DESIGNING AND VISUALIZING A DISTRIBUTION NETWORK

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Bachelor Thesis Industrial Engineering and Management

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PREFACE

In front of you lies my bachelor thesis “Designing and Visualizing a Distribution Network”. This report is part of my graduation assignment for my bachelor studies Industrial Engineering and Management. The research was performed at Company A in City A between April 2018 and September 2018 and consisted of researching the effects on the transport network following from an implementation of Company A’ distribution services in the French products network, in collaboration with Company B.

I wish to thank Company A for having provided me with the opportunity of doing this research and expanding my skill set. I also wish to thank Supervisor Host Company for the continuous support at the office, but more importantly for the trust and autonomy. I also want to thank all colleagues in the office wing and Richard and Linda, my host family, for the enjoyable months.

Next, I want to thank Peter Schuur and Derya Demirtas for the quality and distinct feedback on my reports. Without their help, this report would not have achieved the condition is has now.

Finally, I want to thank my family and friends for the continuous support, which has driven me to reach for higher goals.

Have a nice read,

Niklas Meyknecht
Enschede, September 2019

MANAGEMENT SUMMARY

In this thesis I describe the bachelor's assignment I have performed at the request of Company A, a logistical service provider in the European industry. The main service they provide is distribution of products all around Europe. They are partnered with local producers and large-scale retail organizations. One of these partners is Company B, a French garden center organization with around 200 retailers in France. They currently source their category A products through Company A services. Outdoor products are sourced at French producers.

At the time of the assignment, there was no comparable logistical service provider in France in the outdoor products industry, which Company A saw as an opportunity to expand their business. Company B, whose global market value of outdoor products currently is €70 million (€70M), is willing to make a commitment of products which Company B's retailers would order through Company A. This commitment is defined as a fraction of the global market value, which is referred to simply as market value. Among other things, Company A needed to research how to organize transport around a new distribution center. Additionally, the results needed to be visually insightful to stakeholders, which include transport partners and producers, and the required market share should be high enough to be efficient but low enough as to mitigate the risks of the investment. This is the task I was set to do. The research question was prepared as follows:

How can the road transport network following from the implementation of Company A services in France be optimized, and how can results be visualized?

Optimization in this research is defined as the minimization of transport requirements of the network. As no system currently exists, the goal was to replicate the Dutch system in France with limited available data and knowledge and to observe the consequences and results from different scenarios. This research question can be more commonly described as a location-routing problem (LRP), an extension of the vehicle routing problem in which depot location and vehicle routing are included. Retailers order a number of carts, which are the transport trolleys in which products are stored for transport. When an order is passed, products are retrieved at producers, distributed in a distribution center (DC) and transported and delivered within three days between 08:00 and 12:00 or 14:00 and 18:00. The system should represent 52 weeks of deliveries with a single order each week. Through literature, we gained insights in the methodologies involved in a LRP: The objective function consists of four non-monetary measures: kilometers driven and trucks required to transport demand from DC to depots, and kilometers driven and trucks required to transport demand from depots and retailers. The transport between DC and depots and between depots and retailers are considered separately for the following reason: Transport between DC and depots are considered to transport exclusively Company A' products, whereas transport between depots and retailers will be provided by the transport partners. Their trucks could also transport products for unknown external retailers and are not necessarily assigned to one specific depot and do therefore not always return to originating depot. These measures are normalized, weighted and finally summed to score a given scenario, which we use as our cost function. Within this function we only seek to minimize transport requirements, not the minimization of transport costs. A set of 24 depots was made available by Company A' French transport partners. The depot located in City B, depot 6 (DEP6), is selected by management as DC due to its strategic location. Depots implementation and usage costs are not considered, as they only influence the minimization of transport requirements in monetary cost, which we do not include in our objective function. Literature also defined the need for a search procedure in with which the solution space for our LRP is analyzed.

The LRP can also be defined as a Depot Allocation Problem (DAP) and a Vehicle Routing Problem (VRP), which we both approach using search procedures. With the planning horizon of 52 weeks, we have a chosen depot selection and market value which are fixed throughout the planning horizon. We do generate a transport network for every week using the following procedures, which are therefore repeated for every week of demand. Retailers are assigned to their nearest available depot as a starting solution for the DAP. This solution is improved upon with a TABU meta-heuristic. First, depot demand is determined by summing the total demand of a depot's assigned retailers. Each depot is supplied by n trucks originating from the DC. We assume that the first n-1 trucks are filled fully, with the last truck transporting the remaining demand. We introduce the concept of depot saturation. The saturation of depots determines the depot's ability to accept more retailer assignments, or its need to have retailers unassigned to them. A depot's last truck's fill-rate determines the depot's saturation: unsaturated, saturated and supersaturated. If a depot's last truck's fill-rate is less than the average fill-rate of all last trucks, the depot it is due to is considered supersaturated: the depot's last truck's fill rate is low to such an extent it is recommended to have retailers unassigned until the truck becomes obsolete. If the fill rate is more than average fill-rate of all last trucks, the depot is considered unsaturated: the depot's last truck's fill rate is high enough that it is recommended to fill the truck to full capacity. If a depot's last truck's fill-rate is 100%, the depot is considered saturated and it will not be selected to either have retailer unassigned from or reassigned to them. Additionally, its last truck's fill-rate is not considered when determining the average last truck fill-rate. A random supersaturated depot is selected, and the retailer assigned to this supersaturated depot closest to another non-TABU unsaturated depot is selected and reassigned to this depot. This origin depot is now TABU for this retailer for a given number of turns. A solution is accepted if a minimal number of trucks are required, which can be calculated using the known total demand divided by truck capacity, or if no improvement is measured for a given number of turns.

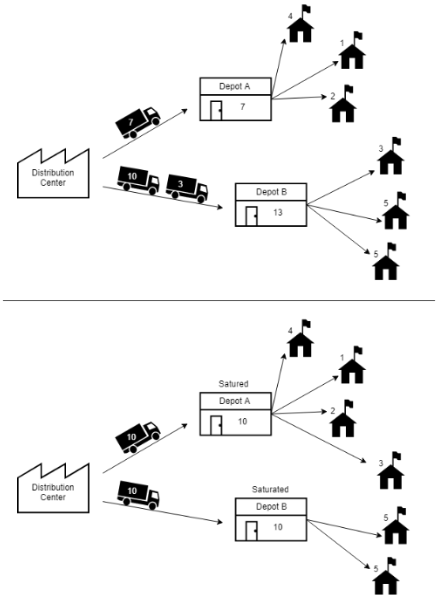


Figure 0-1: Example of the depot saturation method with an initial and final solution

When the allocation process is complete, the VRP is approached. The procedure accounts for retailer delivery windows, truck carrying and driving capacities and the fact that trucks do not return at their originating depot. We do so by using an adapted maximum savings algorithm. First, the distance matrix between all locations is made asymmetric by setting all distances from retailers to depots to zero. Next, each retailer is assigned an exclusive route as a starting solution, in which this retailer is also the end point for the truck. For all possible connections between an origin and destination retailer, the expected savings are calculated by removing the increase in cost of the hypothetical connection from the total savings gained by removing an existing connection. This results in an asymmetrical savings matrix. By setting distances from

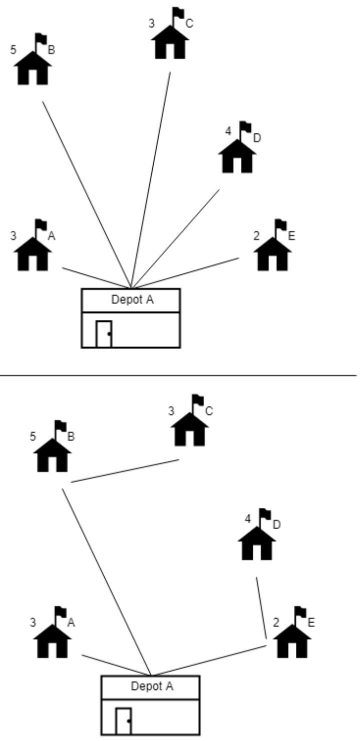


Figure 0-2: Example of the Maximum-Savings method with an initial and final solution

retailers to depots to zero, the direction of a connection influences the savings as only one of the depot-retailer connections will be removed, as opposed to a depot-retailer connection for both retailers in the traditional Maximum-Savings method. The highest saving in the savings matrix is selected and temporarily implemented. The temporary route is checked for feasibility. A temporary route's current carrying amount and driving distance are updated. The delivery schedule of the route following from the new connection is updated by adding the destination route's delivery schedule after the origin route's delivery schedule, which we refer to as a push forward technique (the destination route's schedule is pushed forward). If no constraints are violated, the temporary connection is implemented. If a connection is implemented, or if a connection is infeasible, the savings in the savings matrix are set to zero to prevent the connection from being selected again. In every route, the last retailer in the delivery schedule is also the end point for the route. The heuristic ends when the highest savings are zero or less. With this, routes are created every depot in every week.

To implement the procedures, we required data concerning producers, depots and retailers. Available data was limited, and assumptions had to be made. It consisted of historical sales, transport and location records of a portion of Company B's retailers for category A products procured via Company A' services based in the Netherlands. Additionally, we obtained the production sizes of the 20 biggest producers and location information on the available depots. With the available data, we determined retailer specific demand pattern and developed a conversion method to convert euros to a cart count, which we use to convert a market value to a number of carts. Doing so, we can test different market values and obtain an associated demand. We also provided additional convincing to the decision of using City B as the location for the DC. Finally, real-road distances are gathered using a self-developed tool which gathers driving distances between locations as proposed by online mapping services.

With the data and processes, we developed an analytical model which allows us to replicate a transport network for all 52 weeks of a scenario. In the model, the user can choose between testing scenarios with different market values and a fixed depot selection, of testing scenarios with different depot selections and a fixed market value. A scenario's score is calculated using the previously defined KPIs. These KPIs are normalized, weighted and summed. This sum a scenario's score: the lower the score, the better the scenario.

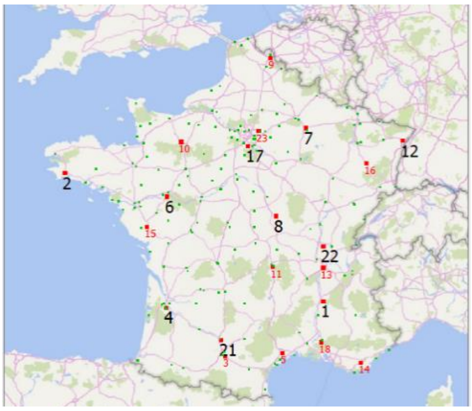


Figure 0-3: Depots present in the most efficient scenarios (ID's in black) including the DC: depot 6

With this model, we tested the system for a range of market values between €5M and €40M, five fixed depots selections and different KPI weights. This led to the conclusion that a scenario's efficiency increases as market value increases, and that this increase in efficiency was unrelated to depot selections. We choose a market value of €20M as being a starting value for further testing as after this market value the increase in efficiency slowed down considerably. Following this, we tested multiple depot selections with this fixed market value of €20M and multiple KPI weights. In order to provide faster results, we split the depots in four geographical regions which we tested separately. For each region, the depots present in the more efficient scenarios were selected and tested on the global level. The 10 depots (including the DC, DEP6) can be seen in Figure 0-3. We tested against different weight combinations and market values of €20M, €30M, €40M and €50M. Three depot combinations provided the most efficient results:

- Combination 91, consisting of the DC and depots 4 and 22
- Combination 123, consisting of the DC and depots 4, 17 and 22
- Combination 223, consisting of the DC and depots 4, 17, 21 and 22

We notice that a combination of the four depots is most efficient each time. We compared the results visually for the different market values proposed and two different KPI weight sets: Set 1 has all KPIs equal with the KPI “trucks required between depots and retailers” set to zero and Set 2 has all KPIs equal. With a market value of €20M and KPI weight set 1, the most efficient depots were depots DEP4 and DEP22. With a market value of €30M or €40M, the most efficient depots were DEP4, DEP17 and DEP22. With a market value of €50M, the most efficient depots were DEP4, DEP17, DEP21 and DEP22. With a market value of €20M or €30M and KPI weight set 2, the most efficient depots were depots DEP4, DEP17 and DEP22. With a market value of €40M or €50M, the most efficient depots were once again DEP4, DEP17, DEP21 and DEP22. In Figure 0-4, the visualization of a generated transport network can be seen. In this case, this is the result of week 8 with a market value of €20M. The active depots are the DC, depot 4 and depot 22. The visualization also shows the yearly and weekly fill-rates of the routes between the DC and depots. Following from these results, we recommend Company A to start by implementing their services with a market value of €20M and depots DEP4, DEP6 and DEP22 with DEP6 functioning as the distribution center. As the market value and thus demand increases, DEP17 and finally DEP21 should also be used in the transport network.

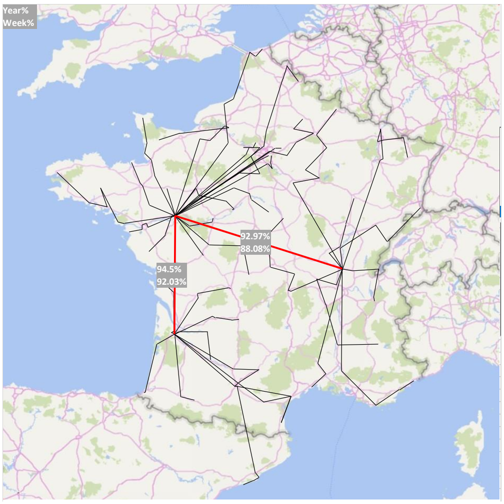


Figure 0-4: Visualization of a generated transport network with recommend depots 4, 6 and 22 (combination 91) and a market value of €20M. DC-depots routes also show yearly fill-rate of the route (above) and fill-rate of the current week (below)

LIST OF DEFINITIONS

Road Transport: All road-based transport driven by trucks

Global market value: The yearly turn-over for outdoor products for Company B

Market value: A share/commitment of the global market value, independent of geographical regions, product categories or suppliers.

Retailer market value: retailer specific share of the market value.

Depot demand: Sum of the demand off al retailers assigned to the depot

Last truck: The last truck n required to transport depot demand from DC to depot, carrying the remainder of demand the rest of which was transported by n-1 fully loaded trucks.

Average last truck fill-rate: average of the last truck fill rates of all depots, for the exception of depots considered saturated

Depot saturation: The depot saturation determines the depot’s ability to accept more retailer assignments, or its need to have retailers unassigned to them.

Supersaturated depot: The depot’s last truck’s fill-rate is less than the average last truck fill-rates of all depots and therefore can have retailers unassigned from them

Unsaturated: The depot’s last truck’s fill-rate is more than the average last truck fill-rates of all depots and therefore can have retailers reassigned to them

Saturated: The depot’s last truck’s fill-rate is 100% and cannot have retailers unassigned from or reassigned to them.

Depot selection: Selection of depots for which a transport network is generated.

Retailer: One of a customer’s businesses that sells the products

Customer: A large-scale retailer organization such as Company B

Category A products: Products intended for category A use, cultivated in Dutch producers

Outdoor products: Products intended for outdoor use, cultivated in French producers

Season: Typical product selling season last during March, April and May. In this period, demand for products typically increases.

Carts: Transport trolleys, cc’s, in which products are transported in the products industry. Retailers must order enough products to fill carts to 95%.

Sequential method: A step by step method without feedback loops between de location problem solving and the routing problem solving

Iterative method: A looping step by step method with feedback loops between de location problem solving and the routing problem solving

Nested method: A method of solving the location problem by partially solving the routing problem simultaneously to estimate the routing problem’s solution’s efficiency.

List of Acronyms

- €##M: ## million euros
- LRP: Location-Routing Problem
- DAP: Depot Allocation Problem
- VRP: Vehicle Routing Problem
- MDVRP: Multi-Depot Vehicle Routing Problem
- VRPTW: Vehicle Routing Problem with Time Windows
- MDVRPTW: Multi-Depot Vehicle Routing Problem with Time Windows
- DC : Distribution Center
- DEP## : Depot number ##
- CDF: Cumulative Density Function
- KPI: Key Performance Indicator
- KM-In: Kilometers driven from DC to depots
- KM-Out: Kilometers driven from depots to retailers
- TR-In: Trucks required to drive from DC to depots
- TR-Out: Trucks required to drive from depots to retailers

CONTENTS

1 INTRODUCTION

In the finalization phase of my bachelor, Industrial Engineering and Management, I was offered the possibility of completing my study through an internship at Company A, researching the logistical consequences and effects following from an expansion opportunity. In this chapter, we introduce Company A and one of their key partners, Company B, and give some background on how Company A functions within their industry.

1.1 COMPANY A & PARTNERS

Company A is a logistical service provider in the European products industry. The main service they provide is distribution of products all around Europe. Daily, thousands of individual products travel across Company A' distribution center (DC), located in City A, The Netherlands. They form the link between products producers, spread out over the Netherlands and neighboring countries, and retailer stores across Europe. The customer base is restricted to large-scale retailer organizations, such as IKEA and Praxis.

[redacted]

Company A was founded in 1882, and originally started as a products producer. In 2017, Company A traded near 100 million products to a total of 12 customers, generating 249 million euros in revenue. The second most profitable country was France, where two key customers of France are active: Truffaut and Company B. The latter plays an important role in this project.

[redacted]

Company B is a garden center, with around 200 retail stores. A large majority is spread around in France. Company B offers animal, house, balcony, terrace and garden products. In 2017, products represented €102 million (€102M) of revenue, consisting of €23M for category A-products, from which €17M are provided by Company A, and €70M of outdoor-products.

[redacted]

1.2 Background assignment

As introduced, €17M of revenue in category A products is currently sourced through Company A, making Company A an important partner for Company B. €70M of revenue in outdoor products is currently sourced through many local (French) producers. These €70M are known as the global market value. On the 18th of April 2018, a meet-up was organized between different stakeholders in the French products industry, during which the prospects of an organized supply chain network for the outdoor products were discussed. Following this meet-up, Company A started “Project Name” with as goal to implement their services in France. This assignment forms a part of this project.

1.3 Current situation

Before engaging in the problem identification phase, the current situation in France and at Company A is summarized and some characteristics are defined. These characteristics apply to both situations. These consists of the transport carts, present in both networks, and the supply restrictions in the French and Company A network.

1.3.1 Carts

In the products industry, a common form of product transport is by cc’s, referred to as carts. A cart is a small transport device in which products can modularly be stored and transported. These carts are used in DCs to allow for an easy organization of different orders. These carts are stored in trucks when they are ready for transport. A standard size truck can carry exactly 43 carts, which is considered a 100% fill-rate.

[redacted]

1.3.2 Category B-products France

The different retailers of Company B order their product individually. When ordering, they reflect on the different market trends, and determine which products to order. The retailers have to consider the restrictions put on by the producers. These restrictions can consist of product availability, minimum order sizes and costs. Producers organize their outbound transport themselves and will therefore only offer their own products except for occasional producer partnerships, which allow them to also offer partnered products. This, however, happens rarely. Exceptions to these operations are a few producers whose transport is being issued by Transport Partner B, a transport company who also runs a large portion of the current France-bound transport for Company A. These producers do offer organized transport.

1.3.3 Category A-products Company A

The processes at Company A can be summarized as an aggregated process of the above. Different producers inform Company A of their stocks for a specific period through the "Name". Through partnerships with the producers, Company A can offer products to their customers, consisting of the range of products each producer produces. Customers' retailers can order carts, which they can fill with products of their choice for different producers. The most important restriction obliges retailers to fill their carts to an acceptable fill-rate (at least 95%). This is enabled trough an IT system, which inform retailers on the expected fill-rate of their to-order carts. Once orders have been received, products are collected at producers and transported to the DC at City A. For smaller producers, transport is organized by Company A or an external transporter. Larger producers organize transport themselves. Key to this process is that products from different retailers and different orders are transported to a central location. Once arrived, the distribution process starts, during which the products are distributed in new outbound carts according to the orders placed. After the distribution process, carts are loaded into trucks which will transport them to the retailers.

1.4 PROBLEMS AND OPPORTUNITIES

In this section, the problems and opportunities for improvement are described. They are categorized by the stakeholder directly involved in the issue.

1.4.1 Producers

Individual producers experience pressure from their customers: They wish ever so cheaper prices and lower ordering quantities. Producers, however, cannot provide their customers with the flexibility they expect. This leads to difficult customer relationships, and producers risk losing customers to competitors. Additionally, with the shrinking of order sizes and the difficulty to predict demand, producers are left with a higher workload.

Company A has identified several opportunities through an implementation of their services in France. First, by aggregating demand of several (smaller) stores through one ordering scheme, order sizes received by the producer will increase, full-time equivalents of products will be reduced and transport of products from producer to store would be improved. Additionally, there is an opportunity of implementing Company A' services to automate the ordering process, resulting in less errors. Finally, Company A sees a lot of opportunities in a union between different producers.

1.4.2 Transporters

At the current moment, problems related to transport are opportunities for better service in the future: inefficient transport is mainly due to ordering and supply habits and are hardly influenceable by the transport providers.

Opportunities observed by Company A are valuable options for an implantation of Company A in France. Currently, there isn't a transport service specialized in the products industry that provides transport nationwide. However, different transport partners, Transport Partner B and Transport Partner A, provide strong opportunities for nation-wide transport with the use of hubs spread over the country. Additionally, fill-rates of trucks has a lot of room for improvement. For instance, transport can be optimized by having products transported in one large batch by one party, instead of multiple parties having to make small deliveries (to potentially the same retailer). Transporters could also profit from a more stable prediction of transport needs and an optimization of transport routes.

1.4.3 Retailer (Company B Retail stores)

Most retailer problems and opportunities were elaborated on during the meeting on the 26th of April. Retailers experience problems with the minimum ordering sizes, especially for smaller retailers. The high minimum order size results in retailers having to order at least 3 carts of products from a producer. The variety of products a producer offers are limited to the partners of a producer, or the union they are part of (an aspect that is currently lacking in the French network.). This forces retailers to order too much of a certain type of product. This causes retailer to be left with a lot of overstock and prevents them from offering a higher variety of products in the same period, as this would result in even more overstocking. Another practical problem is that, when ordering from several producers, products arrive in an uncoordinated fashion. Additionally, they experienced a strong wish for cheaper products. On a higher management scale, Company B believes that they have too many suppliers. They have managed to reduce the number of producers they work with from approximatively 600 to approximatively 300, but this is far from their goal of being able to work with 20 producers, nationwide.

Opportunities Company A sees are, first, the solving of the experienced problems. They see a possibility of providing Company B retailers with orders consisting of products form several producers, with the number of products ordered from one specific producer by a specific retailer being less than a cart of products. By aggregating the products of several producers in the same carts, they can also solve the unconditioned transport issue. Finally, through economies of scale, they foresee a reduction in costs incurred on Retailers, something that is currently not in place. They also see opportunities of being able to select qualitative producers on a nation-wide scale and offer these products to the different retailers. They also noticed a lot of effort goes into the ordering process, mainly due to the required paperwork. With their services, they can digitalize this process, and eventually automate is, also resulting in less costs.

1.4.4 Company A

Company A is currently not active in the logistical network described. However, they do experience problems with it, as it conflicts with their norms and values. The transport network is highly unsustainable, both economically and environmentally. A second problem lies in the nature of the stakeholders. A lot of stakeholders from different background are involved in this network, some of whom are unfamiliar with Company A or lacking in understanding of how the processes work and why they are efficient.

1.5 PROJECT NAME

"Project Name", referred to in Section 1.2 consists, of four research topics. The first topic is the sourcing of partners to collaborate with, which include producers, transport and depot partners. Secondly, internal logistics would be researched. Finally, inbound and outbound transport must be researched. This assignment focusses on the outbound transport.

1.5.1 Research definition

Relating the experienced problems and observed opportunities to the specific topic of this research, outbound transport, leads to a core problem: The outbound transport network is highly inefficient. With an implementation of Company A services in France, the organization of outbound transport can have a big effect on this efficiency of the transport network. The focus of this research is thus to optimize the transport network with an implementation of Company A services in France. With the wide variety of stakeholders involved in this project, the results should also be brought over in an insightful manner. This led to the following research question:

How can the road transport network following from the implementation of Company A services in France be optimized, and how can results be visualized?

To do so, Company A has specified the specificities of the project. First, all inbound transport departing from producers will be directed towards a single DC, just as in their Dutch operations. We use the 20 most utilized producers by Company B, as the latter aim to reduce the number of different producers to such a number. Outbound transport from the DC to retailers can either directly be delivered at the retailers, or flow between depots. 24 depots are placed at our disposal by Company A' French transport partners: Transport Partner A and Transport Partner B. These are also the only transport partners we consider. All retailers must be supplied within three days of ordering. This lead time is generalised by using accepting a one-day lead time for all transport from producers to the DC as well as the preparatory distribution process overnight, a maximum one-day lead time for all transport between the DC and the depots and a maximum one-day lead time between the DC or depots and the retailers. A visualisation can be found in Appendix 7.7. Also, the DC location has been set to the region of City B (the relationship between the producers and the DC location and the conclusion to use City B are shown in Section 3.3). To answer the research question, we are required to deal with the multi-depot vehicle routing problem with time-windows (multi-depot VRP with time-windows, or MDVRPTW), in which different scenarios are evaluated with each other. For each scenario, we analyze transport for 52 weeks (one year), with retailers ordering once a week. Within the VRP, an important requirement is that transport between two locations must be approximated with real geographical travel times and distances instead of straight lines. We elaborate on this in Section 3.4. Moreover, for transport between depots and retailers we assume transport will not exclusively consist of our products, and we therefor assume trucks do not return to depots after having delivered their products. Finally, Company A defines an efficient transport network as a network that satisfies their stakeholder satisfaction goals (e.g. delivery within three days of ordering) and contains minimum transport requirements. All results should also be visualized. To have products to transport, Company B must commit a number of products. This commitment is represented by a fraction of the global market value introduced in Section 1.2, which will be known as the (available) market value. The market value is not defined by certain product categories, certain geographical regions or even certain supplying producers. It rather influences the total ordering size of retailers in France.

Within the project we focus on the transport model in France, and therefor exclude all other countries. We also have limitations with the available data and will therefore make use of assumptions. Finally, this project serves to give a strategic advice and will there not consist of the implementations and evaluations of the project.

