THE OPTIMAL MANAGEMENT OF DELIVERY COSTS

UNIVERSITY OF TWENTE.

Koskamp

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BACHELOR THESIS INDUSTRIAL ENGINEERING AND MANAGEMENT

The optimal management of the delivery costs

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PREFACE

Dear reader,

You are about to read the bachelor thesis "The optimal management of delivery costs". This research has been executed at Koskamp in Den Ham as final assignment for my bachelor Industrial Engineering and Management at the University of Twente. This thesis aims at reducing the delivery costs of Koskamp by optimizing the appointment of customers to warehouses.

At Koskamp, I have gained so much new insights and I am grateful for this opportunity. I want to thank Koskamp that I was allowed to go to the company in Den Ham and work here during this strange time in the COVID-19 pandemic.

A special thanks to my supervisor at Koskamp Marc Boekema, who guided during the research. I want to thank him for all the effort and useful feedback he gave me during the research. During all the meetings we had, you were always excited and curious about the results and progress, which made it also nice for me. He was always available and responded very quick when I needed data or help. Without his insights and feedback during the research, I could not write this thesis.

I also really want to thank my UT supervisor Eduardo Lalla. I really enjoyed our meetings, and he was always willing to provide me feedback. He really helped me out in times where I was stressing very much, he could calm me down and talk sense to me. I learned so much about approaching a problem and writing a thesis thanks to him. I would also like to thank Ipek Seyran Topan for her support during the preparation phase of the thesis and for the final feedback. She really helped me out at the start of the thesis and always asked how things were going and if she could help me out.

Finally, I would like to thank my family and friends for their support during the execution time of this research. They always supported me and helped me to finish this thesis. I especially want to thank my father, as he helped me to keep motivated and provided me with extensive feedback and opinions about the research. Due to this, I was able to improve my thesis.

Bas Roelofs

July 2021

MANAGEMENT SUMMARY

Koskamp B.V. (Koskamp) is located in Den Ham, the Netherlands. Koskamp was founded as a family business in 1969. The company currently has 12 warehouses throughout the Central, North and East of the Netherlands. Koskamp has more than 300 employees with its own ICT, marketing and purchasing department. Koskamp supplies a wide range of car materials such as car tires, tools, license plates and liquids from all A-brands and various private labels. Koskamp also provides a great service as the ordered products are usually delivered within 1 or 1.5 hours to the customer through their own logistics network. Koskamp strives to build a sustainable relationship with customers. Therefore, they also offer advice, training, concepts, and marketing support to increase the success of their customers.

The problem solving approach

The problem that Koskamp is currently facing is in its logistics department, as they want to reduce the delivery costs. It is indicated that the core cause of this problem is that Koskamp has no clear procedure on how to optimize the appointment of customers to warehouses. To solve this problem, this research focused on optimizing the appointment of customers to warehouses by minimizing the total delivery costs. Therefore, the main research question addressed in this thesis is formulated as follows:

How to reduce the delivery costs in relation to the turnover per customer?

To understand what theory can be put behind the problem at Koskamp, a literature study was conducted. We needed to know what type of problem we had and how this could be solved. In this literature study we explore related facility location problems and examples of algorithms on how these could be solved.

After identifying the problem as well as how to solve the problem, a context analysis was conducted. Here we map the current situation at the company in a better way. In this context analysis, we acquired and calculated the data needed for solving the facility location problem. These include the delivery capacity per warehouse, current delivery costs, current utilization rates and demand per customer. We also analyzed the current allocation of customers to warehouses, and we mapped the business process model of how Koskamp currently appoints a new customer to a warehouse. Lastly, we identified the problems of some customers being unprofitable or less profitable.

For solving the problem at Koskamp, we developed mathematical models for different scenarios in Python, this tool is called the optimization tool. Some assumptions had to be made for the models to complete the thesis in the 10 weeks. There is also a trade-off that needs to be considered when changing the allocation of customers or the number of warehouses. A whole excel fil has been created, in which the guidelines are explained. Guidelines are given for the optimization tool, but there are also guidelines for testing if a new possible warehouse location would be a good location and replacement of another warehouse. And lastly, there is a guideline of the appointment tool with which Koskamp can determine to which warehouse they need to appoint a new customer.

With the optimization tool, Koskamp can gain insights into which customers to appoint to which warehouse, which warehouse to close when they consider closing a warehouse and why, and they could test if a new possible warehouse location would be good or not. They can also determine the cost savings and the new utilization rates per warehouse.

Conclusions and recommendations
After the analysis of the outcomes from optimization tool, some main conclusions are made:

Optimizing with all warehouses open and reducing delivery capacity
By changing the appointment of customers 1.9% of the total costs can be reduced. By decreasing the delivery capacity an extra 2,7% of the costs could be saved and the utilization rate will go up with an extra 2%, however this results in reducing service levels. Appointing a customer to multiple warehouses only results in less than 0,01% more cost savings and creates a more complex situation, compared to appointing a customer to only 1 warehouse.

Optimizing while warehouses can be closed
When we optimize the appointment of customers, while closing warehouses, this resulted in 5 warehouses being closed. This results in 9,9% savings of the total costs, while increasing the utilization rate with 15%. However, this option is not ideal, because for the last 2 warehouses we close out of the 5, we only save an extra 1%. Besides, the service level will decrease. Warehouses Arnhem and Assen, were the two warehouses that would first be closed, according to the models and looking at the geographic positioning. If Koskamp were to close 2 warehouses. Lastly, warehouse Bilthoven has a very high ratio between reality and model, which results in this warehouse being unattractive to appoint customers to and therefore losing a lot of customers.

Based on the performed research and stated conclusions, recommendations are made for Koskamp. The main recommendations are as follows:

Recommendations for optimization
We recommend using the appointment tool for appointing a new customer to a warehouse. Koskamp should make use of this every time a new customer arrives. We also recommend using the optimization tool every year to check the customer allocation and which warehouses are more attractive than others. We also recommend using the optimization tool when Koskamp were to close a warehouse or if Koskamp wants to know if a specific warehouse location is a good solution. If Koskamp were to close 1 or two warehouses, we recommend closing warehouses Arnhem and Assen respectively, as these gave the highest savings and looking to the geographic positioning can be easily taken over by surrounding warehouses.

General recommendations
For the above mentioned we recommend using the established guidelines in "Guidelines for appointing a new customer to a warehouse". Here, examples are given, and an explanation is given on how to be able to run both tools and use them in practice. Furthermore, we recommend Koskamp to investigate the situation of Bilthoven, as here the ratio is very high. Reasons for this high ratio are given in this thesis and should be investigated. Lastly, we recommend Koskamp to change the payment method for their drivers.

TABLE OF CONTENTS

READER'S GUIDE

Along the seven chapters, we described how the research at Koskamp is performed. We shortly introduce the chapters. Most figures and tables are made black due to confidentiality.

Chapter 1: Introduction
An introduction to the research is given in the first chapter. Shortly the current situation of Koskamp is described. Moreover, the research methodology is explained and the core problem within this thesis defined.

Chapter 2: Literature study
Literature study is described in the second chapter. Here the main concept of the core problem will be elaborated on. Here a distinction will be made between a Facility Location Problem (FLP) and the Warehouse Location Problem (WLP), and which is more applicable to the situation of Koskamp. This concept will be explained along the most important KPI's there are for these problems and what solution methods there are.

Chapter 3: Context analysis
This chapter provides a better insight in the research, a context analysis at Koskamp is given. The business process model of assigning customers is identified and the delivery costs are modeled and defined. Also, other important KPI's are identified and explained.

Chapter 4: Solution design
In this chapter the models based on the literature study will be explained and implemented. Here we also give the guidelines for using the solution design and a new business process model is created for assigning a new customer to a warehouse.

Chapter 5: Results from solution design
What impact the solution design has on the delivery cost and other KPI's will be analyzed here. Also, conclusions will be made based on the outcomes, and from these conclusions, recommendations can be given.

Chapter 6: Evaluation
In this chapter an evaluation on solution design is give. Here two surveys are done, from which information can be gathered, which tell us if the new technology presented is accepted and useful for Koskamp.

Chapter 7: Conclusions, recommendations, and future research
Conclusions and recommendations about the performed research are given in this last chapter. Besides that, potential future research is explained

1 INTRODUCTION

This chapter presents an introduction of Koskamp and the goal of the research. Section 1.1 gives an introduction of Koskamp. In Section 1.2 the problem identification is given. Section 1.3 gives an overview of the core problems and the motivation.

1.1 COMPANY INTRODUCTION

Koskamp is located in Den Ham, the Netherlands. Koskamp was founded as a family business in 1969. The company currently has 12 branches throughout the Central, North and East of the Netherlands. Koskamp has more than 300 employees with its own ICT, marketing and purchasing department.

Koskamp supplies a wide range of car materials such as car tires, tools, license plates and liquids from all A-brands and various private labels. Koskamp also provides a great service as, the ordered products are usually delivered within 1 or 1.5 hours to the customer through their own logistics network. Koskamp strives to build a sustainable relationship with customers. Therefore, they also offer advice, training, concepts and marketing support to increase the success of its customers.

1.2 PROBLEM IDENTIFICATION

In order to understand the problem at Koskamp, we identified the action problem, the norm and reality, and created a problem cluster based on this action problem.

Action problem

Koskamp has its own logistics "last-mile delivery" network consisting of 12 warehouses, more than 120 delivery vans and a number of trucks that drive internally. Koskamp sets appointments with most customers to deliver within 1 or 1.5 hours. More than 2000 customers use this every day, most of whom order several times a day. In total, this currently results in more than 11 million kilometers per year, which entails the necessary costs and burden on the environment, especially since Koskamp currently does not charge shipping costs. Some customers are currently not profitable for Koskamp. For example, a motorhome garage that orders a light a few times a day does not result in enough margin to cover the logistics costs.

The focus of this bachelor assignment lies on optimizing the delivery costs of Koskamp's logistics, by optimizing the division of customers to warehouses. The division of customers to warehouses can be seen as a Facility location problem (FLP), which is solved by optimizing the placement of warehouses or the optimal division of customers to warehouses to minimize transportation costs.

Overall, Koskamp wants to be able to better manage the logistics delivery costs in order to get the company more profitable. This leads to the **main research question**:

How to reduce the delivery costs in relation to the turnover per customer?

The variables in this research question are as follows. First there are the delivery costs, these are all the costs involved in the delivery process. These are more in detail in the problem identification, and this is where the focus of this research lies. Secondly, we have the turnover per customer, this is the amount of money taken by Koskamp in a certain period or after an order. These two variables are interconnected because fluctuations of both variables affect the profit, which the company wants to increase by reducing the delivery costs.

From the research question, the **action problem** goes as follows:

At Koskamp, the current division of customers to warehouses is not optimized

Norm and reality

An action problem is the discrepancy between a norm and a reality as perceived by the problem owner (Heerkens & Winden, 2017). In this particular situation, the norm is an optimization of the division of customers to warehouses. The reality is that the way customers are divided to a warehouse, is done manually (not optimized via parameters).

Problem cluster

To find the root of the previously stated action problem, a problem cluster will be made regarding all problems related to the action problem. This will lead to the identification of the core problem (Heerkens & Winden, 2017).

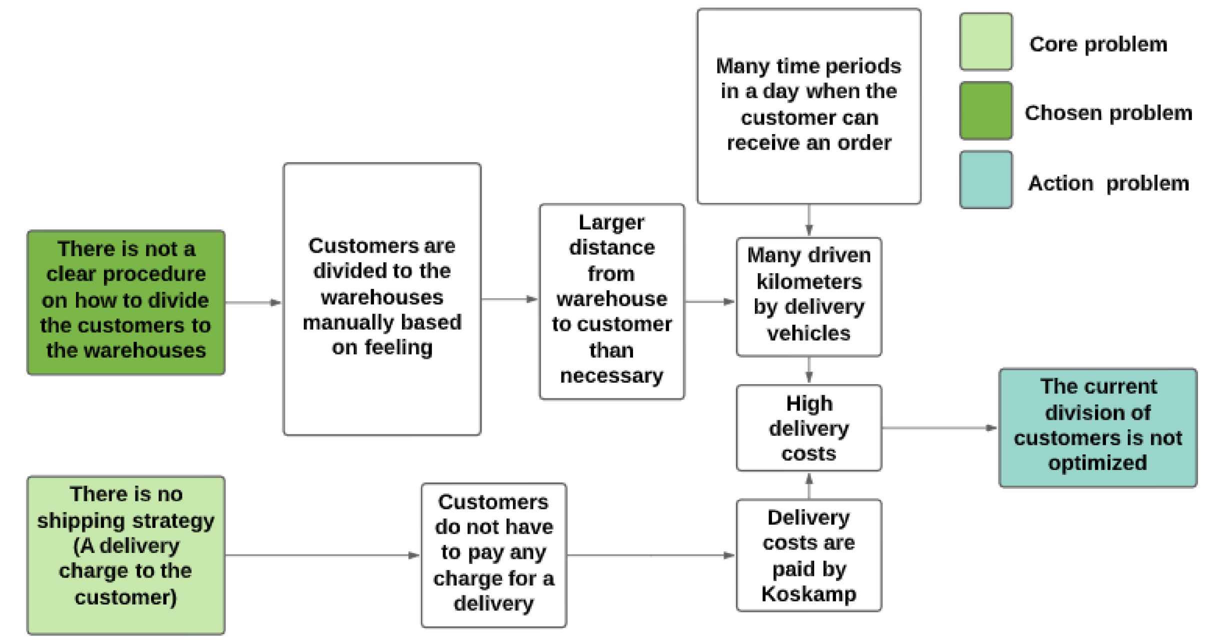

FIGURE 1: PROBLEM CLUSTER OF KOSKAMP LOGISTICS

Starting from the action problem, we see that without the optimal division of customers to the warehouses, delivery costs will be high. This is due to two reasons.

Firstly, we have that Koskamp's delivery vehicles make many kilometers. Koskamp currently has a delivery system where there are several deliveries per day. They have vehicles that deliver every hour and leave the warehouse 8 times per day. And vehicles that deliver every 1.5 hours and leave the warehouse 6 times per day. This results in many kilometers depending on the number of orders in one of the timeframes because the more orders the more distance has to be covered.
Another reason for the high number of kilometers is the larger amount of distance from warehouses to customers than necessary. This is not the case for all customers, however there are customers for which there is a warehouse closer to them than the one that currently delivers to them. Which results in an extra number of kilometers which is not necessary. This is thanks to the practice of dividing the customers to a warehouse based on feeling, not on a theory or certain procedure. Which sums up our first core problem, namely that there is no clear procedure for how to divide customers to a warehouse.

The second reason why the delivery costs are high is because Koskamp pays for the costs of the delivery to the customer. This is due to the fact that customers do not have to pay anything for delivery. And this is the result of the second core problem, that there is no shipping strategy present.

To sum it up, two core problems have been found:

1. There is no clear procedure on how to appoint customers to warehouses
2. There is no shipping strategy present

1.3 Core problem and motivation

Now the problem cluster has been established, a closer look is made on the problems which do not have a cause, these are the core problems. There can be seen that both core problems are very coherent. The first core problem is the most important one and is the problem that will be solved in this thesis, as it has the most impact on the reduction of the delivery costs, and this problem also takes the most time. However, the second core problem is also very important. This problem is less sophisticated and can be solved by simple analysis and critical thinking. And most importantly will result in an even higher reduction of the delivery costs.
We chose to solve the first core problem, where we have to find an optimal way of dividing customers to warehouses. The second core problem was not included, as in this thesis, we only have 10 weeks and solving both would require more time.

1.4 Research methodology

To answer the stated main research question and to solve the action and core problem, research is conducted. First the research approach must be created on what steps to take in order to tackle this problem, which is done in Section 1.4.1. To each of these steps a knowledge question is created in Section 1.4.2. The research design is outlined in Section 1.4.3. And Section 1.4.4 described the restrictions for this thesis. In Section 1.4.5 the validity and reliability of this research is analyzed. Lastly, in Section 1.4.6 we have the deliverables.

1.4.1 Research approach

Since we now know what the problems are, and thus know what we need to solve. We now need to determine what we want to know in order to solve the problems. This is formulated by following the MPSM steps, according to Heerkens and Winden (2017). "*Phase 1: Problem identification*" is done in Section 1.3. "*Phase 2: Solution planning*" is done in this section, where we define the way to the solution. To be able to answer the core problem, the following stages need to be followed.

***Phase 3: Problem analysis*.** At first, knowledge is gathered to understand the performance of the current situation and the way the logistics works at Koskamp. For this a contextual analysis (or quantitative data analysis) is conducted to get an insight into the current situation. Here the current delivery costs and distances from customers to the warehouses are analyzed. But also, other parameters, which give an insight in how the customer is doing for the company and how the company is doing itself, are analyzed.

***Phase 4 & 5: Solution generation & choice*.** There must be determined, what methods and theories can be used to optimize the appointment of customers to warehouse. Here a literature study (SLR study) is conducted in order to find what methods and theories there are that help determine how to solve a Facility/Warehouse Location Problem. The methods and theories are qualitatively analyzed, and the most appropriate method is selected to optimize the appointment of customers to warehouses along the established constraints.

