UNIVERSITY OF TWENTE.

sandd.

Master Thesis

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Improving performances at a postal company by implementation of horizontal collaborative logistics

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Master | Industrial Engineering & Management

Track | Production & Logistics Management

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Summary

Sandd is a postal company in the Netherlands that delivers commercial mail on Tuesdays and Fridays. The last couple of years, the need for Sandd to expand their product portfolio increased, since the volumes, and therefore also the revenues, of the postal market are decreasing. An approach for Sandd to expand their services, is by making more use of their van fleet. This can be done by Horizontal Logistics Cooperation with other companies. An example of a collaborating partner is Company X, a company that delivers comparable products on all workdays in the same regions as Sandd. This research focuses on the synergy potential by integrating the delivery process of both companies and gives answer on the following main question:

"What is the most efficient way for Sandd to integrate the delivery processes of Company X to maximize synergy advantages and allocate savings fairly?"

There are many advantages identified in Horizontal Logistics Cooperation, such as better utilization of resources, economies of scale, economies of scope, growth, on-time-delivery, and cost reductions. The three phase model of Cruijssen and Salomon (2006) helps to increase the success of the collaboration between Sandd and Company X. This model consists of the phases; 1) the selection of suitable partners, 2) the process of estimating the savings, and 3) a fair allocation of savings. The estimate of the savings in this cooperation is obtained by the so-called joint route planning, which means a Vehicle Route Planning with Time Window (VRPTW) is solved by combining datasets of both companies. The VRPTW exists of a construction heuristic and an improvement heuristic, which in this research were the Sequential Insertion Heuristic and Savings Algorithm (construction) and Steepest-descent and First-descent (improvement).

Cruijssen and Solomon (2006) mention three scenarios in joint route planning, namely; 1) the traditional situation without cooperation, 2) joint distribution with the current logistics structures, and 3) optimization of the logistic structures based on the aggregated demand of both companies. Scenario 1 functions as benchmark of Scenario 3, on which this research focuses. An important factor in the optimization of the structures is the sorting process of Sandd, which determines the release dates of delivery addresses. The optimization of the sorting process and the delivery process is included in two sub-scenarios, namely optimizing by keeping the current subdepots by changing the sorting sequence and a total redesign of the subdepots during the construction phase. In the results two datasets are used, on for the region of this research (Roosendaal) and one with a 100% geographical overlap (GO). The geographical overlap represents the potential of a national collaboration. An important factor in collaborations is a fair allocation of the savings. The Shapley Value method is a suitable concepts that allocates savings based on marginal contributions.

The sub-scenario 'redesign of subdepots' gives in the collaboration annual costs savings of approximately €75,000.- (Roosendaal) and €100,000.- (GO). A fair allocation of these savings

results in improvements on price per stop of 5% (Sandd) and 10% (Company X) in Roosendaal and 11% (Sandd) and 16% (Company X) in GO. Figure 0.1 shows the results of this collaboration.

Annual result of sub-scenario Redesign Subdepots		
Geographical scenario	Roosendaal	Geographical overlap
Costs Scenario 1	€ 1,081,002.96	€ 808,122.55
#stops	187920	125312
Costs collaboration	€ 1,007,114.42	€ 708,578.14
Total savings	€ 73,888.54	€ 99,544.41
% savings	6.8 %	12.3 %
Price / stop Sandd	€ 4.83	€ 5.05
Price / stop Company X	€ 6.94	€ 6.66
#vans fleet	30	21

Figure 0.1: Best results on the collaboration

In this collaboration, capacity is left on the days only Company X is deliverd. By making use of this capacity with a third collaborating company the potential of the synergy is shown. An extra delivery of 150 customers on 1 day per week results in extra annual savings of approximately €40,000.-. This indicates the potential of this collaboration and the possibilities to attract other companies.

The best way to collaborate for Sandd and Company X is obtained in a combination of a total redesign of the subdepots of Sandd and total overlap of addresses. Implementing the collaboration results in annual savings of €100.000,-, compared to the current costs of both companies.

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Abbreviations

CS – Central Sort Hal
CI – Confidence Interval
GO – Geographical Overlap
HLC – Horizontal Logistics Collaboration
MIC – Minimal Insertion Costs heuristic
MTVRP – Multi Trip Vehicle Routing Problem
NN – Nearest Neighbour
SA – Simulated Annealing
MTVRPTW-R – Multi Trip Vehicle Routing Problem with Time Windows and Release Dates
TMS – Transportation Management System
VRPTW – Vehicle Routing Problem with Time Windows

1. Introduction

The first chapter introduces the company Sandd and the problem description for this research. Section 1.1 elaborates on the origins of the company and Section 1.2 explains the motivation for this research, followed by the description of the problem in Section 1.3. Section 1.4 gives the objective of this research and Section 1.5 describes the scope. The end of this chapter (Section 1.6) elaborates on the research questions and the research approach.

1.1 Introduction

In 1988 three consultants of AT Kearney did research for PTT (Staatsbedrijf der Posterijen, Telegrafie en Telefonie). They advised PTT to change their logistics due to the liberalisation of the postal market. Their advice consisted of focusing on the business market and delivering on a 72-hour distribution basis, which enabled them to offer delivery of mail at a lower price. PTT did not implement the advice, which gave the consultants the opportunity to start their own company called Sandd (Abbreviation of: **S**ort **and D**eliver) in 1999. Their mission was to build a simple organisation that could deliver business mail with a better price-quality ratio. Nowadays Sandd has approximately 28% of the market share with a volume of 775 million postal items and annual revenues of 146 million euros.

In 2012, Sandd had the ambition to have a volume of 1 billion mail items in 2015 with annual revenues of €250 million, which they did not achieve. The postal market is shrinking faster than expected, therefore, Sandd implemented a self-developed strategy called 'speed up and widen'. 'Speeding up' means attaining more volume and revenues from existing and new market segments of the mail market. This means moving from the market segment with large companies to market segments with smaller companies with higher margins. 'Widening' means obtaining extra revenues from non-mail related products and services. Based on this strategy, Sandd developed extra services and products, resulting in new propositions. With those propositions they want to create new business models to gain more market share and higher revenues.

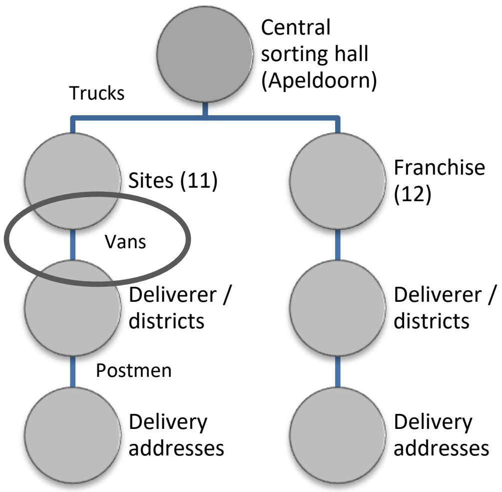


Figure 1.1: Flow of mail through the supply chain of Sandd

The supply chain of Sandd starts at the Central Sorting Hall (CS), located in Apeldoorn, where Sandd collects all mail and sorts it per region. Sandd divided the Netherlands into 23 regions, with in each region a small sorting depot (site) or a franchiser (other companies to which mail delivery is outsourced). Every region is virtually divided into subdepots, to simplify the sorting process. Every subdepot consists of districts and every district consists of delivery addresses. Figure 1.1 shows the flow of the mail from the CS to the addresses. Trucks distribute all mail from the CS to the sites or franchisers. The distribution by truck is outsourced to the distribution company Bakker&Schilder. At the sites the mail is sorted per subdepot and distributed on Monday or Thursday to their postmen by van. These postmen sort the mail on address level and deliver it on Tuesdays and Fridays. This research focuses on the process of delivery to the postmen done by vans, as the circle in Figure 1.1 indicates.

1.2 Motivation

Sandd expanded their product portfolio due to the shrinking market. The management of Sandd expects that volumes in 2020 are 50% less than in 2010. The shrinking market results in lower utilization of Sandd's resources and forecasts show that it will decrease even more. Sandd currently uses around 270 vans for the delivery process. Due to the 72-hour distribution, the vehicles are mainly used on Mondays and Thursdays. Each van is assigned to a fixed route based on average delivery volumes. This makes it possible to have fixed arrival times and sorting deadlines. On Tuesdays and Fridays Sandd uses the vans for districts, which have currently no postmen assigned (Flex district). Table 1.1 gives estimates of the utilization of the fleet. For years, using the remaining capacity was not urgent, since Sandd was growing. The mentioned expectations about the market show that these adjustments might be needed to remain profitable and keep up with competition. It is also obvious that the remaining capacity could give opportunities, which is an argument for Sandd to look for products or services to make use of the remaining capacity of the fleet.

Day	% fleet utilization
Monday	100%
Tuesday	10%
Wednesday	5%
Thursday	100%
Friday	10%
Saturday	0%
Sunday	0%

Table 1.1 Estimates of utilization of vans at Sandd in weight and volume

Recently, Sandd started researching a collaboration with another company, in this research named as Company X. Collaborating is interesting for Company X, due to the widespread network Sandd has. Vice versa, it is interesting for Sandd to collaborate with Company X, since they deliver from Monday until Friday. On the current delivery days of Sandd, the integration could cause problems in the current logistic network, due to capacity restrictions. By combining both processes, the problem becomes more complex, due to the large number of stops in the distribution network and the sorting process. Due to the potential of this collaboration and the complexity of the problem, research is needed to give insight in the opportunities of the collaboration.

1.3 Problem description

The utilization of the fleet at the sites is not optimal in time nor in volume and weight. Several reasons are given causing this underutilization, such as variability in demand, planning on static routes, and a fleet based on peak moments. Due to the lack of transparency of the utilization of vans, some sites hire extra vans, while at other sites vans are not used. Sandd has a lot of opportunities to improve processes and gain more revenues within the market. Therefore, this research focuses on collaborating with other companies to increase utilization of the fleet and obtain synergy. Obtaining synergy has a high potential due to the nearly 100% national coverage of Sandd.

Integrating flows has a major impact on the current process, such as an increase in number of vans, changes in the sorting process and changes in costs and revenues. Currently, it is hard for Sandd to compete with other logistic companies on prices per stop, due to less occupation of resources and the partition of costs on only two days a week. Developing a logistic collaboration can result in economies of scale, resulting in more competitive tariffs.

The collaboration with Company X is not the only possibility to collaborate and to obtain synergy. The collaboration with Company X is therefore used as a case study to give insight into the overall impact and in the consequences for the delivery process of Sandd. To reduce the complexity of the case study, it is done within one site (region), keeping in mind the possibilities for the whole country.

This research supports decisions on tactical level and helps to improve the success of this collaboration. The research focuses on delivery to postmen, which means that for Sandd the delivery days Monday and Thursday are included, and for Company X all weekdays. On each delivery day, Sandd has approximately 14,000 stops nationally. Company X has nationally approximately 600 stops on Monday, and 6,000-7,000 stops daily from Tuesday till Friday. The collaboration means for Sandd an increase of 5-10% in the number of stops on Mondays and 40-50% on Thursdays. On the other days it means a full increase of stops.

The management of Sandd is not sure if synergy benefits can be obtained, due to differences in time windows, different products and the complexity of the sorting process. To summarize, the core problem of this research is:

Sandd does not know how to obtain synergy when collaborating with other companies on the delivery process and has no clear insight in the impact on the performance.

1.4 Objective

The objectives of this research can be divided into four parts.

1. Gain insight into the performance measures of the current situation of the delivery process to postmen from sites with vans.
2. Develop an optimal policy for optimizing the logistic structures of both companies.
3. Gain insight into the fair allocation of costs and benefits for both parties.
4. Gain insight into the effect of this collaboration for Sandd.

These objectives result in an optimal integration of the delivery process.

1.5 Research scope

The research focuses on the synergy potential by integrating the delivery process of both companies. Integrating the delivery process may have a major influence on the processes at the sites. To get an overview of the influence of the integration, this research focuses on the process from the arrival of the mail at sites to the delivery process, including the sorting and route picking process. The case study in this research focuses on one region of Sandd in the Netherlands, namely Roosendaal (Zeeland). This region is selected based on criteria of both companies, such as current contracts, representativeness for the whole country, capabilities of the site and the possibility of starting a test phase.

1.6 Research questions and approach

As mentioned before, this research focuses on the possibilities of obtaining synergy in a collaboration. According to the problem statement from Section 1.3, the following research question is constructed:

"What is the most efficient way for Sandd to integrate the delivery processes of Company X to maximize synergy benefits and allocate savings fairly?"

In order to answer the main question, several sub questions are formulated. Insight in the current situation is needed to see the influence on the processes in the collaboration. Therefore, knowledge about the flows should be obtained. Chapter 2 elaborates on the following sub questions:

1. "What is the current situation of Sandd and Company X?"
   - 1.1 What is the current situation of the general process at Sandd?
   - 1.2 What is the current situation of the process at the sites of Sandd?
   - 1.3 How are processes scheduled at Sandd?
   - 1.4 What is the current situation of the delivery process at Company X?
   - 1.5 Which performance indicators can be used to asses performance of the delivery process?
   - 1.6 What is Sandd's current performance?

After analyzing the current situation and the flows that are integrated, literature about integration of processes and designing of routes is needed. Therefore, Chapter 3 gives answer on the following questions:

2. "What is known in academic literature about integrating flows into an existing logistic network?"
   - 2.1 What literature topics are known about collaboration between two companies in logistics?
   - 2.2 What literature topics are known about optimal integration of logistic processes?
   - 2.3 What literature topics are known about fair allocation of costs and benefits during collaboration?

Based on the literature of Chapter 3, a solution method can be developed. The solution method gives insight into possibilities to obtain synergy from the integration and gives insight in costs, savings and possible revenues. Chapter 4 explains the solution method by answering the following sub questions:

3. "How can the conceptual model be designed to obtain an optimal way of integrating the delivery processes?"
   3.1 Which scenarios can be designed?
   3.2 How can the conceptual model be described?
   3.3 Which data is necessary as input for the solution method?

After building the solution method it is used to support the findings of this research. This results in the following sub questions that are answered in Chapter 5.

4. "What is the best way to collaborate in the delivery process of Sandd?"
   4.1 Which experiments are suitable to test the solution method?
   4.2 What are the findings for the scenarios?
   4.3 What are the results in terms of Key Performance Indicators?
   4.4 What is the impact of integrating the processes?
   4.5 Which aspects must be taken into account for collaboration?

Chapter 6 discusses the results and gives advice on the best way to collaborate with Company X.

2 Current situation

This chapter is divided into six sections. Section 2.1 describes the elements in the supply chain of Sandd. Section 2.2 focuses on the delivery process and Section 2.3 elaborates on the planning and scheduling of these processes. Section 2.4 discusses the details of processes of Company X, followed by a description of the performance measures for the delivery process in Section 2.5. At the end of the chapter, Section 2.6 gives the conclusions.

2.1 General process at Sandd

In order to understand the supply chain of Sandd, this section provides general information about the services, processes, personnel and fleet.

Services

The service that Sandd offers is delivery of commercial mail that fits within a mailbox. The products that Sandd delivers, varies in weight and numbers, which causes an unstable workload. The delivery to the postmen is on Monday and Thursday and the delivery to the addresses by postmen is on Tuesday or Friday. As Figure 2.1 shows, the weights on Fridays, (and consequently Thursdays) are higher than on Tuesdays (and Mondays). Figure 2.1 shows the weight per week of both delivery days of the first six months of 2016. The inequality between both days is caused by requirements of customers (companies that Sandd delivers for) and their mail, such as delivery close to the weekend for advertising.

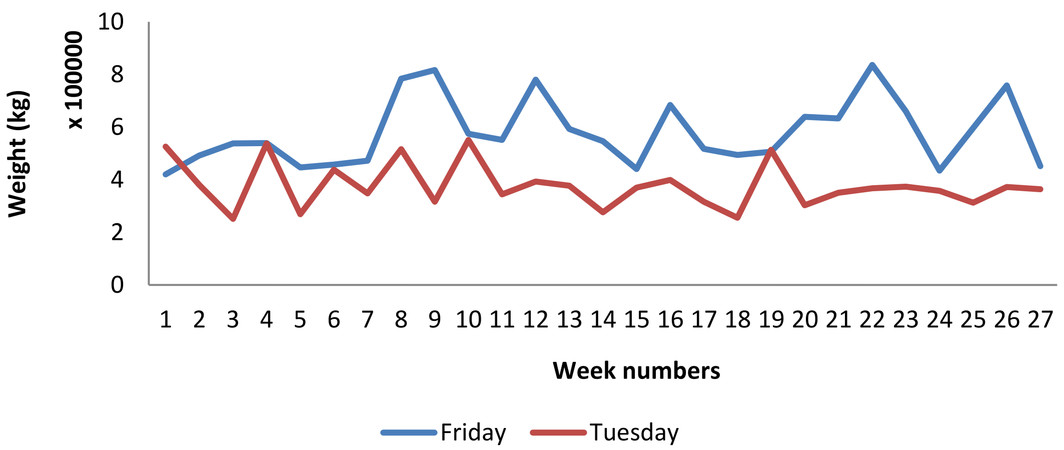


Figure 2.1: Weight per week delivered by Sandd in the Netherlands in 2016

Division of regions

As mentioned in Section 1.1, Sandd divided the Netherlands into 23 regions. In 11 of those regions, Sandd distributes the mail themselves, which is 74% of the total mail delivered. The remaining 26% is done by 12 franchisers. Every region has its own site, at which the mail is sorted. Each region is divided into smaller parts, also referred to as subdepots. These subdepots are divided in districts. Each district has its own postman, yet it could be that one postman delivers in more than one district. Table 2.1 gives a summary of the number of sites, subdepots, districts and delivery addresses. The division of the regions makes it possible for Sandd to deliver more than 8.6 million addresses per day.

Type	Sites	% of volume	Subdepots	Districts	Addresses
Own Sites	11	74%	101	13,931	6,463,274
Franchise	12	26%	41	4,950	2,203,177
Total	23	100%	142	18,881	8,666,451

Table 2.1: Number of sites, subdepots, districts and delivery addresses, based on data from March 2016

Supply chain

The supply chain of Sandd starts at the CS, where the mail is delivered. At the CS, the mail is sorted automated (+/-80%) or manually (+/-20%). Mail for the sorting machine is batched into bundles per subdepot and distributed to the sites. At the sites the mail is sorted further on district level. When the sorting and route picking is finished for each district, vans deliver the mail to the postmen. On Monday or Thursday, the postmen sort it on addresses level and deliver it on Tuesdays and Fridays.

Personnel

To understand the impact of the collaboration on the workload, it is essential to know which types of jobs and number of employees are known in the sorting and delivery processes of Sandd. Figure 2.2 shows the personnel in the selected region (Roosendaal).

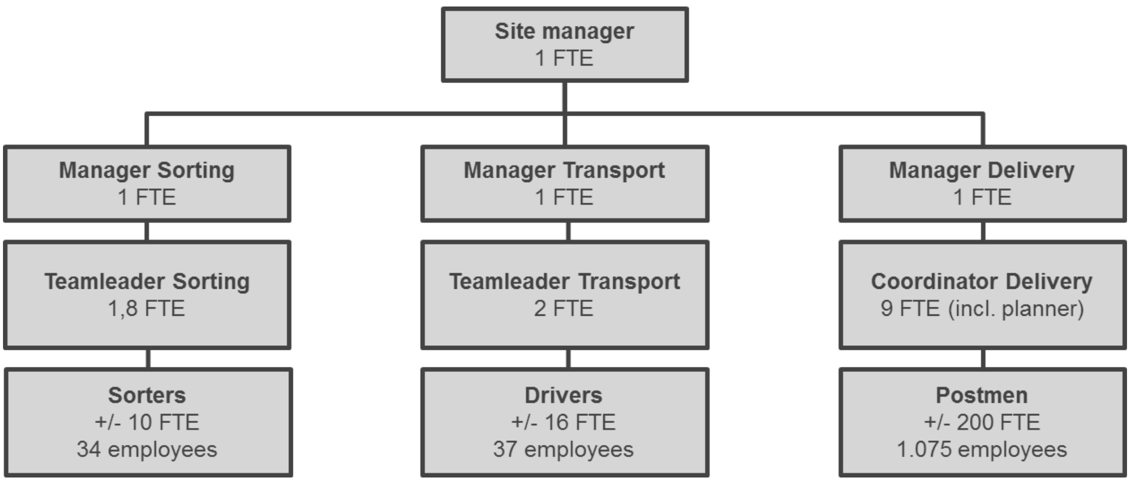


Figure 2.2. Organization chart of the site Roosendaal

Fleet
Currently, Sandd has a fixed fleet of approximately 270 vans. Each van has a maximum loading capacity of 1,020 kilograms and is based on a certain site of Sandd. The number of vans at a site is based on the route structures, which in their turn are based on a policy. This policy states that the routes are robust in 75% of the delivery days, which means that Sandd has to hire extra capacity on approximately 25% of the delivery days. Hiring extra capacity is more expensive than in house capacity. Table 2.2 shows the percentage of days a site hires extra capacity. According to Sandd's policy, the percentages should be around 25%, however, the table shows that almost none of the sites comes close to this percentage. Furthermore, Table 2.2 shows that the some sites have structural shortages on resources or vice versa. Roosendaal needs on 11% of the delivery days extra resources.

Site	% of days hired extra cap.	Site	% of days hired extra cap.
Amsterdam	17%	**Lelystad**	87%
Coevorden	2%	**Limburg Stad**	0%
Den Bosch	15%	**Roosendaal**	11%
Den Haag	85%	**Rotterdam**	8%
Deventer	85%	**Utrecht**	17%
Eindhoven	20%	**Zwolle**	0%
Groningen	2%		

Table 2.2: Number of days per year hired extra capacity in percentage of total days, should be around 25% according to the 75% policy.

2.2 Processes at sites
The product flows of Sandd and Company X are merged at the sites. This section focuses on the processes that are influenced by these flows, shown in Figure 2.3. A floor plan of a site can be found in Appendix B. At the site, two types of mail arrive, namely mail sorted on district level and on depot level. The bundles with mail on depot level have to be sorted further and are processed by the following processes.

Sorting process
In the pre-sorting process, bundles are sorted on subdepot level. These bundles are divided over different flows, that are dedicated to a certain subdepot. Each flow contains approximately 40 districts. The fine-sorting process is done on flow racks. On these racks, full crates can be pushed through for the route picking process. After the fine-sorting process, mail is collected in crates dedicated to a certain district.

Route picking and loading
After sorting, route picking takes place. The filled crates are palletized on route sequence with at most 40 crates per pallet. These pallets can be loaded into the vans, with a maximum of 3 pallets.

Transport to postmen

The focus of this research is mainly on the transportation process. Two types of stops are known, namely a postman is at home and accepts its own mail or the stop is a 'key address', meaning that the driver has a key of the delivery address.

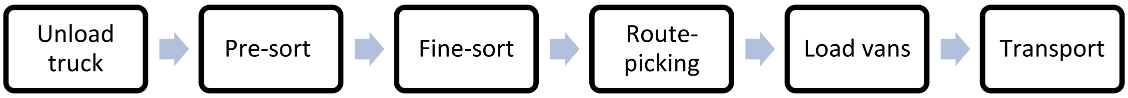


Figure 2.3 Process flows of processes at sites

2.3 Planning and scheduling process

Planning is used at tactical level and scheduling for operational production control. There are two types of planning, namely planning and scheduling of *routes* and planning and scheduling of *sorting*.

Planning and scheduling of routes

As mentioned before, the number of vans are based on the logistic structures with Sandd's 75% policy. The routes are constructed based on weights to deliver to a certain postman. This weight is retrieved from historical data and the 75% policy. Sandd designed its routes in a way that a van can drive two routes per day. Sandd drives the routes in the farthest subdepots first, because in that way, the sorting process for the other subdepots can continue. Sandd uses the same logistic structures every delivery day to make driving structural. Fluctuating weights can cause an exceeding of the capacity restrictions, which make it necessary to schedule the routes on a daily basis. Currently, the planners at Sandd are supported by the Transport Management System (TMS) to make schedules for a certain delivery day. If the capacity is exceeded, only a few addresses of a route are replaced. If too much addresses need to be replaced, extra capacity is hired.

