala et al. (2019).

According to Ge et al. (2019), VMI is implemented to decrease the bullwhip effect. The bullwhip effect is the effect a small change in demand at the end of the supply chain has on the rest of the supply chain. By decreasing inventory levels, a more pull-based approach can be applied by the vendor, which saves cost. In general, retailer orders are misleading for planning production Achabal et al. (2000). This is due to the fact that they do not contain accurate sales info. Due to a time lag and batch order of the retailer, production planning can be scheduled better based on accurate sales data.

Besides, VMI also creates an opportunity for the vendor to increase the availability of the vendor's products at the retailer (Achabal et al., 2000). By making sure that products are on stock at the retailer, higher sell-out of the products can be obtained. This results in tackling unobserved lost sales, which occurs when demand is lost and not observed. Also, a shift of consumer choice over the products offered by concurring parties or in a total higher sell-out can be the result of VMI. This last scenario is also beneficial for the retailer.

Essential in such an agreement between vendor and retailer is the exchange of information. Integration and transparency of both partners is important to help to a good cooperation. Stock level, sell-out, demand forecast and planned promotions are a key of the information exchange Çetinkaya and Lee (2000). Not only exchange of sales data as information flow is considered as important. The retailer has in general a better idea of the changing dynamic market conditions, since it is in contact with its customers (Kadiyala et al., 2019). These data is crucial for a more accurate forecast of the demand and a better management of the inventory level. In case of VMI, the vendor is also responsible for the leftover inventory, which is wished to be minimal. A returning process leads to extra cost for the vendor, so this is not desired.

Trust of the retailer is important for implementing a successful cooperation. Managing inventory by another means losing control by the retailer. Therefore, clear agreements have to be made in advance. But, if things work out in a nice way, loyalty of the retailer can be built up. This results in a barrier for concurring vendors, which is wished for the supplier (Piplani, 2006).

In case of a factory outlet, the retailing store is owned by the vendor which is supply the retailer. In this special case, a vendor owned inventory is the name right name of the vendor taking care of the inventory of the retailer.

2.5.6.1 Supplier owned inventory

A small variation of VMI is supplier owned inventory. This way of managing inventory is controlled by the supplier, in which the customer only pays for the goods when they are being sold (Piplani, 2006). So, the customer only pays for what is needed, when it is needed. From a customer perspective, this concept is more beneficial since it can only pull the desired product out of the inventory of the supplier. However, this results in higher inventory levels of the supplier. Therefore, a cost benefit analysis is necessary from supplier perspective to evaluate the inventory cost, transportation cost and order fulfillment cost. Also, the agreement with the retailer including a minimal amount of pulled items to protect the position of the supplier is important. Sharing information of demand forecast and fill rate are important to let this type of cooperation be successful.

2.6 Order fulfillment

According to the research of Ge et al. (2019), order fulfillment can also be recognized as on the key aspects of supply chain management. However, in case of a factory outlet store, the customer should be able to able to pick and collect its own order. Since the products should be available in the shelves of the store in an offline store, the items can be picked by the customer itself. It should be available in the shelves, which is the goal of the introduced replenishment methods.

The process of order fulfillment at the warehouse is more interesting to zoom in on. The factory outlet store can order at these warehouse and that is the starting point for the order fulfillment at the warehouse. However, order fulfillment in a warehouse is not discussed in detail in this section, since the focus is on replenishment. Therefore, this process of interest can be on retail management level. Since the focus is on the supply chain of factory outlets, there will not be zoomed in on the process of order fulfillment in the remaining of this research.

2.7 Transport

Another mentioned part of the aspect inventory is transport, which focuses on shipping goods from a vendor to another vendor. In a push supply chain, replenishment is being done in a proactive way, since out of stocks are tried to be prevented. If out of stocks are presented, the inventory is not able to keep up with the demand which causes a loss of turnover. Therefore, goods have to be transported before products become unavailable for the customers.

Shipping can be done by an internal or external carrier. Cost of transport can be reduced by making as efficient possible use of the transport equipment. For the company of the carrier, this can lead to a situation in which is desired that trucks should be driving with as much pallets as possible to combine tours. The pallet amount should be minimized to be able to deliver as efficient as possible for the company which ordered the pallets. Here, cost are assumed to be dependent the amount of pallets.

Different problems are formulated in literature to capture realistic transport problems. Three of them are discussed below; the joint replenishment problem, newsvendor problem and modular hub location problem.

2.7.1 Joint replenishment problem

The joint replenishment captures the problem of scheduling sizes of orders and replenishment cycles time (Lin et al., 2019). Here, the lot size can be set higher than initially required to be able to get discount or reducing shipping cost. A group of items is being considered, which makes the approach more usable than the EOQ, KOQ or EOI. It is widely investigated in research and handles different kind of additional constraints, like set delivery intervals, minimal order quantities, receiving cost and storage capacity (Nagasawa et al., 2013).

An example of the joint replenishment problem in the research of Nagasawa et al. (2013) is going to be discussed. First, the considered model assumptions are discussed. Then, the investigated model is introduced and investigated. Here, the parameters, objective function are shown and explained.

The presented model of (Nagasawa et al., 2013) is focusing on a multi-item inventory problem, including periodic demand of suppliers in a single warehouse. Here, a finite period is assumed and a fixed capacity is considered. The ordering cost are stepwise dependent on the ordered quantity and capacity of the carrier. The items do not deteriorate over time and shortages in orders are allowed, in terms of back orders or lost sales. Receiving inspection cost are included and depends on the variety of items ordered.

The model contains the following defined indexes as shown in table 2.1.

Index	Description
i	item
t	day

Table 2.1: Indexes of JRP

The following sets are introduced in table 2.2.

Sets	Description
$I, i \in I$	set of items
$T, t \in T$	set of days

Table 2.2: Sets of JRP

The described model contains the decision variables in table in 2.3.

Decision variable	Description
y_t	number of carriers used on day t
s_t^i	quantity of lost sales of item i on day t
l_t^i	inventory level of item i on day t
x_t^i	quantity of item i ordered on day t
r_t^i	whether item i is received on day t
z_t^i	whether item i is received or a shortage has occurred on day t

Table 2.3: Decision variables of JRP

The following parameters are introduced in the JRP in table 2.4.

Parameter	Description
u_t	usage fee of the carrier on day t
p_t^i	penalty for lost sales of item i on day t
h_t^i	holding cost of one unit item i on day t
a_t^i	receiving inspection cost of one unit item i on day t
d_t^i	demand of item i on the day t
v_i	volume of one unit for item i
c	capacity of the carrier

Table 2.4: Parameters of JRP

The defined objective function contains a minimization of the cost, which consist of four different components. These are the cost included for the carrier, inventory cost, cost for lost sales and receiving inspection cost. The objective function is shown in equation 2.11.

$$minimize \sum_t u_t * y_t + \sum_i \sum_t h_t^i * l_t^i + \sum_i \sum_t p_t^i * s_t^i + \sum_i \sum_t a_t^i * r_t^i \tag{2.11}$$

Included constraints and their meaning in this problem are shown in table 2.5.

Constraint equation	Explanation
$l_{t-1}^i + x_t^i - l_t^i + s_t^i = d_t^i \ \forall i, t$	inventory balancing
$\sum_i v^i * x_t^i \leq c * y_t \ \forall t$	restriction on truck volume if a carrier is used
$s_t^i * \leq d_t^i \ \forall i, t$	create upper bound by defining shortages and no over ordering
$x_t^i * \leq M * r_t^i \ \forall i, t$	check if a product has been ordered on a certain day
$y_t, s_t^i, l_t^i, x_t^i * \ \in \mathbb{Z}_+ i, t$	positive integer variables
$r_t^i * \ \in \{0, 1\} \ \forall i, t$	binary variables

Table 2.5: First part of constraints of JRP

To improve the accuracy of the stated problem above, the constraints in table 2.6 have been added.

Constraint equation	Explanation
$\sum_i v^i * x^i_t \geq c * (y_t - 1)\ \forall t$	using minimum amount of trucks to fulfill ordered items
$y_t * \geq r^i_t\ \forall i, t$	restrict a truck if an order is received
$\sum_t x^i_t + \sum_t s^i_t = \sum_t d^i_t\ \forall it$	ordered items and shortages are equal to demand
$x^i_t * + s^i_t \leq (\sum_t d^i_t) * z^i_t\ \forall i, t$	restrict if an order or shortage should be created
$x^i_t * + s^i_t \leq d^i_t * z^i_t + l^i_t\ \forall i, t$	restrict inventory level (1)
$d^i_t - d^i_t * z^i_t \leq l^i_{t-1}\ \forall i, t$	restrict inventory level (2)
$z^i_t * \ \in \{0, 1\}$	binary variables

Table 2.6: First part of constraints of JRP

Here, the constraint are more or less self-explaining, since they are explanation seems to ground the involved equation. However, for the last two equation on "restrict inventory level", this is not the case. Therefore, these is explained in detail. In the equation which contains the explanation with a (1) in it, the parameter z^i_t for a given day and item is set as a a value of 0 when no shortage has occurred and the demand can be fulfilled by the stock. If an order has to be placed, the value of z^i_t will be 1, which means the the sum of demand and inventory becomes greater than the sum of shortages and sum of orders. In the next equation, which has explanation number (2), this binary value raises value if an order is placed or a shortage occurs. Then, the inventory from the last period to the current period should be greater than 0.

In this problem, a balance is tried to find between creating shortages and placing orders. Here, the limiting capacity of the carrier and the included cost per transport are considered. Defining receiving cost, holding cost, penalties for shortages and transport times makes it possible to determine what is the right point to order. Here, the demand of an item has to be given as input in the model, which is most of the time hard to predict precisely. Therefore, demand forecasting techniques can be used.

2.7.2 Newsvendor problem

The newsvendor or newsboy problem faces uncertain demand, but has to determine the amount of newspapers he orders to sell (O'Neil et al., 2016). Here, the amount of papers he orders, influences the cost he has for ordering the papers. A quantity based discount is formulated in the ordering part of this problem. How much newspapers he sells, is not known at the point he has to place an. What is known, is the price for selling the newspapers, as the cost he faces for having too much or too few newspapers in stock. Here, a fixed cost price can be set per unit of overstock or understock.

The application of this problem seem to be very wide, since identical problems can be observed in FMCG industries. Here, ordering more can lead to discount on the total price, which indicates a unit price which differs on the total ordered amount. Since this problem is focusing on only one product type, it should be extended to be able to handle more items.

A mathematical model is introduced of the research of Zhang et al. (2019). Here, the focus is on a single vendor, which needs to determine the cumulative order quantity of several products for multiple periods to maximize its profit. Assumptions are done on the uncertain demand, which has distribution function $f_{it}(z_{it})$ in which i is the item index and t the time. Resource constraints are presented, which are period variables. All-unit discount is based on the total acquisition over the planned horizon. Also, cost on overstock and understock are presented, as backorders are being placed for out of stocks. Profit can be determined by subtracting the expected revenue from the profit.

The indexes defined in the Newsvendor problem are shown in 2.7.

Index	Description
i	product index
j	price segment index
t	period index
m	resource index

Table 2.7: Indexes of newsvendor problem

The sets are defined in table 2.8.

Sets	Description
$I, i \in I$	set of items
$J = \{1, 2, ..., k_i\}, j \in J$	set of price segments
$TT = \{1, 2, ..., T\}, t \in TT$	set of periods
$MM = \{1, 2, ..., M\}, m \in MM$	set of resources

Table 2.8: Sets of newsvendor problem

The following decisions variables are defined in table 2.9.

Decisions variables	Description
Q_{it}	cumulative amount of product i replenished for supplier until period t
Q_{ijT}	cumulative amount of product i purchased in price segment j in period T
y_{ij}	if the retailer buys product i in price segment j

Table 2.9: Decision variables of newsvendor problem

The parameters are defined in 2.10.

Parameters	Description
k_i	number of price discount segments for products i, offered by the supplier index
p_i	revenue of one unit of product i
H_{mt}	cumulative capacity of resource m until period t
c_{ij}	unit price of product i in discount segment j
d_{ij}^L	lower bound of the quantity of product i on discount segment j
d_{ij}^U	upper bound of the quantity of product i on discount segment j
z_{it}	random variable of the cumulative demand for product i until period t
$f_{it}(z_{it})$	probability density function of the cumulative demand of product i until period$t$
μ_{it}	the mean of $f_{it}(z_{it})$
g_i	the estimated understocking cost of one unit of product i per period
s_i	the estimated overstocking inventory cost of per unit of product i per period

Table 2.10: Parameters of newsvendor problem

The stated objective function is to optimize the profit, which is defined in equation 2.12.

$$maximize \sum_i \left(\int_0^{Q_{iT}} z_{iT} * p_i * f_{iT}(z_{it})\ dz_{iT} - \sum_t \int_0^{Q_{iT}} s_i * (Q_{iT} - z_{iT}) * f_{iT}(z_{it})\ dz_{iT} \right) +$$
$$\sum_i \left(\int_{Q_{iT}}^{\infty} Q_{iT} * p_i * f_{iT}(z_{it})\ dz_{iT} - \sum_t \int_{Q_{iT}}^{\infty} g_i * (z_{iT} - Q_{iT}) * f_{iT}(z_{it})\ dz_{iT} \right) - \sum_i \sum_j^{k_i} c_{ij} * Q_{ijT} \tag{2.12}$$

Here, the objective function contains parts on calculating the expected revenue, in case of overstock. The second terms calculates the revenue in a case of understock. The last part contains the purchasing cost for the items. Here, integrals are presented in the mentioned parts of understock and overstock to calculate the total value considered, while facing a demand defined by a probability density function.

Constraint equation	Explanation
$\sum_i h_{im} * Q_{it} \leq H_{mt}\ \forall m, t$	Capacity limitations on resources
$Q_{iT} = \sum_j^{k_i} Q_{ijT}\ \forall i$	Sums up ordered amounts of different price segments
$Q_{ijT} \leq d_{ij}^U * y_{ij}\ \forall i, j$	Ensures lower bound on purchased quantities
$Q_{ijT} \geq d_{ij}^L * y_{ij}\ \forall i, j$	Ensures upper bound on purchased quantities
$\sum_j^{k_i} y_{ij} = 1\ \forall i$	Only one price segment is used per product
$Q_{i,t-1} \leq Q_{it}\ \forall i, t$	Cumulative check
$Q_{i,t} \geq 0\ \forall i, t$	No negative production in any period
$y_{ij} \in \{0, 1\}\ \forall i, j$	Binary variables

Table 2.11: Constraints of newsvendor problem

Here, the focus is to decide which quantity should be ordered in total to meet the uncertain demand. Cost on overstock and understock are presented and captured in integral equations. By assuming a probability density function for the demand, the objective functions gets more complex and not linear anymore. Therefore, the question is how this objective function, which may describe a scenario in detail, can be evaluated. This consideration is discussed in more detail in section 4.

2.7.3 Modular hub location problem

The hub location problem focuses on locating a hub, which serves facilities in its network in the most cost effective way. The modular hub location problem contains the boundary constraint that the link capacity has a stepwise cost structure (Mirzaghafour, 2013). Assuming that the amount of trucks involved increases the amount of cost per link in the transport network is the reason a stepwise cost structure is being introduced. This scenario can be recognized in practice when an external supplier is presented and cost depends on the amount of trucks of pallets that has to be transported. Here, the amount of pallets or trucks used can only be integer values, which is done more efficient if the pallets or trucks are being loaded at maximum capacity.

The modular hub location problems is focused on how to set up an efficient network to make transport as cost efficient as possible. Including direct links, capacities per link and cost per link are important elements to set up a solution strategy of modular hub location problem.

An example of the modular hub location problem is discussed. The discussed problem in the research of Tanash et al. (2017) is focused on locating hub facilities and the including decisions on connecting origins and destinations. Here, the path based problem are discussed to show an example of the stated problem, of which the flow-based approach is an alternative for setting up a model in this context. The path based problem includes the hub network to minimize the total flow cost. The proposed model assumes N possible locations for the hub and a set of A arcs, defined between different nodes. In these nodes, also origins and destinations are defined. The goods have to be transported via hubs towards the destinations, in which transport between hubs is also possible.

The included transportation cost depends on the number of links between nodes and the distance between these nodes. Here, the number of nodes can be more than one due to the fact that a capacity has been set for the links. Links connecting hubs have a stated capacity of B, while links connecting an origin or destination have a capacity of R for an access arc. Here, the origins (from which the goods have to be transported to the hubs) and destinations are assumed to only be connected to a single hub per origin or destination. So, only one type of access arc can be activated per facility. Therefore, this model is mentioned as a MHLP with single assessments. The transport cost between the arcs can be assumed to be stepwise since it depends on the number of links per nodes.

Besides, cost are set for setting up a hub on a certain location. This is another part of the cost function, next to the cost per access link and link between hubs. This is further discussed after introducing the equations for the objective and constraints.

The following indexes are defined in the MHLP in table 2.12.

Index	Description
i	node
j	node
(k, m)	selected arc between nodes k and m

Table 2.12: Indexes of MHLP

The following sets are defined in table 2.13.

Sets	Description
N	set of nodes, $i, j \in N$
A	set of arcs, $k, m \in A$

Table 2.13: Sets of MHLP

The decision variables are defined in the path based model of (Tanash et al., 2017) in table 2.14.

Decision variables	Description
x_{ijkm}	fraction of flow from i to j, routed via hub arc *(k,m)*
z_{ij}	binary variable which is equal to one if a non-hub on node i is assigned to hub j
y_{km}	number of arcs defined between nodes k and m

Table 2.14: Decision variables of MHLP

Here, the variable z_{ij} requires more explanation. Here, the origins and destinations can be assigned to a hub, which can only be done via one type of access link. Therefore, a binary variable is introduced. When the variable z_{ii} is nonzero, it means that node i is hub node i is assigned to itself. If this is variable equals one, it means that a hub will set up on this certain node. If this is the case, origins and destinations can be connected with these origins and destinations.

The parameters which are used in the stated model are shown in in 2.15.

Parameters	Description
f_i	set-up cost for locating a hub on node i
q_{ij}	transportation cost between node i and j
W_{ij}	amount of flow between node i and j
Q	a big positive number
v_i^1	required number of links from node i to a hub
v_i^2	required number of links from a hub to node i
c_{ij}	transportation cost between hubs i and j
B	capacity for an arc connecting hubs

Table 2.15: Parameters of MHLP

The objective is defined as follows;

$$min \sum_i f_i * z_{ii} \sum_i \sum_j (q_{ij} * v_i^1 + q_{ji} * v_i^2) * z_{ij} + \sum_{(k,m) \in A} c_{km} * y_{km} \tag{2.13}$$

The constraints are defined in table 2.16.

Constraint equation	Explanation
$\sum_j z_{ij} = 1 \ \forall i \in N$	Each non-hub node is assigned to only one hub
$z_{ij} \leq z_{jj} \ \forall i, j \in N$	Each node is only assigned to an hub, if an hub has been opened
$z_{ik} + \sum_{m \in N} x_{ijkm} = z_{jk} + \sum_{m \in N} x_{ijkm}$ $\forall i, j, k \in N, i \neq j$	Flow conservation constraint per hub
$\sum_i \sum_j W_{ij} * x_{ijkm} \leq B * y_{km}$ $\forall (k, m) \in A$	Capacity constraint for arcs between hubs
$y_{km} \leq Q * z_{mm} \ \forall (k, m) \in A$	Hub arc *(k,m)* only selected if m has a hub located
$y_{km} \leq Q * z_{kk} \ \forall (k, m) \in A$	Hub arc *(k,m)* only selected if k has a hub located
$z_{ij} \in \{0, 1\} \ \forall i, j \in N$	Binary variables
$y_{km} \in \mathbb{Z}^+ \ \forall (k, m) \in A$	Positive integer variables
$0 \leq x_{ijkm} \leq 1 \ \forall i, j, k, m \in N$	Fraction limited variable

Table 2.16: Constraints of MHLP

In the constraints above, the focus of the building a network can be setup in certain parts, of which one part is in the variable of z_{ij}. First, if $i = j$, this parameters contains the decision of a hub which is located on a certain node. Second, the arcs between the hubs, origin nodes, destination nodes and other hubs are taken into consideration. Then, the amount of arcs and flow fraction is defined in the other decision parameters. Assuming a single assessment, is the only constraint which contains an equality and excludes trivial solutions in this context. This is all possible if the nodes and arcs can be defined as assumed, which seems to be hard to come up with in this context.

2.7.4 Comparison

The mentioned problems can all be set used when considering a transport problem. By first describing the problem and exploring the boundaries of the problem, several approaches of these problems can be used to make a mathematical model. Here, an objective function can be defined, which has to be maximized or minimized while fulfilling its constraints. In the part below, different states problems in literature are discussed including their solving approach.

The research of Li and Schmidt (2019) investigated a joint replenishment problem of dissimilar items, which results in a challenging problem due to limited transport capacity. Including a stochastic demand, the stated model has a linear objective cost function which is dependent on the expected value of the inventory and demand. The problem is being solved by updating data from a 'chosen' state to a new state, until it reaches a state in which in it minimizes a metric between a solution state and current state. Sindhuchao et al. (2005) is focusing on a joint replenishment problem with limited vehicle capacity and integrated inventory-routing systems. The stated problem is being solved using a branch-and-price algorithm, which makes use of column generation by solving sets of the problem. Nagasawa et al. (2013) investigated the joint replenishment problem including receiving cost and carrier capacity, which results in mixed integer linear programming model. Solving is done numerical by assuming different demands, in which the sensitivity to certain parameters is being discussed.

The newsvendor problem faces quantity discount, which has to be taken into account in orders placements. The research of Toptal (2009) focuses on transportation cost which bothers the vendor and buyer. Here, a piecewise convex cost function is being considered, which includes all-unit discount and truck cost. The algorithm that finds the optimal solution in terms of cost is based on the properties of a convex function, of which the optimal solution depends on the profit function. Zhang et al. (2019) investigates the stated problem over multiple periods, while taking into account supplier discounts. The considered model contains nonlinear equations, which includes another level of complexity than the stated problems below. Lagrangian relaxation is being used as approach to find a solution for the stated problem. In the article of Konur and Toptal (2012), the stepwise unit cost are being considered in the context of an upper and lower bound on the replenishment quantity. Here, the piecewise objective function is being solved by an algorithm, which is based on structural properties of the objective function.

Modular hub location problems have been investigated in different variants, of which an overview is created in Hsieh and Kao (2019). Here, the amount of hubs, non-hub nodes and cost structure are the variables which are changed for the mentioned researches. Set models can be solved by two different categorized solution methods; exacts algorithms and heuristics algorithms. Exact algorithms can be applied for 'small' hub problems and integer programming is the exact approach in this region. Heuristics algorithms solve problems which cannot be solved within reasonable time. However, the outcome cannot be guaranteed as optimal for these category of algorithms. Therefore, integer programming is preferred in most cases and is of interest in the remaining of this paper. In these programming, the cost function can be considered as linear or nonlinear, which is important to consider a suitable solution algorithm (Fard and Alfandari, 2019). The computational complexity increases if a nonlinear cost function is presented, which can be a stepwise function due to the fact that the link capacity cost can vary stepwise. This is an important consideration later in this report.

The mentioned problems including model and solution approaches show that a wide variety of problems have already been investigated in transport. However, these problems are very specific and can be applied to a certain case. From the mentioned problems and strategies to find the most optimal solution, lessons can be learned how to analyze problems. Therefore, in a case study, certain parts overlap with mentioned problems, so that knowledge on these topics can be used.

Cost is not the only way of measuring the supply chain performance, since the customer satisfaction increases the supply chain performance. Satisfaction is hard to measure and depends on multiple factors, of which some of them can be measured and are discussed in the next section.

2.8 Supply chain performance

Improving the performance of a supply chain can only be done, when the performance can be measured. Therefore, this section will dive into the aspect of measuring the performance of a retail supply chain, applicable on the supply chain of factory outlets.

Managing supply chain performance in case of sales would be a too simple approach, since the sales can be dependent on multiple factors as already explained. These factors are retail related and not in the scope of the supply chain. Therefore, comparing the actual sales against the demand forecast could be a nice key performance indicator (KPI). In case of deviations, more cost can be made than actual needed. Thus, the performance of a supply chain can be measured in financial, but also non-financial aspects (Anand and Grover, 2015).

2.8.1 Financial

Measuring the cost involved in a supply chain is a strategy which has been used since the industrial revolution (Anand and Grover, 2015). For a company, cost is an important factor to evaluate, since they are willing to make profit at the end of a month. However, measuring only the cost involved in a supply chain is a too simple approach. If the supply chain should be optimized while taking into account only cost, no order would be fulfilled since all orders include cost. If picking cost are calculated, the optimum would be to make no cost on fulfilling orders. Therefore, operating more efficient which leads to savings indicates a right application of using cost as a supply chain performance indicator. This also takes into account multiple non-financial cost indicators, which is discussed next.

2.8.2 Non financial

According to the research of Anand and Grover (2015), non financial supply chain performance indicators can be discussed in the categories of transport, information technology, inventory and resource. These categories are discussed, as their related indicators involved. For the full list of mentioned categories, the research of Anand and Grover (2015) can be reviewed. In this section, only the most relevant aspects of a factory outlet supply chain are discussed.

2.8.2.1 Transport

The category of transport indicators is all about a delivery at the right time with the goods in the right condition. Here, the frequency and capacity of the delivery are related aspects and influence the possibilities of transportation. Here, the service level of a retailer is an important indicator and can be calculated as part of goods that have been received on time. The satisfaction of the customer is dependent on the delivery, since their process can be dependent on the ordered goods. Therefore, percentage of on time ship rate, shipping errors, delivery frequency and used routing capacity are key performance indicators in this section.

2.8.2.2 Information technology

In the opposite direction of goods in a supply chain, flow of information and money can be modelled (Bayraktar et al., 2020). Information is crucial to decrease the effect of the bullwhip effect, which has been discussed. Flexibility of information sharing is crucial, since imperfections of orders can have a huge influence for other vendors in the supply chain. Sharing point of sale (POS) information can be important for managing the inventory level for a supplier. Also, sharing inventory levels can be crucial to see if orders on certain products are likely in the near future (Chuang et al., 2016). Having the right inventory level is also crucial for the flow of information, since scenarios in which the information system do not match the inventory, cause problems. Therefore, key performance indicators like level of IT implementation, quality of input data, accuracy and reliability of shared information, accessibility of real time information and cost related indicators can be introduced in this category.

2.8.2.3 Inventory

Measuring performance of inventory can go in multiple directions. The focus can be on the floor space and inventory turns, which are points of interest. Here, the inventory turns can be measured as the amount of times inventory is used over a period of time, which can be calculated by dividing the sales over the average inventory level. But, also missing inventory is another indicator of the performance of inventory management. Records on the inventory level should also be error-free, to be able to apply an introduced replenishment policy Bayraktar et al. (2020). Key performance of this category are value of stock-out, stock cover (time inventory will last if current demand continues), replenishment cycle time, inventory accuracy and product flexibility.

2.8.2.4 Resources

Using the right amount of workforce at the right place with a limited budget can influence the performance of a supply chain and influences the cost involved. Human resources can be scaled in terms of productivity to consider and schedule the workers in a more optimal way. Key performance indicators of this category are direct labor cost, distribution cost, value added employee productivity and customer satisfaction.

Based on this categorisation, retailers points of interest can be evaluated to see which performance indicators can applied. Besides, looking at these categories in a new application also raises new insight for introducing related indicators. But, the mentioned indicators capture several aspects and create a good overview of aspects to be taken into account.