***Phase 6: Solution implementation*.** After the method is chosen, there is determined how to implement and evaluate the method along the parameters, taking the restrictions, described in Section 1.4.4, into account. Here a tool will be designed and used to implement the method, this will be done in Python and in consultation with my Koskamp supervisor and UT supervisor. There will also be given a manual for how to use the tool, as well as an explanation on how the tool was created and the optimal solution will be given. In the optimal solution, there will be shown which customers belong to which warehouse. The changes will also be communicated towards the customers.

***Phase 7: Solution evaluation*.** When the customers are optimally appointed, an analysis is made. Here the effects of the optimization are analyzed and compared to the current situation in excel. The differences are pointed out and end results are presented.

Lastly, the conclusions and recommendations are written down after conducting the assignment at Koskamp. Also, insights for future improvements or for future progress are discussed. And further work in light of the findings is considered and discussed.

1.4.2 Research questions

To solve the core problem, as described in Section 1.2, the main research question and accompanying sub-questions have been formulated. The main research question goes as follows:

How to reduce the delivery costs in relation to the turnover per customer?

In order to answer this question, sub-questions have been determined based on the stages of Section 1.4.1. The sub-questions and their importance are described below:

1. *How does the current situation influence the delivery costs?*

This question is related to the first stage of the research approach, namely the analysis of the current situation. This question is of great importance as it serves to identify how the current situation affects the performance of Koskamp. This can later be used to compare the impact the solution has on the situation. This question is answered in Chapter 3.

2. *What methods and theories are relevant for optimizing the appointment of customers to warehouse?*

This question is related to the second stage of the research approach. Before a problem can be solved, there must be known what solutions there are for this problem. This knowledge question serves to identify all methods and theories for a facility/warehouse location problem and serves to give the theoretical framework of this thesis. At the end of this question a method will be chosen, that will be implemented in the next stage. This question is answered in Chapter 2.

3. *How to implement the method/theory to optimize the appointment of customers to warehouse, taking the restrictions into account?*

This question is related to the third stage of the research approach. The previously chosen method now needs to be implemented. Before this can be done, a design and implementation plan are determined. At the end of this question, the method is implemented, and the facility/warehouse location problem will be solved. This question is answered in Chapter 4.

4. *Which scenario reduces the delivery costs of Koskamp?*

This question is related to the fourth stage of the research approach, namely the analysis after implementation. This is of great importance, as here an analysis is done, whereafter a comparison is made between the current situation and the situation after implementation. Here the effect of the optimization in stage three is shown, and there is shown where the delivery costs can be reduced. In Chapter 5, this question will be answered.

5. *What conclusions and recommendations can be made after conducting the thesis at Koskamp?*

This last knowledge question is related to the sixth stage of the research approach. This question is of real importance, as here all conclusions and recommendations will be explained, and future insights and improvements will be discussed. This question is answered in Chapter 7.

1.4.3 Research design

Below an overview is given of the research design, that follows from Section 3.2.

TABLE 1: RESEARCH DESIGN

Research question	Type of research	Research population	Data gathering	Data analysis
1. How does the current situation influence the delivery costs?	Descriptive	Customers and warehouses	Analysis of primary resources and interviews	Quantitative and qualitative, visual representation and graphs explained
2. What methods and theories are relevant for optimizing the appointment of customers to warehouse?	Exploratory	-	Literature study	Qualitative
3. How to implement the method/theory to optimize the *appointment* of customers to warehouses, taking the restrictions into account?	Explanatory	The customers and the warehouses of Koskamp	Literature study and interviews	Quantitative and qualitative
4. Which scenario reduces the delivery costs of Koskamp?	Descriptive	The customers	Analysis of primary resources (after implementation)	Quantitative, visual representation and graphs explained
5. What conclusions and recommendations can be made after conducting the thesis at Koskamp?	-	-	-	-

1.4.4 Restrictions

In order to solve the core problem and action problem within the timeframe of 10 weeks, some restrictions have been established. These form a guideline when executing the study and also give a clear picture of the scope of the research.

- **Key Performance Indicators (KPI)**. The solution method had to be designed using some KPI's, in order to see the effect of the solution method. Examples of these are distance from customer to warehouse and total costs.
- **Clarity.** The solution must be clear for Koskamp, and the stakeholders involved. Some guidelines will be given that will clarify the process and give a good indication of what every involved stakeholder must do when a new customer arrives.
- **Delivery costs the customer is accounted for**. Since for the FLP we do not look at the routes that are established, therefore we cannot calculate the precise costs of a route and thus the delivery costs of a customer in such a route. To still make this a good approximation, we create a ratio. The delivery costs are calculated in a certain way and will be compared with the real delivery costs, from which a ratio can be extracted. This ratio can then also be used with the new division of customers and will give a relative indication of how the delivery costs have changed overall.
- **Temporarily closing of warehouses**. With the tool, there is the option of using a warehouse or not for a certain day. This means that a warehouse will be temporarily closed, which can save costs. However, the warehouse Steenwijk and Leeuwarden may not be closed, as other warehouses are dependent on the supply of the warehouses. Because these warehouses supply the other warehouses of Koskamp, closing them will not be a feasible option.

1.4.5 Assessment of validity and reliability

Validity and reliability are of great importance when conducting research. Reliability is to what extent the same results can be achieved when repeating the research under the same conditions. And validity is to what extent the results really measure what they are supposed to measure. There are two important forms, internal and external validity, whom will be considered.

The internal validity is about the design of the experiment. The validity is ensured in the earliest part of the research, by choosing the appropriate data gathering methods, in Section 3.3 an overview of the data gathering methods used can be found. Here the validity is secured, since the methods are based on existing knowledge, and they will be thoroughly researched.
These methods will be planned carefully and applied consistently for it to remain reliable. Moreover, to ensure reliability the conditions of the research must be standardized, to reduce the influence of external factors that might create variation of the results.

An issue that may occur is in the external validity, the generalizability of the results. Since the main method used, is generalizable, as it can be used for the same kind of problem, however the method is applied to the unique situation of Koskamp within their own logistics department. But the model created for this situation could be adjusted, used, and learned from.

1.4.6 Deliverables

Here an overview of the deliverables at the end of the bachelor thesis at Koskamp will be given. These deliverables follow from the knowledge questions established in Section 3.2.

1. Excel file that gives an overview of the current performance
2. Theoretical framework; literature study and review of relevant optimization methods and motivation of chosen method
3. Optimization tool for optimally appointing customers to warehouses
4. Appointment tool for appointing a new customer to a warehouse
5. Guidelines for using both tools
6. Conclusions and recommendations

2 THEORETICAL FRAMEWORK

In this section, the main concept of the core problem will be elaborated on. Here a distinction will be made between a Facility Location Problem (FLP) and the Warehouse Location Problem (WLP), and which is more applicable to the situation of Koskamp. This concept will be explained along the most important KPI's there are for these problems and what solution methods there are.

The study of FLP and WLP, also known as location analysis, is concerned with the optimal placement of facilities or optimal division of customers to warehouses, to minimize the transportation costs while satisfying the demand of these customers. Basically, a location problem is characterized by four elements: (Adeleke, O. J., & Olukanni, D. O., 2020; Cornuejols, G., Nemhauser, G.L. & Wolsey, L.A., 1983)

1. A set of *locations* where facilities may be built/opened. For every location, some information about the cost of building or opening a facility at that location is given.
2. A set of *demand points (customers)* that must be assigned for service to some facilities. For every customer, one receives some information regarding its demand and about the costs/profits incurred if he would be served by a certain facility.
3. A list of *requirements* to be met by the open facilities and by any assignment of demand points to facilities.
4. A *function* that associates to each set of facilities the cost/profit incurred if one would open all the facilities in the set and would assign the demand points to them such that the requirements are satisfied

There are a variety of types of FLP corresponding to the features of the four elements above. But before this, it is important to first know what the objectives are. The right objectives must be set based on the situation, in order to find and use the right method to solve the problem. The objectives are also very important since based on these the researcher can decide on what KPI's, and what constraints are important and must be used. For the formulation of the FLP we are dealing with, a few things must be considered.

Minisum vs. Minimax Facility Location Problems

A minisum FLP looks to place a new facility in the location that minimizes the sum of the weighted distances between the new facility and the already existing facilities. The minimax FLP, by contrast, looks for the optimal location to place a facility to minimize the maximum distance between the newly placed facility and all existing facilities. (Litoff, A., 2015)

Capacitated vs. Uncapacitated Facility Location Problems

When each (potential) facility has a capacity, which is the maximum demand it can supply, the problem is called a capacitated facility location problem. When the capacity constrains are not needed, we have the simple or uncapacitated facility location problem. Here the assumption is made that each facility can produce and ship unlimited quantities of the commodity under consideration. (Cornuejols, G., Nemhauser, G.L. & Wolsey, L.A., 1983)

Continuous vs. Discrete Facility Location Problems
Finally, in a continuous FLP, the selection for the new facility can be any location within the space, whereas for a discrete FLP there are given set of choices for the facility's location. (Litoff, A., 2015)

Rectilinear vs. Euclidean vs. square Euclidean vs. Roadmap distance
For both the FLP and the WLP there are different ways of calculating or determining the distance between two points. (Farahani, R. Z., & Hekmatfar, M. ,2009)

- *Rectilinear distance*. This distance speaks for itself and is a very appropriate distance measure, and it is easy to treat analytically. As Figure 2 illustrates, there are several paths between X and Pi, however for every path the rectilinear distance is the same. The number of such paths is, of course, infinite (Francis and White, 1974)

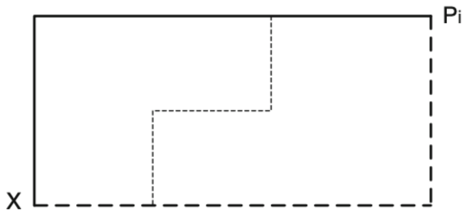

FIGURE 2: DIFFERENT RECTILINEAR PATHS BETWEEN X AND P

- *Euclidean distance*. The Euclidean distance is the distance of a straight line from point A to point B. It can be calculated by using the X and Y coordinates of these points and then use the Pythagoras theorem to calculate the length of the line. Therefore, the Euclidean distance is often called the Pythagorean distance. In Figure 3, we can see how the Euclidean distance is calculated.

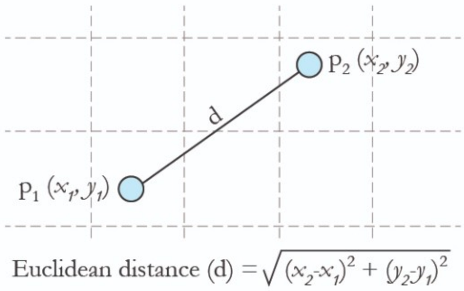

FIGURE 3: EUCLIDEAN DISTANCE FORMULATION

- *Square Euclidean distance*. For the square Euclidean distance, the same equation is used as with the Euclidean distance, however here the square root is not used. As a result, if you were to cluster customers to warehouses this would go faster than when we would cluster with the Euclidean distance and we would get the same answer and we would when using the Euclidean distance.

- *Roadmap distance*. The roadmap distance approach of is a bit different than the other ones, but the most accurate approach. With the help of Google maps or Bing maps, the distances can be retrieved between two locations through the road network. This can be done by retrieving an API key from Google or Bing maps, with which you can attain the distances between two points.

Differences between FLP and WLP

The differences between these two problems are hard to establish since these two problems are correlated very much so there is not much that separates them. The main difference between these two problems is that for the WLP there are a few more options available. These are the period in which you want to solve the problem (single period or multi-period). Also, the number of warehouses that can supply a customer can be established. Lastly, the number of products can be either single product or multiple products.

Solution methods

To solve small WLPs or FLPs, integer programming optimization methods are used. However, for larger WLPs or FLPs, heuristic methods or meta heuristic methods are utilized. In this part a few of these methods will be mentioned. (Farahani, R. Z., & Hekmatfar, M., 2009). Heuristic is problem-dependent solution strategy where Meta-heuristic is problem-independent solution strategy. For example, if we want to get the best shooting speed for a soccer robot, we can use a specific heuristic. This is heuristic way. Because, it doesn't necessarily mean, the same heuristic will also be useful to get the best throwing speed of a basketball to score. But, if we design a strategy with parameters to tune which can be applicable to both problems, then it will be a meta-heuristic. (Ashraf, Faisal., 2021). Since there is a vast amount of solution methods per type of problem, we only describe a few of the exact, heuristic and metaheuristic methods created for some specific problems.

Exact solution methods

Kelly and Marucheck (1984) proposed an algorithm for dynamic WLP. First, the model is simplified and then a partial optimal solution is obtained through iterative examinations by both upper and lower bounds on savings realized if a site is opened in a given time period. A complete optimal solution is obtained by solving the reduced model with Benders' decomposition procedure.

Heuristic and Metaheuristic methods

Vergin and Rogers (1967) introduced a simple heuristic for solving FLP with Euclidean distance. This procedure locates each of new facilities in a temporary location at each step and locates the next new facility according to the facilities located so far. After all n new facilities are located in this manner the process is repeated and the readjustment process is continued until no further movements occur during a complete round of adjustment evaluations.

The application of nonlinear duality theory shows Euclidean minimax FLP can always be solved by maximizing a continuously differentiable concave objective subject to a small number of linear constraints. This leads to a solution procedure that produces very good numerical results. Love et al. (1973) presented a nonlinear programming method for computing the solution to MFLPs using Euclidean distances when the MiniMax criterion is to be satisfied.

Conclusion

In this chapter, we did a literature review to find what the FLP and WLP is and what types of problems there are. We found that this problem can be formulated according to multiple assumptions and classifications. From the literature, we found that it is very important to first understand what the objectives are of the research. Then, the problem must be identified, corresponding to the assumption of an FLP or WLP. And from this a feasible solution method can be chosen and implemented in their problem. This implementation does not have to be exactly what is stated in the solution method, some modifications can and may be done if one can justify their actions. For the problem of Koskamp, we solve the FLP, as this problem had more overlap with the problem at Koskamp. As the FLP is not entirely similar to the problem at Koskamp, the mathematical model has to be altered. The mathematical models are described in Chapter 4.

3 Context analysis

This chapter contains the context analysis of the bachelor thesis performed at Koskamp. This is done by answering the first stated research question.

How does the current situation influence the delivery costs?

This question is answered by first understanding the current way of working and their flaws, which is described in Section 4.1. By analyzing the performance of the warehouses and see where and when many costs are made and what can be saved when temporarily closing a warehouse, which is described in Section 4.2. Section 4.3 outlines the customers of Koskamp and some customers that stand out. In Section 4.4 the problems and challenges of the current situation. Lastly, a conclusion is made in Section 4.5.

The main input of this chapter was provided by interviews and analysis of primary sources. The current work routine, current warehouses and its customers have been analyzed in this chapter. Some figures and tables were made black due to confidentiality in this chapter.

3.1 Current way of working

To understand the current way of working it must be clear how a customer currently is allocated to a warehouse. This can be mapped by creating a business process model (BPM), as can be seen in Figure 4.

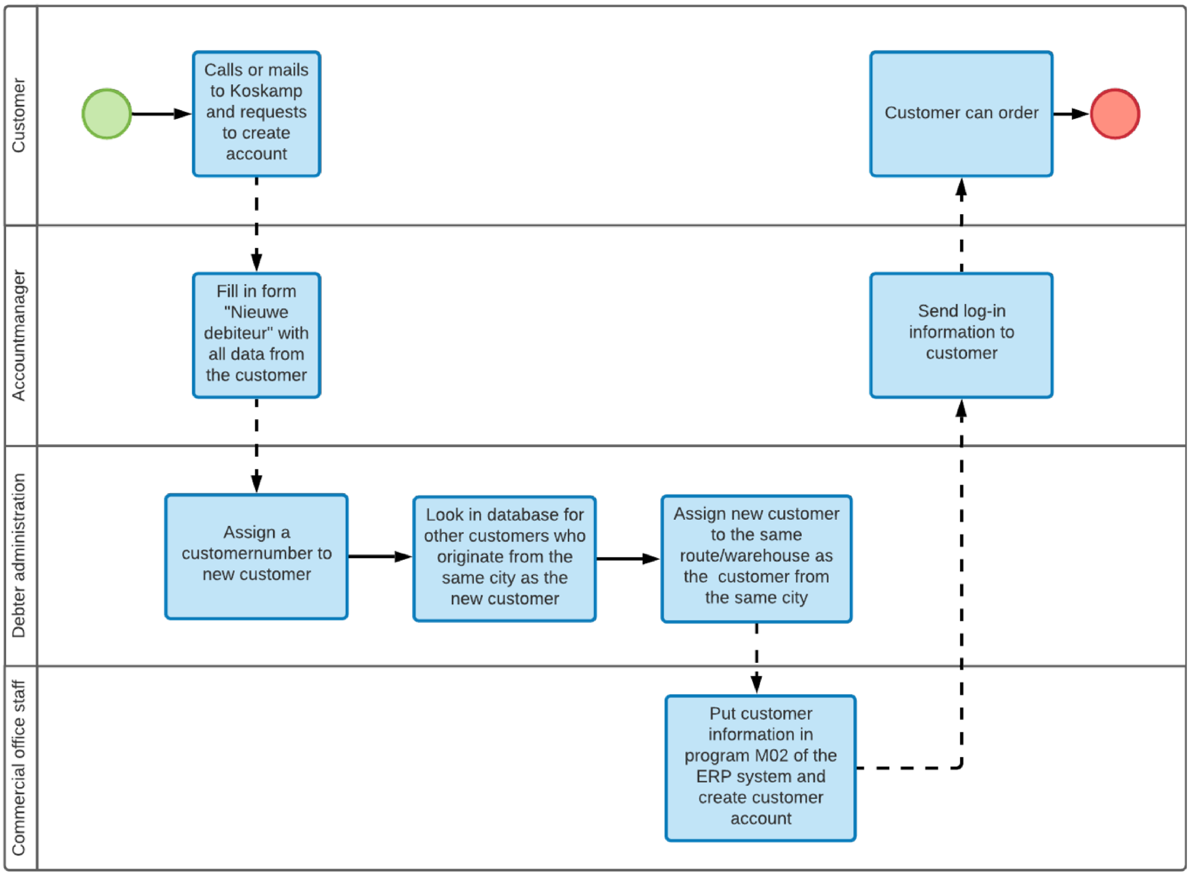

FIGURE 4: BPM ALLOCATION OF CUSTOMERS

From this BPM, we can see that the logistics department of Koskamp is excluded from this process. Currently, the debter administration allocates customers to warehouses based on feeling and with minor insights. By allocating customers this way, extra costs are made, which results in lower profits than there could be achieved. And by excluding the logistics department from this process, no good analysis is done, regarding what warehouse fits this customer the best.