Planning and scheduling of sorting

The planning of the sorting determines the time windows for the delivery process. Each subdepot has a fixed sorting deadline, which makes it possible that routes can depart at approximately the same time every delivery day. The scheduling of employees for sorting is based on the expected amount of mail at a certain day in order to meet the deadlines, which result after the route picking process as release dates for transportation. Figure 2.4 shows the current deadlines of the sorting process at Roosendaal, with the deadlines for route picking and the release dates for transportation.

	Deadlines		
Subdepot	**Sorting**	**Route picking**	**Transportation**
VLN	08:00:00	08:45:00	09:00:00
KHS	08:30:00	09:30:00	09:30:00
GOV	09:00:00	10:00:00	10:00:00
RIJ	09:00:00	10:00:00	10:00:00
ZVL	10:00:00	11:00:00	11:00:00
TBR	12:00:00	13:00:00	13:00:00
BOZ	12:00:00	13:00:00	13:00:00
ETR	12:30:00	13:00:00	13:00:00
RSD	13:00:00	14:00:00	14:00:00

Figure 2.4: Example of schedule at site Roosendaal

2.4 General process of the Company X

In order to map the consequences of a possible collaboration between both companies, an analysis of Company X is needed. This section describes the services and processes of this company.

Services

The main processes of Company X are sorting and delivering products (mainly magazines). Their products arrive at the sorting center and are sorted for retailers nationally. Next to these magazines (80% of the workload), the company delivers some other products, which can be found in Appendix C.

Company X delivers their sorted products on route sequence to Sandd. Figure 2.5 shows the amount of kilograms per day delivered over a period of four weeks in the selected region of Company X. Significant differences are shown between Mondays and Tuesdays until Fridays.

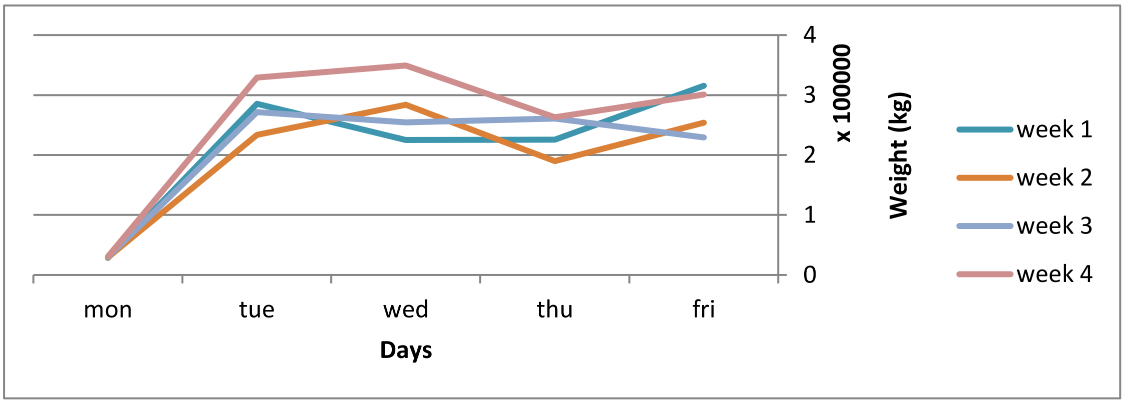


Figure 2.5: Weight delivered for four weeks per day

Delivery process

The sorting process of Company X is not included in this research, since there is no influence possible on this process. The delivery process of Company X is similar to the delivery process of Sandd, since the products are delivered in crates.

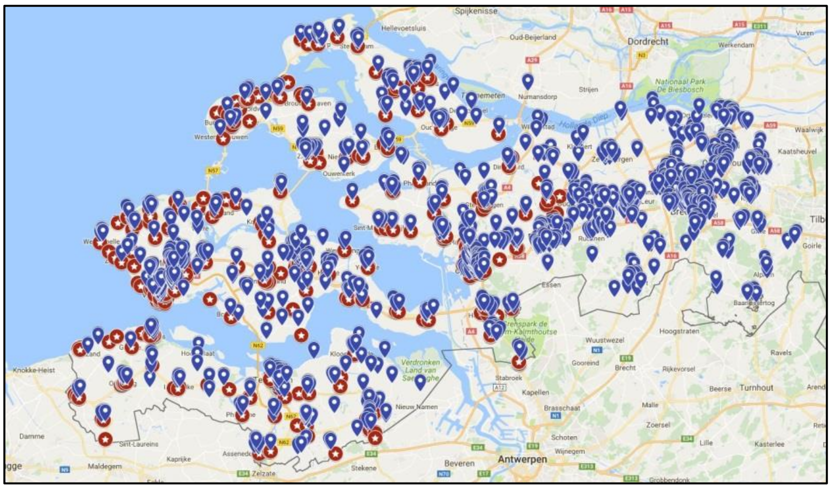


Figure 2.6: Delivery addresses of both companies (Sandd: blue. Company X: Red).

The products of Company X are delivered from the sorting center at sites before 5:00 AM. Company X offers the possibility to deliver the pallets with the crates stacked on route sequence, which minimizes the workload for route picking. The different products have different time windows, these can be found in Appendix B. Figure 2.6 shows the addresses of Company X and Sandd in the selected region.

2.5 Performance indicators

In order to recognize possibilities in the distribution process of both companies, insight in the current performance of the delivery process is needed. As mentioned before, the products of Company X arrive at sites of Sandd; from there, the products follow the same processes as the products of Sandd. The integration of these processes have influence on the performance. Therefore, measures and indicators need to be explained.

Sorting

The performance of the pre-sorters and fine-sorters is measured by the weight they sort per hour. Based on the total number of hours and the weight for a specific day, Sandd calculates the actual performance and compares it with their determined norm.

Route picking

The route picking process is measured by the weight that employees pick per hour. The performance of the route pickers determines the starting time of the vans and is essential for avoiding mistakes in the delivery process. Sandd calculated that the optimal number of employees is two per subdepot. Route picking should also be done for products of Company X.

Transportation

Performance indicators for the transportation process are essential to measure efficiency and impact of a collaboration. Below, the performance indicators are explained.

The performance indicators for transportation

1. **Total number of vans used**

As mentioned before, Sandd uses approximately 270 vans. If less vans could be used, less fixed costs are involved, yet, this limits the flexibility of delivery. Less vans means a higher utilization, but this can influence the quality of delivery, such as on-time-delivery.

2. **Total travel time**

Reducing total travel time could be achieved by higher utilization of vans and more efficient routes, which results in reduced costs. Figure 2.7 shows that the total duration of tours per delivery day does not deviate much.

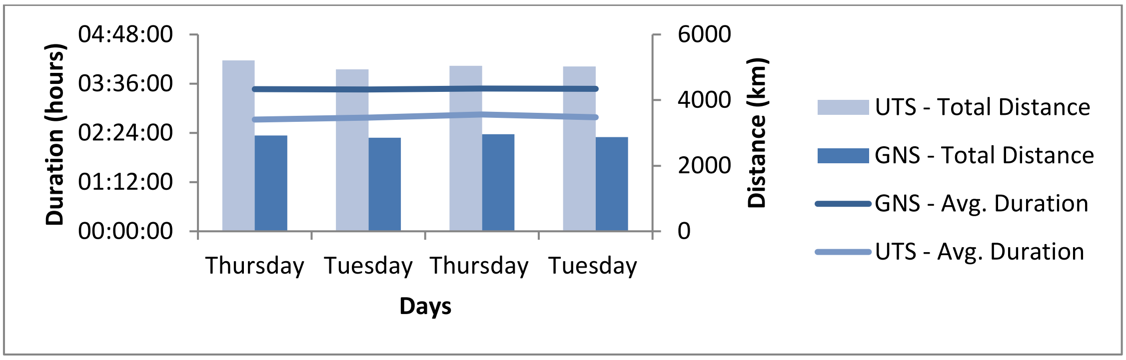


Figure 2.7: Duration and distance of the delivery process of four days at two different sites.

3. Total travel distance

Reducing total travel distance has a positive influence on the lease contracts. Figure 2.7 shows that the total driven distance per day at a specific site, does not deviate much. It shows a difference between urban and suburban areas. An urban area (UTS, Utrecht) has higher total distances and lower total durations per delivery day, which is for suburban, or rural, areas the other way around. This is caused by number of routes, population density, and the distances between postmen.

4. Number of tours

The number of tours is directly connected with the number of times the vans have to be loaded. More tours will increase the total travel distance, yet, it reduces the number of vans needed. Based on Sandd's route planning strategy, the number of tours are approximately two routes per van per day.

5. Stops delivered per hour

Performance of the transport per delivery day is measured by the number of stops per hour. The productivity is calculated by dividing the number of stops by the number of hours for that day. This gives insight in the performance per route per day, which gives Sandd an insight in their productivity per day.

6. On-time-deliveries

Quality of delivery within time windows is given by the percentage of on-time-deliveries. A lot of the deliveries at region Utrecht (UTS) are done outside the time windows, as shown in Figure 2.8, while the norm of Sandd is to deliver 99% in time. The not-on-time-deliveries are probably caused by traffic in urban areas, since the suburban performance is usually 100% (Figure 2.8). The negative peak in Figure 2.8 is an exception, and caused by a special order, which can be neglected.

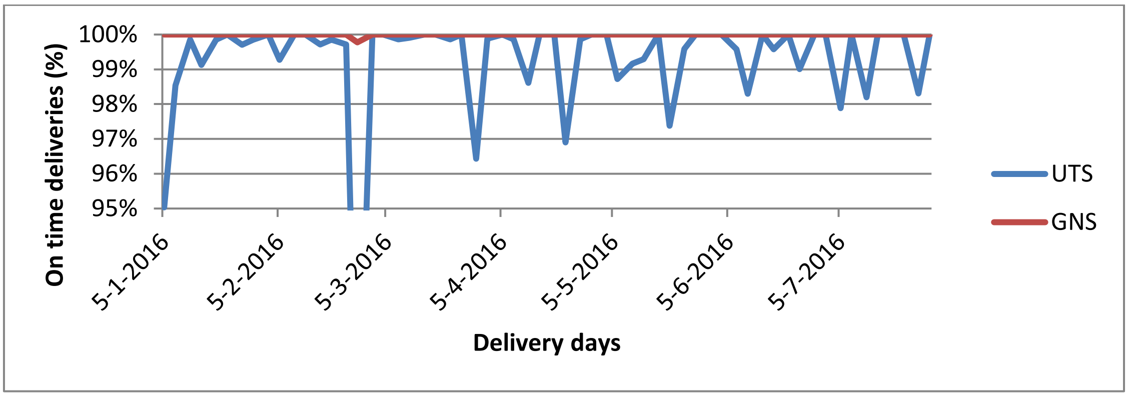


Figure 2.8: Percentage of delivery within time windows at two sites.

7. Capacity utilization

Using a quite static routing policy with fluctuating weights, ensures variation in the utilization of the vans per route. Utilization is measured in used weight of the capacity, given in percentage. Figure 2.9 shows the average utilization of the vans at all routes at the sites Utrecht (UTS) and Groningen (GNS) on the right axis in combination with the weight that is transported during a specific delivery day on the left axis. It is clear that on days with a lot of weight, mostly Thursdays, the utilization of the vans is higher. On days that the weights are less, often Mondays, the utilization even falls below 50% (0.5). Remarkable is that on 23th of June, the site Utrecht hired extra capacity, while average utilization per route was only 75% over 77 routes.

Figure 2.9: Weight combined with utilization on four days at two sites.

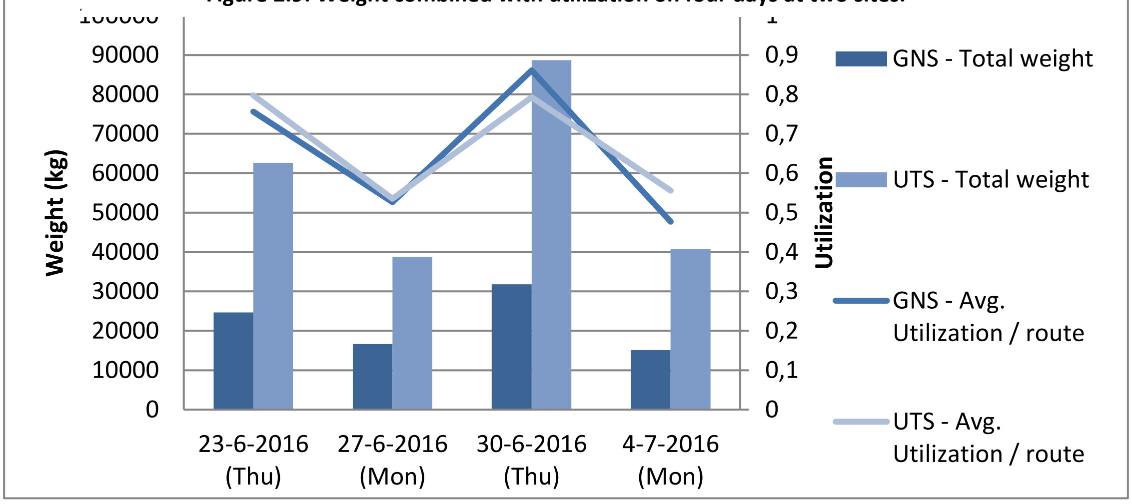


Figure 2.10 shows the frequency of the utilization per route on a busy and an average delivery day. The cumulative results (right axis) show that on a busy day (for example 23-6-2016), around 65% of the routes are utilized 80% or more. On an average day (for example 4-7-2016), the utilization of the vans per route is lower, namely around 95% of the routes is utilized 80% or less. The utilization gives insight in the weight that can be added by Company X.

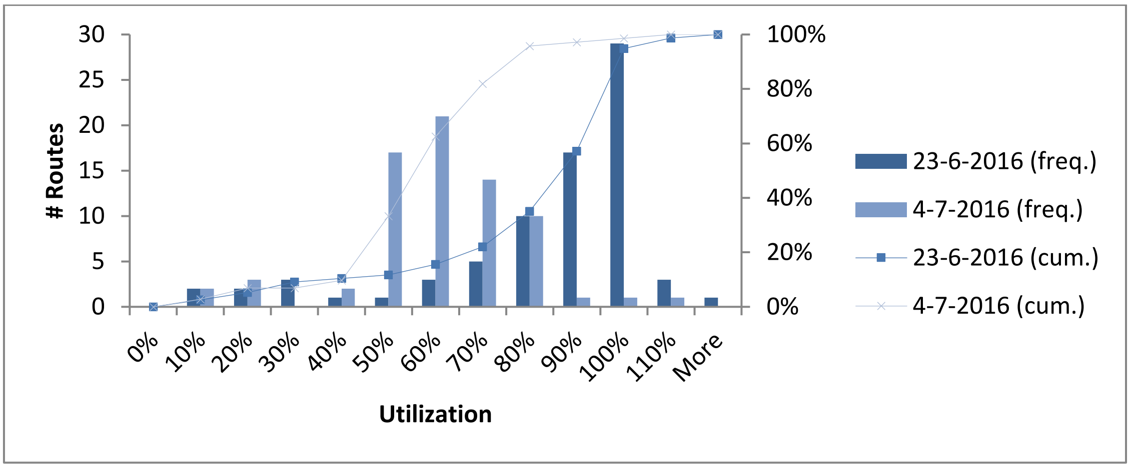


Figure 2.10: Frequency of routes with their utilization.

2.6 Conclusion on current situation

In Section 2.1, the general situation at Sandd is described. The workload of the mail at Sandd is quite unstable, which results in hiring extra capacity for some sites. At some sites the percentage of the extra capacity is up to 87% of the delivery days, while Sandd's policy says it should be around 25%. Section 2.2 states that from the CS, the mail is distributed to the sites, continued with the sorting process, including pre-sorting, fine-sorting and route picking. After completion of the sorting process, the transportation to postmen is done. Section 2.3 describes that the planning of the routes is based on the 75% policy, which means that the routes are robust on 75% of the delivery days. This results in adjusting routes or hiring extra vans on 25% of the delivery days. The release dates of the routes are based on the deadlines of the sorting process. Based on average workload, deadlines of the sorting process are determined. In Section 2.4 it is described that the processes of Company X are integrated into the supply chain of Sandd from delivery at the sites. Their product portfolio exists for 80% of products (comparable with magazines) packed in crates. They deliver from Monday until Friday, with a relative low workload on Mondays and high workload on the rest of the days. All products have their own time window. Section 2.5 elaborated on the performance indicators of the sorting and delivery process of Sandd. For the sorting and route picking process the performance is measured in weight per hour. The following indicators are identified:

1. Total number of vans used
2. Total travel time
3. Total travel distance
4. Number of tours
5. Stops delivered per hour
6. Delivery in time windows
7. Capacity utilization

3 Literature review

This chapter discusses the relevant literature related to integrating flows into Sandd's supply chain. As described in Chapter 2, the focus of this research is on a collaboration in the delivery process of Sandd with Company X. This collaboration is considered as horizontal cooperation, meaning that redesign of the structures can result in synergies and cost savings.

Section 3.1 elaborates on the concept of horizontal cooperation in general, followed by horizontal cooperation focused on logistics in Section 3.2. Section 3.3 describes the literature to implement horizontal logistics cooperation with joint route planning and Section 3.4 discusses the literature for the solution method of this research. Section 3.5 gives several methods to allocate the cost savings followed by conclusions in Section 3.6.

3.1 Horizontal cooperation

Since the last century, logistical innovations are developing fast; therefore, the need for companies to innovate and reduce costs increases. Reducing costs on the logistics function of a company that moves millions of tons each year can result in serious savings just by reducing distribution costs by a few cents per ton (Schmoltzi & Wallenburg, 2011). It could give a reduction of prices and a stronger position in the market, according to Adenso-Diaz, Lozano, and Moreno (2014). A way to reduce costs, is by collaborating with partners who are working in the same area. Collaborating is recognized in several concepts; such as vertical cooperation, joint efforts in promotion, R&D, product development etc. There is extensive literature on these concepts, however, there is less literature on horizontal collaborations, especially when focusing on road transportation (Simchi-Levi, Kaminsky and Simchi-Levi, 2007, Leitner, Meizer, Prochazka & Sihn, 2011). Cruijssen, Bräysy, Dullaert, Fleuren, and Salomon (2007) refer to horizontal collaboration as "two or more firms that are active at the same level of the supply chain and perform a comparable logistics function". The European Union (2001) defines horizontal collaboration as "a concerted practice between companies operating at the same level in the value system". A comparable explanation is given by Simatupang and Sridharan (2002), who state that a collaborative supply chain simply means that "two or more independent companies work jointly to plan and to execute supply chain operations with greater success than when acting in isolation".

Types of collaborations

A lot of different definitions for horizontal supply chain links exist, such as cooperation, collaboration, alliance and partnership. Schmoltzi and Wallenburg (2011) mention that the boundary between these terms is vague and definitions are used interchangeably. Figure 3.1 shows five types of cooperation. First of all, Cruijssen (2006) identified two commonly used types, namely arm's length cooperation and horizontal integration. In arm's length cooperation, the collaboration is limited. Communication and exchanges occur incidentally, yet, cooperation may be over a long period. Cruijssen (2006) state that there are no strong commitments or joint operations for this type of cooperation. Furthermore, in Figure 3.1, horizontal integration is mentioned. This type of cooperation is recognized as the extreme case of horizontal cooperation; tending towards a merger between companies.

Lambert, Emmelhainz, and Gardner (1999) identified three types of cooperation depending on the level of integration. In Type I cooperation, the relationship consists of mutually recognized partners that coordinate their activities and planning, though to a limited degree. Type II is a cooperation in which the participants also integrate parts of their business planning. In a Type III cooperation, the participants have integrated their operations to a significant level and they see each other as an extension of themselves (Cruijssen, 2006). Type III is often referred to as strategic alliance.

For structuring all the cooperative relationships, Schmoltzi and Wallenburg (2011) summarized these definitions as horizontal cooperation. This research is focused on a Type III cooperation, tending towards horizontal integration.

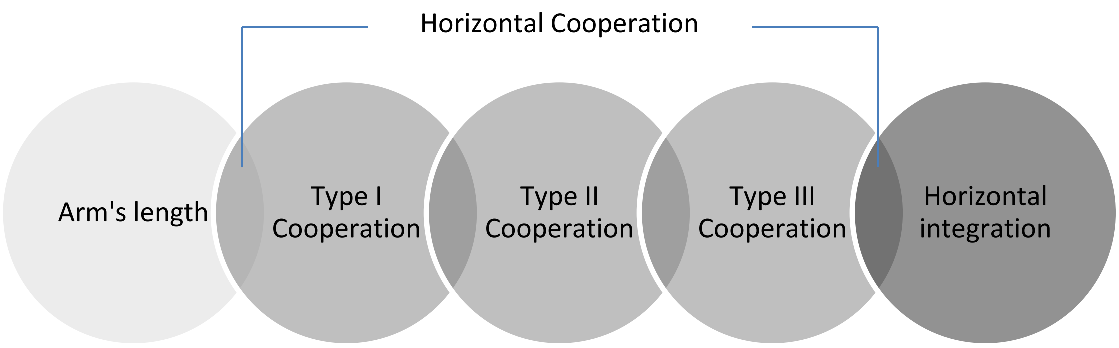


Figure 3.1: Types of horizontal cooperation

3.2 Horizontal logistics cooperation

The cooperation types explained above could be used by firms in general, yet, the focus of this research is on cooperation in logistics. In logistics, companies can make three different choices, namely; outsourcing, keeping logistics execution in-house, or cooperating to obtain synergies (Razzaque and Sheng, 1998). Cruijssen et al. (2007) state that “outsourcing and horizontal cooperation focus on achieving synergy and economies of scale in order to increase the competitiveness of their logistics networks”. When companies choose to cooperate in the logistics section, change and redesign of their logistic processes is needed. This concept is recognized in literature by Horizontal Logistics Collaboration (HLC). HLC occurs at a tactical level to improve efficiencies and utilization of vehicles in transportation and can occur at strategic level in order to optimize supply chain networks (Rodrigues, Harris, & Mason, 2015).

HLC can induce many advantages, such as better utilization of resources, economies of scale, economies of scope, growth, having a greater bargaining power (Cruijssen et al., 2007), reduces environmental impact (Ballot & Fontane, 2010), on-time-delivery improvements (Fawcett, Magnan & McCarter, 2008) and cost savings. An important force behind the formation of cooperating companies, is the expectation of a positive net present value (Parkhe, 1993), including the fact that cooperation can lead to a better performance of both companies (Nguyen, Dessouky, & Toriello, 2014). This is proved by a research of Cruijssen and Salomon (2004), where they use a case study to analyze the effect of cooperation, resulting in cost savings ranging from 5% to 15%.

As mentioned above, two important advantages are economies of scale and economies of scope. Economies of scale in logistics refer to the decreasing unit costs when an identical service is provided more frequently, or to more addresses. An example of economies through horizontal cooperation in a transportation setting, is joint route planning (Cruijssen et al., 2007). Bahrami (2002) also discusses the economies of scale in joint route planning, using a case study of two German consumer goods manufacturers, Henkel and Schwarzkopf, which have merged their respective distribution activities and gained significant savings. Economies of scope are recognized as the cost impact of adding new products or services to a product portfolio, which is an important incentive for horizontal cooperation. Horizontal cooperation is characterized by 4 dimensions (Cruijssen, 2006):

1. Decision level (operational, tactical and strategic)
2. Competition among partners (presence / absence)
3. Combined assets (orders, logistics facilities, rolling stock, market power, supporting processes and expertise)
4. Objectives (cost savings, growth, innovation, quick response and social relevance).