2.9 Conclusion

In this chapter, literature has been studied to develop insight in supply chains of factory outlets. First, the aspects of a supply chain have been investigated. Two different type of supply chains were recognized, which are the pull and push supply chain. Here, the focus is on push supply chains, since these are used focused on having goods on stock when the demand is there. This type of supply chain is used in retail, which can be useful in further supply chains. In these supply chain, the definition of vendors has been explained. Also, the aspects of demand, inventory and order fulfillment has been discussed. The aspect demand of a retail supply chain is focused on a forecast, which is important to schedule the amount of stock presented in the supply chain. Inventory can be split in different key topics, which are replenishment, transport and inventory placement, which is shown in figure 2.17.

Supply chain aspect	Sub-aspect
Inventory	- Replenishment - Transport - Inventory placement

Table 2.17: Overview supply chain aspect inventory

These perspectives are related in the context of a factory outlet, of which the concept is explained in this chapter. Selling excess stock in combination with exclusive merchandise in an outlet shop, which is located in an outlet centre, seems to be a successful formula. The supply chain of such an outlet store has been investigated, in which customer returns and overstock of the warehouse are supplied to the store.

Since an outlet supply chain is a push supply chain, the key topics which are considered as important are the following. First, the forecast of the demand is important, to be able to get a sufficient amount of stock when demand is presented. Demand can vary due to variation of a lot of factors, which results in different forecasting methods. These can be categorized in three main categories (see figure 2.18); stochastic models, machine learning and deep machine learning. Stochastic models require less computational effort than the other two, but also might have a lower accuracy.

Supply chain aspect	Methods
Demand forecasting methods	- Stochastic - Machine learning - Deep machine learning

Table 2.18: Overview demand forecast approaches

The second topic in a push supply chain is the replenishment, which influences the stock level of different products. Different approaches are discussed for performing replenishment, of which an overview is shown in figure 2.19. Different policies are introduced for replenishing, which can be focused on continuous or periodic review of the stock. Here, orders can be placed based on a minimal stock level, desired stock level or minimal order amount. In different methods like the EOQ, KOQ and EOI, assumptions are being made to come up with analytical equations. Therefore, they do not seems that applicable in practice. However, considered reasoning can be learned from these models to be able to capture the reasoning behind these methods.

Supply chain aspect	Approaches
Replenishment	- EOQ - EOI - KOQ - Replenishment policies

Table 2.19: Overview replenishment approaches

The topic of order fulfillment is considered as case specific and is not further discussed in detail. Due to the fact that the focus is on a factory outlet store, the order fulfillment of the customer in store is considered as not that important. It is related to the shelves in the store, which is managed by the store personnel.

The third topic of transport has also been reviewed in this chapter. Here, considerations about using transport equipment as efficient as possible involves different difficulties. Therefore, three problems in literature are discussed (see figure 2.20; the joint replenishment problem, newsvendor problem and modular hub location. The first problem tries to combine replenishment of multiple products in once, while the other problems deal with stepwise transportation cost, which are dependent on the integer value of the amount of pallets/trucks required. Modelling methods and used algorithms in literature have been discussed, of which the consideration between non-linear and linear model has a huge influence on the complexity of the models.

Supply chain aspect	Related problems in literature
Transport	- Joint replenishment problem - Newsvendor problem - Modular hub location problem

Table 2.20: Overview faced transport related problems in literature

At the end of this chapter, supply chain performance has been discussed. Measuring the performance is necessary to be able to measure if improvements realize their desired effect. Besides the financial KPI, also non-financial KPI's can be recognized, which are discussed in the following categories; transport, information technology, inventory and resources (shown in figure 2.21).

Supply chains aspect	KPI category
Performance	- Financial - Non-financial ▪ Transport ▪ Information technology ▪ Inventory ▪ Resources

Table 2.21: Overview supply chain performance KPI categories

3 L'Oreal outlet supply chain

In this section, an analysis on the the L'Oreal outlet supply chain is going to be discussed. First, a more detailed introduction of the outlet store is presented in section 3.1. Here, the concept of an outlet store considered by the business is being discussed. Then, an analysis will follow on the supply chain of the L'Oreal outlet in section 3.2. Afterwards, the subsystem of interest of the L'Oreal outlet supply chain is selected in section 3.3. Next, the current replenishment process of the outlet store of L'Oreal is discussed in section 3.4. A conclusion will summarize and evaluate the content of this chapter.

3.1 L'Oreal outlet

In this research, general gained knowledge on outlet supply chains is applied on the case study at the outlet store of L'Oreal. By the term outlet a factory outlet is meant, which is different than other discount stores. Factory-outlet stores are owned by the brands itself and sell only their own inventory for a lower price. Therefore, a factory outlet store can be controlled by the brand, which creates possibilities for implementing improvements and marketing strategies. According to the research of Reynolds et al. (2002), this type of store has become more popular since more emphasis is placed on price, brand names, shopping convenience and store location by the customers.

3.1.1 Assortment

An outlet supply chain is a supply chain which transports products which can be considered as 'excess'. There are multiple reasons why these products are not available anymore for these regular customers. If products are not selling that well anymore, they can be replaced by other products. Also, products can be replaced by a new variant of the same type of product. The product itself can be slightly changed, like the packaging or content. Since L'Oreal keeps innovating its products, several products are being replaced by new products. Then, the overstock at the warehouse of these replaced products can be sold in the outlet. This can also happen when brands are being discontinued, which may happen due to changing trends. Besides, if products are not selling that good as has been estimated in a demand forecast, overstock can be presented at the warehouse. In the next section, the definition of these type excess stock of products of the assortment of the L'Oreal outlet are discussed.

3.1.1.1 Slow movers

Products are being ordered at a factory by forecasting the amount of products which can be sold. Due to the fact that the demand of the customer is varying, as are the agreements of the customer which quantities they can order, the forecast accuracy can differ from the real demand. If the total demand is lower than expected, less products are being sold than are ordered at the factory. This can happen due to changing trends in the market or promotions of competitive products. They can be recognized by products which are have a relative low sell-out and are called slow movers in the remaining of this report. According to L'Oreal, slow movers are identified if over more than 6 months of forecasted demand of stock is presented at the warehouse. Products which are being ordered a lot and are selling well, can be identified as fast movers.

3.1.1.2 Obsoletes

Products can be replaced or renewed, which can be prioritized over the old products to sell to customers. Then, the replaced product do not have a forecasted demand any more, which means that no orders are expected for this specific product. These products can be identified as obsoletes. Stock of obsolete products can be presented at the DC of of L'Oreal or at the DC of the customers. If the products are saved at the warehouse of the customer, these products can be sold for a reduced price, be dumped or returned to L'Oreal. Agreements have been made with these customers on returning products, which is discussed with the sales teams. At the warehouse L'Oreal, these products are received to be dumped or transported for other purposes like deals and outlets, which depends on the condition in which these products are received.

Destroying products includes several additional cost, like handling, transport and destruction cost. Besides, it is not sustainable to destroy this products, which should be prevented to reduce the company's footprint. Cost wise, the production cost can be assumed as lost and also includes additional cost for destruction, like handling and transport cost. This includes several expenses for these products, which is not desired.

An alternative for sales of slow movers and obsoletes (SLOBs) at the outlets stores are the 'deals' with other parties, which have to buy these products in high quantities. What should be prevented is that these products should be sold for a low price for this deals and being sold by this customer for a higher price. Then, competition is being created between the old stock and the new assortment of products, which leads to less sales on the new assortment. This is not desired and should be prevented, in which alternatives are evaluated to see for which purposes this excess stock can be used. Special event are organized for the employees and friends of these employees of L'Oreal, in which they are able to sell the excess stock with high discounts. Here, the stock is being sold and the employees are satisfied, which seems an effective solution in practice.

3.1.1.3 NYX

The introduced slow movers and obsoletes can be of 2 different categories. The first category of the products are the products of the regular CPD category. The second product category is the make-up of the brand NYX professional. Of this brand, slow movers and obsoletes are being sold at the outlet store. The products of this brand are not exclusive for the outlet, but cannot be bought at regular customers of the CPD division. The make-up line can be found at luxurious perfumeries like Douglas. This is to create some exclusivity in the outlet and offer a more complete assortment to the customer. These products have to be ordered at a different warehouse than the CPD products, which is discussed later in this chapter. This is the reason why the supply chain of this product type is not the main focus. The warehouse of NYX ships its products to all over Europe. Therefore, supplying products to the outlet is a very small part of the logistics operation of this warehouse. So, the supply of this type of products is captured in the supply chain of the outlet but not further investigated in the remaining part of this research.

So, the factory outlet of L'Oreal sells slow movers and obsoletes, which can be seen as excess stock. Also, the excess stock of NYX products are being offered to make the assortment more attractive and can be seen as more exclusive products. These products are being sold at the store, which is discussed in detail in the next section.

3.1.2 Retail

L'Oreal is selling the excess stock in an offline outlet store. The choice between an e-commerce and offline store is going to be discussed in this section. The outlet store offers products with high discounts, which means that the demand for these products is higher than in the shop of a customer. These products are sold, which means that no cost for destruction have to be made. Besides, products are sold, which also creates turnover. However, the products have to be transported to the outlet store. This can also happen directly to the customer, which is the case for an online store. Both store types include transportation cost, but the amount of size of the orders at the warehouse differs. In a physical outlet, cost are made for the store location, staff, cash system etc. In case of an online outlet, software has to be developed, picking and packaging cost are made and the web shop has to be kept up to date.

The quantity which is available for sales at the outlet is hard to estimate. First, the amount of products being sold to regular retailers can vary. Second, the amount of products which are being sold at the retailers to consumers can very and depends on multiple factors. Factors of influence are competitive discounts, mood of the customer, presentation of the product in the store and many more. Both factors influence the amount of products which are available to be sold at the outlet. Besides, products can be damaged during transportation, which means that less products are available at the outlet.

When selling these products in an offline or online outlet store, the behaviour of the customer is again important. According to the research of Shyam and Gupta (2018), shopping pattern, lifestyle and income of the customer of the outlet has influence on its purchases. Besides, customers have raising expectations of the retailers, regarding conveniences, wide variety of products, friendly interaction and a high value for money effectiveness. All these factors influence the sell out at the outlet store, which is hard to estimate. Capturing all these parameters in demand forecasting models based on historical averages, time series with regression analysis and machine learning techniques, can still not give a deterministic outcome. Therefore, the focus of this report will not be on forecasting the demand at the outlet store, but by making the supply chain more efficient.

In general, the outlet store is managed by the business of the supplying company. The selling company is then fully in control of the assortment of the outlet, the prices of the products and the supply chain under the restriction of the factory outlet centre. Here, the factory outlet centre forces stores to sell products with a minimum amount of discount, which makes such an outlet centre attractive for customers.

The supply chain teams takes care of supplying sufficient stock at the right time, place and in the right amount. Also, the place of which they are offered can be important. It would be wise to offer these products at places at which these products do not compete with products of the same brand, since this will cause a loss of turnover. By making a factory outlet store online, the market becomes more transparent for customer. In this case, they are able to choose between 'old' and regular products, which can have a negative effect on the sales of the regular products. Therefore, an offline store is preferred.

Besides, the outlet store should be made such that the customer is tempted to by more due to all the discounts. By promoting the products and creating an environment in which the customer is tended to buy more, since it seems to be more beneficial for them Reynolds et al. (2002). These arguments overrule the benefits of an online outlet, which is high accessibility. Only an internet connection is required to be able to buy at an e-commerce website. Logistic wise, an online store requires a challenge on supplying a lot of small orders and managing the online assortment, which can be varying. In case of an offline outlet, larger orders can be made, which is another argument to confirm that installing an offline outlet is wiser than creating an online outlet.

Due to the discount on the products which are being sold at the outlet, less turnover is being made per product. Therefore, selling a huge load of products is interesting for the outlet to set up a profitable store. This includes logistic challenges on supplying the outlet and saving the stock. Therefore, managing the deliveries and inventory is important in this retail store. But, the products which can be ordered for the outlet have to be transported from the warehouse, so the store does need information which products can be ordered. Therefore, the supply of the outlet can be managed in different ways, which is going to be discussed.

3.2 Outlet supply chain L'Oreal

In this section, the supply chain of the L'Oreal outlet is going to be discussed in detail. First, the vendors are discussed one by one. In the end, these flows between these vendors are discussed in an overview.

3.2.1 Factory outlet

Within L'Oreal, the supply chain of of the factory outlet is investigated. As already introduced, at the end of the supply chain, there is an outlet store. This physical store sells the products to their customers, which consume the products. This store is located in the designer outlet centre in Roermond.

The outlet store has space for products in the shelves, stock room of the store and an external storage location. Deliveries can be received at the backdoor of the store or at the external storage location, which is called the 'Kooi'. Transport from the external storage location can be done via cages by an employee, of which several are available at the outlet.

3.2.2 Warehouse Nivelles

The outlet is being supplied by 2 different distribution centres. The first one is the NYX warehouse, which is located in Nivelles. This warehouse only distributes make-up goods from the professional make-up line of NYX. Ordering can be done via the ERP system SAP, with a lead time of 7 days. Therefore, the orders are being placed more than one week ahead to be able to foresee what is necessary to have on stock. This warehouse distributes to several countries in the EU. Therefore, the orders of the outlet have less influence on the total ordering process than of the next warehouses.

3.2.3 Warehouse Mollem

The other supplier of the factory outlet store is the CPD warehouse, located in Mollem. From this warehouse, all the products except the NYX make-up are being ordered. A third party manages this warehouse, which means that a 3PL (third party logistics) construction can be observed. The supply planning team of L'Oreal manages the stock level at the warehouse, so they keep in contact with the warehouse. All the stock for supplying customers all over the Benelux is stored at this location. This includes the overstock and customer returns, which are the primary articles for sales at the factory outlet store. The lead time of orders at this warehouse is 2 days.

At this warehouse, products can be ordered in full boxes, of which only 1 type of products is presented in a box. An exception is being made for make-up products. The make-up obsoletes and slow movers are being put in mixed boxes, according to a predefined scheme. Since these products are relatively small of size, boxes are filled to be transported to the outlet store. This makes transportation more efficient in terms of space. On these mix boxes, no replenishment policy is applied, since they are all unique and contain a unique combination of products. Therefore, they are only being ordered once to be sold at the outlet. They have to be taken into account in the ordering and delivery process, but are not a part of the replenishment policy.

3.2.4 Carriers

Since L'Oreal does not own any trucks, transport from the warehouse is done by external carriers. Transmission is the supplier who is responsible for transporting orders from the warehouse in Mollem to the outlet store. Orders from the warehouse in Nivelles are being transported by System Plus in case of a delivery of above a certain size. In case of small orders, orders are being transported in mixed boxes and transported via UPS. These carriers all have their own agreements with L'Oreal regarding shipment scheduling and their tariffs.

3.2.5 CPD Factories

The products which are being sold at the outlet, are supplied to the warehouse by different factories. The demand planning team makes a forecast on the demand, such that the factories know how many products they should produce. The orders on these products are being placed by the supply planning team, which take care of the stock level of the warehouse. If new products are being launched, certain products at the warehouse are marked as obsoletes. If products are not selling at much as expected, they can be marked as slow movers. Then, these products at the warehouse are opened for orders of the outlet. Therefore, no focus is on the production side of the factories in this report. For the delivery from the fabric to the warehouses, the factories are responsible and take care of the transport.

3.2.6 NYX Factories

The products of the brand NYX are being shipped from different factories to the NYX warehouse. The colleagues in France take care of the stock in that warehouse, which transport to countries all over Europe. The transport from the fabric to the warehouse is being done by L'Oreal. As already explained, the supply chain of the NYX factories is not investigated in the remaining part of this research.

3.2.7 Retailer returns

In the CPD warehouse, also returns of customers are being saved and handled. The returning process is going to be explained in this subsection. When new products are being launched and sold to customers like Etos, Trekpleister and Kruidvat, 'old' products can be returned to L'Oreal. An external company is hired to collect all the products of the customers. These products have to be in a good condition and may not be damaged. The external company, Carier, will collect these products and deliver them to the warehouse in Mollem. Then, there must be decided what must be done with this stock.

If new products are being launched, returned products are 'bought' back by L'Oreal. This includes that selling as much as possible to the retailers is not always the right option, since an overstock at customers can be bought back by L'Oreal. Then, a lot of cost is being made due to transport and stocking the products. For the customer, this seems to be beneficial, since they do not have to deal with overstock. Therefore, the sales teams agree with the customer which products and in which quantity, products may be returned.

However, having sufficient stock presented at the retailer also can be desired. Having more products on stock can lead to an increment of sales and can lead to more attractive spots in the store (promotions and displays). The benefits of this sales increment may overrule the cost of returning products, which is a reason why supplying sufficient products to the customer is important.

In cooperation with the marketing teams of Netherlands, Belgium and the e-commerce team, a comparison of the returned products is made regarding predicted sales of previous months with those of the coming months. Based on this, a list with available products for the outlet is being created. Based on this list, orders for the outlet store can be placed at the warehouse.

The returned make-up products are relatively small articles of size, compared to the products of other categories. Therefore, the returned make-up articles are being placed in mixedboxes. This saves space when transporting these products to the outlet store. Not make-up returned products can be ordered by box at the CPD warehouse.

If products are not even sold at the outlet store, there can still be a certain amount of stock at the DC warehouse. If this is the case, liquidations deals are being made by the sales team. However, this is not in scope of our research and will not be zoomed in on.

3.2.8 Collecting party

When new products are being launched, 'old' products can be returned to L'Oreal. The marketing and sales team will make an agreement with their retailers to see which products they can return. They are bought back by L'Oreal, who is also responsible for picking these items at the stores of the retailers. Since L'Oreal does not have any transporting resources, an external company is hired for picking these products.

Collecting the products at the retailers store is done by an external company Carier. The packages of products are prepacked by the stores and this company collects these at their warehouse. The items in these packages are counted by Carier, since they are a independent company from the perspective of L'Oreal and the retailers. The retailers also get a financial compensation based on the results of the enumeration of Carier. Counting happens manually, which may result in human errors. When the collected items are shipped to the warehouse in Mollem, the stock level can be set wrong due to these human errors. The transport to the warehouse in Mollem is being organized by L'Oreal, which directly instructs carrier to collect these products in store. So, these products will not be shipped via the DC of the retailer.

3.2.9 Overview

The mentioned warehouses, fabric, carriers and outlet store can be put in an overview of the factory outlet supply chain of L'Oreal. The result is visible in figure 3.1.

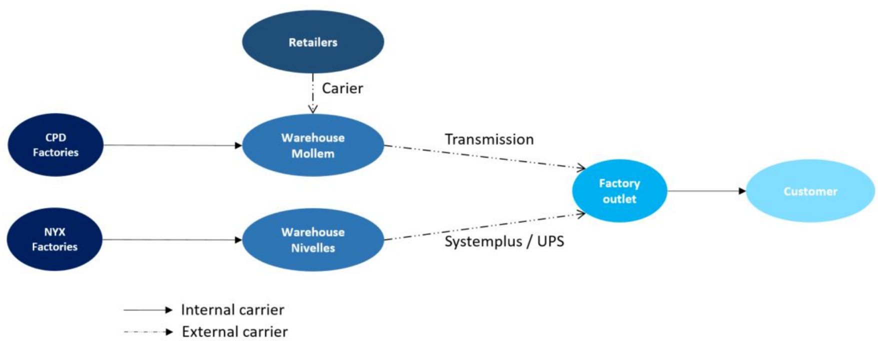

Figure 3.1: Overview outlet supply chain L'Oreal

3.3 Supply chain system of interest

As already presented, the outlet store of L'Oreal is of interest. The amount of products which become available to order for the outlet, is hard to estimate. The amount of slow movers and obsoletes depend on that many factors, that is almost impossible to come up with estimations on these flows in the supply chain. Therefore, the focus is on the supply from the CPD warehouse to the outlet store.

The outlet can order products at two warehouses. The NYX warehouse (which is managed by a third party) transport their products over whole Europe. Therefore, the orders of the outlet store are considered not that important for them and is just a small part of their total delivery amount. Besides, the focus of the outlet is to sell overstock and obsoletes, which are transported from the CPD warehouse. Therefore, the focus will not be on the ordering process of the NYX products and will not be investigated further in the remaining part of this research. It is presented in the ordering process of the outlet, but will not be discussed in detail. In the end, the replenishment policy for the CPD products can also be applied for the NYX products, but these are not considered in the first place.

So, the ordering process at the CPD warehouse is of interest. Due to the fact that the warehouse is hired by L'Oreal (3PL construction), L'Oreal has limited influence of the process inside the CPD warehouse. However, the ordering process of the outlet store can be influenced. According to L'Oreal, more cost are being made at the transport process for replenishing the outlet store than necessary. Therefore, the replenishment process of the outlet store is going to be investigated. Here, the stock of the store also is a part of the system which are investigated. Here, the focus is on assessing a more optimal delivery frequency and size. The way of bringing the products from the shelves in the store to the customer is not investigated. Therefore, the part of the outlet stores which is focused on selling is not considered. This splits to block of the outlet store of which only one part is a part of the investigated system. The system which is going to be investigated is marked with a red circle in figure 3.2.

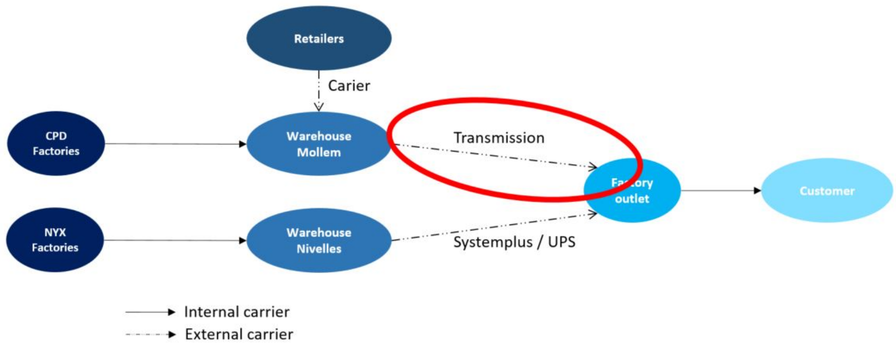

Figure 3.2: Overview outlet supply chain L'Oreal

The current replenishment process of the L'Oreal outlet is going to be discussed in the next section.

3.4 L'Oreal Outlet Replenishment

In this section, the replenishment strategy of the CPD factory outlet is introduced. The inventory of the outlet is being managed by the retail supply chain team, which is located at the office department of L'Oreal in Hoofddorp. Therefore, a vendor owned inventory can be recognized in this situation. The orders are being placed by the retail supply chain team at the office, which follow a certain process for placing orders to get products delivered at the store. This includes that the store personnel does not need to place any orders, such that they can focus on their job in the store.

In this section, the replenishment process of L'Oreal is being explained. The used demand forecast method is explained, as the inventory management. Here, the safety stock and stock policy are zoomed in on. Hereafter, the order fulfillment is being discussed as well.

3.4.1 Demand forecast

The demand at the outlet is hard to forecast exactly, due to the fact that the behaviour of the customers depends on multiple factors. These factors change day by day and can be out of control. The weather changes the amount of visitors at the outlet centre and can have an influence on the sell out.

Therefore, averaging the sell-out over multiple days and weeks should limit the effect of different events, like the weather. Beautiful sunny days can compensate the rainy days. Averaging is also a simple approach which seems to be easy executable in practice.

For replenishing, the demand is taken into account. This is done by calculating the average sell-out of the products over the last 10 weeks. Here, the arithmetic mean is being calculated. This is called a moving average approach. Next to this, the sell out of the previous week of which the orders are being placed, is used to check what the difference is with this calculated average.

If this method is suitable for replenishment of the L'Oreal factory outlet, is evaluated at the end of this section. Due to the fact that the replenishment process contains multiple connected aspects, a review is done after explaining the whole replenishment process.

3.4.2 Inventory

Orders at the CPD warehouse are being placed every week. Each Monday, orders are sent to the CPD warehouse in Mollem, of which deliveries on Wednesday and Thursday take place. First, the desired safety stock level approach is discussed. Afterwards, the corresponding safety stock and weekly review are discussed and converted in a stock policy.

3.4.2.1 Safety Stock

Products which are being sold at the outlet are being categorized in three categories; A,B and C products. These categories are based the percentage of sell out in SKU's of the previous week before the replenishment day . The categorisation is based on the following approach

- If the percentage of total sell out over the previous week of this items compared to the total sell out of all the products is below 0,035%, the product is marked as a slow mover. The corresponding category is C and includes that only 1 week of average sell-out is sufficient to have on stock. Therefore, the safety stock is set as 1 week of average sell-out of the latest 10 weeks in this category.
- If the percentage of total sell out over the previous week of this items compared to the total sell out of all the products is above 0,035% but lower than 0.1%, the product is marked as a 'medium' mover. The corresponding category is B and includes that 2 weeks of average sell-out of the latest 10 weeks is sufficient to have on stock. Therefore, the safety stock is set as 2 weeks of average sell-out in this category.
- If the percentage of total sell out over the previous week of this items compared to the total sell out of all the products is above 0.1%, the product is marked as a fast mover. The corresponding category is A and includes that 3 weeks of average sell-out of the latest 10 weeks is sufficient to have on stock. Therefore, the safety stock is set as 3 weeks of average sell-out in this category.

In case of the launch of a new product in the outlet store, a certain batch is ordered. This batch is put in shelves at the outlet, to see if these products are bought by the customers. If this is the case, the ordered amount are replenished by week to have sufficient products on stock. Turnover is being missed if products are presented at the warehouse but are not on stock at the outlet. When products are not on stock at the warehouse, they cannot be sold at the outlet anymore. Then, new products have to be ordered to fill up the space at the shelves and offer a complete assortment to the customer. Due to the fact that the percentage of sell out is low after the launch of the product at the outlet, the categorisation of the introduced product may lead to a misleading set amount of safety stock. This value may be set too low, compared to the sell-out of the last weeks. Therefore, the sell-out is also taken into account when ordering a batch of new goods.

3.4.2.2 Stock policy

The safety stock policy applied is based on a periodic review. A weekly review on the stock level gets followed by 2 delivery moments. According to the guidelines of the introduced replenishment policies, a periodic review strategy can be recognized. The desired safety stock level is introduced in the previous subsection, which can differ per product category. Therefore, the goal is to replenish up to this described stock level. The desired stock level is set as a safety factor times the average demand. Here, the lead time is not taken into account at all. Besides, the safety factor is dependent on the average demand. This results in the following applied safety stock formula for product$j$, shown in equation 3.1. Here, SS_j presents the safety stock of product j, $D_{avg,j}$ the average demand of the product j over the last 10 weeks and SF_j the safety factor of product j. This value of the safety factor depends on the demand and can have the values 1,2 or 3.

$$SS_j = D_{avg,j} * SF_j(D_{LW,j}) \tag{3.1}$$

However, due to the fact that only full boxes (of 6 pieces) can be ordered at the outlet, another limitation is set to the replenishment policy. This includes a replenishment policy with a minimum amount to order. This is partly in according with the replenishment strategy R, S, Q_{min} with $R = 7days$, S is the prescribed safety stock level of the previous subsection and Q_{min} is a full box. Only the aspect that only full boxes can be ordered (with in total 6, 12, 18,... items for hygiene products) is left out of scope in the set policy.