1.5.2 Plan of approach

During this research, I will aim towards reaching an optimized transport strategy which will serve as advice for Company A. Optimization follows from improvements based on the current situation. With an implementation of Company A services in France in the system in which there isn't any currently, a clear majority of options will form an optimization. The enveloping plan of approach is to build a What-If analysis to assess which scenarios are most efficient.

To answer the research question, several sub-questions must be answered, related to the different aspects that play a role in this transport network and its optimization and visualization. For these sub-questions, data and information is gathered through literature research, (semi-)formal interviews with stakeholders, available datasets and data generation in the case of missing data.

1. *Which insights can literature give us on solving comparable problems?*
   1.1. What are the methodologies in similar problems?
   1.2. What theories exist to solve these problems?
   1.3. What methods have been applied in the past?
   1.4. What is our choice of methods?

Through a literature review, we analyze which methodologies apply to our situation. We first research the methodologies that apply and common theories in which routing network problems are commonly addressed. Second, we analyze past research to discover how routing problems were solved and how we can use these to answer our research question. Finally, we define the method we use in the project.

2. *How is the French transport network organized?*
   2.1. What are the characteristics of Company B Retailers?
   2.2. What are the characteristics of depots?
   2.3. What are the characteristics of transport?

The research question aims to define how the network is currently organized. The limited data available is processed to obtain insightful data on ordering habits, depot and DC locations and transport characteristics. Additionally, it determines how we can convert a market value to a cart demand.

3. *How is the transport network influences by a varying market value and depot selection?*
   3.1. *What is an adequate market value for initial testing?*
   3.2. *Which depots contribute most to a more efficient network?*
   3.3. *How does the market value influence the more efficient depots?*

The research question aims to determine how the network efficiency varies under altering conditions. First, we research the effect of the market value on the network efficiency with arbitrary example networks to determine which market value we should use as a begin point to satisfy Company B's need for a low market as well as to provide a network whose efficiency is satisfying enough. Second, we research which depots provide the most efficient depot under this market value. These depots are finally tested against varying market value to also analyze the effect of an altering market value on the choice of efficient depots.

4. *Conclusion and recommendations*

From the previous research questions we can draw conclusions and answer the key research question. We also offer our recommendations to Company A, consisting of depot combinations to use at different market values.

1.6 Deliverables

The deliverables are visualizations of the data and the results, which should at least include a visualization of the transport network.

2 THEORETICAL FRAMEWORK

In this section, we explore the literature on depot implementation strategies. In Operations Research, this is also known as the Location Routing Problem (LRP), consisting of a Location/Depot Allocation Problem (DAP) and a Multi-Depot Vehicle Routing Problem (MDVRP). In Section 2.1, we explore the methodologies involved. In Section 2.2, we expand on the different search procedures that apply in an LRP. In Section 2.3, we review past application of LRP solving methods. In Section 2.4, we define our LRP and we develop the methods we use to approach the LRP.

2.1 THE LOCATION-ROUTING PROBLEM

According to Tai-Hsi Wu (1999), the LRP is defined to find the optimal number and locations of the depots, simultaneously with the depot allocation, vehicle schedules and distribution routes so as to minimize the total system costs. Francis & Goldstein (1973) published a list of 216 references, which was later complemented by Rand (1976). The latter argues that seven choices need to be made when determining the procedures to be adopted in a depot location study. We will focus on five: the objective, the potential locations, the present sites, the search procedure and the planning horizon.

2.1.1 Objective

The objective has typically been to minimize costs, and it often thought that this is reached through a lowest number of depots. On an economical scale, the costs resulting from depots largely depends on the fashion in which depots function together. In his report, Beattie (1973) found different variable costs determine the total cost of a depot, considering only transport and depot costs. It is more important to have depots in the right place, than to have the right number (Beattie, 1973).

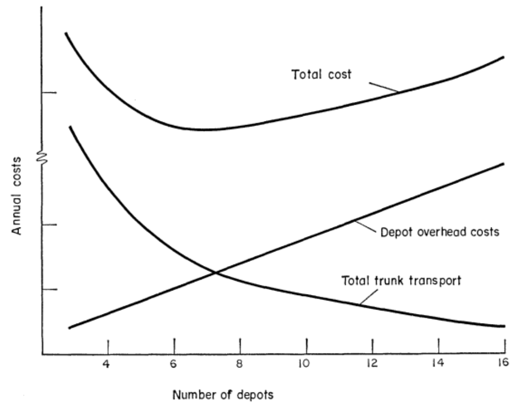


Figure 2-1: Annual cost vs number of depots (Beattie, 1973)

In addition, Mercer (1970) adds that as the distance from a depot increases, the market share declines with the presence of large number of competitor or a well-defined competition.

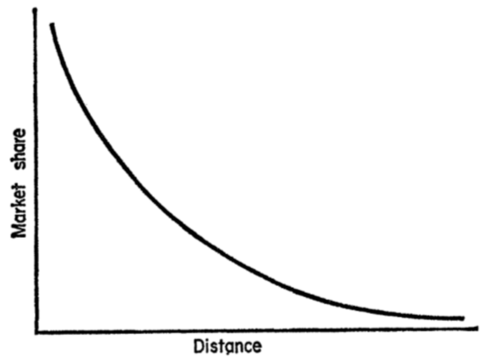


Figure 2-2: The market share and distance relationship (Rand, 1976)

These examples show that an objective function should be chosen taking in account all relevant factors to the situation. Examples of objectives include customer relationship by allowing decreased delivery time and therefore allowing them to carry a lower inventory, or the return of investments following from a larger market share due to a lower customer distance.

2.1.2 Potential location & Present Sites

When approaching a LRP, the depot location possibilities must be defined. Revelle, Marks, & Liebman (1970) provide the researcher with two approaches: All points on a plane, or points on the network. When considering all point on a plane, an infinity of options is available each characterized by some form of distance measurement to the nodes (i.e. retailers). When considering points on a network, a finite amount of locations is known before-hand, in which all options are also characterized by some form of distance and time measurement. These two options are also called an infinite of a feasible location set, which can be compared to a continious or discrete location set. When using a feasible location set, present known sites can be used as the location set. Revelle, Marks, & Liebman (1970) collected different researches and summarized their depot location strategies. Methods all revolve around an objective function (as discussed above) in which the goal mostly is to minimize transport and location costs. Additionally, the capacities of the depots can be considered, defining the difference between capacitated and uncapacitated LRPs.

Mercer (1970) acknowledges both methods, but also gives critic to both. The infinite set approach cannot guarantee a (near) optimal solution but merely a best solution for a given starting point. Also, found solutions can be infeasible when applied in practice, due to region specificities or laws and regulations. Finally, no method exists to determine the optimal number of depots. The finite set approach is criticized by its limitation to find an optimal solution. To do so, many locations are required. An additional consideration when using a finite number of locations approach is to use present known sites, for instance when considering a merger between two companies.

2.1.3 Search Procedure

Along with the choice between an infinite or finite set approach is the choice of search procedure. The search procedure dictates in which fashion the LRP will be tackled. Mercer (1970) shows four methods; simulation, heuristics, integer programming with feasible set and the infinite set approach; are classified based on the complexity of the cost function, of objective function, and the search procedure for finding depots.

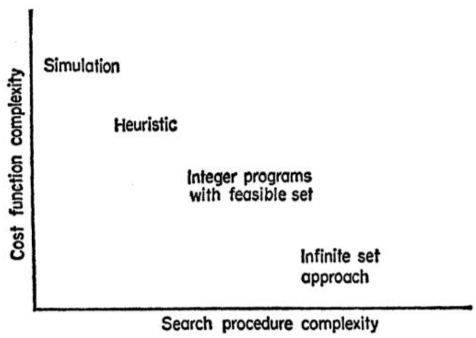


Figure 2-3: The relationship between complexity in search procedures and cost functions. (Mercer, 1970)

The choice of search procedure is applicable to many VRPs. Common methods are exact methods, heuristics, metaheuristics and simulation studies. Exact methods allow the finding of optimal solutions through an algorithmic approach but are very time-consuming in real-world situations. Heuristics have been developed to shorten the processing time by continuously improving a given or random starting solution, however they do not necessarily give an (near) optimal solution and can get trapped in a local optimum. Meta-heuristics are procedures designed to find a heuristic to find solutions for optimization problems. They have a larger search space than typical heuristics and can temporarily accept deteriorating solutions, preventing them being stopped at a poor level local optimum. Finally, simulation is a solving method. In a simulation the conditions of a real-world system are replicated. Optimization occurs by analysing the stochastic influences on given solutions and deciding on the most efficients ones. Search procedures will be further researched in Section 2.2

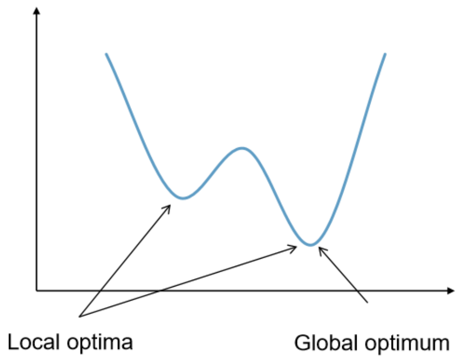


Figure 2-4: Examples of local and global optima. On the x-axis is represented the solution space and on the y-axis is represented the solution efficiency.

2.1.4 Planning Horizon

Some researchers claim that depot locations are strategic problems, as opposed to VRPs which are tactical problems because routes can be redefined frequently, whereas depot locations are usually for longer periods of time, and thus over a longer planning horizon. The same planning framework was there for inadequate (Nagy & Salhi, 2006). These claims were revoked after investigations proved that the use of a location-routing framework would reduce costs over long planning horizons (Salhi & Nagy, 1999). Therefore, a framework should be defined by the researcher. It was also advised to use a long planning horizon as opposed to a static situation.

2.2 SEARCH PROCEDURES FOR THE LRP

The LRP and the MDVRP are spin-offs of the VRP, a well-known and researched challenge in the operations research. The LRP is defined as the process where the optimal number, the capacity, and the location of facilities are determined, and the optimal set of vehicle routes from each facility is also sought (Marinakis, 2009). The MDVRP focusses on the assignment of retailers to depots based on an available set of depots and the ensued routing of vehicles. As described in Section 2.1, the LRP and MDVRP require an objective function, a choice of approach between infinite and finite depot sets, a planning horizon and search procedures. In this section, we will address search procedures applied in previous research which tackled LRPs and MDVRPs.

2.2.1 Exact methods

Exact methods are methods which guarantee an optimal solution to a given problem. Due to their computation time, these methods are usually only applied on small theoretical problems. Cooper L. (1961) proposed a method where the location of *m* number of depots were optimally placed on a plane surface by finding the point which minimized the Euclidian distance between the destinations and the different depots, as one of the first solutions to the location problem defined by Alfred Weber in 1909 (Revelle, Marks, & Liebman, 1970). Nagy & Salhi (2006) summarized several different methods applied by previous researchers.

2.2.2 Heuristic methods

When applying heuristics to a LRP, the problem becomes twofold: a locational problem and a routing problem. Salhi & Nagy (1999) described three methods within which heuristics can be classified: sequential, iterative and nested methods.

Sequential methods process the LRP by first locating the depots and secondly by approaching the routing problem. In this method, there is no feedback loop. Iterative methods combat this problem by following a loop in which the output for each sub problem is used as feedback for the other sub problem to be tackle more efficiently. Nested methods view the location problem as key, with the routing problem being referred to in a subroutine. The routing problem generally isn't fully solved, and estimations are used to serve as feedback for the location problem.

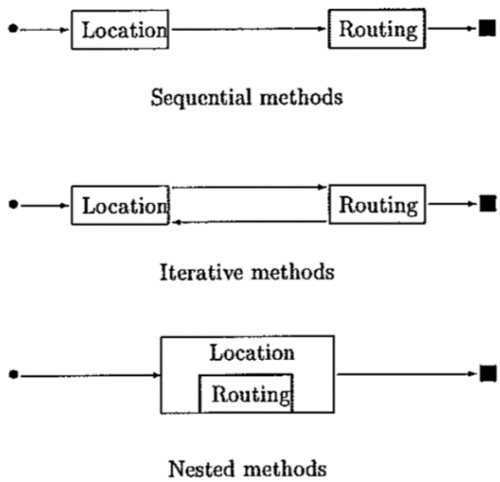


Figure 2-5: An illustration of the three types of solution methods of the LRP (Salhi & Nagy, 1999)

Lim & Wang (2005) showed two methods, a two-stage and a one-stage method, which tackled the MDVRP. These methods are comparable to the sequential and the nested methods, showing the methods apply for MDVRP heuristics as well.

2.2.3 Meta-heuristics

Heuristics are mostly problem dependent, meaning they are developed to fit a very specific problem. Meta-heuristics are problem independent techniques. Osman & Laporte (1996) define it as an iterative generation process which guides a subordinate heuristic. Meta-heuristics can be classified, among others, in the following categories:

- Local and global search: as defined in Section 2.1.3, this determines whether the meta-heuristics aims to reach a local or a global optimum. Global search meta-heuristics use probabilistic methods to allow a deterioration of the current optimal solution.
- Single and population-based solutions: They define the size of the solution set from which the meta-heuristics' iterations improve on. A single-solution-based solution set means that a single solution is altered and selected. A population-based solution set means the meta-heuristic determines an ideal solution from multiple possible solutions.

Common meta-heuristics are applied a variety of fields, including operations research. A common meta-heuristic is TABU. This method generates a neighborhood of solutions from a starting solution using different iterations. Within this neighborhood, the best scoring solution is implemented. This solution does not necessarily have to be an improvement on the initial solution. When a iteration is implemented, this iteration is considered forbidden, or TABU, for a number of iterations. This process repeat until an ending criterion has been met, after which the best scoring solution over all iterations is implemented. Simulated Annealing also explore a neighborhood, but selects a solution based on a randomness factor. From a neighborhood, a single solution is selected. Through a cooling factor, a probabilistic function determines whether this solution is accepted or not. This function is influenced by the observed improvement or deterioration, and the number of steps already taken. Genetic algorithms translate multiple solution into a genetic code, which are combined to create a new genetic code. This is done by selecting how the origin codes interact with each other to combine their genomes in one child genetic code.

2.3 Applications in literature

As defined, exact methods and heuristics intended to solve VRPs are designed for specific problems. Therefore, a vast number of them exist. Additionally, a lot of theories are taken as a basis to improve on by new researchers. Well known algorithms commonly found in new research are the Sweep algorithm and the maximum-savings algorithm (Clarke & Wright, 1964). A simple extension of the maximum-savings algorithm was done by Pichpibul & Kawtummachai (2013) who allowed it to serve open VRPs, a scenario in which trucks do not return to their origin depot. Gillett & Johnson (1976) proposed a sweep algorithm for multiple depots, first assigning retailer nodes to their nearest depot after which tours are built. Solomon (1987) describes four methods of approaching a VRP with Time Windows (VRPTW): a maximum-savings heuristic, a nearest-neighbor heuristic, a time sweep-heuristic and an insertion heuristic. He also notes that, starting from an initial solution in which each retailer is routed directly to a depot, every iteration results in a push forward of the retailer in the delivery schedule (push-backward also being possible). Solomon & Desrosiers (1988) reviewed a variety of objectives different from a distance minimization. Cases are noted in which the amount or required vehicle are minimized, or the number of jobs assigned to vehicle are maximized to reduce vehicle idle time. Column generation techniques are also noticed as a possibility of approaching VRPP with time-windows (VRPTW) and with multiple depots (MDVRPTW). In LRP, Depot Allocation Problem (DAP) and VRP are solved separately regarding a master optimization goal. Cordeau, Laporte, & Mercier (2001) developed a meta-heuristic for the MDVRPTW assigning retailers to their nearest depot and optimizing the depot VRPs with an insertion technique across the multiple depots. Wu, Low, & Bai

(2002) present a sequential metaheuristic optimizing the LRP by considering the problem as a DAP and a VRP, considering depot capacities. Both problems are solved using tour and retailer swaps or insertions respectively. To improve results, the DAP follows a SA framework and the VRP follows a combination of both TABU and SA. Renaud, Boctor, & Laporte (1996) describe a TABU meta-heuristic involving a three-step method, FIND. In the last two steps, the solution neighborhood consists a single vertex being altered. The latter is TABU whenever that depot it is assigned to changes. The meta-heuristics neighborhood thus consists of a single solution (Section 2.2.3) as opposed to many proposed TABU implementations.

2.4 CHOICE OF METHODS

Most of the sources use an objective based of fixed and variable costs for depots usage and vehicle usage. Others focus on different aspects of the transport network such as the minimization of truck idle time or the number of trucks used. The optimization goal, as defined by Company A, is to provide efficient transport. Our objective will therefore consist of the minimization of kilometers driven by trucks, and the minimization of truck usage. We leave depot usage costs out of the studies as our objective is to provide minimum non-monetary transport requirements which are not influenced by depots costs. We consider delivery time as a hard constraint. We also use a selection of 24 present sites as a depot location set. Our planning horizon is a year of 52 time-instances (weeks). The search-procedure follows a sequential method. At first, retailers are allocated to available depots. The depot selection is fixed for all 52 instances, however depot-retailer allocation and vehicle routes will be recalculated each instance.

For each week, an initial DAP-solution will be created by assigning all retailers to their nearest depot. The DAP-solution is improved via a TABU meta-heuristic. First, the total demand of all retailers assigned to a depot is determined for each depot, called the depot demand. Second, as depots are supplied by the DC, n trucks are required to transport the depot demand to the depots. We assume that n-1 trucks are filled to maximum capacity, with the last truck transporting the remaining demand. This truck's fill-rate is called the last truck's fill rate. We introduce the concept of depot saturation. Saturation of depots determines the depot's ability to accept more retailer assignments, or its need to have retailers unassigned to them. A depot's last truck's fill-rate determines the depot's saturation: unsaturated, saturated and supersaturated. If a depot's last truck's fill-rate is less than the average fill-rate of all last trucks, the depot it is due to is considered supersaturated: the depot's last truck's fill rate is low to such an extent it is recommended to have retailers unassigned until the truck becomes obsolete. If the fill rate is more than average fill-rate of all last trucks, the depot is considered unsaturated: the depot's last truck's fill rate is high enough that it is recommended to fill the trucks to full capacity. Finally, depots can become saturated: if a depot's last truck's fill rate is 100%, the depot's retailer allocation is considered optimized and will therefore not be selected for either having a retailer unassigned from or reassigned to them and its last truck's fill rate will not be considered when determining the average last truck fill-rate. Next, a random supersaturated depot is selected. One of the retailers assigned to this depot will be reassigned to an unsaturated depot. Of all the supersaturated depot's assigned retailers, the retailer closest to a non-TABU unsaturated depot will be reassigned to this depot. This iteration is now TABU for a given number of iterations. This process is repeated until a minimum number of trucks required to transport all demand to all depots is reached, or until no improvements have been observed for a given number of turns. The minimum number of trucks required can be calculated by dividing total demand by truck capacity. With the search-procedure, we tactically aim to reduce the required amount of trucks: the supersaturated depot's last truck's fill-rate is reduced as a retailer, and thus its demand, is reassigned. The aim is to reduce the last truck's fill-rate until it becomes obsolete. For the unsaturated depot's last truck, we aim to increase its fill-rate until it reaches maximum capacity.

When the allocation process is complete, the VRP is approached. The solving procedure accounts for retailer delivery windows, truck carrying and driving capacities and the fact that trucks do not return at their originating depot. We do so by using an adapted maximum savings algorithm. First, the distance matrix between all locations is made asymmetric by setting all distances from retailers to depots to zero, which enables trucks to not return to depots and end at the final retailers. Next, each retailer is assigned an exclusive route as a starting solution, in which this retailer is also the end point for the truck. For all possible connections between an origin and destination retailer, the expected savings are calculated by removing the increase in cost of the hypothetical connection from the total savings gained by removing an existing connection. This results in an asymmetrical savings matrix. By setting distances from retailers to depots to zero, the direction of a connection also influences the savings as only one of the depot-retailer connections will be removed, as opposed to the removal of the depot-retailer connection for both retailers in the traditional Maximum-Savings method. The highest saving in the maximum savings matrix is selected and temporarily implemented. The temporary route is checked for feasibility, it's current carrying amount and driving distance are updated and the delivery schedule of the route following from the new connection is updated by adding the destination route's delivery schedule after the origin route's delivery schedule, which we refer to as a push forward technique (the destination route's schedule is pushed forward). If no constraints are violated, the temporary connection is implemented. If a connection is implemented, or if a connection is infeasible, the savings in the savings matrix are set to zero to prevent the connection from being selected again. In every route, the last retailer in the delivery schedule is also the end point for the route. The heuristic ends when the highest savings are zero or less. With this procedure, routes are created every depot.

2.5 Conclusions

In this section we reviewed the methodology concerning the LRP. In Section 2.1, we reviewed five choices which must be taken to structure the LRP. The choices regard the objective function with which a solutions efficiency is measured, the determination of the number of potential depot locations and the potential presently known sites, the search procedures with which the problem is addressed and the planning horizon of the LRP. In Section 2.2, we elaborated on the search procedures and presented how LRPs are solved using exact methods, heuristics or meta-heuristics. In Section 2.3 we show how the theories have been applied in the past. In Section 2.4, we determine which choices apply to our problem, and how we attempt to solve it. With an objective set to minimize trucks count and kilometers driven, 24 presently known depot sites and a planning horizon of 52 weeks, we tackle the LRP sequentially by first approaching the DAP and secondly the MDVRP. Solutions for the DAP are generated using a TABU meta-heuristic, and solutions for the MDVRP are generated using an adapted Maximum Savings heuristic. In both problems, we consider the relevant constraints and objectives within these problems. Finally, a solution for the LRP is proposed, whose performance is measures according to our objective function. The resulting score will allow for the comparison between multiple scenarios and their proposed LRL solutions.

3 DATA ANALYSIS OF THE CURRENT TRANSPORT NETWORK

This chapter consists of the data collecting process. We collect data from databases, (semi-formal) interviews and internet, and we process the data to make it workable. In Section 3.1, we analyze retailer information to obtain retailer locations, sizes and demand patterns and we develop a method which converts a market value to a number of carts ordered. In Section 3.2, we show insights in producer supply. In Section 3.3 we present the available depots and their locations and substantiate Company A' call to use depot 6 (DEP6) as a DC. In Section 3.4, we define the transport constraints and obtain a real-road driving distance matrix between all available locations.

3.1 HISTORICAL RETAILER DEMAND AND RETAILER GEOLOCATION

To estimate future demand, a historical analysis is required. The historical analysis of demand for outdoor products of the Company B retailers in the French network is hard to obtain: Company A has only been involved in the supply of category A products sourced from the Netherlands. Additionally, Company B is unwilling of sharing their data with us. We must therefore find another way of estimating the demand history of Company B retailers using data we can obtain. We have chosen to use the transaction history of all products sourced by Company B through Company A. This data set contains information about different Company B retailer that can allow us to analyze historical demand. By doing so, we make two assumptions:

Assumption 1: *Retailer ordering history of category A products sourced through Company A is an accurate representation of the retailer ordering history of category B products sourced through local producers*

Assumption 2: *Retailers ordering through Company A represent the totality of Company B retailers in France.*

Assumptions allow progress in the progress and prevent cutbacks in the reliability and feasibility of the project, as historical data is essential. This is the most accurate data source available to Company A. Also, not all Company B retailers order through Company A, resulting in assumption 2.

We have three datasets at our disposition for the analysis: the transaction dataset the transport dataset and the producer dataset. The transaction dataset contains the transaction history of all Company B retailers. It's a spreadsheet of transactions, containing time and customer information, order information such as products ordered, the price and expected fill-rates of the carts. This last measurement is used while ordering to ensure that an order is, ideally, always optimally filled as introduced in Section 1.3.3. This dataset also provides information on the value of carts. The transport dataset contains historical information concerning carts recorded after the distribution process as they are loaded in trucks to be transported to the retailers. It contains information about the loading date, expected delivery date, customer information and the number of carts to be transported. This dataset provides more factual information of the number of carts transported following from an order. From this dataset we also obtained location information of retailers. The producer dataset was provided by Company B and contained monthly supply information of their top 20 producers.

3.1.1 Global ordering distribution

First, we analyze the global ordering history, consisting of the ordering history of all retailers combined. Through this analysis, we wish to identify trends that apply to all customer. Data is analyzed using pivot tables and charts. The following tables contain the weekly ordering volume. Table 3-1 separates all three years to identify particularities that apply to only a specific year, whereas Table 3-2 aggregates this information into one year.

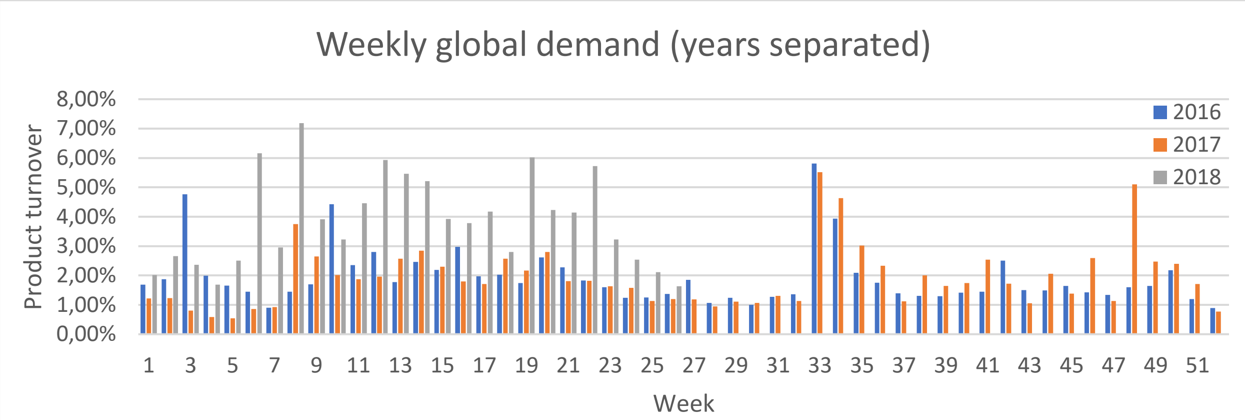


Table 3-1 Weekly global demand between 01/01/2016 and 05/06/2018. Product turnover refers to the relative demand in carts in weeks within that year.