The above mentioned dimensions help to determine suitable partners in the first step of the three-phase model for logistics cooperation, introduced by Cruijssen and Salomon (2004). This model forms the base for this research, consisting of the following phases:

1. Selection of suitable partners
2. Estimate on the savings in transportation costs due to cooperation
3. An algorithm that gives an allocation of the realized synergy benefits among partners

After the selection of a suitable partner, a leader of the collaboration should be chosen. Audy, Lehoux, D'Amours, and Rönnqvist (2009) have identified six different forms of leadership for cooperation. In this research, Sandd is the leader in the cooperation, which corresponds to the form of leadership '*a producer leads the collaboration'*. Audy et al. (2009) state it as "the leader aims on minimizing transportation costs by finding or implementing other customers drop points that can provide a good equilibrium in extra costs and revenues".

Phase 2 in the model focuses on estimating savings on distribution costs due to cooperation. These savings result from joint route planning, according to Cruijssen (2006). Cruijssen (2006) states that joint route planning is used for "delivery from a single distribution center to specified drop-off locations at customer's sites". In literature three scenarios in cooperation are recognized:

1. The traditional situation without cooperation
2. Joint distribution within the current logistics structures

3. Optimization of the logistics structures based on the aggregated demand of both companies

Mason, Lalwani, and Boughton (2007) name Scenario 2 “process innovation” and Scenario 3 is referred to as “structure optimization”. In these two scenarios, applicability of joint route planning is recognized. Joint route planning focuses on obtaining synergy in logistics.

Synergy
This research refers to synergy as the difference between distribution costs in the traditional situation of both companies and the costs for a collaboration. A restructuring is seen as the situation where all orders are collected and route schemes are set up simultaneously (Scenario 3). The scenarios are similar to the types of synergy in logistics mentioned by Vos, Iding, Rustenburg, and Ruijgrok (2003). They define three types of synergy: *Operational synergy*, *coordination synergy* and *network synergy*. *Operational synergy* concerns only a single process or activity to better utilize existing resources. *Coordination synergy* takes place more often over several activities and these processes are in harmonization, while using the existing network. This type of synergy is similar to Scenario 2. *Network synergy* can be obtained by restructuring the complete logistics network on a long-term cooperation, which corresponds with Scenario 3. The upper bound of synergy under horizontal cooperation is recognized as a merger and acquisition by Gupta and Gerchak (2002), which is an extreme form of horizontal integration.

Objectives
In order to obtain the right and most important objectives of horizontal cooperation, such as cost savings and growth, it is important for both companies to know how an optimal cooperation can be obtained. Dullaert, Cools, Cruijssen, Fleuren, and Merckx (2004) state that many transportation companies hesitate to participate in a cooperation because of:

1. “It is unclear when savings are realized and how large these savings are”.
2. “There is not enough trust that one of the participants is privileged”.

Whipple and Frankel (2000) mention that the formation of cooperation is often difficult, due to needed changes in mindset, culture, and behavior. Many factors play a crucial role in the success, such as information sharing, incentive alignment, relationship management, contracts, and ICT. In addition, all partners in cooperation need to receive payback for their input (Mason et al., 2007). Growth is another important objective of HLC. Companies can establish financial growth, geographically extend their network and increase their product portfolio (Mason et al., 2007). In order to start a cooperation, clear insight is needed into the costs savings for the participating companies (Dullaert et al. 2004). This can be obtained by considering the right methods for the design of delivery routes and a fair allocation mechanism of the savings.

Conclusion on horizontal cooperation
The level of integration in the cooperation of this research refers to a type III cooperation, which is integrating processes to a significant level and it is tending towards a horizontal

integration. Important advantages of this integration are economies of scale and economies of scope. Essential phases in horizontal collaboration are as follows (Cruijssen, 2004):

1. Selection of suitable partners
2. Estimate on the savings in transportation costs due to cooperation
3. An algorithm that gives an allocation of the realized synergy benefits among partners

The focus of this research is on Phase 2 and 3. Phase 2 includes calculating the benefits of the cooperation, resulting in synergy benefits. Phase 3 is explained further on and focuses on cost allocation. Three types of synergy are recognized and are calculated with comparing the following situations:

1. The traditional situation without cooperation
2. Joint distribution within the current logistics structures – Operational / cooperation synergy.
3. Optimization of the logistics structures based on the aggregated demand of both companies – Network synergy.

In order to get the most profit from the collaboration, network synergy should be obtained. Network synergy can be obtained by implementing joint route planning and gaining trust by a fair allocation mechanism.

3.3 Joint route planning

This part refers to Phase 2 of Cruijssen and Salomon (2004), namely, estimating the savings of the cooperative distribution. As mentioned before, this research focuses on strategic cooperation with Sandd as being the leader in the collaboration. According to Sebastian (2012) decisions in the tactical phase during formation of cooperation include:

1. Service selection: Definition of the routes on which services are offered and the characteristics of each service.
2. Traffic distribution: Includes the routes, the services used, the terminals passed through and the operations at these terminals.
3. Terminal policies: Specification of the consolidation activities at each terminal (e.g. sorting, storing, picking, cross-docking)
4. Empty balancing strategies: Repositioning of empties such as vehicles, pallets and containers.

This research focuses on the decisions in traffic distribution. Cruijssen et al. (2007) focused on joint route planning by using the Vehicle Routing Problem with Time Windows (VRPTW) for construction of the routes. VRPTW comes from a set of heuristics that include time windows when constructing routes. Cattaruzza, Absi, and Feillet (2016) introduced a new multi-trip vehicle routing problem with time windows and release dates (MTVRPTW-R). Their focus is on last mile delivery from City Distribution Centers, where consolidation takes place. They take limited vehicle capacity, minimizing fleet size and the fact that only finished goods can be transported into account for developing the routes, recognized as the multi-trip aspect. They modeled these release dates by including time windows, adjusting them by the release times, and making sure tours do not depart before these time windows. Another method, introduced by Crainic, Gajpal, and Gendreau (2015), is to divide an area into multiple zones resulting in multiple small VRPTWs. Smaller zones makes it possible to solve smaller subsets. In the collaboration of this research, release dates play an important role. Therefore, it is assumed that including a VRPTW with release dates is a suitable solution method.

3.4 Solution method

To do experiments in this research, solution methods are used. As explained in Section 3.3, VRPTW with release dates is suitable for this research. Joint route planning consists of three phases, namely gathering input for the model, selecting construction heuristics, and optimization of the constructed routes.

Route construction

The objective of a VRPTW is to construct routes from an origin to multiple destination nodes, using identical vans that visit each address exactly once and returns to the origin. During construction, time windows and capacity may not be violated (Cruijssen et al., 2007). VRPTW heuristics make initial solutions relatively fast with a reasonable solution and improve that solution later on. Generally, these heuristics are only measured in terms of objective function value and speed, yet, more criteria for algorithm performance of heuristics exist. Examples are: ease of implementation, robustness, and flexibility (Barr, Golden, Kelly, Resende & Stewart, 1995; Cordeau, Desaulniers, Desrosier, Solomon & Soumis, 2002).

In most combinatorial optimization problems, such as VRPTW, the initial solution has impact on the final solution (Despaux & Basterrech, 2014), which makes the use of a good route construction heuristic important. Bräysy and Gendreau (2005a) describe and compare three construction heuristics, in which they found that the sequential insertion heuristic performed the best on their objectives (Bräysy & Gendeau, 2005a). In this heuristic, first a 'seed' address is selected and the remaining unrouted addresses are added into the route until one of the restrictions is exceeded. The seed addresses are selected on two criteria, namely on finding either:

1. The geographically farthest unrouted customer relative to the site.
2. The unrouted customer with the lowest allowed starting time for service.

The next customer to insert is based on the maximum benefit of a direct route minus the insertion costs on each feasible place within the routes. When no more addresses with feasible insertions can be found, a new route is started until all addresses are scheduled.

Another heuristics that are well known are Savings Algorithm, Nearest Neighbour (NN) and Minimal Insertion Cost (MIC). The Savings Algorithm (Clarke and Wright, 1964) selects addresses that have the largest savings when merging, until no addresses are remaining. The NN start with the nearest address of a starting point and inserts always the nearest city from the last addresses. MIC starts with a seed, such as farthest address and inserts the address with the best feasible insertion cost on the route.

Improvement heuristics

In order to improve the initial solution, an improvement heuristic is used. Lenstra and Rinnooy Kan (1981) proved that solving a VRP with constraints is NP-hard, which means only small instances can be solved to optimality. This research has a large instance, therefore, it needs a heuristic to solve the VRPTW. This is mostly the case for real-life instances (Bräysy & Gendreau, 2005b). Local search heuristics can help find local optima, yet, heuristics are needed that can escape from a local optimum to find better solutions. By creating neighbour solutions, which is explained later on in this section, the solution can be improved. An example of an improvement heuristic is Simulated Annealing (SA). SA only accepts worse neighbour solutions with a certain probability, which makes it able to escape from local optima.

Simulated annealing

SA is an algorithmic approach for solving combinatorial optimization problems. To understand SA, one must first understand local search. A combinatorial optimization problem can be seen as the problem to find the global optimum from a set of solutions with a cost function that leads to a value for each solution (Johnson, Aragon, McGeoch, & Schevon, 1989). Using the initial solution, local search tries to improve the solution by searching for neighbour solutions that improve the objective function. In that way, it reaches local optima (Figure 3.2), while there could be a better solution, known as global optimum (shown in Figure 3.3). The difficulty with local search is that it cannot escape from local optima.

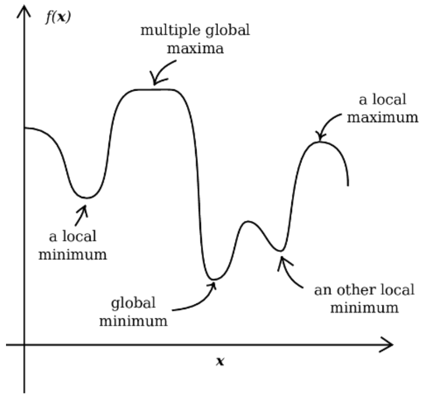


Figure 3.2: Local and global optima given in a graph (Tunguz, 2017)

SA is an approach that is able to escape from local optima by occasionally accepting worse neighbour solutions (Johnson et. al, 1989). From the initial solution, neighbour solutions can be found using an exchange-operator. Better solutions are always accepted and worse solutions are accepted based on an acceptance probability. In the beginning, almost all solutions are accepted. This allows the method to 'explore' the solution space. During the execution, the acceptance probability decreases, which means that the method is more selective in accepting a worse neighbour solution. At the end, only neighbour solutions that improve the solution are accepted (Pirlot, 1996), which makes the solution comes closer to an optimal solution when the cooling parameter reaches the stop criterion (c_{stop}). The choices for these parameters are explained in the next section. The pseudo code shows how the SA is formulated, based on Pirlot (1996) .

Simulated Annealing

Initialization:

Find random initial solution S

Choose

Value cooling parameter	$c=c_0$
Decreasing factor	α
Markov chain length	k
Stop criterion	c_{stop}

Algorithm:

While $c > c_{stop}$

  For 1 to k **do**

    Generate neighbour solution S_j

    If $S_j < S_{current}$ **then**

      $S_{current} = S_j$

      If $S_j < S_{best}$ **then**

        $S_{best} = S_j$

      End if

    Else accept S_j with acceptance probability $e^{\frac{S_i - S_j}{T}}$

      $S_{current} = S_j$

    End if

  End for

  $c = c * \alpha$

End while

Choosing parameters

The four parameters mentioned above need to be specified. Starting with the initial temperature c_0. According to Aarts and Korst (1989), it should be large enough to accept almost all neighbour solutions. This can be achieved by choosing the value such that the acceptance ratio is close to 1. This value can be found by using a small positive value of c_0 and multiplying it with a constant factor, larger than 1, until the acceptance ratio is close to 1. The stop criterion c_{stop} is chosen in such a way that the acceptance ratio is close to 0, which means that almost none of the worse transitions are accepted. Figure 3.4 shows the acceptance ratio relative to the temperature and Formula 3.1 gives the acceptance ratio.

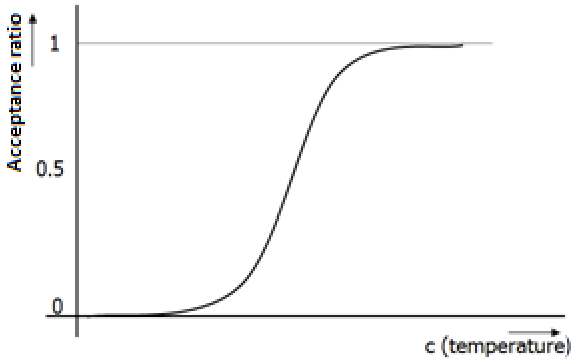


Figure 3.3: Acceptance ratio graph for Simulated Annealing

$$\text{Acceptance ratio} = \frac{Number\ of\ proposed\ solutions\ (worse)}{Number\ of\ accepted\ solutions\ (worse)} \tag{3.1}$$

The decreasing factor α typically lies between 0.8 and 0.99, since one usually wants small changes in the value of the cooling parameter. Theoretically, the length of the Markov Chain k depends on the size of the problem, yet, normally a value is chosen based on the decreasing factor. If the decreasing factor is close to 1 the Markov chain could be lower, and vice versa.

Steepest-descent and First-descent

The solution method also includes the improvement heuristics Steepest-descent and First-descent. Steepest-descent evaluates all neighbourhood solutions and accepts the neighbour that decreases the objective function the most (Beek, 2011). First-descent evaluates the neighbourhood solutions until a decrease of the objective function is found and executes the move. Each heuristic has its benefits, since First-descent heuristic finds an improvement more quickly and Steepest-descent yields the best improvement.

Neighbour solutions

There are many methods to find neighbour solutions, such as changing a sequence of a route of a given solution (Bräysy & Gendreau, 2005b). Most of those mechanisms are edge-exchange algorithms, examples of these algorithms are listed below: (More information can be found in the research of Bräysy and Gendreau (2005b)).

1. 2- opt operator
2. K- opt operator
3. Relocate operator
4. Exchange operator
5. Cross – exchange
6. The Geni-exchange

Using these operators, Bräysy and Gendreau (2005b) found in their research that Bräysy (2003) has the best heuristic with an acceptable computing time. In that heuristic the Or-opt exchange is used. The heuristic switches s addresses in a sequence to another random chosen route and place in that route. The Or-opt heuristic is a combination of several k-opt operators. It starts with s-opt, until no sequence of s that improves the solution is found. If no sequence that improves can be found, it reduces *s* by 1. Or-opt starts initially with *s* equal to 3. Since the performance of this heuristic is good, it is used for the solution method.

Two types of operators are used in this research for finding neighbour solutions, namely moving addresses and swapping addresses between or within routes. Moving addresses means selecting *s* addresses and replace them in a random route, as shown in Figure 3.4. The operators that are used are no edge-exchange mechanisms, yet, they exchange addresses.

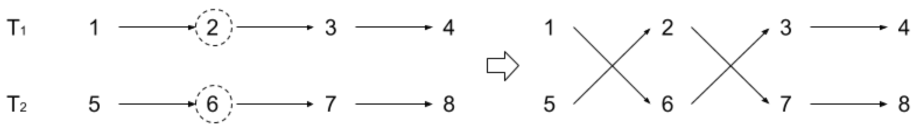


Figure 3.4: Swapping customer 2 and 6 between two routes.

Swapping jobs means selecting *s* addresses in a random route and swap them with *s* addresses in a random route, as shown in Figure 3.5. Swapping jobs makes it possible to find neighbour solutions when capacity restrictions are met.

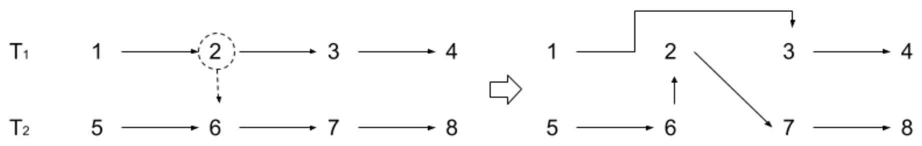


Figure 3.5: Moving customer 2 to another route

Release dates

Effective integration of the production and distribution processes became imperative, according to Van Buer et al. (1999). This integration is applicable on the sorting process and distribution process of Sandd. Usually, the distribution schedule is based on the production and scheduling is done separately with no or little integration. Obviously, such a sequential approach is not optimal. Chen and Vairaktarakis (2005) as well as Pundoor and Chen (2005) show that there is a significant benefit by using an optimal integrated production-distribution schedule, compared to a schedule generated by a sequential approach. However, literature on production and distribution integration is quite scarce. As explained earlier in this research, time windows can be adjusted according to the finish times of the sorting process. The starting times of the time windows are changed into the finishing times of the sorting processes and function as release dates for the departure of the tours.

Robustness

An essential factor for the implementation of a schedule is the robustness of a certain schedule. Robustness is the number of disturbances a certain schedule can absorb without changing the initial schedule, or is referred to as a solution that is immune to variations in the data. Taking uncertainties into the objective can result in a robust plan and makes a certain schedule more workable in practice. An example to include robustness in the objective function, is to minimize the weighed sum of costs of using non-regular capacity. Due to limited knowledge of implementation of robustness in the objective, Chapter 5 only shows measures of the robustness of the final solution.

Conclusion on joint route planning and production

Cruijssen et al. (2007) proposed joint route planning to solve their delivery problem by using VRPTW. The Sequential Insertion Heuristic performs the best, according to Bräysy and Gendreau (2005a). As good improvement heuristics Simulated Annealing is proposed to escape from local optimum. Steepest-descent and First-descent are proposed to find improvements more quickly. The operators swapping and relocating are used to find neighbour solutions. To become more effective, integration of the production and distribution processes is needed. This integration is introduced by the release dates of the sorting process. Robustness is not used in the optimization objective, since literature is scarce.

3.5 Allocate cost savings

This section refers to Phase 3 of Cruijssen and Salomon (2004), developing an algorithm that gives an allocation of the realized benefits among the partners. As mentioned before, a main issue and important impediment in horizontal cooperation is the allocation of the cost savings (Cruijssen, 2006). A good allocation method makes sure no mistrust occurs. Many ways to allocate costs or savings in joint route planning are known. Cruijssen (2006) mentions some simple rules of thumb to distribute savings proportionally to a single indicator of either size or contribution to the synergy, namely:

1. Proportional to the total load shipped
2. Proportional to the number of customers served
3. Proportional to the logistics costs before the cooperation
4. Proportional to the distance travelled for each shippers' orders
5. Based on inter-drop distances of the constructed joint routes
6. Based on direct distances from depot to outlet
7. Proportional to number of orders

Cruijssen (2006) states that these rules are easy and transparent, yet, to ensure a fair allocation, the marginal contributions to the total have to be quantified accurately. In order to cope with that, they propose cooperative game theory. That theory models the process of negotiation in cooperation and allocates the generated savings, which is recognized as intelligent pricing. According to Noble and Gruca (1999), using forward-looking and customer-oriented pricing is way more promising, since order sets can differ in the number of orders, the geographical spread of the drop points, the location of the shippers' warehouse, the narrowness of time windows, and the average and standard deviation of the order sizes. Despite the potential of intelligent pricing, limited number of companies take the benefits of it and use the simple rules of thumb. Due to the potential of cooperative game theory, the next chapter elaborates on this subject.

Cooperative game theory

Cooperative game theory models the process of negotiation, as explained above, by including the joint activities of the collaborating companies and allocate the generated revenues (Cruijssen, 2004). The allocation of jointly generated synergy savings may be critical in horizontal logistics collaboration (Thun, 2003).

A method to implement such allocation correctly is the Shapley Value method. The concept helps to assign the generated benefits (v(N)) fairly to the right company, where N is the coalition between all companies and N_i a specific company in the coalition. v(N) *is* based on the values v(S), in which v(S) is the subset of all possible coalitions (Cruijssen, 2004). The Shapley Value mainly focuses on the coalition of delivery itself, yet, overhead costs are often involved. In order to cover overhead costs, a pre-determined percentage of the savings are reserved for the company that provides the resources and overhead. That is known as the synergy claim, given by $p \in [0,1]$. The percentage should be determined on the level of activities that have to be done for the collaboration, such as extra sorting and providing resources. The calculation of the value for a certain collaboration S is given in the following formula (3.2):

$$\boldsymbol{v(S) = (1-p)\max\{\, \sum_{i \epsilon S} C_0(i) - C(S), 0 \,\}} \tag{3.2}$$

Here, $C_o(i)$ are the costs that a company *i* makes in their original situation. C(*S*) are the costs for cooperation between companies in coalition *S*. Calculating all the possible coalitions gives the possibility to determine a fair allocation of the costs, given by the following formula:

$$\emptyset_{\boldsymbol{i}}(\boldsymbol{v}) = \sum_{S \in N\{i\}} \frac{|\boldsymbol{S}|!(\boldsymbol{n}-|\boldsymbol{S}|-\mathbf{1})!}{\boldsymbol{n}!} \; (\boldsymbol{v}(\boldsymbol{S} \cup \{\boldsymbol{i}\}) - \boldsymbol{v}(\boldsymbol{S})) \tag{3.3}$$

The fair allocation of the Shapley Value method comes from the fairness properties that the concept possesses, namely:

1. Efficiency, this property of the Shapley Value ensures that the total value of the grand coalition is distributed among the players, i.e. no value is lost.
2. Symmetry, this means that two players that create the same additional value to any coalition receive the same share of the total value.
3. Dummy, this property states that players that do not contribute anything to any coalition except their individual value indeed receive exactly their individual value as a final share of the total value.
4. Monotonicity guarantees that if all of a player's marginal contributions increase, his payoff increases.

Cruijssen (2004) states that all these properties make perfect sense from a practical perspective. From these calculations a tariff per stop can be easily calculated, namely dividing the costs for a certain company ($\emptyset_{\boldsymbol{i}}(\boldsymbol{v})$**)** by the number of stops *n*. Giving the following formula (3.3) from Cruijssen (2004):

$$t_i^S = \frac{\emptyset_i(v)}{n} \tag{3.4}$$

This gives a fair and specific price for the stops for Company X, resulting in a higher chance of acceptance of the collaboration.

Conclusion on allocation of cost savings

Often allocations are not fair and on the long run no full advantage is obtained in collaborations, due to lack in trust and fairness. Cooperative game theory could form a solution for fair allocation of generated savings. An example of such a game is the Shapley Value method; this concept allocates the savings correctly. With that allocation a tariff per stop can easily be calculated.

3.6 Conclusion

This chapter introduces three types of scenarios in Horizontal Logistics Cooperation, namely: 1) Traditional situation, 2) Joint distribution within the current logistics, and 3) Optimization of the logistic structures. Optimizing the logistic structures is done by joint route planning, for which VRPTW is a suitable solution method. The best performing route construction heuristic for the VRPTW is Sequential Insertion Heuristic according to Bräysy and Gendreau (2005a). Since the initial solution is essential in the performance of the improvement heuristics, Savings Algorithm, Nearest Neighbor, and Minimal Insertion Costs are also used. The improvement heuristic that is able to escape from local optimum is Simulated Annealing. In collaborations it is essential that savings are allocated fairly, since the Shapley Value method is a good concept to allocate savings fairly, it is used in this research.

4 Solution design

This chapter discusses the modelling choices and the design of the solution method, and gives answers to the question ""How can the conceptual model be designed to obtain an optimal way of integrating the delivery processes?" The design is based on the literature from Chapter 3. To simplify the model, Section 4.1 introduces the assumptions. Section 4.2 explains the implementation of the theoretical aspects of the model, whereafter Section 4.3 explains how the data for the solution method is collected. The end of this chapter describes the conclusions (Section 4.4).

4.1 Assumptions

The processes in real life include a lot of small tasks that makes the processes complex to model. The influence of some tasks is minimal, therefore making assumptions simplifies the model. These assumptions are based on knowledge of employees and findings during the research.