3.4.3 Order fulfillment by vendor

As already explained, each Monday orders are being placed by the retail supply chain team. This goes according to the following process;

- Every Monday, the order list is being updated. From the ERP system SAP, data about stock levels at the warehouses and outlet store from every product of this order list are being extracted. This data is being put into this order list file to see which products can be ordered. Also, from the cash system of the outlet, data about sell-out is being gathered. In this order list, based on the mentioned replenishment policy, an order proposal for all the products is being generated.
- This order proposal is being send to the store personnel of the outlet. Since they have knowledge on planned promotions or other actions in the store, they can adjust the proposal on these points. They also check the stock in the stock room of the store and the Kooi. They see if there is sufficient place to receive the proposed orders and check if the stock level in the file is correct. But, due to the fact that they have to check two locations and do not handle the product balance per location, a clear overview of the stock is not presented. However, based on the experience they have, they can estimate if the stock level meets the demand for the upcoming week. If they are done, they send their adjusted order proposal to the retail supply chain team.

  In the mean time, this team meets the retail manager teams to discuss about the sell-out of the outlet. Based on their recommendations, they handle the adjusted order proposal of the store personnel, which leads to the final order. The to order products are being split in deliveries on two different days. Here, a delivery on hygiene products is scheduled on wednesday, while the make-up products are being delivered on thursday. The location per delivery is set to the Kooi (or in exceptional cases) the store and is dependent of the request of the store personnel, since they know where there is sufficient space to stock the delivery.
- The final order is send as input in SAP. From this order, a purchase order (PO) is being created. This order contains the list of requested items to order, which should be 'purchased' by the outlet store. Here, the outlet purchases products of the warehouse, but the products are still owned by L'Oreal. Based on a purchasing price, a stock transfer is being executed from the warehouse to the outlet store.

  From this purchase, an outbound delivery (OD) has to be created. An outbound delivery contains all the information about the activities that lead to delivery. Data about picking, loading and sending the delivery is saved over here. This outbound delivery is being confirmed after a 'Goods Issue' (GI) check has been performed by the warehouse. This check uses data in SAP to see if stock and prices are available for the product and is done after the picking has finished in the warehouse. This information is crucial for the information to be able to let the inventory and financial management flow smooth. Also, the status of the products is being checked if they are available for sales at the outlet. If these checks indicate that that the products are on stock, the price and status are correct, an OD can be created. This OD is being send to the warehouse.
- Based on the outbound delivery, the warehouse starts the picking processes and gets the order ready for shipment. The warehouse confirms this OD in the local SAP of the warehouse via a

GI check. If this has been done, the carrier (Transmission) gets informed about the deliveries in the same week, which should take place on Wednesday and Thursday.

- Based on the requested delivery date, the carrier picks up the delivery at the Warehouse early in the morning. They deliver at the outlet between 9.00 and 10.00 in the morning, since the outlet centre does not allow any trucks to be presented after 11.00. Based on the decision of the store, they deliver at a certain location. Due to the fact that the outlet store has limited time to unload the truck, the driver of the truck is being payed to help to unload the truck.

  When the order is being delivered, the retail supply chain team has to book the order in the stock of the outlet. Since stock of the warehouse is being booked off in the SAP system of Belgium, it is being booked to a virtual location. The stock has to be booked to the stock of the outlet from this virtual location. The fact that the SAP system in Belgium is different than the SAP system in the Netherlands, the delivery cannot be booked directly in the stock of the outlet.

So, these steps are involved in placing, confirming and delivering an order from the CPD warehouse to the stock of the outlet. From here, it is the task of the store personnel to transport the product from the Kooi and the stock room to the shelves of the outlet store. When products are being sold, they are scanned at the cash system (MARS). This cash system books all the sold, samples and returned items in the stock of the outlet in MARS. In this way, the stock of the outlet is being updated in SAP every day.

3.5 Replenishment review

In this section, the replenishment strategy of the L'Oreal supply chain outlet is being reviewed. Here, the discussed supply chain aspects introduced in the previous chapters are used to be able to review which aspects are incorporated well and which can be improved.

3.5.1 Demand forecast

The used demand forecast approach belongs to the stochastic category and is a moving average approach over the last 10 weeks. The method is easy executable by using the sell-out data of the past weeks. By only using weeks in which the products was open for sales at the outlet store, this methods only considers the weeks in which the products can be sold. The averaging filter smooths high peaks in sell-out which can have different causes. Promotions or changing trends can be the cause of these peaks. This might results in changing sell-out for similar products. Therefore, an averaging filter seems to be a proper approach in this solution.

However, the approach might not be perfect due to the fact that seasonality is included in this branch. Facing many aspects which can result in a different sell-out, leads to the conclusion that the sell-out of future periods is not dependent of sell-out in the past. Therefore, it is not completely right to use this deterministic approach. Facing seasonality can be captured by evaluating seasonal relatives, which is a ratio of the sell-out in a different week compared to the overall average. By incorporating products of different categories and changing trends in the market, this might be hard to capture exactly.

Including seasonality for product categories is also hard due to the fact that the assortment changes over time. In the next year, other products are sold at the outlet due to the fact that excess stock gets sold and overstocks are being created on different products. Therefore, including seasonality can be very difficult and requires a good understanding of the market in beauty. Since this will not be the focus of this report, this will not be further investigated.

Using a moving average approach, the choice of the amount of weeks considered has influence on the demand forecast. Considering larger periods, demand forecast of next weeks are more smooth and filter out extremely high or low sell-outs. Considering a smaller periods leads to a more responsive and variable demand forecast and is able to react faster to trends. The considered period of 10 weeks seems to filter out these peak, which can be due to promotions or other related events. Therefore, a period of 10 weeks can be seen as 'long enough' to smooth the demand forecast, since promotions in store are changing every week. Besides, according to (Kong, 2020), changing the period in the moving average approach does not need to have a direct positive influence on the forecast accuracy.

According to (Kong, 2020), exponential smoothing is an alternative approach for moving average, in which the forecast of the demand in the 'next' week is the sum of a factor *alpha* times the actual demand of the previous week and $1 - \alpha$ times the demand forecast of last week. This approach seems to be more variable and tries to chase demand, but is dependent on the choice of the parameter *alpha*. By choosing a value close to one, the demand forecast of the next week is almost equal to the actual sales of the 'current' week, which can be seen as chasing the demand. By choosing a lower value for this parameter, a more smoothing combination can be used, which also considers the sell-out as more important related to the moving average approach. This moving average approach can lead to a different forecasting results, which can be investigated in further researches. As shall be discussed in the next section, this is already taking into account in the desired safety stock level. Therefore, a conclusion on this demand forecast method will follow in the next subsection.

3.5.2 Replenishment

The replenishment strategy is focused on a periodic review of the stock. The safety factor of the depends on the sell-out of the previous week, which divides the products in fast, medium and slow movers. As already explained, the desired safety stock level is calculated by multiplying the demand forecast by 1,2 or 3 for respectively slow, medium and fast movers. Therefore, the sell-out of the last week is considered as crucial in the replenishment strategy. Orders are being placed after discussions with the retail team and store personnel in which only full boxes can be ordered.

The set demand forecast in combined with the described replenishment policy is used as replenishment strategy. As observed, the demand forecast and replenishment cannot be completely separated from each other. Due to the fact that an averaging filter is used in the demand forecast, the included safety factor seems to aim at a safety stock level which keeps up with changing trends and seasonality. Since orders are being placed every week, stock outs are tried to be prevented. Also, feedback from the store personnel should be taken into account in the replenishment strategy, since they also influence the replenishment orders.

The replenishment strategy does not take into account the lead time and cancellations. Since delayed deliveries from the warehouse in Mollem are exceptional, they are not incorporated at all. Also, the lead time of 2 days results in flexibility, which seems to fulfill the demand. Since the focus of this research will not be on the demand forecast, which is combined with the replenishment strategy, the stated replenishment strategy is assumed to be suitable in the situation of the factory outlet sale of L'Oreal. The key topic of focus is discussed in the last part of this section.

3.5.3 Inventory placement

Inventory is placed in two different locations, which are the store and the Kooi. As already mentioned, the store has limited storage capacity. Therefore, an external storage location is being used, which has more storage capacity than the store. These two location are being managed as one storage location, according to the vendor which orders the goods. However, the goods have to be transported from the Kooi to the store, which has to be done by an employee. The store personnel has to pick goods, which can be saved at store. Therefore, the employee has to know which products are required in the store. Since they also have an idea which products are selling well, they are able to handle this better than anyone else.

The inventory placement per storage location is managed by labels and per category. This makes it visible more easy to find required products. Due to the fact that the storage location only is a few meters long, the inventory placement is not considered as that important. Therefore, it is not evaluated further in this research.

3.5.4 Transport

The store personnel decides which products are being delivered on which day, which are two options for now (Wednesday and Thursday). The amount of units per delivery are being compared to judge if changes are required to balance the units per delivery of hygiene and make-up products. Besides, they decide on their own if the delivery should arrive in store or at the Kooi. Since they have an idea in which storage location their is sufficient stock space, they are able to make this decision. Here, the deliveries to the Kooi are standard due to the high amount of stock space at this location.

Their can be doubt if this approach is the best in this situation. Due to the fact that no inventory is being managed at these location, no insight is created in the stock and available place per location. Since these capacities are also not determined, their could be questioned how this can be handled more efficient. Delivering at the store has a benefit that the products can be put in shelves immediately, but the stock space is small compared to the Kooi. If deliveries are being done at the Kooi, the products should be transported via cages.

In the current situation, cost for transport goods to the outlet are relatively and are desired to be reduced by the supply chain team. If the goods are picked and stacked at pallets at the CPD warehouse in Mollem, transport is being scheduled by Transmission. They determine cost for the following aspects;

- Transporting pallets, which depends on the amount of pallets delivered.
- Surcharge for delivering in a certain time slot (in the morning or evening).
- Surcharge for letting the truck driver help to de-stack the pallets.
- Surcharge for letting the truck wait longer than the reserved time slot. For delivering 1-5 pallets, 30 minutes are reserved for the truck driver to unload. For delivering 6-10 pallets, this is 45 minutes. From 11 pallets to a full truck loading, 60 minutes are reserved to unload the truck.

Since Transmission has also the task to return the pallets to the CPD warehouse and the outlet store does not have space to save the pallets, the truck waits for the pallets until the store personnel has de-stacked the pallets. Therefore, the time slot can be exceeded, which results in extra cost, which is not desired.

To investigate what a right balance is between location of delivery, delivery frequency and delivery size, further research is performed in the remaining part of this report. This includes getting some more knowledge on the cost structure which the transport towards the outlet has at the moment. Also, exploring boundaries on the transport side of replenishing is explained before in depth modelling should be applied to come up with an optimization problem. How can the transport of the replenishment of the outlet be optimized is the main topic in the remaining part of this research.

3.6 Conclusion

In this section, the supply chain of the L'Oreal CPD outlet in Roermond has been reviewed. The store sells 2 different type of excess stock to its customers; regular CPD products and NYX products. These products are being supplied by two different warehouses. These warehouses are being supplied by multiple factories, which are mentioned to clarify the bigger picture of the supply chain. The regular CPD products are being shipped from the warehouse in Mollem, which also receives returned products of customers. The NYX warehouse does not receive customer returns. The focus is on the transport from the CPD warehouse in Mollem, since the most amount of products are being shipped from this warehouse to the outlet. Besides, this NYX warehouse delivers to all its customers around Europe. Therefore, the orders of the outlet are very small compared to the total amount of ordered products. Thus, there is zoomed in on replenishment process of the outlet of the regular CPD products, which includes the transport from the warehouse to the stock of the outlet store. This is shown in figure 3.3.

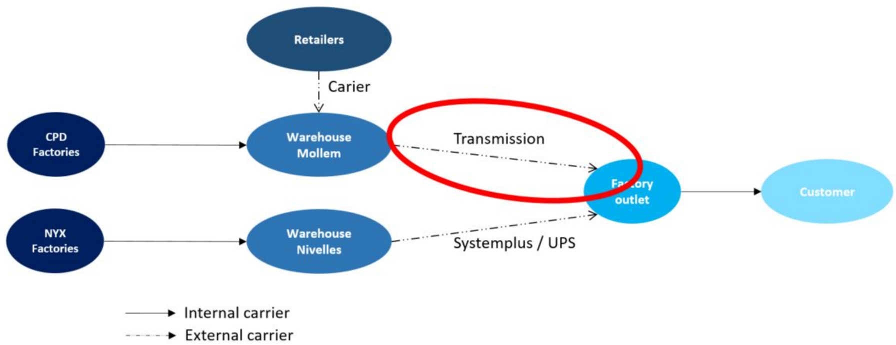

Figure 3.3: Overview outlet supply chain L'Oreal

The used replenishment policy is based on the following approach. First, a demand forecast is being calculated per SKU. This is done by calculating the average sell-out over the past 10 weeks in which the product was active. If the product was not active, the average sell-out is being calculated over the weeks in which the product was active. Based on this calculated forecast of demand, the desired stock level per SKU is being calculated. This is based on the sell-out of the last week of the period over which the demand forecast has been calculated. Based on the sell-out in this week, classes of fast, medium and slow movers are being generated. For those classes, a safety factor of respectively 3, 2 and 1 are set. Then, the desired safety stock levels can be determined by multiplying this factor by the calculated demand forecast.

This replenishment policy is based on a periodic review of the stock. Here, after a week, orders are being placed for all the set SKU's. Here, replenishment will take place based to the the desired stock level, by taking into account a minimal order amount of a full box. Besides, feedback of the store personnel and retail team to set the right amount of orders. This the policy is a form of the R, SS, Q_{min} policy with $R = 1week$, $SS = SF(D_{LW}) * D_{avg}$ and $Q_{min} = afullbox$ with additional feedback of the store personnel and the retail team.

Supply chains aspects	L'Oreal outlet approach
Demand forecast per SKU	Moving average of 10 weeks
Review of stock	Periodic, weekly
Safety stock	$SS = D_{avg} * SF(D_{LW})$
Replenishment policy	$\{R, S, Q_{min}\} \rightarrow \{1\ week, SS, box\}$ + feedback

Table 3.1: Overview supply chain aspects and L'Oreal outlet approach

Regarding the transport and inventory placement, less structure is being observed. Orders can be delivered at two location. One of these is the stock room at the outlet, which has a smaller stock capacity than the other place of delivery. This other place is an external storage location and is called 'Kooi'. When products are being delivered at the Kooi, larger deliveries can take place, but these products have to be transported via carts towards the store. Having larger and less deliveries, includes that deliveries has to be done at the Kooi. However, this includes another transport from the 'Kooi' to the store. To investigate what is the most optimal for balancing the location of delivery, delivery size and delivery frequency, a model is proposed in the remaining of this research.

4 Model selection

In this section, a modelling approach is explained to use for the mentioned transport problem. To describe an optimization problem as mentioned before, two distinguishing approaches can be recognized. These are introduced in the beginning of this chapter, to select the most suitable one in the scenario of transport problem which is applicable for the case study of L'Oreal. Based on the discussed system, a suitable modelling method is selected, which is done by comparing the methods. Then, described models from the literature are discussed to see which parts can be used for the selected model for the case study of L'Oreal. A conclusion will finalize this section.

A modelling method is selected for a general transport problem, which has an internal and external storage location. Here, the goal is to reduce involved cost, which depends on multiple factors like the delivery size, delivery location and delivery frequency. Also, cost are presented for extra unloading time, which is similar to the presented cost structure in the case study of L'Oreal. Comparison to the stated problems and the models found in literature are discussed in this section.

4.1 Modelling methods

A model is a simplified representation of a system that aims to capture only those system aspects, which are of interest of the modeller (Altiok and Melamed, 2010). Models can be used to understand, test and predict certain performance of a system. Capturing every aspects of a system can be very complicated, but it depends on the system which is investigated. In real-life, certain events cannot be captured in a model, so that is why these events are simplified to be able to be described. These substitutions for reality can influence the performance, which is a reason why models should be tested to see how well they are able to capture reality. So, simplifying reality is one big step in modelling, validating and verification are the parts which should be performed too to check if the simplifications are done correct.

Modelling a system can be done in different ways, which is a choice of the modeler. In this report, the focus is on mathematical models, which have different aspects involved. According to (Altiok and Melamed, 2010), mathematical models are built up by the following parts;

- Model formulation, which contains of different system components, parameters, attributes and performance metrics. Also, random phenomena could be captured in this part, which can be described by probability density functions or other statics.
- Evaluators, which perform the computation of the model to be able to determine it's output. These evaluators can be used in two different scenarios. The first one is focused on a "what if" scenario, in which known changes can be implemented to see what the influence on the output is. The other one is focused on the optimization of the performance, to find the best possible configuration.

According to the research of (Altiok and Melamed, 2010), two main categories of mathematical models can be recognized. These are the analytical and simulation model, which are described in the following subsections.

4.1.1 Analytical

An analytical models consists of a system of equations and constraints, to represented the system which is investigated. These type of models include randomness which can be analyzed using probability theories. In this way, random events can be described in this type of model. Evaluators try to solve the mentioned problem formulation, which might be hard in complex models. Therefore, a numerical algorithm may be used to be able to find the most optimal solution. This requires more computing time and memory, of which the output should require an error analysis. However, the solution can be much better traceable due to the fact that the used equations and constraints represent the behaviour of the system, which makes an analysis on errors easier than in the next introduced type of mathematical models.

4.1.2 Simulation

When real-life systems are too complex to capture in a numerical description of equations and constraints, a simulation model can be built. Here, the system description also contains operational rules, which combines the model representation and evaluator in one model. The model is being computed several times, of which the outcome is tested based on statistics to see how representative the output is. Here, replication of computing random events leads to a statistical based estimation of the metrics of performance. Here, complex situations can be implemented, of which only an algorithm should be presented. However, for more complex situations, this may lead to a long run time, on top of experimental errors involved in the approximation involved in estimating a representative output. Due to the statistical expertise involved, using a simulation requires knowledge on another discipline in the situation.

4.2 Model selection

According to the research of (Altiok and Melamed, 2010), the two approaches can be evaluated by one main criteria. Simplicity to capture the model by using mathematical expertise in equations, is the key to determine if an analytical model should be used. In the selection of a valuable model, a trade off is made. In a model, the reality is being simplified by making certain assumptions. This can lead to a 'simple' analytical model, which can be evaluated in a more simple way. But, these assumptions have to make sense such that this model still stays captures the behaviour of the system is reality. On the other hand, by not making several assumptions, the model can become so complex that is not easy anymore to find a solution. Then, an algorithm has to be applied to come up with a feasible solution of this model.

In the research of (Altiok and Melamed, 2010), an advice for selecting a suitable modeling method is given. When a model can be captured in a 'simple' analytical model, it should be preferred due to the compromise between adequate fidelity and computational cost. If a complex analytical model is build, a numerical evaluator should be chosen to have a wider range of application possibilities. If all else fails, then choose a simulation approach, but questions are raised about statistical reliability.

So, the first question is which assumptions should be made to come up with a model that is valid for reality, which captures a system in the model. These assumptions should not fade a crucial part of the real system, since it will not be valid for reality. These assumptions should be made in a way, that the built model can be solved by an algorithm which is able to find a solution. This will first be reflected on the discussed transport problems of section 2.7.

4.2.1 JRP

In the joint replenishment problem (see 3.5.1, the demand is assumed to be known (see 2.4. Besides, a single supplier and warehouse are assumed to be presented in the situation, which describes a single flow direction of goods. Also, the possibility of supplying more or less is assumed to be feasible in this model. The cost structure, captured in the objective function in equation 2.11, is assumed to be presented as usage fees, penalties for lost sales, holding cost and receiving cost. If in reality also cost are presented for ordering on a certain day, then the mentioned model may not be a good representation of reality. Then, a significant part of the cost structure is being lost in the assumptions. If including the mentioned phenomena makes the model significant more complex, then there may be a valid reason for the mentioned exclusion. Then, it must be mentioned in the assumptions to give the reader an explanation of the simplifications of reality. A validation step should indicate how well the described model describes reality, which illustrates the role of assumptions in models.

4.2.2 Newsvendor

In the newsvendor problem (see 2.7.2), a probability density function is assumed to be able to capture the demand of several products in equation 2.12. If this may be a suitable way to capture the demand in reality, this choice can be justified by the modeler. Simpler methods (like assuming a constant demand) can simplify the reality even more, but lead to a less accurate result. However, by assuming constant demand, the complexity of the objective function reduces significantly. Therefore, it might be good to considerate this before building the model. Besides, overstock and understock are assumed to be feasible and effect the profit. Also, the ordered amount is able to vary, which can only be done if this is confirmed by the supplier. These assumptions are crucial for evaluating a model in a certain situation.

4.2.3 MHLP

In the mentioned MHLP (see 2.7.3, the assumption of a single assessment leads to several equations which are specific for the mentioned scenario. Then, it is immediately possible to calculate the amount of arcs required per origin and destination. As shown, this also leads to a cost structure which is suitable for that certain situation. Here, inventory cost are not presented and creating understock or overstock is not feasible. Therefore, these assumptions are crucial in this situations.

So, assumptions are crucial for building a model and expressing the system in mathematical equations. Therefore, the assumptions of the proposed model for supplying an outlet store are discussed and compared to those made in the mentioned models.

Zooming in on the transport problem of the CPD outlet of L'Oreal in Roermond, an optimization problem can be recognized. In this situation, a mathematical situation is a reasonable option to see if the performance of the transport process can be optimized. If an analytical model can be built, depends on the complexity of the random occurring events involved. Due to the fact that the focus will not be on the demand of the customers of the outlet but on the transport from the warehouse of the outlet, a situation is considered in which the randomness seems to be limited. Therefore, based on the proposed assumptions, a system is foreseen as feasible to capture in an analytical model. A numerical evaluator is applied, which is due to the fact that no straight forward solutions are expected.

By having a modelling method selected, aspects of the mentioned models in the literature are discussed to see how they can be applied on the mentioned transport model for replenishing outlet stores.

4.3 Applicable aspects of historical models

Based on the described situation of the transport model in the previous chapters, certain parts of described models in literature can be captured in the transport model. The introduced models are evaluated to see how applicable they are in the situation of the described transport problem. The transport problem can be captured by the transport scheduling of goods for replenishing a store with an internal and external storage location. Transport of goods is scheduled from a single distribution centre, in batches on pallets on multiple days, of which the location is free to choose but has to deal a with limited capacity per location. The described models in literature are evaluated in the context of the described situation.

4.3.1 JRP

The JRP captures a scheduling problem of goods, in which the amount of trucks used is variable, see table 2.3. This can be used for the transport problem, of which the amount of scheduled pallets per delivery is variable. In the JRP, inventory balancing and demand is taken into account for scheduling deliveries (see table 2.4. Due to the fact that replenishment is based on a demand forecast, the 'real' demand is not known. Therefore, orders have to placed based on a demand forecast, which means that the exact demand cannot be stated in the transport model. Therefore, the demand will not be taken into account in the transport model, but the amount of ordered products is stated to schedule the deliveries.

The described transport model in the next section is going to be order based. Here, the ordered amount is based on the demand forecast, replenishment policy and feedback of the store personnel in the case of the L'Oreal outlet. In the JRP, inventory balancing, shortages and lost sales are possible and taken into account in the objective function (equation 2.11. Since the demand is not taken into account in the transport problem, these aspects are not integrated in the transport model. The stock level is being managed by the replenishment strategy and is thus partly incorporated in the transport problem. The described model could be extended by taking into account demand variability, but this is not investigated in this research.

4.3.2 Newsvendor

The newsvendor problem captures the problem of facing an unknown demand, which can be similar when orders for replenishment have to be placed. Also, quantity discount is presented for placing orders, which is also presented in the transport problem for hiring an external carrier in the case study of L'Oreal. Here, the stepwise cost function should be captured in the transport model to simulate quantity discount. In the newsvendor problem, understocking and overstocking has influence of the cost function (see equation 2.12, which is not taken into account in the transport model, since there are no inventory cost presented. In case of the newsvendor problem, transporting goods is not captured, since it is a decision based problem on the order size. Here, the demand and ordered amount are the variables which are determined. In the case of the transport problem, the ordered amount is assumed to be already known, which is different than the stated newsvendor problem.

4.3.3 MHLP

The modular hub location problem focus on scheduling arcs, to be able to deliver and pick up the goods that have to be distributed. This can be seen as similar for the transport problem, in which the arcs are the scheduled pallets to be delivered. In the transport model, a different price is set for the amount of arcs between a node and a hub, in which a node in the MHLP can be seen as a delivery at a certain day on a certain location in the transport problem. For the transport problem, there will not be a hub to locate, since the delivery locations and origins are fixed. This differs the mentioned transport problem and the MHLP. For the two mentioned delivery locations of the transport problem, a single assessment can be recognized due to the fact that only one delivery can be handled per day, which are explained later. In the mentioned MHLP, the single assessments is valid for the origins as for the destinations.

4.3.4 Cost structure

What is all different for the mentioned model, is the cost structure. For the transport model, the cost structure consists of different parts than the cost functions of the problems mentioned in literature. For the JRP, the cost function takes into the cost of the carrier, inventory cost, cost for lost sales and receiving inspection cost (see equation 2.11). The newsvendor problem includes cost on overstocking, understocking and purchasing cost (see equation 2.12). The MHLP problem takes cost on setting up hubs, setting up links between nodes and hubs and transportation cost (see equation 2.13). As already discussed, different aspects are taken into account for the described transport problem for the L'Oreal outlet.

First, the cost function is delivery size dependent, which is described by the cost per numbered pallet. This tariff depends on the total amount of pallets delivered, in which standards prices are given by the transporting company. Second, extra cost are included when goods are delivered at the external storage location, since these have to be transported to the store by the store personnel. Third, cost per delivery are considered since the outlet centre only allows supplying trucks in the morning. Therefore, time slots of at the transporting company have to be reserved per delivery. Fourth, extra waiting cost are taken into account, which are presented for exceeding the time slot for unloading the truck.

No inventory cost are presented, which were presented at the mentioned problems in literature. Also, no cost for lost sales or differences between expected sales and stock level are taken into account, which differs the stated model from the mentioned models in literature. The transport model is focusing on all the aspects which contribute to the total transporting cost of the carrier for a specific situation.

By defining and comparing applicable parts of the models found in literature of the previous models, certain parts of a new defined transport model are already explained. These parts are connected and combined with new parts in the next chapter of this research. At the last part of this chapter, the concept of the transport model in a context of model predictive is discussed.

4.4 Model predictive control

The described type of model is going to be designed in the next section of this report. The application of this model can be understood by introducing model predictive control (MPC). Model predictive control is a technique to deal with multi variable control problems, of which the described dynamic process is being optimized with a time horizon (Morari and Lee, 1999). Here, the horizon can be finite or infinite, which depends on the application. Here, the future response of a certain system is being predicted to be able to optimize the behaviour of this plant. Based on the control interval, the optimal input sequence is being calculated, which should be send to the input of the system. This process is repeated for the future intervals, which lead to a desired behavior if the model captures the specialized control needs (Qin and Badgwell, 2003).

MPC has been used in supply chain problems, as is investigated in the research of Perea-Lopez et al. (2003). Here, MPC introduces a feed forwards effect in the supply chain, of which inventory of several vendors is taken into account. Here, disturbances are modelled to see what the ideal flow of goods according to the described optimization tools should be. Here, the supply chain from a manufacturer until the retailer is taken into account, which differs the research from the described transport problem of an outlet store. MPC is described as a combination of a model and an optimization tool based on this model. Here, the optimal control can be found by maximizing the objective function of the system, which is based on predicted outputs.

The flow of MPC is shown in figure 4.1. Here, a model is introduced which captures a real life system in equations. Based on historic inputs and outputs, outputs are being predicted in which the model should follow is referred trajectory, which can be to have a certain behaviour, which is minimal cost in the research of Perea-Lopez et al. (2003). Here, the optimizer determines what the future inputs of the system should be according to the described cost function and constraints of the real life system. The model will react on this inputs and takes it into account as input for predicting the output at the next discrete time points, which goes on. How many times this cycle is being repeated, depends on the frequency of which outputs are required for the system and what the planning horizon of the model is.