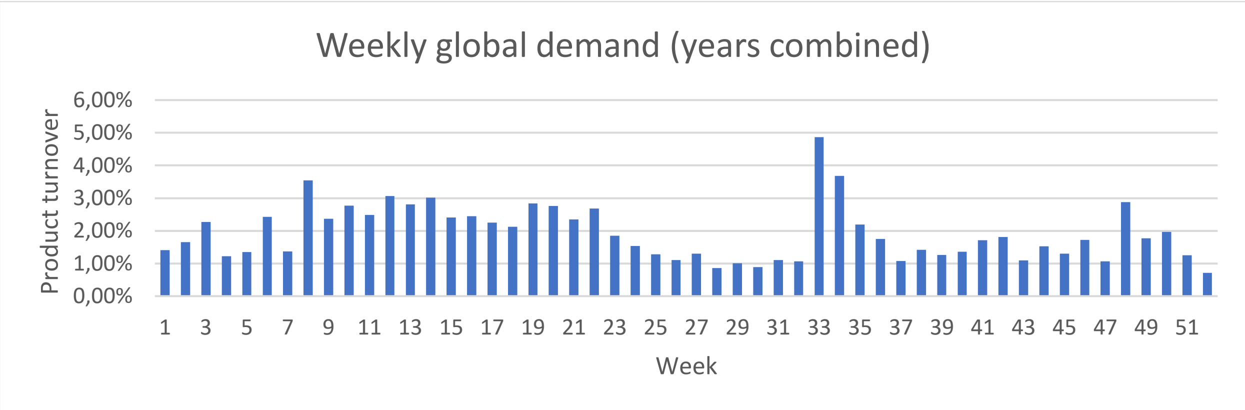


Table 3-2 Weekly global demand with yearly data combined between 01/01/2016 and 05/06/2018.

We can notice two trends: sudden peaks and seasonal demand. Sudden peaks are caused by discount periods, which can apply to some or all retailers. The peaks in week 3 of 2016 and 6 & 8 of 2018 are explained sporadic discount periods. Peaks in week 33 and 34 of 2016 and 2017 are caused by the Rentrée discount period, popular in France when the school year starts. In week 48 of 2017, a Christmas discount is observed. The remaining change of ordering volume follows from seasonality. Seasonality of demand is present in the whole flower industry. Practically all retailers Company A provides to follow a comparable seasonal pattern. The months March, April and May are considered "on-season". The ordering volume increases significantly during this period. Week 8 to 22 represent an average of 2.66% ordering volume, compared to average of 1.62% outside these bounds, including discount periods.

Ideally, we wish to identify seasonality and discount demand separately, to accurately estimate order volume in a prediction model. However, no distinction can be made between these orders. We therefore cannot separate discount orders from regular order. We assume that the occasional discount orders belong to the regular demand. As a side-note, the Rentrée and Christmas discounts have a significant probability of occurring in the future as well and are therefore important to consider.

Assumption 3: *Discount orders belong to regular demand.*

3.1.2 Retailer demand

In this section, we analyze the different retailer sizes and elaborate on some specific cases. Doing so, we wish to develop insight in the variety of retailers present in the French network to substantiate possible future decision that will have to be made. The following histogram shows the number of times retailers have ordered.

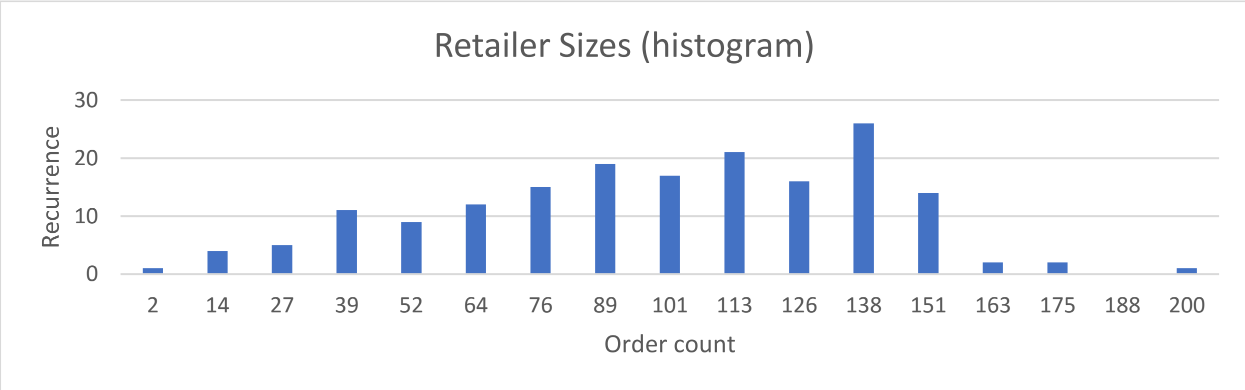


Table 3-3 Retailer sizes based on the amount of times ordered. On the horizontal axis, the number of times ordered over the period are indicated, with the count of their recurrence on the vertical axis.

The average number of times ordered is 93.3. Over 131 weeks of data, retailers order every 0.71 weeks on average, or approximately twice over three weeks. The variance is also high. Retailers follow an individual ordering schedule. In the following chart, all retailer ordering sizes relative to the retailers total ordering size are compared to determine whether differences in ordering size and ordering frequency result in a difference in demand patterns. If not, we could suggest using a universal demand pattern for all retailers.

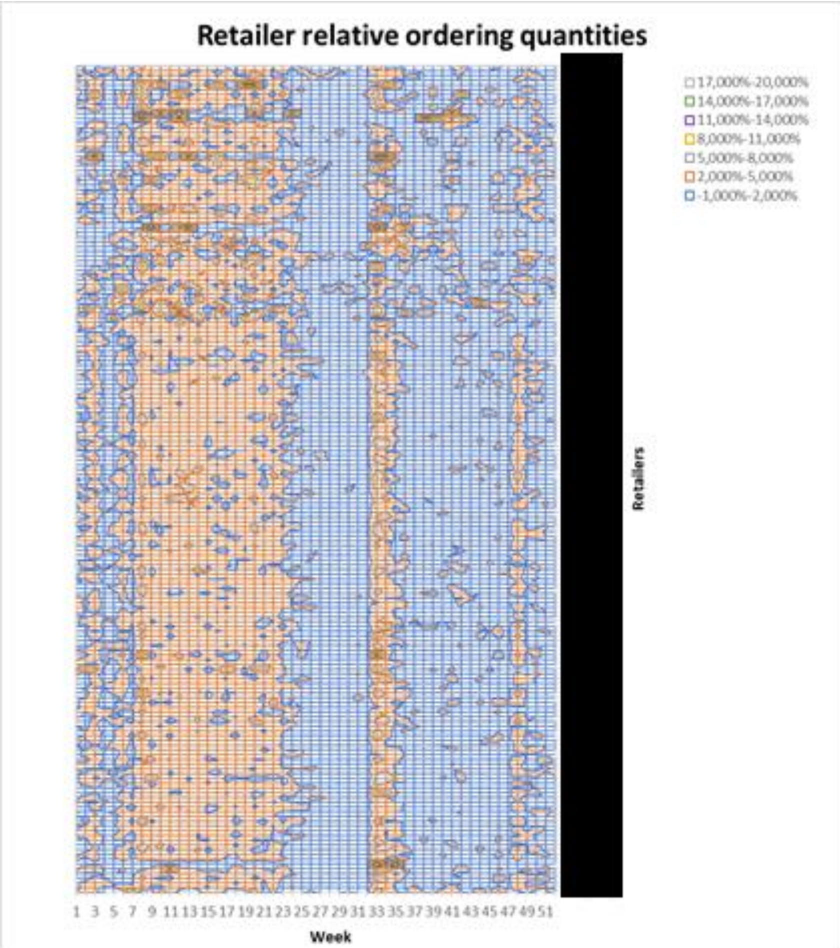


Table 3-4 Weekly ordering size per retailer. The 52 weeks in a season are represented on the horizontal axis. The retailers are represented on the vertical axis. The ordering size is represented on the z-axis, shown in colors.

We performed as statistical test to determine whether all retailers follow the same global ordering trend. Our hypothesis, h0, is that all retailers follow the same distribution. The average week specific ordering size over all retailers are determined and used as a global relative ordering size per week, which would apply for all retailers.

A popular statistical test is the Chi-squared test. However, the occasional order counts of 0 prevent the usage of this test. Our data also consists of more than 20% of orders less than five. Also, we expect retailers to occasionally order 0 products. A relatively unknown statistical significance test is the G-test, a replacement for the Chi-squared. It is more fit for our data and we have therefore opted to use it. The following functions and restrictions apply to both the Chi-squared and the G-test:

G-test

$$G = 2 * \sum_i O_i * \ln(\frac{O_i}{E_i})$$

$$O_i \geq 0 \; for \; all \; i$$
$$E_i > 0 \; for \; all \; i$$

Chi-Squared test

$$\chi^2 = \sum_i \frac{(O_i - E_i)^2}{O_i}$$

$$O_i \geq 5 \; for \; at \; least \; 80\% \; of \; i$$
$$E_i \geq 1 \; for \; all \; i$$

Using a 95% significance, we concluded that we must reject our hypothesis. Thus, retailers do not follow the determined distribution pattern. We performed an additional test using a weighted distribution in which high ordering retailers have more influence on the distribution, which also resulted in the hypothesis being rejected. We conclude from this that the retailers do not follow a global ordering trend. All must be assessed individually. The statistical hypothesis tests can be found in Appendix 7.3

3.1.3 Cart value

In the analytical model, we create a what-if analysis based on the global market value. Eventually a transition from market value to cart count is necessary. Cart value can be calculated using $\frac{Cart\ Count}{Cart\ Value}$, resulting in the fraction of a cart one can purchase with one euro. Combining the transaction dataset with the transport dataset, we find the value of transported carts. A histogram of the recurrence of cart values is charted in Table 3-5.

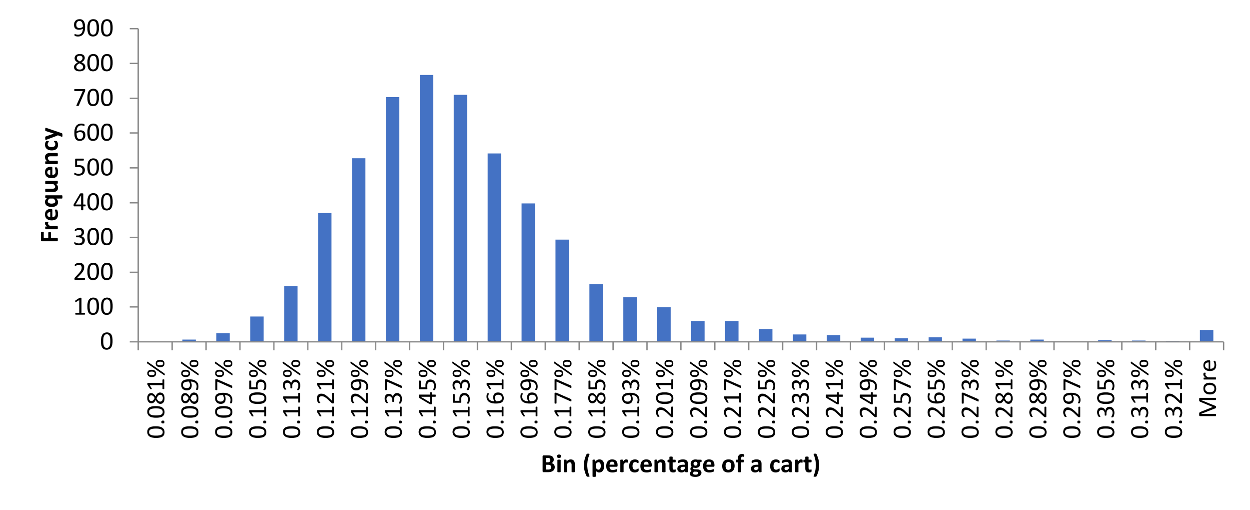


Table 3-5 Histogram of fractions of carts purchasable with one euro

The high deviation in cart values led to the decision to use a distribution for the cart value, instead of using an average. Using an average cart value leads to an unvarying retailer demand when implemented in the analysis. Testing a same depot selection and market value multiple times would lead to identical results. Using EasyFit, the fitting distribution found is a three-parameter log-logistic with the parameters given below. We reversed the Cumulative Density Function (CDF) to retrieve a specific cart value based on a random variable:

$$Cart\ value = \beta * \left(\left(\frac{1}{rand}\right) - 1\right)^{-\frac{1}{\alpha}} + \lambda$$

$$rand = [0,1]$$

$$\alpha = 4.6834$$
$$\beta = 0.00070558$$
$$\lambda = 0.00074104$$

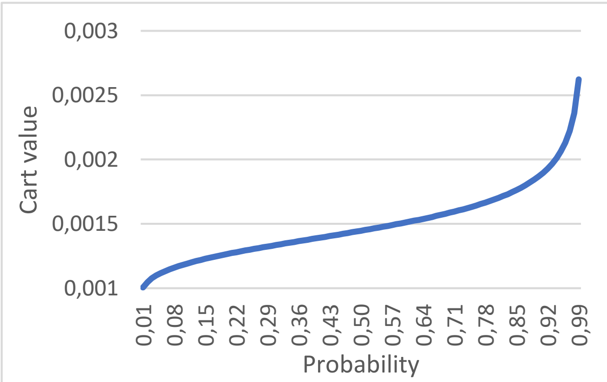


Table 3-6 Graph of the Cart Value function

This distribution fits only given the market values observed in the data. Cart values can vary as demand increases or decreases. We assume the function is reliable and accurate for a changing market value.

Assumption 4: *The cart value function is reliable and accurate.*

Finally, the value of carts for outdoor products in the French industry is less than the value of carts for category A products at Company A. The transport team at Company A estimates that for a given value a retailer can order twice as much outdoor products carts. This means retailers can buy twice as high fraction of a cart with one euro. We therefore multiply the resulting cart value by two.

Assumption 5: *The value of outdoor-products carts is half the value of category A-products carts.*

The conversion is done after the global market value has been distributed over all retailers and weeks to provide every retailer with an arbitrary cart value every week, to approach a scenario in which carts have different values. Thus, retailers with identical order value might order different numbers of carts. We end with the following function calculating the carts ordered based on a given budget.

$$Carts = round\left(MV * CS * 2 * \left(\beta * \left(\left(\frac{1}{rand}\right) - 1\right)^{-\frac{1}{\alpha}} + \lambda\right)\right)$$

$$MV = Global\ Market\ Value$$

$$CS = Customer\ Share$$

3.1.4 Geolocation analysis

Using a tool available in Excel, 3D Maps, we link the findings in Section 3.1 so far to coordinates on a map. GIS locations are provided in the transport dataset. This section focusses on showing how the data is spread over France. In the figure below, all available retailers are depicted on a map.

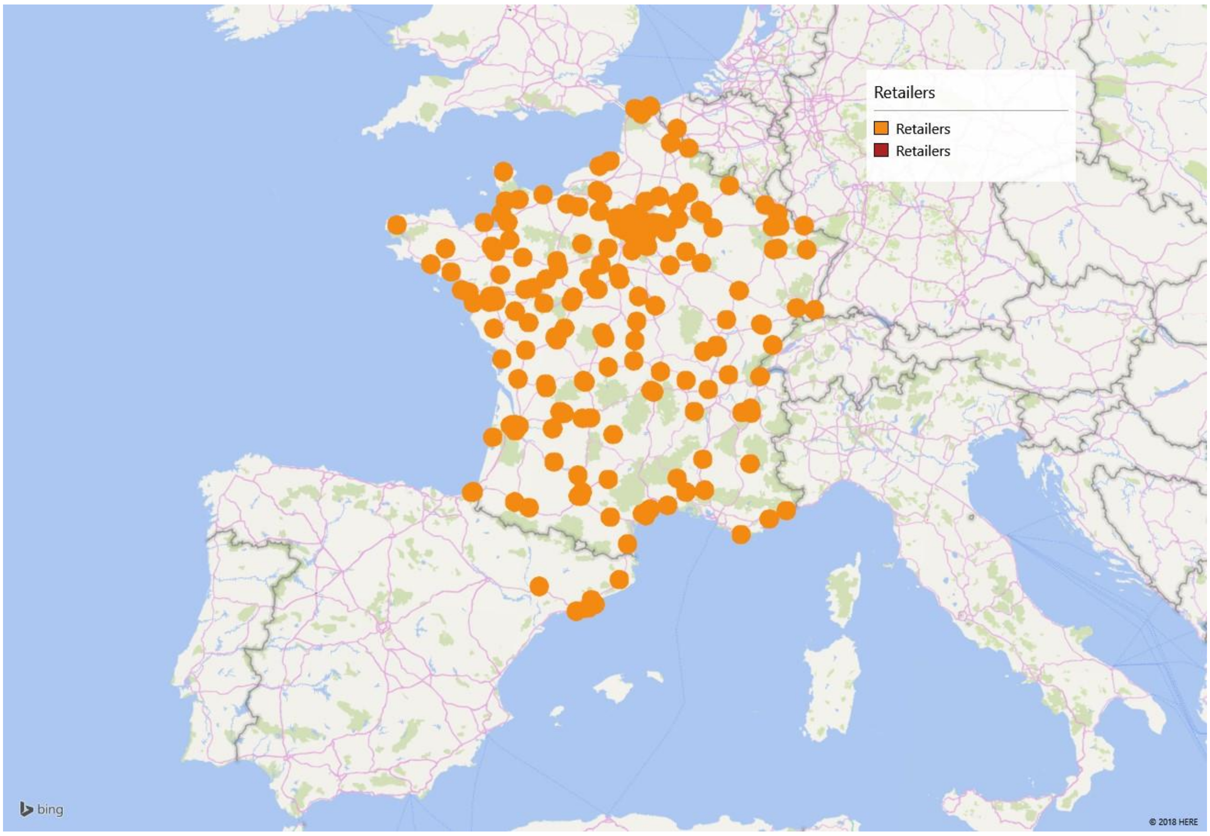


Figure 3-1: Retailer locations

Some retailers are in Spain and in Portugal. The scope defined in Section 1.5.2 cites we include only the French and eastern Spanish retailers. From a strategical point of view, we argued that as the eastern Spanish retailers are relatively close to France, we can include them in our research. The other foreign retailers are too far to include in the network. We therefor assume the eastern Spanish retailers are included in the French transport network.

Assumption 6: *Eastern Spanish retailers are included in the French transport network.*

In Figure 3-2, we include the total carts ordered by each retailer, indicating where the large demand areas are located. We identify a clear distinction between areas of high demand, such as the Paris region, and area of lower demand, such as the Marseille region.

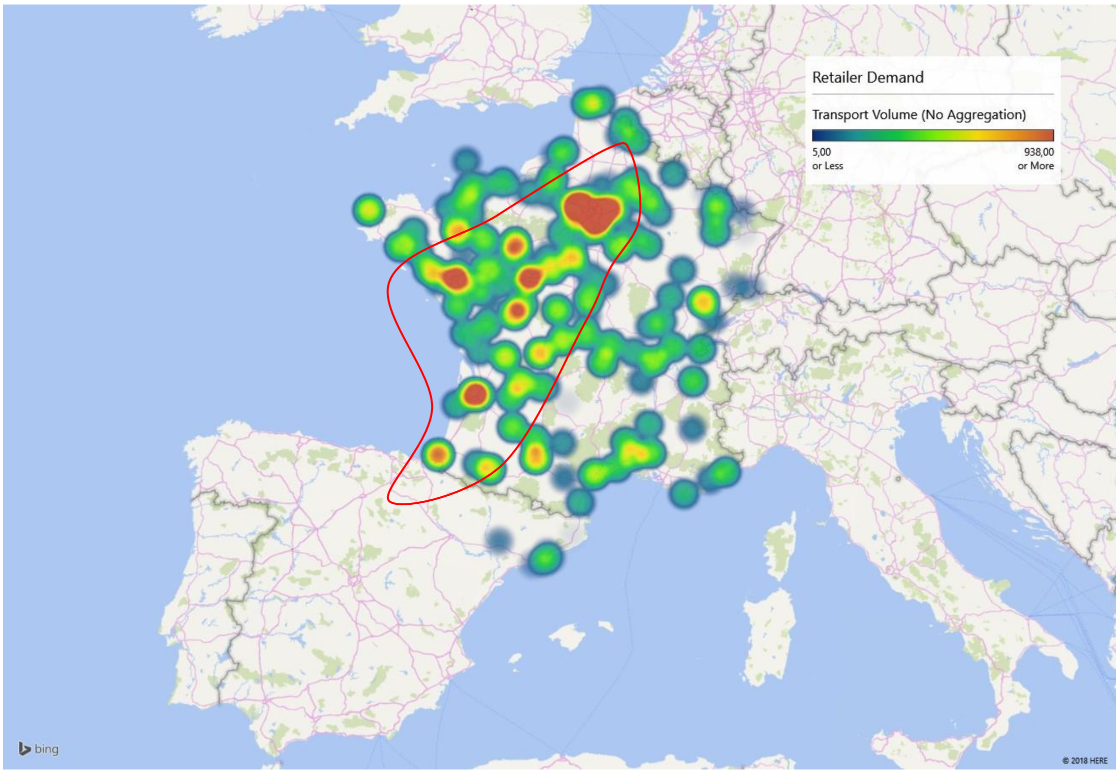


Figure 3-2: Retailer demand. The highest demand area is encircled in red.

3.1.5 Additional characteristics

Through semi-formal interviews with the Company A Transport team, we know retailers can only accept deliveries during their opening hours, which are between 08:00 and 12:00, and between 14:00 and 18:00. Some retailers only accept deliveries during one of these timeslots, but the Transport team sees a growing trend of retailers receiving deliveries during both time slots. We therefore assume that all retailers can be delivered to during both time slots.

Assumption 7: *Retailers can be delivered at between 08:00 and 12:00, and between 14:00 and 18:00.*

Additionally, we have assumed the ordering frequency of depots. As we do not have exact data, we have limited our research by assuming retailers order only once a week, thus 52 times a year.[1]

Assumption 8: *Retailers order once a week at most.*

3.1.6 Conclusion Historical retailer demand and retailer geolocation

In this sub-section, we analyzed available on retailers. Due to restrictions described in Section 1.9, we made some assumptions concerning the reliability of our data. Nevertheless, we conclude that due to a considerable difference in retailer sizes and ordering patterns, all retailers should be assessed individually when estimating their demand. This leads to the usage of empirical ordering data in the future. Additionally, we charted the different retailers (and their demand) on a map from which we concluded that including the eastern Spanish retailers to our scope is a good strategical decision. We also concluded that retailers can be delivered at during time-slots applicable to all retailers, that

[1] Later during the project, on the Date, Company B's Sales Manager explained he expects his retailers to order twice or thrice a week, due to the freedom of restrictions (e.g. minimum 3 carts per nursery) offered by Company A' services. However, this was too late to implement in our research.

retailers order once a week and that France-sourced carts occupy twice as much volume as Netherlands-sourced carts, resulting in French carts having twice as high volume for the same value.

3.2 PRODUCER SUPPLY

Using the producer dataset, we mapped the available data on producers. It contains the 20 producers who supply the most products to Company A, along with the monthly production volume.

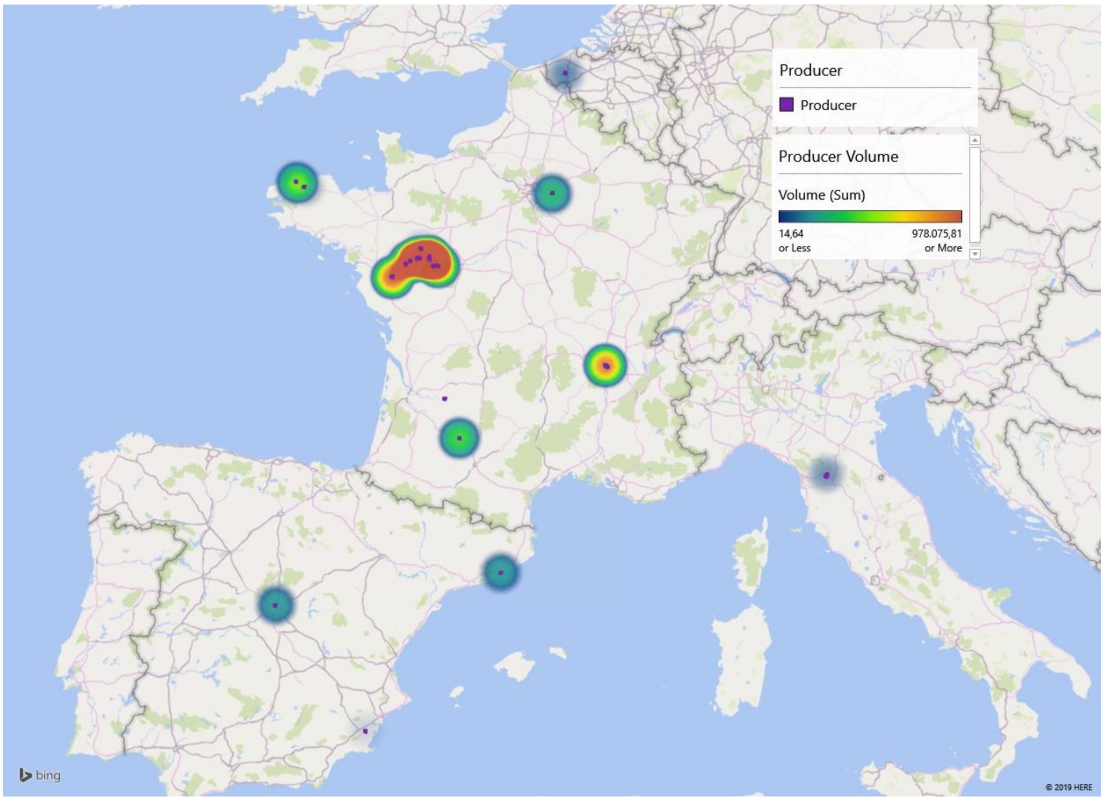


Figure 3-3: Producer supply and locations

We can identify a supply peak in the region of City B. According to data, this region represents 68% of the total supply. The volume was, however, undefined for all producers and thus we can only compare producers between one another. We use the assumption of unlimited supply to simplify the project.