1. Demand of a delivery address is given in weight, instead of pieces of mail.
2. The performance of sorting is based on average sorting speed per site, not specific per employee.
3. Route picking cannot start before all sorting for a specific subdepot is finished.
4. Unloading and internal transport is omitted.
5. All delivery points have the address of the postman that serves a specific district. If a district is vacant it is disregarded, since it is done by a Sandd employee from the site.
6. The distance in kilometers between two locations is equal in both directions, which is identical for the duration in minutes between locations.
7. Returns are not taken into account, since they have no influence on the routing structure.
8. The fleet exists of m identical vans with capacity Q.
9. The fleet can be extended by extra hired vans every single day.
10. Drivers are not allowed to drive more than 9 hours a day.
11. Extreme peak days, which occurs three or four times annually are excluded. These situation need an extra delivery day and would make the model unnecessarily complex.

4.2 Conceptual model

This section gives answer on the question "How can the solution design be described?". Based on the assumptions mentioned in Section 4.1, the model represents only the delivery process including release dates of the sorting and the route picking process. The solution design gives insight into the total transportation costs and helps to visualize the savings of the collaboration. To give good representation of the total costs, the research includes strategic scheduling and operational scheduling. Operational scheduling includes simulating the delivery process with the fluctuating demand and measures the robustness of the structures. This section explains the decisions for the modelling.

Strategic scheduling

To calculate the savings in the collaboration in this research, traditional situations that can function as a benchmark are needed. The strategic scheduling gives schedules for the scenarios. The scenarios from literature in our research are explained in Chapter 3 and are as follows:

1. The traditional situation without cooperation
2. Joint distribution within the current logistics structures
3. Optimization of the logistics structures based on the aggregated demand of both companies

The conceptual model for strategic scheduling focuses on the third scenario. The model includes construction and improvement heuristics to optimize the logistic structures of both companies.

The problem is defined in terms of a graph G = *(V,E)*, where V = {*v0, v1, v2 …vn*} is a set of vertices with v0 as depot. The model uses *m* identical vans with capacity *Q,* which is complemented with an unlimited pool of identical vans when restrictions are exceeded. The addresses with demand q_i are connected by vertices *E* = $\{(v_i,v_j) \mid v_i,v_j \in V, i \neq j\}$, with a distance matrix C = $\{c_{ij}\}$ and durations (t_{ij}) retrieved from the Google Distance Matrix API. The time windows are determined by the planning of the sorting process. The notation of the parameters for the VRPTW are as follows:

1. e_i : opening time window at customer i
2. l_i : closing time windows at customer i
3. s_i : service time at customer i
4. c_{ij} : distance from customer i to customer j
5. t_{ij} : travel time from customer i to customer j

During the construction and improvement phases, the solution should meet the following restrictions to become feasible:

1. Routes start and end at the depot
2. Each location is visited once
3. Mail is delivered within the time windows
4. Capacity restrictions are not exceeded
5. Sorting is finished before departure
6. Driving hours restrictions are not exceeded

In order to construct an initial solution, or schedule, the Sequential Insertion Heuristic (SIH), Savings Algorithm, Nearest Neighbour (NN) and Minimal Insertion Cost (MIC) are used. The construction of these initial solutions is done in two ways. First, by selecting addresses based on distances and based on durations. SIH starts a route with selecting the farthest delivery address(es) from the depot as seed. In case of ties, the address with the lowest allowed starting time becomes seed. The heuristics NN and MIC select the farthest or nearest address as seed, which are tested both. The Savings Algorithm selects the address for which the highest savings are generated. Further construction of the routes is done by assigning addresses to routes according to the heuristics policy. SIH selects the address that has the highest benefit of inserting that address into the route rather than using a direct route. In Figure 4.1, the process flow of SIH is shown. The other heuristics are logical and are essentially the same, except for the selection policy.

Each construction heuristic has a certain policy of selecting an address to insert into a specific route. The data that is used in that selection process, has influence on the final result. Usually, the selection process is based on mutual distances. However, durations are influenced by the type of route, which has influence on the solution, therefore, schedules based on durations are included.

The selection of seeds has influence on the performance of the heuristics. On some delivery days, a van has time left. In these cases, selecting the farthest address as seed result in inefficient routes, since no other addresses can be inserted due to time restrictions. Therefore, the model includes that the remaining time minus the duration of the selected address needs to be greater than 70 minutes. This decision is based upon the performance of approximately 6 stops per hour, which indicates that a stop takes on average 10 minutes and a route needs to include at least 8 stops (25% of average) to become more efficient.

After constructing the initial solutions, the improvement heuristics Simulated Annealing (SA), Steepest-descent and First-descent are used. These heuristics determine the strategic schedule for a certain delivery day.

During the improvement phase, neighbour solutions are generated by swapping or relocating addresses between or within routes. Figure 4.2 gives the flowchart of relocating addresses in or between routes. The selection of the addresses to swap or relocate is done randomly in SA. In the other heuristics, it is done by evaluating all neighbour solutions. Swapping addresses between routes is interesting, since most routes are close to the capacity restriction and therefore addresses cannot be relocated. This restriction prevents many potential swaps from being accepted. Reallocating addresses in routes can reduce the number of vans and routes, which can be interesting for improvements.

As mentioned in Section 3.4, release dates of the sorting processes play an important role in finding the best schedule. Therefore, this research includes two sub-scenarios that try to optimize the logistic structures by changing the release dates of certain addresses by adjusting the planning of the sorting process. These scenarios are explained in Chapter 5.

The model is programmed in Plant Simulation, which makes it possible to create offline schedules and simulate it in an online environment.

Operational scheduling
The simulation of the delivery process is possible by simulating the strategic schedule over a certain period of time. It gives the possibility to gain insight into the impact on logistic structures and makes it possible to measure the robustness of the strategic schedules. The fluctuation of weights can result in exceeding the capacity restriction, therefore, reallocation of delivery addresses is needed. If relocation into other routes is not possible due to restrictions, extra resources are needed, which increases total costs. The results of the simulation give a more accurate estimate of the total annual costs. These results are used as input for the Shapley Value method to calculate a fair price per stop per company, explained in Section 3.5. The decisions in the simulation are shown in Figure 4.3.

The combination of strategic and operational scheduling, enables to give a good indication of the expected costs of the collaboration with Company X. Chapter 5 explains all the different scenarios that are included in the solution method.

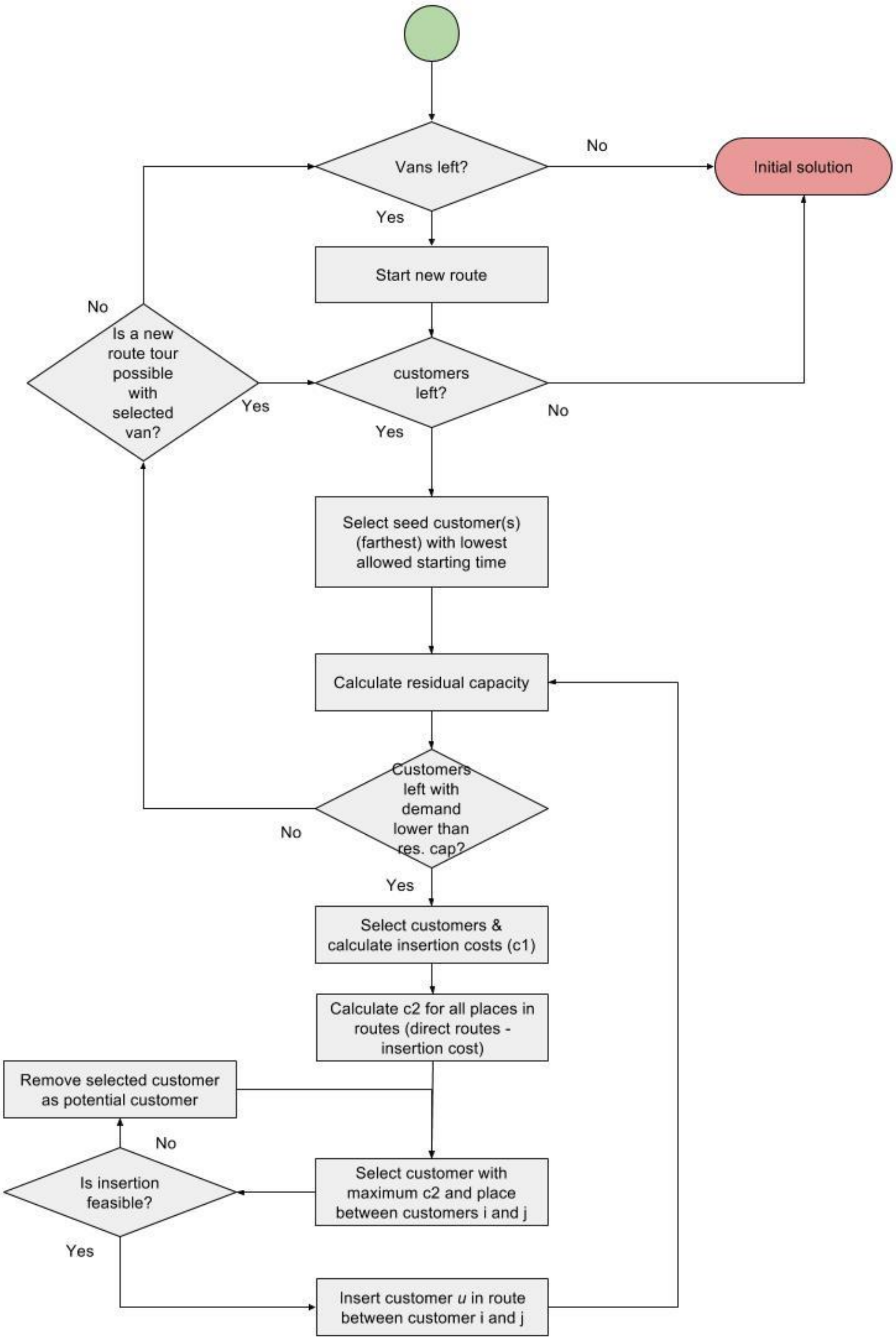


Figure 4.1: Flowchart Sequential Insertion Heuristic

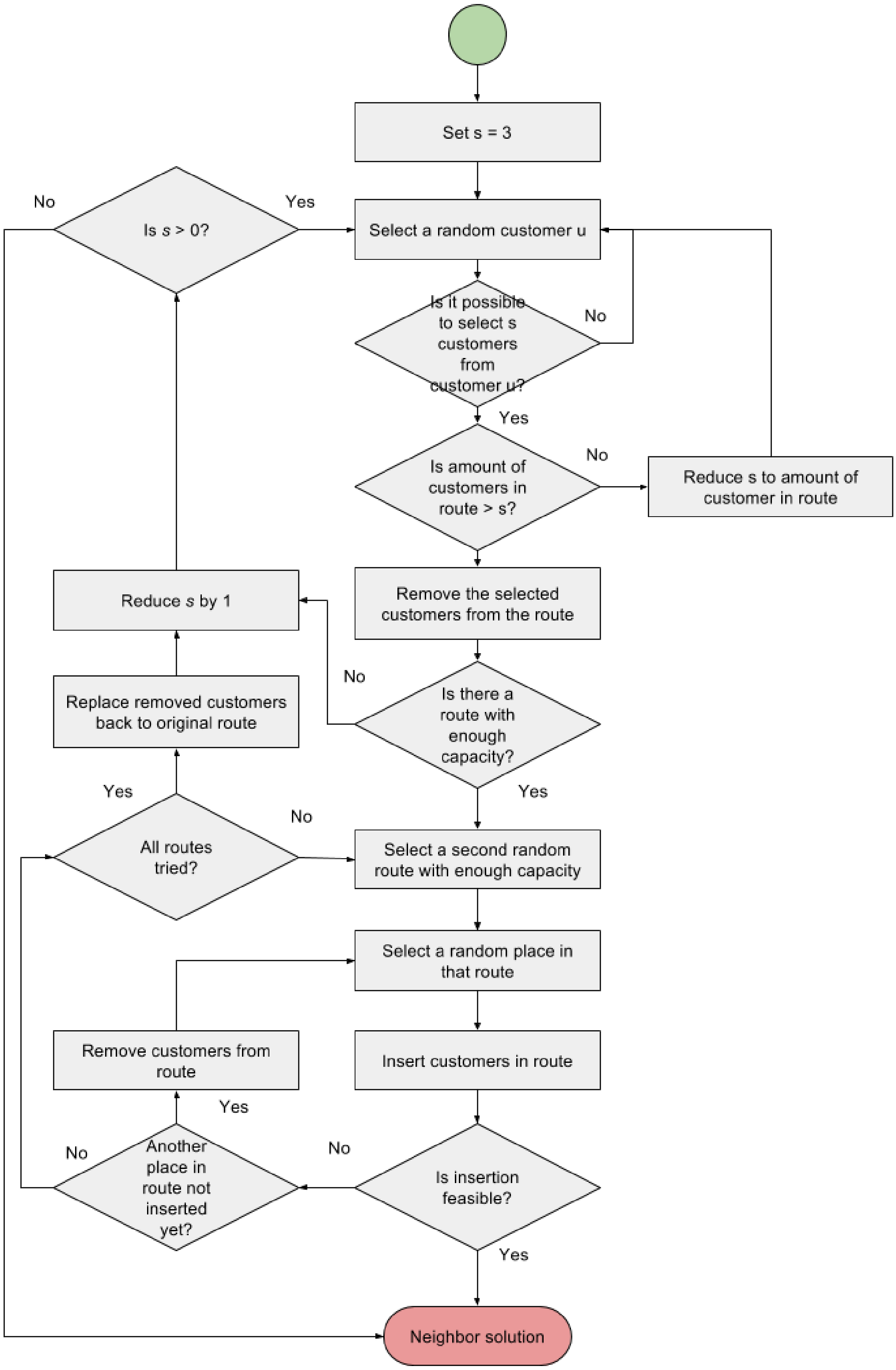


Figure 4.2: Flowchart of replacing customer(s) in between or within route

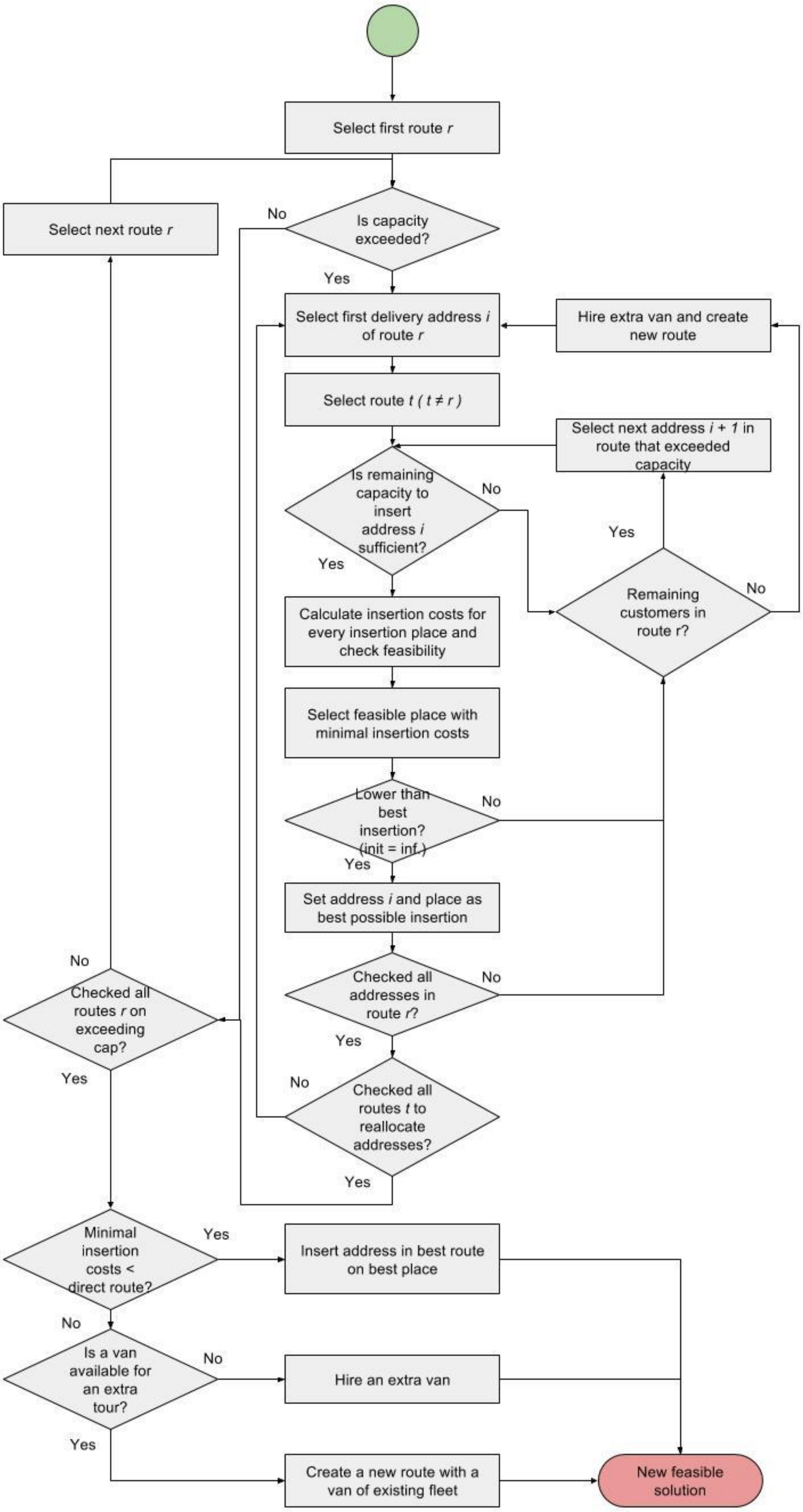


Figure 4.3: Reallocate addresses from routes that exceed capacity during operational scheduling

4.3 Data gathering

This section describes all data that is used as input for our model to run the simulation.

Network

The network in this research consists of addresses, represented by nodes, to which Sandd and Company X deliver their mail or products.

Distances

Each node in the graph G is connected by vertices. The costs of these vertices are expressed in distances and retrieved from the Google Maps API. It is assumed that these distances are equal in both directions, which might differ slightly in reality. All these distances together form a distance matrix with c_{ij}, which are the costs for the distance between locations *i* and *j*.

Durations

The Google Maps API also gives the possibility to retrieve the duration of travelling between two addresses, which gives t_{ij}. The Google Maps API calculates with the average speed of a car, which is comparable to the speed of Sandd's vans. For simplicity, it is assumed that the load of the vans has no influence on the speed.

Time windows

The opening of the time window (e_{ij}) is defined by the sorting process for the addresses of Sandd. The opening of the time windows for Company X is determined by the delivery of their products at the site. The closing times (l_{ij}) are the delivery deadline for both companies.

Demand

An important factor in the complexity of the problem is the fluctuating demand. In order to get a good estimate of the weights per delivery address of both companies, the corresponding distribution function with the historical data of a company is analysed. The data of Sandd shows that it fits the lognormal distribution function, which is explained in Appendix F. The datasets of Company X show that a normal and a lognormal distribution function both fits good. The lognormal distribution function fits good with the data of Sandd; therefore, the lognormal distribution function is also selected for Company X.

Fleet

Sandd prefers to use their own fleet for delivery, since hiring flex fleet is proven to be more expensive. Due to fluctuation in demand, it might be needed to hire extra resources on some days. The size of the flex fleet varies on a daily base, and depends on the demand for a specific day. The fixed fleet is determined by the strategic schedules.

Costs

The objective is to minimize the total costs of the delivery process and therefore, the focus in this research is on the total costs for delivery. The variable costs consist of the total distance driven, hours driven and costs for hiring the flex fleet. Drivers need to be hired at least 4 hours per day. Fixed costs are based on the fleet that Sandd owns.

4.4 Conclusions

This chapter describes the decisions made for modeling the solution method, and answers the question "How should the solution method be designed to obtain an optimal way of integrating both processes?".

Section 4.1 describes the assumptions made to simplify the modeling of the process. These assumptions result in a solution method that represents the main processes. As construction heuristics, Sequential Insertion Heuristic, Savings Algorithm, Nearest Neighbour, and Minimal Insertion Costs are used. As improvement heuristics, Simulated Annealing, Steepest-descent and First-descent are used. The improvement is done by finding neighbour solutions by swapping or relocating addresses between or within routes. Operational scheduling is including by a simulation model, this gives insight in the robustness of the schedules and represents the annual costs due to fluctuating weights. Section 4.3 explains the data that is used in the model. The demand of both companies fits the lognormal distribution function well, based on historical data.

5 Solution tests

This chapter elaborates on the experimental design (Section 5.1), gives the results and answers the question "What is the best way to collaborate in the delivery process of Sandd?". Section 5.2 describes the scenarios, followed by the experiments in Section 5.3. Section 5.4 elaborates on the validation of the data and verification of the model. Section 5.5 gives a description of the choices that are made in the scenarios and the results are discussed.

5.1 Experimental design

This section elaborates on the experiments and the parameters that are used in the scenarios. The objective of the experiments is to minimize costs, that consist of lease, fuel and labor costs. However, this collaboration also influences the performance indicators mentioned in Section 2.5. These performance indicators are:

1. Number of vans
2. Total travel time
3. Total travel distance
4. Number of tours
5. Average utilization
6. Stops per hour
7. Deliveries within Time Windows

The objective function is integrated in the optimization heuristics. Initially, SA is used as optimization heuristic. In SA, the initial solution does not have a big influence, since SA changes the initial solution randomly by accepting many possible neighbour solutions in the early stages. In this research, there are many restrictions and large sets of addresses. Therefore, SA needs many iterations to escape from the local optima and to find improvements on the initial solution.

To find improvements more quickly, local search heuristics are suitable in large-size problems. Consequently, two other optimization heuristics are included, namely First-descent and Steepest-descent. These heuristics are able to find improvements more quickly, yet they cannot escape from a local optimum. For those heuristics a good initial solution is more important, therefore the model included several construction heuristics.

Usually, the initial solution for SA is constructed randomly, however the size of the problem is too large and therefore, it is preferable to have an initial solution that is close to optimal. For that reason, the construction heuristics are used for the initial solutions. The selected construction heuristics are explained in Section 3.4 and a short overview is listed below:

1. Nearest Neighbour
2. Minimal insertion cost
3. Savings algorithm
4. Sequential Insertion Heuristic

The weight per delivery address in the construction phase is based on the lognormal distribution function and a certain chosen percentile. The percentile is the value where a certain percentage of scores falls below that percentile (grey area in Figure 5.1), indicated by *p*. Applying this on the routes, means that if all weights dedicated to a certain route are equal, or below the value corresponding to the percentile in their distribution function, the capacity restriction is not exceeded. The choice of *p* has direct influence on the total annual costs, since it influences the number of times routes need to be adjusted. Costs are increased by making detours or hiring extra resources. Choosing *p* is a trade-off between flexibility and costs.

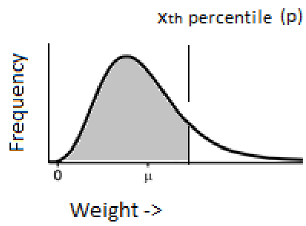


Figure 5.1: Percentile (p) on the lognormal distribution function

Two improvement operators are included in order to find neighbor solutions. These operators are able to find neighbour solutions within routes or between routes. By only using the swap operator, the heuristic is not able to remove routes, since in all cases the number of addresses in a route remains the same. Combining the operators makes it possible to eliminate routes. The improvement operators are:

1. Relocating addresses
2. Swapping addresses

For SA, several input parameters need to be determined, which is explained in Section 3.4. These parameters have to be set in such a way that the running time is acceptable. This research experiments with these parameters to improve the solution. Appendix J explains how the values of the parameters are determined. The parameters are:

1. Length Markov chain
2. Start temperature
3. Cooling factor
4. Stop temperature

5.2 Scenarios

This section introduces the sub-scenarios used in this research retrieved from the scenarios explained in Chapter 3. Those scenarios from literature are focused on collaborative logistics and are listed below:

1. The traditional situation without cooperation
2. Joint distribution within the current logistics structures
3. **Optimization of the logistics structures based on the aggregated demand of both companies**

The goal of this research is equal to what is stated in Scenario 3. This section introduces sub-scenarios of the third scenario and include the release dates of addresses determined by the sorting process, therefore these sub-scenarios are only subject to the days that Sandd transports. The other days are not influenced by these release dates. The sub-scenarios are listed and explained below.