In the research of Perea-Lopez et al. (2003), uncertainty is presented since the demand of the customer at the end of the supply chain is taken into account. Therefore, disturbances at the

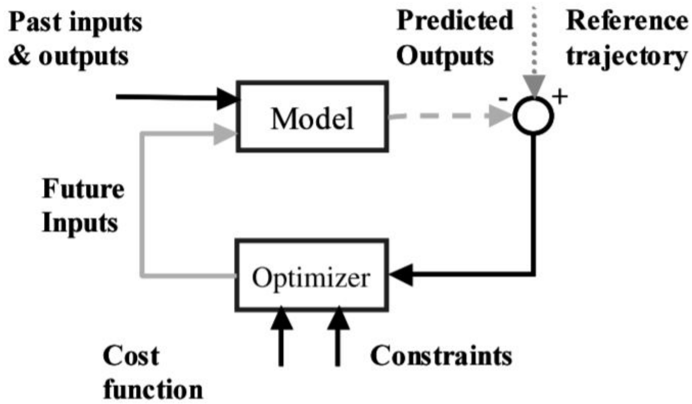

Figure 4.1: Strategy of MPC Perea-Lopez et al. (2003)

end are presented to unexpected change of demand, which can have many causes. These are non-stationary, which behaviour is different than the considered transport problem. Here, the model transport goods, based on orders, which are the result of the replenishment strategy. Only in extraordinary cases, additional orders are placed throughout the week, if something has been missed in the set replenishment strategy. Thus, there may be assumed that the orders can be stationary for a week in the considered transport problem, which reduces the uncertainty, which is differing than the approach in the research of Perea-Lopez et al. (2003).

So, by designing a model, a control system in which it can be used, should be designed. Considering the input, boundary conditions and output of the stated system, a planning horizon should be defined. Based on the planning interval, a frequency of running the defined model should be investigated. The stated frequency should be in accordance with planing horizon to make sure that desired behaviour of the system is controlled. This is going to be discussed after the model introduction in the next chapter.

4.5 Conclusion

In this section, a proper modelling method is investigated to use in the application of a transport problem for the outlet store of L'Oreal. Mathematical modelling methods have been assumed to be used, since the problem of interest is a optimization problem, which consists of a model formulation and an evaluator. Two main categories of modelling methods have been discussed, which are analytical and simulation models. Analytical models consist of a system of equation and constraints, which are being solved by an evaluator. This can be a numerical algorithm, which requires analysis on the output. A simulation model can be used if real-life systems are too hard to capture in equations and consists of a system description which also includes operational rules. Therefore, research based on simulation models is rather based on statistics.

Due to the fact that the focus of the transport problem of the outlet is not on the demand, the expected randomness in the model seems to be limited. This can be observed based on the assumptions of a model. Based on these assumptions, the complexity can be reduced but should not fade the crucial parts of the system. Since certain complexity is not expected, an analytical modelling method has been preferred in this situation. Here, stepwise cost will be taken into account, which has already been investigated in literature. The new designed transport model in the next chapter is different from the comparable models is literature due to the multiple storage location, receiving cost at only one storage location and stepwise transportation cost due to multiple cost functions. A model for the mentioned delivery scheduling problem will be designed in the next chapter.

5 Transport model development

In the following section, a model is built for maximizing the performance of the transport from a warehouse to an outlet store, which has two storage locations. These two locations have different properties regarding capacity and receiving cost. Therefore, a transport model is defined, which will be named as a delivery scheduling transport model (DSTM). This abbreviation is used in the remaining of this research to refer to the designed transport model. The transport model is built for general applications, after which it is specified for the L'Oreal CPD outlet case in the next chapter. The DSTM is introduced by the following components. First, the assumptions that are made, are discussed in detail. Second, the indexes and defined sets are introduced. Afterwards, the parameters and decisions variables are presented as the third part of the model description. Expressed in equations, the defined objective and constraints are introduced as the last part of the model description. In this section, the model will also be verified by random parameters which are introduced to check the implementation of the model.

5.1 DSTM

The model formulation of DSTM is introduced for the transport by considering it's assumptions, indices and sets, parameters, decision variables, objective function and constraints.

5.1.1 Assumptions

The following assumptions are included by developing the mentioned model;

- In this model, a situation is assumed with one warehouse and one store. At this warehouse, orders can be placed for replenishment. These orders can be delivered in two locations. One of them is the store location. In this store, the products can be sold to the customers. A single store is considered in this model. The other storage location is an external location, of which the products should be shipped to the store to be able to sell them to the customers. This is shipment is taken into account as extra cost per item delivered at the external storage location.
- A maximum amount of pallets is set to be able to limit the amount of incoming products per storage location. Here, the maximum is higher at the external storage location, since there is more space available to save products. The stock room per location is sufficient to save all the delivered goods.
- Each unique box of products will have a parameter which states the stated volume of a pallet per box. Here, inefficient stacking per pallet is not taken into account and is captured by increasing the pallet volume per box.
- The storage cost of the external location is €0, since it is a part of the rent of the store. This includes that the inventory cost are zero for having an external storage location.
- There will always be personnel available to receive the delivery and unload the truck. The time of processing a delivery depends on the amount of pallets delivered, which results in a processing time that depends on the amount of pallets delivered.
- Interchanges between the stock room of the store and the external storage location are left out of scope and are not considered in detail in this model. Only the fact that transport should take place from the external storage location to the store to be able to sell the items to the customers is considered.

- The transporting company is able to handle all the scheduled deliveries in time, which also includes the desired time slot of delivering only in the morning. Only one delivery per day is possible.
- Of one delivery, the tariff per pallet will differ. When more pallets are being delivered in once, discount per pallet is taken into account.
- A penalty for waiting time of the truck driver is set, when pallets are scheduled for delivery in which extra unloading time is expected.
- Cancellations by the warehouse are also not taken into account, since the orders are based on the available stock level of the warehouse.

5.1.2 Indices and sets

In this section, the indices and sets of the proposed model are described. These are the following;

- The index i represents the amount of distinct articles which are being considered. In total, N products are considered. Therefore, the set $I = [1, 2, ..., N]$ is defined and $i \in I$.
- The index j represents the possible days for delivery. In total, DD different possible delivery days are considered. Therefore, the set $J = [1, 2, ..., DD]$ is defined and $j \in J$.
- The index k represents the amount of pallets considered, which is explained later. In total, MP pallets can be delivered on one day. Therefore, the set $K = [1, 2, ..., MP]$ is defined and $k \in K$.
- The index l represent the considered place of delivery. Here, two delivery places are considered, which are the store and external storage location. These locations are numerated respectively with numbers 1 and 2. So, this means that $l \in [1, 2]$.

5.1.3 Parameters

In this section, the parameters of the proposed model are described. These are the following;

- As included in the assumptions, the amount of pallets in one delivery determines the transport cost. Here, the larger the delivery, the more discount is presented. Therefore, a cost per numbered pallet is included as PC_k. In this parameter, cost for reserving a time slot of the transport company is being integrated for the first numbered pallet. The unit of this parameter is € .
- The penalty for expected waiting cost for a delivery of size k relative to a delivery of size *k-1* pallets is W_k. Here, the value of W_1 is set as the expected waiting cost for a delivery of 1 pallets. The expected waiting cost is presented more in detail in the next section.
- If a delivery will not take place at the location of the store, the products are delivered at the external location. Then, additional cost are presented for moving these items from the storage location to the store. For this movement, a parameter F is included, which presents the transportation cost per box of items for the movement from the external storage location to the store. The unit of this parameter is € /box.
- The items which are considered, have been ordered in different quantities. The amount of boxes which have been ordered of a certain product i, is set as O_i. The unit of this parameter is boxes.
- Prioritization of selected items is possible, which is done by setting a limit on the possible delivery days. The parameter LD_i describes the latest possible numbered delivery day of item i, which means that the possible delivery days can have integer values between the minimum of 1 and maximum of LD_i.

- The amount of space of a pallet of a box of product type i captures is set as P_i. The unit of this parameter is pallet space per box.
- M. M represents a huge positive number, which has no specific unit and is used for implement a certain if-statement in one of the constraints.
- The parameter u_{max}, l represents the maximum allowed size of a delivery on storage location l. The unit of this parameter is pallets.

5.1.4 Decisions variables

The considered variables are explained below;

- The variable $X_{i,j,l}$ presents a scheduled delivery of a box of product type i on day j on location l. Due to the fact that the unit of this variable is in boxes, means that only full boxes can be ordered. Therefore, this number should always be positive and an integer, so $X_{i,j,l} \in \mathbb{N}\ \forall i, j, l$. The unit of this decision variable is boxes.
- The variable $D_{j,l}$ represents the 'amount' of scheduled delivered pallets on day j on location l. Here, 'amount' is not meant literally due to the fact that only full pallets can be scheduled in reality. However, with this parameter, the amount of pallet space per delivery is being considered. Therefore, $0 \leq D_{j,l} \leq K\ \forall j, l$. The unit of this variable is pallets.

  As explained, the stated variable $D_{j,l}$ can have a value of 2,5 pallets. This means that the model has determined that on day j and location l, products are delivered which have a total pallet size of 2,5. In reality, 3 pallets have to be scheduled in payed to be able to move these products to this storage location. This logic is implemented, of which the following decision variable also plays an important role.
- The variable $PU_{j,k,l}$ is a binary value, which represents if the k-th pallet is being reserved for transport on delivery day j for location l. Here, physical pallets are considered up to a maximum of K, which is linked to the previous introduced set of considered pallets.

  If 3 pallets are being used for delivery on day *j1* and location *l1*, the value of $PU_{j1,1,l1}$, $PU_{j1,2,l1}$ and $PU_{j1,3,l1}$ will be 1, of which the variables $PU_{j1,k,l1}$ with $k > 3$ will be zero.

5.1.5 Objective

The objective function is based on a cost function, which has been evaluated of the models found in literature in section 4.3.4. Inventory cost are not presented, since the external storage location is included with the rent of the store location. Transportation cost can be calculated by multiplying the reserved amount of pallets by the tariff per pallet. In this case, the transport company gives 'discount' when multiple pallets should be delivered in once. Therefore, the variable of PC_k presents the cost involved for transport the k-th pallet per delivery. Here, a maximum of K pallets is being set. Here, also waiting cost are presented, which depends on the size of the delivery. So, the total transport cost per numbered pallet is the sum of variables PC_k and W_k, in which W_k represents the expected waiting cost for a delivery of size k pallets.

Extra receiving and ordering cost are presented in the case of external storage location. The receiving cost and ordering cost at the external storage location are higher, due to the fact the products have to transported to the store before they can be sold. This includes multiple actions by the store personnel, which have to sort and pick these products to move these. The difference in this extra cost on delivering on the external storage location is being captured by multiplying the scheduled delivery size times a certain factor F, which present the extra handling and ordering cost per box when delivering at this external storage location. This is called receiving cost and is dependent on the selected delivery location. Including this cost next to the the transport cost leads to the objective function, shown in equation 5.1.

$$minZ = \sum_{j=1}^{DD}\sum_{k=1}^{K}\sum_{l=1}^{2} PU_{j,k,l} * (PC_k + W_k) + \sum_{i=1}^{N}\sum_{j=1}^{DD} X_{i,j,2} * F \tag{5.1}$$

5.1.6 Constraints

The following restrictions are included in the model;

- The desired amount of products to fill the stock of the store to a sufficient level is being set in this model. This amount is set by parameter O_i, which present the desired amount of ordered boxes of products of type i. To guarantee that the products are scheduled, a constraint is set. This constraint will also limit the possible delivery days of an item to LD_i, which means that no total is calculated over all the delivery days. The constraint which is shown in equation 5.2.

$$\sum_{j=1}^{LD_i}\sum_{l=1}^{2} X_{i,j,l} = O_i \ \forall i \tag{5.2}$$

- The amount of scheduled pallets per delivery on a single day depends which goods are being scheduled per delivery. Here, the parameter P_i is being introduced, which represents the pallet volume of a box of products i. By making use of this variable, the decision variables $X_{i,j,l}$ and $D_{j,l}$ can be coupled, as is shown in equation 5.3.

$$\sum_{i=1}^{N} P_i * X_{i,j,l} = D_{j,l} \ \forall j,l \tag{5.3}$$

- The amount of pallets should be shipped by the transporting company, is an integer value. The different pallets are numbered and have a different price regarding the transport cost. Therefore, the binary variable $PU_{j,k,l}$ has been introduced and is nonzero if the k-th numerated pallet is used for transport on day j to location l. Here, the value of the scheduled amount of pallets $D_{j,l}$ should be rounded up to the closest integer. Capturing this rounding in a constraint is done in equation 5.4, in which M is a big positive number.

$$PU_{j,k} * M - (D_{j,l} - (k-1)) \geq 0 \ \forall j,k,l \tag{5.4}$$

  Here, as soon as a delivery is scheduled an a day, the value of $PU_{j,k,l}$ will jump with a value of 1 since this represents a certain amount of pallets used. The value of $k-1$ is being subtracted since the value has to be rounded up, which seems to realize this behaviour.

  Consider an example of this constraint by assuming a value of 2,5 for $\sum_{l=1}^{2} D_{j,l}$ for $j = 1, l = 1$. Then;

  - For k=1, $PU_{1,1,1} * M - (2,5) \geq 0$, so pallet '1' is scheduled for delivery to be able to satisfy this equation, since $PU_{1,1,1}$ has to be 1. Note that this variable is binary, so this is the only possible value.
  - For k=2, $PU_{1,2,1} * M - (1,5) \geq 0$, so pallet '2' is scheduled for delivery to be able to satisfy this equation, since $PU_{1,2}$ has to be one.
  - For k=3, $PU_{1,3,1} * M - (0,5) \geq 0$, so pallet '3' is scheduled for delivery to be able to satisfy this equation, since $PU_{1,2}$ has to be one.
  - For k=4, $PU_{1,4,1} * M - (-0,5) \geq 0$, so the value of $PU_{1,4}$ can be 0 or 1. Since the objective function wants the lowest possible cost, the value of $PU_{1,4}$ is set to 0 if the factor in the objective function is positive. Since the parameters regarding transport cost and waiting cost determine this factor, a restriction for this logic is set in the next constraint.

- To restrict that only the 'next' pallet can be scheduled for a delivery if the previous pallet has been scheduled, a constraint is set, which is show in equation 5.5.

$$P_{j,k,l} \geq P_{j,k+1,l} \; k \in \{1, 2, .., MP-1\} \; \forall j, l \tag{5.5}$$

- In the previous set constraints, Dj, l is not limited yet. A minimum of 0 can be obtained due to the set values of $X_{i,j,l}$. An upper bound for the delivery size is $u_{max,1}$ for the store delivery and $u_{max,2}$ for the delivery at the external storage location, which is shown in equation 5.6.

$$D_{j,l} \leq u_{max,l} \; \forall j, l \tag{5.6}$$

- Only 1 delivery per day can be handled by the store personnel, which is constrained in equation 5.7. If this is done for the first pallet for all the delivery days, a limit is set for all the delivery days.

$$\sum_{l=1}^{2} PU_{j,1,l} \leq 1 \; \forall j \tag{5.7}$$

- The scheduled deliveries are ordered from largest to smallest, to be able to sort the output of this model.

$$\sum_{l=1}^{2} D_{j,l} \geq \sum_{l=1}^{2} D_{j+1,l} \; for \; j = 1, 2, 3, 4 \tag{5.8}$$

5.1.7 Problem formulation

The problem can be captured in one set of equations. Based on the indexes, parameters and decisions variables, the problem can be captured in the following way:

Index	Description
i	product type
j	delivery day
k	numbered pallet of a delivery
l	delivery location

Sets	Description
$I = [1, 2, .., N], i \in I$	set of distinct products
$J = [1, 2, ..., DD], j \in J$	set of delivery days
$K = [1, 2, ..., MP], k \in K$	numbered pallet of a delivery
$L = [1, 2], l \in L$	set of delivery locations

Decision variables	Description
$X_{i,j,l}$	scheduled delivery of product i on day j on location l
$D_{j,l}$	cumulative size of the delivery on day j on location j in pallets
$PU_{j,k,l}$	scheduled use of k-th pallet on delivery day j on location l

Parameters	Description
PC_k	Transport cost of the *k-th* pallet of a delivery
W_k	Expected waiting cost of a delivery of size k pallets
F	Receiving cost for external storage location in € /box
O_i	Ordered amount of boxes of product i
LD_i	Latest numbered delivery day of product i
P_i	Pallet volume of a box of product i
M	Big positive number
$u_{max,l}$	Maximum delivery size at storage location l

Objective; $minimize\ Z\ =\ \sum_{j=1}^{DD}\sum_{k=1}^{K}\sum_{l=1}^{2} PU_{j,k,l} * (PC_k + W_k) + \sum_{i=1}^{N}\sum_{j=1}^{DD} F * X_{i,j,2}$

Constraints	Description
$\sum_{j=1}^{LD}\sum_{l=1}^{2} X_{i,j,l} = O_i\ \forall i$	Meet ordered demand
$\sum_{i=1}^{N} P_i * X_{i,j,l} = D_{j,l}\ \forall j, l$	Calculate total size of delivery in pallets
$PU_{j,k,l} * M - (D_{j,l} - (k-1)) \geq 0\ \forall j, k$	Schedule use of pallets based on delivery size
$P_{j,k,l} \geq P_{j,k+1,l}\ k \in \{1, 2, .., MP - 1\}\ \forall j, l$	Restrict numbered pallet usage
$\sum_{l=1}^{2} PU_{j,1,l} \leq 1\ \forall j, l$	Limit amount of deliveries per day to 1
$\sum_{l=1}^{2} D_{j,l} \geq \sum_{l=1}^{2} D_{j+1,l}\ for\ j = 1, 2, 3, 4$	Sort deliveries by size
$0 \leq D_{j,l} \leq u_{max,l}\ \forall j, l$	Limit delivery size
$X_{i,j,l} \in \mathbb{N}\ \forall i, j, l$	Integer variable
$PU_{j,k,l} \in \{0, 1\}\ \forall j, k$	Binary variable

Analyzing the model as presented above, the following components can be defined in the system input, system configuration and system output. In figure 5.1, the symbols for the input, system configuration and system output have been categorised. Here, the order information has been captured in the parameters of order amount O_i, pallet space per ordered box P_i, amount if items N and latest delivery day for item i LD_i. Here, the system configuration is set by the amount of possible delivery days DD, maximum amount of pallets per delivery MP, transport cost per pallet PC_k, expected waiting cost per pallet W_k, extra cost for receiving goods at the external storage location per box F and the maximum allowed amount of pallets to be delivered at the storage locations $u_{max,l}$. The output of the model is a delivery schedule of how many boxes of a product are shipped on a day $X_{i,j,l}$ and the amount of transport pallets on a delivery day to a certain storage location $PU_{j,k,l}$. Based on the delivery schedule of the products on a single day, also the total pallet space of a single delivery can be observed as an output decision variable in figure 5.1.

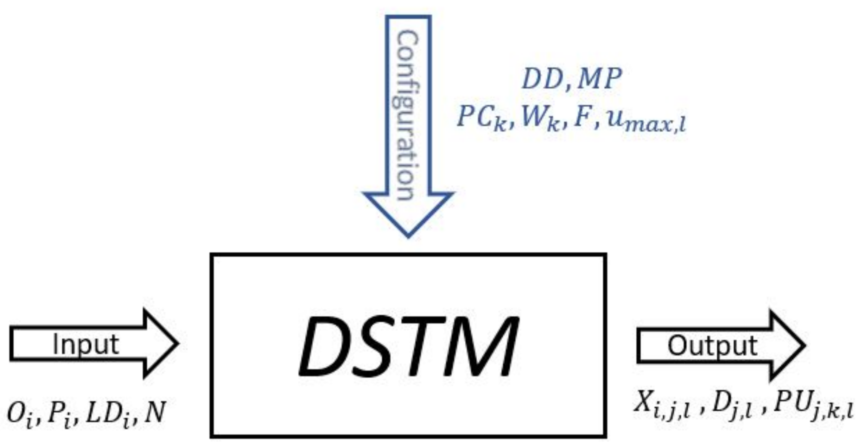

Figure 5.1: System analysis of DSTM

By knowing the DSTM in detail, the application and implementation of the model is discussed next.

5.2 Implementation

The described model has been implemented in MATLAB R2020a, in which the function of a mixed integer linear programming model can be used to calculate the most optimal solution. Here, general symbols can be used to program a model, which can be solved after defining the symbols. Here, the optimal situation can be determined, since the solver approach is set by the defined function by a solver based approach. The model will run until the gap with the optimal solution is zero, in which the default options of the function can be used.

5.2.1 Static model

The described model can be used in the following static situation in which an order has been placed to be delivered within a certain amount of days. Based on the orders, the input is given for the system. The configuration can be determined and depends on the constraints, which is introduced in the next chapter for the case study. The DSTM will schedule the goods to be delivered on certain delivery days and the amount of pallets that can be used for such a transport. This has been depicted in figure 5.2. Here, the order is split up in certain parts to be delivered via a certain amount of pallets to be delivered on multiple delivery days.

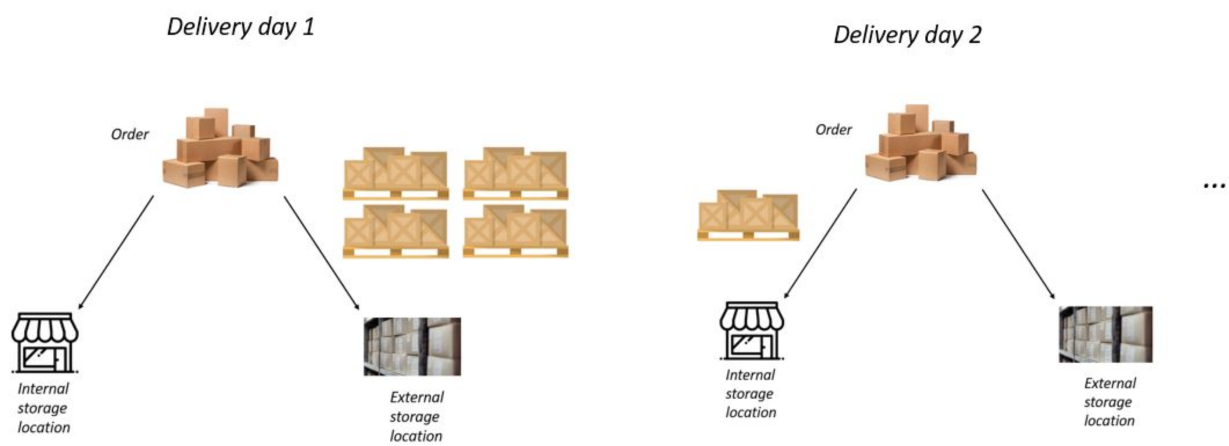

Figure 5.2: DSTM depicted

5.2.2 Dynamic model

The dynamic application of the DSTM can be done when a certain delivery schedule has been proposed, after which additional orders are being placed to be delivered within the same time frame. This includes a change in the original stated situation, which can be necessary due to unexpected demand. Therefore, a delivery rescheduling should be done, which is a dynamic situation in which the model will find the optimal delivery schedule for the goods to be delivered and the new order.

For the application of the transport model in the outlet store, the planned horizon for which the model schedules the deliveries is described. As already explained for a general application, DD possible delivery days are taken into account and O_i can be any order placed on a certain date for a certain period. So, a finite planning horizon is considered in this model. By considering the parameter L_i, the considered delivery days for a certain item can be limited. Here, full quantities or partial quantities can be prioritized. By splitting up the quantities and giving the parts a different index, the value of L_i can be determined for all the quantities to be delivered. Scheduling goods at a certain period, for example at the end of the possible delivery days, can be done by restricting certain values of $X_{i,j,k}$ to be zero for certain j. However, this is not considered in this research, since delivering at the beginning of the possible delivery days is desired for the replenishment of the outlet store.

The transport model can be executed for a considered period, which can be a week. If during this week, additional orders can be placed due to an unexpected occurrence, then the model can be executed again, which means that the planning horizon would overlap with the first considered planning horizon. Then, the ordered amount can be combined of the two scheduled deliveries, of which the already delivered products can be removed.

This delay can be prevented by reducing the planning horizon, such that the initial planning horizon stays fixed. Then, products are still delivered withing the original planned period, which is desired for the store personnel such that they can expect the goods within the initial stated period.

In the case of L'Oreal, a weekly consideration with the transport model is being scheduled. Due to the fact that the lead time for the deliveries is 2 days, the model will schedule the deliveries on Thursday, for the week afterwards. On this Thursday, the order list is being updated, send to the store personnel, which sends feedback with the final ordered amount. Then, the supply chain team collects the data from the order list and the further required data for calculating the most optimal delivery schedule. Based on this schedule, orders are being send to the warehouse, which takes care of the further process for sending the goods.

5.2.3 Application

The described model is going to be used in the static situation, which represents the situation of the case study mentioned in chapter 3. Additional orders are not discussed in this analysis of the supply chain of the outlet. So, the dynamic model will not be discussed in the remaining of this research. The model can be used for orders which can vary of size of a few up to a multiple hundred amount of distinct products to be ordered in a cumulative size of a multiple of thousand ordered boxes. Here, the cumulative pallet space is maximized at 30 pallets, which is based on the total amount of transported pallets on a weekly basis. This indicates the scale of the input that is given to the model, which gives an idea on the possible applications. The most optimal solution is calculated within a couple of minutes by MATLAB. A further increase can be possible with this model, since the configuration does not have any limitations in scaling up, but will not be considered in this research. The effect on the computational time will not be investigated, but an increase when having more distinct items seems to create a more complex problem (due to more constraints), which can result in a higher computation time. However, this will not be investigated in this research.

5.3 Verification

According to Sargent (2010), verification of a model is all about checking if the model is 'right'. With the term right, it is meant that the model is implemented according to its described specifications. So, implementing the model as described has to be checked to be able to check if it has been done right. Here, the defined balances in the model should be tested to see if is has been done correctly, in which the behaviour should be understandable, which cannot be guessed to be right. Only by checking this in detail, these conclusions can be made up. This is also confirmed in the article of Packer (2019), in which verification is stated as a test of a model to prove that it meets all its specified requirement of its development. In the mentioned research, verification can be as simple as checking the specifications and comparing it to the code logic. Actual testing of the model only has a small role in this step. Deterministic runs can be tried to run to see if the desired results is in accordance with the real output of the model.

In the case of the described transport model, boundary conditions of the described problem has been set as constraints for the problem. Based on the values of the decisions variables and parameters of the test run, they can be checked if they are implemented right. Also, the decision variables can be checked based on logic, in which only the second pallet can be scheduled for a delivery when the first one already has been scheduled. Tracing this type of event can be checked to verify that the model has been implemented correctly.

For checking if the implementation of the model was done correctly, indices, sets and parameters are defined. These sets and parameters are introduced by purpose to see if the model has been implemented right. No connections are made between the introduced parameters in this section and the transport model applied in the case study of L'Oreal. For the verification step, the following indexes and sets are defined;

- 10 different products are defined, so $N = 10$
- 8 delivery days are possible, so $DD = 3$
- 4 pallets can be shipped at most during one delivery, so $MP = 4$.