Assumption 9: *producers can always supply demand*

3.3 DEPOTS

In Section 1.5.2 we introduced the specifics of the assignment. We work with 24 depots, one of which will be used as a DC, provided by Company A' transport partners. In Figure 3-4, all 24 depots are shown. A few depots are located relatively close to another. We choose to combine these locations into one depot. These depots are encircled. This leaves us with 21 depots, one if which serves as a DC. This depot is indicated with an arrow. In the next section, we substantiate why this location was chosen.

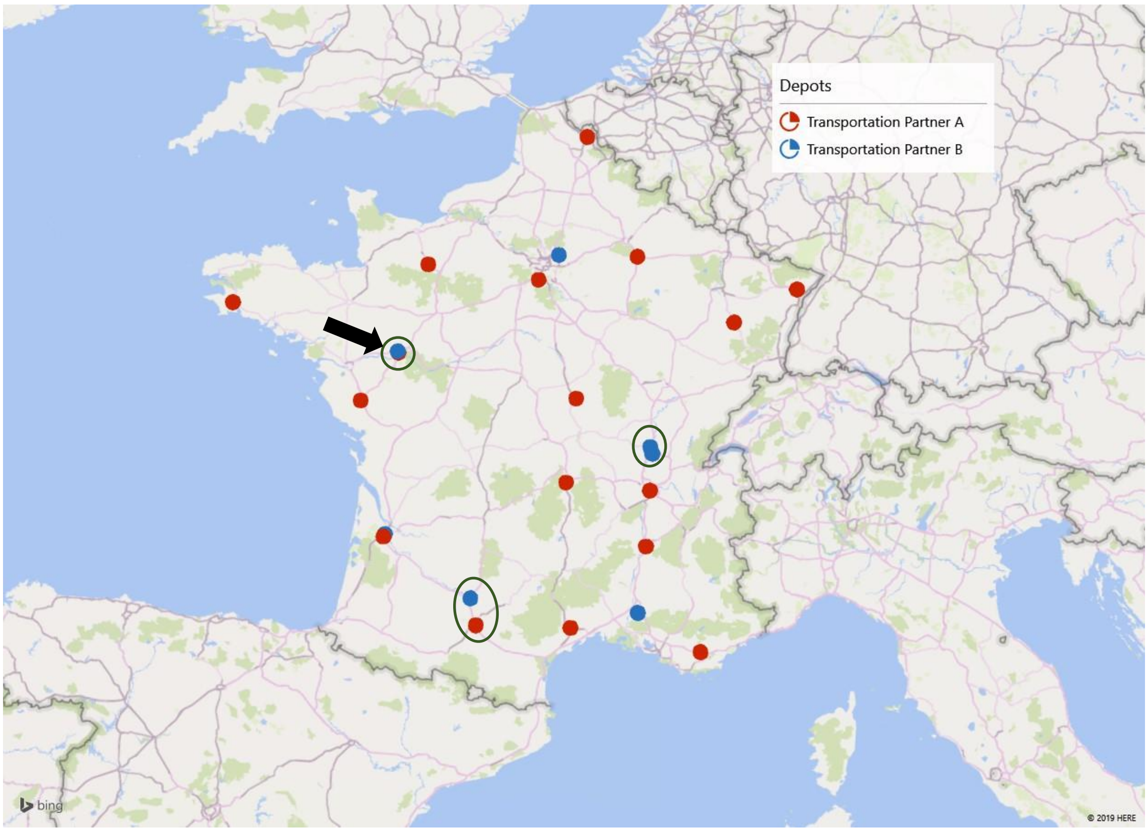


Figure 3-4: Depots locations, categorized by provider

3.3.1 Distribution center

Company A has made the call to consider City B as the basis for the DC. City B represents 68% of the producer supply, and a depot is already located in the same area. With the gathered information, we can substantiates Company A's call to focus on the optimization of outbound transport. We developped a score for each retailer based on the expected driven kilometers if a producer were required to transport all of their volume to each of the depots. With a fixed total number of products transported, we can identify which depots are closest to the largest supply areas.

DEP1	DEP2	DEP3	DEP4	DEP5	DEP6	DEP7	DEP8
6.61	4.47	5.77	4.07	7.03	1.81	5.37	3.83

DEP9	DEP10	DEP11	DEP12	DEP13	DEP14	DEP15	DEP16
6.01	3.24	4.5	7.94	5.8	9.03	2.42	6.71

DEP17	DEP18	DEP19	DEP20	DEP21	DEP22	DEP23	DEP24
3.65	7.69	1.82	4.04	5.24	5.16	4.19	5.14

Table 3-7: Depot scores. Scores are calculated by multiplying the producers production volume by the distance to hypothetical DC's. (x1 billion)

This is also visually confirmed when charting producer production against depot locations, as can be seen in Figure 3-5. DEP6 is the depot located in the center of the highest production volume. From this deduction follows an important decision: transport from producers to the DC is dependent on which type of products we order in our transport network. As we do not make a distinction between products types in our research as denoted in Section 1.5.2, we do not assess from which location our products are sourced. The amount of products sourced and transported to the DC is therefore only influenced by the market value and by which depot is selected as a DC. Additionally, in a realistic situation the first producers from which will be sourced will be the closest ones. As shown in Section 2.2, the section near City B consists of 68% of supply, or a market value of around €47.6M. It is unlikely that Company B is willing to commit to a higher market share from the start, and we can therefore expect that, in the first few years, all products will be sourced around City B. As the distances between producers and DC are relatively small compared to DC, depots and retailers, we leave producer transport out of our scope through the assumption that the producer transport does not affect the transport network's efficiency.

Assumption 10: *Transport from producers to DC does not affect the global transport network*

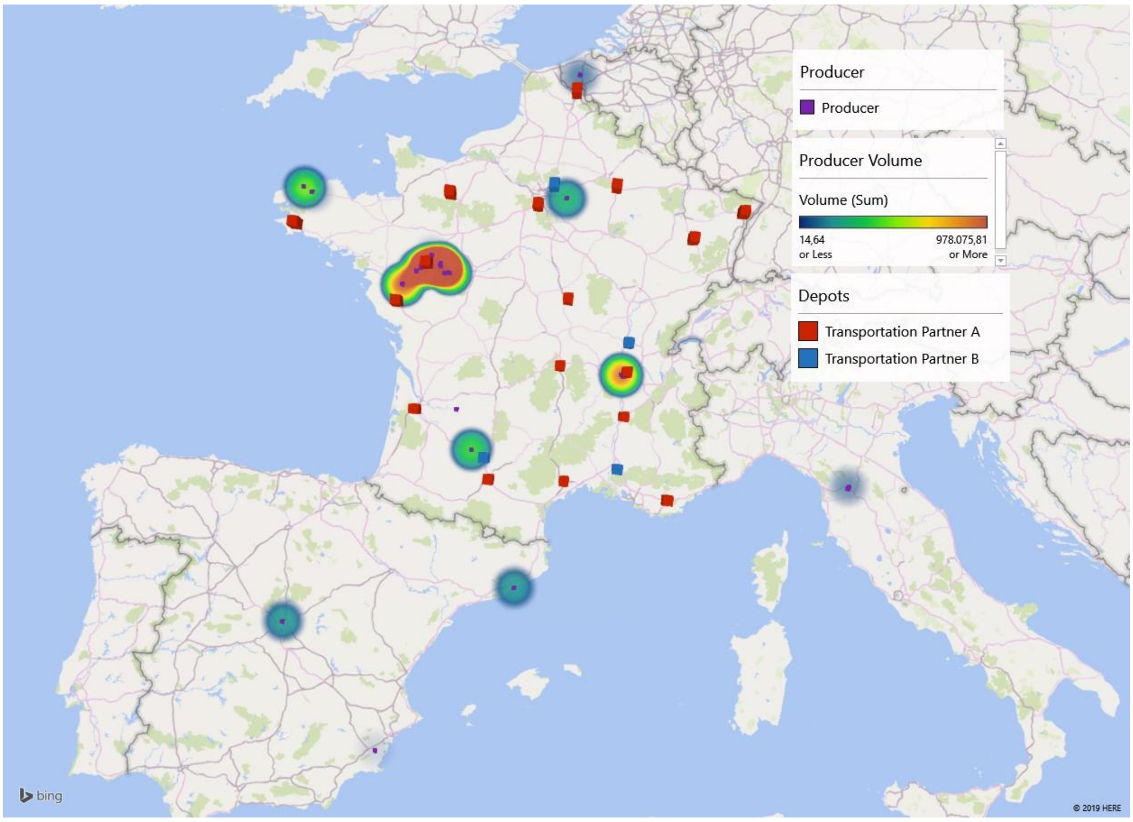


Figure 3-5: Depots locations represented over producer production volume

3.3.2 Conclusion

In this section we analyzed depots locations. Depots from two main providers, Transport Partner B and Transport Partner A, are located throughout France. One of these depots should also function as a DC: the main location where are products are delivered too from the producers. We concluded that DEP6 is ideally located as it is closest to the epicenter of supply. Additionally, we concluded that calculating a transport network for inbound transport, from producers to DC, was insignificant for the end results and are therefore left out of our scope.

3.4 Transport

3.4.1 Transport characteristics

Information on the characteristics of transport presented by the Company A transport team. Transport is limited by load capacity, driving speed and delivering time. For their expert opinion, the Transport team estimates the average driving speed of trucks being 70 km/h. Delivering products (from arrival to departure) takes on average 30 minutes. The capacity of trucks is 43 carts. Additionally, truck drivers are limited to 10 driving hours by the European regulations. If a truck driver is idle for less than 30 minutes, the idle time is counted as working time.

3.4.2 Distance matrix

To explain the choices made in this section, a historical background gives perspective. During the reign of Napoleon, the military played a great role. Located around Paris, the capital, they needed to travel long distances to reach military fronts. To support them, roads were built. These roads all started in Paris and expanded to the edges of the reign. These roads were the basis of the highways that we know today. A characteristic is that these roads are ideal for connecting north to south, but not so to connect east to west.

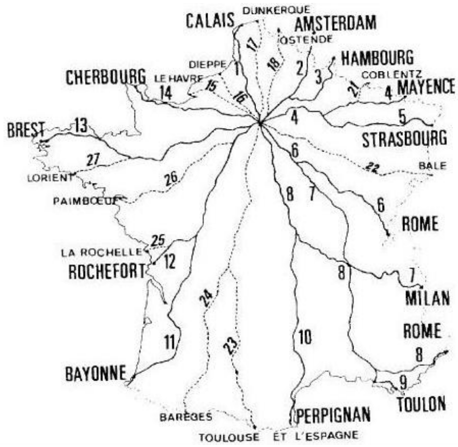


Figure 3-6: Origins of the French highways: Les Routes Napoléonnienes

To determine the distances between two locations, we have at our disposition their geographical positions. We could use a "as the crow flies" Harversine formula, in which the straight line between the two point is calculated. However, due to the nature of the French highways, this would give us an unreliable distance. The quickest route between two points usually follows north- and southwards highways. To counter this problem, we developed a script which collects route information between two GPS-coordinates, as calculated by Bing Maps. The real-road driving distances are output by the script in a distance matrix. It does so for all origin and destination coordinates we provide it with.

3.5 Conclusion

In this section we obtained and analyzed data on retailers, producers, depots and transport partners. We conclude that retailers have different ordering patterns and sizes. We determined that there is no global distribution for all retailers and that therefore all retailer demand patterns should be assessed individually. We also determined how to convert a monetary value, the available market value for instance, to a number of carts using the three-parameter log-logistic distribution. We also gathered the delivery windows, which are identical for all retailers. By collecting and mapping producer locations and production volume and depot locations, we also added arguments to the selection of DEP6 as DC due to its proximity to the highest production volume. In further advancements of the project, we assume supply is unlimited. Also, we do not further research the inbound transport network between producers and the DC. Transport itself is limited by a truck capacity of 43 carts, driving speed of 70 km/u on average, (un)loading times of 30 minutes and truck driver regulates, which prevent a driver from working more than 10 hours per day. Finally, we also created a tool to obtain a real-road driving distances between all locations, as the north- and southbound nature of French highways would lead to unreliable results if straight line distances between locations were used.

4 CONCEPTUAL MODEL

To approach out the LRP described in Section 2, we require a tool which can process the data gathered in Section 3 for us as the scale is very large. In this chapter, we develop a conceptual model according to which the analytical model can run. In Section 4.1, the global function of the analytical model is presented, along with the objective function. In Section 4.3, the demand generation process is shown. In Section 4.4, the depot allocation heuristic is explained in its functioning. In Section 4.5, the vehicle routing heuristic is explained in its functioning. In Section 4.6, the visualization process in described.

4.1 FUNCTIONING OF THE ANALYTICAL MODEL

The conceptual model contains multiple sub-sections, each performing a different task in the analytical model. First, the component gathers all required data found in Section 3 and user inputs. This component can activate the demand generation component which generates demand for all retailers, the depot assignment component which assigns retailers to depots and the vehicle routing component, which creates the routes in the network. Together, this generates a transport network, containing routing information for 52 weeks. Multiple networks are generated and compared according to Key Performance Indicators (KPI). The best scoring network is output, after which the visualization component can visualize the KPIs and the driven roads.

The analytical model consists of a what-if analysis, in which different alternatives are compared. In this research, we search information regarding the available market value and depots. This model will be coded in Excel VBA, which has memory limitations. For this research, the conceptual model is designed to separate the market value and the depot selection choices. The user is limited to a choice:

- Generate the transport network for a range of different market values with a fixed depot selection set
- Generate the transport network for a range of different depot selections with a fixed market value

Choices can be made in an interface. The user can propose a lower and upper bound and interval for their market value, or they propose a selection of depots of which they wish to test all possible combination sets. Of course, large ranges of depots selection cause a longer computation time.

The required inputs consist of location information for all retailers and depots, retailer demand trends, transport characteristics, a distance matrix and a map of France. Output are transcript of the transport network and KPI results. The KPI scores for all generated transport networks are also output.

For all component a flowchart has been made to describe the process. Each flowchart can be found in appendix 7.4 along with the legend. For clarity, a summarized flowchart of the conceptual model can be found below.

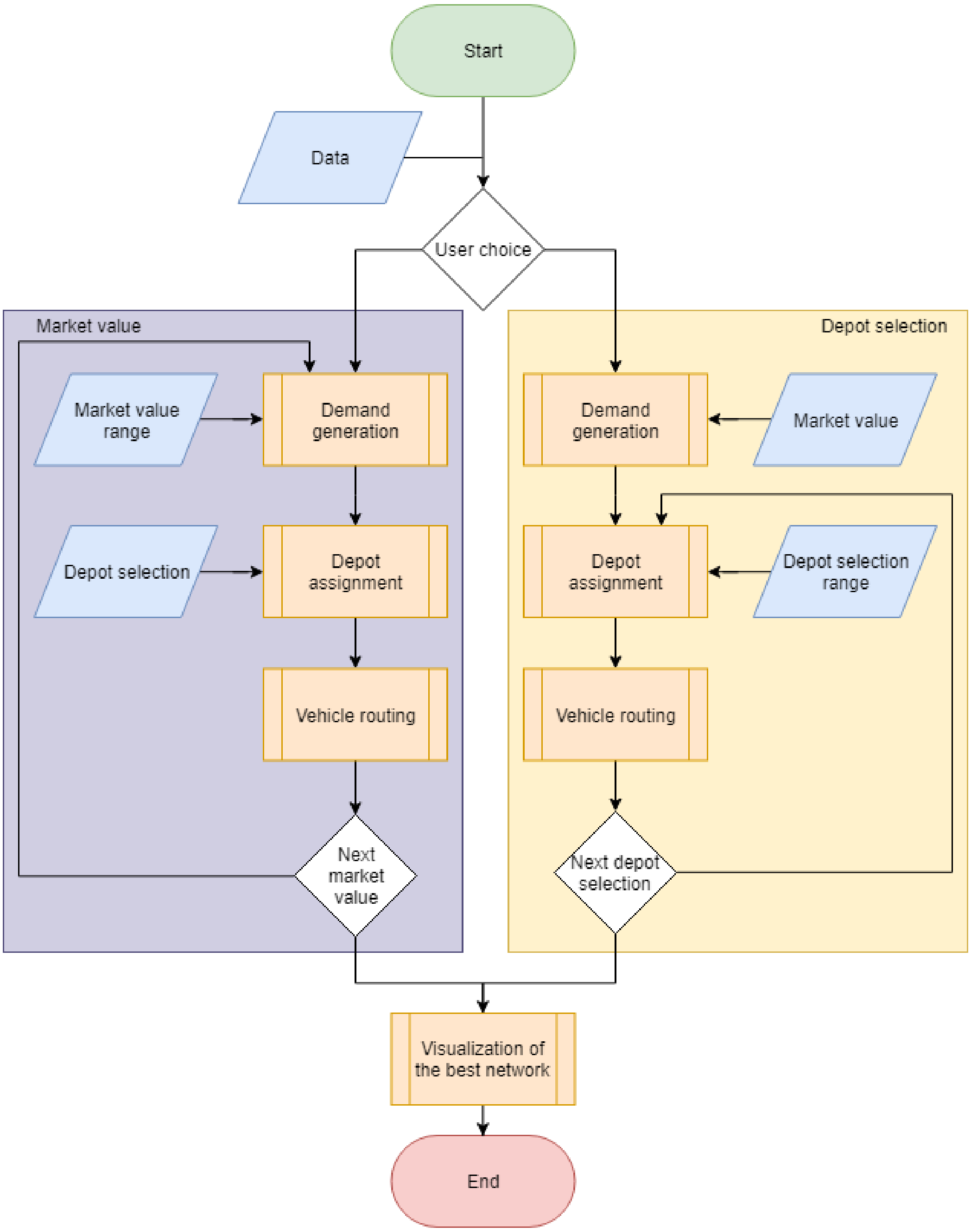


Figure 4-1: Summarized conceptual model. On the left, a range of market values is tested with a fixed depot selection. On the right, a range of depot selections is tested with a fixed market value.

4.1.1 Objective function

Transport networks are evaluated according to an objective function, as discussed in Section 2.1.1. We defined our objective function with the number of required trucks for transport and the number of driven kilometres. A distinction is made between transport from the DC to depots and transport from depots to retailers. The latter will most likely not consist exclusively of Company A' products as transport is organized by the transport partners. We cannot guarantee the transport will behave as our model predicts. By separating the two transport categories, we can assign different weights and vary which measures we believe are more important or reliable. Also, we leave depot usage costs out of the studies as our objective is to provide minimum non-monetary transport requirements which are not influenced by depots costs. This leads to the following KPIs:

- Kilometers driven from DC to depots per product (KM-in)
- Kilometers driven from depots to retailers per product (KM-out)
- Trucks required to drive from DC to depots per product (TR-in)
- Trucks required to drive from depots to retailers per product (TR-out)

In order to compare the four KPIs, they are normalized and weighted. The normalization allows for all KPIs to be compared with one another. This is done by dividing a scenario's KPI score by the sum of all scores for that specific KPI. The weighting allows the user to determine how KPIs influence a scenarios score. For instance: we have two transport networks with a total demand of 2000 and the following KPI scores. In Table 4-1 the total scores both example scenarios are shown, along with the total scores. In Table 4-2, the normalized scores are shown. The scores can now be compared to one another. We do so on Table 4-3, where we also assign weights to each KPI.

KPI	**Example 1**	**Example 2**	**Total**
KM-in	1000	1200	2200
KM-out	7000	6000	13000
TR-in	50	60	110
TR-out	75	60	135

Table 4-1: KPI scores for the example networks

KPI	**Example 1**	**Example 2**
KM-in	0.455	0.545
KM-out	0.538	0.462
TR-in	0.455	0.545
TR-out	0.556	0.444

Table 4-2: normalized KPI scores for the example networks

KPI	**Weights**	**Example 1**	**Example 2**
KM-in	2	0.455	0.545
KM-out	1	0.538	0.462
TR-in	1	0.455	0.545
TR-out	0.5	0.556	0.444
Score		2.181	2.319

Table 4-3: Example scores in a weighted situation

4.2 Overarching component

In the overarching component, the analytical model first collects the information found in Section 3. User-defined choice mentioned in Section 4.1 are also gathered. Bases on this choice either a range of market values or multiple depot selections are used to generate transport networks. If a range of market values is given, each different value in the given range is selected consecutively and a transport network is generated for each market value and a fixed depot selection. If a selection of depots is given, all possible depot combinations are generated and selected consecutively. Also, the fixed market value also results in a fixed demand for all generated transport networks. When all networks have been generated, they are compared based on the objective function and the scores for all KPIs.

4.3 Demand generation

In Section 3.1 we discussed the trends in retailer demand and the relationship between monetary value and cart count. We found that all retailer demand patterns follow a comparable seasonal pattern but that their demand patterns must be generated individually. We also determined how to convert a monetary value to a cart count using a three-parameter log-logistic distribution. This distribution determine which fraction of a cart is equal to one monetary value. Based of retailer sizes, demand pattern, a given market value and cart value, we can determine demand for all retailers in a year. If we are generating transport networks with varying depot selections but a fixed market value, the generated demand will be identical for all iterations.

4.4 DEPOT ASSIGNMENT

In Section 2.4, we discuss how we tackle the DAP. In this section we elaborate on the heuristic adding insights on how the logic works. Additionally, the conceptual model of this process can be found in Appendix 7.4.4. For each week, the allocation process is redone. First, retailers are assigned to the nearest available depot. The total demand of retailers assigned to one depot determines the so-called depot demand. To supply this demand, it must be transported from the DC to the depots. A situation as illustrated in Figure 4-2 can be observed, assuming our current truck capacity is 10. Demand for each retailer and the resulting depot demand is also illustrated. For each depot, *n* trucks are required to transport the products. We assume that *n-1* trucks are filled to maximum capacity, with the last truck carrying the remaining demand. Based on this last truck's fill-rate, depots are assigned a status: supersaturated, unsaturated or saturated. If a depot's last truck's fill-rate is less than the average fill-rate of all depots' last trucks, the depot it is due to is considered supersaturated: the depot's last truck's fill rate is low to such an extent it is recommended to have retailers unassigned until the truck becomes obsolete. If the fill rate is more than average fill-rate of all last trucks, the depot is considered unsaturated: the depot's last truck's fill rate is high enough that it is recommended to fill the trucks to full capacity. When a depot's last truck's fill-rate is 100%, this depot is considered saturated and will not be selected to have retailers unassigned from or reassigned to them. Additionally, the last-truck's fill-rate is not considered when determining the average last truck fill-rate. Next, a random supersaturated depot is selected. In the example, only depot B is supersaturated. Of all retailers assigned to depot B, the retailer closest to a non-TABU unsaturated depot is selected and reassigned to this depot. The origin depot of this retailer is now TABU for this retailer for a given amount of iterations. The depot last truck's fill rate is re-determined and the process repeats itself. During the process, the amount of trucks required for transport is tracked. This TABU meta-heuristic aims to reach a minimum amount of trucks. If no improvement is measured for a given amount of iterations, the TABU accepts the best observed depot-retailer assignment.

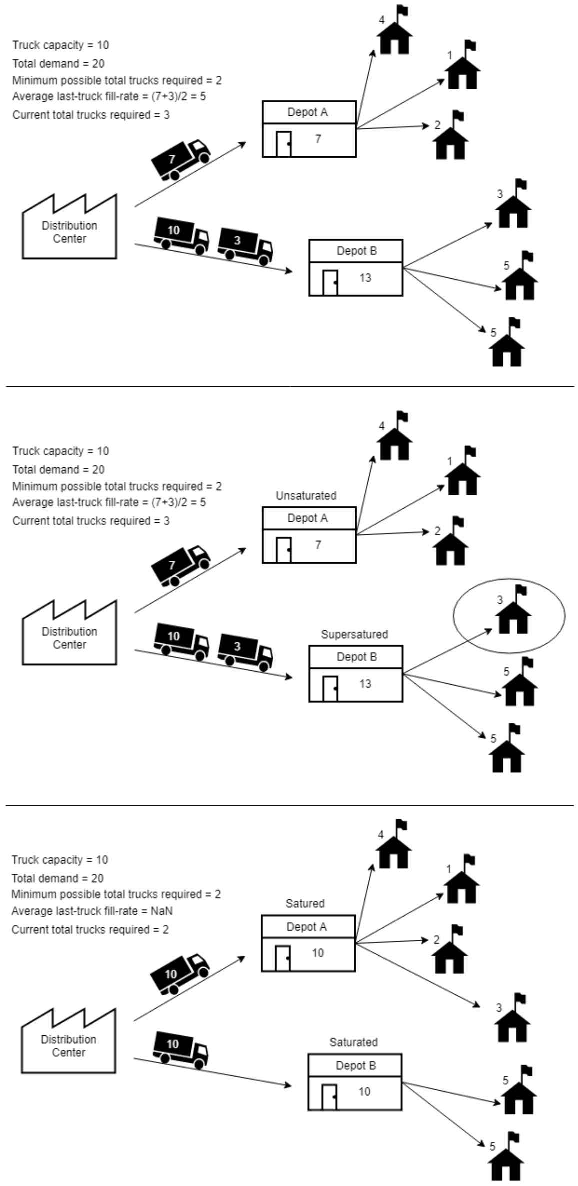


Figure 4-2:Depot assignment process: retailers are reallocated based on the expected gain in efficiency.