1. Keep current subdepots and change sorting schedule of subdepots
2. Redesign subdepots based on optimization of routes

The results of these sub-scenarios depend on the input in the model. These input parameters function also as sub-scenarios and are listed below:

1. Number of schedules
2. Allocation of addresses

Change sorting schedule of subdepots

The first sub-scenario keeps the addresses assigned to the subdepots as original and changes the current sorting schedule. Benefits in the collaboration can be obtained by changing the sequence of the sorting schedule, since the logistic structures change due to the new locations of delivery addresses. Currently, Sandd has a fixed sorting schedule and the sorting process is able to meet certain deadlines per subdepot, which functions as release dates for departure of the routes. This scenario interchanges the subdepots in the sorting process and tries to obtain synergy between subdepots, meaning that routes can go across more subdepots. To interchange the subdepots, workloads of the subdepots need to be approximately equal. Figure 5.2 shows the workload per subdepot in percentage relative to the total workload. It shows that almost all workloads are approximately equal, except for subdepot TBR. That subdepot is more urban, which means more commercial mail is sent to that region. The capacity of the sorting process is very flexible, since Sandd is able to meet deadlines regardless of the weights. Therefore, it is assumed that subdepots are interchangeable and Sandd still meets the deadlines.

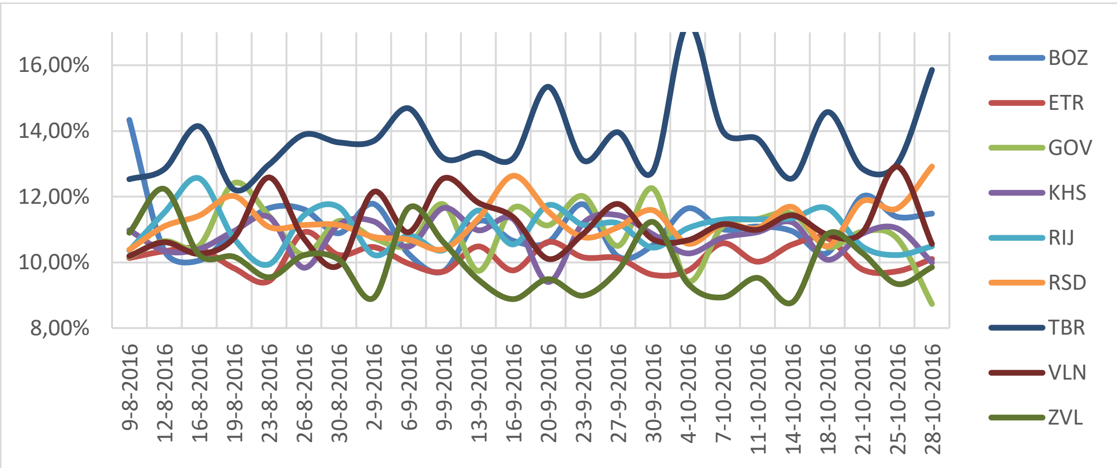


Figure 5.2: Percentage per subdepot of total weight delivered per day of the selected region.

Redesign subdepots

The second sub-scenario optimizes the delivery process by redesigning the subdepots. In this scenario the release dates of the addresses that Sandd has to deliver are determined during the construction phase by assigning the addresses to a certain subdepot with a specific release date. This results in addresses to insert into a route during the construction phase, since time windows are more flexible. The assumptions in this sub-scenario are that all subdepots have approximately the same workload, as explained above, and that it is equal if the number of districts in each subdepot falls between 138 and 158. These numbers are based on the current division of districts in the subdepots, as shown in Table 5.1.

Subdepot	# districts
BOZ	155
ETR	138
GOV	154
KHS	150
RIJ	155
RSD	156
TBR	158
VLN	155
ZVL	148

Table 5.1: Subdepots with number of districts

Number of schedules

An important parameter in applying these sub-scenarios is the choice of percentile *p*, as explained in Section 5.2. This parameter determines the weight per address for the construction phase. Figure 5.3 shows that the range of total weight to deliver is large, which indicates that how higher the selected percentile is, the more often there is remaining capacity in a route. On the other side, the number of times that the routes need to be adjusted is lower with a high percentile. This makes it an important trade-off. Currently, Sandd has a fixed logistics structure used on both delivery days. This collaboration makes it necessary to have different structures on each delivery day, since the number of stops on each day differs a lot.

Figure 5.3 shows that there are two peaks in the frequencies per delivery day, which indicates that one can have benefits of having two schedules for a specific delivery day. In practice it means that Sandd has to select a certain schedule, based on the expected weights to deliver on that day. The idea behind this approach is that the utilization of the vans increases, resulting in costs savings. Section 5.5 explains how to select the right percentiles.

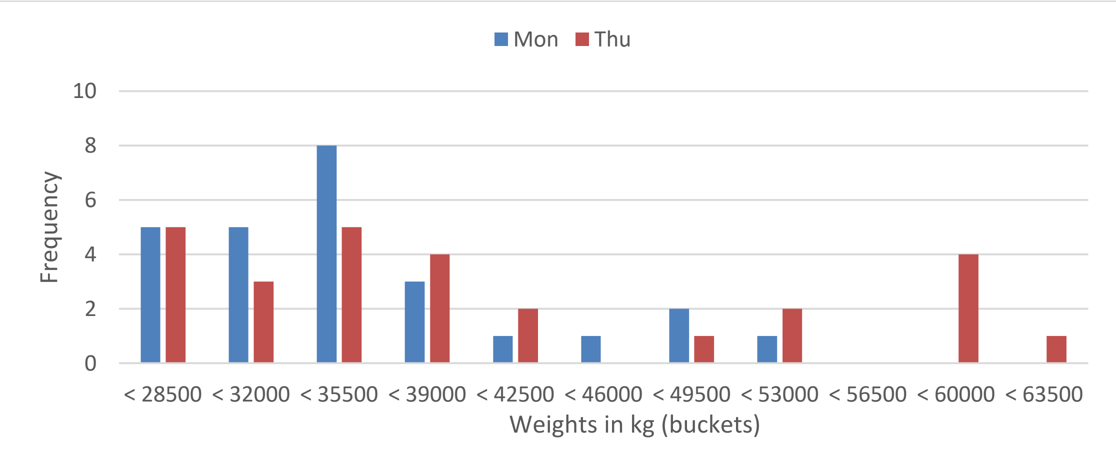
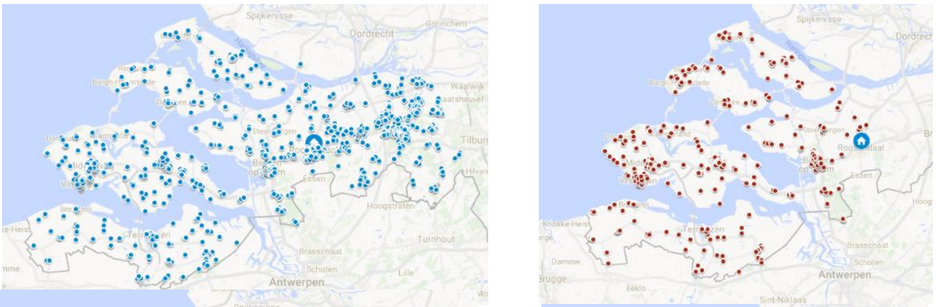


Figure 5.3: Frequency of total weight per day delivered in the selected region over a period of 6 months.

Allocation of addresses

The degree of synergy is highly influenced by the geographical location of the delivery addresses of both companies. To increase the synergy, the overlap of the delivery addresses of both companies should be close to 100%. The overlap of the region Roosendaal (Sandd) with the addresses of Company X based on zip codes is approximately 55%. This research aims on optimizing synergy and since Company X delivers their products nationally, a 100% overlap is included in this research. This geographical region can give insight in the potential of collaborating nationally. The 100% overlap is achieved by excluding the addresses of Sandd that have no geographical overlap with the addresses of Company X. Resulting in two geographical sub-scenarios in this research. The addresses of Sandd are shown in Figure 5.4 on the left and for Company X on the right. Combining these addresses results in the geographical sub-scenarios in Figure 5.5, defined as 'Roosendaal' and Geographical overlap (GO).



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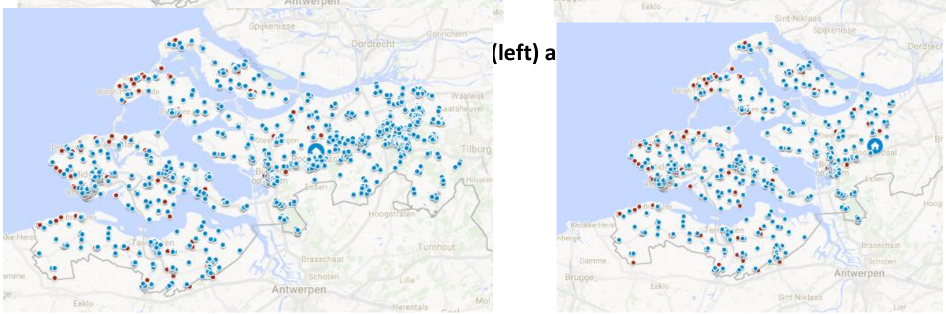

Figure 5.5: Geographical scenario Roosendaal (left) and Geographical overlap (right)

Since the number of addresses on the days only Company X is delivered is still marginal to the other days, this research includes another scenario in which an extra collaboration is introduced. This collaboration consists of a company that delivers products to certain addresses on Tuesday, Wednesday or Friday. Since this company is fictional, addresses are randomly selected from the addresses in the dataset of Sandd that have a geographical overlap with Company X.

The goal of this research is represented by several sub-scenarios of Scenario 3, which is recognized as `Optimization of the logistics structures based on the aggregated demand of both companies´. The two sub-scenarios that optimize the logistics structures are ´changing the sorting schedule´ and ´redesign of subdepots´ and the sub-scenarios that should result in a further optimization are 'Number of schedules' and 'Allocation of addresses'.

5.3 Experiments

Figure 5.6 shows all possible combinations of the sub-scenarios, explained in Section 5.2. The figure represents 'Scenario 3' in which each path leads to different results. The number of paths shows that there are many possible experiments. To reduce the number of experiments, the research is divided into phases to select the best performing heuristics.

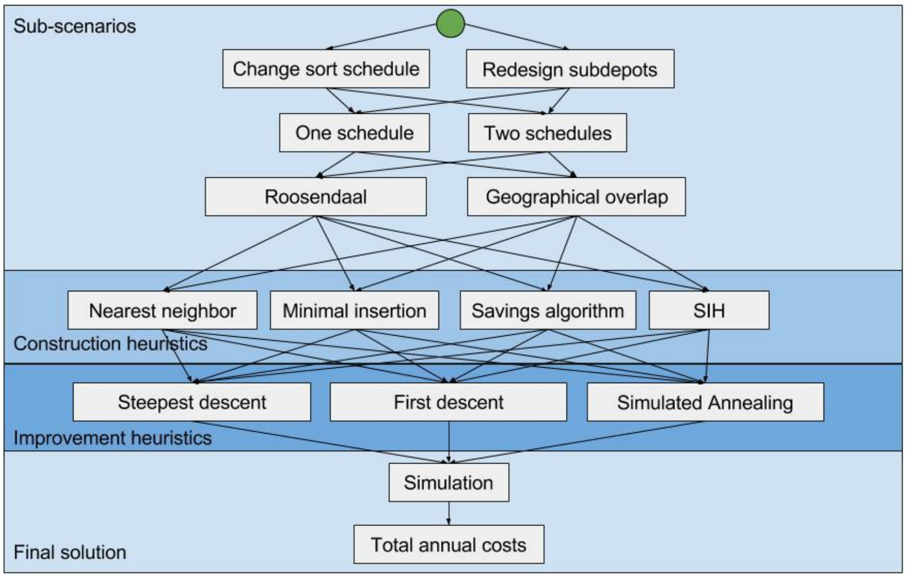

Figure 5.6: All possible paths for experiments

The first phase gives the performances of the construction heuristics. The performances are given on the combination of the sub-scenarios 'redesign of subdepots' on the geographical overlap, since this combination is expected to perform as best. The percentile is based on Sandd's current policy, which is the 75th percentile. The result represents routes for a Thursday, since that is the busiest delivery day and has the highest complexity. This represents the performance of the heuristics good and helps selecting the best heuristics.

Phase 2 compares the improvement heuristics with the initial solutions from Phase 1. Results help to select the best performing improvement heuristics, looking at running time of the algorithms and the improvement of the initial solution.

Phase 3 uses the best performing heuristics and explains choices made in the approaches 'changing sorting schedule' and 'redesign subdepots'. This phase compares the results of the heuristics on the different sub-scenarios and selects the best scenario to give a more extensive analysis of the operational performance of the solution. This analysis consists of creating schedules for all delivery days and use it for a simulation, which gives insight in the robustness and indication of the total annual costs. The Shapley Value method allocates these costs fairly over Sandd and Company X. To show the potential of synergy an extra scenario with another fictional collaborating company is included. This extra situation shows the potential of a better utilization of the vans on the days during a week.

5.4 Validation and verification

This section validates the data and verifies the model. Validation and verification is important to show that the results are reliable and represent reality.

Data validation makes sure that the data is correct and usable. It is the process of ensuring that the model is sufficiently accurate (Robinson, 1999). The model needs to give results that reflect reality, which is the reason for validation of the model. The validation compares the data from the Transport Management System (TMS) with the data in the model. The model uses data obtained from the Google Distance Matrix API, which is not exactly equal to the data used in TMS. Comparing the results of Sandd's current schedules gives an indication of the correctness of the data. Table 5.3 shows that the difference between the systems is 200 km over 45 routes, which is a difference of 4%. It is assumed that this difference is accurate enough, such that the data is correct. Comparing all mutual distances of the stops ensures the validity of the data. Table 5.3 also shows the differences between durations of both systems, which is also 4%. Remarkable is that the distance is lower in the solution and the duration is higher compared to the TMS, which is caused by the speed of a vehicle a system uses to calculate the durations. The data in the model is representative, since Google Maps is proven to be a reliable source. The mutual differences are small, which Appendix I shows by comparing each route.

Model	Distance	Duration
The research model	5392.2 km	174:55:10
TMS	5592.2 km	167:24:00
Difference	200 km	-7:31:01
%	4%	-4%

Table 5.2: Comparison between our model and TMS with the structure of Sandd

Verification of a model is the process to ensure the model design is right (Robinson, 1999). The model includes several checks to make sure that the model is correct and the output of the data is right.

The verification of the Simulated Annealing heuristic is done by comparing the shape of the results of the acceptance ratio. As explained in Section 3.4, the acceptance ratio needs to have the same shape as in Figure 3.4. Figure 5.7 shows that the SA heuristic has approximately the similar shape, which shows that in the beginning most neighbour solutions are accepted and when the temperature decreases, the number of accepted neighbour solutions decreases. That indicates that the parameters are set right, such that a reasonable number of iterations is done to find a good solution.

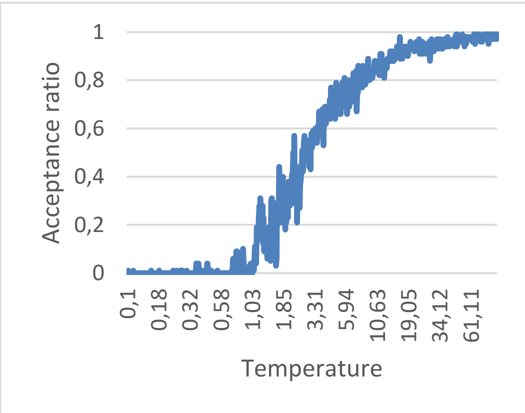

Figure 5.7: Acceptance ratio of a certain experiment in the Simulated Annealing heuristic

5.5 Results of experiments

This section discusses the results of the phases as mentioned Section 5.3. These phases determine the best possible integration of the logistics structures for both companies and give advice to improve the success of the collaboration in the final results.

Phase 1

Phase 1 selects the best performing construction heuristics. The performance indicators, number of vans and total estimated transportation costs, determine the performance of the construction heuristics, since these are the most important factors in this collaboration.

The costs for transportation consist of leasing, fuel and labor costs. Lease costs are based on the total distance per van per year. The costs for fuel are based on a fuel consumption of 1 liter per 8 kilometers. The wages for the drivers are determined by Sandd and paid per hour. The minimum number of hours paid per day per driver is 4 hours, even if less hours are driven and for hiring extra resources a higher rate is used.

Table 5.3 shows the results of the construction heuristic for the area with geographical overlap (GO). It shows that the Savings Algorithm and Sequential Insertion Heuristic perform well on the performance indicators 'number of vans' and on 'estimated transportation costs'. The other heuristics perform worse, which is caused by the fact that at the end of the construction phase the routes become very inefficient. The remaining addresses are spread, which results in long routes with few addresses and a higher number of vans. Phase 2 uses the Savings Algorithm and Sequential Insertion Heuristic to determine the performance of the improvement heuristics.

		KPIs	NN (closest seed)	MIC (closest seed)	NN (farthest seed)	MIC (farthest seed)	Savings	SIH
Geographical overlap	Distance	Number of vans	25	23	23	26	21	21
		Total travel time	159:30:01	174:22:47	179:35:29	193:49:27	159:13:51	158:19:58
		Total travel distance	6462	8047,118	8134,803	9305,36	6485,552	6677,067
		Number of tours	34	42	45	49	41	43
		Average utilization	91%	73%	68%	63%	73%	72%
		Stops / hour	5,9	5,4	5,3	4,9	5,9	6,0
		Estimated Costs	€ 4,176.31	€ 4,554.03	€ 4,647.81	€ 5,123.24	**€ 4,045.36**	**€ 4,056.27**
	Duration	Number of vans	25	23	24	23	21	21
		Total travel time	161:52:27	172:07:00	177:55:14	175:21:05	159:48:32	156:55:56
		Total travel distance	6701	8265,156	8177,72	8634,638	6791,432	7027,501
		Number of tours	35	42	45	44	41	44
		Average utilization	88%	73%	68%	70%	73%	70%
		Stops / hour	5,8	5,5	5,3	5,4	5,9	6,0
		Estimated Costs	€ 4,245.13	€ 4,546.86	€ 4,659.50	€ 4,646.34	**€ 4,094.56**	**€ 4,080.06**

Table 5.3: Results of the construction heuristics on a geographical overlap on a Thursday

Phase 2

This phase selects the best performing improvement heuristics based on running time of the algorithms and their improvements on the initial solution. The selected heuristics are Simulated Annealing, First-descent and Steepest-descent.

The heuristics are looking for neighbour solutions to improve their current solution. These neighbour solutions are created by using neighbour operators as explained in Section 3.4. For SA, the stops to swap are chosen randomly and the other two heuristics enumerate all neighbour solutions until their selection procedure is satisfied.

The speed of the algorithms improves by reducing the size of the evaluated neighbourhood. The set of moves can be limited to only those that are likely to lead to a better solution, therefore the heuristic does not allow proposed moves with a distance between the stop to swap and its new predecessor is over 60 kilometers. It is based on the average distance of routes in Sandd's current solution, which are approximately 120 kilometers. If a route contains one address, the distance from site to that address is on average 60 kilometers. Therefore, it is assumed that addresses farther than that do not lead to more efficient routes.

Each optimization runs for 15 minutes to compare the performance of the heuristics. Table 5.4 shows the results of the improvement heuristics on the initial solution constructed by the Savings Algorithm on GO. The figure shows that the improvement heuristics do not find large improvements on the initial situation, which is caused by the long runtime per iteration. Due to the long runtime, caused by programming limitations, the number of iterations for SA is limited. This makes it hard for the algorithm to explore the search space and exploit the visited better solutions. The other heuristics are able to find improvements, since they only accept better solutions. Despite the potential of SA, it is excluded due to time restrictions in this research. The next phase uses the heuristics Steepest-descent and First-descent for the final results.

	Move	Swap	Initial solution	SA	Steepest-descent	First-descent
Estimated Costs	50%	50%	€ 4,045.36	€ 4,045.36	€ 4,014.01	€ 4,011.01

Table 5.4: Results of the improvement heuristics on the area with geographical overlap on a Thursday

Phase 3

This phase explains the choices that are made in the two sub-scenarios 'changing sorting schedule' and 'redesign of subdepots' and describes the selection of the percentiles for the sub-scenario with two schedules.

The sub-scenario 'changing the sorting schedule' tries to increase the synergy by changing the sequence of subdepots in the sorting process. This sequence determines the release dates of the routes and time windows of the addresses. To increase the synergy, the time windows of the addresses of both companies need to be approximately equal. Figure 5.8 shows that the addresses of Company X are located on the left hand side of the site and have a time window from 8:00 until 14:30. To obtain synergy in this area, it is preferable to give the overlapping addresses of Sandd equal time windows. In Figure 5.8 each color represents a subdepot of

Sandd with its current release date of the sorting process (see legend). There are many possible combinations with 9 subdepots and 6 deadlines, therefore the number of combinations is reduced by making some assumptions. The subdepots without geographical overlap (RIJ, TBR, ETR and RSD) are sorted at last, which are the release dates 14:00 and 13:00. ETR gets 14:00, since this subdepot has the least synergy potential. It reduces the problem to 5 subdepots with 4 deadlines, which results in 60 unique combinations.

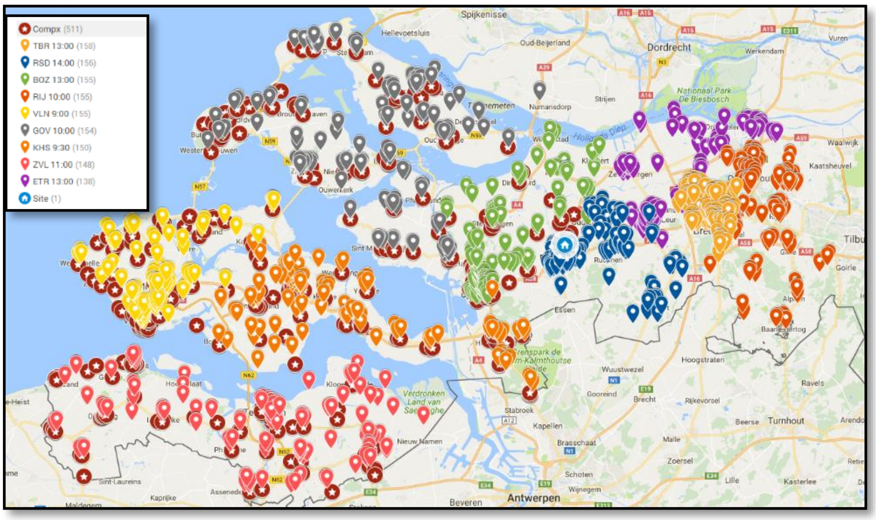

Figure 5.8: Delivery addresses of Sandd and Company X in the region Roosendaal. Each color represents a subdepot of Sandd.

The second sub-scenario is a 'total redesign of the subdepots' as explained in Section 5.2. In this heuristic the earliest departure time, or release date, is 9:00:00, since that is the earliest possible finish time of a subdepot. It is not preferred to construct routes that depart before a subdepot is finished, since no synergy can be obtained in that way. If the address to insert is a Sandd address, this address is assigned to the subdepot with finishing time 9:00:00. When the maximum number of addresses for a subdepot is reached, the next earliest possible starting time is selected. The subdepots after the construction phase need to contain at least 138 delivery addresses and at most 158. The number of subdepots the geographical overlap uses is reduced to 5, since 5 subdepots have overlap with the addresses of Company X.

Section 5.2 explains that including two schedules per delivery day could decrease annual costs due to a large range of weights. The idea is that each schedule intercepts a peak, which is introduced per peak as a ´low´ weight schedule and a ´high´ weight schedule. Each peak corresponds to a certain percentile select on the frequency that falls below that boundary. Monday with low weights that peak corresponds to the 67^{th} percentile, since 67% of the scores fall below 39,000 kilogram. Resulting in high weights corresponding to the 90^{th} percentile, and for Thursday in respectively, the 63^{rd} and the 95^{th} percentile.