The following parameters are defined for the verification step;

- All the pallets will cost €10 per pallet to be transported. So, PC_k=€10.
- The waiting cost are zero if the total shipped amount of pallets per delivery day will be 3 or less. If 4 pallets are delivered, the waiting cost is €5 in total, so the only nonzero value is $W_4 = 5$.
- The receiving cost at the external storage location are €0,50 per box.
- Of all the items, 5 boxes are ordered, so $O_i = 5$.
- The first 3 items have to be delivered at the first delivery day, so $L_i = 1/i = 1, 2, 3$. The other items can be delivered during the first 4 delivery days, so $L_i = 4/i = 3, 4, ..., 10$.
- The first 5 items have a pallet size of 0,1 pallet per box, so $O_i = 0, 1/i = 1, 2, ..., 5$. The last 5 items have a pallet size of 0,2 pallet/box, so $O_i = 0, 2/i = 5, 6, ..., 10$.
- The maximum amount of delivered pallets at the first storage location is 2 pallets. The maximum amount of allowed delivered pallets at the second storage location is 4 pallets, so $u_{max,l} = \{2, 4\}$

The results are shown discussed based on the decision parameters $D_{j,l}$, since the decision variables are dependent on the outcome of variables $X_{j,k,l}$ and linked the amount of scheduled pallets $PU_{j,k,l}$. The results of this parameters are shown in table 5.1, in which only the nonzero values are shown. Here, the value of the objective function is *Z=€50.*

$D_{j,l}$	*l=1*	*l=2*
j=1		2,5
j=2	2,0	
j=3	2,0	
j=4	1,0	

Table 5.1: Nonzero Decision variables $D_{j,l}$ for the mentioned test run

Thus, the model determined that in this situation of scheduling goods with a cumulative size of 7,5 pallets, 4 deliveries should be scheduled of respectively 1 ,2, 2 and 3 pallets. In total, €92,5 is the value of the objective function, which is built up by transport cost (€80) and receiving cost at the external storage location €12,50. Here, no waiting cost is presented due to the fact that no deliveries are scheduled of a size of 4 pallets. To see if the model has been implemented right, the set constraints are checked one by one in the following part of this section.

- By adding up the scheduled items of the same for the different locations and delivery days, gives the same result as the ordered amount of items. So, the first constraint shown in equation 5.2 is implemented correctly.
- By checking that the total amount of scheduled pallet space by the goods for every delivery day and location, the numbers shown in 5.1 can be obtained. So, the constraint shown in equation 5.3 is also fulfilled.
- By checking the logic of scheduling pallets for a delivery on a certain location and day, this constraint can be checked. In the outcome of the model, only the binary values of $PU_{1,2,1}$, $PU_{1,2,2}$, $PU_{2,1,1}$, $PU_{2,2,1}$, $PU_{3,1,1}$,$PU_{3,2,1}$ $PU_{4,1,1}$ and $PU_{4,2,1}$ are nonzero. Due to the fact for delivering on the considered location in 5.1, respectively 3, 2, 2 and 2 scheduled pallet can obtained. Therefore, the constraint of equation 5.6 is implemented right.
- By comparing the values of the decision variables $PU_{j,k,l}$, the logic of scheduling numbered pallets has been implemented correctly. Therefore, constraint 5.5 has been implemented correctly.
- As visible in table 5.1, at most 1 delivery per day has been scheduled. This confirms that constraint 5.7 has been implemented right.
- In table 5.1, the deliveries has been scheduled in size in which the largest deliveries is scheduled for the first delivery day. So, equation 5.8 has been integrated correctly.
- The deliveries has been limited in size, which is in accordance with the limit set per delivery location, as can be checked in table 5.1. So, equation 5.4 has been implemented right.
- The set constraints of integer and binary variables has also been met. The values of $X_{i,j,l}$ are integers and the values of $PU_{j,k,l}$ are binary, which was desired by the last constraint.

By checking all the constraints and the described logic of the model, there can be concluded that the model has been implemented correctly in MATLAB. Therefore, the check if the model has been implemented right has been performed. Therefore, the next step is to investigate if the model describes the assumed simplification of reality.

5.4 Conclusion

In this section, a transport model has been proposed. First, elements of found problems in literature have been compared and selected, based on the described replenishment transport problem at the outlet of L'Oreal. Based on these elements, a general mixed integer linear programming has been introduced for the described transport model. This model has been implemented in MATLAB, in which the most optimal solution can be determined. Here, the assumptions, indices, sets, decision variables, parameters, objective function and constraints have been introduced. What is unique about the transport problem, is the option to deliver to two locations of the same vendor. Here, the external location is considered as a less ideal location, since the products have to be transported to the internal storage location of the outlet store to be able to put them in the shelves. However, more storage space is presented at the external locations than in the internal storage location, in which the daily sell-out is the reason space is created in the stock room. Therefore, this unique situation is captured in having a choice of delivering on the internal or external storage location.

6 Case study; DSTM for L'Oreal outlet

In this section, the introduced transport model introduced in the previous chapter is specified for the case study of L'Oreal The developed transport model has been programmed in MATLAB R2020a, in which the function of a mixed integer linear programming model can be used. A test case is described to validate the performance of the DSTM, which is a crucial step in this research. Using this test case, a validation step of the model can be performed. Afterwards, the KPI's of the DSTM are introduced to be able to measure the performance of the model in experiments. A conclusion will finalize this chapter.

In this section, a specific model configuration is introduced. Here, a single configuration is selected based on the constraints explored in the case study. Narrowing done the scope of the introduced model is done to be able to compare the performance of the model to the introduced test case performance. After validations can be performed in this test case, experiments are executed using different configuration in chapter 7.

6.1 Case study

As already explained, based on a weekly review, deliveries are being scheduled for the L'Oreal outlet store. Based on the feedback of the store personnel, the products per delivery are scheduled for the two deliveries. Due to the transport which is being executed by an external company, cost are being paid per used pallet. Based on the amount of pallets delivered, a fixed time slot is being reserved by this company to unload the truck. Since the pallets have to be returned by that same truck, exceeding the unloading time will cost extra money. For supplying 1-5 pallets, 30 minutes are reserved to unload the truck. For supply 6-8 pallets, 45 minutes are reserved. Exceeding the mentioned unloading times will cost is further investigated in this chapter.

In the period of March 2019 till February 2020, 118 deliveries were scheduled to the outlet store in Roermond. The frequency of a delivery size per pallet is shown in figure 6.1. In this figure, only integer values are evaluated on the horizontal axis, which are indicated by the bars in this figure. Here, the average size of a delivery was 4 pallets in the mentioned period. The frequency of deliveries with a lower amount than 7 pallets was shown in table 6.2. 24 deliveries have been scheduled with more than 6 pallets, of which the average size was 10 pallets.

Based on this amount of pallets, transport cost can be determined. Next to transport cost, also waiting cost and receiving cost at the external storage location are taken into account. The cumulative extra waiting cost per delivery size is shown in figure 6.2. Here, as is considered in this figure, more waiting cost are presented as the delivery gets bigger than 6 pallets. This is due to a unloading time of 30 minutes for a delivery of 1 till 5 pallets in total and 45 min for a delivery of 6 or more pallets. This stepwise behaviour of unloading time is also presented in the average waiting cost, which is presented in red in figure 6.2. This figure indicates that if more than 6 pallets are transported in one delivery, the average waiting cost increases significantly. Therefore, these delivery size should be limited to reduce the waiting cost.

What can be observed in this model is that the average waiting cost of a delivery of 5 pallets is larger than the average waiting cost of a delivery of 6 pallets. This behaviour seems odd, since the average waiting cost decrease if more pallets are delivered. However, this behaviour can be explained. Due to the fact that an extra 15 minutes is being scheduled by the transporting company to unload the truck. Thus, waiting time should decrease when scheduling a delivery of this size.

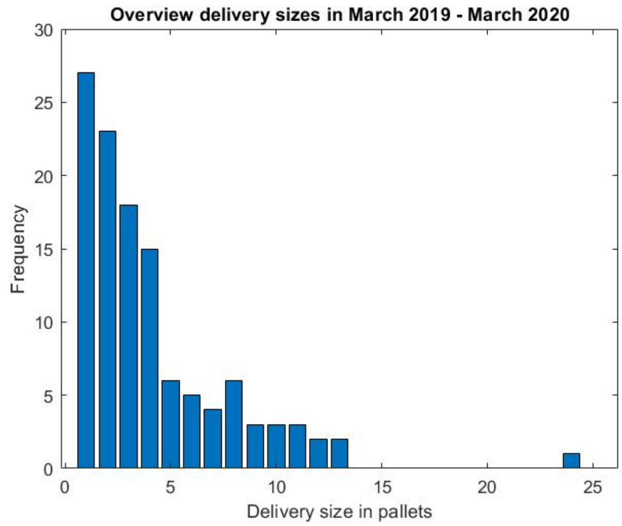

Figure 6.1: Sizes of scheduled deliveries to L'Oreal outlet in period March 2019 - February 2020

As shown in table 6.1, the amount of deliveries including exactly 5 pallets is less compared to the amount of smaller deliveries scheduled. However, relatively high waiting cost can be observed for deliveries of 5 pallets and relatively low occurrences in which no waiting cost are presented. Therefore, the expectation is that on average, higher waiting cost can be observed for a delivery of this size. Therefore, if 'large' deliveries would be scheduled, in terms of waiting cost it is preferable to schedule a delivery of at most 6 pallets.

The extra cost related to reserving a time slot at the external carrier is fixed per delivery. Since two weekly deliveries were scheduled in the mentioned period, these cost do not vary and should be incorporated in the transport cost of the case study.

6.1.1 Constraints

The capacity of the transportation company is not the limiting factor. What is the limiting factor for the transport, is the receiving party, which is the outlet store. Due to the fact that a limit capacity in stock in the store, only smaller deliveries can be received at this location. When larger orders are being received at the store, there is no space to save the stock. Therefore, large deliveries should be scheduled to the Kooi. However, products have to be shipped to the store to be able to put these products in the shelves of the store. The balance between the delivery scheduling is investigated in the following transport model.

Therefore, the transport model can schedule smaller deliveries than are presented at the moment. Here, the goal is to reduce cost, which can be done by reducing the amount of scheduled pallets, reducing the exceeded unloading time of the truck and the receiving cost at the external storage location.

In the next part of this section, the introduced DTSM is specified for the case study of L'Oreal.

6.1.2 Indices and sets

In this section, the sets for the specific model for the L'Oreal outlet model are set.

- The amount of distinct articles will stay variable, since this differs per replenishment cycle. Later, different deliveries are compared to judge the performance of the model. Different orders are investigated and discussed later in this research.

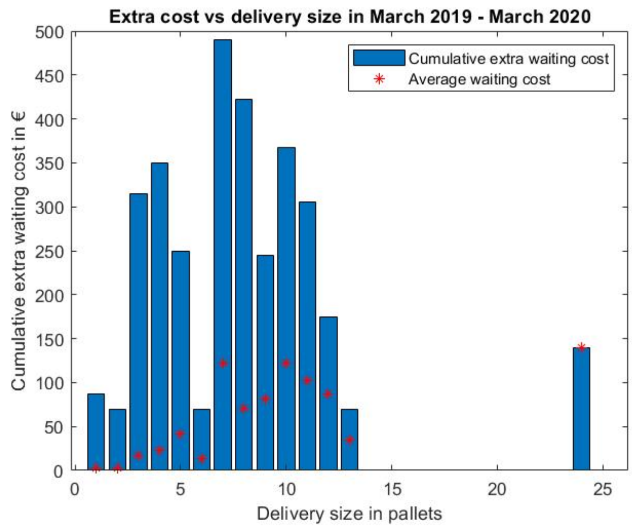

Figure 6.2: Cumulative waiting cost per delivery size in period March 2019 - February 2020

- In total, 5 possible days for delivering are possible. Due to the fact that the weekends are the most busy periods and the transport company is not able to handle deliveries in the weekend, 5 days for delivering are possible. So, $DD = 5$
- Per delivery, a maximum of 6 pallets is set. The store personnel is not able to handle larger deliveries in an efficient way, which can be observed in the extra waiting cost per delivery size. This is investigated for parameter W_k in the next subsection. Therefore, $MP = 6$.

6.1.3 Parameters

In this section, the parameters for defining the specific model for the L'Oreal outlet model are set. These are;

- The included pallet cost depends on the amount of pallets transported and is determined the transport company. For the first pallet, additional cost of €15 are charged, since a specific time slot have to be reserved of the transport company. The transport cost per numbered pallet can be observed in table 6.1. Here, discount can be reviewed for ordering multiple amount of pallets, except for pallet number 6. For pallet 1-5, the truck driver waits for 30 minutes, until an extra fee is charged. For pallet number 6-8, this is elongated to 45 minutes. To provide that customers order 6 pallet instead of 5, it is probably more cost efficient to transport less than 6 pallets for the transporting company.

Pallet number	Cost per numbered pallet
1	€54,51
2	€34,32
3	€28,90
4	€23,61
5	€29,45
6	€24,94

Table 6.1: Set of values for PC_k

- The expected waiting cost have been determined based on the data available in the period March 2019 - February 2020. In the table of 6.2. Here, the amount of appearances of extra waiting per delivery size can be observed. Here, only in exceptional cases extra waiting cost are presented for a delivery size in pallets of 1 and 2, which means that W_1 and W_2 is set to 0.

In the case of a pallet of deliveries of size 3, 4 and 5, the same waiting time is available for the truck driver, while the unloading time is higher for the store personnel. Therefore, higher waiting cost is the result and observed in table 6.2 for deliveries of 3 and 4 pallets. For deliveries of this size, the waiting cost are set to the average waiting cost per delivery, which will € 17,50 for a delivery of 3 pallets and € 23 for a delivery of size 4 pallets. In the case of a delivery of 5 pallets, 30 minutes is still the scheduled time for unloading the truck. In table 6.2, fewer deliveries of 5 pallets can be observed than the number of smaller deliveries, of which at 50% of the deliveries, high waiting cost can be observed. However, the other 50% of the deliveries have relatively low delivery cost, which is remarkable. If more deliveries are scheduled of this size, there can be investigated if these cases or exceptional or a similar distribution can be observed. For a delivery size of 5 pallets, the expected waiting cost are set to the average expected waiting cost, which is € 41,50 for a delivery of 5 pallets in total.

For a delivery of 6 pallets, additional 15 minutes are reserved for the truck driver for unloading the truck. Therefore, a lower amount of expected waiting can be observed as average waiting cost, which is € 7,00. In table 6.2, a relatively low amount of deliveries can be observed of this size, but 3 out of 5 deliveries were unloaded within the reserved time. Therefore, deliveries of this are desired to deliver large quantities and reducing the waiting cost.

	Waiting cost						
Delivery size in pallets	€0	€17,50	€35	€52,50	€70	> €70	Total deliveries
1	25	0	0	0	0	1	26
2	20	2	1	0	0	0	23
3	13	0	0	2	3	0	19
4	6	0	6	2	0	0	15
5	1	2	0	0	2	1	6
6	3	2	0	0	0	0	5

Table 6.2: Amount of presented waiting cost of deliveries in period March 2019 - February 2020

Due to the fact the waiting cost are presented as a factor times the binary value of $PU_{j,k,l}$, the waiting cost are set relative to the amount of pallets scheduled, which gives the overview as presented in table 6.3. Here, the average waiting cost have been set for a delivery of a certain size, which can be observed from the data of table 6.2. The negative value of the W_k indicates the relative cost when 6 pallets are shipped in total, the the waiting cost for numbered pallet 3, 4 and 5 have to be compensated.

Pallet number	Waiting cost per numbered pallet
1	€ 0,00
2	€ 0,00
3	€ 17,50
4	€ 5,50
5	€ 18,50
6	€ -34,50

Table 6.3: Set of values for W_k

- The parameter F is a hard parameter to set. The extra cost related for transporting the goods from the Kooi to the store cannot be measured exactly and should be estimated. These cost are set as extra receiving cost at the external storage location and should only capture extra cost made at this external location. The store personnel is able to transport the goods via cages from the external storage location to the store, in which receiving and handling cost are captured in this parameter. This cost should only represent the extra cost related to delivering at the external storage location and should not overlap with cost that are also made for deliveries at the integral storage location. Therefore, assume that 200 boxes can be transported in half an hour, in which the extra cost are €40 per hour for the store personnel. Therefore, F parameter is set to €0,10/box.

- The ordered quantity O_i depends on the replenishment cycle and the ordered products. Therefore, specific scenarios of replenishment orders are scheduled and discussed later in this research.
- LD_i is set to 5 days for all the products, since deliveries with priorities are not assumed to be presented in the weekly orders at this moment. If products have to be scheduled with priority, this can be changed by adjusting this parameter.
- The amount of pallet space of a box depends on the considered products and can be found in the EPR system of L'Oreal.
- M is set to $1 * 10^3$.
- Transporting to the stock room of the store can be done with a pallet size of at most 1,5 pallets, so $u_{max,1} = 1,5$. The limit for transporting goods to the Kooi is 5, which is the maximum amount of pallets considered per delivery, so $u_{max,2} = 6$.

  Note that the maximum delivery size of the outlet store is based on the daily sell-out. Here, space is being created in the stock room due to sell-out. Therefore, goods can be transported to the stock room of the store from the warehouse or the Kooi. Therefore, a daily limit for delivery size can be set to receive at maximum 1,5 pallets each day.

The described model has the goal to reduce the overall cost for replenishing the L'Oreal outlet store. By scheduling and limiting deliveries in size, less transport cost in total should be made, which could be in terms of used pallets. By scheduling and limiting deliveries in size, less waiting cost should be made. Also, reducing the deliveries in size gives a possibility to instruct the store personnel to unload the truck such that the truck driver does not need to help. Designing this process in detail, is left out of scope. The transport to the external storage location is being limited and described such that the smaller deliveries are scheduled to the stock room of the store.

6.1.4 Test case

The model is tested with a relatively large single delivery for which 8 pallets are used. This is the delivery of the 2th of April 2019. Here, 84 distinct items are scheduled, with a total ordered amount of 1261 boxes. This data can be used to check if the model fulfills its purposes and is implemented right.

For a delivery of this size, the stated transport cost of 8 pallets are €226,07. Here, additional cost of €15 for scheduling the delivery in the morning and waiting cost of €70 should were made. This means that a total cost of delivering at the outlet store is €311,07, which was delivered at the external storage location. Extra cost for transporting the goods to the store are not taken into account into the mentioned test case, which were presented in real life.

Using this test case, a validation step is performed to see if the model meets its purposes.

6.2 Validation

Validation and verification are often blended and they do not imply the other, according to Sargent (2010). So, validation is still a crucial step for the described transport model. Validation is all about checking if the model is right and meets an accurate representation of the reality. Here, model assumptions have to be described to understand which simplifications have been done to be able to capture the system in a model. If crucial parts of the system has been left out of the model, realistic behaviour of the model cannot be expected. To be sure that that this is not the case, the model has to be validated by comparing the model results with real-world knowledge. This can be done by changing values of parameters of factors and check of the outcome of this model meets the expected behaviour. If cost are raised or constraints are removed, then the outcome of the model should change in accordance with realistic behaviour.

6.2.1 Data validation

For the described transport model, values of parameters and factors are changed to check what the result is on the related decisions variables in the next subsection. First, a data validation should be performed after which the used data for the configuration of the model can be checked. Also, the role of the input is discussed. Besides, the effect on the result of the objective function are compared. When running the model in the described test case of subsection 6.1.4, an objective value can be determined of €351,61, in which 2 deliveries have been scheduled in the most optimal solution. One delivery of 6 pallets has been scheduled to the external storage location, in which a delivery has a slight amount of waiting cost of a large delivery. €7 is the amount of waiting cost which is expected on average for a delivery of this size. Besides, waiting cost of €63,40 have been taken into account for transport from the external storage location to the internal storage location. Also, a delivery of 2 pallets have been scheduled to the store, in which the scheduled goods have a cumulative pallet size of 1,5 pallets. Here, no waiting cost and receiving cost are presented, only transport cost for scheduling the goods to be delivered to the store.

This outcome seems to be comparable to the real life situation which is mentioned in 6.1.4. Here, less transport cost can be observed, higher waiting cost and receiving cost at the external storage location is not taken into account. However, by scheduling the transport by this the introduced transport model, less cost are made in total when the receiving cost are taken into account at the external storage location, since the total cost of the test case is €311,67 + €126,1 = €437,77. Here, all the boxes have been transported to the external storage location, since only one large delivery was scheduled. Therefore, savings can be realized by splitting up this delivery, in which extra waiting cost can be lowered a lot and receiving cost can be reduced by scheduling a delivery to the store.

The data used for the configuration of the DSTM was set based on the constraints of deliveries at the store (DD), feedback of the store (MP and $u_{max,l}$), transport cost (PC_k), expected extra waiting cost W_k and estimated extra transport cost for receiving deliveries at the external storage location F. Here, the role of the feedback of the store depends how many pallets can be shipped in one large delivery, but can be of limited since the waiting cost will increase a lot for deliveries of more than 6 pallets (see figure 6.2). The role of the maximum amount of pallets to be delivered is based on the sell-out and available space for stock at the internal storage location, which is hard to determine in detail and is sell-out dependent. Based on the feedback of the store, this number seems to be chosen in the correct way to limit the spread or limit the flow to this storage location. The transport cost has been fixed by the transport company, so no discussion is possible on this data. The waiting cost is based on the expected value, which is the average of the waiting cost. However, the logic of the time slots of the transport company has been implemented correctly, which can be observed in 6.3. The cost related to the transport from the internal to the external storage location seems to increase a lot due to the high quantities which are ordered at the outlet. However, these extra cost seems to be realistic since a lot of time is being lost when employees are necessary to transport the goods to the shelves.

The role of the input is tested by experiments. The implementation of the amount of items and ordered units is based on an order placed in the mentioned period. Therefore, O_i and N are selected in which no discussion should be possible. The amount of pallets scheduled in total depends on the pallet volume of a certain box of items P_i and should take into account pallet stacking inefficiencies. To check if the correct amount of pallets have been scheduled, a comparison is made to the amount of scheduled pallets in the past. The parameter LD_i is set to DD since the static model is being tested.

6.2.2 Structural validation

To validate the model, the described transport model configuration can be changed to be able to check if the model represents the real life system that should be captured in the model. Therefore, certain parameters are changed of which expected logic is tested to evaluate the model's behaviour. The following changes are applied and tested, to see how the outcome of the model is effected;

1. Increasing relative waiting cost for a delivery of 6 pallets by setting W_6 to €20 instead of €-34,5. This would mean that transporting a delivery of that size becomes less attractive. Multiple smaller deliveries would be expected, in which can be expected that the sixth numbered pallet will not be used, since the cost for this numbered pallet are relatively high.
2. Setting the waiting cost for numbered pallet 3 to €0. A change of setting W_3 to 0, means that the waiting cost parameters for numbered pallet 4 should also be revised. This can be done by setting W_4 to €23, of which the parameter of waiting cost for numbered pallet 5 stays the same. This means that scheduling deliveries with in total 3 used pallets will become more attractive since less cost are presented compared to pallet 4. However, still the greatest quantity discount is presented when scheduling 6 pallets, which can only be done for deliveries at the Kooi. Therefore, scheduling 2 deliveries at the Kooi of 3 pallets instead or one single delivery of 6 pallets is investigated to see what brings the lowest total cost. If 2 deliveries are scheduled, two time slots have to be reserved at the transporting company, which brings €30 cost in total extra. If one large delivery of 6 pallets is scheduled, extra waiting cost of €7 and a single time slot must be reserved (€15). Since this brings the lowest extra total cost (extra receiving cost stays constant), the outcome of the model should be the same as the found result in the verification step.
3. Setting the extra transport cost F to €0,5 per item. By raising the cost for transporting items to the Kooi instead of the store, a higher objective value is expected, including a change in delivery size and frequency. For smaller deliveries, the extra transport cost can be set to 0 by delivering only at the store. However, if multiple smaller deliveries should be scheduled, extra transport cost are included for reserving the time slot at the transporting company. Since more than 1200 boxes should be scheduled to be delivered, €600 of extra cost of extra receiving cost would be presented if deliveries were only scheduled at the external store location. Therefore, multiple goods which are relative small of size are scheduled in smaller deliveries at the store, which is expected to be the outcome of the model.
4. Setting the possible delivery days for the first 70 items to 1 day. By setting $LD_i = 1$ for $i=1,2,...,70$, a more sub optimal situation has been prescribed, which should result in a higher objective value. If all these goods can be scheduled for delivering 6 pallets in total, higher transport cost for transporting the goods to store are expected, but no change in delivery size and frequency should be observed in the solution of the model.
5. Limiting the maximum delivery size to 5 pallets. By setting $u_{max}=5$, smaller deliveries should be observed. If quantity discount is presented with the limited delivery size, can be observed by checking the factor in which the decision variable $PU_{j,k,l}$ is multiplied, which can be calculated by adding up the waiting cost and transport cost per numbered pallet. Therefore, more deliveries are expected which are smaller of size, which should result in a higher objective value, since the highest quantity discount can be observed when scheduling 6 pallets per delivery.

The introduced validation step will evaluated one by one after reviewing the results of the model shown in table 6.4.

1. Since the quantity discount has been erased by adding up waiting cost for the sixth numbered pallet, this pallet will not be scheduled. The capacity of this pallet has been created by scheduling multiple smaller deliveries, which have the lowest price for scheduling deliveries per pallet. For these smaller deliveries, waiting cost and extra transport cost from the Kooi to the store are €0. Here, the delivery capacity and scheduled amount of pallets in total should

Number	Model changes deliveries	Expectation		Total deliveries	Delivered pallets		Z
		Delivery size	Objective		Store	Kooi	
1	W_6=€ 20	Smaller	Increase	4	2, 2, 1	4	€ 390,61
2	W_3, W_4={0,23}	No change	No change	2	2	6	€ 351,61
3	*F=0,5 € /box*	Smaller	Decrease	5	2, 1, 1, 1	3	€ 472,41
4	$LD_i = 1 \ i \leq 70$	No change	Increase	2	2	6	€ 389,91
5	$u_{max,2} = 5$	Smaller	Increase	3	2, 1	5	€ 386,12

Table 6.4: Overview changes and resulting behaviour of the model

allow that only one pallet is delivered on multiple delivery days. As expected , the objective value increases, since more cost are made by not having quantity discount for scheduling the sixth pallet. Therefore, the calculated delivery schedule meets the expected logic behaviour.

2. By scheduling no waiting cost for numbered pallet 3, no difference is made on the delivery schedule of the model. This was expected and can be explained. The optimal solution is found in the verification step stays valid, since the extra cost for reserving multiple time slots at the transporting company is higher than the expected waiting cost for a single delivery of 6 pallets. Therefore, no changes in the resulting delivery schedule can be observed.
3. Since extra transport for transport the goods from the store to the Kooi is more than the extra cost for reserving times lots of the transporting company in this scenario, smaller deliveries are scheduled to the store. However, due to the fact that only 1.5 pallet can be scheduled in total to be delivered at the store, delivering one full pallet is the most effective method in this situation. This results in an increase in the objective function, which sounds logic in this situation.
4. By restricting products to be delivered on the first day, more boxes are shipped to the Kooi in the largest delivery, which is scheduled at the first delivery day. Therefore, the delivered pallet amount will stay the same, while the extra transportation cost from the Kooi to the outlet increases. Therefore, the objective value increases as expected, which means that the model implemented to meet realistic behaviour when prioritizing goods.
5. By limiting the amount of scheduled pallets, smaller and more deliveries are expected. This can be observed from the delivery schedule, of which at maximum 5 pallets are scheduled per delivery. Since the quantity discount of the sixth numbered pallet is not presented any more, a higher objective value can be observed, which validates this experiment of the model.