3.2 The warehouses

After identifying the current way of working, the warehouses are analyzed. This analysis looks at the performance of the warehouses and looks to identify important parameters and factors for the optimization process.

Performance of the warehouses

To understand the performance of each warehouse, the margin after subtraction of the delivery costs had to be determined. The turnover was already given by Koskamp, however the delivery costs still had to be determined. We created a model to calculate the delivery costs, this model consists of the following costs:

- ***Fuel costs***. These are variable costs, so these costs change when more kilometers are driven. To calculate the fuel costs per customer, the fuel costs had to be expressed in a constant cost per km. This constant, we called the *fuel costs per km*, is calculated as follows:

$$\frac{Total\ fuel\ consumed\ over\ a\ year\ x\ fuel\ price\ per\ Liter}{Total\ driven\ kilometers\ over\ a\ year}$$

  This information was gathered from the fuel cards of the delivery cars of Koskamp. Besides this we know that a customer is visited multiple times, so this must be considered when calculating the fuel costs. A visit can be seen as an order by the customer. The travel distance that this customer then costs is equal to the distance of a trip from Koskamp to the customer. The fuel costs for a customer will then be calculated as follows:

$$([Total\ \#\ of\ visits]\ X\ [Travel\ distance\ for\ 1\ visit])\ X\ [Fuel\ costs\ per\ km]$$

- ***Maintenance costs.*** These are also variable costs and change when the number of kilometers changes. For the maintenance costs, a constant must be created as well. This constant is called the maintenance costs per car per km. This constant is calculated as follows:

$$\frac{Total\ maintenance\ costs\ over\ a\ year}{Total\ driven\ kilometers\ over\ a\ year}$$

  As with the fuel costs, the number of visits to a customer must be considered. The maintenance costs are calculated as follows:

$$([Total\ \#\ of\ visits] X\ [Travel\ distance\ for\ 1\ visit])\ X\ [Maintenance\ costs\ per\ car\ per\ km]$$

- ***Salary costs***. These are also variable costs and change when the travel times changes. The delivery employees are paid with the minimum wage, so this information could be found on the government website. As the salary is in hours, the distance should be expressed in travel time. Additionally, the average service time per visit should be included, which is 1 minute or 1/60 hours. Also, for the salary costs, the number of visits must be considered. The salary costs are then calculated as follows:

$$([Total\ \#\ of\ visits] X\ [Travel\ time\ for\ 1\ visit] + \frac{1}{60})\ X\ [Salary\ costs\ per\ hours]$$

The ***total delivery costs*** formula then goes as follows:

$$Total\ delivery\ costs\ =\ Fuel\ costs\ +\ Maintenance\ costs\ +\ Salary\ costs$$

With the total delivery costs calculated by the model and the actual delivery costs a ratio can be extracted, which can be used to give the relative change per new scenario for the actual delivery costs. The way the total salary costs were calculated wasn't accurate, as these were calculated based on the travel and service time per customer, however salary costs are of course constant as the staff get paid for a whole day of 8 hours.
Before calculations could be made, the distances and travel time from warehouse to the customer had to be determined. This was done by connecting VBA (Excel) with Bing maps. In VBA, formulas were created which requests the distance and travel time between coordinates in Bing maps. The required input values are the coordinates from both locations where you want to know the distance between, and a key attained from Bing maps.

In Table 1 an overview is given of the turnover, delivery costs and margin after subtraction of the delivery costs of each warehouse. The delivery costs are calculated with the formulas described above and were calculated per customer of the corresponding warehouses. The delivery costs per warehouse were determined by summing up the costs of each individual customer. From Table 1, there can be seen that the total delivery costs are nearly 40% of the total gross margin.

TABLE 1: WAREHOUSE PERFORMANCE

[redacted]

Vehicle & delivery capacity

For the Facility Location Problem to be solved, the capacities of the warehouses must be known. These capacities are important because this is a constrain which tells how much demand a warehouse can deliver. The demand a warehouse can deliver is called the delivery capacity. The delivery capacity of a day is calculated as follows:

{[# of vehicles that drive 6x /day] X 6 + [# of vehicles that drive 7x /day] X 7 + [# of vehicles that drive 8x /day] X 8} X [Average vehicle capacity]

The # of vehicles could be attained from Qlik sense, and the vehicle capacity had to be estimated. The vehicle capacity had to be estimated, since there are a lot of different sizes per article, so for the vehicle capacity we took an average of 50 units. The delivery capacity is calculated this way because the vehicles leave 6, 7 or 8 times per day, this means that the vehicles have this average vehicle capacity every time they leave the warehouse. Since we look for the daily capacity, it is important to know if every day the number of departure times, and thus delivery times is the same. We found that this is not the case, Koskamp delivers from Monday to Saturday every week, but for Saturday the vehicles drive 2 times per day and with fewer vehicles. For Saturday the 2 time windows are bigger, so instead of a time-window of 1 hour or 1.5 hours they now have a time window of 2 hours. However, the bigger time windows do not mean that the capacity of one vehicle becomes more. This means that the delivery capacity for Saturday is different than for the days of the rest of the week. In Table 2 we can see what this means for the delivery capacity from Monday to Friday. The number of days in a year, when we only consider Monday to Friday, is 253 days. In Table 3 we can see the capacity on Saturday for each warehouse. The number of Saturdays in a year, when Koskamp delivers to customers, is 51 days. This differs from the total number of days in a year, as the Sundays are not incorporated, as well as the national holidays.

TABLE 2: DELIVERY CAPACITY PER WAREHOUSE FROM MONDAY TO FRIDAY

[redacted]

TABLE 3: DELIVERY CAPACITY PER WAREHOUSE ON SATURDAY

[redacted]

Demand
To solve the Facility Location Problem, the demand of the customers must be known in advance. The demand was retrieved from Qlik Sense. This demand had to be analyzed on fluctuations per season and per time window.
Below in Figure 5, there can be seen that the fluctuations per month do not differ a whole lot, except for august. From August to the next highest month (April), we see that the difference is about 30.000 products. Furthermore, we see that the months June, October, November, and March have the highest demand in a year. Overall, we can say that over the year there is a constant demand trend.

[redacted]

FIGURE 5: DEMAND FLUCTUATIONS PER MONTH

In Figure 6 below, we see that the demand from Monday to Friday does not fluctuate much, however, Saturday the demand is much lower. On Saturday only 3% of all demand over a whole year is provided, the remaining 97% is provided from Monday to Friday. This is the result of what is explained in the capacity part. Namely, that on Saturday there are fewer vehicles, which drive 2 times per day. For Saturday the 2 time windows are bigger, so instead of a time window of 1 hour or 1.5 hours they now have a time window of 2 hours. Thus, on a Saturday they drive much less, which results in what Figure 4 presents. Because the demand and capacity of the Saturday are different this must be considered when establishing the tool.

[redacted]

FIGURE 6: DEMAND FLUCTUATIONS OVER A YEAR PER WORKDAY

Below in Figure 7, we see the demand per warehouse in blue, this demand is expressed in the number of units per working day from Monday to Friday. As Koskamp delivers from Monday to Saturday and is closed on the national holidays, the number of working days could be calculated. And because the Saturday is different from the rest of the workdays, the Saturday is analyzed separately. From the figure below, we can see that the demand from Monday to Friday per warehouse deviates quite a bit. In Figure 5, the demand is the blue bar and overlaps the orange bar which is the delivery capacity.

[redacted]

FIGURE 7: YEARLY DEMAND VS. YEARLY DELIVERY CAPACITY PER WAREHOUSE (MON – FRI)

What is very interesting to see from Figure 7, is that the utilization rate of the delivery capacity is quite low. The utilization rate is a percentage that tells how much of the available capacity is used. As we can see in the figure, only a minor amount of the orange bar is filled. Which means that the delivery capacity is only occupied this minor amount.

In Table 4, we see the utilization rates per warehouse. From this, we again see that the utilization rates are rather low. For the implementation of the optimization tool, this will also be an interesting and important variable to measure. With the optimization tool, we can temporarily close a warehouse, it will be interesting to see how the utilization rates will vary per scenario and what impact it has on the costs.

TABLE 4: UTILIZATION RATES PER WAREHOUSE FROM MON – FRI

[redacted]

We separately look to the Saturday since the demand and capacity is different on the Saturday. In Figure 8 on the next page, we can see that the delivery capacity is better utilized compared to the workdays from Monday to Friday, as the orange bar is more filled by the blue bar than in Figure 7. However, for some warehouse not much has changed, because when we look to Table 5, we see that some utilization percentages are very close to what they were for the Monday to Friday in Table 4. Besides we again see that the demand served by each warehouse deviates quite a bit. Concluding we can say, that also for the Saturday the demand could be shared between the warehouses to improve the utilization rates, but only if this decreases the total costs.

[redacted]

FIGURE 8: YEARLY DEMAND VS. YEARLY DELIVERY CAPACITY PER WAREHOUSE (SAT)

[redacted]

TABLE 5: UTILIZATION RATES PER WAREHOUSE ON SATURDAY

We want to combine both the Monday to Friday with the Saturday, to make a yearly estimation. We can see what this combination does to the complete demand in Figure 9, and what this means for the utilization rates per warehouse in Table 6. With this information, we can make a comparison in Chapter 5 with the solution.

[redacted]

FIGURE 9: YEARLY DEMAND VS. YEARLY DELIVERY CAPACITY PER WAREHOUSE (OVERALL)

[redacted]

TABLE 6: UTILIZATION RATES PER WAREHOUSE

Cost savings with temporary warehouse closure

For the FLP, there is the possibility of closing a warehouse. This means that the costs of operating the warehouses can be saved. These costs include the following:

- **Salary of the warehouse staff for picking and packing.** Each warehouse has a different amount of warehouse staff and when a warehouse temporarily closes, this means that these salary costs do not have to be paid anymore.
- **Salary of the delivery staff for shipping.** The same goes for the delivery staff, as described previously with the number of vehicles per warehouse, for each vehicle a delivery employee is necessary. If a warehouse temporarily closes, these delivery staff are not necessary and do not have to be paid anymore as well.
- **Energy costs**. The energy costs of the warehouses are minor, but still must be taken into account. These costs are low since the warehouses are foreseen of LED lighting, they have a few to no heaters and no equipment uses much energy.
- **Delivery costs from their suppliers**. Before a warehouse can supply its customers, the warehouse must be foreseen from the supplies. This is done by suppliers, most of the times the supply is delivered free of charge, however, some warehouses use the SameDay delivery, which means they have to pay a certain price for this service.
- **Delivery costs from internal transport**. At Koskamp, the warehouses Steenwijk and Leeuwarden supply the other warehouses. This process brings a lot of costs with it, as Koskamp must pay for the drivers and the fuel of the trucks for example. However, due to the reason that other warehouses are very dependent on the warehouse Steenwijk and Leeuwarden, both cannot be closed. Therefore, the costs of delivery from internal transport will not be taken into account, as only these warehouses have these costs.
- **Depreciation costs**. For every vehicle Koskamp has to pay a price to be able to use them, these are called the depreciation costs. When a warehouse closes, this means that these vehicles will not be used anymore and thus these costs fall away as well.

To sum up, all the above-mentioned costs, except for the delivery costs from internal transport, are the costs that will be saved when temporarily closing a warehouse. These costs will be expressed per day since the capacity and demand will also be expressed per day. With this information, there can be calculated how much costs there are made and could be saved for each warehouse when temporarily closing one. Since these costs are confidential, the numbers will not be shown in this thesis paper. However, they will be used for the optimization of the FLP problem.

3.3 The customers

Customers are very important for the performance of a company, without the turnover from a customer, no profit can be made. This means that customers have quite some influence on how a company is performing, but the company itself also has some influence on the performance. By analyzing the customers per warehouse individually, there can be seen what influences affect the costs and make the company overall less profitable. We will explain the main reasons why some customers of Koskamp are unprofitable or less profitable. The following combinations of reasons apply to these customers:

- *Large distance from customer to warehouse + many orders*, which results in high delivery costs. If every order is not that big, in the sense of turnover, this customer will be even less profitable than it already is. Even if the turnover is quite high, the delivery costs are also very high, which will result in lower margins or unprofitable customers.
- *Low turnover + Many orders*, which not necessarily means that the delivery costs are high, but if the turnover is too low compared to the delivery costs then this will lead to unprofitable customers.
- *Large distance from customer to warehouse + low turnover*, which leads to the same as described for the combination of low turnover + many orders.

For solving the FLP, it is important to know the division of customers from the current situation, then we can afterwards compare what changed and what impact it had on the performance of the warehouses. Below in Table 5, the number of customers per warehouse is given. In this table there are still 15 customers, which are supplied by more than 1 warehouse.

TABLE 7: NUMBER OF CUSTOMERS PER WAREHOUSE

[redacted]

To give a clearer picture of Table 5, and the division of customers over the Netherlands, we made Figure 9. In this figure, we can see how the customers (dots) are divided per warehouse and how these customers are divided over the Netherlands. Here we can also see that some customers are divided to a warehouse which is further away than some other warehouse. After the new division of customers, it will be interesting to see how this will deviate.

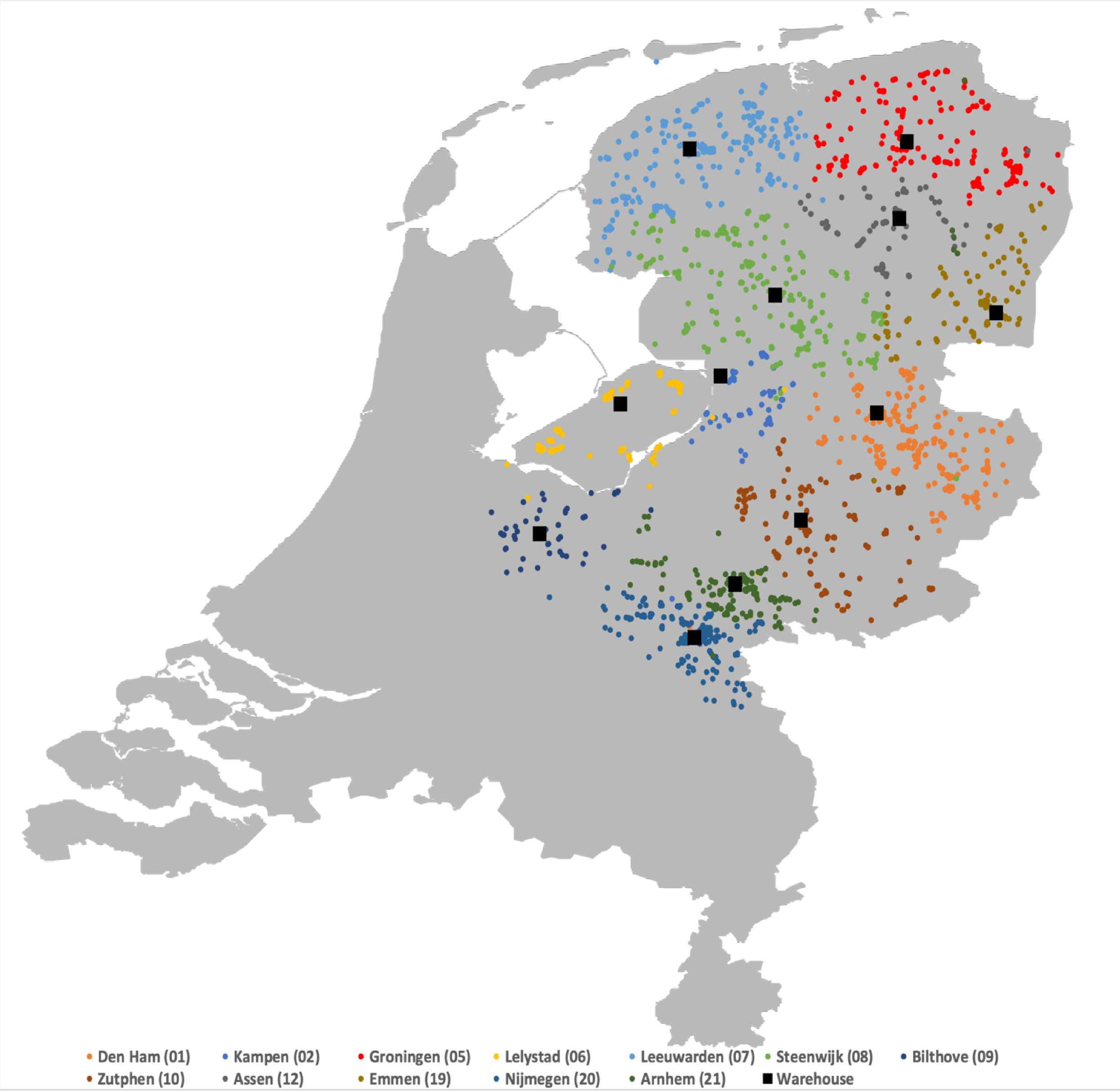

FIGURE 10: CURRENT DIVISION OF CUSTOMERS

In Figure 10, we presented the number of customers that order per month over a year. What we see here is that the number of customers who order per month is constant, however the number of customers who order per month increased a bit in the months from 2021.