Table 5.5 shows the estimated costs for the two schedules with the corresponding percentiles using the best performing heuristics. The results indicate that costs can be saved, however the lower the percentile, the more often the high weight needs to be used. A simple calculation shows that the cost savings are minimal. For example, on 100 different Thursdays, on average 63 times the low weight schedule is used, 32 times (95 – 63) the high weight schedule, and 5 times a schedule with even higher costs. Resulting in minimum average costs per Thursday of

€4,060.90 (0.63*€3,879.58 + 0.37*€4,369.64). Comparing this with the current solution with the 75th percentile and assuming that the costs of the high weight schedule are representative for adjusting, routes it results in a cost improvement of approximately €40.- per Thursday ((0.75 * €4011,01 + 0.25* €4369.64) - €4,060.90). This small reduction cannot compensate the increased complexity in planning and flexibility of employees, therefore it is not included the final results.

	Monday			Thursday		
	Current	**Low weights**	**High weights**	**Current**	**Low weights**	**High weights**
Percentile	75th	67th	90th	75th	63th	95th
#vans	16	16	18	21	20	22
Total time	125:30:48	120:58:23	140:50:12	157:17:22	153:56:13	170:58:23
Total distance	5134	4733	6264	6457	6106	7298
#tours	32	31	42	41	40	48
stops / hour	7.5	7.8	6.7	6.0	6.1	5.5
Est. costs	€ 3,173.64	€ 3,049.47	€ 3,628.51	€ 4,011.01	€ 3,879.58	€ 4,369.64

Table 5.5: Results on performance indicators using more schedules for a specific day.

The simulation uses the schedule constructed by the best performing heuristics in this research and gives insight in the expected annual transportation costs. The simulation runs 100 times to make reliable conclusions. One simulation represents exactly one year, which is 52 weeks. The weight per district per day in the simulation is based on the districts average percentage of the total weight from the historical data, which helps to prevent the portfolio effect. The total weight to deliver per day for the whole region is generated with the distribution function (lognormal) and the corresponding parameters μ and σ. The assumption that each delivery day only Company X needs to be delivered is the same, reduces the number of calculations, since one calculation represents three days. Appendix L confirms that these days are approximately equal by showing that the three days have similar addresses to deliver per day.

Final results

In order to optimize the logistics structures, the best performing heuristics are used to calculate the performance of the sub-scenarios. The remaining sub-scenarios are 'changing sorting schedule' and 'redesign of subdepots' in the geographical sub-scenarios Roosendaal and GO. A simulation gives insight in the expected annual transportation costs and the Shapley Value allocates the generated savings.

To visualize the improvement of the collaboration, a benchmark is needed, which in this case is the total costs of the initial situation (Scenario 1 from Chapter 3). Figure 5.8 shows the total costs per day for delivery for both companies in the traditional situation. The total costs include overhead, handling and transportation. Table 5.6 shows the total costs per week for both companies with the current price per stop. It is remarkable that the price per stop for GO is higher than for Roosendaal, since the allocation of the site is less optimal in GO. This results in less efficient routes and therefore results in higher costs. The costs for handling and overhead in GO are reduced in ratio with the stops in that region relative to Roosendaal.

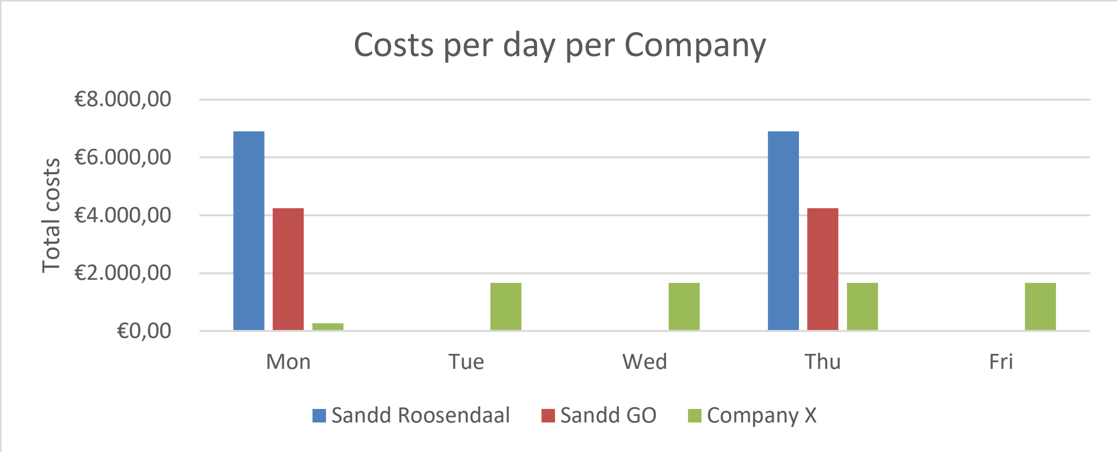

Figure 5.9: Daily costs for delivery in the traditional situation (Scenario 1)

Traditional situation			
	Sandd Roosendaal	**Sandd GO**	**Company X**
# stops per week	2708	1506	895
Price / stop	€ 5.10	€ 5.64	€ 7.72
Total	€ 13,809.74	€ 8,489.88	€ 6,910.48

Total weekly and annual costs for collaboration		
	Weekly	**Annual**
Scenario 1 Roosendaal	€ 20,720.22	€ 1,081,002.96
Scenario 1 GO	€ 15,400.36	€ 808,122.55

Table 5.6: Weekly costs for transportation in the traditional situation (Scenario 1)

The goal of this research is to optimize synergy by experimenting with different sub-scenarios. The results of the sub-scenarios ‘Change sorting schedule’ and ‘Redesign subdepots’ on the geographical sub-scenarios are given in Table 5.7, which represent the expected annual costs based on the simulation. Only the transportation costs are subject to change, since the costs for handling and overhead in this research are fixed. The best results are obtained from the sub-scenario ‘redesign subdepots’, since this sub-scenario is subject to less restrictions than ‘changing the sorting schedule’.

Scenario 3: optimization of structures				
	Change sorting schedule		**Redesign subdepots**	
	Roosendaal	**Geographical overlap**	**Roosendaal**	**Geographical overlap**
Handling	€ 126,059.99	€ 42,115.62	€ 126,059.99	€ 42,115.62
Transport	€ 908,362.36	€ 660,632.53	€ 815,054.44	€ 629,785.03
Overhead	€ 66,000.00	€ 36,677.49	€ 66,000.00	€ 36,677.49
Total annual cost (est.)	€1,100,422.35	€ 739,425.64	€ 1,007,114.42	€ 708,578.14

Table 5.7: Annual costs for collaboration after optimization (Scenario 3)

Table 5.8 shows the improvement of the collaboration on both geographical sub-scenarios relatively to the traditional situation. The results show that cooperating results in cost savings of approximately €99,544.- (12.3%) in GO and €73,888.- (7.6%) in Roosendaal. According to these results, it can be concluded that with a higher overlap the savings in percentage will increase.

	Roosendaal	Geographical overlap
Scenario 1	€ 1,081,002.96	€ 808,122.55
Scenario Redesign subdepots	€ 1,007,114.42	€ 708,578.14
Cost savings	€ 73,888.54	€ 99,544.41
Improvement	7.6%	12.3%

Table 5.8: Differences in total annual costs after optimization relative to the traditional situation.

As explained in literature, these savings need to be fairly allocated to enhance the success of the collaboration. By using the Shapley Value method, the costs are fairly allocated to the two parties in the collaboration, based on their marginal contribution. Table 5.9 shows the results of the calculation using the Shapley Value method. The price per stop improves in Roosendaal with €0,27 (5%) for Sandd and €0,78 (10%) for Company X and in GO with €0,64 (11%) for Sandd and €1,06 (14%) for Company X.

Shapley Value method				
	Roosendaal		Geographical overlap	
	Sandd	Company X	Sandd	Company X
Scenario 1	€ 718,106.36	€ 362,896.60	€ 445,225.95	€ 362,896.60
Marginal contribution	€ 644,217.82	€ 289,008.06	€ 345,681.54	€ 263,352.20
Costs per company	€ 681,162.09	€ 325,952.33	€ 395,453.74	€ 313,124.40
Price / stop (new)	€ 4.83	€ 6.94	€ 5.05	€ 6.66
Price / stop (old)	€ 5.10	€ 7.72	€ 5.69	€ 7.72
Improvement	5%	10%	11%	14%

Table 5.9: Results of the Shapley Value using redesign of subdepots

The improvements per stop show the potential of the synergy in this collaboration. The improvements for both companies on the price per stop is higher and are closer to each other, since the ratio of stops of both companies are more equal. The ratio of stops in Roosendaal is approximately 1 on 3 for Company X and Sandd relative to 1 on 1.5 in GO.

Table 5.10 shows an example of the usage of the fleet in the collaboration per day in the region GO. The peak of the number of vans that are needed on Thursday determines the size of the fleet, which results in remaining capacity on the other days. This peak limits the benefits of the collaboration on the other days, since the costs for the fleet count per day. Figure 5.11 shows the distribution of the costs and shows that the costs for the fleet are equal on all days. However, the percentage of the costs of the fleet is higher on the days less addresses are delivered, which is reflected in the price per stop per day. It declares the small savings in the region Roosendaal, since the difference in number of vans needed per day is large.

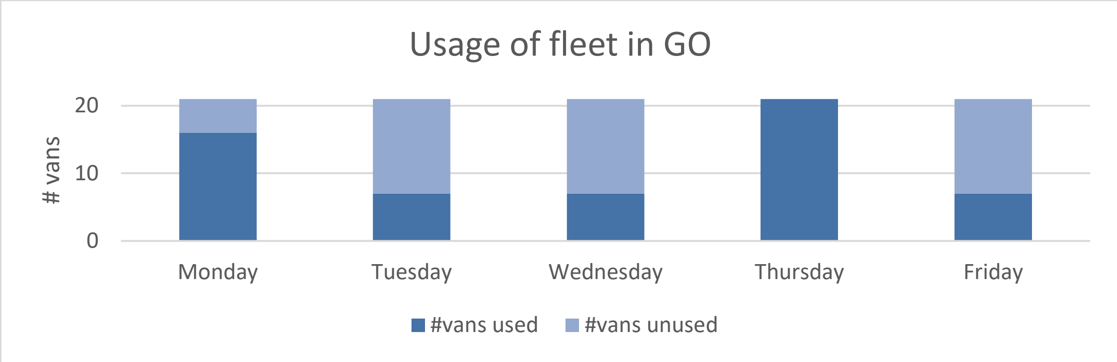

Figure 5.10: Usage of the fleet per day in GO

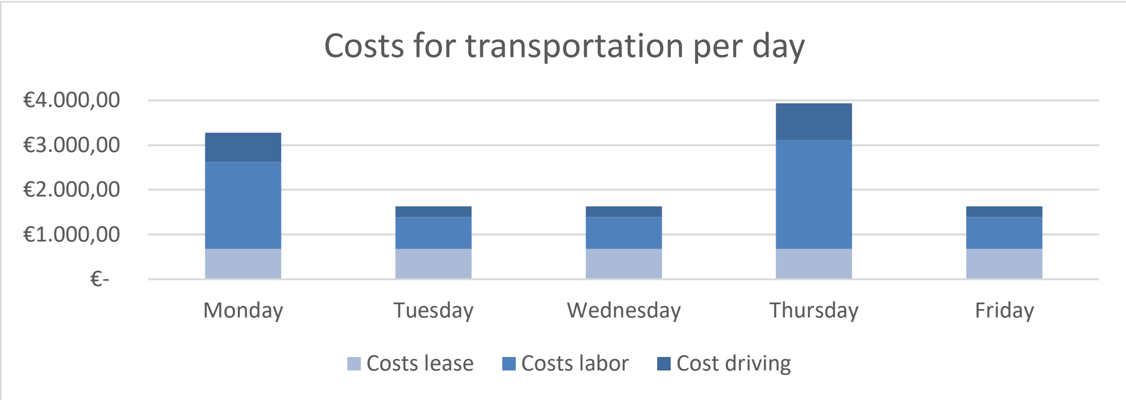

Figure 5.11: Daily costs for divided over the costs factors

The collaboration of Sandd and Company X results in a total saving of approximately €100.000,- annually in the region GO. This collaboration has impact on the process, which is shown with the performance indicators discussed in Chapter 1. Table 5.10 shows the results of the performance indicators in the collaboration for the region GO. It is clear that the total distance and travel time increases due to the collaboration. However, an important measure in the efficiency of the routes is the performance indicator ‘stops per hour’. This performance indicator is on Monday and Thursday on average higher than the current situation, which indicates a more efficient delivery process. Due to the less efficient routes on Tuesday, Wednesday and Friday, the average performance per week is less.

Chapter 3 mentions that the robustness of a schedule is an important factor. Figure 5.11 shows the average number of times a specific route is adjusted during a year, which represents robustness of the routes. The schedule in the graph is a Thursday from the sub-scenario ‘Redesign of subdepots’ in GO, the best result in the research. Many routes are adjusted often, with a maximum of approximately 10 times per year and indicates that the schedule is not very robust. However, the costs for extra resources are included in the total annual costs using the simulation. This schedule shows the best results on costs per year. Therefore, no further research is done on improvement of the robustness of the schedule.

Performance on KPIs						
In collaboration						
KPIs	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Weekly**
Number of vans	16	7	7	21	7	21
Total travel time	122:51:19	44:48:00	44:48:00	150:52:31	44:48:00	408:07:50
Total travel distance	4957	1821	1821	6029	1821	16449
Number of tours	31	10	10	40	10	101
Average utilization	71%	91%	91%	77%	91%	84%
Stops / hour	6.3	4.8	4.8	6.3	4.8	5.4
Estimated Costs for transport	€ 3,279.38	€ 1,633.34	€ 1,633.34	€ 3,931.86	€ 1,633.34	€ 12,111.25

Table 5.10: Performance on the KPIs

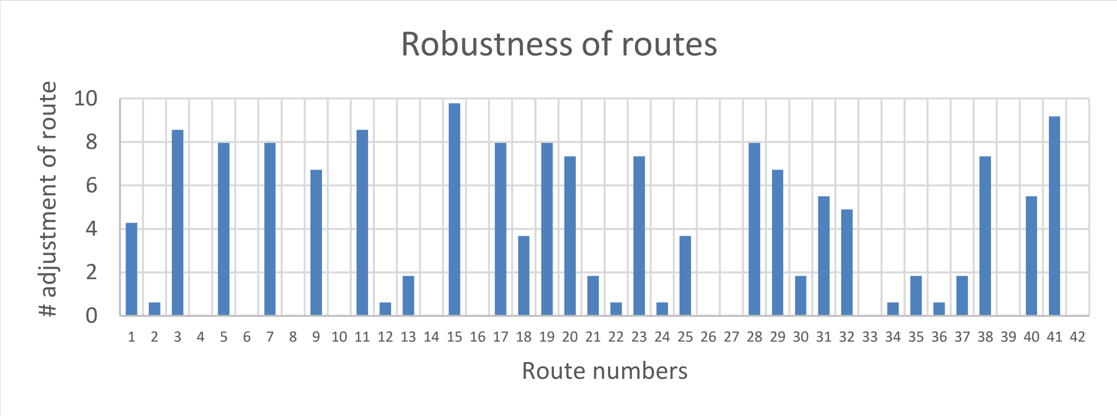

Figure 5.12: Number of times routes are adjusted on average per year of a specific schedule

Results of the sub-scenarios				
	Change sorting schedule		Redesign Subdepots	
	Roosendaal	**Geographical overlap**	**Roosendaal**	**Geographical overlap**
Scenario 1	€ 1,081,002.96	€ 808,122.55	€ 1,081,002.96	€ 808,122.55
# stops	187920	125312	187920	125312
Total costs collaboration	€1,100,422.35	€ 739,425.64	€ 1,007,114.42	€ 708,578.14
Total savings	-€19,413.39	68,696.91	€ 73,888.54	€ 99,544.41
Price / stop Sandd	€ 5.16	€ 5.25	€ 4.83	€ 5.05
Price / stop Company X	€ 7.93	€ 6.99	€ 6.94	€ 6.66
# vans fleet	32	25	30	21

Table 5.11: Results of the sub-scenarios

Sandd can obtain major cost savings when collaborating with Company X. However, Sandd can make the collaboration more attractive for Company X by assigning more savings to this company, since this collaboration is good opportunity to improve collaborations with other companies. By doing this, the chance of acceptance of Company X increases. By taking the current costs for delivery and assigning the savings to Company X a stop price for Company X of €5,68 can be obtained. However, Sandd needs to get some benefits of this collaboration, therefore, Figure 5.13 shows the possible prices per stop in order to cover the costs of this collaboration for the region GO. Figure 5.14 shows the results for Roosendaal.

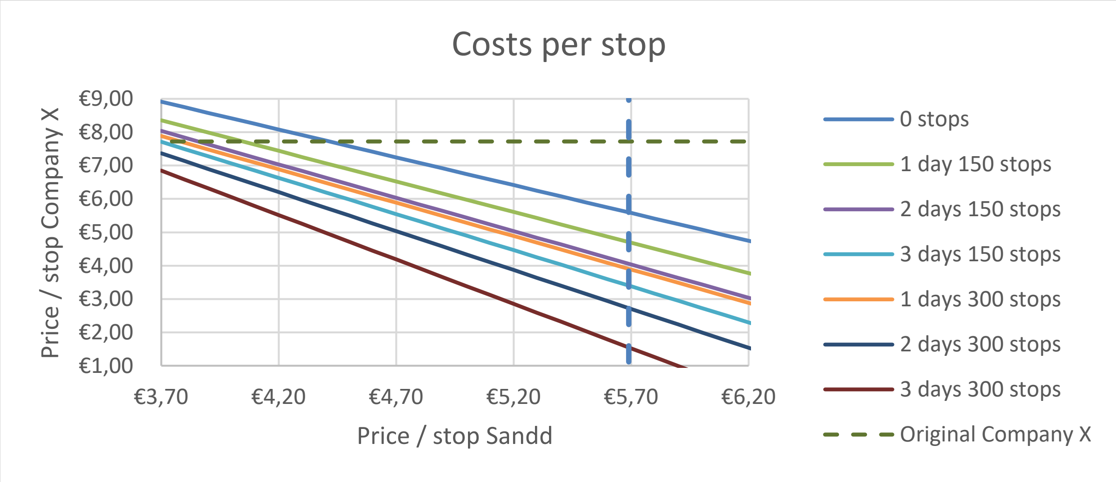

Figure 5.13: Prices per stop

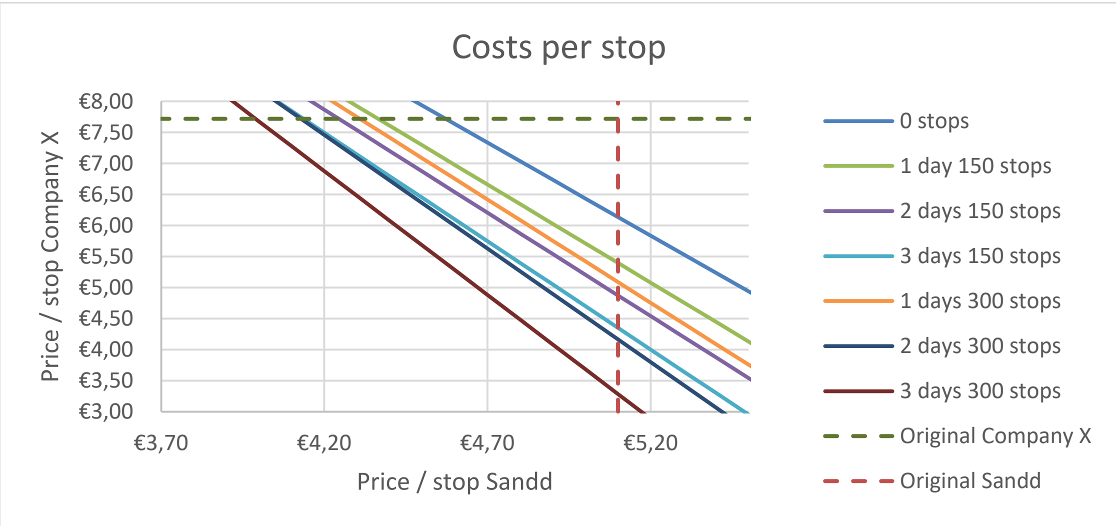

Figure 5.14: Prices per stop by covering the total costs

Influence third collaboration

In the collaboration of Sandd and Company X, only 7 vans are used on the delivery days of Company X (Tuesday, Wednesday, and Friday). Hence, this results in 23 vans in Roosendaal and 14 vans in GO that are not used on these days as shown in Figure 5.10. Therefore, an extra collaboration on these days can result in extra synergy benefits by using the remaining capacity. To investigate a potential third company in the collaboration, extra scenarios with delivery addresses on the mentioned days are included. This company is represented by a new proposition of Sandd, in which it is assumed that they deliver products to addresses that have a geographical overlap with the addresses of Company X. The addresses are randomly selected from the dataset of addresses that Sandd delivers on Thursday, since these addresses are equally distributed.

To investigate this extra collaboration, six new scenarios are created. These scenarios consist of 150 or 300 extra addresses on Tuesday, Wednesday, Friday or combinations of these days. These extra scenarios are shown in Table 5.12, where a distinction is made between 150 and 300 extra stops in combination with stops on 1, 2, or 3 days. The costs per stop of the new proposition are based on the traditional price per stop of Sandd, which are used in the benchmark. Table 5.12 shows that when there are 150 extra stops on one day a week, the savings are approximately €140,333.95 (16.5%) per year, indicating that with 7800 stops extra per year, savings increase with approximately €40.000,-. It shows that after establishing the initial collaboration the savings grow faster.

Results on scenarios in extra collaboration							
Stops	**0**	**150**			**300**		
Days		**1**	**2**	**3**	**1**	**2**	**3**
Scenario 1	€ 808,122.55	€ 851,615,35	€ 895,108.15	€ 938,600.95	€ 891,130.15	€ 974,137.75	€ 1,057,145.35
# stops	125312	133112	140912	148712	140912	156512	172112
Total costs collaboration	€ 708,578.14	€ 711,281.40	€ 725,018.85	€ 738,756.31	€ 717,969.80	€ 751,399.80	€ 784,829.80
Savings	€ 99,544.41	€ 140,333.95	€ 170,089.30	€ 199,844.64	€ 173,160.35	€ 222,737.95	€ 272,315.55
Price / stop Sandd	€5.05	€ 4.82	€ 4.69	€ 4.58	€ 4.67	€ 4.51	€ 4.39
Price / stop Company X	€ 6.66	€ 6.23	€ 5.91	€ 5.60	€ 5.88	€ 5.35	€ 4.82

Table 5.12: Results of the extra collaboration on geographical overlap

5.6 Conclusions

This chapter describes the results of the experiments on our solution method and answers the question "What is the best way to collaborate in the delivery process of Sandd?".

Section 5.2 describes the sub-scenarios 'Changing sorting schedule', 'redesign of subdepots', using two schedules on a delivery day, and using two different geographical datasets. The assumption that the workload in all subdepots is equal, is essential for the construction heuristics.

Section 5.4 describes that there is a small difference in the data of the system of Sandd and the model, it is assumed that these differences can be ignored. Section 5.5 shows that the best performing construction heuristics are Sequential Insertion Heuristic and Savings Algorithm. The best performing improvement heuristics are Steepest-descent and First-descent, in our research. The scenario of using two schedules has not much influence on the total costs, since the savings do not outweigh the extra costs for the planning department. The best results are obtained by the 'redesign of subdepots' with annual improvement of €73.888,54 (Roosendaal) and €99.544,41 (GO). The improvement on the price per stop using the Shapley Value method are 6,8% (Sandd) and 12,3% (Company X).