Therefore, the model changes the delivery schedule in accordance with logic behaviour. Therefore, realistic behaviour can be observed in which the model meets its purposes. So, there can be concluded that the model has been implemented right and it meets its purposes. This completes the validation step, which meets the end of this subsection.

6.2.3 Performance validation

In the validation step, the implemented logic has been checked, which could have an effect on the objective function. In this subsection, the initial outcome of the model was checked and compared to the real life historical situation. As already described, the single delivery scheduled on the 2nd of April in 2019 had cost included on transport of 8 pallets (€ 226,07), additional cost of € 15 for scheduling the delivery in the morning and waiting cost of € 70. Besides, extra receiving cost of € 121,60 were made to receive all the goods at the external storage location and transport them to the store, which makes the total amount of cost € 433,30. By comparing this value to the objective value of the test case, which was € 351,61, savings of almost € 80 can be made by scheduling the delivery schedule of the goods by the DSTM. This difference can be explained by the waiting cost and receiving, which are reduced by the DSTM model since the delivery has been split up. Here, one large delivery of size was transported to the external storage location, with relatively low waiting cost. Another small delivery was scheduled at the internal storage location, in which no receiving and waiting cost are presented, but another fee has to be paid for another delivery slot reservation in the morning of the transport company. However, these extra cost are less than the saved cost for waiting and extra transport cost to the store. So, in this case, savings can be realized by scheduling the replenishment schedule with the DSTM model, which is further investigated in the following chapter.

6.3 KPI

For the introduced DSTM two KPI's can be defined. The first one is the total transport cost of the delivery schedule, which is the objective value of the model. The second defined DSTM is the delivery size in terms of pallets which are transported. Here, scheduling more and smaller deliveries is preferred to limit the workload on the store personnel, which can be captured in a KPI by comparing the amount of deliveries and the amount of pallets delivered per delivery. No strict equation is set to be minimized on this KPI, which is the case at the first introduced KPI.

6.4 Conclusion

In this chapter, the described model has been implemented and programmed in MATLAB. To see if this has been done correctly, a test case has been described. Based on this test case, a validation step has been performed by comparing different scenarios by changing the parameters of the model. Besides, the performance and data of the model has been validated as well, to confirm the validation of the model. Besides, KPI's have been defined, which are used to measure the performance of experiments in the next chapter.

7 Experimental plan

The introduced transport model has been implemented correctly, which has been checked in the verification step. To see if the implemented model is the right model in its application has been checked by validating the DSTM. The next step in this research is model experimenting, which is discussed in this chapter. Here, the last introduced research questions is going to be answered to see what can be the benefits of scheduling the goods for replenishment of the L'Oreal outlet by the introduced model. Different input scenarios are feed in the model to evaluate the performance of the DSTM in this section. Afterwards, different configurations of the model are discussed, which includes a sensitivity analysis. Besides, the performance of the DSTM is going to be discussed by comparing the outcome of the model to scheduled deliveries in the past, from which conclusions will finalize this chapter.

7.1 Experimental plan

According to Sargent (2010), for experiments, the quality of the experiments are more important than the quantity. Here, the experiments should only be executed to find answers on stated research questions. By thinking what is really necessary from the model, experiments should be selected. Here, the number of scenarios should be selected to be able to check if the behaviour of the model is consistent. Besides, the outcome of the model should be analyzed to be able to understand the behaviour of the model and see in which applications it can be useful. Here, the role of the input should be analyzed, which can be done by studying the change on the outcome when changing only one parameter. Besides, the combined effect in such models should also be analyzed.

For this research, the research questions that should be answered is "Which savings can be realized by scheduling transport according to the described transport model for replenishing the factory outlet store of L'Oreal?". First, their should be investigated if savings can be realized by scheduling transport by the mentioned transport model. If this is the case, the value of this savings can be determined in scenarios in the past. Here, different scenarios are described, which are known orders and can be observed in the past. In the scenarios, a different amount of products are ordered, which can accumulate to a variable amount of pallets that should be scheduled. Based on these scenarios, the effect of the input variables parameters of orders can be investigated and how this effects the outcome of the model in comparison to the past. Here, the performance can be measured by the introduced KPI's, which are the delivery sizes and total transport cost.

7.2 Scenarios

By using the introduced transport model, orders on weekly basis can be rescheduled to see how these can be split up in smaller deliveries. In the present situation for replenishing the outlet store of L'Oreal, two deliveries were scheduled per week. This means that by rescheduling the deliveries by the transport model, savings of at most 1 pallet can be realised in certain scenarios. This can be the case if both deliveries have been scheduled in which at least 50% of a single pallet at both deliveries was empty, which can be merged to be delivered in one pallet. Besides these kind of transport cost, also other types of cost are taken into account.

The maximum size of the deliveries scheduled by the model is limited, such that the store personnel is able to handle the deliveries. This means that the average cost for a transported pallet will increase, since the tariff per pallet decreases if the delivery increases in size. However, the waiting cost for smaller deliveries are expected to be lower, since smaller deliveries are easier to unload in the stated time for smaller deliveries, which has been taken into account in the model. Cost can be saved by rescheduling deliveries, in which there is going to be investigated if this can be done by scheduling smaller deliveries. The cost for transporting the goods from the Kooi to the store are not taken into account in the given cost in the scenarios in the past and will therefore be considered apart from the other cost to be compared to see if savings can be realized.

Scenarios are given as different kind of input and configurations in this section. An overview of the inputs and configurations of the DSTM can be found in figure 7.1. The defined input is being varied expect for parameter LD_i, since this parameter is only varied in the dynamic application of the DSTM. To be able to compare the outcome of the DSTM to scenarios in the past, the latest delivery date of product i is set to DD, which is 5 days in the case study of the DSTM. Here, inputs are varying due to the fact that weekly orders are different and dependent on the sell-out during the week, which determines the amount of products that needs to be ordered for replenishment. Different configuration are discussed to evaluate to role of parameters which are not set by strict boundaries in the system, which have been mentioned in section 6.1.3. These are the maximum delivery size at the internal storage location and the receiving cost at the external storage location.

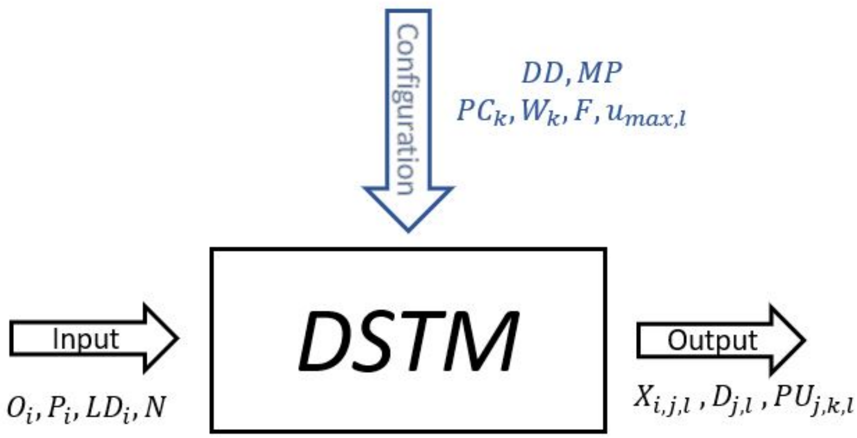

Figure 7.1: System analysis of DSTM

7.2.1 Input

To investigate if savings can be realized by scheduling transport by the transport model, the following weekly orders of the store are rescheduled by using the transport model. Different orders in total pallet size are investigated to evaluate the performance of the transport model. The following criteria are defined to select the input scenarios;

- The selected input scenarios should vary in term of ordered amount of products measured in pallets. Due to the fact that the replenishment strategy results in different order size of a varying amount of products, the effect of a different amount of pallets to transported should be investigated.
- Weekly orders should be selected which should be below and above the limit of 6 pallets, which is the set in which the waiting slot of the transport company elongates compared to smaller deliveries.
- Deliveries with high waiting cost should be selected to investigate if these cost type can be reduced. Due to exceeding the time slot of the transport company, delays occurs in the schedule of the truck. Therefore, adapting the delivered products per day can result in a better match between the set unloading slot and the real unloading time, which will be investigated.

Based on the criteria below, input scenarios are selected. To select orders of different pallet sizes, an overview of the frequency of the rounded up order size in pallets is shown in figure in 7.2.

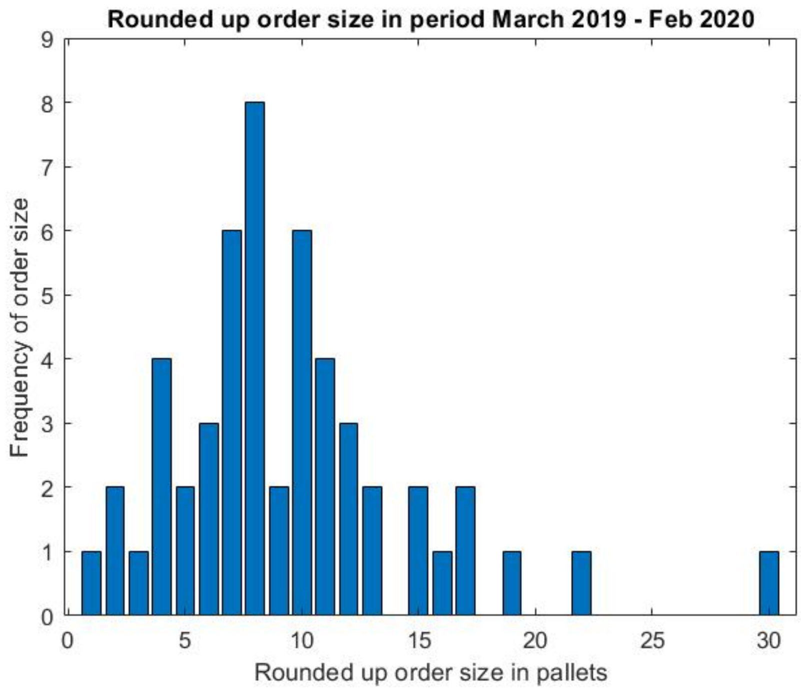

Figure 7.2: Frequency of rounded up order size in pallets in period March 2019 - February 2020

From figure 7.2 single deliveries of different order sizes are selected. Here, different order sizes illustrate the aspects of seasonality, in which busy periods can occur. So, a single delivery of a rounded value of 8, 10 and 15 pallets are selected to be investigated what the performance of the model will be when large orders are being placed. Besides, these deliveries are scheduled to investigate orders with high waiting cost and include an order size of more than 6 pallets. Here, the orders of 8 and 10 pallets are selected due to the high amount of occurrences in the selected period. The orders of 15 pallets has been selected to be able to investigate on of the largest placed orders which is representative for an order in one of the busiest periods of the year. Besides, smaller orders of rounded up 4 and 5 pallets are selected to investigate the behaviour of the models when the total order size is lower than 6 pallets. Besides, the frequency of the orders of this size is larger than orders of a size of 1 till 3 pallets. The choice for the selected order sizes are made due to the fact that they are characteristic for the varying demand at the outlet centre, in which a various amount of products are ordered per week due to changing traffic. Therefore, the selected input scenarios are ;

- Orders in week 43 of 2019, deliveries on 23-10-2019 (2 pallets) and 24-10-2019 (2 pallets).
- Orders in week 52 of 2019, deliveries on 18-12-2019 (2 pallets) and 19-12-2019 (3 pallets).
- Orders in week 37 of 2019, deliveries on 12-10-2019 (5 pallets) and 13-10-2019 (3 pallets).
- Orders in week 15 of 2019, deliveries on 10-04-2019 (5 pallets) and 11-04-2019 (5 pallets).
- Orders in week 27 of 2019, deliveries on 03-07-2019 (13 pallets) and 04-07-2019 (2 pallets).

Here, the cumulative size of the deliveries is different. This includes different orders, in which hygiene products and make up products are ordered. The hygiene products are larger of size and thus reserve more pallet space than the make-up products which are smaller of size. Here, the total amount of ordered boxes differs as the pallets space per ordered box, which is the changed input for the mentioned cases.

The input of the weekly orders in the DSTM is defined in table 7.1.

Deliveries week	Distinct items in order	Total order size in boxes	Cumulative pallet space of order
	N	$\sum_{i=1}^{N} O_i$	$\sum_{i=1}^{N} O_i * P_i$
43	114	1672	3,14
52	173	2127	4,26
37	228	3314	7,70
15	317	2745	9,70
27	190	4543	14,13

Table 7.1: Overview of selected orders in 2019 which configure as input for the DSTM

In the scheduled deliveries in 2019, no maximum delivery size was set and all the considered deliveries were delivered at the external storage location. Only by exception small deliveries were delivered at the internal storage location, but these are not considered in these test scenarios. Since deliveries at the external storage location are assumed to be standard, this is considered in the outcome of the model to make it compare with the model performance. Based on the mentioned delivery location, receiving cost can be determined of the deliveries in 2019, which are not taken into account in previous evaluations of cost in the case study of L'Oreal. So, these cost are added up to the transport cost which was reported in 2019 and consists of waiting cost, cost for reserving time slots of the transporting company and delivery size dependent transport cost. The split per cost component of the mentioned scenarios in 2019 is shown in table 7.2

Deliveries	Delivered pallets		Transport	Waiting	Reserving	Receiving	Total cost
week	Store	Kooi	cost	cost	cost	cost	in 2019
43	-	2, 2	€ 147,48	€ 0,00	€ 30,00	€ 167,20	**€ 344,68**
52	-	2, 3	€ 176,38	€ 17,50	€ 30,00	€ 212,70	**€ 406,61**
37	-	5, 3	€ 229,44	€ 70,00	€ 30,00	€ 331,40	**€ 660,84**
15	-	5, 5	€ 311,40	€ 70,00	€ 30,00	€ 274,50	**€ 685,90**
27	-	13, 2	€ 394,95	€ 70,00	€ 30,00	€ 454,30	**€ 949,25**

Table 7.2: Realized cost per scenario in 2019

As shown in table 7.2, every week there are two deliveries scheduled to be delivered at the external storage location. So, the output of decision variables $PU_{j,k,l}$ has been shown in table 7.2 together with the objective value. Since we are not interested on the delivery schedule on product level, $X_{i,j,l}$ is not shown in this figure. The value of total pallet size per delivery is also not shown due to the fact this total pallet size per delivery is not related to a KPI and determines the amount of pallets to be delivered. This is already captured in the second column of table 7.2. The results shown in table 7.2 can be compared to resulting delivery schedule of the DSTM.

7.2.2 Configurations

To perform sensitivity analysis on the developed model, the related parameters in the configuration of figure 7.1 which are not set by hard boundaries in the system are varied to see the effect on the outcome of the model. A sensitivity analysis is going to be executed for the following two parameters; $u_{max,1}$ and F.

The maximum amount of pallet space to be delivered at the internal storage location ($u_{max,1}$) is set 1,5 pallets to limit the amount of goods which are transported to the store. This can be varied due to changing daily sell-out, which results in changing stock space at this location. During holiday periods, the sell-out during the week can be higher, due to more traffic in store. However, during

Parameter	Default value	C1	C2	C3	C4	C5	C6
$u_{max,1}$	1,5	0	1	1,25	1,75	2	3

Table 7.3: Values for different configurations (abbreviated as C) for $u_{max,1}$

regular working weeks, the sell-out is centred during the weekends. Therefore, this limit can vary due to changing the demands. Therefore, the parameter is set to 1,25 and 1,75 pallets, which represents a varying demand due to seasonality. Here, scheduling a second pallet to be delivered can increase or decrease the efficiency, since a changing percentage of goods to be scheduled at this location can be investigated. Besides, rounding off this maximum is going to be evaluated by setting this parameter to 1 and 2 pallets. To investigate the more extreme cases of the model, the parameter is set to 0 and 3 pallets. An overview of the different configuration for this parameter can be observed in table 7.3.

Parameter	Default value	C1	C2	C3
F	0,10	0	0,05	0,20

Table 7.4: Values for different configurations (abbreviated as C) for F

Also, the receiving cost at the external storage location are varied to investigate the effect of this variable on the performance of the model. Here, the receiving cost is dependent on the related transport cost from the store employee to transport the goods to the Kooi to the store. Here, an estimation has been made based on the productivity on the amount of boxes which can be transported per hour, in which cost is related to the cost of the employee. Here, the productivity is doubled and halved, which results in receiving cost of €0,05 and €0,20 per box. Besides, a more extreme situation can be observed by changing this parameter to 0, in which no receiving cost at the external location is presented. The effect of this different kind of configuration is going to be discussed in the sensitivity analysis in section 7.5.

The input of these items has been used in the DSTM to calculate the most optimal delivery schedule. The result can be observed in table 7.1, in which the scheduled deliveries can be observed as well as the receiving cost at the external storage location, which is not shown in the previous table 5.1.

7.3 DSTM performance

In the section, the mentioned input of table 7.1 is feed in the model. The mentioned configuration is mentioned in chapter 6, so the results of the model in this configuration are evaluated. The performance of the model can be evaluated by the mentioned KPI's, which are delivery size and total transport cost. Therefore, the resulting delivery schedule per input is visualized in a table, which shows the delivery size in pallets. Besides, the total transport cost are shown, which will also be shown per cost type (transport cost, reserving cost, waiting cost and receiving cost).

Deliveries week	Delivered pallets Store	Kooi	Transport cost	Waiting cost	Reserving cost	Receiving cost	Total cost
43	2, 1, 1	-	€152,76	€0,00	€45,00	€0,00	€197,76
52	2, 1, 1, 1	-	€192,27	€0,00	€45,00	€0,00	€252,27
37	1, 1	6	€256,49	€7,00	€45,00	€144,60	€453,09
15	1, 1, 1, 1	6	€335,51	€7,00	€75,00	€84,10	€501,61
27	1, 1, 1	6, 6	€473,47	€14,00	€75,00	€252,90	€815,37

Table 7.5: Delivery schedule and cost of DSTM with input of table 7.1

In table 7.6, the KPI's of the resulting schedule of the DSTM are visible, as well as the results in

2019.

	2019			DSTM				
Deliveries	Delivered pallets		Total cost	Delivered pallets		Total cost	Savings	Relative savings
week	Store	Kooi		Store	Kooi		cost	to 2019
43	-	2, 2	€ 344,68	1, 1, 2	-	€ 197,76	€ 146,84	43%
52	-	2, 3	€ 406,61	1, 1, 1, 2	-	€ 252,27	€ 154,34	38%
37	-	5, 3	€ 660,84	1, 1	6	€ 453,09	€ 207,75	30%
15	-	5, 5	€ 685,90	1, 1, 1, 1	6	€ 501,61	€ 184,29	27%
27	-	13, 2	€ 949,25	1, 1, 1	6, 6	€ 815,37	€ 133,88	14%

Table 7.6: Comparison of delivery schedule and cost of DSTM vs 2019

7.4 Detailed analysis per input scenario

In this section, the results shown in tables 7.5 and 7.6 are going to be discussed and compared.

7.4.1 Performance per input

In this subsection, the performance of the DSTM shall be evaluated. The defined KPI's in the previous chapter are being used to measure the performance of the delivery schedule in 2019 and compare it to the performance of the DSTM. An overview of these KPI's is shown in table 7.1. First, the performance of the DSTM evaluated per input scenario is going to be discussed with the performance of 2019. Afterwards, a comparison will follow on the output of the DSTM in different scenarios.

- Week 43. Considering the input of week 47, a small difference in the delivery schedule of the DSTM and the schedule in 2019 can be reviewed. One more delivery has been scheduled by the DSTM, of which all the deliveries has been done to the store. Therefore, savings have been made on the receiving cost, which compensate the extra made reserving cost and result in a total savings of € 146,92, which is shown in table 7.7.

Delivery week 43	Transport cost	Waiting cost	Reserving cost	Receiving cost	Total cost
DSTM	€ 152,76	€ 0,00	€ 45,00	€ 0,00	€ 197,76
2019	€ 147,48	€ 0,00	€ 30,00	€ 167,20	€ 344,68
savings	*€ -5,28*	*€ 0,00*	*€ 15,00*	*€ 167,20*	*€ 146,92*

Table 7.7: Comparison of performance DSTM and 2019 of order of week 43

- Week 52. The scenario of the order 52 resulted in a savings of almost 40 % when scheduling the deliveries via the DSTM. This is due to the savings on receiving cost at the external storage location, which can be reduced by scheduling the deliveries to the store. Therefore, extra cost made on reserving cost and extra transported pallets, which includes a smaller amount than the saved receiving cost.

Delivery week 52	Transport cost	Waiting cost	Reserving cost	Receiving cost	Total cost
DSTM	€ 192,27	€ 0,00	€ 45,00	€ 0,00	€ 252,27
2019	€ 176,38	€ 17,50	€ 30,00	€ 212,70	€ 406,61
savings	*€ -15,89*	*€ 17,50*	*€ -15,00*	*€ 212,70*	*€ 154,34*

Table 7.8: Comparison of performance DSTM and 2019 of order of week 43

- Week 37. The input of the order of week 37 was scheduled in 5 small deliveries of maximum 2 pallets by the DSTM. Here, the deliveries to the store of two pallets were not allowed to schedule goods of at most 1,5 pallet space of boxes per delivery. Therefore, two pallets have been transported, but including a full pallet of 'unused' pallet space in total. However, extra transport have been made to reduce the receiving cost by €186,80. So, the extra transport cost for transporting more pallets can be compensated by the mentioned savings, which is due to the relatively high amount of boxes to be transported including low volume of pallet space.

Delivery week 37	Transport cost	Waiting cost	Reserving cost	Receiving cost	Total cost
DSTM	€256,49	€7,00	€45,00	€144,60	€453,09
2019	€229,44	€70,00	€30,00	€331,40	€660,84
savings	*€-27,05*	*€63,00*	*€-15,00*	*€186,80*	*€207,75*

Table 7.9: Comparison of performance DSTM and 2019 of order of week 37

- Week 15. Here, two deliveries in these week of 5 pallets per deliveries have been rescheduled by the DSTM to 4 smaller deliveries of 1 pallet and one large delivery of 6 pallets. Here, savings have been realized on waiting cost (€-63)and receiving cost (€-190,40), while the transport cost (€24,11) and reserving cost (€45,00) increased. Savings are realized since more deliveries have being scheduled, in which the largest delivery has low waiting cost. Besides, less receiving cost are being determined due to a high amount of products scheduled to be delivered at the store (1904) while less products (841) are delivered at the Kooi.

Delivery week 15	Transport cost	Waiting cost	Reserving cost	Receiving cost	Total cost
DSTM	€335,51	€7,00	€75,00	€84,10	€501,61
2019	€311,40	€70,00	€30,00	€274,50	€685,90
savings	*€-24,11*	*€63,00*	*€-45,00*	*€190,40*	*€184,29*

Table 7.10: Comparison of performance DSTM and 2019 of order of week 15

- Week 27. In this scenario, two large deliveries have been scheduled and three relative small deliveries by the DSTM. However, the largest scheduled delivery by the DSTM was only half of the size in pallet space of the scheduled delivery in real life. Therefore, savings are made on waiting cost and receiving cost. The smaller deliveries include 2014 boxes to be shipped in total to the internal storage location, which is done by transporting 3 pallets. For scheduling the other 2529 boxes, many more pallets are being transported to the external storage location. However, still savings are being made compared to the result of 2019 due to lower receiving cost. An overview of the savings per cost type can be defined in table 7.11.

Delivery week 27	Transport cost	Waiting cost	Reserving cost	Receiving cost	Total cost
DSTM	€473,47	€14,00	€75,00	€252,90	€815,37
2019	€394,95	€70,00	€30,00	€454,30	€949,25
savings	*€-78,52*	*€56,00*	*€-45,00*	*€201,40*	*€133,88*

Table 7.11: Comparison of performance DSTM and 2019 of order of week 27

7.4.1.1 Comparison

Comparing the output of the DSTM using different inputs is next to discuss in this section. An overview on the cost components per input scenario can be observed in figure 7.3. Savings are realized by scheduling the deliveries via the DSTM, in which the following behaviour can be observed in table 7.6. The amount of deliveries has increased to more than two deliveries per week, due to the limit on the delivery size and defined cost structure. These smaller deliveries are mostly of 1 or 2 pallets in total, which can be scheduled without any waiting cost. Preferably, these pallets are scheduled to the store, in which also no receiving cost are defined in the cost structure. If larger deliveries are scheduled, a delivery of 6 pallets can be observed. This is due to the low included waiting cost for a delivery of this size and a lower tariff per pallet, which is due to quantity discount. However, a delivery of this size has to be scheduled to the external storage location, in which the amount of items to be shipped should be as low as possible to be able to reduce the receiving cost. These savings made on scheduling more boxes of smaller size to the store results in overall savings, which concludes the comparison on the output of the DSTM.

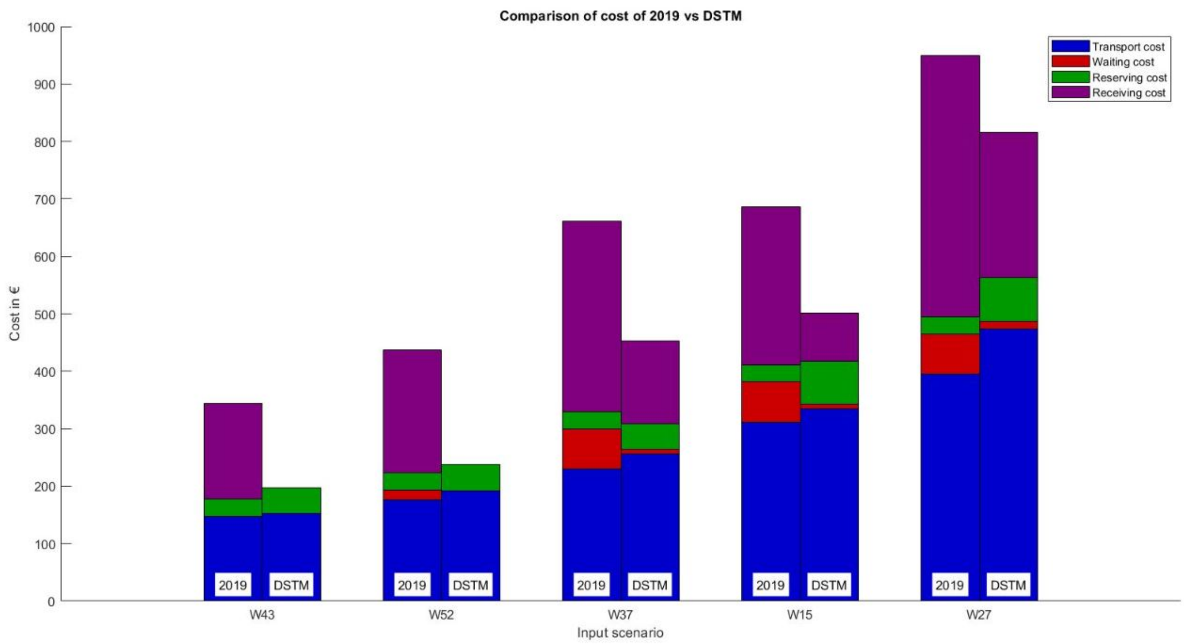

Figure 7.3: Cost per input scenario for 2019 vs DSTM

Considering the input sorted which is size based, gives an indication that the total cost raises, but there could be questioned if any quantity discount can be observed in the pattern of figure 7.3. Therefore, the total cost scheduled by the DSTM has been divided by the total order size in pallets and is shown in figure 7.4. Here, a decreasing pattern occurs, which is observed for the case of 2019 and DSTM. Here, higher relative savings can be observed for smaller deliveries by scheduling deliveries by the DSTM, but still the quantity discount can be observed in which the relative savings for high quantity by the model is lower than in 2019. For the DSTM, the savings in which input scenario of week 15 shows outstanding savings, which has an order size of 9,70 pallets. Savings have especially been made due to lower receiving and waiting cost. Here, the average cost per ordered pallet increases for the DSTM in the input scenario of week 27. This can be due to scheduling multiple smaller deliveries of 1 pallets, which raises the transport and reserving cost. Besides, more products are ordered, which results in higher receiving cost at the external storage location. Therefore, an order of this size is not optimal according to the average cost per ordered products in pallets. Therefore, this behaviour can be further investigated in further researches to see if a minimum can be observed in the average transport cost per pallet.

