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More bang for the buck

Werner Haafkes

Industrial Engineering & Management
Production & Logistics Management

Supervisors:
Dr. P.C. Schuur
Ir. H. Kroon

MANAGEMENT SUMMARY

This report describes the research project that has been conducted towards the logistic performance at Glasboer Nederland. The main focus of this project is on the distribution of flat glass between the production facility and the end customers. A new logistics system has been introduced a few years ago. Now the products flow through a few hubs instead of all local distribution centres. However, the expected reduction in costs have not been realised yet, which resulted in the inducement to do research regarding this topic. The aim of this research is to investigate if improvements in efficiency can be realised in order to reduce costs and attain a high service level.

During the first weeks of this research project we identified several problems which possibly cause higher distribution costs than necessary. Our focus will be on the following problems.
The main problem is the relatively low buck utilisation, which is around 14,5 square meters of glass for Glasboer Nederland. It is proven that an average buck utilisation of 20 square meters is not uncommon. Thus trucks are underutilised, because the glass bucks are not full when they are transported. Some claim that not combining orders with different lead times is the main cause. An order with a lead time of 4 days that was placed on Monday will be placed on another buck than an order with a lead time of 3 days that was placed on Tuesday, even though they both are transported on Friday. The reason for this is that they are produced during different production runs. Only orders that are produced in the same production run with the same destination can be assigned to the same buck if capacity allows it. Others claim that the large amount of destinations are the main reason for a low buck utilisation. Glasboer Nederland chooses to transport most pick-up orders directly on a separate buck for each destination to reduce handling activities at the hubs. Sometimes for example the establishment in Hengelo just needs 2m^2 of glass. A buck, and thus floor space at a truck, should be reserved for this small volume. If this would have been delivered by glass rack transport via the hub in Holten, it would probably have fitted on one of the other bucks that are transported to Holten for glass rack (delivery) transport. In that case the large truck with bucks does not need to drive to Hengelo, but one of the smaller glass rack trucks should visit Hengelo during their route.

The second problem we will address is the fact that there exist parallel distribution flows for the wholesalers (Glasboer Nederland) and the producers (Glasboer Roden and Glasboer Maastricht), since they have separate planning departments, external transport contracts, etc. It seems there is little incentive to further develop as GLASBOER as a whole.

In order to quantify what is the largest reason for having a relatively low buck utilisation we conducted a simulation study. First we defined different scenarios that are used to simulate the effect of combining orders with different lead times. Secondly we defined scenarios that are used to simulate the effect of transporting relatively low volumes (less than fifteen square meters) of pick-up orders to satellites within customer delivery routes with glass rack transport. Based on the results of our simulation study we can conclude that fragmentation of production orders based on their destination (delivering pick-up orders to satellites standard with buck transport) has a much more negative impact on buck utilisation than fragmentation of production orders based on their lead times. When all satellites that require less than fifteen square meters of glass for pick-up receive their glass via glass rack transport, an increase in buck utilisation of 32 percent is expected. When orders with different lead times but the same delivery date are grouped in the same production runs, an improvement in buck utilisation of sixteen percent can be realised. There are reasons to transport pick-up orders directly on bucks to satellites. Satellites should receive these orders before 10AM, which is not always possible by glass rack transport according to the planner. Based on this information we investigated whether Glasboer Nederland can increase its coverage throughout the Netherlands, such that the distance between hubs and customers/satellites are decreased. It should be easier to deliver pick-up orders to satellites with glass rack transport that way, since destinations in delivery routes will be closer to the depot (hub) and earlier deliveries are possible when needed.

In the next part of our research we wanted to find out if we can improve the coverage degree (or average proximity of a delivery address to a hub) of the distribution network of GLASBOER and decrease the total distribution costs. We used the p-median problem to determine the optimal hub locations based on a chosen number of hubs (p). The initial setting contained three hubs, Amsterdam, Holten and Eindhoven. These are the most appropriate locations based on location, storage space, expedition space, expedition equipment and outside terrain for unloading and loading vehicles. To accommodate incremental changes that can be achieved in a short period of time we keep these locations as hubs. By minimising the cumulated distances between frequently visited postal codes and potential hub networks we found the hub networks in table 1. We have compared the potential hub networks by doing relevant cost calculations. Based on representative sample data we have constructed efficient routes for each of the alternatives using route optimisation techniques and algorithms. We calculated driving distances and driving times for these routes to be able to calculate variable costs. Changing the amount of hubs in GLASBOER's hub network does not change the fixed costs, since the extra locations are already physically present and extra trucks are not needed. We therefor consider facility costs as sunk costs and lease costs as irrelevant for this comparison of hub networks. Variable costs for fuel, driver's wages and external transport are incorporated in the number shown in table 1.