The number of vans needed on the busiest day has much influence on the total costs, therefore, extra scenarios with 150 or 300 extra addresses on Tuesday, Wednesday or/and Friday are included. Results show that further collaboration obtain savings easily, since a collaboration with 150 addresses extra on 1 day a week results in extra savings of €40,000.- annually.

Sandd can consider to assign a part of the cost savings to Company X. If Sandd assigns all cost savings to Company X, it can result in a minimum price in the geographical overlap of €5,68 per stop for Company X, instead of €6,66.

6 Conclusion and recommendations

The first section (6.1) of this chapter summarizes the research questions, followed by a short description of the findings during. In addition to that, the conclusions are given. Section 6.2 elaborates on the limitations of the research. Section 6.3 gives recommendations for improvements whereafter in Section 6.4 the suggestions for further research are discussed.

6.1 Conclusions

As mentioned in Chapter 1, the goal of this research is to give insight in the results of a collaboration between Sandd and Company X, focusing on collaborative logistics. According to the problem statement from Section 1.3, the following research question is constructed:

"What is the most efficient way for Sandd to integrate the delivery processes of Company X to maximize synergy benefits and allocate savings fairly?"

By analyzing the current situations of both collaborating companies, it can be concluded that Company X and Sandd deliver comparable products in the same regions which results in a possibility to integrate. Furthermore, an important factor in scheduling of the routes is the sorting process of Sandd, which determines the release dates. To be able to meet certain deadlines in the sorting process, regions of Sandd are divided in subdepots, containing a certain number of districts. The region that is investigated in this research is Roosendaal (Zeeland), which is divided into 9 subdepots and contains approximately 1369 districts. The mail of Sandd is delivered on two days per week, therefore, the vans of Sandd drive twice a week (Monday and Thursday). Since the mail market is decreasing, the urge to expand the services of Sandd arises. A possibility to expand their service is to collaborate horizontally with Company X, which delivers on all days per week.

Literature shows that important advantages in Horizontal Logistics Collaboration are economies of scale, growth and obtaining cost savings. Cruijssen and Salomon (2006) introduce a three phase model to efficiently establish a collaboration, consisting of; 1) the selection of suitable partners, 2) the process of estimating the savings, and 3) a fair allocation of the savings. In addition to that, they have described three scenarios to compare the results in Phase 3, namely; 1) the traditional situation without cooperation, 2) joint distribution with the current logistic structures, and 3) optimization of the logistic structures based on the aggregated demand of both companies. The focus of this research is on the third scenario, by implementing a Vehicle Routing Problem with Time Windows (VRPTW) in the solutions method. For this VRPTW, the construction heuristics Sequential Insertion Heuristic and Savings Algorithm showed the best performance of the problem. The Steepest-descent and First-descent showed the best results in the improvement phase.

One of the most important factors in the success of a collaboration is the allocation of the savings. The Shapley Value method has the best characteristics to allocate the generated savings fairly, since it allocates the savings based on marginal contributions.

Since the sorting process of Sandd has a major influence on the construction of the schedules, two sub-scenarios to optimize the integration of these processes are introduced. The first sub-scenario optimizes the schedules by changing the sorting schedule, while keeping the current subdepots. The second sub-scenario optimizes the schedule by redesigning the subdepots based on the construction heuristics. The results include two geographical regions, Roosendaal and a geographical overlap (GO), since a 100% overlap (GO) gives insight in the possibilities to expand the collaboration nationally. In GO, the number of addresses of Sandd is reduced to the addresses that have a 100% overlap with Company X.

The sub-scenario 'redesign of subdepots' has in both geographical regions the best performance. The results in Figure 6.1 show annual savings of approximately €75,000.- (Roosendaal) and €100,000.- (GO) in the collaboration between Sandd and Company X. The costs in this calculation consist of handling, transportation, and overhead costs. The Shapley Value method shows, according to its fairness, an improvement of 5% (Sandd) and 10% (Company X) in price per stop. In GO, it results in an improvement of 11% (Sandd) and 16% (Company X).

Result of scenario Redesign Subdepots

Geographical scenario	Roosendaal	Geographical overlap
Costs Scenario 1	€ 1,081,002.96	€ 808,122.55
#stops	187920	125312
Costs collaboration	€ 1,007,114.42	€ 708,578.14
Total savings	€ 73,888.54	€ 99,544.41
% savings	6,8 %	12,3 %
Price / stop Sandd	€ 4.83	€ 5.05
Price / stop Company X	€ 6.94	€ 6.66
#vans fleet	30	21

Figure 6.1: Final results of the collaboration

The results of an extra collaboration (with a third party, next to Company X), which makes use of the fleet on the days only Company X delivers, show that the degree of synergy increases fast after establishing the initial collaboration. Results show that the savings increase by approximately €40.000,- annually if a company is included with 150 stops on 1 day per week. This gives Sandd the opportunity to offer competitive prices for other companies that want to collaborate.

The answer on the main question is that a redesign of the subdepots is needed in combination with a 100% overlap with the addresses of Company X. This research shows that a redesign of the subdepots with a 100% geographical overlap gives the best results. The improvement of €100.000 annually results in an improvement of 11% (Sandd) and 16% (Company X) on price per stop. Based on these results, it can be concluded that Company X is a good candidate to collaborate with. The savings of this collaboration are in the beginning marginal, yet, by attracting other companies (third or even fourth parties), the savings can increase a lot.

6.2 Limitations

Due to the complexity of the problem, there are some limitations in the research. To create a model within sufficient time, assumptions are made to simplify the modelling process. These assumptions have influence on the quality of the results and, therefore, they can differ from reality. This section elaborates on the effects and consequences of these limitations.

The first limitation is that include only weights are included in our delivery process, while normally volume is also a constraint. For the mail of Sandd itself, it is not directly a problem, yet for Company X the size of the products are not known. 80% of their products are delivered in crates, yet, the other 20% can be different, which can cause problems.

The second limitation is focused on the travelling of the vans. An important cost factor is excluded, are the costs for damage. In this collaboration the number of driving hours and kilometers increases, and since it is expected that these costs for damage are correlated with the travelled distance, it has a direct influence on the costs for delivery and changes the outcomes. Another important factor in transportation are the delays caused by traffic jams or other delays, such as road constructions. The solutions in this research do not include these factors, since durations and distances between delivery addresses are static. This can result in in driving at certain locations where often traffic jams occur and has an influence on the delivery performance. The distances in our matrix are assumed to be equal in both directions, which in reality is not always the case, since it is never exactly equal. Due to the time and the possibility of obtaining that data, only one direction is included.

A third limitation is the usage of historical data of a timespan of one year, since it is known that the number in the mail market decrease. Therefore, the data in this research does not represent the future exactly. However, starting a collaboration becomes even interesting if numbers are decreasing fast. Another limitation in the research is the reliability of the historical data of Company X. The data is over a period of 4 weeks, which includes only 4 records per day to calculate the parameters for the simulation. One can argue the reliability of this dataset and period, yet Company X was not able to share more data.

Another limitation in our research is the location of the site in the geographical overlap. Due to adjusting the region Roosendaal to GO, the location of the site is not optimal and influences the costs. These limitation can be taken into account in further research.

6.3 Recommendations

A recommendation for Sandd is to implement a redesign of their subdepots if they want to calculate the cost savings in a collaboration. In the calculation of the benefits of a collaboration, they need to use the right data and corresponding distribution functions, such as more data from Company X.

To make collaborations more successful, it is important that all factors are included in the analysis of the collaboration. If for example two companies collaborate and a third company is interested in collaborating, Sandd should present the new costs savings to all collaborating companies and not take the benefits for themselves. Giving all parties in a collaboration insight in the costs improves the collaboration on the long term.

The model is able to redesign subdepots, yet TMS is not able to do that, therefore a recommendation is to implement such a function in the system. This enables Sandd to give insight in the savings of possible collaborations with potential companies faster. Using a certain format for each collaboration, only some parameters are needed to determine the possibilities of a collaboration. In addition to that, Sandd needs to further develop a fair allocation method to ensure the trust in a collaboration.

6.4 Further research

The complexity of the delivery process at a postal company is shown in this research. Many factors have influence on the delivery process, such as the sorting process and the release dates of subdepots. To model such complex situations, a lot of assumptions are needed, however it still gives a good representation of the reality. The results show the possibilities of collaborations, which Sandd probably needs in the future. The analysis of such collaborations can be improved by including aspects that are excluded in this research. This section describes the aspects that can be included in further research.

Our results show that a full geographical overlap has clear benefits on the savings in a collaboration, therefore, it is interesting to include more addresses of Company X until it has a full overlap with Roosendaal. In that way the whole region 'Roosendaal' can obtain the potential of the synergy. That new situation is expected to have larger improvements, since the location of the site is more optimal.

Continuing on the location of the site, it is interesting for Sandd to do research on the location of their site. If Sandd collaborates with other companies, the optimal location of the site can change, therefore it is interesting to de research on the location of the site, or even on the size of the regions of Sandd.

A bottleneck in the total savings is the number of vans that is needed on the busiest day, namely Thursday. The number of vans is much higher than the number of vans that is used on the days that only Company X delivers, therefore, the potential of the initial collaboration is minimized. It is interesting for Sandd to do research on the possibilities to reduces the volumes on Thursdays, which reduces the number of vans and improves the results on the collaboration. An example is; offering customers of Sandd or Company X discounts if they change from delivery day. Another way to improve the collaboration is increase the utilization by collaborating on days with remaining capacity.

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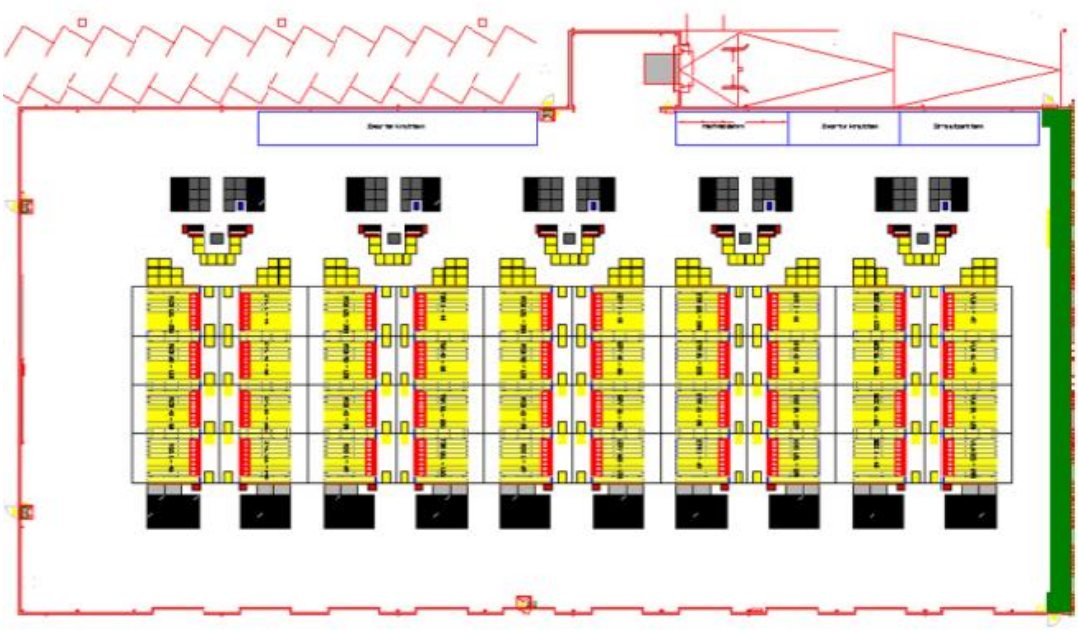
Appendix

A. Statistical analysis of the delivery data of weights at Sandd

Average	75,5 kg
Standard error	0,05 kg
Median	71,9 kg
Mode	80 kg
Standaarddeviation	24,1 kg
Sample variance	581,6 kg
Kurtosis	3,7
Symmetry	1,1
Range	381,3 kg
Minimum	10,8 kg
Maximum	392,2 kg
Sum	16264750
Amount	215286
Confidence level(95,0%)	0,101875

B. Map of a site



C. Products of the Company X

Products	Percentage	Deadline
Magazines	80%	14.30
Goods Pick & Pack (For example Hallmark displays)		18.00
Sealpackages (Packages that don't fit in a crate)		18.00
Packages (Packages from other customers)		18.00
Newspapers (International)		6.00
Crates (Green: regular, Blue: ZZG (medicines))		14.30
Carton boxes		14.30
Ugglies (bags with products that do not fit in crates)		14.30
Buckets		14.30

D. Mathematical formulation

Objective function

$$\boldsymbol{Min} = \sum_{k\epsilon V}\sum_{i\epsilon N}\sum_{j\epsilon N} c_{ij}x_{ijk}$$

Variables

e_i *earliest arrival time at customer i*
l_i *latest arrival time at customer i*
s_i *service time at customer i*
t_{ij} *travel time from customer i to customer j*
d_{ik} *departure of vehicle k from the depot*
fs_i *finishing of sorting process for customer i*
q_i *demand of customer i*
c_{ij} *costs traveling from customer i to customer j*
s_{ik} *time vehicle k starts to service customer i*

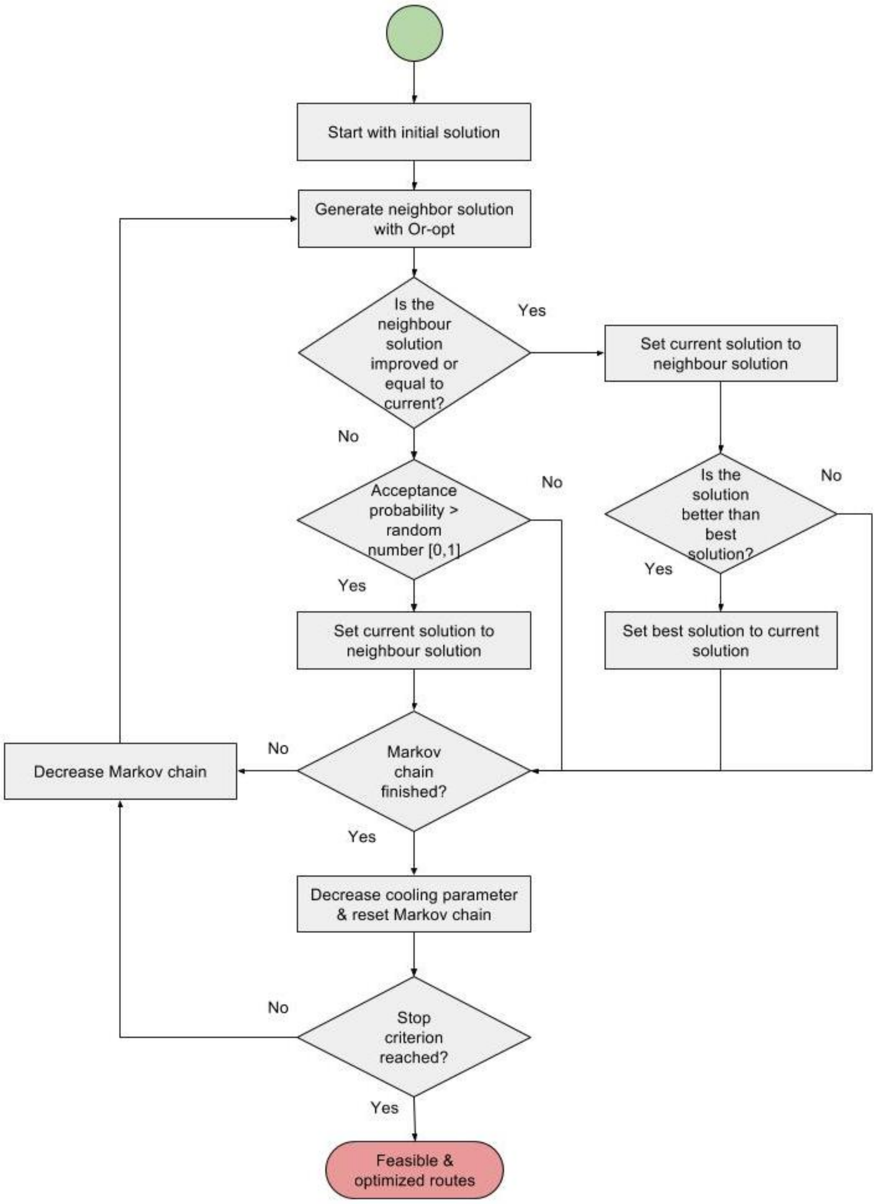
Constraints

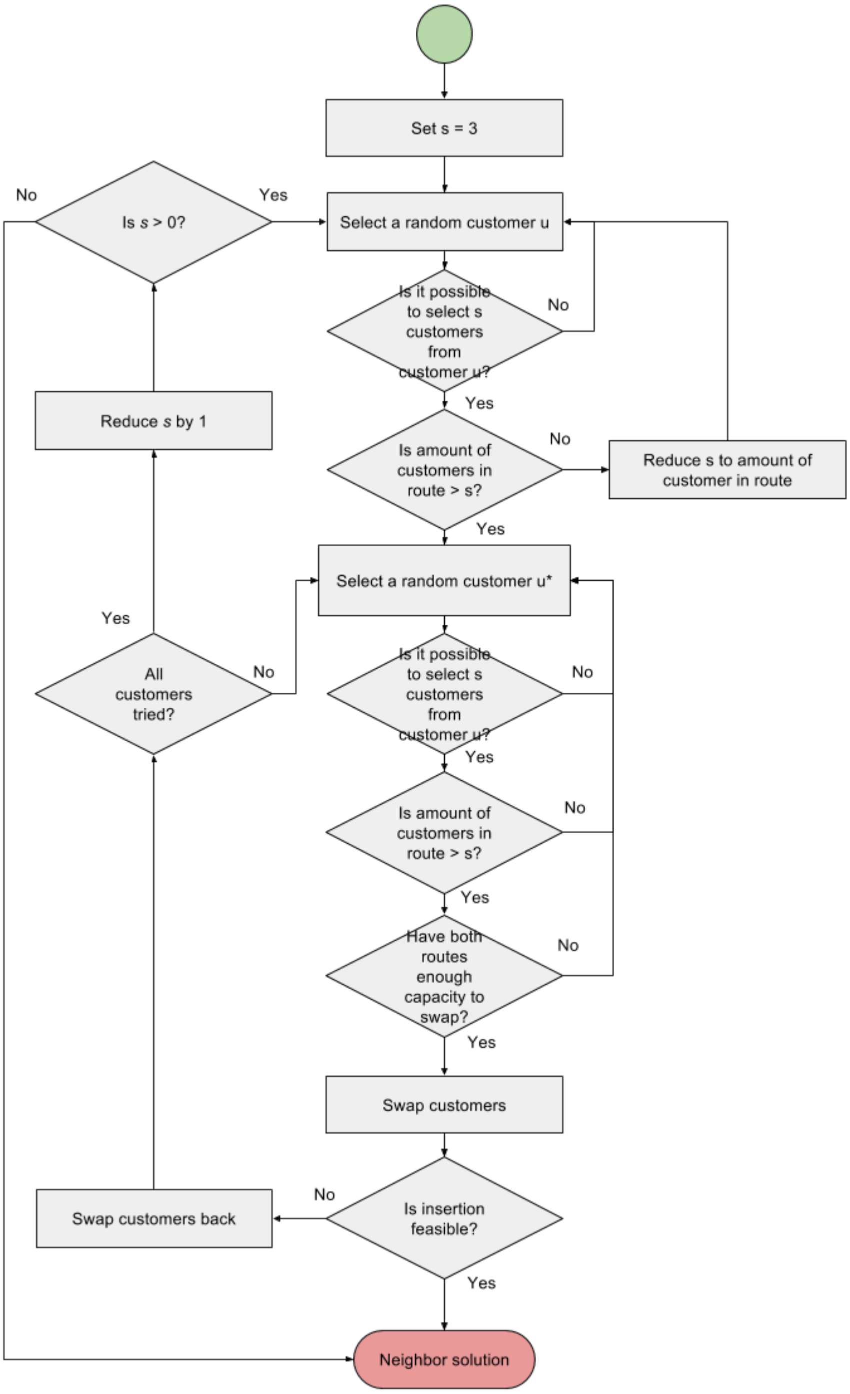
$\sum_{k\epsilon V}\sum_{j\epsilon N} \boldsymbol{x_{ijk}} = \boldsymbol{1},\ \forall \boldsymbol{i} \in \boldsymbol{C}$ Each customer visited exactly ones

$\sum_{i\epsilon C} \boldsymbol{q_i} \sum_{j\epsilon N} \boldsymbol{x_{ijk}} \leq \boldsymbol{q},\ \forall \boldsymbol{k} \in \boldsymbol{V}$ No vehicle exceeds capacity

$\sum_{j \epsilon N} \boldsymbol{x_{0jk}} = \mathbf{1},\ \forall \boldsymbol{k} \in \boldsymbol{V}$	Vehicle leaves depot
$\sum_{i \epsilon N} \boldsymbol{x_{ihk}} - \sum_{j \epsilon N} \boldsymbol{x_{hjk}} = \mathbf{0},\ \forall \boldsymbol{h} \in \boldsymbol{C},\ \forall \boldsymbol{k} \in \boldsymbol{V}$	After arriving the vehicle leaves the customer
$\sum_{i \epsilon N} \boldsymbol{x_{i,n+1,k}} = \mathbf{1},\ \forall \boldsymbol{k} \in \boldsymbol{V}$	Vehicle arrives at depot again
$\boldsymbol{s_{ik}} + \boldsymbol{t_{ij}} - \boldsymbol{K}(\mathbf{1} - \boldsymbol{x_{ijk}}) \leq \boldsymbol{s_{jk}}, \forall \boldsymbol{i}, \boldsymbol{j} \in \boldsymbol{N}, \forall \boldsymbol{k} \in \boldsymbol{V}$	Vehicle cannot arrive at customer j before $s_{ik} + t_{ij}$
$\boldsymbol{e_i} \leq \boldsymbol{s_{ik}} \leq \boldsymbol{l_i}, \forall \boldsymbol{i} \in \boldsymbol{N}, \forall \boldsymbol{k} \in \boldsymbol{V}$	Service is within time windows
$\boldsymbol{x_{ijk}} \in \{\mathbf{0}, \mathbf{1}\}, \forall \boldsymbol{i}, \boldsymbol{j} \in \boldsymbol{N}, \forall \boldsymbol{k} \in \boldsymbol{V}$	Integrality constraint

E. Flowchart Simulated Annealing

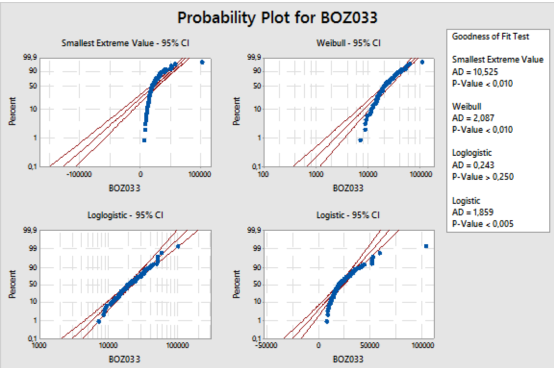


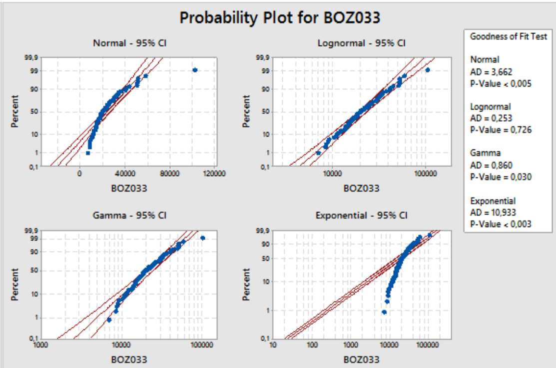

Set s = 3
Select a random customer u
Is it possible to select s customers from customer u?
No
Yes
Is amount of customers in route > s?
No
Reduce s to amount of customer in route
Yes
Is s > 0?
No
Yes
Reduce s by 1
Select a random customer u*
Yes
All customers tried?
No
Is it possible to select s customers from customer u?
No
Yes
Is amount of customers in route > s?
No
Yes
Have both routes enough capacity to swap?
No
Yes
Swap customers
Is insertion feasible?
No
Swap customers back
Yes
Neighbor solution

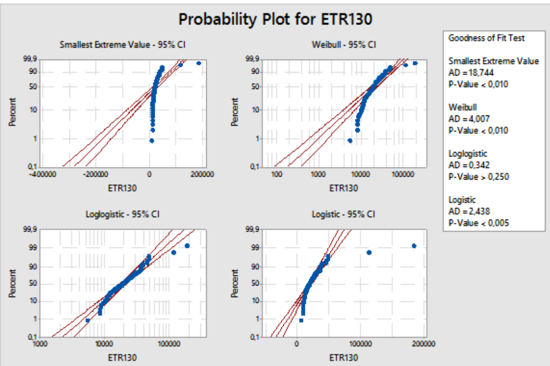
F. Probability plots data Sandd

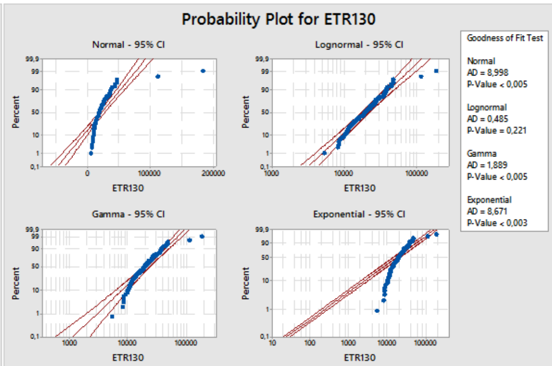
To find the corresponding distribution function for the data of Sandd, the historical data of random selected delivery address over different distribution functions that are available in Plant Simulation are plotted, with a 95% confidence interval (CI). In the probability plots it is shown that 4 of the functions have a P-value above 0,05, which is the minimum, since a 95%-CI is used for this research, therefore, they are most likely to fit the data. To decide which fits best, a few more delivery addresses are plotted, which are shown in Appendix 8.7. It shows that the lognormal-distribution is the best fitting function in all these datasets, since the P-value is always the highest. Knowing that the lognormal-distribution function fits well, μ and σ can be calculated per district based on the historical data. The same was done for the data of Company X in Appendix 8.8.