[redacted]

FIGURE 11: CUSTOMER FLUCTUATIONS PER MONTH

3.4 Potential limitations concerning the measurements

We performed this research in the last semester of 2020-2021. During this time the COVID-19 pandemic could have caused some threat to the validity of this research. By comparing the data, we analyzed from 2020-2021, with data from 2018-2019 we can see how the demand was affected for Koskamp. By subtracting the total demand of these two whole years, we only see a small reduction compared to a non-COVID-19 year. There is a limited reduction of only 5%. There are no other limitations that have an effect on the research.

3.5 Problems and challenges

After this context analysis, a few problems and challenges have been identified related to the core problem, "*At Koskamp, the current division of customers to warehouses is not optimized*".

Not all of them will be addressed and solved in this thesis. The following problems and challenges were identified:

- *Current process of the assignment of customers to warehouses.* In the current process, the logistics department is not included, and thus no good analysis will be done before dividing a customer to a warehouse. This will later result in lower profits or in complaining customers.
- *Unprofitable customers.* As explained in the previous chapter, some customers are unprofitable, because of a combination reasons. The low turnover and number of orders is something that cannot be controlled, however what can be controlled is the distance from customer to warehouse and thus the division of customers to warehouses. Besides this Koskamp also has control over which customers to accept and which not to accept. By not accepting or leaving some customers, who will order to few times or who only make a small amount of turnover the overall profit of Koskamp will increase.
- *Low utilization rates.* What was also discovered in this analysis, is that the utilization rate of the delivery capacity is quite low. This is a burden to the delivery costs as more vehicles are used than necessary.

3.6 Conclusion

At Koskamp, the assignment of customers to warehouses should be optimized and costs should be minimized. By executing a context analysis, we were able to get a better understanding of how the customers are currently assigned to warehouses by creating the BPM. After this, we analyzed the current performance of each warehouse, by subtracting the total delivery costs of the gross margin. The demand fluctuations per month and weekday have been analyzed to know if this could affect the research quality. And to be able to solve the FLP, the demand per customer, delivery capacity per warehouse and potential cost savings when temporarily closing a warehouse have been identified and the utilization rates have been calculated to see how these change after solving the FLP problem. And lastly, the potential reasons for low performing customers have been identified, along with demand changes over a year and during a week.

4 Solution design

The aim of this thesis is to find the optimal appointment of customers to warehouse, by doing so the delivery costs will be reduced. In this part the solution will be presented and explained. The following question is answered:

How to implement the method/theory to optimize the appointment of customers to warehouse, taking the restrictions into account?

As described in the literature review in Chapter 2, the problem of appointing the customers to warehouse can be seen as a FLP or WLP. Here multiple solution and type of problems were addressed. In Section 4.1, different scenarios will be analyzed and explained. In these scenarios the new warehouse of Arnhem will be considered instead of the current one. Because Koskamp is moving to a new warehouse in Arnhem, it is more convenient for them to know which customers to appoint to this warehouse. In Section 4.2 the model for each scenario will be explained and described. In Section 4.3 guidelines will be provided on how to appoint customers to warehouses in the future and how and when to use the tool. Lastly, in Section 4.4 the conclusion will be given.

4.1 The scenarios

Before we start with describing the model, it is important to know the objectives for each scenario. We will be describing multiple scenarios, with each the same objective, but with slightly different constraints. By creating multiple scenarios, we can see which scenario will decrease the costs the most and will therefore be the most preferable. Below multiple scenarios are described, these will be optimized and in Chapter 5 the results will be analyzed. Moreover, by creating multiple scenarios, Koskamp can determine which scenario they prefer at some point in time, and they can then implement this solution.

Scenario 1: *Minimize the costs with all warehouses + a customer can be served by only 1 warehouse*

Compared to the current situation, there is only 1 main difference. At Koskamp, some customers are served by multiple warehouses. In the model this will change to only 1 warehouse, and the customer will be appointed to warehouses based on the objective function of minimizing the total costs.

Scenario 2: *Minimize the costs with all warehouses open + a customer can be served by multiple warehouses*

Compared to the current situation, the difference is that now all customers have the privilege of being serviced by multiple warehouses. And they will be appointed based on the objective function, rather than based on minor analysis.

Scenario 3: *Minimize the costs + warehouses can close + a customer can be served by only 1 warehouse*

Compared to the current situation, there is only 1 main difference. At Koskamp, some customers are served by multiple warehouses. In the model this will change to only 1 warehouse and there is the possibility of some warehouse being closed since they are unnecessary. And lastly, they will be appointed based on the objective function, rather than based on minor analysis.

Scenario 4: *Minimize the costs + warehouses can close + a customer can be served by multiple warehouses*

Compared to the current situation, the difference is that now all customers have the privilege of being serviced by multiple warehouses and there is the possibility of some warehouse being closed since they are unnecessary. And lastly, they will be appointed based on the objective function, rather than based on minor analysis.

Scenario 5: *Minimize delivery costs + warehouses can close + unlimited warehouses capacity*

This scenario is created to check whether the outcomes of scenarios 3 and 4 seem logical. In scenarios 3 and 4, the operating costs are playing an important role in minimizing the total costs. In this scenario, we excluded the operating costs, to see which warehouses can close to minimize delivery costs. Here the geographic positioning and the ratio between model and reality are the keys that determine which warehouse to close to minimize delivery costs.

4.2 THE MODELS

The models that will be implemented in Python are based on the FLP, described in Chapter 2. The problem of Koskamp can be seen as a Capacitated Multiple Facility Location Problem (CMFLP). However, instead of locating warehouses based on the demand, we assign customers to existing warehouses and determine whether warehouses should be closed or open. Based on the scenarios described in Section 4.1, we create the corresponding models. The model of each scenario differs since each scenario has different or additional constraints. These models will be used to estimate the relative change of the total costs per scenario.

Scenario 1

Let us now formulate scenario 1 as a mathematical optimization model. Consider *n* customers i = 1, 2, …, n and *m* warehouse j = 1, 2, …, m. Each warehouse j has certain operation costs, when open, O_j. Besides we have the total delivery costs where customer i is being supplied by warehouse j, c_{ij}. Each customer i has a certain demand, D_i. And we have that warehouse j has a certain capacity, C_j. From this an integer-optimization model for the CMFLP can be formulated as follows:

$$\text{Min} \sum_{j=1}^{m} O_j * y_j + \sum_{i=1}^{n} \sum_{j=1}^{m} c_{ij} * x_{ij} \qquad (1)$$

$$\text{S.t.} \sum_{j=1}^{m} x_{ij} = 1, \forall\, i \ \in I \tag{2}$$

$$\sum_{i=1}^{n} D_i * x_{ij} \leq C_j * \ y_j, \forall\, j \ \in J \tag{3}$$

$$x_{ij} \in \{0,1\}, \forall\, i \ \in I;\ \forall\, j \ \in J \tag{4}$$

$$y_j = \ 1, \forall\, j \ \in J \tag{5}$$

The objective function (1) is the classical economic objective of minimizing costs. These costs are the operation costs of each warehouse and the costs of supplying customer i by warehouse j. Constraint (2) indicates that customer i may only be served by 1 warehouse, x_{ij} says whether customer i is supplied by warehouse j. Constraint (3) makes sure that the sum of all demand supplied by warehouse j is smaller or equal to the capacity of warehouse j. Constraint (4) then indicates that x_{ij} equals either 0 or 1. And lastly, constraint (5) says that all warehouses should be open.

Scenario 2

The difference with scenario 2, compared to scenario 1, is that now customers may be served by multiple warehouses. What changes to the model is that c_{ij} now stands for the cost per unit served by warehouse j to customer i. And x_{ij} stands for the amount serviced from warehouse j to customer i. This means that only the right part of the objective function changes. This results in the following model:

$$\text{Min} \sum_{j=1}^{m} O_j * y_j + \sum_{i=1}^{n} \sum_{j=1}^{m} \ c_{ij} * x_{ij} \tag{1}$$

$$\text{S.t.} \sum_{j=1}^{m} x_{ij} = D_i, \forall\, i \ \in I \tag{2}$$

$$\sum_{i=1}^{n} x_{ij} \leq C_j * \ y_j, \forall\, j \ \in J \tag{3}$$

$$x_{ij} \leq D_i * \ y_j, \forall\, i \ \in I;\ \forall\, j \ \in J \tag{4}$$

$$x_{ij} \geq 0, \forall\, i \ \in I;\ \forall\, j \ \in J \tag{5}$$

$$y_j = 1, \ \forall\, j \ \in J \tag{6}$$

The objective function (1) is the classical economic objective of minimizing the costs. These costs are the operation costs of each warehouse and the costs of supplying customer i by warehouse j. Constraint (2) requires that each customer's demand must be satisfied. Constraint (3) makes sure the capacity of each warehouse j is observed. Then constraint (4) provides a variable upper bound to the demand satisfied by a warehouse, this is like constraint 3 and is used to create a stronger formulation. Constraint (5) provides a variable lower bound to the demand satisfied by a warehouse. And lastly, constraint (6) says that all warehouses should be open.

Scenario 3

The difference with scenario 3, compared to scenario 1, is that now the warehouse may be closed. So not all warehouses have to be open. What now changes to the model is only minor, as the model is the same as scenario 1, except for line (5), the last constraint. This now becomes the following:

$$y_j \in \{0,1\}, \forall\, j \ \in J \qquad (5)$$

Constraint (5) now says that the warehouse is either open ($y_j = 1$) or closed ($y_j = 0$). This also means for the capacity constrain, that the capacity is observed when warehouse j has $y_j = 1$.

Scenario 4

The same counts for scenario 4, compared to scenario 2, this scenario is only different in the sense that now warehouse can be closed. This changes the last constraint, line (6), which now becomes:

$$y_j \in \{0,1\}, \forall\, j \ \in J \qquad (6)$$

Constraint (6) now says that the warehouse is either open ($y_j = 1$) or closed ($y_j = 0$). This also means for the capacity constrain, that the capacity is observed when warehouse j has $y_j = 1$.

Scenario 5

To check whether the outcomes of the previously mentioned scenarios make sense geographically wise, we constructed this extra scenario. This extra scenario only focuses on the delivery costs and makes sure that the warehouses have unlimited capacity. By excluding the influence of the operating costs, the problem only focuses on the geographic efficiency. This results in an almost similar model, where the only difference is that C_j is a great number resulting in unlimited capacity:

$$\text{Min} \sum_{i=1}^{n} \sum_{j=1}^{m} c_{ij} * x_{ij} \qquad (1)$$

$$\text{S.t.} \sum_{j=1}^{m} x_{ij} = 1, \forall\, i \in I \tag{2}$$

$$x_{ij} = \{0,1\}, \forall\, i \in I;\ \forall\, j \in J \tag{3}$$

$$\sum_{i=1}^{n} D_i * x_{ij} \leq C_j * y_j, \forall\, j \in J \tag{4}$$

$$y_j = \{0, 1\}, \forall\, j \in J \tag{5}$$

Assumptions and tradeoff

For Koskamp we are solving the FLP, and we are allocating customers to warehouses in an optimal way, however we do not investigate the routing part for supplying these customers, since we did not approach this problem as a vehicle routing problem. However, these routes should be taken into account, when considering changing the customer allocation or closing a warehouse or reducing the capacity of a warehouse.

To deal with this routing issue, the following assumptions have been made:

1. The # of times a vehicle departs from the warehouse per day remains the same (Delivery capacity will stay the same, except when we remove or add a vehicle).
2. The working days remain fixed on 8 hours per day. (Salary costs per driver will stay the same and the delivery capacity will remain the same).

If we were to close a warehouse or to reduce the number of vehicles per warehouse (reduce capacity), a trade-off must be made:

Decreasing costs vs. increasing UL rate vs. decreasing service level as a result of decreasing delivery capacity.

All of these have influence on each other, which will be explained in Chapter 5. For the latter part of the trade-off, Koskamp may have to alter their routes. For example, increase the length of some routes, and thus decrease the number of times a vehicle departs the warehouse, this than results in a decreasing delivery capacity as well as a decreasing service level.

4.3 Guidelines for appointing customers to warehouse

As described in Chapter 1, Koskamp has two requirements. First, Koskamp wants to know what customers to appoint to which warehouses by minimizing the costs. Second, they want some guidelines on how to appoint new customers. In this thesis, we provide models for appointing customers to warehouse from scratch, however we don't want or need to run these models every time a new customer arrives. Therefore, some guidelines and an appointment tool are established for Koskamp to be able to appoint customers to warehouses in the future based on analysis and without running the whole model every time. In the excel file called "*Guidelines for appointing customers to warehouses*", there is explained how to appoint a new customer to a warehouse and how to use the model for running the different scenarios and how to create the right excel files for the model to run on. In this guideline file,

we also explain how Koskamp could use the model in case they want to add a warehouse or substitute a warehouse with a new one. With this model they can see how this would influence their costs. In this excel file, there is explained precisely what the user needs to do, for both tools to run.
With this appointment tool in mind a new Business Process Model (BPM) is created, see Figure 12. This new BPM must include an analysis for appointing customers to warehouse and must include the logistics department. As can be seen in the figure below, the steps for appointing a customer to a warehouse is now assigned to the logistics department, rather than to the debter administration.

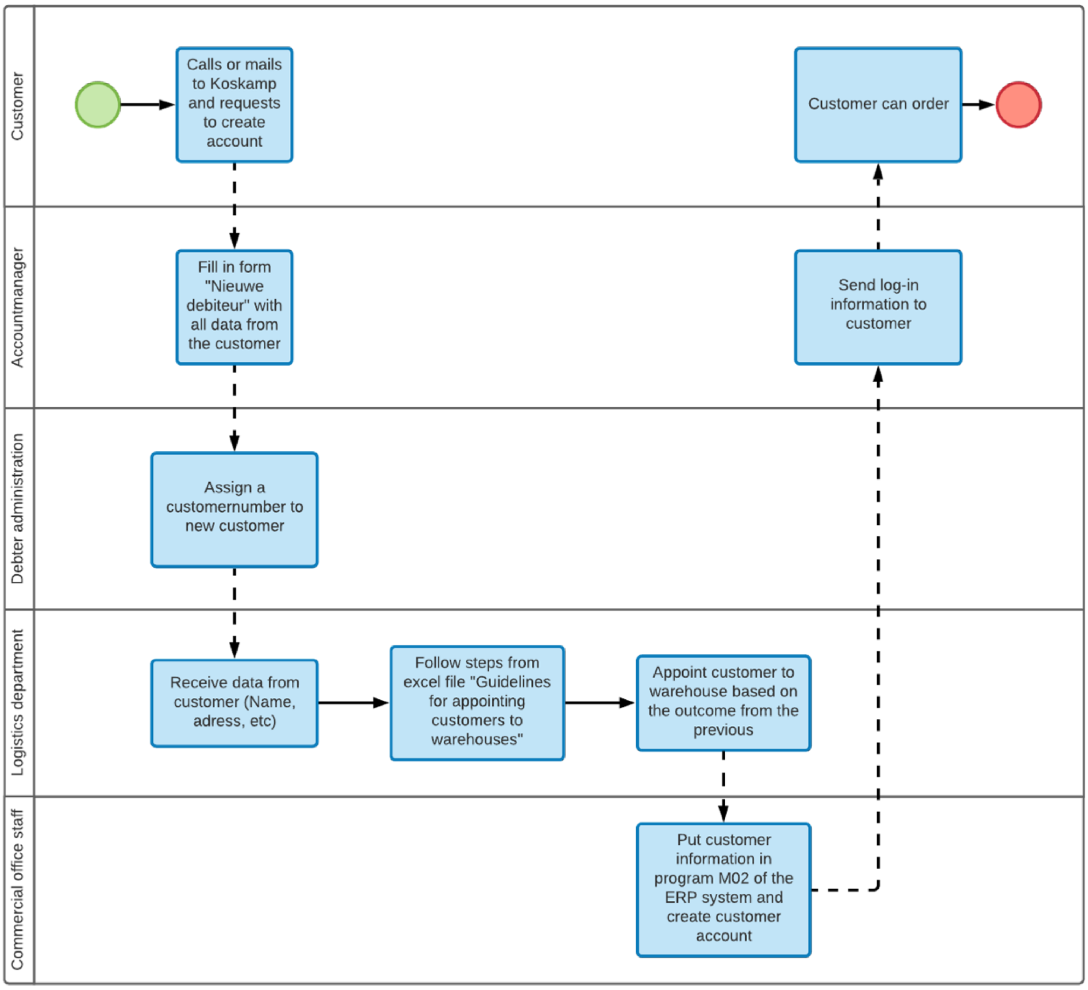

FIGURE 12: NEW BPM FOR ALLOCATING A CUSTOMER TO A WAREHOUSE

By assigning the process, of appointing customers to warehouses, to the logistics department, we now create an extra pool in the process, which makes sure that this process is done based on an analysis. This will make sure that the costs are minimized based on the delivery costs to a warehouse.