TABLE 1: WEEKLY VARIABLE COSTS PER HUB NETWORK

Hub network	**#Hubs**	**Costs glass rack transport (1 week)**	**Costs buck transport (1 week)**	**Total costs (1 week)**
Amsterdam, Holten, Bergen Op Zoom, Eindhoven, Nieuwegein (current)	5	€ 9.550	€ 9.725	€ 19.275
Amsterdam, Holten, Eindhoven (initial plan)	3	€ 9.945	€ 8.374	€ 18.319
Amsterdam, Holten, Eindhoven, Beuningen	4	€ 9.545	€ 8.511	€ 18.056
Amsterdam, Holten, Eindhoven, Beuningen, Meppel	5	€ 9.539	€ 8.575	€ 18.114
Amsterdam, Holten, Eindhoven, Beuningen, Meppel, Hoorn	6	€ 9.335	€ 8.707	€ 18.042

Based on these results, we can conclude that the total variable distribution costs will decrease if Glasboer Nederland decides to appoint up to six locations as hub locations. The costs for buck transport will not increase much, since it appeared that the chosen satellites have to be visited with buck transport quite often, because of the large number of pick-ups at those locations. When we calculated the optimal hub locations using the p-median problem, we also considered pick-up orders in our data. Therefor locations that receive a lot of those pick-up orders, are more likely to be preferred as hubs. The costs for glass rack transport are declining significantly by incorporating more hubs, because of the declining distances that have to be driven by glass rack transport routes. The glass rack vehicles will still need to transport the same volumes, thus the fixed costs will not change significantly.

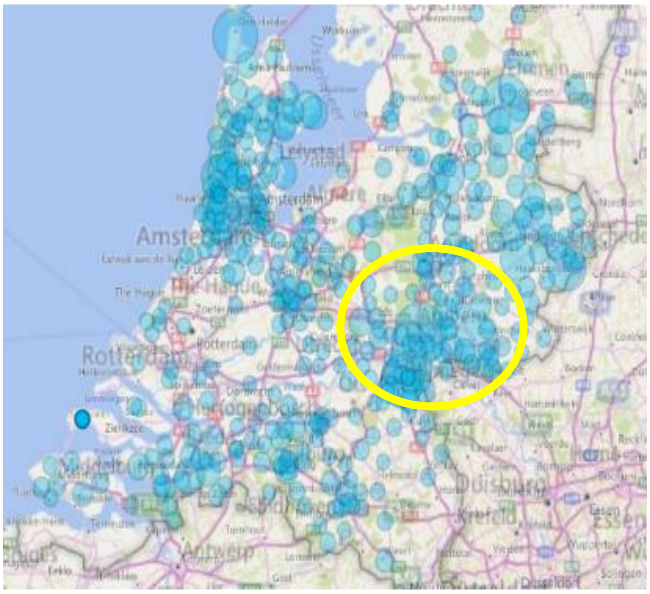

FIGURE 1: AMOUNT OF CUSTOMER ORDERS PER POSTAL CODE AREA

It has been shown that the best hub to open next to the three 'main hubs' (Amsterdam, Holten, Eindhoven) is Beuningen. As figure 1 shows, there are a lot of customers in the area Beuningen, Ede and Varsseveld (marked with yellow) which are not covered well by the current hub network. When opening another extra hub, Meppel will be the best option, since there is also a decent customer market in Drenthe. Besides that Meppel lays on the buck transport route to Holten and will not have a very negative impact on buck transport costs. After Meppel, Hoorn is the best option to appoint as hub. This will significantly reduce the driving distances in the Northern part of North Holland.

Increasing the number of hubs based on the most promising locations, will also improve the reachability of the satellite locations. Our expectation is that it will be easier for the planning department to plan pick-up batches that have a volume of less than 15m^2 into glass rack truck delivery routes respecting the time windows for pick-up orders. It won't be necessary to send an expensive buck transport vehicle that often to a satellite location in that case.

Summarising, we concluded that fragmentation of production orders based on their destination are the main cause for the lower than desired buck utilisation. In other words, the small volumes of pick-up orders that are transported directly on bucks to satellite establishments turned out to be the most harmful for the overall buck utilisation. We realised that satellites are too far away from the closest hub, such that on-time delivery of pick-up orders at these satellites via glass rack transport cannot be guaranteed. After constructing alternative hub networks and calculating their variable distribution costs, we came to the conclusion that appointing extra hubs will decrease the total distribution costs. Thus Glasboer Nederland can improve its coverage throughout the Netherlands and thereby reduce the distances to their customers and satellite locations, whilst at the same time decreasing costs.

Based on our findings, we advise Glasboer Nederland to consider the following recommendations:

- Change the current hub network incrementally to the hub network proposed above, by first moving the hub function from Nieuwegein to Beuningen. Then moving the hub function from Bergen Op Zoom to Meppel. Finally opening a new hub in Hoorn.
    - We advise the management team of Glasboer Nederland to take this action first. We expect that this will fetch the largest benefits and it can be realised in a short period.
- Since increasing the number of hubs will decrease the risk pooling effect, the variation in number of orders per area will increase. To cope with this variation we recommend to the distribution planning department to make a pre-planning in advance of placing a production order at the factory. Based on the orders that are already known just before the moment of placing an order at the factory, a route planning should be made. For each route a buffer should be incorporated to cope with urgency orders. Keep track of the number of urgency orders per day and per area (for example 2-digit postal code) to be able to forecast the number of urgency orders on a specific day. Discuss the possibilities of making a pre-planning with for example a consultant of the supplier of the routing software Ritplan.
    - We suggest it would be best if the distribution planners are prepared to make pre-plans as soon as the number of hubs are increased, since the variation in the amount of orders per area will probably increase immediately.
- Decrease facility costs by downsizing satellite locations that are not considered to be used as a hub in the near future. They can retain their function as paint shop and reserve some floor space for a few bucks for pick-up glass orders.
    - This recommendation is less urgent than the previous two. As soon as the hub network proves itself as efficient and cost effective, the management of Glasboer Nederland can make their decision about downsizing satellite locations.