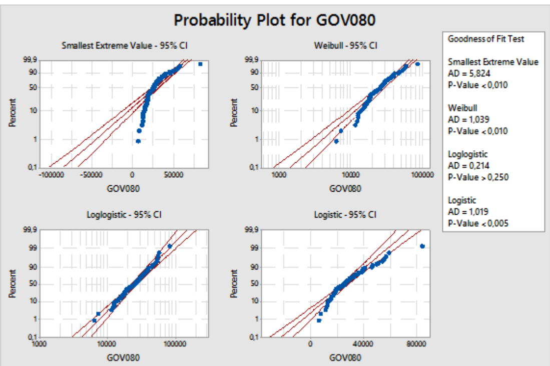
Probability plots of historical data of Sandd

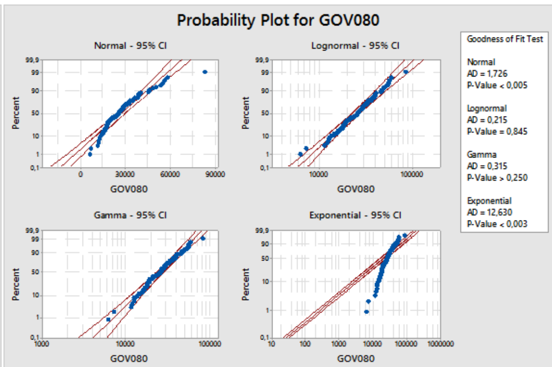


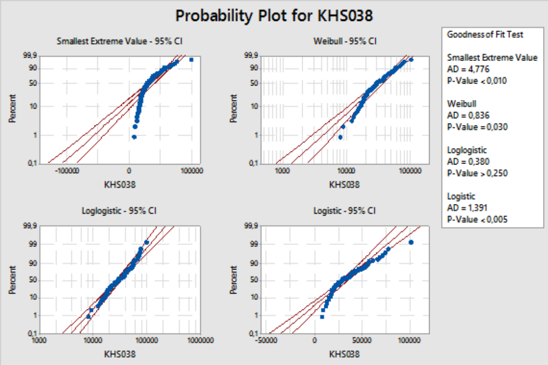


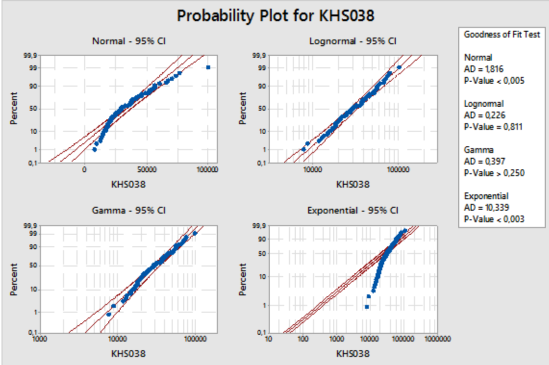


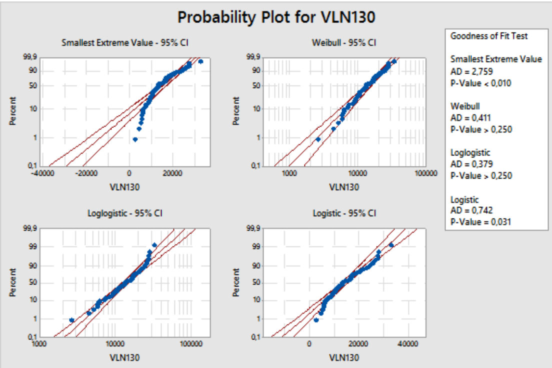


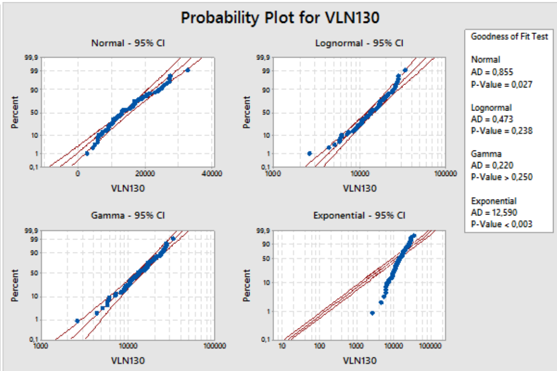




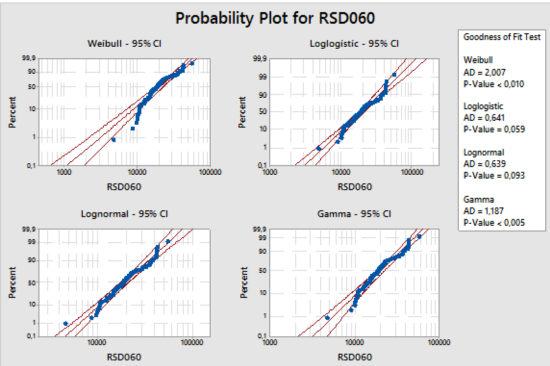


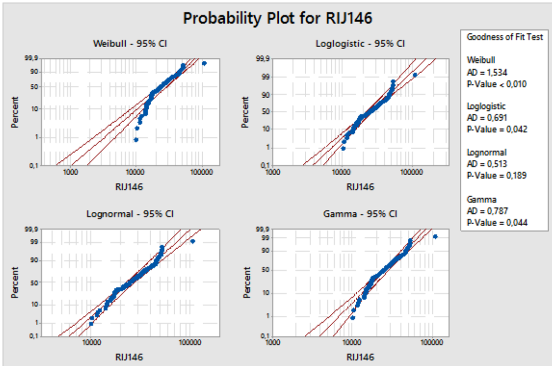


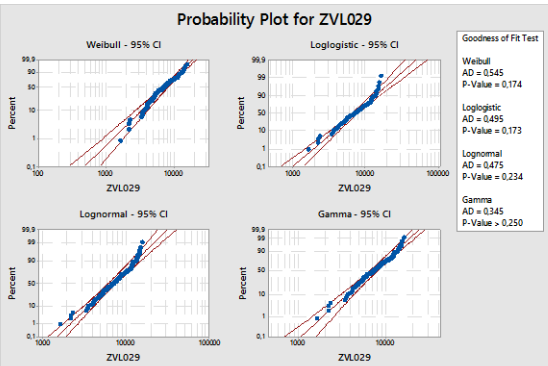


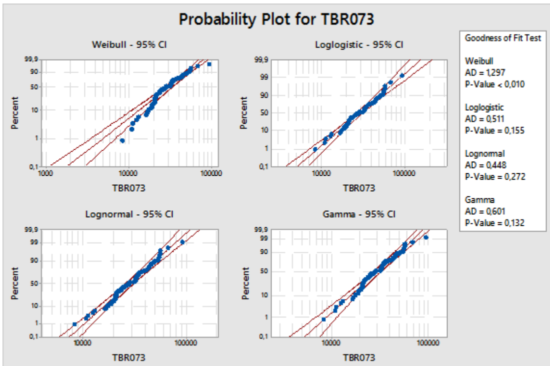


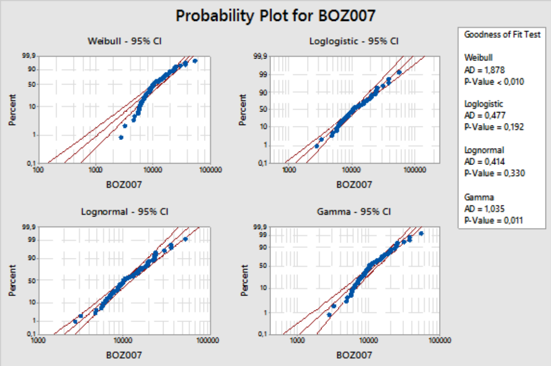
G. Probability plots relevant distribution functions Sandd

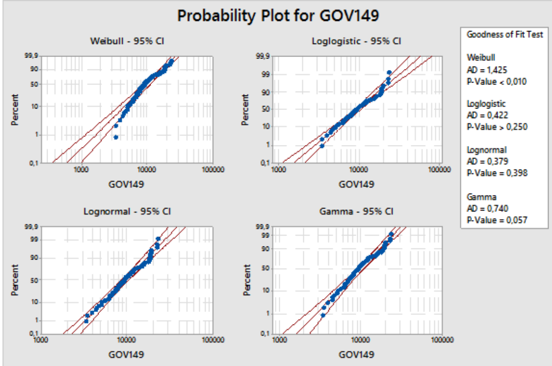




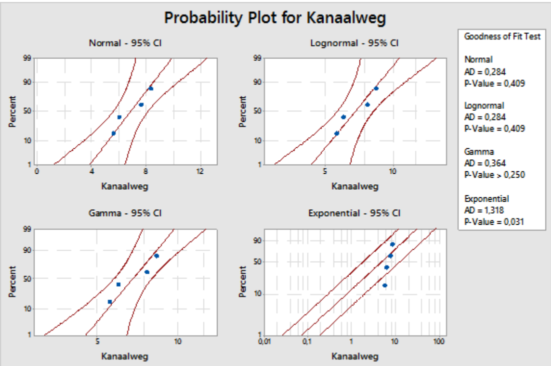


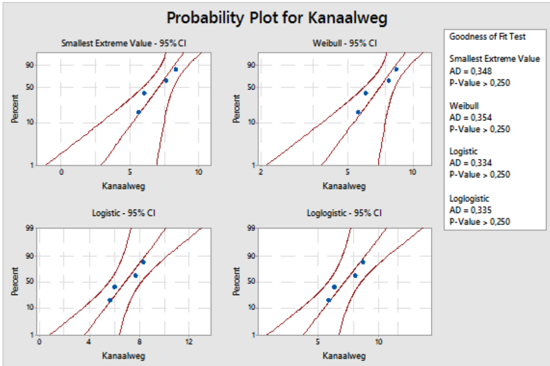


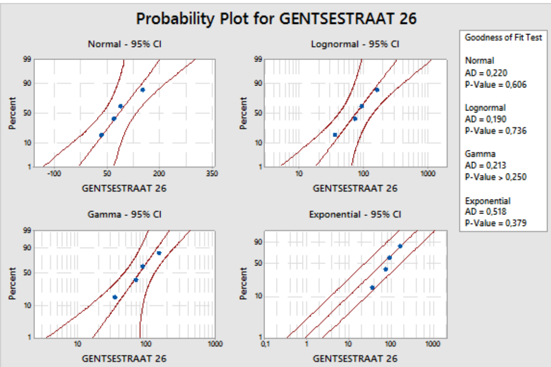


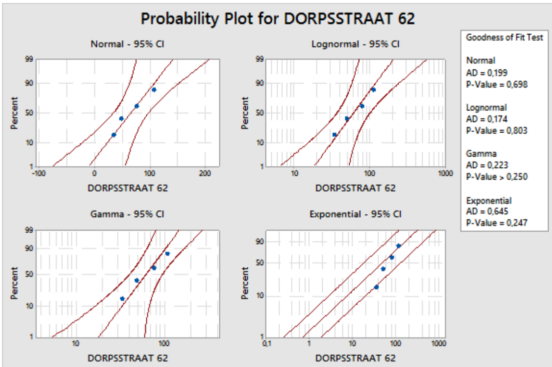


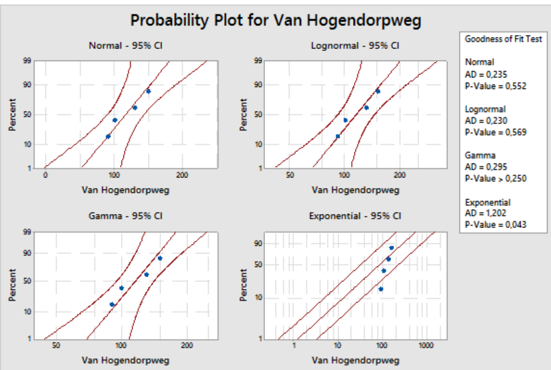
H. Probability plots data Company X

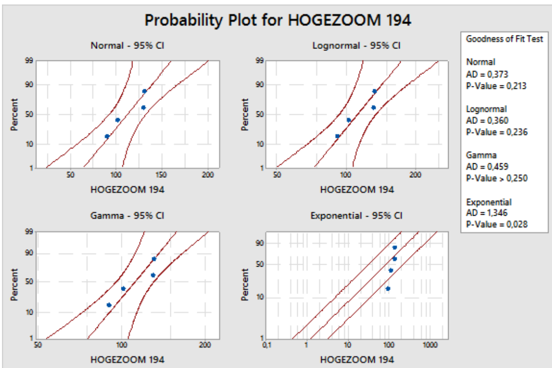












I. Validation of the routes by our model and TMS at Sandd

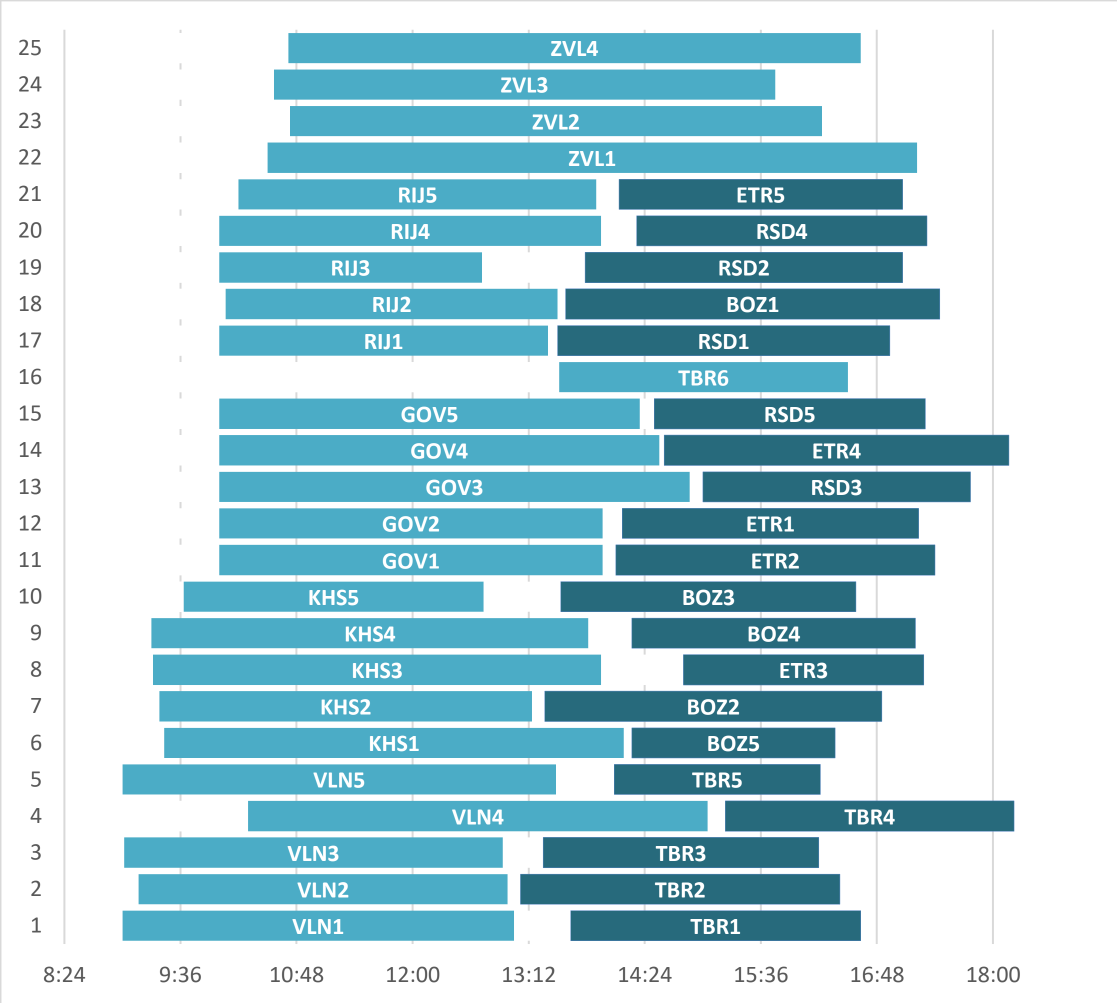
Subdepot	TMS	Model	Difference	%	Duration			
BOZ1	73,2	74,2	-1,0	1%	03:52:00	03:08:44	00:43:16	-23%
BOZ2	82,1	58,3	23,8	-41%	03:29:00	02:41:47	00:47:13	-29%
BOZ3	66,1	69,8	-3,7	5%	03:03:00	02:50:28	00:12:32	-7%
BOZ4	59,6	64,0	-4,4	7%	02:56:00	02:44:23	00:11:37	-7%
BOZ5	47,7	50,8	-3,1	6%	02:06:00	02:17:30	00:11:30	8%
ETR1	62,5	52,9	9,6	-18%	03:04:00	02:32:00	00:32:00	-21%
ETR2	69,3	70,8	-1,5	2%	03:18:00	03:23:50	00:05:50	3%
ETR3	41,5	40,6	1,0	-2%	02:29:00	01:37:25	00:51:35	-53%
ETR4	116,7	106,2	10,5	-10%	03:34:00	03:40:14	00:06:14	3%
ETR5	106,1	103,6	2,6	-2%	02:56:00	02:49:10	00:06:50	-4%
GOV1	108,5	106,8	1,7	-2%	03:58:00	03:12:55	00:45:05	-23%
GOV2	155,6	135,3	20,3	-15%	03:58:00	03:25:16	00:32:44	-16%
GOV3	187,3	166,1	21,2	-13%	04:52:00	03:46:16	01:05:44	-29%
GOV4	156,6	138,3	18,3	-13%	04:33:00	03:46:18	00:46:42	-21%
GOV5	137,0	116,0	21,0	-18%	04:21:00	03:29:39	00:51:21	-24%
KHS1	166,9	171,7	-4,8	3%	04:45:00	04:18:06	00:26:54	-10%
KHS2	132,0	135,7	-3,6	3%	03:51:00	03:41:42	00:09:18	-4%
KHS3	181,7	176,3	5,4	-3%	04:38:00	03:54:50	00:43:10	-18%
KHS4	127,2	129,3	-2,1	2%	04:31:00	03:25:30	01:05:30	-32%
KHS5	79,2	80,5	-1,3	2%	03:06:00	02:48:03	00:17:57	-11%
RIJ1	119,5	118,2	1,4	-1%	03:24:00	03:35:31	00:11:31	5%
RIJ2	103,3	98,0	5,3	-5%	03:26:00	03:22:41	00:03:19	-2%
RIJ3	103,1	99,4	3,7	-4%	02:43:00	02:47:15	00:04:15	3%
RIJ4	159,5	163,3	-3,8	2%	03:57:00	03:32:28	00:24:32	-12%
RIJ5	128,2	122,2	6,0	-5%	03:42:00	03:34:07	00:07:53	-4%
RSD1	106,6	82,3	24,3	-30%	03:26:00	02:43:51	00:42:09	-26%
RSD2	70,1	61,7	8,4	-14%	03:17:00	02:50:55	00:26:05	-15%
RSD3	29,9	33,7	-3,8	11%	02:46:00	02:56:30	00:10:30	6%
RSD4	57,2	57,1	0,1	0%	03:00:00	02:24:52	00:35:08	-24%
RSD5	50,1	54,4	-4,3	8%	02:48:00	02:12:24	00:35:36	-27%
TBR1	97,4	83,1	14,3	-17%	03:00:00	03:00:06	00:00:06	0%
TBR2	83,7	84,6	-0,8	1%	03:18:00	03:07:09	00:10:51	-6%
TBR3	87,0	80,9	6,1	-8%	02:51:00	02:47:17	00:03:43	-2%
TBR4	99,7	94,4	5,3	-6%	02:59:00	02:51:05	00:07:55	-5%
TBR5	77,1	64,9	12,2	-19%	02:08:00	02:00:53	00:07:07	-6%
TBR6	95,6	94,8	0,9	-1%	02:59:00	02:57:14	00:01:46	-1%
VLN1	183,1	189,9	-6,9	4%	04:03:00	04:19:54	00:16:54	7%
VLN2	181,5	181,3	0,2	0%	03:49:00	04:00:16	00:11:16	5%

VLN3	179,0	184,8	-5,8	3%	03:55:00	04:11:27	00:16:27	7%
VLN4	212,8	210,6	2,1	-1%	04:45:00	04:58:15	00:13:15	4%
VLN5	209,0	208,4	0,6	0%	04:29:00	04:08:23	00:20:37	-8%
ZVL1	304,2	301,0	3,2	-1%	06:43:00	06:29:13	00:13:47	-4%
ZVL2	243,1	244,6	-1,5	1%	05:30:00	05:01:17	00:28:43	-10%
ZVL3	215,8	213,7	2,1	-1%	05:11:00	04:37:54	00:33:06	-12%
ZVL4	224,8	221,6	3,2	-1%	05:55:00	04:55:20	00:59:40	-20%
Total	5578,1	5395,8	182,3	-3%	167:24:00	153:00:23	14:23:37	-9%

J. Calculating the parameters for Simulated Annealing per experiment

To calculate the parameters for the SA, it is determined that the heuristic is allowed to run for 20 minutes. One iteration takes around 0.1 seconds. The length of a Markov Chain is determined to be 200 iterations, this means that the temperature is decreased every 20 seconds (200 * 0.1). This results in 60 steps to decrease from c_0 to c_{stop}, let it be respectively 100 and 0.1. With this knowledge, α can be calculated by solving the following equation $\alpha \leq \sqrt[30]{\frac{0.1}{100}}$ = 0,89.

K. Current delivery schedule for vans



L. Map in which is shown that Company X stops overlap