4.5 Vehicle Routing

The vehicle routing process is also mentioned in Section 2.4, which we visualize using an example. The procedure accounts for retailer delivery windows, truck carrying and driving capacities and the fact that trucks do not return at their originating depot. We do so by using an adapted maximum savings algorithm. First, the distance matrix between all locations is made asymmetric by setting all distances from retailers to depots to zero. The example distance matrix is shown in Table 4-4. Next, each retailer is assigned an exclusive route as a starting solution, in which this retailer is also the end point for the route. In Figure 4-3, the depot and retailer routes are shown. We also indicate the demand per depot. In our example, we have a truck capacity of 10, a driving capacity of 10 and a delivery schedule between 8:00 and 12:00 for all retailers. For every route, truck load, total driving time and current schedule is kept track of. Next, a savings matrix is created. This matrix shows the potential savings to be gained by connecting two nodes, as can be seen in Table 4-5. Potential savings to be gained by connecting an origin and destination retailer can be calculated by removing the cost of the new connection from the cost of the connection towards the destination retailer that would be removed. In our case, this would mean removing the cost (in hours) of driving between two retailers from the cost of driving between the depot and the destination retailer. Note that savings depend on the direction of the connection. This is due to the asymmetrical distance matrix and the fact that routes end at the final retailer in their delivery schedule. Take for instance connection A-B and B-A. The first connection leads to a savings of 2, whereas the reversed connection would lead to a loss of 3. The next step is to select the connection which leads to the highest savings. This connection is tested for feasibility and should follow the following constraints:

From\to	Depot	A	B	C	D	E
Depot	-	2	7	8	4	3
A	0	-	5	8	5	5
B	0	5	-	3	5	9
C	0	8	3	-	3	8
D	0	5	5	3	-	2
E	0	5	9	8	2	-

Table 4-4: Distance matrix (in driving hours) between all origin and destination locations

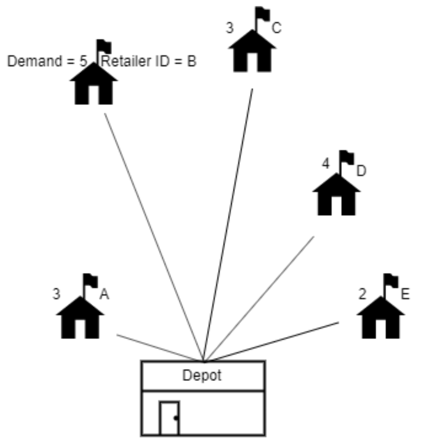


Figure 4-3: : Depot and retailer locations, including demand.

Savings	A	B	C	D	E
A	-	2	0	-1	-2
B	-3	-	5	-1	-6
C	-6	4	-	1	-5
D	-3	2	5	-	1
E	-3	-2	0	2	-

Table 4-5: Savings matrix (in driving hours) between all origin and destination locations

- Constraint 1: A retailer has a maximum of two connections.
- Constraint 2: The origin retailer should be at the end of its route's delivery schedule.
- Constraint 3: The destination retailer should be at the start of its route's delivery schedule.
- Constraint 4: The retailers should not already be in the same route
- Constraint 5: The resulting route's demand should not exceed truck capacity.
- Constraint 6: The resulting route's driving time should nog exceed the driving capacity.
- Constraint 7: The resulting delivery schedule should reach all retailers within delivery windows

The initial routes and capacities can be seen in Table 4-6. The highest savings in Table 4-5 is the connection B-C. Creating this connections will keep all constraints satisfied. The connection is implemented and the savings for this connection is set to 0. The next connection providing the most savings would be connection D-C, however the destination retailer, retailer C, is not at the start of the delivery route. This connection is infeasible due to constraint 3, and the savings are set to 0. The following connections are also infeasible: B-C (constraint 4), A-B (constraint 5, 6 & 7), D-B (constraint 5, 6, 7), C-D (constraint 5, 6, 7). The next best connection is connection E-D, which is implemented as all constraints are satisfied. Finally, connection D-E becomes infeasible due to constraint 4. The resulting route capacities can be seen in Table 4-7. The implemented and prevented connections are shown in Figure 4-4.

Route (Rt #)	Rt 1	Rt 2	Rt 3	Rt 4	Rt 5
Load	3	5	3	4	2
Total drive time	2	7	8	4	3
Delivery schedule					
08:00	A	B	C	D	E
09:00					
10:00					
11:00					
12:00					

Table 4-6: Route capacities in the starting solution

Route (Rt #)	Rt 1	Rt 2	Rt 3	Rt 4	Rt 5
Load	3	8			6
Total drive time	2	10			5
Delivery schedule					
08:00	A	B			E
09:00					
10:00					D
11:00		C			
12:00					

Table 4-7: Route capacities with all implemented connections

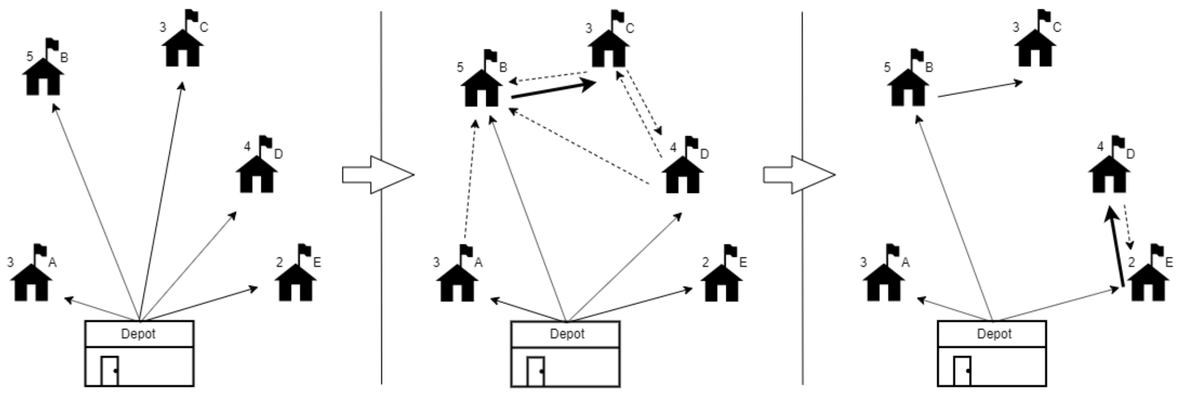


Figure 4-4: The routing process. The full lines indicate connections. Bolded lines indicate newly implemented connections. Dashed lines indicate connections which did not satisfy the constraints.

Using this process, we can establish routes through which retailers are delivered. As previously mentioned, depot-retailer assignment and vehicle routing is performed weekly with a fixed total market value and depot selection. This process is thus repeated for every depot and for every week.

4.6 VISUALIZATION

Once the best scoring transport network has been selected, relevant KPIs and the routes need to be displayed. We can show KPI information for the complete year. Visualizations of the transport network are shown one at the time (the user can choose which week to visualize at any time). We use the previously generated data to display routes in an Excel sheet. First, all location geographical coordinates are converted to excel-coordinates. This is done by first converting the geographical coordinates to UTM coordinates. Doing so converts spherical coordinates to X,Y coordinates on a plane.

$$X = r * Rad(\varphi)$$

$$Y = \ln\left(\frac{\tan(2 * Rad(\gamma) + \pi)}{4}\right)$$

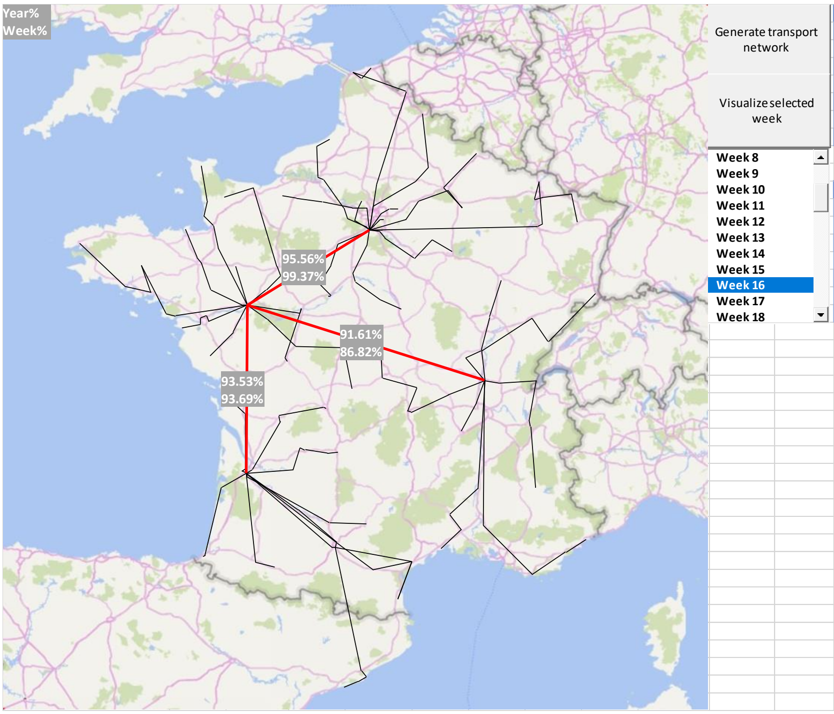
$$\varphi = Longitude\ in\ degrees$$
$$\gamma = Latitude\ in\ degrees$$
$$Rad = Converts\ degrees\ to\ radians$$
$$r = 6371000, Radius\ of\ the\ earth\ in\ meters$$

We now know the coordinates of all locations relative to the UTM coordinates (0,0), which is located in the Gulf of Guinea, in Africa. We wish to know the locations of all locations in relation to the map coordinates (0, 0) on the map we will be using. We therefore have to perform an extra step. We use the same functions to determine the UTM coordinates of the location in the lower-left corner of our map, shown in Figure 4-5. We refer to these coordinates as X_0 and Y_0. We now determine the new coordinates of the locations on this map. We refer to these coordinates as $\bar{X}$ and $\bar{Y}$.

$$\bar{X} = X - X_0$$
$$\bar{Y} = Y - Y_0$$

Figure 4-5: Empty map of France

We know now the coordinates of all locations on the map. Next, we insert the map in an excel sheet with a predetermined size, which we also use to determine the number of fractional number of pixels per coordinate-unit. Using the routing information generated through all processes previously explained, we insert a line between all origin and destination locations in the routing network. We calculate between which pixels a line should be drawn using the map coordinates and the number of pixels per coordinate. A distinction is made between route from the DC to depots and the depots to retailers by drawing the first type of routes with a thicker line. Finally, the relevant KPI information is gathered and displayed. A visualization can be seen in Figure 4-6.



Total	DEP4	DEP6	DEP17	DEP22
Demand	12714	16404	20559	10248
Truck In	314	398	498	259
Fillrate	0,935296602	0,955505203	0,955586619	0,916106568
Truck Out	830	1000	1244	744
Fillrate2	0,349701734	0,375777371	0,374579663	0,313257556
Distance In	116458	0	135920	133041
Distance Out	135359	127666	153667	136846

Week	DEP4	DEP6	DEP17	DEP22
Demand	282	303	470	224
Truck In	7	8	11	6
Fillrate	0,936877076	0,880813953	0,993657505	0,868217054
Truck Out	16	18	26	14
Fillrate2	0,409883721	0,391472868	0,42039356	0,372093023
Distance In	2596	0	3002	3082
Distance Out	2715	2385	3158	2718

Figure 4-6: Visualization of the transport network and the relevant KPI's.

4.7 Conclusion

In this section we create a model which can process the data collected in Section 3 to create transport networks by approaching the LRP, by using the processes described in Section 2.4. First, we address the global functioning of the analytical model and explained how the KPIs are normalized, weighted and finally summed and how multiple scenarios could be compared to one another. Next, we addressed the component which generates the transport networks according to the user choices. The first sub-component is demand generation. Based on the historical data, the market value is divided over all retailers and weeks. A retailer's specific market value is converted to a cart number using the conversion method described in Section 3.1.3 to create an actual demand in number of carts. The next sub-component is the depot assignment, which assigns retailers to depots and aims to optimize the depot assignment according to the required number of trucks to transport demand from the DC to the depots. Finally, the Vehicle Routing sub-component creates the depot-retailer routes using an adapted maximum savings algorithm. This completes the transport network generation process. Multiple transport networks are compared according to user's choices. All KPI scores are output, and the best scoring network, according to KPI weights, is output using the visualization component which draws all driven routes over a map. This component also shows KPI scores.

5 EXPERIMENTS AND RESULTS

In this chapter, we calculate the results using the calculation model. In 6.1, we address the limitations of the model and the experiment design, including the two variables and the KPI weights. In 6.2, we recapitulate the different assumptions we have made so far. In 6.3 we analyze the effects of different market values and determine which market value is ideal. In 6.4 we analyze which depot combinations are best.

5.1 EXPERIMENT DESIGN

We have a large range of options that can be tested. We determined an efficient method for experimenting with different scenarios. In Section 4.1, we already addressed the memory limitations of VBA. We will use the implemented method to test for an efficient starting market value. This will be tested against different fixed depots selections. Next, we test multiple depot selections using the market value. We will test the depot selections by dividing all depots into four geographical regions. For each region, all combinations using only these depots will be tested, except for the depots required to make the transport network feasible (e.g. adding a southern depot if we analyze the northern region as else southern depots can be delivered to.). For each region, the depots that contribute most to a more efficient network are selected, and all four regions' best depots are used to test all combinations of depot selection against a changing market value. To test the networks, we use the objective function, KPIs and weights described in Section 4.1.1

5.2 ASSUMPTIONS

Throughout the thesis, we have made assumptions. We wish to remind readers of these assumptions, as they should be thought of when assessing the validity of these experiments.

Assumption 1: *Retailer ordering history of category A products sourced through Company A is an accurate representation of the retailer ordering history of category B products sourced through local producers*

Assumption 2: *Retailers ordering through Company A represent the totality of Company B retailers in France.*

Assumption 3: *Discount orders belong to regular demand.*

Assumption 4: *The cart value function is reliable and accurate.*

Assumption 5: *The value of outdoor-products carts is half the value of category A-products carts.*

Assumption 6: *Eastern Spanish retailers are included in the French transport network.*

Assumption 7: *Retailers can be delivered at between 08:00 and 12:00, and between 14:00 and 18:00.*

Assumption 8: *Retailers order once a week at most.*

Assumption 9: *Producers can always supply demand*

Assumption 10: *Transport from producers to DC does not affect the global transport network*

5.3 MARKET VALUE

The French outdoor products market has a global market value of €70M. Company A' goal is to determine an efficient fraction of the global market value from which they can start to enter the French market. Company B is reluctant to commit to ordering all their products through Company A as once and therefore cannot offer the totality of the global market value. We determine which minimum commitment provides a transport network efficient enough to base our depot selection upon. The chosen market value serves as a commitment from Company B in which they promise to source that portion of the market through Company A. For an initial market value, we test for all millions between €5M and €40. This results in 36 different transport network each tested with 5 different depot selections MV1, MV2, MV3, MV4 and MV5.

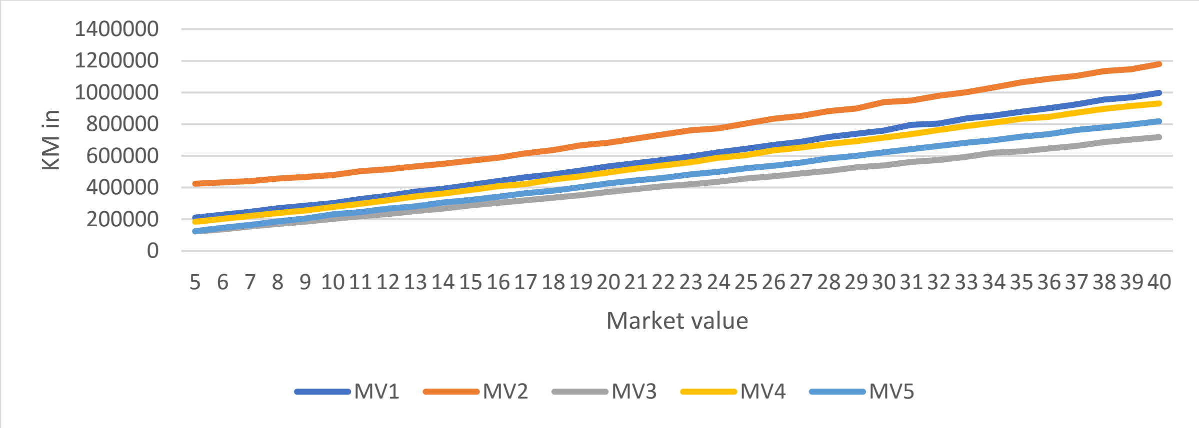


Figure 5-1: Kilometers driven between DC and depots (vertical axis) with an array of market values (horizontal axis) and 5 depot selections.

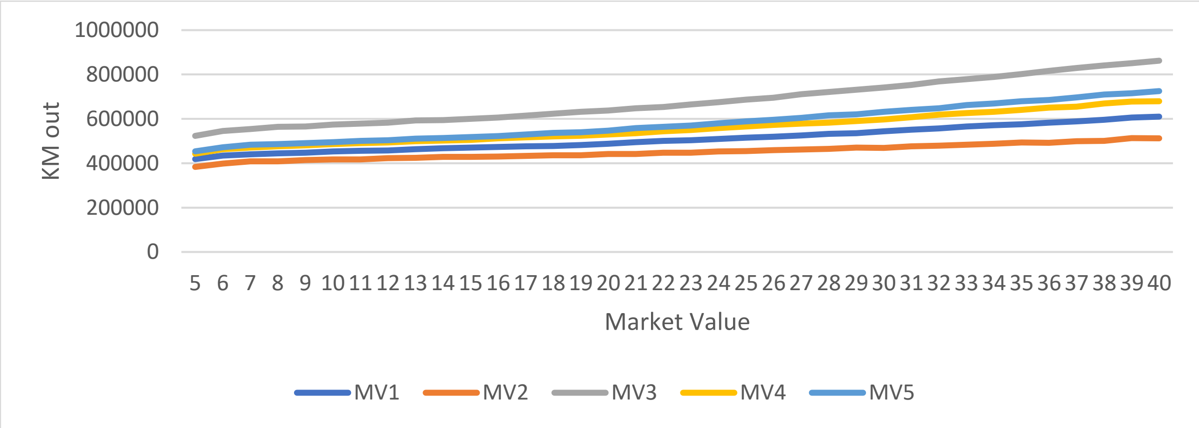


Figure 5-2: Kilometers driven between depots and retailers (vertical axis) with an array of market values (horizontal axis) and 5 depot selections.

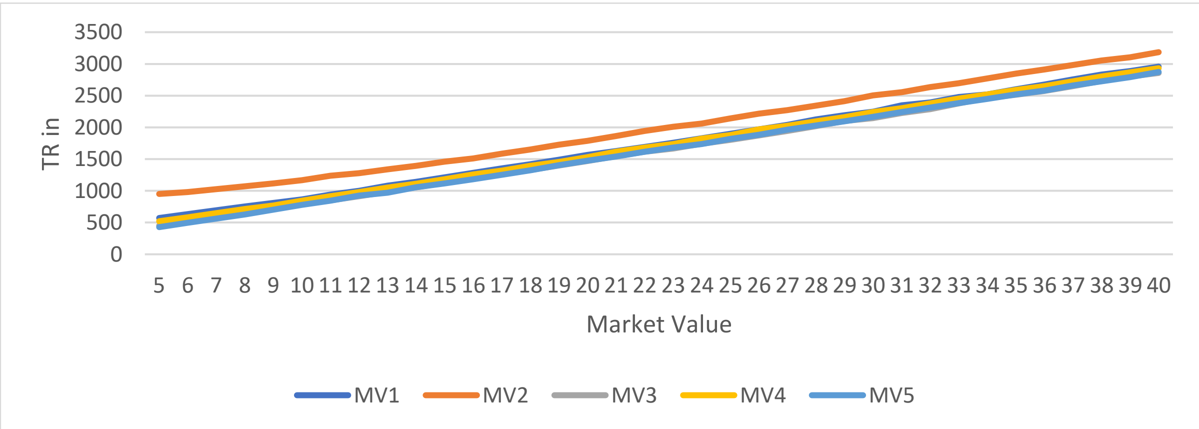


Figure 5-3: Trucks required between DC and depots (vertical axis) with an array of market values (horizontal axis) and 5 depot selections.

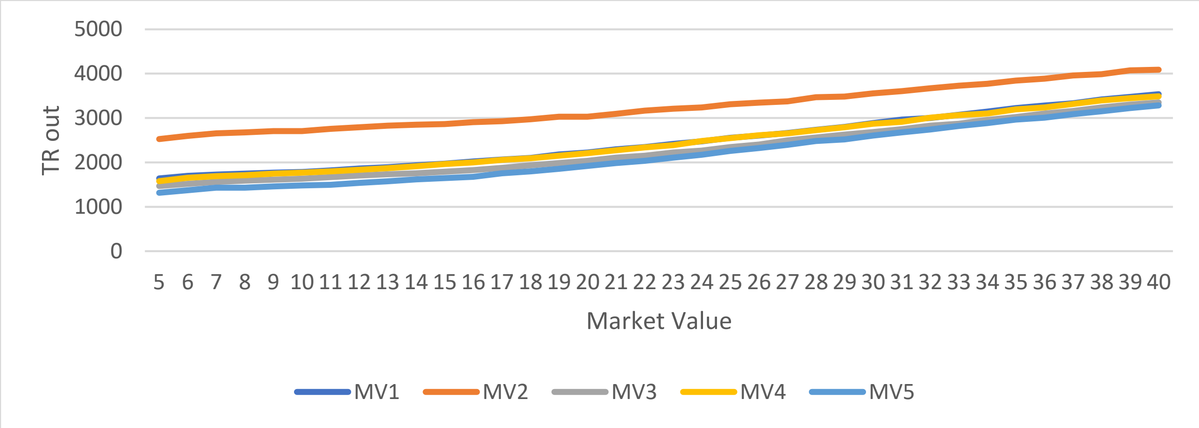


Figure 5-4: Trucks required between depots and DC (vertical axis) with an array of market values (horizontal axis) and 5 depot selections.

First, we can see that the different scenarios MV1, MV2, MV3, MV4 and MV5 follow a comparable increase in KPI scores as the market value increases, with the difference in score between different scenarios being due to depot selections. We induce that, with a fixed depot selection, the market value increase does not have significant different influences. Therefore, market value will influence scenarios with a different depot selection in the same fashion.

However, we cannot determine from the above charts if certain market values provide a better increase in efficiency: All measures increase, which is to be expected as a higher market value. We have therefore added four new KPIs which remove the effect of increasing KPI scores with demand:

- Kilometers driven per cart from the DC to depots: $\frac{KM\text{−}in}{cart}$
- Kilometers driven per cart from the depots to retailers: $\frac{KM\text{−}out}{cart}$
- Fill rate of trucks driven from DC to depots: $\frac{Cart}{TR\text{−}in/43}$
- Fill rate of trucks driven from depots to retailers: $\frac{Cart}{TR\text{−}out/43}$

For each of these measures, we determine the decrease or increase observed as market value increases.

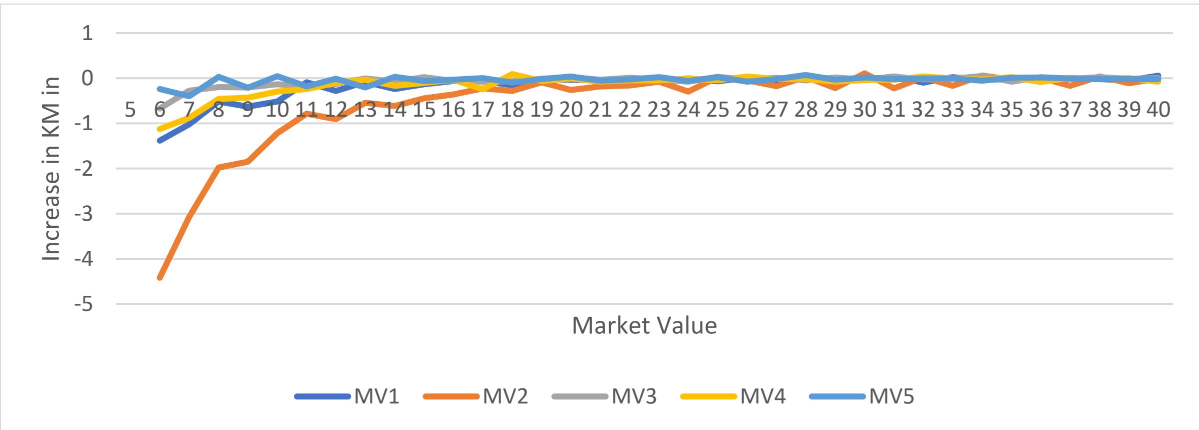


Figure 5-5: Deviation in kilometers driven per cart between DC and depots (vertical axis) with an array of market values (horizontal axis) and 5 depot selections.

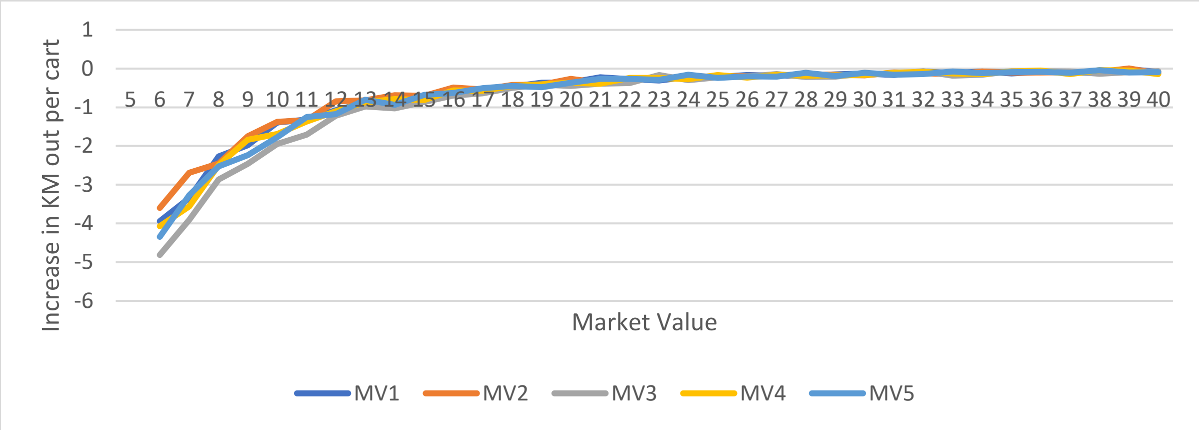


Figure 5-6: Deviation in kilometers driven per cart between depots and retailers (vertical axis) with an array of market values (horizontal axis) and 5 depot selections.

We notice the deviation in kilometers driven is negative, meaning the number of kilometers driven per cart decreases. This is true for both the KM-in and KM-out. The KM-out per cart decreases for all 5 scenarios whereas the KM-in only decreases substantially for the selection MV5.