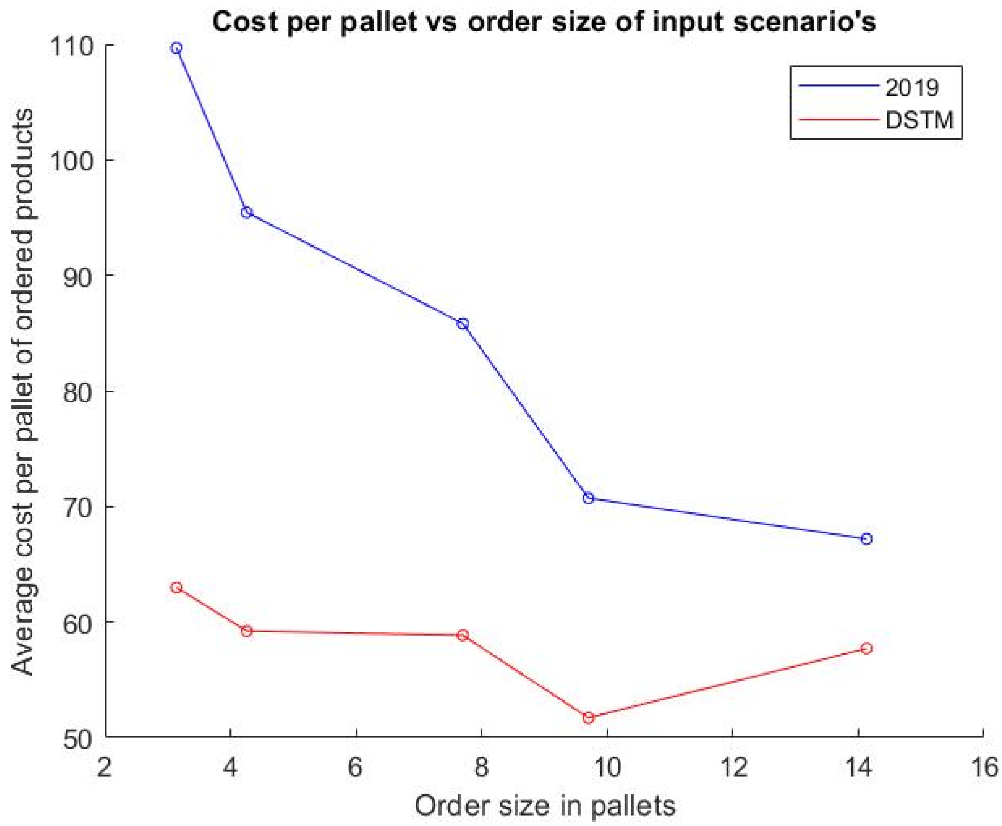

Figure 7.4: Relative cost per order size in pallets per input scenario

7.5 Sensitivity analysis

Next, the mentioned variants of configurations are investigated while using different input scenarios. The role of parameter $u_{max,1}$ is going to be investigated by forming a hypothesis on the effect of changing this parameters to the mentioned values. Then, the configuration can be set in the model and the mentioned design alternatives are feed in the model. Afterwards, the results are evaluated and compared to the stated hypothesis. If this is done, a similar investigation will follow for parameter F.

7.5.1 $u_{max,1}$

As already discussed, the sensitivity analysis for parameters $u_{max,1}$ is going to be investigated in this subsection.

7.5.1.1 Hypothesis

Parameter $u_{max,1}$ has been set to limit the volume of goods to be delivered to the internal storage location, due to the limited size of the stock room. The benefit of delivering goods to this storage location is that no receiving cost are included for transporting the goods to this storage location. When lowering this parameter to 1 or 1,25 pallets or increasing it to 1,75 or 2 pallets, a direct effect will become visible in the scenarios of week 43 and 52. Here, the DSTM scheduled deliveries of 2 pallets to the internal storage location, which means that there are goods scheduled on the second pallet to be delivered at this storage location. However, if this parameter can be changed, more or less goods are allowed to be transported via a single delivery to this storage location. When decreasing the mentioned parameter, the objective function will raise in these cases.

In the scenarios of the input of week 15, 27 and 37, a direct impact is not expected when changing this parameter to 1 or 1,25 pallets, since the DSTM did not schedule deliveries of 2 pallets to the store. However, when raising this parameter to 1,75 or 2 pallets, another consideration will become important. Here, the savings on receiving cost are compared to the extra transport cost when scheduling more deliveries to the external storage location.

Considering the most extreme values for the mentioned parameter, more cost are expected in all scenarios when no deliveries are allowed at external storage location. In all cases, deliveries have to be rescheduled in which more receiving cost are made, which increases the objective value. When rescheduling the deliveries by raising the cumulative pallet space per delivery at the internal storage location to 3 pallets. In all scenarios, scheduling less deliveries of bigger size to the internal storage location shall be questioned to be as cost efficient as possible. Dependent on the behaviour of the model when raising the parameter to 1,75 and 2 pallet, the effect of changing the parameter to 3 pallets can be explained.

7.5.1.2 DSTM performance

In table 7.12, an overview is being shown of the delivery scheduled deliveries by the DSTM using design alternatives for parameter $u_{max,1}$ can be observed.

$u_{max,1}$	0		1		1,25		1,75		2		3	
week	S	K	S	K	S	K	S	K	S	K	S	K
43	-	4	1, 1, 1, 1	-	1, 1, 2	-	2, 2	-	2, 2	-	2, 2	-
52	-	5	1, 1, 1, 1, 1	-	1, 1, 1, 1, 1	-	1, 2, 2	-	1, 2, 2	-	2, 3	-
37	-	2, 6	1, 1	6	1, 1	6	1, 1	6	2, 2, 2, 2	-	2, 2, 2, 2	-
15	-	4, 6	1, 1, 1, 1	6	1, 1, 1, 1,	6	1, 1, 1, 1	6	2, 2, 2, 2, 2	-	2, 2, 2, 2, 2	-
27	-	3, 6, 6	1, 1, 1	6, 6	1, 1, 1	6, 6	1, 2, 2	4, 6	1, 2, 2	4, 6	3, 3, 3, 3, 3	-

Table 7.12: DSTM delivery schedule for design alternatives of $u_{max,1}$

In figure 7.5, an overview is being shown of the objective value of the DSTM using design alternatives for parameter $u_{max,1}$ can be observed.

7.5.1.3 Role of $u_{max,1}$

Next, the configurations are discussed one by one to see the effect on the delivery schedule and the KPI's;

- C1. Here, no deliveries are allowed to the internal storage location. Therefore, the objective value raises due to the receiving cost. Besides, larger deliveries are scheduled than in the reference case, which is also not desired.
- C2. No effect can be observed in the first three scenarios since no deliveries of more than 1 pallet were scheduled by the DSTM in the default configuration. In the last two scenarios more smaller deliveries are scheduled due to this lowered parameter, which results in more cost in both cases.
- C3. A similar pattern can be observed in the third mentioned configuration as in the second configuration. For the deliveries of week 15, 27 and 37, no change in the delivery schedule can be observed. In the scenario of week 43, no change can be observed since the second delivery contains less than 1,25 cumulative pallet space of products. In the scenario of week 52, higher cost are made due to more deliveries of smaller size which is due to the chance of the mentioned parameter.
- C4. In the last scenario, differences can be observed in the delivery schedule of the DSTM. In all the other scenarios, the original delivery schedule of the default configuration stays the

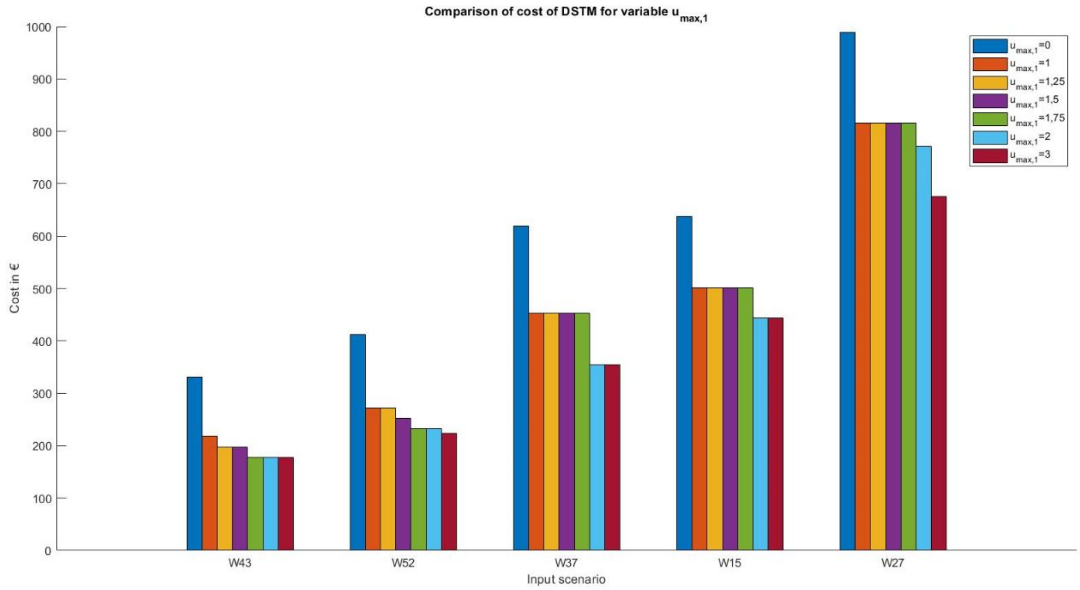

Figure 7.5: Objective value of DSTM for design alternatives of $u_{max,1}$ per input

most optimal schedule. Only in the last scenario, combining deliveries to the internal storage location leads to a cost reduction.

- C5. In this configuration, savings are realized in all configuration. Due to the fact that 2 fully loaded pallets to the internal storage location can be delivered, the delivery schedule differs from the one in the default configuration. Especially in the large delivery (week 15, 27 and 37), savings are realized which have not been observed in previous configurations. For the last two scenarios, the same delivery schedule as in C4 can observed.
- C6. In this configuration, larger deliveries are scheduled to the internal storage location in week 27 and 52. Here, the saved receiving cost compensate the extra expected waiting cost of a delivery of this size. In the other scenarios, the same delivery schedule can be observed as in C5.

In figure 7.6, an overview can be observed on the average pallet cost per ordered products in pallets. Here, a decreasing pattern can be observed for all scenarios, which confirms that the average cost per ordered pallet of products decreases when increasing this parameter. Here, having more data points in the range of $u_{max,1}$ is an explanation why the lines cross in this part of the figure. When the optimal delivery schedule changes due to a different parameters, savings are realized which results in a drop of the line. Due to this parameter in only used a single time in one constraint equation and this maximum is increasing only, optimal solutions stay valid as the parameter increases in which only more optimal delivery schedules can be found. Therefore, a decreasing line can be found, in which again the scenario of week 15 has the lowest average cost due to the relatively high amount of products ordered and a low amount of products shipped.

In the comparison mentioned above, conclusions will finalize this part of the sensitivity analysis. When no delivery can take place at the internal storage location, the cost will raise due to more receiving cost. In configuration 2 and 3, the larger deliveries of 6 pallet for the input scenarios of week 15, 27 and 37 stay the most optimal delivery schedule. Only a small increase of cost can be observed for the smaller orders of week 43 and 52. When raising the order volume to be delivered in one delivery to the internal storage location, savings can be realized. Here, the maximum amount of delivered pallets is scheduled by the model to reduce the receiving cost in both configurations.

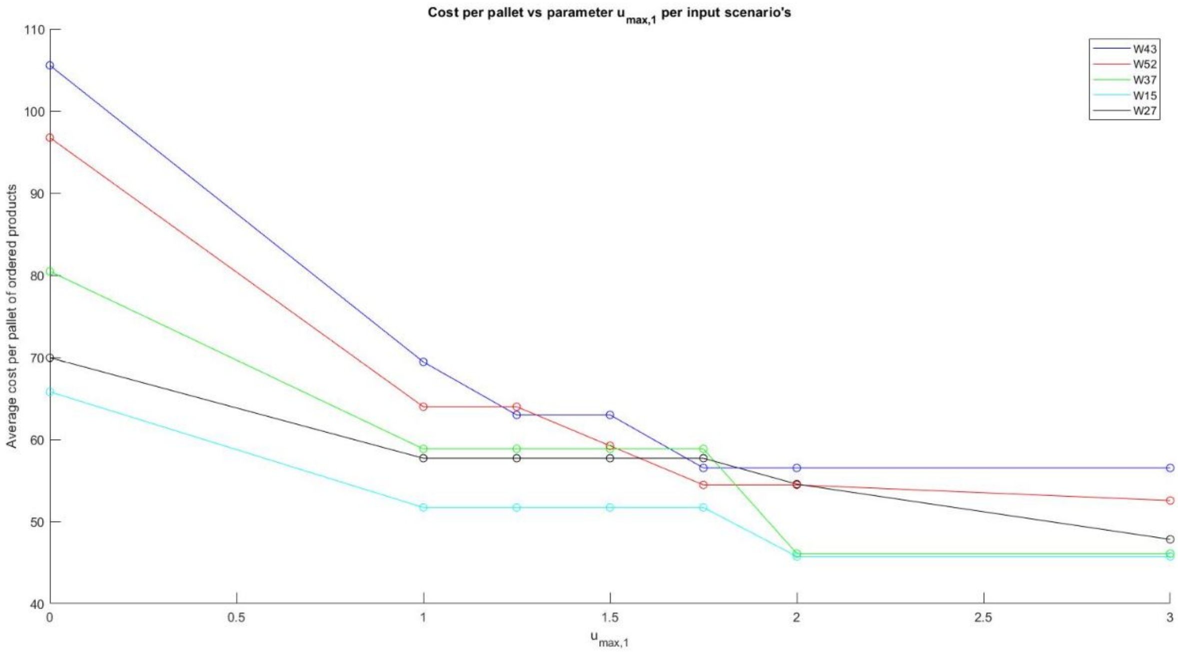

Figure 7.6: Average transport cost per pallet of DSTM for design alternatives of $u_{max,1}$ per input

In the scenarios of week 15, week 37 and week 43, a further increment of the parameter from configuration 5 to configuration 6, since more waiting cost are related to a delivery of 3 pallets in total. Considering the delivery size as KPI, in configuration 4, 5 and 6, more deliveries of 2 or 3 pallets are scheduled, while this used to be 1 and 6 pallets in the default configuration. Therefore, the maximum delivered pallets for delivery is being lowered and the deliveries are more common in size. The effect on the workload on the store personnel could be a topic for further investigations.

When raising the delivery capacity at the internal storage location to 3 pallets, no deliveries are scheduled to the external storage location. In this case, there could be investigated if the external storage location can be closed, due to the fact that no deliveries are scheduled to this location. Having one storage location less reduces the complexity and makes life easier for the store personnel. However, from a practical point of view, there could be questioned if there is sufficient storage space presented at this location, in which the daily sell out can be less than the products delivered. Besides, having too much stock at this location may lead to less overview for the store personnel. Therefore, an extension of the model which takes into account the available storage space for the internal storage location, can lead to a more detailed conclusion on the possibility to close the external storage location.

7.5.2 F

As already discussed, the design alternatives for parameters F are going to be investigated in this subsection.

7.5.2.1 Hypothesis

Changing the receiving cost parameter F, defined in € /box, is going to be done to investigate how deliveries are rescheduled when changing the objective function. When this parameter is lowered to € 0/box and € 0,05, scheduling more boxes to the internal storage location will include less cost. Therefore, the objective function will decrease if deliveries are scheduled to the Kooi, which was done by the DSTM in scenarios of week 15, 27 and 37. Besides, when changing this parameter to 0, deliveries to the internal and external storage location are identical in the model, which means that larger deliveries can be scheduled without receiving cost. In the other configuration, scheduling larger deliveries can be checked on cost effectiveness by the model. Here, there can be questioned if more and larger deliveries to the internal storage location are more cost effective. Raising this parameter to €0,20/box will lead to scheduling more smaller deliveries to the internal storage location, since the receiving cost of the original delivery schedule can be much more. Due to the fact that many small boxes are being ordered, doubling the receiving cost while a limited amount of goods can be scheduled to the internal storage location, will lead to a higher objective values when deliveries are scheduled to the external storage location.

7.5.2.2 DSTM performance

In table 7.13, an overview is being shown of the delivery scheduled deliveries by the DSTM using design alternatives for parameter F can be observed.

F	0,00		0,05		0,20	
week	S	K	S	K	S	K
43	-	4	1, 1, 2	-	1, 1, 2	-
52	-	5	1, 1, 1, 2	-	1, 1, 1, 2	-
37	-	2, 6	1, 1,	6	1, 1, 2, 2	3
15	-	4,6	1, 1, 1, 1	6	1, 1, 1, 1	6
27	-	3, 6 ,6	1, 2	6, 6	2, 2, 2	4, 6

Table 7.13: DSTM delivery schedule for design alternatives of F

When changing the value of the F to a €0,20/box, the resulting objective value of the DSTM is shown in figure 7.7.

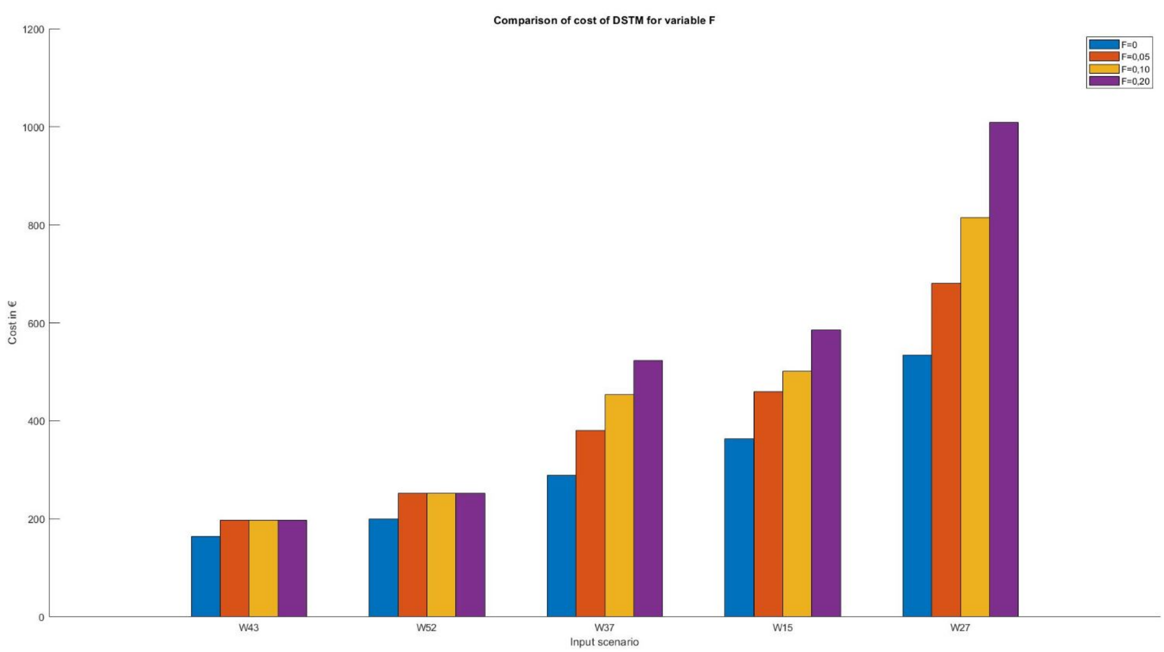

Figure 7.7: Objective value of DSTM for design alternatives of F per input

7.5.2.3 Role of F

Next, the configurations are discussed one by one to see the effect on the delivery schedule and the KPI's;

- C1. In the first configuration, all the deliveries have been rescheduled to the largest possible deliveries. This is due to the fact that scheduling more deliveries includes more reserving cost. However, still savings are being made compared to the default configuration, which can be due to no receiving cost. In this configuration, larger deliveries are scheduled, which is not desired.
- C2. In this configuration, the delivery schedule in the second scenario is the only configuration in which the delivery schedule changes (two deliveries to the internal storage location are combined). In the first and third scenario, the objective value decreases due to lower receiving cost. In the last two scenarios, no changes can be observed due to no delivery at the external storage location in the original delivery schedule.
- C3. In this configuration, still nothing changes on the delivery schedule and objective value of the scenarios of week 43 and 52. In the other scenarios, the objective value increased due to higher receiving cost. This leads to a rescheduling of delivery for the scenarios of week 27 and 37. These smaller deliveries to the internal storage location lead to more transport cost, but reduces the receiving cost.

In figure 7.8, the average transport cost per ordered products of pallet for the set configurations and input scenarios are shown. Here, the average cost per pallet increase when raising the parameter F, until a limit has been reached for certain scenarios. This limit occurs when no pallets are scheduled to the external storage location for week 43 and 52. Changing this parameter has no effect on the total cost, which does also not change the average cost per pallet. In all the other scenarios, orders are scheduled to the external storage location, in which receiving cost are still valid. A similar increasing line can be observed, which is due to a certain number amount of products delivered at the external storage location. Here, the order of W15 shows the lowest cost per ordered pallet of products, which is due to the relatively high pallet space and low amount of products. Here, the effect of the receiving cost is lower since less products are shipped to the external storage location while scheduling transport can be done via a single large deliveries and multiple small deliveries. However, in the third scenario C3, the smallest order of scenario W43 and W52 have a lower average cost per ordered products in pallets than scenario W37 and W27. This is due to the fact that these orders are larger and deliveries have to take place at the external storage location. Therefore, the effect on changing the parameter of the receiving cost is large and raises the average cost per ordered products in pallets. Therefore, quantity discount does not occur in all cases for the different configurations.

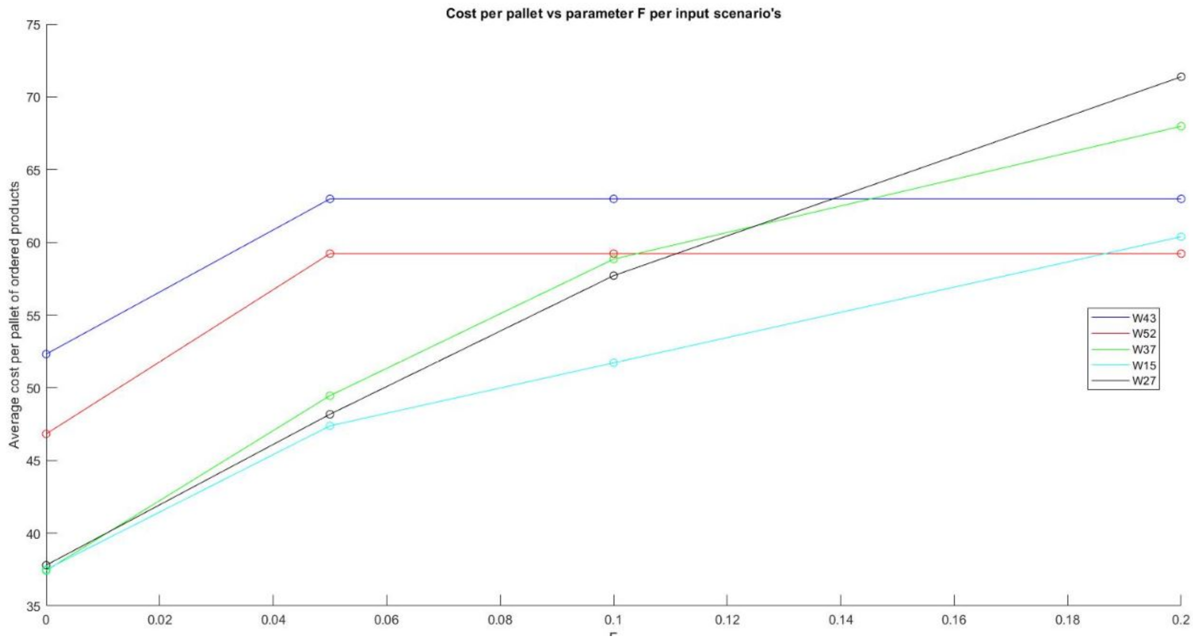

Figure 7.8: Average transport cost per pallet of DSTM for design alternatives of F per input

As visible in table 7.13 and figure 7.7, the objective values of the first three scenarios has changed in all configurations. The effect of this parameter is only visible in situation in which the DSTM schedules deliveries to the external storage location in its default configuration. Raising the cost will lead to more goods which are delivered at the internal storage location. Lowering the receiving cost tariff to a value of 0,05 will not have an effect of the delivery schedule in a remarkable amount. When the parameter has been set to 0, the delivery sizes increase since their can be delivered to the external storage location without any extra cost.

7.6 Conclusion

In this section, experiments have been performed with the DSTM. First, different scenarios are introduced, including their input values. Then, design alternatives for the model introduced to be able to vary the configuration of the model. Afterwards, the result of the DSTM has been analyzed and compared to the KPI's of the deliveries in 2019. This is done per scenario, in which the results of the DSTM has been compared in the end. A sensitivity of two parameters finalizes this section. Here, increasing $u_{max,1}$ can lead to savings, which can be done by splitting up a large delivery of 6 pallets to multiple smaller deliveries in certain scenarios. Therefore, there can be investigated what the role of this outcome is in the transport problem. The role of the receiving cost parameter is on forcing the model to see if scheduling to the external storage location becomes less or more attractive. If this parameter is being raised, more goods will be delivered to the internal storage location, which raises the objective value.

The research question which should be answered in this section is; "Which savings can be realized by scheduling transport according to the described transport model for replenishing the factory outlet store of L'Oreal?". Savings can be realized organizing the deliveries of the ordered goods by the DSTM, in which the objective is to minimize the included costs. Here, transport cost of pallets, waiting cost, reserving cost and receiving cost are taken into account. Based on different input scenarios, savings up to 43% can be made, in which the receiving cost and waiting cost are the main cost components which can be reduced.

8 Conclusion and recommendation

In this section, the research questions will be answered and the result of this report will be evaluated. This will be done by a conclusion and recommendation in this chapter.

8.1 Conclusion

In the second chapter of this research, a literature has been performed to investigate supply chain management and replenishment strategies. Here, outlet supply chains have been investigated to see which supply chain aspects are differing for this type of supply chain. An outlet supply chain differs from a regular push based retail supply chain on the assortment, in which the outlet does not sell the same products as regular retailers or stores. Big brand names like L'Oreal have an outlet store to sell their excess stock, which is done in a retail environment. These assortment of excess can be combined with exclusive merchandise from the brand to make an outlet store more attractive for the customers, which can be added next to discount on the offered products. For this outlet store, the assortment is varying due to the goal of emptying the stock of the warehouse or selling returned products, which can also be done at an outlet store. Therefore, replenishment should be focused on having sufficient stock at the store to sell of this excess stock, which has a set total stock amount at the warehouse which can be sold.

In a push supply chain, which is used for retailers in outlet store, different kind of replenishment strategies are used. Different replenishment policies are introduced, as well as well know theoretical concepts like EOQ and KOQ. For the mentioned replenishment policies, review period of the stock, safety stock level and replenishment quantity are parameters which can be tuned. For these stock levels, many options are possible based on the lead time and estimated demand.