4.4 Conclusion

In this chapter, the research question "How to implement the method/theory to optimize the appointment of customers to warehouse, taking the restrictions into account" is answered. Based on the literature study about facility location problems, models are programmed in *Python,* to optimize the appointment of customers to warehouses. These models are connected to the scenarios and will say which warehouse should be opened and which may be closed, which customers are divided to which warehouse, and what the total costs are. These total costs consist of the operating costs of a warehouse and the delivery costs of supplying customers. With this information, analysis can be done, and the scenarios can be compared to the current situation along multiple variables. In the next chapter, this analysis will be done and compared with the current situation. With the guidelines established, Koskamp will also be able to do this analysis themselves by running the models for future situations.

5 Results from solution design

In this chapter, the outcomes of the models from Chapter 4 are analyzed. This is done by answering the following research question:

"Which scenario reduces the delivery costs of Koskamp?"

In this chapter the results of each scenario, described in Chapter 4, will be analyzed, and compared with each other and the current situation. For all scenarios, some experiments are executed, and the results will be presented in this chapter. We will look at the relative changes in the total delivery costs and what impact this has on the utilization rates. We will look at how the number of customers per warehouse differs in each scenario and compared to the current situation. Some figures are made black due to confidentiality.

5.1 Optimizing the scenarios 1, 2, 3 & 4

First, we optimize and compare the results from the main scenarios with the current situation and with each other. In scenarios 1 and 2 all warehouses are operational and in scenarios 3 & 4 warehouses can be closed. The difference between them is that in scenario 2 and 4, a customer can be served by multiple warehouses, rather than served by only one warehouse in scenario 1 and 3. For all scenarios and experiments we decided to put the maximum of the utilization rate at 80% over a year, because this ensures that there is 20% of the delivery capacity left. Some days the demand may be higher, the maximum utilization rate of 80% than ensures that this extra demand can be dealt with.

The cost savings per scenario are given in Figure 13 below. In scenario 3 and 4, there are 5 warehouses that must be closed to achieve this result, which is quite a lot. However, doing this results in 9.9% costs decrease compared to the current situation. Scenario 1 and 2 on the other hand, have fewer savings (1,9%), but here no warehouses need to be closed.

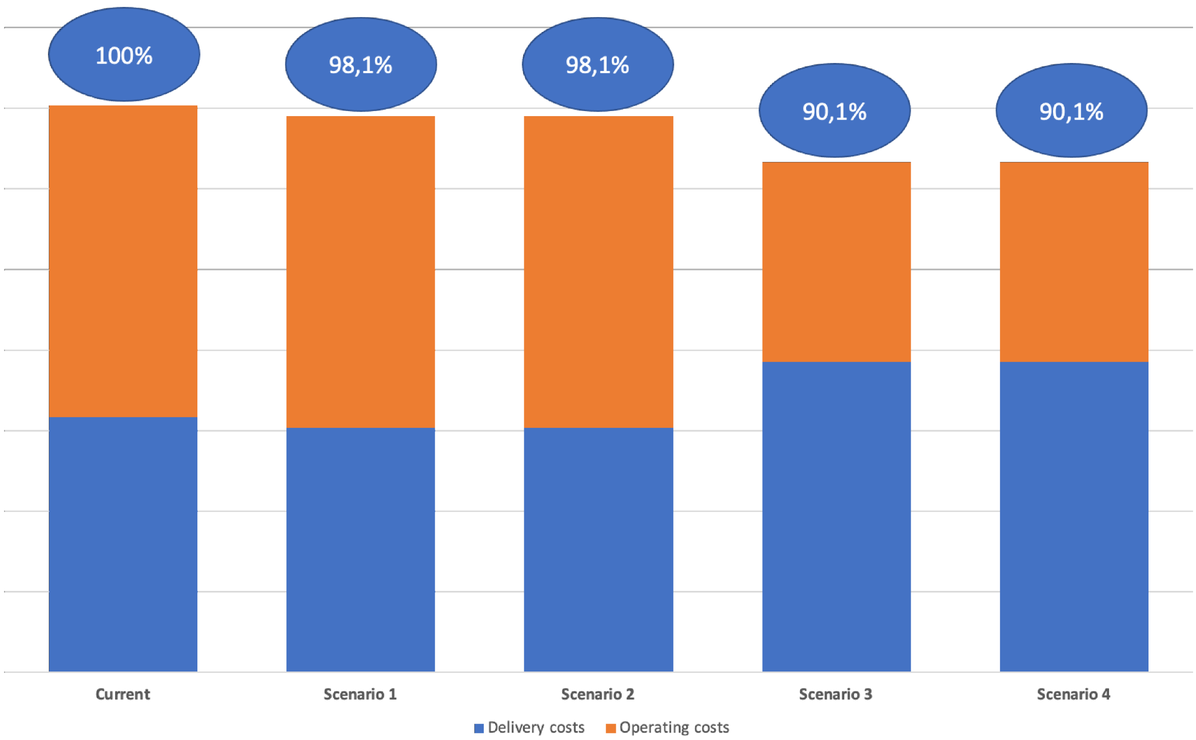

FIGURE 13: OPTIMAL COST SAVINGS PER SCENARIO

[redacted]

FIGURE 14: # OF CUSTOMERS PER WAREHOUSE PER SCENARIO

In Figure 14, we see that the number of customers increases for the warehouses that are still open in scenarios 3 and 4. This increases the utilization rates, however, this may have influence on the service level and on the real savings of these scenarios. Since now also the distance to some customers goes up, as the closer warehouses are closed, the existing routes may have to be altered to serve these customers that are now allocated to them. This alteration of the existing routes will have an influence on the delivery capacity (and thus utilization rates), and on the estimated cost savings when extra vehicles are added to satisfy demand. Although the assumptions are pretty tight, more realistic would be that the routes are changed and adapted with the new customer allocation, due to the increased utilization rates. Leading to the extension of working hours and/or the number of times a vehicle drives per day and/or the number of vehicles needed to satisfy demand. But as already described in the assumptions in Section 4.3, this is not part of the scope this thesis.

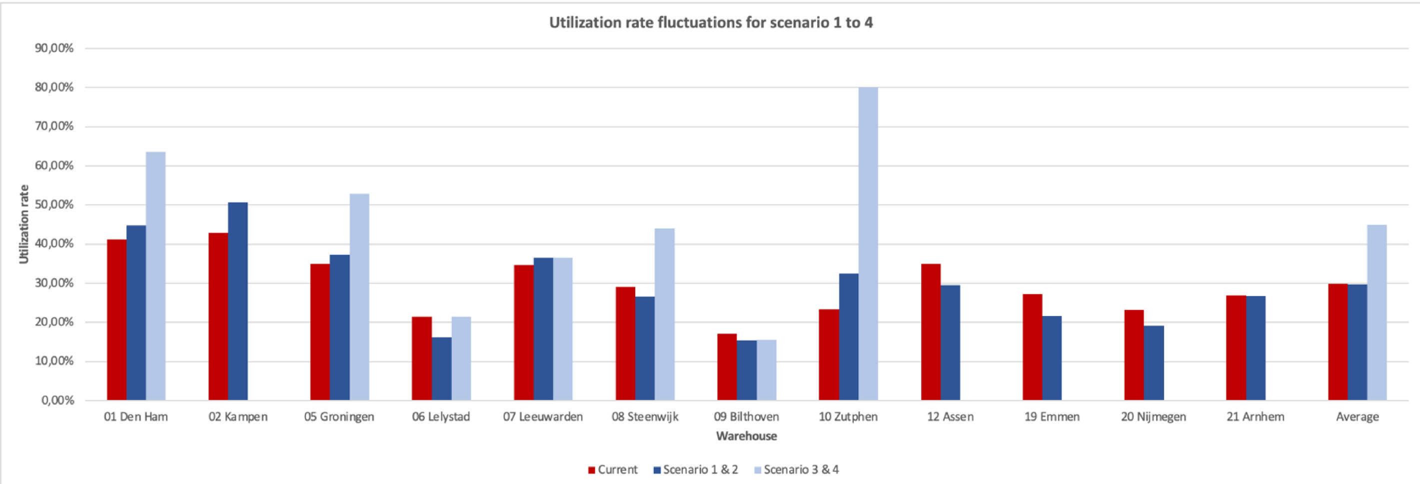

FIGURE 15: UTILIZATION RATES COMPARISON BETWEEN CURRENT AND SCENARIOS

To get an insight into how the service level may be affected, we calculate a factor which influences the service level. This factor is calculated by dividing the number of customers per warehouse by the number of vehicles per warehouse. If this factor goes up, it suggests that the service level could decrease, because more customers must be served by the same number of vehicles. If this factor goes down, it suggests that the service level stays the same and could be increased.

From Figure 15, we can see how the utilization rates differ for each scenario compared to the current situation. The average utilization rate increases with 15% when closing 5 warehouses, but here the service level changes. This can be confirmed by Figure 16 below, here we see the factor that indicates what direction the service level may go, and for scenarios 3 and 4 it suggests that the service level decreases, as there is indicated that on average the number of customers per vehicle increases with 10 customers.

In order to keep the same service level, vehicles have to be added to these warehouses, which will lead to fewer savings than approximated by the tool. Warehouse Zutphen especially stands out amongst the other warehouses, because here the utilization rate is almost multiplied by 4. This also means that 4 times as much work must be done here and thus meaning that if they do not increase delivery capacity at the warehouse Zutphen the service level will decrease.

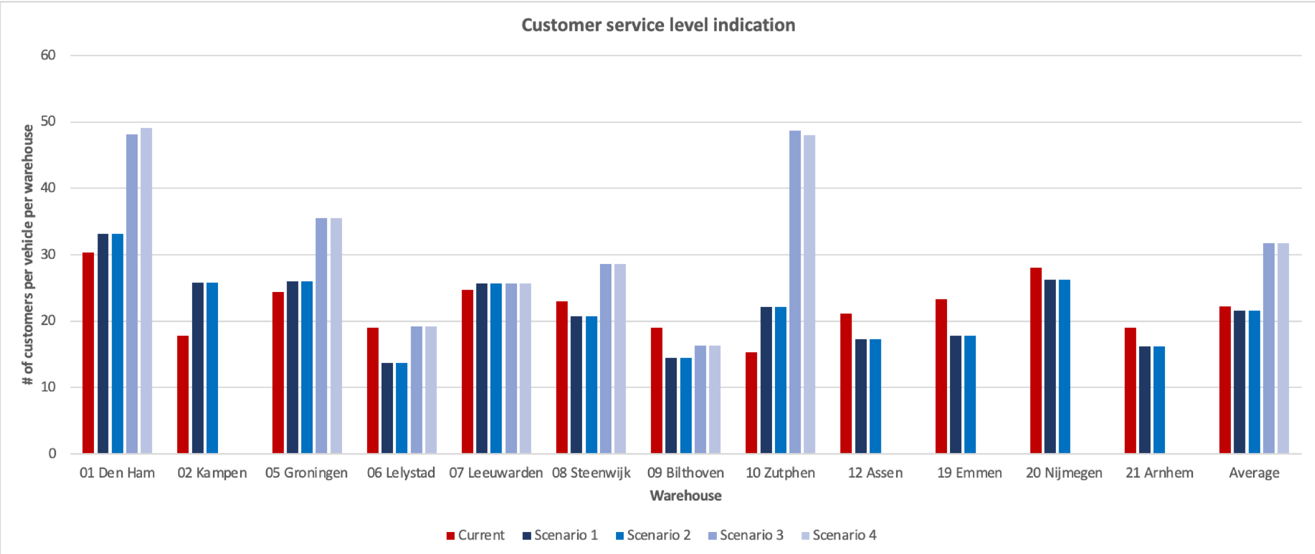

FIGURE 16: CUSTOMER SERVICE LEVEL INDICATOR FLUCTUATION

If we look at how the new customer allocation for scenario 1 looks in the scatterplot in Figure 17, we see that some of the extra number of customers appointed to Zutphen are located closer to other warehouses. This is the case, because the ratio between actual and the model is low compared to these other warehouses. Especially the difference between the ratios of Zutphen and Bilthoven are big (0,7 compared to 2,8). The ratio of warehouse work as a magnet, the lower the ratio the stronger the magnet will be. And the more attractive the warehouse will be for a customer.

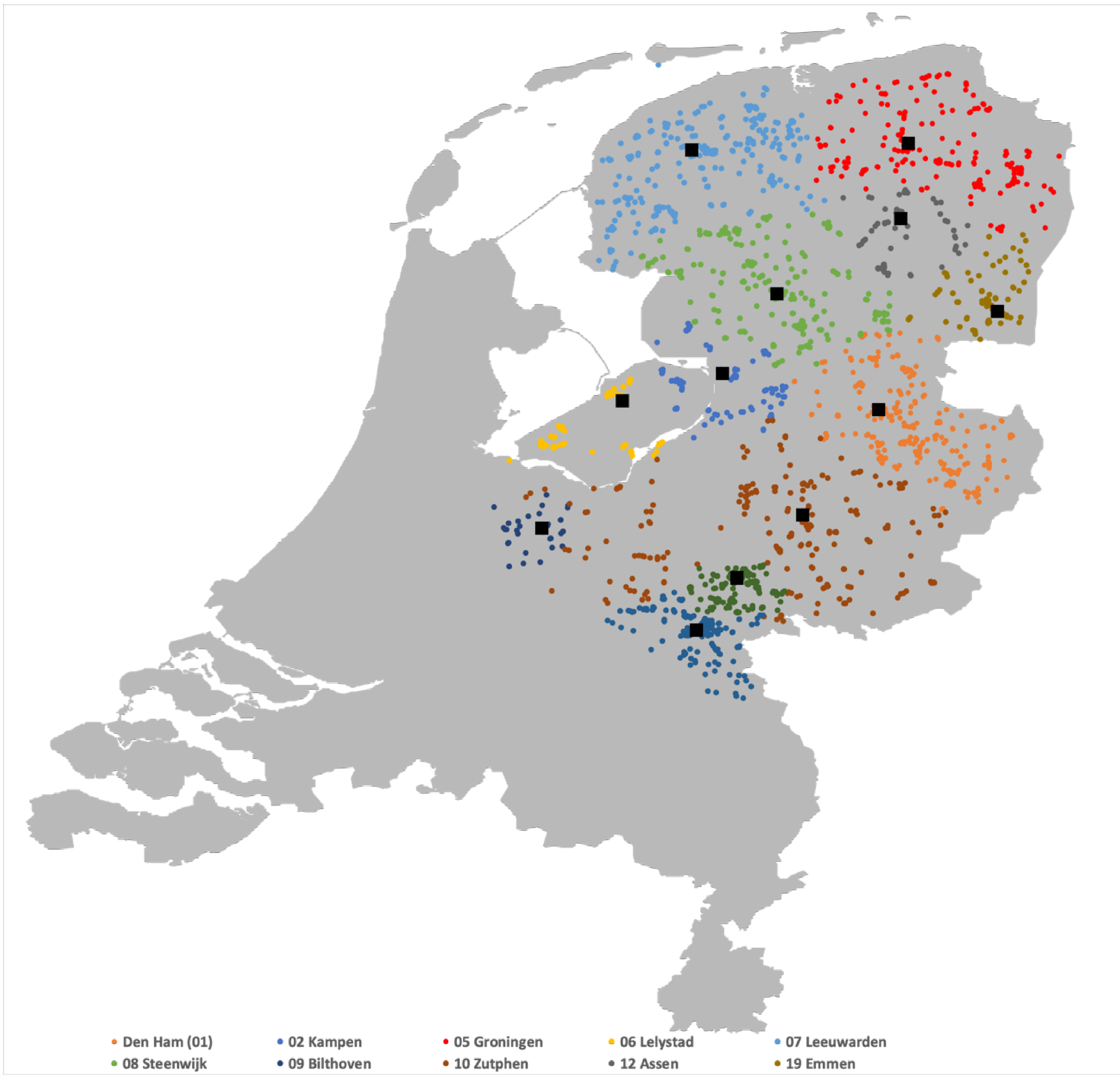

FIGURE 17: ALLOCATION OF CUSTOMERS FOR SCENARIOS 1 & 2

Koskamp needs to investigate why the ratio of Bilthoven is this much bigger compared to the other warehouses. Since the drivers are paid based on the number of kilometers, it seems feasible that the drivers at Bilthoven will drive more kilometers instead of optimizing the routes and reducing kilometers. Furthermore, I recommend analyzing the utilization and routes of both warehouses Arnhem and Nijmegen as it seems that these warehouses are close with overlapping areas. The same can be said about warehouses Lelystad and Assen, these are located between multiple other warehouses. When these are closed, the surrounding warehouses could take over these customers.