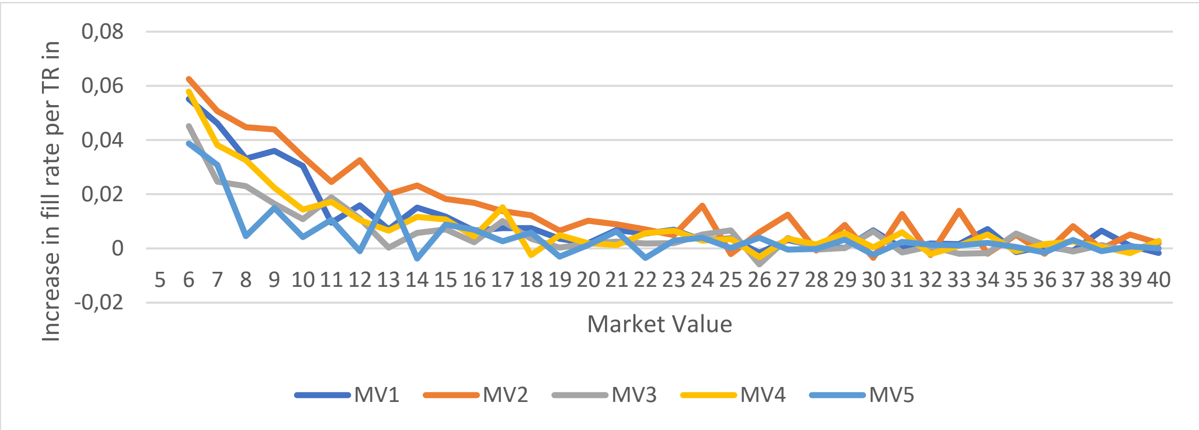


Figure 5-7: Deviation in fill-rate of trucks between DC and depots (vertical axis) with an array of market values (horizontal axis) and 5 depot selections.

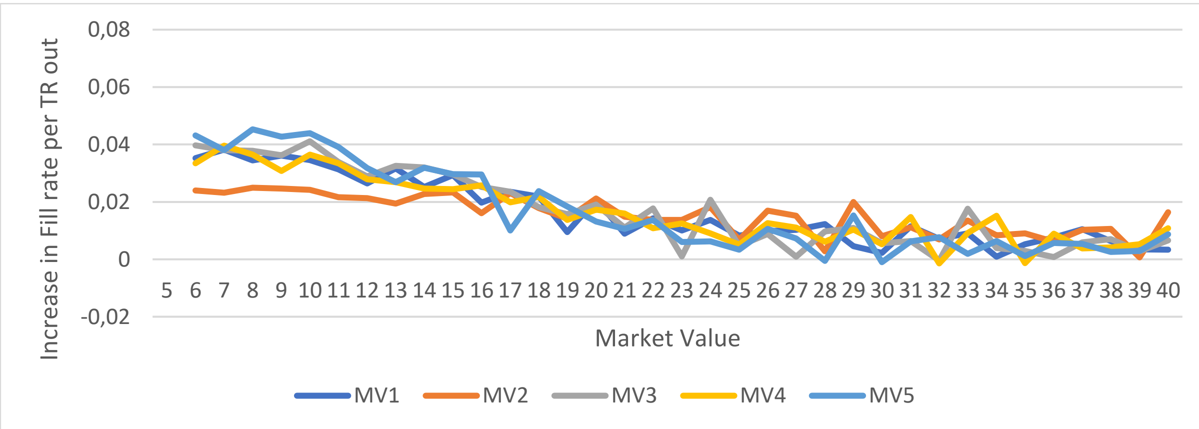


Figure 5-8: Deviation in fill-rate of trucks between depots and retailers (vertical axis) with an array of market values (horizontal axis) and 5 depot selections.

With these charts we notice the deviation is positive, meaning an increase in fill-rate for trucks as the market value and demand increases. Both the TR-in and TR-out fill-rates follow a comparable increase.

With both the kilometers driven and the fill-rate of trucks, we see that as the market value, and thus demand, increases the efficiency of the network increases as well. This could hint towards the decision to use the highest possible market value as a starting point. However, the goal is to achieve a low commitment with high efficiency. Upon seeing the results, we have chosen to use the €20M mark as a baseline. The network efficiency increases more up until then. After the €20M mark, the increase in efficiency starts to deteriorate.

5.4 Depot selection

There is a total of 20 depots to select from (excluding the DC, DEP6). This results in 1007988 feasible depot combinations (4194304 in total). With VBA's limitations, it would cost over 6 months to generate all networks, under the assumption the soft- and hardware will not break down. We therefore separated the depots in four regions. We tested all combination of depots within a region, adding only necessary fixed depots to make the network feasible. For instance, the yellow region is unfeasible without the addition of DEP17 and DEP22.

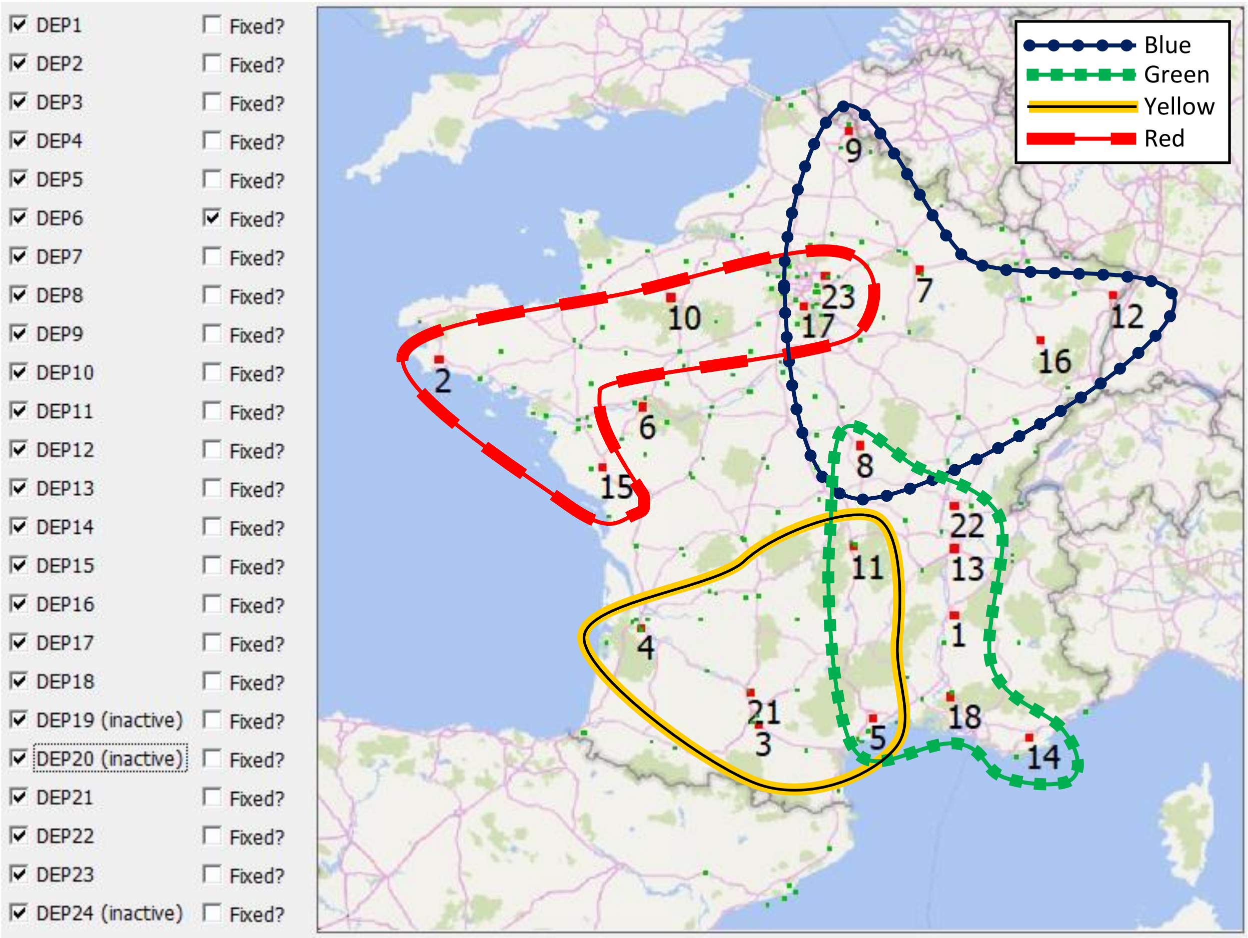


Figure 5-9: Depot regions from which depot combinations were generated separately

For every region and with two KPI sets (shown in Table 5-1), we determined the average score of every depot for each network in which the depot was used. For instance, DEP22 was present in 128 combinations in the green region. We calculate the average score of these networks, as DEP22 contributed to these networks' efficiency. We do so for all depots within each region. The scores show the average efficiency for networks in which the depots were present. The KPI sets presented in Table 5-1 were used since transport between depots and retailers is most likely not exclusively reserved for Company A' carts. There is a realistic chance that cart get delivered by far more trucks than our model calculates. We therefore opted to not considered this option. We also figured the distance between depots and retailers was still relevant.

KPI	Set 1 values	Set 2 values
KM in	1	1
TR in	1	1
KM out	1	1
TR out	0	1

Table 5-1: KPI and their assigned weight sets

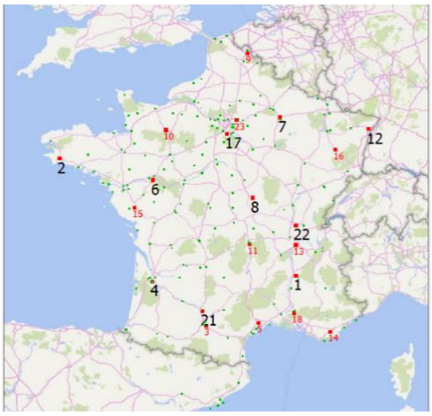


Figure 5-10: Best scoring depots

In Appendix 7.6, the results for every depot in their relevant region are shown. The best scoring depots for each region were: DEP1, DEP2, DEP4, DEP6, DEP7, DEP8, DEP12, DEP17, DEP21 and DEP22. 282 combinations are feasible with this selection. Using this selection, we generate the transport network for all combinations. We did so for market values of €20M, €30M, €40M and €50M. In Figure 5-11, the selected depots are shown with their location in France. The best scoring depots can be seen in Table 5-2 and the depots they consist of can be seen in table

	Market values							
	€20M		€30M		€40M		€50M	
Combination	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2
91	1	2	2					
123	2	1	1	1	1	3	2	4
223		10	4	3	2	1	1	1

Table 5-2: The best scoring depot combinations with two KPI weight sets and a market value of €20M, €30M, €40M and €50M

Combination	DEP1	DEP2	DEP4	DEP6	DEP7	DEP8	DEP12	DEP17	DEP21	DEP22
91	0	0	1	1	0	0	0	0	0	1
123	0	0	1	1	0	0	0	1	0	1
223	0	0	1	1	0	0	0	1	1	1

Table 5-3: Depot combination IDs and the depots they consist of.

Elaborated tables containing the best generated combinations can be seen in Appendix 7.6. We notice the three best scoring combinations consist of a combination of DEP4, DEP6 (DC), DEP17, DEP21 and DEP22. The visualizations of these results are shown in Table 5-4. Higher resolution visualizations along with network KPI information can be found in Appendix 7.7. We have also tested these depots against 81 KPI weight combinations in which each KPI would have the value of 1, 0.5 or 0. The results show the same depots being present in the most efficient networks: DEP4, DEP6 (DC), DEP17, DEP21 and DEP22. A surprising solution was combination 250, consisting of depots DEP1, DEP2, DEP4, DEP6 (DC), DEP7, DEP8, DEP17, DEP21 and DEP22. This combination only scores good, however, in scenario's in which we believe all transport between the DC and depots has weight zero. This is not in line with our optimization goals.

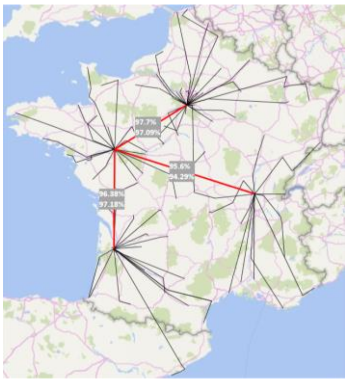
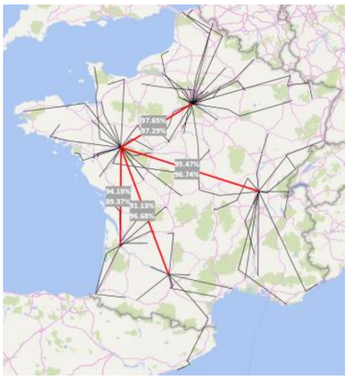
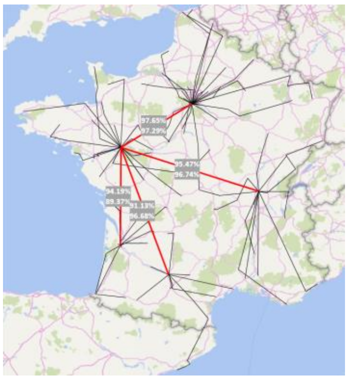
	Weights	
Market value	1110	1111
€20M		
€30M		
€40M		
€50M		

Table 5-4: Visualization of best ranking combinations for different market values

5.5 CONCLUSION

In this section we experimented with different values for market value and depot selection. First, we determined an initial market value with which we could analyze depot selections. We concluded the market value influences the network efficiency due to an increase in demand, but that this was not related to depot selections. We chose €20M as an initial market value as at this point the increase in network efficiency started to decrease. Next, we separated the 20 available depots in 4 geographical regions for which we generated networks separately using the initial market value. For each region, the depots which contributed most more efficient networks were selected. The depots were used to generate networks for the whole network with a market value of €20M, €30M, €40M and €50M. With a market value of €20M and KPI weight set 1, the most efficient depots were depots DEP4 and DEP22. With a market value of €30M or €40M, the most efficient depots were DEP4, DEP17 and DEP22. With a market value of €50M, the most efficient depots were DEP4, DEP17, DEP21 and DEP22. With a market value of €20M or €30M and KPI weight set 2, the most efficient depots were depots DEP4, DEP17 and DEP22. With a market value of €40M or €50M, the most efficient depots were once again DEP4, DEP17, DEP21 and DEP22.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 SUB-QUESTIONS

In Section 1.7, we defined our plan of approach and stated four sub-questions. These questions have been answered in their respective sections. In this section show the conclusions drawn from the research done to answer them.

1. *Which insights can literature give us on solving comparable problems?*

1.1. What are the methodologies in similar problems?

In Section 2.1, we reviewed methodologies involved when approaching Location-Routing Problem. First, the problem must be defined according to the problem's characteristics: the objective function, the potential depot locations, the availability of present sites, the solution search procedures and the planning horizon. We have defined our objective function according to the number of trucks used and their kilometers driven. We make use of 24 depots known depots, present sites, and follow a planning horizon of 52. The search procedure used if described in the answer of research question 1.4.

1.2. What theories exist to solve these problems?

In Section 2.2, we reviewed different search procedures. They can be classified as exact methods, heuristics and meta-heuristics. Exact methods solve a problem but are limited in problem size and solving speed. Heuristics aim to find good enough answers that might not be optimal but do approach optimal solutions. Meta-heuristics are heuristics that apply different heuristics to a starting solution. They can also accept deteriorating solution but also approach near-optimal solution as result.

1.3. What methods have been applied in the past?

In Section 2.3 we review literature presenting (meta-)heuristics for the LRP and individually for DAP and VRPs, MDVRPs and VRPTWs. Various methods are combined to create new heuristics and occasionally new methods are presented. Researchers use a variety of objectives to measure different aspects of the network.

1.4. What is our choice of methods?

Based on the done research, our method explained in Section 2.4 solves the LRP sequentially by first addressing the DAP and afterwards the MDVRPTW. The DAP is addressed through a self-developed method we call depot saturation. Based on the transport towards depots, required to supply a depot's assigned retailers, a depot is given a saturation level. This saturation level determines a depot's ability to accept more retailer assignments, or its need to have retailers unassigned to them. Iterations between depot-retailer assignments lead towards a better distribution of retailers, and thus transport, to depots. A TABU component is added, which iterates depot-retailer assignments until a minimum number of trucks are required to transport demand to depots, or if an acceptable solution is found. The MDVRPTW is approached using an open maximum-savings heuristic, which uses a push-forward technique to deliver retailer within the delivery hours. The heuristic keeps track of vehicle load, driving time and delivery schedule.

2. *How is the French transport network organized?*

2.1. What are the characteristics of Company B Retailers?

Our findings are based on the transaction and transport history of Company B retailers a Company A and thus not on the actual demand of French products. In Section 3.1, we concluded that every retailer has a different demand pattern and that they should all be assessed individually. We also determined how we can convert a retailer market value to a retailer demand in carts using a three-parameter log-logistic distribution. Finally, we settled on the ordering frequencies and delivery windows of retailer.

2.2. *What are the characteristics of depots?*

In Section 3.3 we show the 24 depots available, of which we use 21. Company A had at this point already chosen DEP6 to be a distribution center, which will also function as a depot, however we have given some extra insights as to why this is strategic by analyzing depot locations with supply intensity locations in Section 3.2 and 3.3

2.3. *What are the characteristics of transport?*

In Section 3.4 we discuss the characteristics of transport. Transport of products is organized in carts, which are transported in trucks. Trucks can transport 43 carts and travel an average of 70 km/h. Loading and unloading carts costs an average of 30 minutes. They are limited to 10 hours of working time a day. Additionally, the nature of the French roads prevents us from using a straight-line distance between points as a distance matrix. We developed a tool to calculate the real-road driving distances between locations (producers, depots, retailers) to be used in both the data collection and the analytical model.

3. *How is the transport network influences by a varying market value and depot selection?*

3.1. *What is an adequate market value for initial testing?*

In Section 5.3 we experimented with a range of market values to see how the transport network is influenced by changes in market value and therefore demand. We concluded that the network efficiency increases as the market value increases. However, the increase in efficiency slows after the market value is higher than €20M. We chose this market value as an initial value as the efficiency is high enough and the market value low enough to justify a commitment from Company B.

3.2. *Which depots contribute most to a more efficient network?*

The depots were divided in four geographical regions within which the networks of all possible combinations were generated. The depots which contributed most to the more efficient networks are DEP1, DEP2, DEP4, DEP6, DEP7, DEP8, DEP12, DEP17, DEP21 and DEP22.

3.3. *How does the market value influence the more efficient depots?*

Using these depots presented in Section 5.4, we generated transport networks for all depot combinations and market values of €20M, €30M, €40M and €50M and two different weight sets. With a market value of €20M and KPI weight set 1, the most efficient depots were depots DEP4 and DEP22. With a market value of €30M or €40M, the most efficient depots were DEP4, DEP17 and DEP22. With a market value of €50M, the most efficient depots were DEP4, DEP17, DEP21 and DEP22. With a market value of €20M or €30M and KPI weight set 2, the most efficient depots were depots DEP4, DEP17 and DEP22. With a market value of €40M or €50M, the most efficient depots were once again DEP4, DEP17, DEP21 and DEP22.

6.2 RECOMMENDATIONS

In this section, we provide an answer to the research question, which will additionally serve as a recommendation. The research question was composed as follows.

How can the transport network following from the implementation of Company A services in France be optimized, and how can results be visualized?

In Section 6.1, we answered the questions defined in the plan of approach proposed in Section 1.5.2. An implementation of Company A services in France requires a commitment that enough products can be transported. Company A has access to both partnerships. Company B can provide a market commitment. In Section 5.3, we analyzed market values between €5M and €40M. We recommend achieving a market value of €20M for a settlement in France as the efficiency of the generated market is relatively stable. Transport Partner A and Transport Partner B can provide Company A with 24 depots. One depot, depot 6, will serve as a distribution center. Of the remaining depots, depot 4, depot 17, depot 21 and depot 22 proved to be the most efficient. Transport Partner A can provide depot 4, depot 6 and depot 22. Transport Partner B can provide depots 6, depot 17 and depot 21. When starting with a market value of €20M, depots 4 and 17 can be implemented. If the services provided by Company A satisfy Company B and retailers order more products through these services, Company A can improve their network by adding more depots to their transport network. The results were visualized by drawing the routes followed by trucks between the DC and the depots, and between the depots and the retailers. These visualizations show the network in specific weeks and give information on the performance of the KPIs.

To summarize, we recommend Company A to penetrate the market with a market value of €20M and using a distribution center in City B, depot 6, and starting with depots 4 and 22. As the market value and thus demand increases, depot 17 and 21 should also be used.

6.3 FURTHER RESEARCH

The future research consists of two parts: future research for this specific project and future research for the implemented solving methods. For future research for the project “Project Name” we recommend further analyzing demand of retailers. Also, we suggest researching alternatives in which products are distributed more than once per week.

For the DAP solving method, we recommend implementing a nested method whose objective function is influenced by the total kilometers driven between DC and depots and between depots and retailers. The latter kilometers driven could be estimated using the expected kilometers driven. For the MDVRPTW solving method, we recommend implementing an extra improvement step for route. To do so, we recommend implementing a combination of iterations within routes and between routes.

EPILOGUE

With these last words I wish to end my thesis in which I research the implementation of a distribution network in France in the industry. Although the project has taken a long time for me to complete, I have enjoyed all the time I have spent on it. First, Company A is a very welcoming company at which I enjoyed spending time during the first three months of my research. Spending my time at the office has allowed me to get acquainted with the industry as well as the people involved. Also, being able to visit Company B in Paris to showcase my first findings of the project was very valuable to me. Most of all, I am thankful for having been given the opportunity to further explore two topics I particularly enjoy: vehicle routing and coding. The largest portion of the project consisted of creating a heuristic which would allow us to approach this specific routing problem and creating the analytical model. Both costed lots of research time and energy, but I would gladly do it again.

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7 APPENDIX

7.1 LEAD TIME

[redacted]

Figure 7-1: Three-day schedule. Retailers can order in day 1. The products are collected from the producers and overnight the distribution process is performed. On day 2, all products are transported to the depots. On day 3 the products are delivered at retailers.

7.2 DATASETS

[redacted]

Figure 7-2: Transport dataset

[redacted]

Figure 7-3: Transaction dataset

[redacted]

Figure 7-4: Producer data set

B

7.3 STATISTICAL TESTS

7.3.1 Unweighted global distribution

1. Problem definition: we have $N = 175$ retailers order each ordering for $M = 52$ weeks. The number of carts ordered by retailer i in week j is called $\boldsymbol{X_{i,j}}$.
   $\boldsymbol{X_{i,j}}$ is calculated by $\boldsymbol{X_{i,j}} = Y_{i,j} * C_i$.
   C_i represents the total sum of carts customer i orders in a year.
   $Y_{i,j}$ is the observed percentage of carts of customer i in week j.
   We wish to test the hypothesis that $Y_{i,j}$ follows a general pattern over all retailers with an average ordering size for all retailers, e.g. all retailers follow the same demand pattern, taking into account only seasonal demand patterns.
2. $H_0: F(Y|i,j) = \frac{\sum_i Y_{i,j}}{N}$ & $C_i = \frac{\sum_j C_i}{M}$
   $H_1: F(Y|i,j) = Y_{i,j}$ & $C_i = C_i$
3. $G - Test: G = 2 * \sum_{i,j} O_{i,j} * \ln\left(\frac{O_{i,j}}{E_{i,j}}\right)$
   With O = Observed value and E = expected value
4. With H_0 we have $df = (i-1) * (j-1) = 8874$
5. $G = 31306.578$
6. Refute H_0 if $G < -c$ or $G > c$
   With $\alpha = 0.05$, $c = 8873.333$
7. $G > c$, therefore we refute H_0
8. We consider proven that, with a significance level of 95%, the carts ordered by retailers does not follow a global distribution, unweighted against the retailers' sizes.

7.3.2 Weighted global distribution

1. Problem definition: we have $N = 175$ retailers order each ordering for $M = 52$ weeks. The number of carts ordered by retailer i in week j is called $\boldsymbol{X_{i,j}}$.
   $\boldsymbol{X_{i,j}}$ is calculated by $\boldsymbol{X_{i,j}} = Y_{i,j} * C_i$.
   C_i represents the total sum of carts retailers i orders in a year.
   $Y_{i,j}$ is the observed percentage of carts of retailers i in week j.
   We wish to test the hypothesis that $Y_{i,j}$ follows a general pattern over all retailers weighted against the retailers' sizes by the function of $X_{i,j}$.
2. $H_0: F(Y|i,j) = \frac{\sum_i Y_{i,j}}{N}$ & $C_i = C_i$
   $H_1: F(Y|i,j) = Y_{i,j}$ & $C_i = C_i$
3. $G - Test: G = 2 * \sum_{i,j} O_{i,j} * \ln\left(\frac{O_{i,j}}{E_{i,j}}\right)$
   With O = Observed value and E = expected value
4. With H_0 we have $df = (i-1) * (j-1) = 8874$
5. $G = 2801.774$
6. Refute H_0 if $G < -c$ or $G > c$
   With $\alpha = 0.05$, $c = 8873.333$
7. $G > c$, therefore we refute H_0
8. We consider proven that, with a significance level of 95%, the carts ordered by retailer does not follow a global distribution, weighted against the retailers' sizes.