For the L'Oreal factory outlet store, the following replenishment strategy is used. On a weekly review, orders are placed for replenishment according to the $\{R,S,Q_{min}\}$ policy. Here, a demand forecast is calculated based on a moving average of sell-out during the last 10 weeks times a factor. This factor is calculated on the sell-out of the last week and determines if 1,2 or 3 weeks of stock is desired to have on stock. Besides, a minimum order quantity has been set on 6 units, which is a full box of products to be ordered. This replenishment policy results will be reviewed by the store personnel, which know the best what they want to sell during the coming week. Based on this outcome, orders are being placed which are delivered in two weekly deliveries in the current situation.

For modelling the replenishment order based transport process of the factory outlet store, a mixed integer linear programming method can be used due to the limited amount of randomness included in the model. Due to pinning the orders, the delivery schedule can be determined via a model in which the minimum amount of cost should be involved. Here, a stepwise cost function was modelled due to transport cost per pallet, expected waiting cost per delivery size and reserving cost per delivery. All these cost types determine the stepwise cost function value based on the delivery size. The introduced model is unique due to the fact that two storage locations are considered, which belong to the same vendor. Here, extra receiving cost are taken into account due to the extra related transport cost to the other storage location, which has a different capacity set on maximum delivery set. Therefore, a scientific contribution can be recognized, which has been investigated with stepwise cost function based on different cost aspects.

This transport process can be captured in a model, which schedules the amount of pallets to be delivered at the internal and external storage location. Therefore, a situation in which this model can be applied should have stepwise scheduled transport equipment in a two vendor system with possible multiple storage location at the destination. Here logic can be implemented on scheduling pallets and its cost, in which several cost types should be taken into account. These are transport cost, waiting cost, reserving cost and receiving cost.

Savings can be realized by scheduling the transport of the replenishment orders by the DSTM. Due to scheduling more smaller deliveries to the internal storage location or delivering one large delivery of 6 pallets, waiting cost can be saved. Besides, receiving cost can be lowered by scheduling a relatively high amount of boxes to the internal storage location in small deliveries, which lowers the receiving cost.‘

So, the main research question can be finally answered. The performance of the transport process of replenishing the factory outlet store of L'Oreal can be optimized by scheduling the deliveries via the DSTM. Here, savings can be realized in splitting up the deliveries in smaller deliveries, which includes less waiting time and cost for the truck driver. Besides, by scheduling small deliveries to the store, the workload for the store personnel decreases, as well as the receiving cost to transport goods from the external to the internal storage location. 5 scenarios have been selected which include different weekly orders and characterize the order pattern of the store in a year, in which the order amount and size differ due to changing demand. In all 5 scenarios, the delivery schedule determined by the DSTM shows savings, which is mainly due to lower receiving and waiting cost while increases the reserving and transport cost a bit. However, these extra cost on the mentioned cost components are lower than the savings on receiving and waiting cost. Therefore, the set configuration has been set and shows that savings have been made in these scenario, in which an optimization have of the transport process have been executed.

The designed model is the result of this model, which has been specified for the case study of L'Oreal. Here, a configuration has been set which seems to be most suitable for the case study of L'Oreal. In the sensitivity analysis of this research, the variables which are not set by hard boundaries are varied to be able to investigate the effect of different configurations of the model. Based on the outcome of this, changes in the case study and set model configuration has been explored. Here, knowledge is gained on the direction in which parameters should be changed to be able to increase the performance of the model. Lowering the receiving cost at the external storage location and increasing

8.2 Recommendation

The recommendations of this research will be split up in scientific recommendations for further research and recommendations for the company of the case study.

Further research can be done of the role of the input, in which also the margins of packing efficiency can be taken into account. Here, the pallet space per box can be questioned and set withing certain boundaries, which effects the overall outcome of the model. This could be investigated in more detail. Besides, the stock space at the both locations can also be restricted and can be dependent on the sell-out. In this way, the capacity restriction at the internal storage location can be taken into account in more detail. Besides, periodic behaviour could be included in the replenishment strategy, since seasonality is presented in the outlet stores. However, due to changing trends and assortment, this might be hard to capture in detail but this could lead time to more accurate orders.

A reflection on the selected input scenarios is that a variation in orders products in pallet size is varied, in which 5 scenarios are selected. However, investigating deep in the role of this parameter can be done by choosing more order sizes and multiple inputs of the same order size. This could be based on the shown frequency of ordered products in terms of pallet size, shown in figure 7.2. There could be investigated if the expected behaviour is characteristic and reliable for varying inputs. Having only 5 scenarios of input have been investigated in this research, but no hard conclusion can be made on the total savings on a yearly basis and the expected savings per input scenario. Here, the pattern of quantity discount can also investigated in more detail to see which if any order size range results in minimal transport cost per ordered pallet of goods, in which the role of input will be further investigated. This could be a deep dive topic in further research.

Besides, further research can be done of the possibility to close the external storage location and see what the effect is of having a single storage location. Here, the stock capacity should be considered in detail to see how the order and delivery schedule can be optimized in this situation. Complexity regarding stock management can be reduced by having only one storage location, which saves also cost in terms of receiving cost. However, having only one location could require deliveries every day a week to be able to keep up with the sell-out, which can be hard in high traffic times. The DSTM can still be used in this configuration, in which the delivery schedule to the internal storage location can be obtained.

For L'Oreal, there should be questioned if the proposed DSTM can be integrated automatically, in combination with the replenishment strategy. For now, manual orders have to processed, in which several steps could be automated in the ordering processes. However, communication with the most important eyes on the outlet floor (the store personnel) stays important to be able to have a successful collaboration between outlet business and supply chain.

Appendix A

Master Thesis Assignment
Mechanical Engineering, Track: Transport Engineering and Logistics

Optimizing transport scheduling for replenishing a single vendor with multiple storage locations

A case study for replenishing the factory outlet store of L'Oreal

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Abstract. Supply chain studies are widely available in literature, in which many developments have been described. The role of data is getting more and more important in the supply chain, in which data-driven approach can lead to higher efficiencies or less cost. In this research, the transport process for replenishment purposes will be investigated. By making use of available data on ordered items, deliveries can be scheduled to reduce the related transport cost and delivery sizes. Here, delivery sizes are wished to be reduced to lower the workload of the store personnel during deliveries. Therefore, we present a mixed integer linear programming model for this problem for scheduling the deliveries of replenishment orders as cost efficient as possible, when transport cost, waiting cost, reserving cost and receiving cost are taken into account.

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1 Introduction

When considering a physical goods which sells fast moving consumer goods (FMCG) to consumers, the customers immediately want to buy the product when they are the physical store. If they decide to buy a certain product, they expect that there will be sufficient stock to keep up with the demand of the required product. Therefore, a sufficient amount of goods should be presented, which can saved in the stock room of the store. However, what will be a sufficient amount of stock to be able to foresee each customer of its specific demand? And which process is behind foreseeing the store of a sufficient amount of goods? These questions will be a key topics of this research on factory outlet stores.

Factory outlet stores are an unique type of shopper experience due to the connected brand names to an outlet centre [Jones et al., 1997]. Here, big brands locate a store within an outlet centre, which results in a shopping facility including shops of big brands. These brands usual sell their product to retailers, but consumers can buy their products directly from a brand at such a store. Here, the term outlet can be used due to the high discount of which these brands sell their products to consumers. According to Ngwe, brands are offering a different assortment than regular retailers at this shop. They combine excess stock, replaced products, returned goods and less desirable goods in combination with exclusive merchandise against high discount [Ngwe, 2017]. Therefore, the supply chain must be a push based strategy due to the fact that the products have to be presented when products want to buy it. A nice example of this is that suncare should be on stock when the sun is out, since consumers want to use this product immediately.

However, the assortment of these products changes due to stock outs of the excess stock and different kinds of returned products at different times. Therefore, replenishment of the stock of the outlet store must be flexible to have a sufficient amount of stock at the stores to be able to keep up with the demand. Orders can be placed at the warehouse of the brand to replenish the stock. Replenishment policies should be able to indicate how many products should be ordered. Here, the related cost for replenishing the outlet should be minimized. In the performed case study of this research, relatively high cost were observed fo transporting replenishment orders compared to regular retailer orders from the warehouse perspective of the L'Oreal DC.

Therefore, a model will be developed in this research to optimize the performance of transport processes for replenishment orders with multiple storage locations. Therefore will be investigated what is known in literature on delivery scheduling models for transport processes for replenishment in chapter 2. In section 3, an analysis will be made on the supply chain of an outlet store and the transport process in this supply chain. In section 4, the designed model will be introduced. With this model, experiments are performed in the case study of L'Oreal in section 5. A conclusion and discussion will follow in sections 6 and 7.

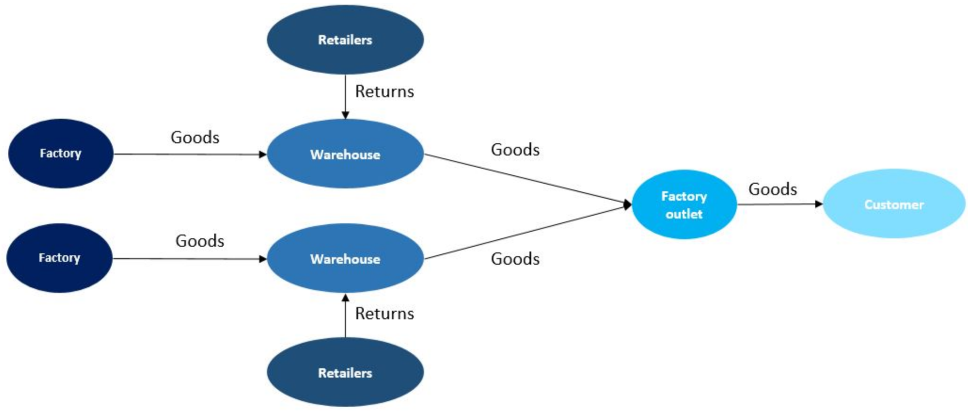

Fig. 1. Factory outlet supply chain

2 Literature review

In literature, replenishment processes can be split up in three different topics [Zhao et al., 2020]; inventory, order fulfillment and transport. These topics are discussed one by one to be able to analyze the supply chain of a factory outlet store. The aspect inventory is related to the decisions on how many products are ordered and at which frequency orders are being placed [Ge et al., 2019]. Here, supply chains in which multiple distinct items are considered, increases the complexity of the mentioned decisions compared to single item supply chains. For multi item supply chains, suggested economic order quantities (EOQ) [Sitepu et al., 2019] can be used to help to place orders. However, replenishment policies are more popular for this type of supply chains, in which a continuous or periodic review of the stock level can be considered [Kabadayi and Keskintürk, 2012,Kumar et al., 2013]. Based on this review type, replenishment policies can be applied on desired stock level, minimal stock level and minimum order quantity.

For the order fulfillment of replenishment process, the warehouse should be able to handle the replenishment orders. Here, the integration of these orders should be aligned with the processes in the warehouse, which also receives orders from regular customers. Since the warehouse is responsible of managing the order replenishment orders, which will not be further zoomed since this includes several processes within a warehouse.

What is the aspect which will be investigated in detail, is the transport process for moving the goods from the warehouse to the shelves of the store. Here, transport includes cost since transport equipment has to be scheduled to the store. However, scheduling transport can be done in various ways, which have been captured in models found in literature. In the joint replenishment problem (JRP), considers the scheduling of transport for replenishment orders for multiple goods [Lin et al., 2019]. Here, reduced tariffs are presented when larger orders are being placed. Besides, the model schedules deliveries in which backorders and lost sales are possibilities to postpone certain orders. Besides, also receiving cost for inspection are taken into account and dependent on the amount of distinct items ordered per delivery [Nagasawa et al., 2013]. Another transport model found in literature is the newsvendor. Here, an unknown demand is being faced while orders have to be placed. Understock and overstock both include a cost aspect, as quantity discount is presented on the order size [Zhang et al., 2019]. Therefore, decisions have to be made on scheduling deliveries and which quantities should be ordered. The last introduced model from literature is the modular hub location problem, in which hubs have to be located to make as less transport cost as possible. Here, transport should be scheduled between the different origins, hubs and destinations to see how an optimal network can be designed [Tanash et al., 2017]. The focus in this problem is on scheduling transport between nodes in the network. In all problems, stepwise transport cost have been implemented due to a integer amount of trucks or routes have been scheduled.

3 Outlet supply chain analysis

The gained knowledge in literature will be used to analyse the supply chain for factory outlet stores. A network as shown in figure 1. Here, factories supply the warehouses by stock, which can become excess stock at a certain point when it can be sold in the outlet. Besides, retailers return goods to the warehouse due to the fact that they order a new collection of product in accordance with the brand. Then, these products can be ordered by the outlet store for replenishment orders to sell the goods to the consumers.

In this research, the focus will be on the transport process from the warehouse to the factory outlet store. Here, orders are being placed based on a replenishment policy introduced in section 2. This order can be delivered all in once or in smaller deliveries. Since the products have to be stacked on pallets per delivery, scheduling of pallets to be delivered at several moments can be done to make the transport as cost efficient as possible. Deliveries can be scheduled to two storage location, which are the internal storage location, located behind the store, and an external storage location. The last mentioned storage location has a higher storage capacity since more storage space is available. Therefore, larger deliveries can be scheduled to this location. Cost are presented based on the amount of pallets scheduled as transport cost. Besides, cost are presented as reserving cost per delivery, waiting cost due to the unloading time of the delivery and receiving cost. All these cost are dependent on the agreements and tariffs of the transport company, which have been investigated at the supply chain of L'Oreal. Therefore, a stepwise cost function can be recognized. Here, a model will be realized to schedule the amount of deliveries, the amount of pallets per delivery and the location of the delivery while minimizing the total cost. Since the decisions should be made on placed orders, the included randomness is limited in this model. Therefore, an analytical mathematical can be developed to capture the stated problem.

4 DSTM formulation

In this section, a model will be formulated to schedule deliveries for replenishing a single vendor with multiple storage locations while minimizing the cost. The developed model will be defined as the delivery scheduled transport model (DSTM). The model is a mixed integer linear programming model, which will be introduced by the following parts; assumptions, indexes, sets, parameters, objective function and constraints.

The following assumptions are made when developing the model;

- In this model, a situation will be assumed with one warehouse and one store which orders goods for replenishment. The stores has two storage locations, in which receiving cost are presented only at the external storage location due to extra cost for shipping the items to the store. Goods are transported from the warehouse via pallets, which can be varied per delivery.
- A maximum amount of pallets is set to be able to limit the amount of incoming products per storage location. Here, the maximum will be higher at the external storage location, since there will be more space available to save the products involved. The stock room per location is sufficient to save all the delivered goods.
- Each unique box of products will have a parameter which states the stated volume of a pallet per box. Here, inefficient stacking per pallet is not taken into account and is captured by increasing the pallet volume.
- Cost are determined based on the amount of pallets per delivery, expected waiting cost per delivery, receiving cost and reserving cost.
- There will always be personnel available to receive the delivery and unload the truck..
- The transporting company is able to handle all the scheduled deliveries in time.
- Cancellations by the warehouse are also not taken into account.

Index	Description	Sets	Description
i	product type	$I = [1, 2, .., N], i \in I$	set of distinct products
j	delivery day	$J = [1, 2, ..., DD], j \in J$	set of delivery days
k	numbered pallet of a delivery	$K = [1, 2, ..., MP], k \in K$	numbered pallet of a delivery
l	delivery location	$L = [1, 2], l \in L$	set of delivery locations

Table 1. Indexes and sets of DSTM

In the DSTM model, the introduced indices and sets are described in table 1. There will be indexes on products, delivery days, pallets and delivery locations. In the DSTM model, the introduced sets are shown in table 2. Based on the indexes shown above, sets are created on products, delivery days and numbered pallets. The set of storage locations contains of two values, which are the internal and external storage location respectively.

In the DSTM model, the introduced decision variables are shown in table 2. These delivery variables will represent the delivery schedule on item level, cumulative pallet space per delivery day and location and a binary value to represent if pallets are scheduled for delivery or are unused.

Decision variables	Description
$X_{i,j,l}$	scheduled delivery of product i on day j on location l
$D_{j,l}$	cumulative size of the delivery on day j on location j in pallets
$PU_{j,k,l}$	scheduled use of k-th pallet on delivery day j on location l

Table 2. Decision variables of DSTM

In the DSTM model, the introduced parameters are shown in table 3. Here, parameters on transport cost, waiting cost, receiving cost and maximum delivery sizes per storage location have been introduced. Besides, parameters on order amount, latest delivery day and pallet have been defined per ordered item.

Parameters	Description
PC_k	Transport cost of the *k-th* pallet of a delivery including reserving cost
W_k	Expected waiting cost of a delivery of size k pallets
F	Receiving cost for external storage location in €/box
O_i	Ordered amount of boxes of product i
LD_i	Latest numbered delivery day of product i
P_i	Pallet volume of a box of product i
M	Big positive number
$u_{max,l}$	Maximum delivery size at storage location l

Table 3. Parameters of DSTM

The objective function is shown in equation 1, which takes into account the following cost. Here, transport cost and waiting cost are defined per numbered amount of pallet per delivery. Here, the tariff per numbered pallet will be set such that the overall cost function can be set for the whole delivery. Also, receiving cost at the external storage location are considered to take into account the extra cost for transporting the goods from the external storage location to the store. This cost is defined per scheduled box.

$$minimize\ Z\ = \sum_{j=1}^{DD}\sum_{k=1}^{K}\sum_{l=1}^{2} PU_{j,k,l} * (PC_k + W_k) + \sum_{i=1}^{N}\sum_{j=1}^{DD} F * X_{i,j,2} \tag{1}$$

The constraints of the DSTM are shown in table 4. These constraints force the model to schedule all the goods to be delivered, take into account the cumulative pallet space per delivery to schedule the right amount of pallets. Therefore, a restriction has been made on the usage of numbered pallets. Besides, constraints have been to organize the deliveries, limit the delivery frequency to one delivery per day and limit the delivery size per storage location. Besides, variables are defined as integers and binary variables.

Constraints	Description
$\sum_{j=1}^{LD}\sum_{l=1}^{2} X_{i,j,l} = O_i\ \forall i$	Meet ordered demand
$\sum_{i=1}^{N} P_i * X_{i,j,l} = D_{j,l}\ \forall j,l$	Calculate total size of delivery in pallets
$PU_{j,k,l} * M - (D_{j,l} - (k-1)) \geq 0\ \forall j,k$	Schedule use of pallets based on delivery size
$P_{j,k,l} \geq P_{j,k+1,l}\ k \in \{1,2,..,MP-1\}\ \forall j,l$	Restrict numbered pallet usage
$\sum_{l=1}^{2} PU_{j,1,l} \leq 1\ \forall j,l$	Limit amount of deliveries per day to 1
$\sum_{l=1}^{2} D_{j,l} \geq \sum_{l=1}^{2} D_{j+1,l}\ for\ j = 1,2,3,4$	Sort deliveries by size
$0 \leq D_{j,l} \leq u_{max,l}\ \forall j,l$	Limit delivery size
$X_{i,j,l} \in N\ \forall i,j,l$	Integer variable
$PU_{j,k,l} \in \{0,1\}\ \forall j,k$	Binary variable

Table 4. Constraints of DSTM

5 Case study: L'Oreal outlet

The introduced model of section 4 is specified for the case study at the outlet store of L'Oreal. Here, the introduced parameters have been divided in two categories; input parameters and configuration parameters. Input parameters

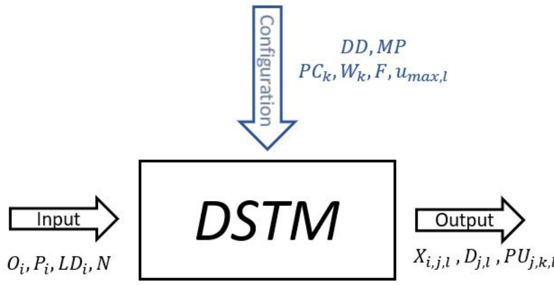

Fig. 2. Factory outlet supply chain

are introduced per scenario in which the model schedules the deliveries, while the configurations parameters are set once to be able to specify the model in it's application. An overview of the categorisation of the parameters is shown in figure 2.

The configuration has been selected based on the analysis of the current transport process of the transport of replenishment orders and is shown in table 5. 5 deliveries are possible during per week, since the peak of traffic is during the weekends, in which stock should be presented. The transport cost per delivery are fixed by the transport company, in which reserving cost has been taken into account by raising the cost for the first scheduled pallet by €15. For unloading the truck, the transport company has reserved 30 minutes for deliveries of 1-5 pallets, 45 minutes of deliveries of 6-8 pallet. The expected waiting cost per delivery size are shown in table 5. This elongation can be observed for deliveries of 6 pallets, in which less waiting cost are charged by the transporting company. Based on average waiting cost per delivery size, the parameters of W_k are set. Since the waiting cost for deliveries of 6 pallets are relatively high, the maximum amount of delivered pallets DD is set to 6. Due to limited storage capacity, a maximum will be set of 1,5 pallets of goods to be delivered at the internal storage location. The receiving cost is based on the estimated productivity of collecting and transport goods from the external to the internal storage location as €0,10/box.

Configuration parameters	1	2	3	4	5	6
DD	5 days					
MP	6 pallets					
PC_k	€54,51	€34,32	€28,90	€23,61	€29,45	€24,94
W_k	€0	€0	€17,50	€5,50	€18,50	€-34,50
F	€0,10/box					
$u_{max,l}$	1,5	6				

Table 5. Parameters of DSTM

To perform experiments with the specified model, 5 weekly orders are feed in the model to be able to evaluate the performance of the model. Of these orders, two orders were scheduled in which the deliveries and cost are shown in figure 7. Here, the parameter LD_i will be set to the maximum amount of possible delivery days, to evaluate the static model behaviour and compare this to the performance of the deliveries in 2019. Therefore, the model input will be specified by introducing the amount of items that will be shipped, the total amount of ordered units, the cumulative pallet space per order and scheduled deliveries per input scenario, which is shown in 6.

Here, MATLAB R2020a has been used to implement the DSTM, in which the solver based approach of the function *intlinprog* can be used for calculating the optimal solution of the DSTM. Here, the program will continue until the optimal solution is found, which is within several minutes. The resulting delivery schedule and resulting cost of the output of the DSTM in these scenarios are shown in table 7. Here, the deliveries which are shown in italics.

Input scenario	N	$\sum_i^N O_i$	$\sum_i^N O_i * P_i$
W15	317	2745	9,70
W27	190	4543	14,13
W37	228	3314	7,70
W43	114	1672	3,14
W52	173	2127	4,26

Table 6. Input for DSTM

Deliveries week	2019 Delivered pallets Store	Kooi	Total cost	DSTM Delivered pallets Store	Kooi	Total cost	Savings cost	Relative savings to 2019
15	-	5, 5	€ 685,90	1, 1, 1, 1	6	€ 501,61	€ 184,29	27%
27	-	13, 2	€ 949,25	1, 1, 1	6, 6	€ 815,37	€ 133,88	14%
37	-	5, 3	€ 660,84	1, 1	6	€ 453,09	€ 207,75	30%
43	-	2, 2	€ 344,68	1, 1, 2	-	€ 197,76	€ 146,84	43%
52	-	2, 3	€ 406,61	1, 1, 1, 2	-	€ 252,27	€ 154,34	38%

Table 7. Comparison of delivery schedule and cost of DSTM vs 2019

An overview of the cost type per delivery can be observed in figure 3. Here, the DSTM schedule small deliveries in terms of pallet size with high quantities to lower the receiving cost for the mentioned scenarios. Larger quantities are shipped to the external storage location via a delivery of 6 pallets to be able to realise a reduction of the waiting cost than in the situation in 2019. This means that the transport and reserving cost raise, but lower in amount than the savings that are realized. Therefore, delivery scheduling via the DSTM results lowered cost and smaller deliveries, which is desired for the store personnel to reduce the peak workload of large deliveries.

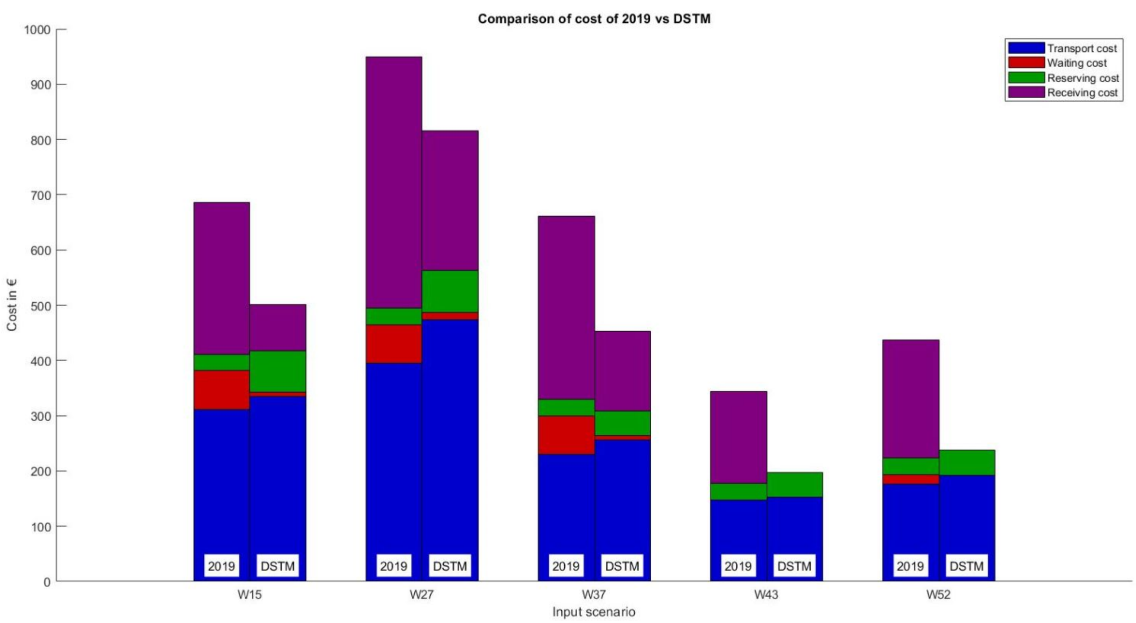

Fig. 3. Comparison of delivery schedule and cost of DSTM vs 2019

6 Conclusion

Based on analysis of factory outlet supply chains in literature, the replenishment process of a factory outlet store could be analyzed. Based on described models in literature, a transport could be designed which schedule deliveries of replenishment orders of a single warehouse to a store, which has two storage locations. While taking into account a stepwise cost function based on transport cost, waiting cost, reserving cost and receiving cost, an optimization problem can be described. This model has been implemented in MATLAB to investigate if savings can be realized by scheduling deliveries more cost efficient for the outlet store of L'Oreal. Analyzing the results and comparing the cost components lead to the conclusion that savings can be realized up to 43% for scheduling the transport of replenishing orders by the DSTM, which proves the applicability of the model in the mentioned situation.

7 Discussion

The introduced model can be further investigated by describing its performance on a yearly basis to see if savings can be realized in all the scenarios. Here, a representative selection has been analyzed in this paper to experiment with the DSTM. Besides, sensitivity analysis could be performed to investigate the effect of this input on the performance of the model and how this influences the realized savings per scenario. Parameters like the pallet space per ordered box P_i could be investigated to see if the made assumption on this parameter also realizes the desired performance of the model as desired. Also, design alternatives of the model can be investigated to see the effect of the resulting scenarios, in which there could be investigated if higher savings in other applications are realisable.

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