5.2 Optimizing while decreasing the number of warehouses

Here we will be looking at the impact closure of a warehouse has on the cost savings as well as the utilization rates per warehouse and overall. What we saw in Figure 13 was that the cost savings of scenarios 3 and 4 were 9,9%. Although the optimal values for scenarios 3 and 4 have a great savings percentage, we can see from Figure 18, that after reducing the # of warehouses with 1 warehouse each time till the optimal value, the cost savings decrease quite a bit. So, closing 5 warehouses may be the optimal value, however, does not mean this is the most optimal solution in practical sense and the most efficient way of cost reduction. Therefore closing 5 warehouses does not seem optimal, because after we close more than 3 warehouses the total extra cost savings are only 1%. Because of these reasons, as well as the reason that Koskamp is not interested in closing more than 3 warehouses at the time, we continue for closing 1, 2 and 3 warehouses for further experiments.

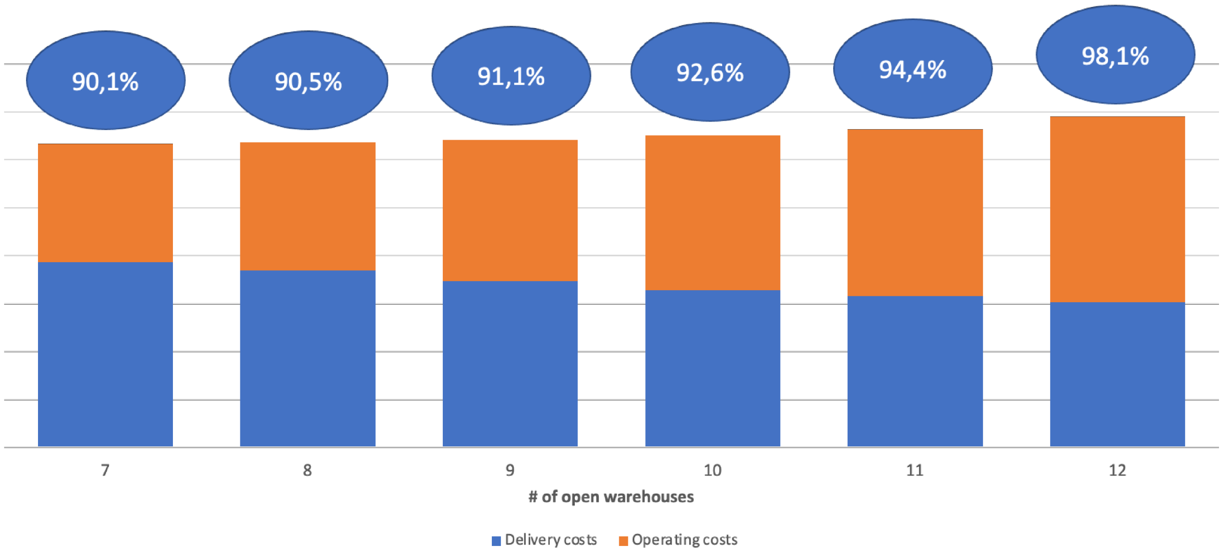

FIGURE 18: COST SAVINGS WHEN CLOSING 5 TO 1 WAREHOUSES

In Figure 19 on the next page, we can see the number of customers per warehouse. Here we can see which warehouses are closed when we close 1, 2 and 3 warehouses. First, warehouse Arnhem closes, then warehouse Assen and lastly warehouse Nijmegen. In this graph we can see how the number of customers fluctuate every time we close a warehouse, here we again see Zutphen stands out the same way as it did in Section 5.1.

[redacted]

FIGURE 19: CHANGE IN THE # OF CUSTOMERS PER WAREHOUSES

If we then look at the utilization rates in Figure 20, we can see that these increase with the number of warehouses you close. For some warehouses, mainly Zutphen and Groningen, the utilization rate increases quite much compared to what it was. When this happens, the service level will go down, as we saw in Section 5.1, because you must serve much more demand than before. To compensate the decreasement of the service level, Koskamp should increase the delivery capacity of these warehouses. But this decreases the cost savings, as well as the utilization rate calculated by the model. From both figures 19 and 20 we can also conclude that warehouse Arnhem is the first warehouses to be closed according to the model, in terms of positioning and thus costs. Then warehouse Assen and lastly warehouse Nijmegen.

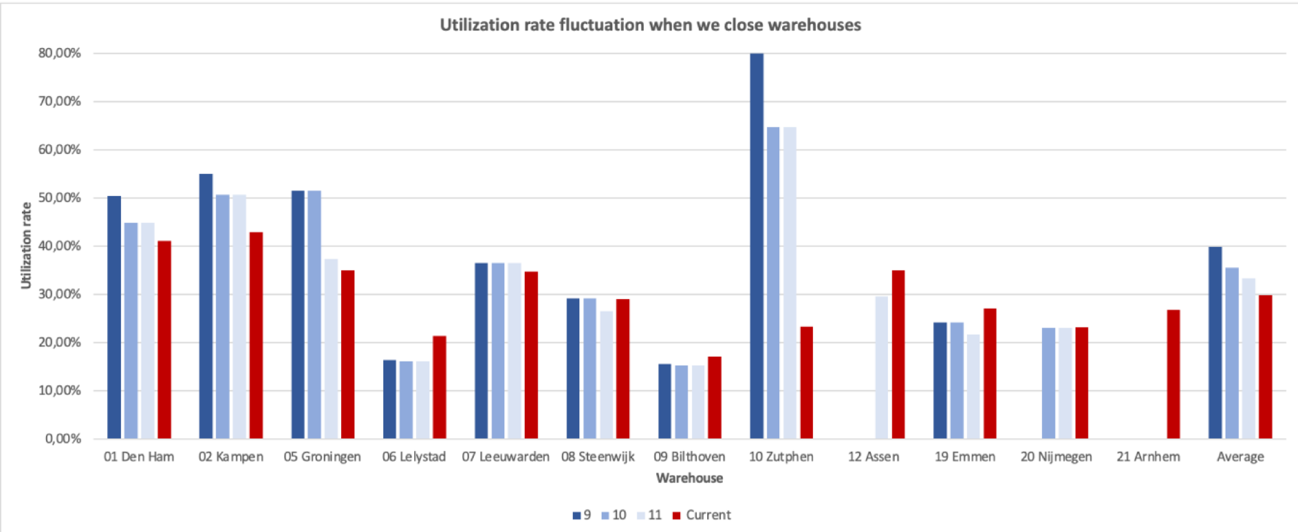

FIGURE 20: CHANGE IN DE UTILIZATION RATE PER WAREHOUSE

5.3 OPTIMIZING WHILE DECREASING THE DELIVERY CAPACITY PER WAREHOUSE

We want to see how the costs, utilization rate and factor for the service level change when we remove vehicles from the warehouses where the number of customers decreases. We do this for scenario 1, since closing warehouses and decreasing the number of vehicles is not logical as you decrease the capacity with both actions. To get a better look on the impact of reducing the capacity with 1 vehicle, we only do this while keeping all warehouses open. We assume here that removing a vehicle, means removing a route from a warehouse. Removing a vehicle will influence the service level, as you remove a vehicle / a route, which means that some of the existing routes need to be extended in order to satisfy demand. For this reason, we only look at changing the capacity with 1 and 2 vehicles.

From scenario 1, the warehouses Lelystad, Steenwijk, Bilthoven, Assen, Emmen, Nijmegen and Arnhem had a decreasement in the number of customers. Therefore, we reduce the number of delivery vehicles for only these warehouses. In Figure 21, we can see the cost savings when we decrease the delivery capacity with both 1 and 2 vehicles for these warehouses. When we remove a vehicle, we save the salary costs of a drivers and the depreciation costs of the vehicles.

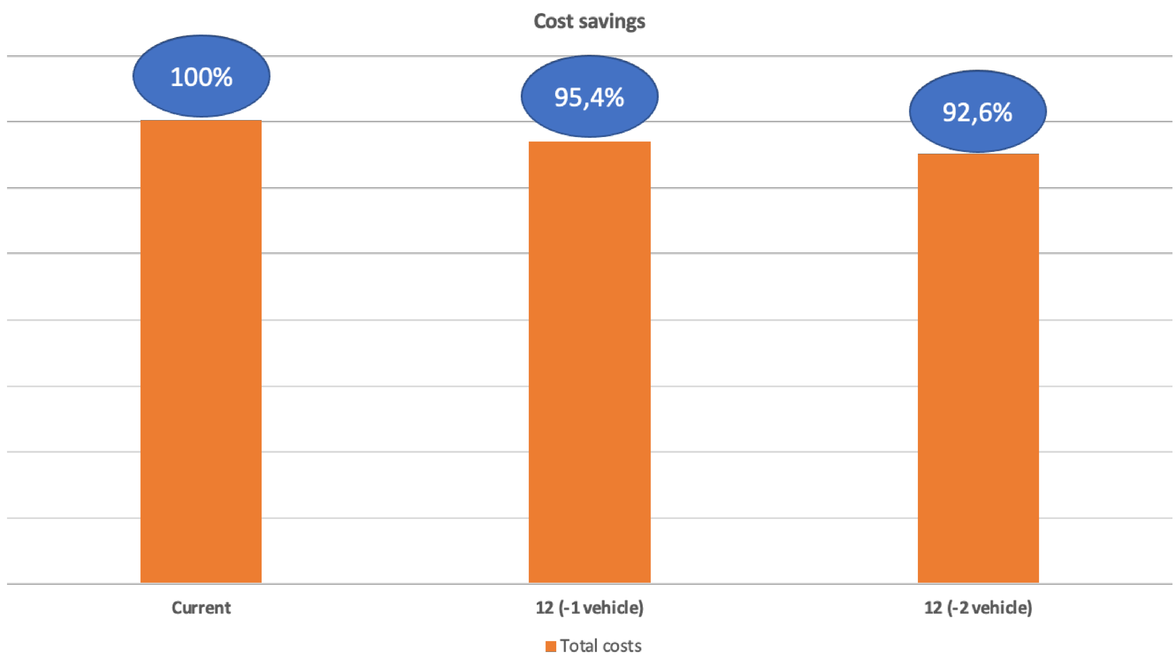

FIGURE 21: COST SAVINGS WHEN REDUCING THE # OF VEHICLES PER WAREHOUSE

[redacted]

FIGURE 22: CHANGE IN # OF CUSTOMERS WHEN WE REDUCE THE NUMBER OF VEHICLES

To understand what this means for the number of customers per warehouse, we need to look to Figure 22. Here we again see that Zutphen gains almost 50% of its original number of customers. However, when we look at Figure 23, we see that the utilization rate has the same increasement as for example Bilthoven. This is because even though the demand decreases at Bilthoven, the delivery capacity decrease here as well. At Zutphen the delivery capacity does not decrease, but the number of customers increase.

The results of reducing delivery vehicles are a reduction in the total costs and an increase in the utilization rate. However, this means that fewer vehicles must do the same amount of work. This again results in a decreasing service level, therefore the feasibility of removing a vehicle must first be checked.

FIGURE 23: CHANGE IN THE UTILIZATION RATE WHEN WE REDUCE THE NUMBER OF VEHICLES

5.4 Optimizing with the uncapacitated FLP (Scenario 5)

In this paragraph we optimize the model where we have unlimited delivery capacity for all warehouses, and we only consider the delivery costs in the model itself. By doing this the model will optimize the costs only based on the delivery costs, thus on the geographic position. From the scatterplot in Section 5.1, we concluded that based on the geographic positioning, it looks most likely to close warehouses Arnhem or Nijmegen, Assen and Lelystad, if we were to close 3 warehouses. We also saw in the scatterplot, that Zutphen took over a lot of customers from warehouses which are located closer to these customers, especially Bilthoven stood out. Moreover, when we started to close warehouses in Section 5.2, we saw that Bilthoven was not to be closed, this is because closing Bilthoven only results in minor savings, as the operating costs are very low compared to other warehouses.

By optimizing this uncapacitated model, we can see whether closing warehouses Arnhem or Nijmegen, Assen and Lelystad is indeed the most optimal when looking at the delivery costs only. In Figure 24 below, we see that the following warehouses must be closed in the following order: Bilthoven, Assen and Arnhem. Instead of warehouse Lelystad, now warehouse Bilthoven must be closed. As described at the start of this chapter, Bilthoven stood out because the number of customers that were appointed to this warehouse was very low, due to the high ratio between model and reality. This could confirm our hypothesis, that the drivers at Bilthoven make extra kilometers than originally intended for these routes.

[redacted]

FIGURE 24: CHANGE IN # OF CUSTOMERS

Another reason for Bilthoven being the first warehouse to be closed in this model, could be that they drive from the warehouse to the customer and back, or in other words there is too few customers that can be served at the same time-window. This reason can already be confirmed by Figure 25 below, as here the utilization rate of Bilthoven is very low compared to other warehouses.

What can also be concluded from this figure, is that the demand from Arnhem is distributed to Zutphen and Nijmegen after closure. The same can be said for warehouse Assen, where its demand is distributed to Groningen, Steenwijk and Emmen. Which all confirm what we saw from the scatterplot in Section 5.1.

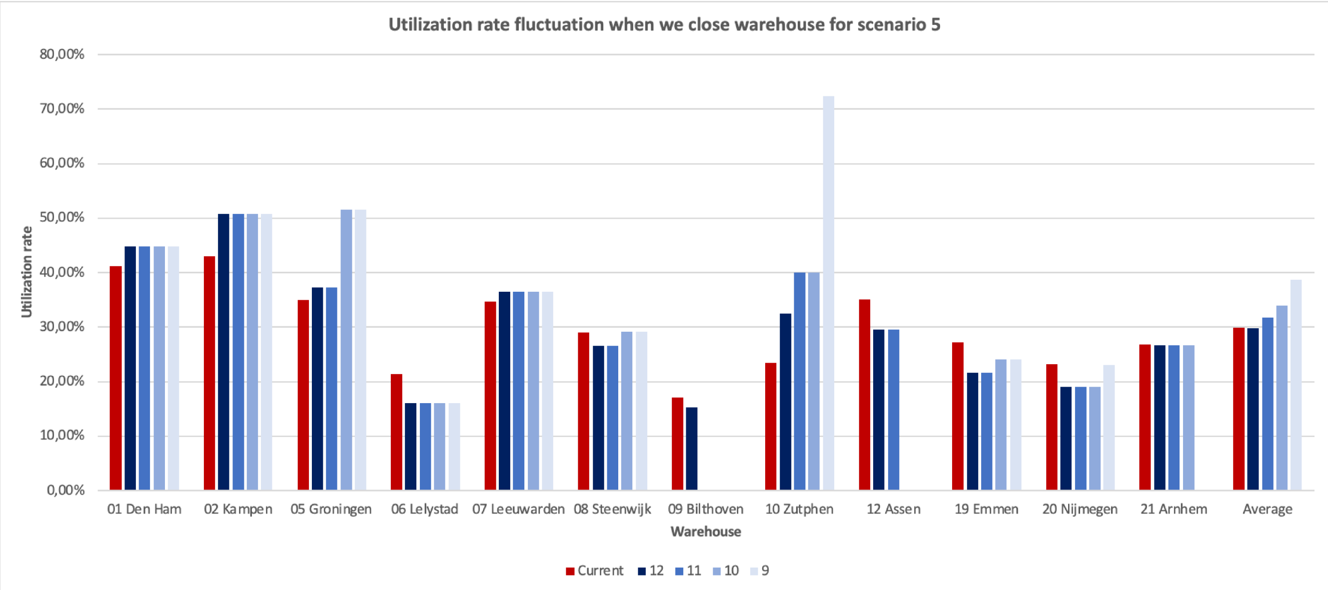

FIGURE 25: CHANGE IN THE UTILIZATION RATES

5.5 Conclusion

In this chapter the research question *"Which scenario reduces the delivery costs of Koskamp?"* is answered. Based on the model in Chapter 4, the tool was programmed in Python. With this tool and the required input data, experiments were executed, and these were analyzed. From the results of all scenarios presented in Table 8 and 9 on page 55 and 56 multiple conclusions can be drawn, these are presented below. We also present the computer used for attaining these results.