7.4 FLOWCHARTS

7.4.1 Legend

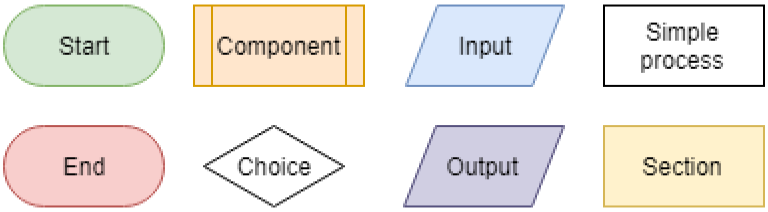

Figure 7-5: Legend of the flowcharts

D

7.4.2 Overarching Component

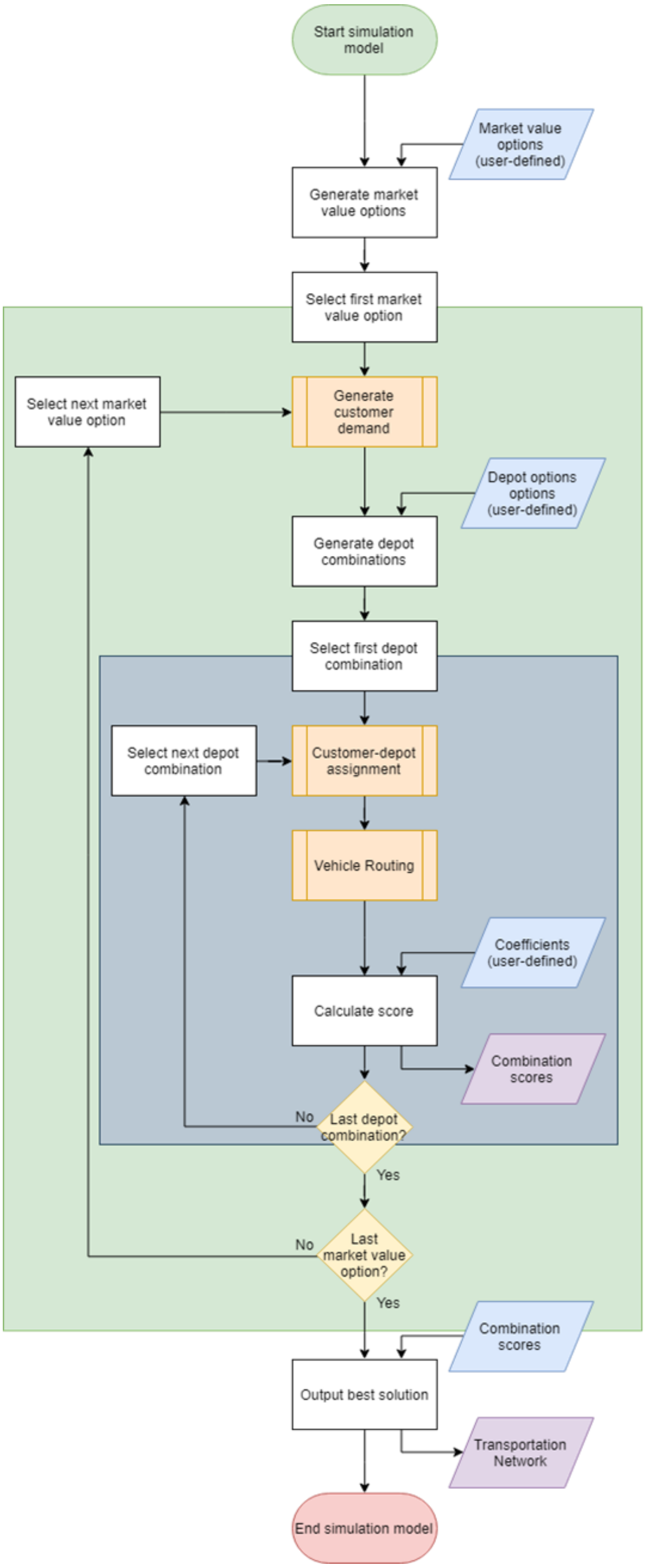

Figure 7-6: Flowchart of the global function of the analytical model

7.4.3 Demand Generation

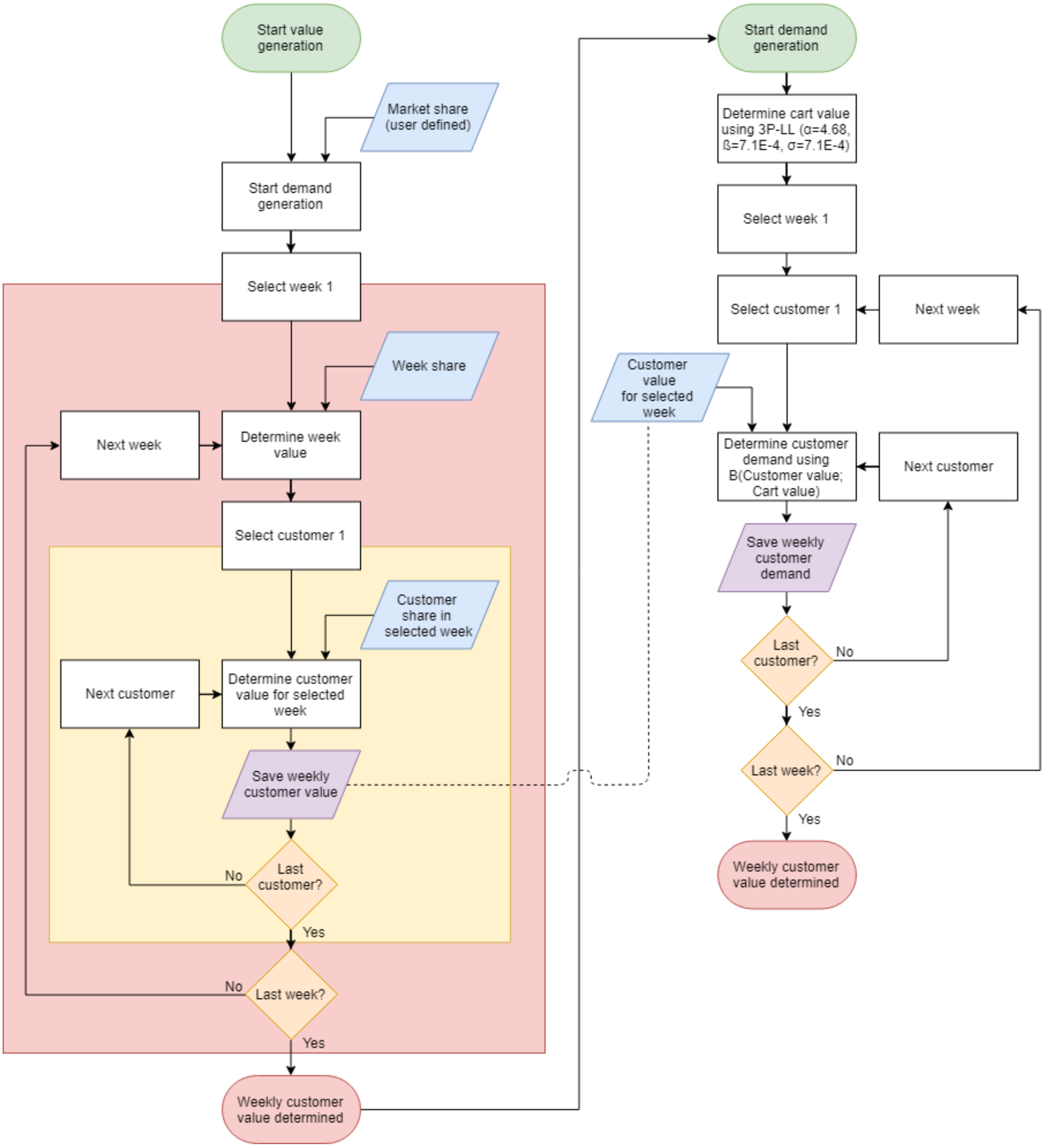

Figure 7-7: Flowchart of the demand generation process, consisting of the assignment of a fraction of market value (left), and the conversion from customer value to customer demand in carts (right)

7.4.4 Depot Assignment

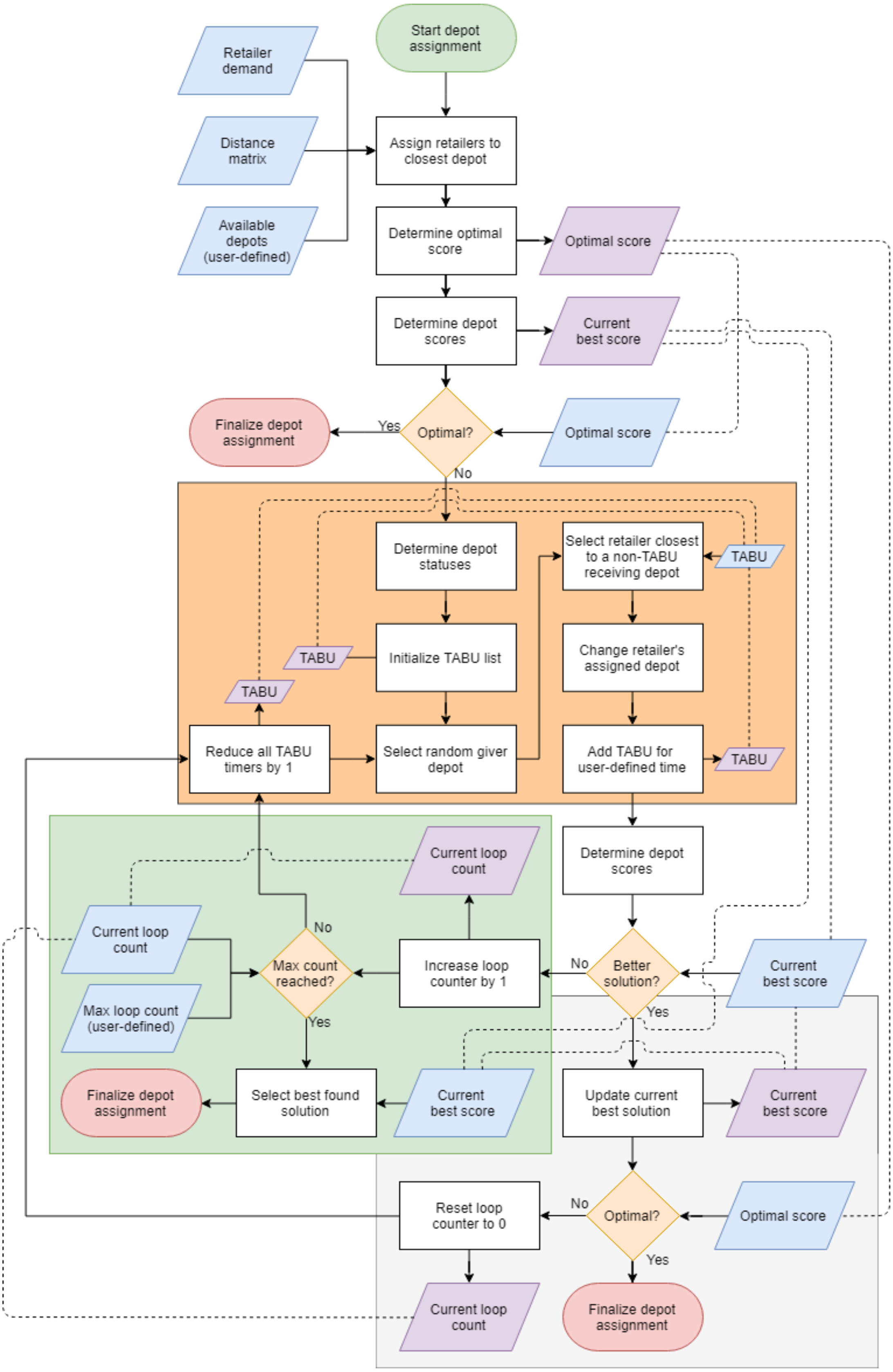

Figure 7-8: Flowchart of the depot assignment process, including the TABU process (orange), the non-improving solution loop and counter (green) and the check for optimality (grey)

7.4.5 Vehicle Routing

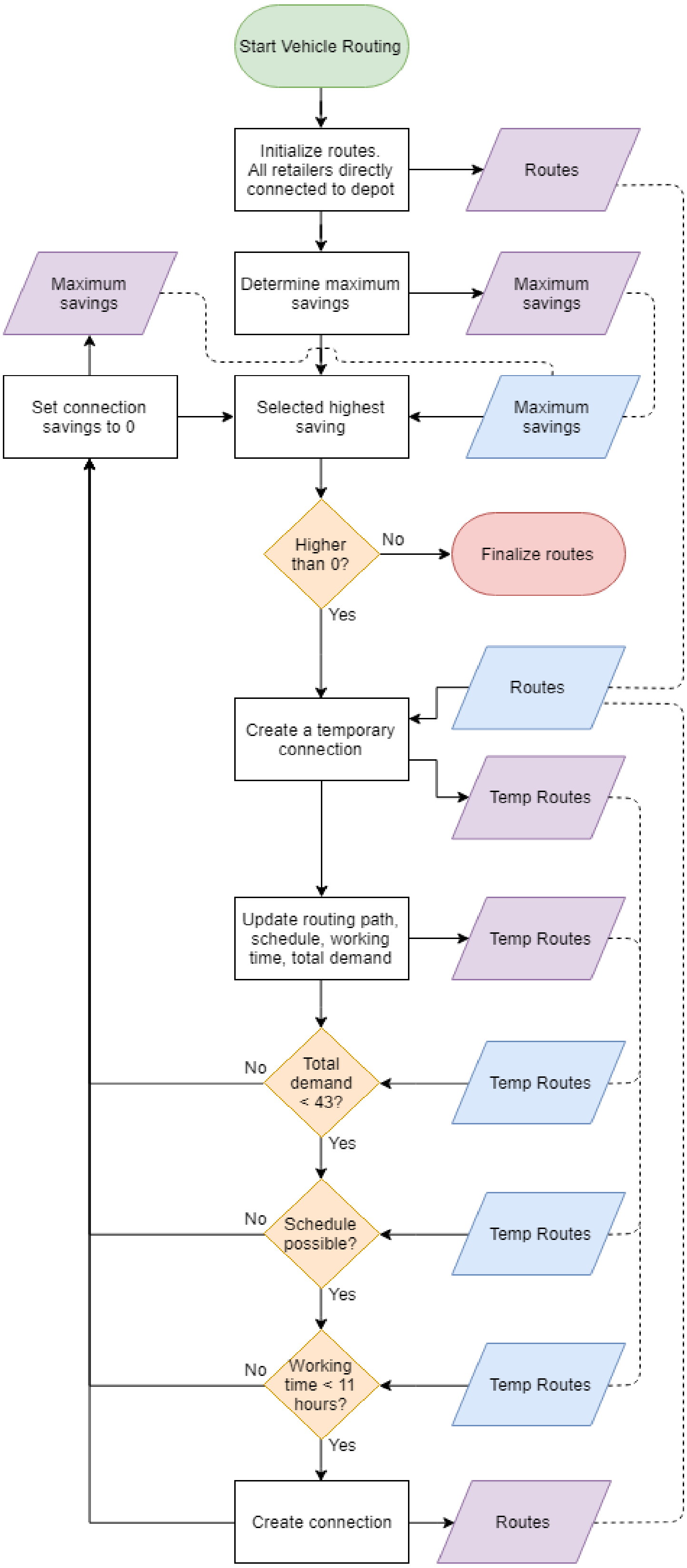

Figure 7-9: Flowchart for the vehicle routing

7.4.6 Visualization

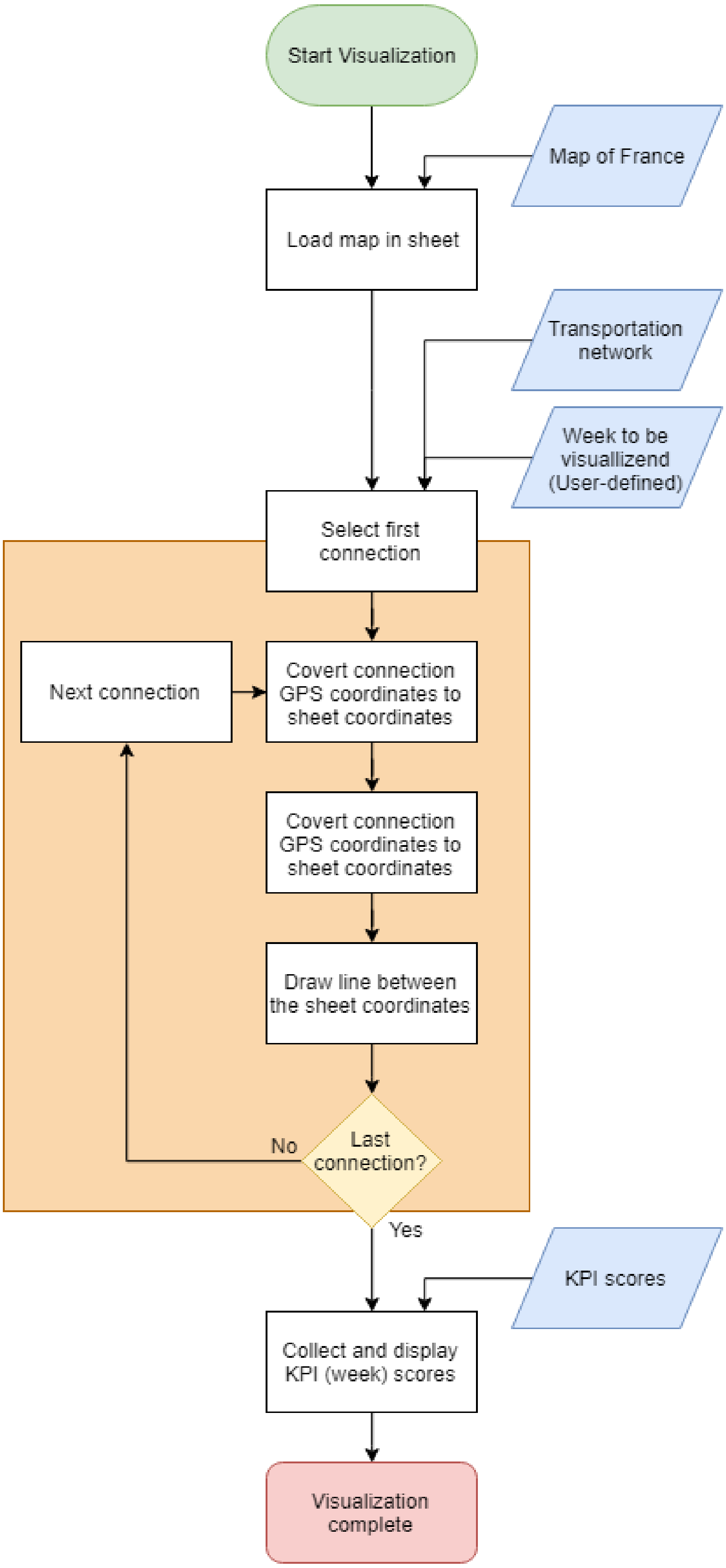

Figure 7-10: Flowchart of the network visualization. The loop connecting different nodes is depicted in orange

7.5 Regional depot scores and depot combination scores

Depot	Yellow	Green	Blue	Red
DEP1		0,0120		
DEP2				0,0942
DEP3	0,1016			
DEP4	0,1005			
DEP5	0,1015	0,0120		
DEP6	0,1000	0,0119	0,0469	0,0938
DEP7			0,0472	
DEP8		0,0119	0,0472	
DEP9			0,0474	
DEP10				0,0948
DEP11	0,1014	0,0120		
DEP12			0,0473	
DEP13		0,0120		
DEP14		0,0120		
DEP15				0,0944
DEP16			0,0472	
DEP17	0,1000	0,0119	0,0459	0,0937
DEP18		0,0120		
DEP21	0,1012	0,0119	0,0469	0,0938
DEP22	0,1000	0,0119	0,0469	0,0938

Depot	Yellow	Green	Blue	Red
DEP1		0,0160		
DEP2				0,1259
DEP3	0,1356			
DEP4	0,1346			
DEP5	0,1352	0,0160		
DEP6	0,1333	0,0159	0,0625	0,1250
DEP7			0,0632	
DEP8		0,0160	0,0632	
DEP9			0,0634	
DEP10				0,1267
DEP11	0,1356	0,0160		
DEP12			0,0630	
DEP13		0,0160		
DEP14		0,0161		
DEP15				0,1264
DEP16			0,0631	
DEP17	0,1333	0,0159	0,0619	0,1255
DEP18		0,0160		
DEP21	0,1350	0,0159	0,0625	0,1250
DEP22	0,1333	0,0160	0,0625	0,1250

Table 7-1: Depot's average transport network scores for the regions they fall under. On the left, KPI weight set 1 is used. On the right, KPI weight set 2 is used.

	Market values							
	€20M		€30M		€40M		€50M	
Combination	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2
19					10			
69						6		7
91	1	2	2					
92	7	9						
93	4	3						
123	2	1	1	1	1	3	2	4
124			9	9	8			
125	9	7	3	4	4	7	5	
127					9			
131	10	4	6	2	3	4	3	3
133				7		9	8	8
139			10		7			
155	3	8	8					
157	8							
159	5	5	7					
21+ --9	6	6	5	8	6		7	

J

223		10	4	3	2	1	1	1
224						8	9	9
225				6			6	10
235				10				
239				5		2	4	2
240						5		5
241						10		6
255							10	

Table 7-2: Ranks (1 to 10) for all depot combinations present in the top 10. For both KPI weight sets and market values, the best combinations are indicated by a red 1. The depots present in combinations can be found in Table 7-7

Combination	DEP1	DEP2	DEP4	DEP6	DEP7	DEP8	DEP12	DEP17	DEP21	DEP22
19	1	0	1	1	0	1	0	1	0	0
69	1	0	1	1	0	1	0	1	1	0
91	0	0	1	1	0	0	0	0	0	1
92	1	0	1	1	0	0	0	0	0	1
93	0	1	1	1	0	0	0	0	0	1
123	0	0	1	1	0	0	0	1	0	1
124	1	0	1	1	0	0	0	1	0	1
125	0	1	1	1	0	0	0	1	0	1
127	0	0	1	1	1	0	0	1	0	1
131	0	0	1	1	0	1	0	1	0	1
133	0	1	1	1	0	1	0	1	0	1
139	0	0	1	1	0	0	1	1	0	1
155	0	0	0	1	0	0	0	0	1	1
157	0	1	0	1	0	0	0	0	1	1
159	0	0	1	1	0	0	0	0	1	1
219	0	0	0	1	0	0	0	1	1	1
223	0	0	1	1	0	0	0	1	1	1
224	1	0	1	1	0	0	0	1	1	1
225	0	1	1	1	0	0	0	1	1	1
235	0	0	0	1	0	1	0	1	1	1
239	0	0	1	1	0	1	0	1	1	1
240	1	0	1	1	0	1	0	1	1	1
241	0	1	1	1	0	1	0	1	1	1
255	0	0	1	1	0	0	1	1	1	1

Table 7-3: The depot combination IDs, and the depots present within these combinations.

	Market values							
	€20M		€30M		€40M		€50M	
Combination	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2
91	1	2	2					
123	2	1	1	1	1	3	2	4
223		10	4	3	2	1	1	1

7.6 VISUALIZATION OF RESULTS

7.6.1 Market Value of €20M

7.6.1.1 *Set 1*

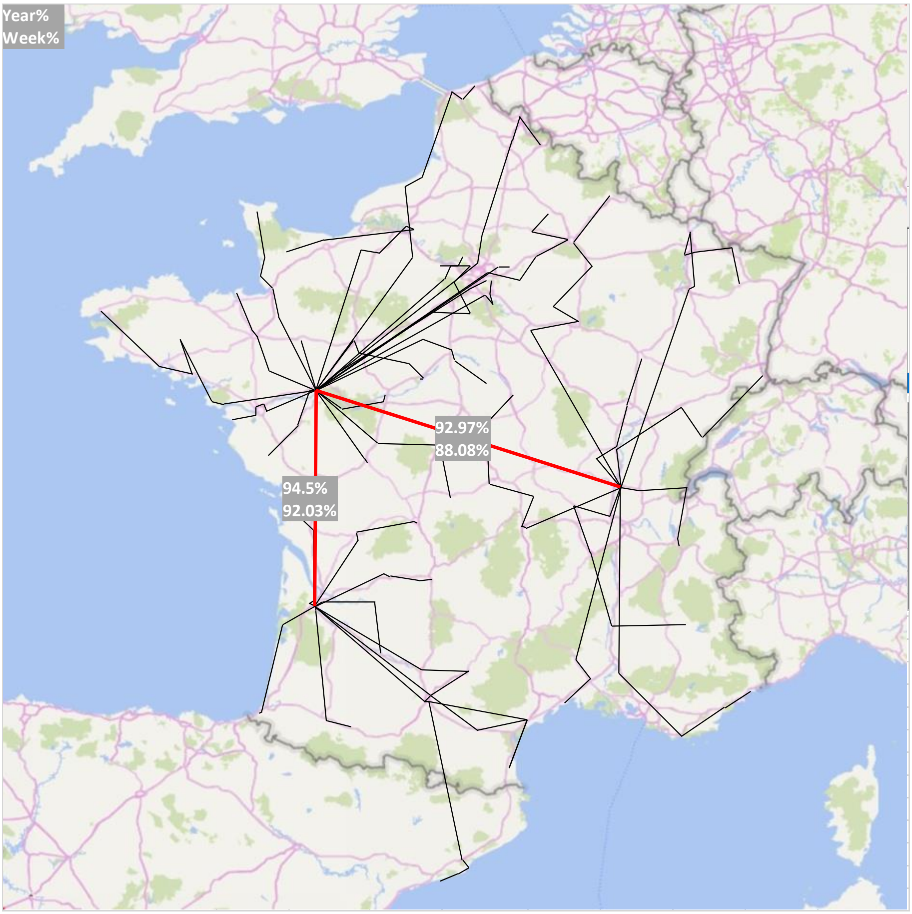

Figure 7-11: Visualization of the transport network in week 8 with a market value of €20M and KPI set 1

Total	DEP4	DEP6	DEP22
Demand	**13156**	**32905**	**14088**
Truck In	**323**	**786**	**349**
Fillrate	**0.944974018**	**0.970917361**	**0.929745093**
Truck Out	**862**	**1862**	**974**
Fillrate2	**0.347176999**	**0.405733336**	**0.326794688**
Distance In	**119793**	**0**	**179269**
Distance Out	**139109**	**318742**	**206027**

Table 7-4:Transport network results with a market value of €20M and KPI set 1

Week 8	DEP4	DEP6	DEP22
Demand	277	744	303
Truck In	7	18	8
Fillrate	0.920265781	0.96124031	0.880813953
Truck Out	16	40	18
Fillrate2	0.402616279	0.43255814	0.391472868
Distance In	2596	0	4109
Distance Out	2714	6764	4322

Table 7-5:Transport network results in week 8 with a market value of €20M and KPI set 1