Optimizing scenarios 1, 2, 3, 4 & decreasing the number of warehouses

Here we found that with the optimal solution for scenarios 1 and 2, Koskamp could save 1,9% of their total costs by only changing the allocation of customers. We also found that with the optimal value for scenarios 3 and 4, Koskamp could save 9,9% of their total costs and increase the average utilization rate with 15% when they would close 5 warehouses. However, we see from Table 9 that closing 5 warehouses is not worth it, as we only save an extra 1% in cost savings when we close the last two warehouses out of the 5. Moreover, the more warehouse you close the lower the service level will be if you don't increase the delivery capacity by adding delivery vehicles.

We also concluded that the differences between scenarios 1 & 2 and between scenarios 3 & 4 was very low. Meaning that supplying a customer with multiple warehouses only improved the cost savings with a percentage lower than 0,01% and will make serving these customers more complex. Therefore scenarios 1 and 3 are recommended.

From the scatterplot in Section 5.1, we saw the new allocation of customers for scenarios 1 and 2. Here Zutphen received a lot of customers which were located closer to other warehouses, especially Bilthoven stood out. This is the case, because the ratio between actual and the model is low compared to these other warehouses (0.7 of Zutphen, against 2,8 of Bilthoven). Koskamp needs to investigate this difference, but we can already give two possible reasons:

1) Since the drivers are paid based on the number of kilometers, it seems feasible that the drivers at Bilthoven will drive more kilometers instead of optimizing the routes and reducing kilometers.
2) Another reason is that they drive from the warehouse to the customer and back, or in other words there is too few customers that can be served at the same time-window. Which can be seen in the utilization rate figures, where the utilization rate of Bilthoven is very low compared to other warehouses.

Decreasing delivery capacity

If we would decrease the number of vehicles per warehouse the total costs could decrease even more. By reducing 1 vehicle from each warehouse, the savings would be 2,7% more and the average utilization rate would be 2% more than in the main scenarios 1 and 2. And reducing the number of vehicles with 2, would increase the cost savings with another 2,7% and would increase the average utilization rate with another 2,9%. However, there is a big downside in doing this, since removing the number of vehicles reduces the delivery capacity which decreases the service level Koskamp can provide to its customers for some warehouses. But at the same time, for warehouses where a lot more customers are allocated to, it could be better to add a delivery vehicle to increase the service level.

Scenario 5
After optimizing the model with unlimited capacity and solely based on delivery costs, we saw that warehouses Bilthoven, Assen and Arnhem should be closed. We do not recommend closing warehouse Bilthoven, instead Koskamp should investigate how this ratio can be so high compared to other warehouses. Moreover, closing warehouse Lelystad seems more logical from a geographic point of view.

What we can conclude as well is that warehouses Assen and Arnhem have much overlapping areas with other warehouses, which is the reason why they are to be closed. Because when these warehouses close, the surrounding warehouses can pick up their customers against not too much extra delivery costs. But at the same time, you would save the costs of operating the warehouses you close. Therefore, we recommend closing either both or one of these warehouses if Koskamp wants to close warehouses.

What we see with this model is that the outcomes of the warehouses that should be closed, say either of the two things about these warehouses:

1. The ratio, between model and reality, is very high of this warehouse. This can be due to the two reasons mentioned previously for Bilthoven.
2. The warehouse can be easily managed by surrounding warehouses. With easy we mean that closing this warehouse will result in savings and the customers originally allocated to this warehouse can be managed by the surrounding warehouses, while only increasing the delivery costs with a minor amount.

Computer specifications
The computer on which these models are optimized has the following specifications:
Type: MacBook Pro (Retina, 15-inch, Mid 2015)
Processor: 2,2 GHz Quad-Core Intel Core i7
Memory: 16 GB 1600 MHz DDR3
Graphics: Intel Iris Pro 1536 MB

	Current	Scenario 1			Scenario 2
# of open warehouses	*12*	*12*	*12*	*12*	*12*
Reduced capacity with 1 vehicle for warehouses	-	-	Lelystad, Steenwijk, Bilthoven, Assen, Emmen, Nijmegen, Arnhem	-	-
Reduced capacity with 2 vehicles for warehouses	-	-	-	Lelystad, Steenwijk, Bilthoven, Assen, Emmen, Nijmegen, Arnhem	-
Costs decreasement	-	1,9%	4,6%	7,4%	1,9%
# of customers serviced by multiple warehouses	15	0	0	0	0
Average utilization rate	29,9%	29,7%	31,7%	34,6%	29,7%
Average # of customers served per vehicle	22	22	23	26	22
Computation time (s)	-	2,34	2,44	2,46	2,22
Trade-off	-	*Reduction in costs against a small reduction in utilization rate*	*Decreasement costs + increasing utilization rate against a minor decreasing service level*	*Decreasement costs + increasing utilization rate against a decreasing service level*	*Reduction in costs against a small reduction in utilization rate*

TABLE 8: RESULTS COMPARISON

	Scenario 3				Scenario 4				Scenario 5		
# of open warehouses	*7 (Optimum)*	*9*	*10*	*11*	*7 (Optimum)*	*9*	*10*	*11*	*9*	*10*	*11*
Closed warehouses (In the respective order, where Arnhem is the first one to be closed)	Arnhem, Assen, Nijmegen, Kampen, Emmen	Arnhem, Assen, Nijmegen	Arnhem, Assen	Arnhem	Arnhem, Assen, Nijmegen, Kampen, Emmen	Arnhem, Assen, Nijmegen	Arnhem, Assen	Arnhem	Bilthoven, Assen, Arnhem	Bilthoven, Assen	Bilthoven
Costs decreasement (%)	9,9%	8,9%	7,4%	5,6%	9,9%	8,9%	7,4%	5,6%	8,0%	4,4%	2,5%
# of customers serviced by multiple warehouses	0	0	0	0	1	1	0	0	0	0	0
Average utilization rate	44,9%	39,9%	35,6%	33,3%	44,9%	39,9%	35,6%	33,3%	38,7%	33,9%	31,7%
Average # of customers served per vehicle	32	27	25	24	32	27	25	24	27	24	23
Computation time (s)	6,15	4,62	2,96	3,12	3,50	4,03	3,48	2,58	4,98	5,22	2,68
Trade-off	*Decreasement costs + increasing utilization rate against a decreasing service level*				*Decreasement costs + increasing utilization rate against a decreasing service level*				*Decreasement costs + increasing utilization rate against a decreasing service level*		

TABLE 9: RESULT COMPARISON CONTINUED

6 TOOL EVALUATION

In this chapter is described how to evaluate the solution approach implemented in this thesis. The solution approach consists of two tools and the guidelines for appointing a new customer to a warehouse. The first tool is the optimization tool created in Python, where all customers are appointed to warehouses in an optimal way. The second tool is the appointment tool created in Excel, here the output gives the best warehouse to appoint a new customer to. For Koskamp to understand the tools and make use of them, some guidelines were created on how to use both tools.

In Section 6.1, we describe the tools briefly. Before the solution approach could be reviewed, a literature review was conducted to get more insights on how to evaluate the solution approach and design. In Section 6.2, the method of evaluation will be explained. In Section 6.3, the survey is explained, and the results are presented. Lastly, in Section 6.4 the conclusion of the evaluation results is given.

6.1 TOOL DESIGN

The design of the estimation tool and the appointment tool, designed and created in Chapter 4, will be presented in this section. We briefly explain both tools, for a more detailed explanation, we refer to the guidelines file.

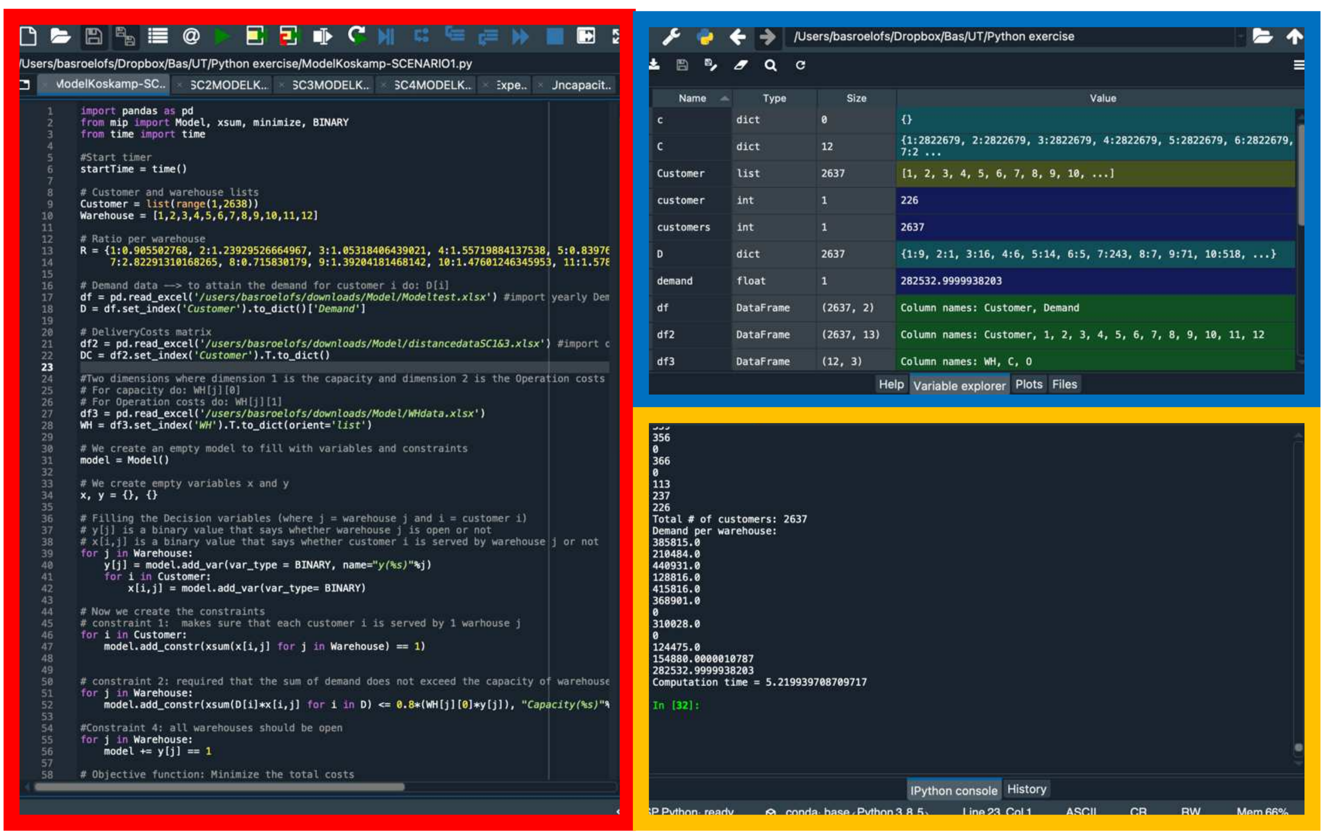

FIGURE 26: DASHBOARD OPTIMIZATION TOOL

From Figure 26, we see the dashboard of the optimization tool. The red part is the interaction part, here code is presented which represents the mathematical model. Python gathers the required input data from specific excel files, this excel data can be altered for experiments. There are multiple tabs open, every tab is a separate model and represent different scenarios. More experiments can be done, by changing the number of open warehouses, the maximum utilization rate, or which warehouses should be open or not. The blue part is the information part, here the output of the created variables can be checked. In the yellow part we have the outcome, here the output information of the optimal solution can be attained from the created scenario in the red part. Here the open warehouse, customers per warehouse, demand per warehouse and delivery costs per warehouse can be found.

Customer	Adress, location	Coordinates	Expected demand (preferably units	Approximate required turnover to cover 1 visit to customer	Appoint to WH:
X	Edisonstraat 9, Almelo	52.3388027844532, 6.6835170116242	36	#VALUE!	#VALUE!

Warehouse	Latitude	Longitude	Coordinates
WH den Ham	52.45802	6.494841	52.45802,6.494841
WH Kampen	52.56193128918078	5.88353081225715	52.56193128918078, 5.88353081225715
WH Groningen	53.221958027157335	6.611775083434319	53.221958027157335, 6.6117750834343
WH Lelystad	52.483330852689974	5.492544083420423	52.483330852689974, 5.4925440834204
WH Leeuwarden	53.202618655806276	5.763044069939852	53.202618655806276, 5.7630440699398
SteenWijk	52.789982766421524	6.096568083426134	52.789982766421524, 6.0965680834261
Bilthove	52.117702803746	5.176820948472534	52.117702803746, 5.176820948472534
Zutphen	52.15594968495148	6.197218098755459	52.15594968495148, 6.1972180987554
Assen	53.00556308333456	6.58174108343027	53.00556308333456, 6.58174108343027
Emmen	52.74007291796579	6.959996685272329	52.74007291796579, 6.9599966852723
Nijmegen	51.82562487627422	5.781563885255207	51.82562487627422, 5.7815638852552
Arnhem	51.97713659301197	5.940705904368801	51.97713659301197, 5.9407059043688

KEY:
AgBw38lOqSml4Qza-85HA6_RJ4eRGhU0qqcRXlG-BrvdBLuXpRCYNB8-nEQnlxVc

To WH	Delivery capacity (per year)	Demand served by WH (per year)	Delivery capacity left (per year)	Distance	Travel time	Ratio (Actual / model)	Travel costs	Maintenance costs	Salary costs	Total delivery costs for 1 visit
Den Ham	860400	620000	68320	#VALUE!	#VALUE!	0,905502768	#VALUE!	#VALUE!	#VALUE!	#VALUE!
Kampen	415000	330000	2000	#VALUE!	#VALUE!	1,239295267	#VALUE!	#VALUE!	#VALUE!	#VALUE!
Groningen	855300	633000	51240	#VALUE!	#VALUE!	1,158502471	#VALUE!	#VALUE!	#VALUE!	#VALUE!
Lelystad	799600	622071	17609	#VALUE!	#VALUE!	1,557198841	#VALUE!	#VALUE!	#VALUE!	#VALUE!
Leeuwarden	1138700	804740	106220	#VALUE!	#VALUE!	0,839760842	#VALUE!	#VALUE!	#VALUE!	#VALUE!
SteenWijk	1265200	607167	404993	#VALUE!	#VALUE!	0,874525356	#VALUE!	#VALUE!	#VALUE!	#VALUE!
Bilthove	384600	233564	74116	#VALUE!	#VALUE!	2,822913102	#VALUE!	#VALUE!	#VALUE!	#VALUE!
Zutphen	774300	300515	318925	#VALUE!	#VALUE!	1,113513613	#VALUE!	#VALUE!	#VALUE!	#VALUE!
Assen	566800	428601	24839	#VALUE!	#VALUE!	1,392041815	#VALUE!	#VALUE!	#VALUE!	#VALUE!
Emmen	516200	400029	12931	#VALUE!	#VALUE!	1,476012463	#VALUE!	#VALUE!	#VALUE!	#VALUE!
Nijmegen	812250	338079	311721	#VALUE!	#VALUE!	1,578288214	#VALUE!	#VALUE!	#VALUE!	#VALUE!
Arnhem	1057700	213828	632332	#VALUE!	#VALUE!	1,785986649	#VALUE!	#VALUE!	#VALUE!	#VALUE!
			WE MULTIPLY THE CAPACITY BY 0.8 TO KEEP 20% AVAILABLE FOR FUTURE COMPLICATIONS							

FIGURE 27: APPOINTMENT TOOL DASHBOARD

For the appointment tool in Figure 27, we created an excel file which tells, after the input is given, to which warehouse the customer must be appointed. The input is the customer information and expected demand, as can be seen in Figure 28, but also the delivery capacity and the current served demand must be determined per warehouse to calculate the delivery capacity leftover. With this input the required turnover to cover 1 visit to this customer is given and the warehouse to which this customer must be appointed to. These costs are calculated as described in Section 3.1.

Customer	Adress, location	Coordinates	Expected demand (preferably units	Approximate required turnover to cover 1 visit to customer	Appoint to WH:
X	Edisonstraat 9, Almelo	52.3388027844532, 6.6835170116242	36	#VALUE!	#VALUE!

FIGURE 28: APPOINTMENT TOOL OUTPUT

6.2 UNIFIED THEORY OF ACCEPTANCE AND USE OF TECHNOLOGY

The method Unified Theory of Acceptance and Use of Technology (UTAUT) is used to validate the solution approach of this thesis. Since in the solution approach, new technology is presented to Koskamp in the form of models/tools in Python and Excel, this method is very applicable. Because with this method the likelihood of success of new technological artifacts, like models, dashboards, or other forms of user-technology. The method, depicted in Figure 29 uses a questionnaire with 6 constructs:

1. **Performance expectancy**: The degree to which the user believes that using the technical artifact will help in improving their job performance.
2. **Effort expectancy**: The degree to which the sure thinks the artifact is easy to use.
3. **Social influence**: The perceived notation that the user thinks others believe the user should use the system. This is not relevant as this it is up to the user whether to use this.
4. **Facilitating conditions**: The degree to which the user believes that an organizational and technical infrastructure exists to support use of the system
5. **Behavioural intention**: This is about the intention to work with the artifact and accepting the tool in the daily and/or yearly operations.
6. **Use behaviour**: This is about the way the users will work with the artifact.