7.6.1.2 *Set 2*

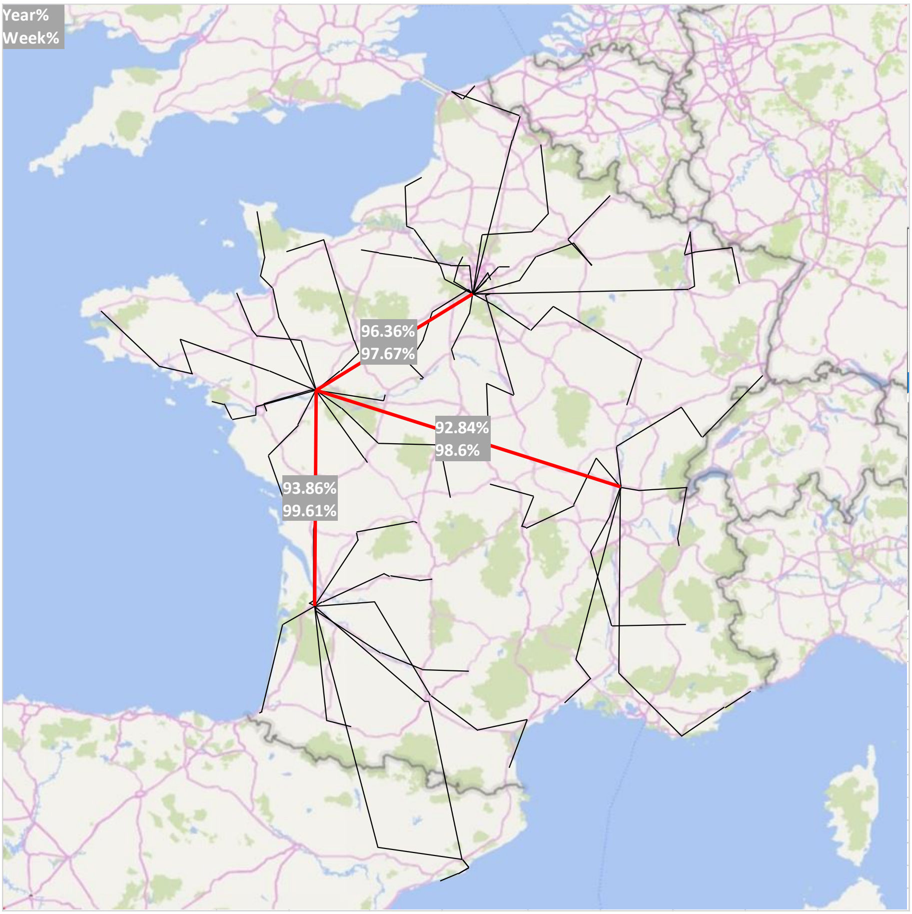

Figure 7-12: : Visualization of the transport network in week 8 with a market value of €20M and KPI set 2

Total	**DEP4**	**DEP6**	**DEP17**	**DEP22**
Demand	**12769**	**16216**	**20704**	**10230**
Truck In	**314**	**393**	**497**	**254**
Fillrate	**0.938586844**	**0.956849832**	**0.963567963**	**0.928413302**
Truck Out	**850**	**1004**	**1248**	**738**
Fillrate2	**0.342347482**	**0.369235201**	**0.376683639**	**0.314206842**
Distance In	**116458**	**0**	**135647**	**130471**
Distance Out	**136331**	**126686**	**156887**	**136422**

Table 7-6:Transport network results with a market value of €20M and KPI set 2

Week 8	**DEP4**	**DEP6**	**DEP17**	**DEP22**
Demand	257	335	504	212
Truck In	6	8	12	5
Fillrate	0.996124031	0.973837209	0.976744186	0.986046512
Truck Out	16	20	28	12
Fillrate2	0.373546512	0.389534884	0.418604651	0.410852713
Distance In	2225	0	3275	2568
Distance Out	2662	2527	3648	2569

Table 7-7:Transport network results in week 8 with a market value of €20M and KPI set 2

7.6.2 Market Value of €30M

7.6.2.1 *Set 1*

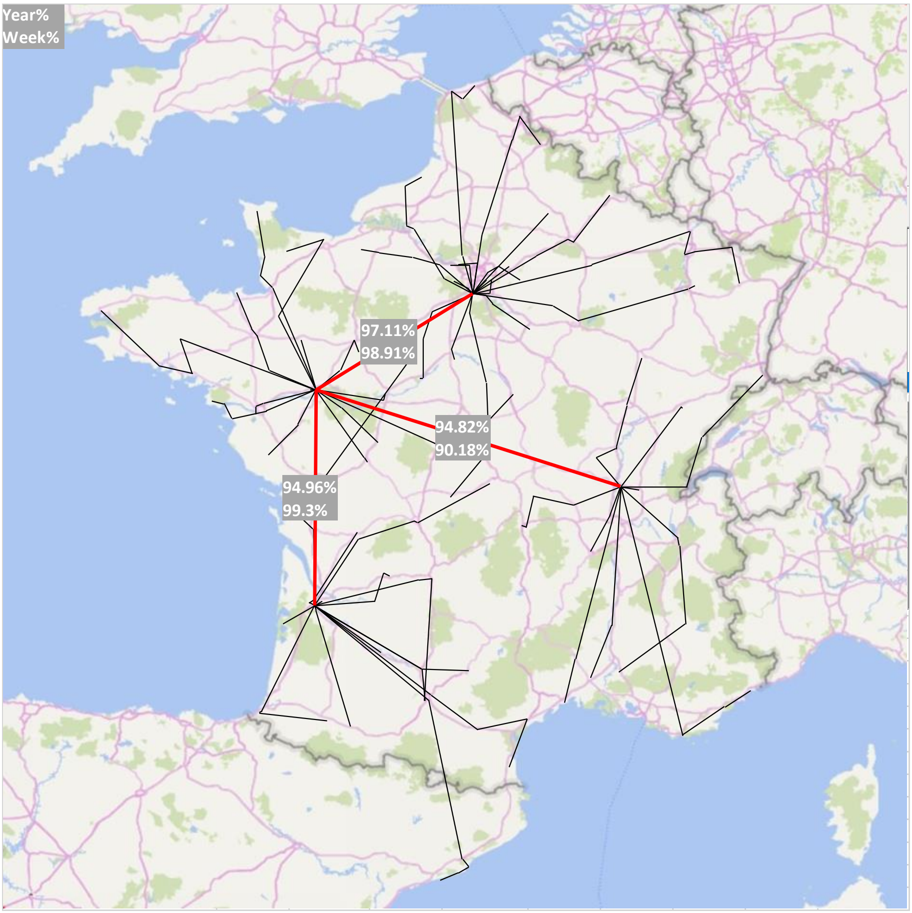

Figure 7-13: Visualization of the transport network in week 8 with a market value of €30M and KPI set 1

Total	DEP4	DEP6	DEP17	DEP22
Demand	19365	24652	30647	15165
Truck In	473	598	731	371
Fillrate	0.949637984	0.952699814	0.971082449	0.948218733
Truck Out	1140	1426	1712	948
Fillrate2	0.387054937	0.396789437	0.409918088	0.362741479
Distance In	175428	0	199509	190573
Distance Out	156402	150948	174881	153245

Table 7-8:Transport network results with a market value of €30M and KPI set 1

Week 8	DEP4	DEP6	DEP17	DEP22
Demand	427	476	723	349
Truck In	10	12	17	9
Fillrate	0.993023256	0.92248062	0.989056088	0.901808786
Truck Out	26	28	38	20
Fillrate2	0.381932021	0.395348837	0.44247246	0.405813953
Distance In	3709	0	4640	4623
Distance Out	3815	2954	3832	3193

Table 7-9:Transport network results in week 8 with a market value of €30M and KPI set 1

7.6.2.2 *Set 2*

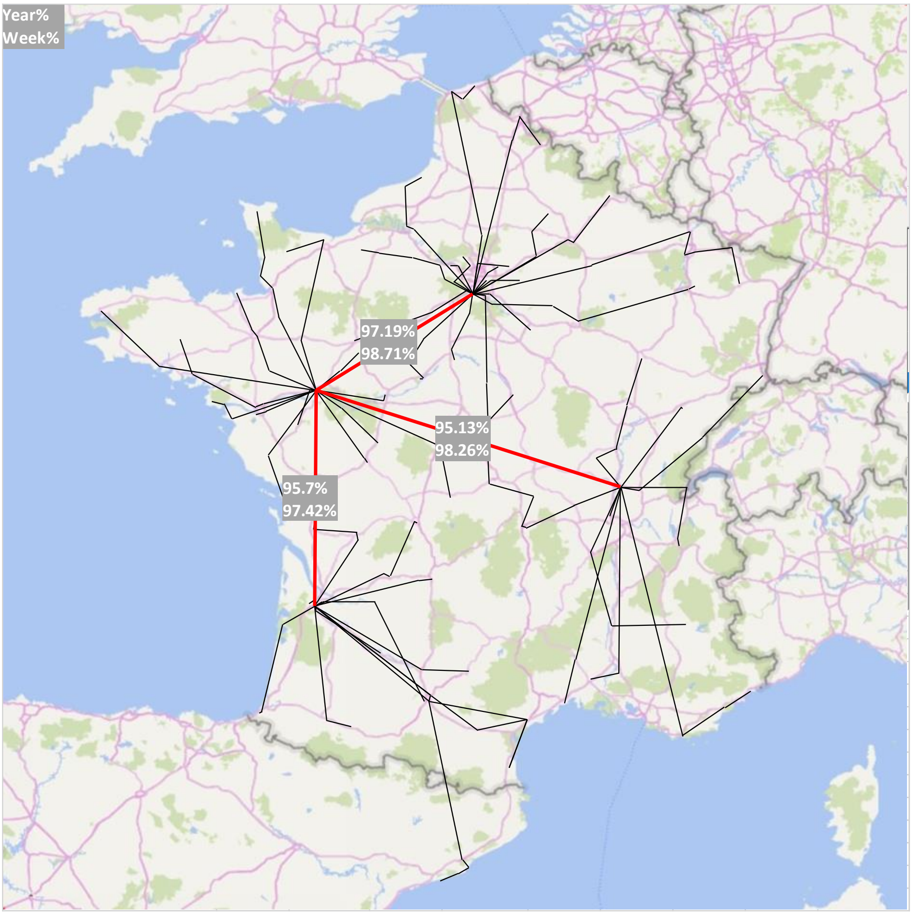

Figure 7-14: Visualization of the transport network in week 8 with a market value of €30M and KPI set 2

Total	DEP4	DEP6	DEP17	DEP22
Demand	19544	24661	30902	15269
Truck In	474	590	738	372
Fillrate	0.957003441	0.967242164	0.971928365	0.951279744
Truck Out	1160	1430	1712	944
Fillrate2	0.38436322	0.396594543	0.415027333	0.367249646
Distance In	175799	0	201420	191082
Distance Out	158260	150900	174786	153642

Table 7-10:Transport network results with a market value of €30M and KPI set 2

Week 8	DEP4	DEP6	DEP17	DEP22
Demand	257	335	504	212
Truck In	6	8	12	5
Fillrate	0.996124031	0.973837209	0.976744186	0.986046512
Truck Out	16	20	28	12
Fillrate2	0.373546512	0.389534884	0.418604651	0.410852713
Distance In	2225	0	3275	2568
Distance Out	2662	2527	3648	2569

Table 7-11:Transport network results in week 8 with a market value of €30M and KPI set 2

7.6.3 Market Value of €40M

7.6.3.1 *Set 1*

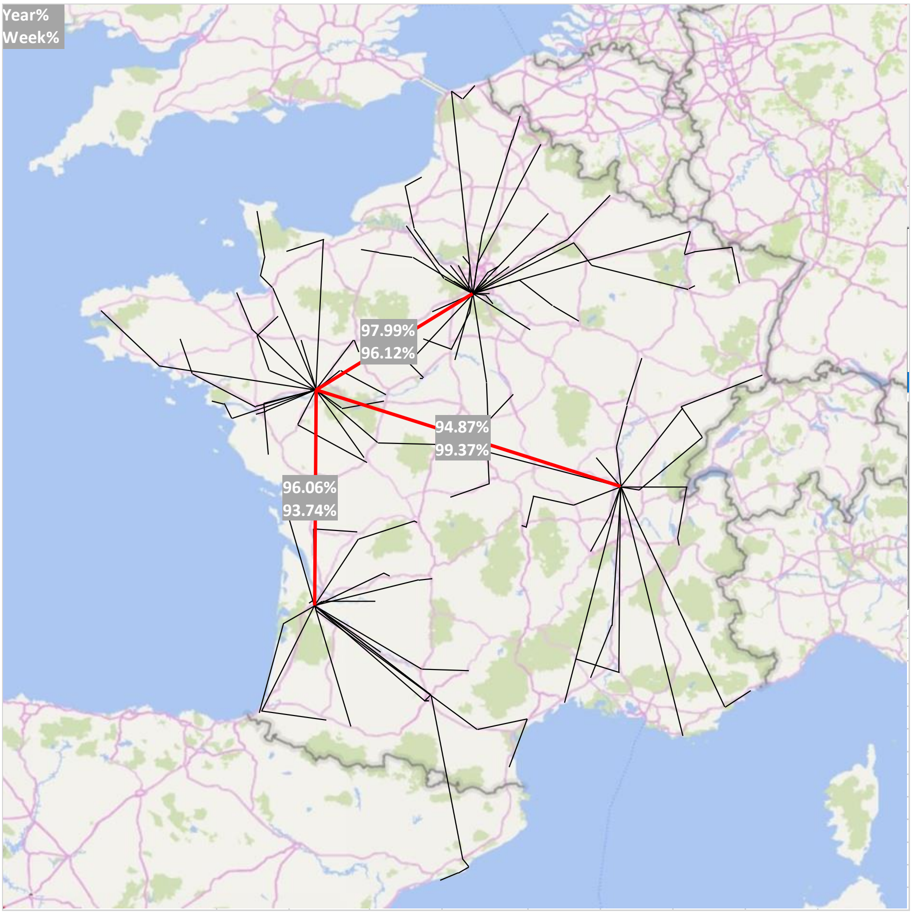

Figure 7-15: Visualization of the transport network in week 8 with a market value of €40M and KPI set 1

Total	DEP4	DEP6	DEP17	DEP22
Demand	**25802**	**32968**	**40611**	**20395**
Truck In	**622**	**785**	**963**	**497**
Fillrate	**0.960597073**	**0.975324504**	**0.979906174**	**0.948655179**
Truck Out	**1440**	**1806**	**2182**	**1190**
Fillrate2	**0.406032326**	**0.416896806**	**0.42655158**	**0.390055984**
Distance In	**230697**	**0**	**262833**	**255292**
Distance Out	**181211**	**174977**	**200328**	**174280**

Table 7-12:Transport network results with a market value of €40M and KPI set 1

Week 8	DEP4	DEP6	DEP17	DEP22
Demand	524	591	992	470
Truck In	13	14	24	11
Fillrate	0.937388193	0.981727575	0.96124031	0.993657505
Truck Out	30	34	54	26
Fillrate2	0.40620155	0.404240766	0.427217916	0.42039356
Distance In	4822	0	6550	5650
Distance Out	3754	3198	4583	4003

Table 7-13:Transport network results in week 8 with a market value of €40M and KPI set 1

7.6.3.2 *Set 2*

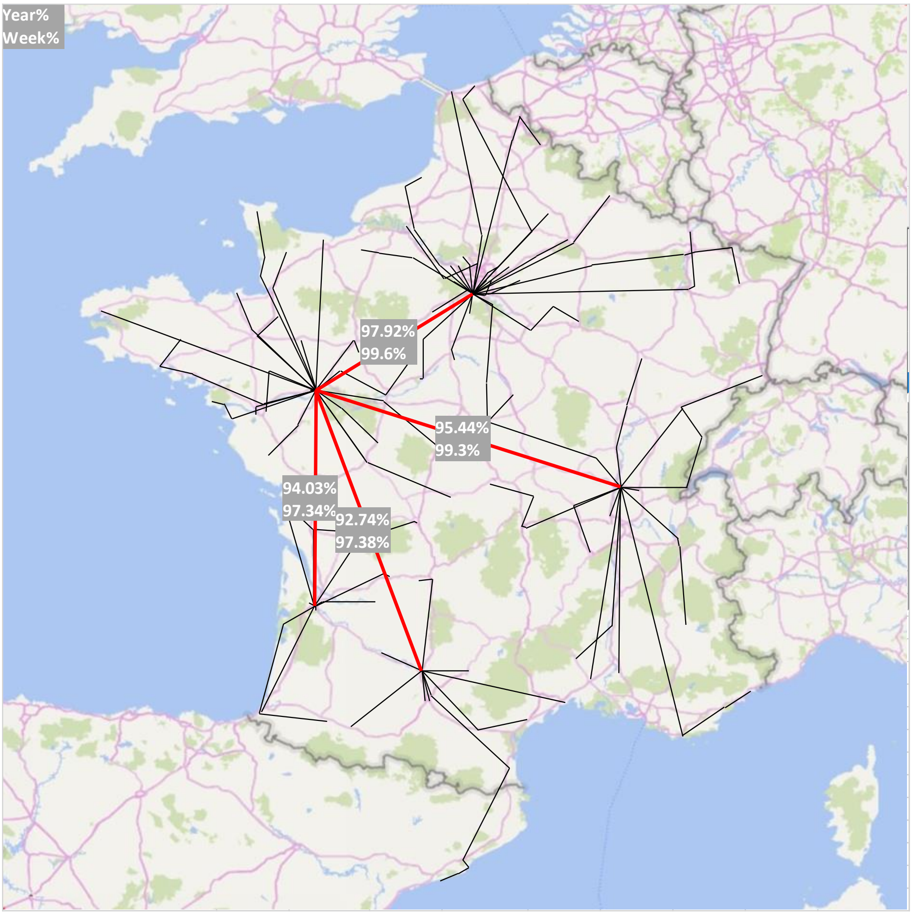

Figure 7-16: Visualization of the transport network in week 8 with a market value of €40M and KPI set 2

Total	DEP4	DEP6	DEP17	DEP21	DEP22
Demand	**15231**	**33473**	**40924**	**11811**	**19393**
Truck In	**375**	**796**	**969**	**294**	**470**
Fillrate	**0.940318105**	**0.975277725**	**0.979211734**	**0.927384007**	**0.954419**
Truck Out	**884**	**1832**	**2156**	**732**	**1116**
Fillrate2	**0.393139902**	**0.415666404**	**0.432498399**	**0.361114023**	**0.39495**
Distance In	**139078**	**0**	**264468**	**147472**	**241421**
Distance Out	**73537**	**175324**	**197161**	**83089**	**161751**

Table 7-14: :Transport network results with a market value of €40M and KPI set 2

Week 8	DEP4	DEP6	DEP17	DEP21	DEP22
Demand	293	654	985	335	427
Truck In	7	16	23	8	10
Fillrate	0.973421927	0.950581395	0.995955511	0.973837209	0.993023
Truck Out	18	38	52	20	26
Fillrate2	0.378552972	0.400244798	0.440518784	0.389534884	0.381932
Distance In	2596	0	6277	4013	5137
Distance Out	1518	3730	4695	1669	3760

Table 7-15:Transport network results in week 8 with a market value of €40M and KPI set 2

7.6.4 Market Value of €50M

7.6.4.1 *Set 1*

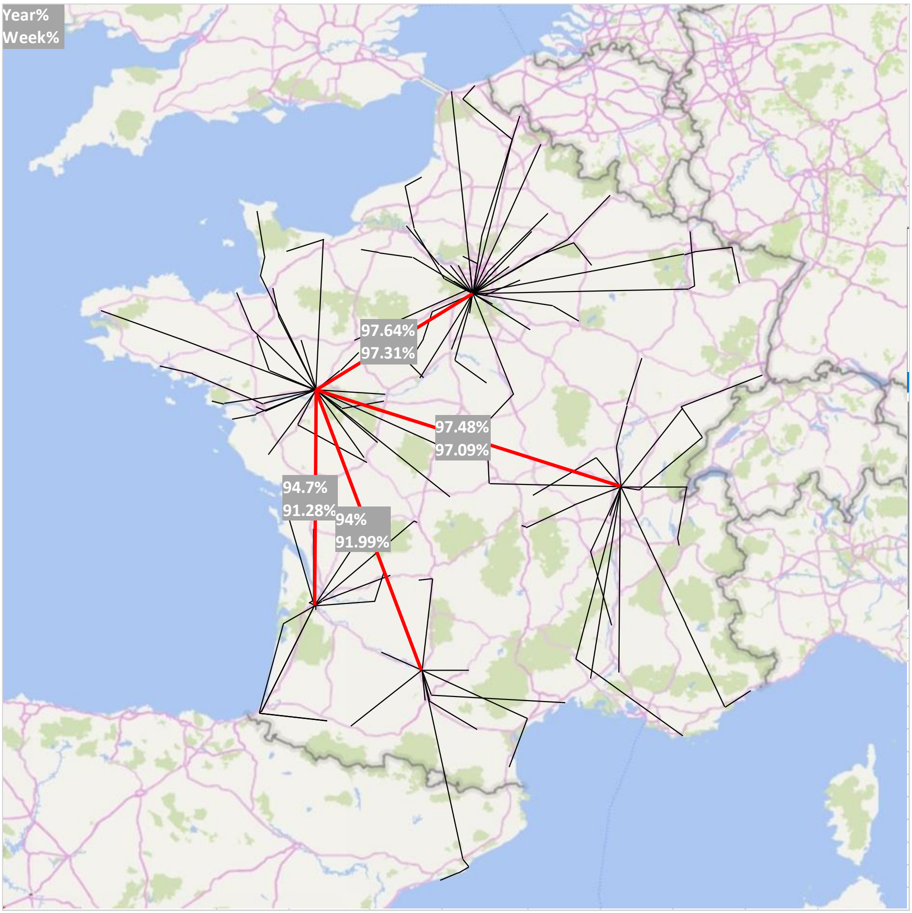

Figure 7-17: Visualization of the transport network in week 8 with a market value of €50M and KPI set 1

Total	DEP4	DEP6	DEP17	DEP21	DEP22
Demand	**19349**	**41137**	**51776**	**14147**	**24470**
Truck In	**473**	**976**	**1230**	**347**	**582**
Fillrate	**0.947011728**	**0.977470448**	**0.976351936**	**0.939988358**	**0.974757**
Truck Out	**1074**	**2142**	**2568**	**820**	**1332**
Fillrate2	**0.407010272**	**0.435897019**	**0.458159619**	**0.389322209**	**0.414924**
Distance In	**175429**	**0**	**335707**	**174054**	**298959**
Distance Out	**83797**	**196336**	**221729**	**88487**	**179131**

Table 7-16:Transport network results with a market value of €50M and KPI set 1

Week 8	DEP4	DEP6	DEP17	DEP21	DEP22
Demand	314	757	1339	356	501
Truck In	8	18	32	9	12
Fillrate	0.912790698	0.978036176	0.973110465	0.919896641	0.97093
Truck Out	18	42	68	20	26
Fillrate2	0.405684755	0.419158361	0.457934337	0.413953488	0.448122
Distance In	2967	0	8734	4514	6164
Distance Out	1629	3827	5584	1757	3867

Table 7-17:Transport network results in week 8 with a market value of €50M and KPI set 1

7.6.4.2 *Set 2*

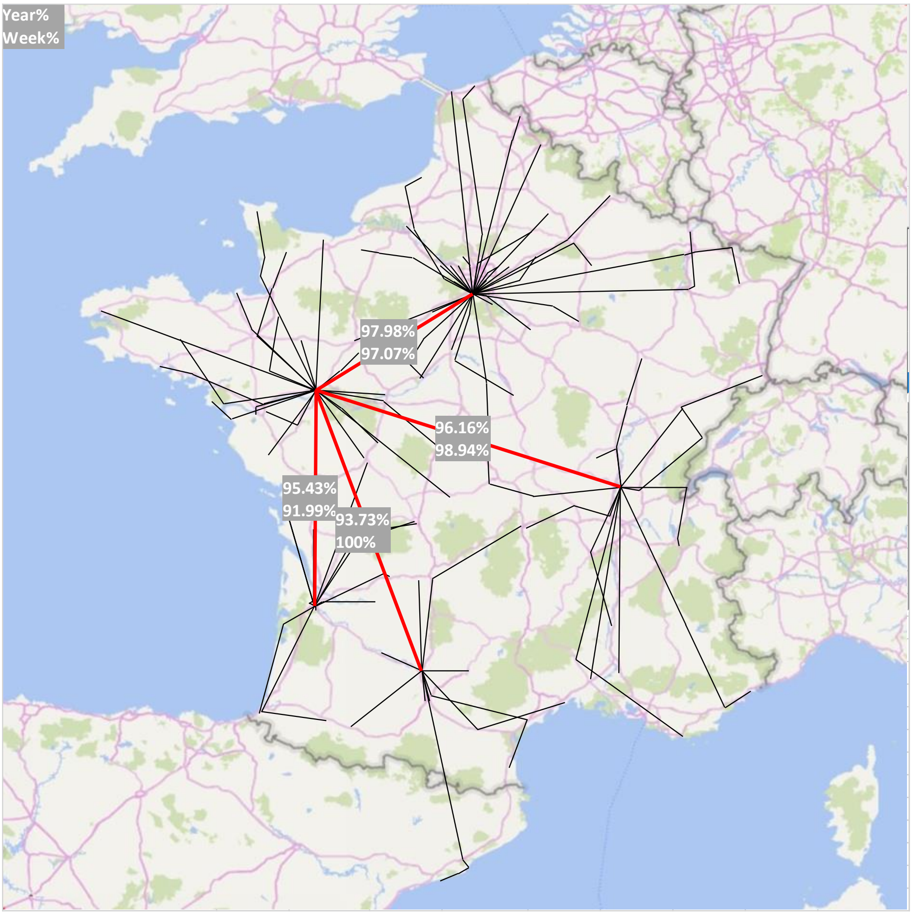

Figure 7-18: Visualization of the transport network in week 8 with a market value of €50M and KPI set 2

Total	DEP4	DEP6	DEP17	DEP21	DEP22
Demand	19112	41488	51430	14473	23857
Truck In	462	992	1217	355	575
Fillrate	0.954335345	0.969865881	0.9798095	0.937336044	0.961649
Truck Out	1050	2168	2594	828	1326
Fillrate2	0.41131627	0.43555666	0.453686257	0.395099806	0.410374
Distance In	171348	0	332157	178062	295361
Distance Out	82757	197773	222829	89687	179213

Table 7-18:Transport network results with a market value of €50M and KPI set 2

Week 8	DEP4	DEP6	DEP17	DEP21	DEP22
Demand	356	714	1294	387	468
Truck In	9	17	31	9	11
Fillrate	0.919896641	0.976744186	0.970742686	1	0.989429
Truck Out	20	40	68	22	24
Fillrate2	0.413953488	0.415116279	0.44254446	0.409090909	0.453488
Distance In	3338	0	8461	4514	5650
Distance Out	1902	3831	5689	1992	3767

Table 7-19:Transport network results in week 8 with a market value of €50M and KPI set 2