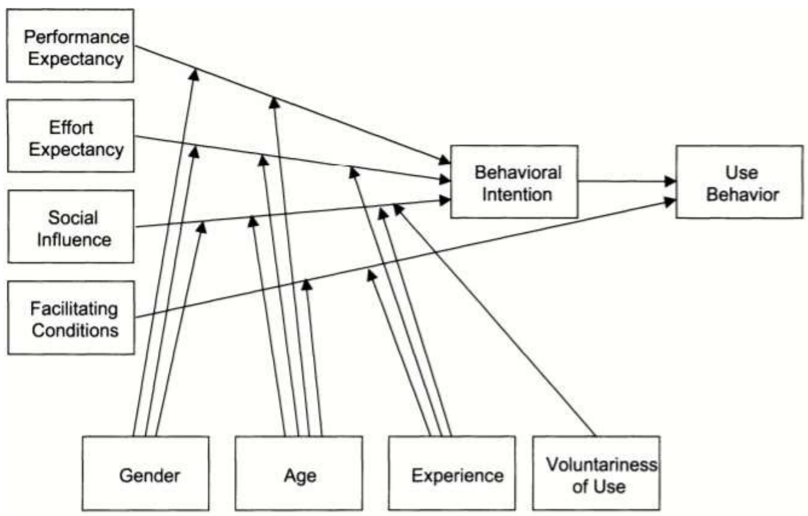

FIGURE 29: UTAUT MODEL. COLLECTED FROM VENKATESH, MORRIS, DAVIS, AND DAVIS (2003).

As can be seen from Figure 29 above, the method also uses 4 other variables, which have an influence on the 6 constructs mentioned above. These 4 variables are used to understand the input of an interviewee point of view. These variables are gender, age, experience, and voluntariness of use.

6.3 The interview

To evaluate with an interview, a presentation was done in which the results of the experiments from Chapter 5 and the guidelines described were explained. Here we also showed how the tools work and what their use is. After the presentation the interview was conducted. In this interview multiple questions were asked. There was only one participant for this interview, because only 1 person will make use of the tools created in this thesis.

For the interview, a five-level Likert scale was used. The answers the participant could give are strongly disagree, disagree, neutral, agree, strongly agree. The strongly disagree has a score of 1 and the strongly agree a score of 5. Thus, values between 1 and 2 are negative feedback, the value 3 means neutral feedback, and 4 till 5 means positive feedback. Because only one person will use the tools created in this thesis, we only had one participant, the manager of the branches.

Table 10: Interview results

Nr.	Type of Question	Optimization tool (FLP)	Appointment tool
1	PE-1	5	5
2	PE-2	4	5
3	PE-3	5	5
4	PE-4	5	5
5	EE-1	4	5
6	EE-2	3	5
7	EE-3	4	5
8	EE-4	1 (= 5 reversed question)	1 (=5 reversed question)
9	ATT-1	5	5
10	ATT-2	3	3
11	ATT-3	3	4
12	ATT-4	3	4
13	FC-1	4	5
14	FC-2	5	5
15	FC-3	5	5
16	FC-4	3	5
17	SE-1	5	5
18	SE-2	5	5
19	SE-3	4	5
20	BIU-1	5	4
21	BIU-2	5	4
22	BIU-3	5	5
Average Performance Expectancy		**4,75**	**5**
Average Effort Expectancy		**4**	**5**
Average Attitude Towards Technology		**3,5**	**4**
Average Facilitating Conditions		**4,25**	**5**
Average Self-Efficacy		**4,67**	**5**

Average Behavioural Intention of Use	**5**	**4,33**

In Table 10, the results of the evaluation are given. The average value for the questions ranges from 3,5 to 5 for the optimization tool, and for the appointment tool this ranges from 4 to 5. Since there is no negative feedback, as we do not have a score lower than 3, we can conclude that there is a positive opinion about both tools created for Koskamp and that these are generally accepted. We also see that the Behavioural Intention of Use is very high for both tools, which suggests that Koskamp find the tools useful to use in practice and really wants to use them in practice.

There was also some general feedback for both tools. For the appointment tool, we got the following feedback: “It's good that the tool not only shows which warehouse is closest/cheapest to deliver but it also shows the costs for delivery from each warehouse. This leaves room for your own interpretation and comparison.”
For the guidelines regarding the appointment the following feedback was provided: “The guidelines in combination with the presentation and explanation are sufficient to be able to work with them. Depending on the end user, you could formulate certain words/terms differently.”

For the optimization tool, the following feedback was provided: “My experience with programming (Python) is limited. That is why it is difficult for me to give substantive feedback about the tool/programming.”
For the guidelines regarding the optimization tool the following feedback was provided: “Using the clear guidelines, an inexperienced employee can work with the tool. The guidelines ensure that the tool can be used by the user.”

6.4 Conclusion

In this chapter we briefly described the design of the tools. We also discussed how the solution can be evaluated at Koskamp. Out of literature review we found a method on how to evaluate the tools and based on what constructs. With this method we created the questions for the survey. Later we described the results of this evaluation. From this we could conclude, that based on the evaluation both tools are accepted and very useful for Koskamp. The only thing was that the user did not have any knowledge about Python, however, will the help of the guidelines this is not a problem.

7 Conclusions, recommendations and future research

Within this thesis, a facility location problem has been tackled by creating a tool that gives the optimal solution for reducing the costs. By analyzing the current situation input data for the tool was gathered. After implementation of the optimization tool, suggestions were provided to minimize the total costs. With the other tool, the appointment tool, Koskamp can appoint customers to warehouses in an optimal way and keep costs minimized. Each chapter in this thesis was related to a research question, that was answered and summarized in the conclusions at the end of each chapter. All these conclusions have contributed to the goal of answering the main research question of this thesis. In this chapter, we will give the final conclusions and recommendations after conducting this thesis. This is done by answering answer the last research question:

What conclusions and recommendations can be made after conducting the thesis at Koskamp?

The results of this thesis were presented to Koskamp. The conclusions and recommendations are respectively given in Section 7.1 and 7.2. Section 7.3 outlines the contribution to theory and practice. Lastly, Section 7.4 outlines the limitations and ideas for future research.

7.1 Conclusions

In the analysis of Chapter 5, we made conclusions after analyzing the results from the designed scenarios and experiments. Out of the research the following conclusions can be stated:

Scenario 1 & 2

By only changing the customer allocation, Koskamp could decrease costs with 1,9% in comparison with their current total costs. Here the average utilization rates only decrease with 0,2%. The trade-off here is the decreasing costs against the small decreasing average utilization rate. The service level also stays the same. Appointing a customer to multiple warehouses (Scenario 2) only results in less than 0,01% more cost savings and creates a more complex situation, therefore appointing customers to multiple warehouses is not optimal for the scenario of opening all warehouses.

Scenario 3 & 4

Optimizing scenarios 3 and 4, where we close warehouses, resulted in 9,9% savings of the total costs, while increasing the utilization rate with 15%. However, this option is not ideal, because for the last 2 warehouses we close out of the 5, we only save an extra 1%. Besides, the service level will strongly decrease.

Based on the outcomes of scenarios 3 and 4, when we were to close 3 warehouses, we should close warehouses Arnhem, Assen and Nijmegen, respectively. Closing warehouse Arnhem reduced costs with 5,6% and increases the utilization rate with 3,5%; Closing warehouse Arnhem and Assen reduces costs with 7,4% and the increases utilization with 5,8%; closing warehouse Arnhem, Assen and Nijmegen reduces costs with 8,9% and increases the utilization rate with 10%. And for every warehouse we close, the service level decreases. Lastly, appointing a customer to multiple warehouses (Scenario 4) only results in less than 0,01% more cost savings and creates a more complex situation.

Scenario 5
Based on geographical positioning of the warehouses, we would suggest closing warehouses Leystad, Assen and Arnhem, if we were to close 3 warehouses. Since these have much overlapping areas with other warehouses. This can be checked with this scenario, as this only focuses on delivery costs. Based on the outcomes of scenario 5, where we have unlimited capacity and only focus on the delivery costs, we should close warehouses Bilthoven, Assen and Arnhem, respectively. Warehouse Bilthoven is the first one to be closed since this warehouse has a very high ratio, which results in this warehouse being unattractive to appoint customers to.

Reducing the delivery capacity
Decreasing the delivery capacity, by decreasing the number of delivery vehicles for the warehouses where the number of customers decreases in scenarios 1 & 2, results in a 2,7% costs decrease of the current total costs and a 2% increases the utilization rate per vehicle you remove. However, this also decreases the service level, because the warehouses have the same workload but fewer delivery vehicles.

General conclusions
Using the excel tool for appointing a new customer to a warehouse will minimize the delivery costs and makes sure this is done based on analysis. And reducing the number of vehicles per warehouse or the number of warehouses will result in a decreasing service level for some warehouses where the utilization rate is already high and an increasing utilization rate and decreasing total costs.

7.2 Recommendations

Based on the conclusions, the tools designed and the evaluation of these tools, the following recommendations are listed:

Recommendations for the appointment of new customers
We recommend Koskamp to change their business process of appointing a new customer to a warehouse to the format presented in Chapter 4.3. When appointing a new customer, we recommend Koskamp to use the appointment tool in the excel file “Guidelines for appointing a new customer to a warehouse”. By using this tool, the appointment of a customer is based on analysis in which we minimize the delivery costs.

Recommendations for optimization
We recommend Koskamp to use the optimization tool every year, to check whether the customers are appointed to the right warehouses, but also to investigate which warehouses are more attractive to appoint customers to. Furthermore, we recommend using the optimization tool when Koskamp considers closing a warehouse. This tool presents the optimal solution for closing a warehouse. If Koskamp want to check if closing warehouse X would save costs, this could also be checked with the tool.

Based on the results and conclusions, we recommend that if Koskamp were to close 1 or two warehouses, to close warehouses Arnhem and Assen respectively, as closing these results in the highest savings and looking to the geographic positioning can be easily taken over by surrounding warehouses. For closing a warehouse, Koskamp should consider the outcomes of the tool as well as the geographic positioning of the warehouses.

Moreover, if Koskamp want to check whether a potential new warehouse location is a good solution, we recommend using the optimization tool as well. Lastly, we recommend considering the trade-off, as well as the assumptions made, when Koskamp uses the optimization tool.

General recommendations

For all the above mentioned, we recommend using the guidelines established in the excel file "Guidelines for appointing a new customer to a warehouse". In here examples are given and an explanation is given on how to be able to run both tools and use them in practice. Furthermore, we recommend Koskamp to investigate the situation of Bilthoven, as here the ratio is very high. In Chapter 5, some reason for the high ration is given, which we recommend being further investigated. Lastly, we recommend Koskamp to change the payment method for their drivers.

7.3 Contribution to theory and practice

Theoretical contribution

The optimization tool is based on the theory of the Facility Location Problem (FLP). We created both the capacitated and uncapacitated FLP. In the theory, they provide the inputs needed for the model to run, however we never see models for determining these inputs. In this paper, we provide a model for determining the delivery costs, which we use to calculate the cost matrix.

Practical contribution

The optimization tool as well as the appointment tool is the practical contribution to Koskamp. By using both models as a decision support tool, the company can gain practical insights based on the performed research. Both tools will help Koskamp in making practical decisions based on research. From Chapter 6, the practical contribution can also be supported.

7.4 FUTURE RESEARCH

This bachelor thesis has been executed in the scope of ten weeks. Extensive research was therefore not possible. In this section, we provide some future research recommendations:

- For future research we recommend extending the tool in Python, in the way that it locates the most optimal locations for putting the warehouses based on the customer locations.
- Another extension of the model we recommend is to investigate how to incorporate the service level and fluctuating delivery capacity into the model, so that the optimization tool keeps this into account. That the input value will be the minimum service level and the output gives the required capacity needed to keep this service level when you close a warehouse for example.
- We also recommend investigating on how to optimize the routing part of Koskamp. This is a complex vehicle routing problem and in the given time for this thesis would have not let to the most optimal and practical solution.
- To reduce costs even further, we recommend looking into the time-windows which jointly have a low order rate. What we see in Figure 26 is that there are currently 20 time-windows, from which 11 time-windows have a joint order rate of only 10% of the total order-demand. This is a problem that needs solving.

[redacted]

FIGURE 30: ORDER RATES PER DEPARTURE TIME

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APPENDIX A: GUIDELINES

For the guidelines open the accompanying excel file called "Guidelines for appointing customers to warehouses".

APPENDIX B: QUESTIONNAIRE

Questionnaires for the tool in Excel is identical, the only thing that must be replaced is the word Python for Excel.

Nr.	Question (Q)
-	I have experience with Python and how it works
-	I have experience with Python and how it works
1	PE-1: Ik vind de tool in Python handig voor mijn baan
2	PE-2: Het gebruiken van de tool in Python verhoogt de effectiviteit van mijn taken
3	PE-3: Het gebruiken van de tool in Python verbetert de kwaliteit van mijn werk
4	PE-4: Het gebruiken van de tool in Python verbetert de kwaliteit van de output van mijn werk
5	EE-1: De interactie met de tool in Python is duidelijk en begrijpbaar met behulp van de guidelines
6	EE-2: Het is voor mij gemakkelijk om ervaren te worden met de tool in Python met behulp van de guidelines
7	EE-3: Ik vind de tool in Python makkelijk te gebruiken met behulp van de guidelines
8	EE-4: Het duurt te lang om te leren hoe je de tool in Excel gebruikt, dat het het niet waard is
9	ATT-1: De tool (in Python) gebruiken is een goed idee
10	ATT-2: De tool in Python maakt werk interessanter
11	ATT-3: Het gebruiken van de tool in Python is leuk
12	ATT-4: Ik vind werken met een tool in Python leuk
13	FC-1: Ik heb de middelen die nodig zijn om de tool in Python te kunnen gebruiken
14	FC-2: Speciale en specifieke instructies voor het gebruik van de tool in Python heb ik tot mijn beschikking
15	FC-3: Een specifiek persoon of groep is bereikbaar voor hulp met problemen van de tool in Python
16	FC-4: Het gebruiken van de tool in Python is verenigbaar met andere aspecten van mijn werk
17	SE-1: Ik kan een taak volbrengen als: niemand aanwezig is om te vertellen wat ik stap voor stap moet doen
18	SE-2: Ik kan een taak volbrengen als: ik iemand kan bellen wanneer ik vastloop
19	SE-3: Ik kan een taak volbrengen als: ik veel tijd krijg voor het voltooien van mijn taak waarvoor de tool in Python is gemaakt
20	BIU-1: Ik heb de intentie om de tool in Python elk keer te gaan gebruiken wanneer er een nieuwe klant moet worden ingedeeld in tenminste de komende 6 maanden
21	BIU-2: Ik voorspel om de tool in Python elk keer te gaan gebruiken wanneer er een nieuwe klant moet worden ingedeeld in tenminste de komende 6 maanden
22	BIU-3: Ik ben van plan om de tool in Python elk keer te gaan gebruiken wanneer er een nieuwe klant moet worden ingedeeld in tenminste de komende 6 maanden

Questionnaire in English:

Nr.	Question (Q)
-	Ik heb ervaring met Excel en hoe het werkt
1	PE-1: I find the tool in Excel useful for my job
2	PE-2: Using the tool in Excel increases the effectiveness of my tasks
3	PE-3: Using the tool in Excel improves the quality of my work
4	PE-4: Using the tool in Excel improves the quality of the output of my work
5	EE-1: The interaction with the tool in Excel is clear and understandable using the guidelines
6	EE-2: It's easy for me to get experienced with the tool in Excel using the guidelines
7	EE-3: I find the tool in Excel easy to use using the guidelines
8	EE-4: It takes too long to learn how to use the tool in Excel, it's not worth it
9	ATT-1: Using the tool (in Excel) is a good idea
10	ATT-2: The tool in Excel makes work more interesting
11	ATT-3: Using the tool in Excel is fun
12	ATT-4: I like working with a tool in Excel
13	FC-1: I have the resources needed to use the tool in Excel
14	FC-2: I have special and specific instructions for using the tool in Excel
15	FC-3: A specific person or group can be reached for help with problems of the tool in Excel
16	FC-4: Using the tool in Excel is compatible with other aspects of my job
17	SE-1: I can complete a task if: no one is there to tell me what to do step by step
18	SE-2: I can complete a task if: I can call someone when I get stuck
19	SE-3: I can complete a task if: I get a lot of time to complete my task for which the tool was created in Excel
20	BIU-1: I intend to use the tool in Excel every time a new customer needs to be assigned in at least the next 6 months
21	BIU-2: I predict to start using the tool in Excel every time a new customer needs to be assigned in at least the next 6 months
22	BIU-3: I plan to use the tool in Excel every time a new customer needs to be classified in at least the next 6 months