Recall the issue that there exist parallel distribution flows for the wholesalers (Glasboer Nederland) and the producers (Glasboer Roden and Glasboer Maastricht), since they have separate planning departments, external transport contracts, etc. We dived into existing literature about benefits that collaboration within a supply chain can have and will address these benefits to GLASBOER below.

It seems that the different branches of GLASBOER within the Netherlands merely operate as individual companies. They aim to improve individual performance without considering the overall chain and value for the end customer. To ensure that every decision benefits GLASBOER Europe as a whole, the measured performance of each separate chain should also be directly linked to the overall performance.

Glasboer Nederland has agreements with their GLASBOER supplier about order quantities, volumes, etcetera. This results in demand floors and ceilings that creates demand amplification. An example is that Glasboer Nederland orders extra volumes in advance, when the allowed order volume has not been met for that day. This way, the manufacturer has no idea of the order quantities and volumes that the wholesalers actually need, which might give them a distorted view of short term demand. When there is more transparency regarding customer orders, they can better complement each other on a daily basis.

For the management that oversees the branches of GLASBOER within the Netherlands we have the following recommendations:

- We advise to promote transparency and mutual trust amongst GLASBOER branches, such that all of them are encouraged to work according mutual benefits and understand the impacts of certain decisions on the operations of another part of the company.
- We advise to hire an external consultant that reviews the performance measurements for GLASBOER in the Netherlands as a whole and introduces a rewarding system that makes sure that made decisions should enhance the end value of products before serving the final customers.
- Furthermore we recommend to conduct further internal research considering the aspects of a collaborative supply chain as explained in our theoretical framework. An independent person or entity should penetrate the organisational functions of the GLASBOER branches in the Netherlands and should investigate the possibilities towards a collective department for activities such as sales, production planning and distribution planning between GLASBOER branches.

This way transparency will be increased, understanding for each other’s processes and choices are obtained and mutual trust and commitment will arise. Production and distribution can be based on collective customer demand at both the manufacturer and the wholesaler. This will result in a significant reduction in order variance which will make it easier to meet the total customer demand with the same production capacity. Also distribution will be more efficient because of scale benefits (shorter driving distances for the same volumes). These statements can be quantified if an independent project initiative has access to order information of customers of all GLASBOER branches.

PREFACE

In front of you lies the master thesis that describes the final project I have been working on during my study. When I finished most of the courses within my Master's program, I started orienting on possible graduation projects that would fit my interests and the requirements of the program. First it was not easy to find an assignment that satisfied the requirements from the university, my own wishes and the companies' expectations. But after a period of searching, having conversations with different companies, and accepting some disappointments, I was approached by Glasboer Nederland. They offered me a challenging assignment within the framework of their logistic processes. I was immediately enthusiastic because it fitted within my personal interests and the framework of the track Production & Logistics Management that I chose for my Master Industrial Engineering & Management. I was pretty free to determine the scope of the project myself, which allowed me to use a lot of concepts and skills I acquainted during my study within this project. I was able to do my thing, but when needed the threshold was not high to ask questions when I had them. I really enjoyed having contact with people from different departments within the company and getting to know the activities that are carried out at these departments. This was also very informative. I learned a lot from the meetings and conversations I had and the different views people can have on certain issues. I realised it is very hard to find a good solution for certain problems since one can look at an issue from various perspectives from which none can be ignored. I also enjoyed the conversations I had with my supervisors, both at the company and the university. I learned a lot from them. I want to thank my external supervisor for the nice project he trusted me to do and the guidance, feedback and information he gave me. I am thankful to Peter Schuur and Henk Kroon for the valuable hints, feedback and suggestions I received during the meetings we had. Finally I want to thank everyone at the company and in my personal environment who has been involved in this project and/or showed interest and support!

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1 INTRODUCTION

Within the framework of Production and Logistics Management we performed research towards the logistic performance of Glasboer Nederland. Glasboer Nederland is a sub division of the larger organisation GLASBOER Europe. They produce, process and distribute flat glass for construction, automotive and solar sectors. Their headquarters are in France.

In this Master assignment the focus will initially be on the Dutch Branches of GLASBOER within the Netherlands. GLASBOER has eighteen locations spread within the Netherlands among which two major glass production facilities and sixteen distribution facilities. The latter form the branch Glasboer Nederland which sell and distribute glass, paint and non-paint products throughout the Netherlands.

Formerly glass was transported from the production facilities to the different local distribution facilities in the Netherlands and from there further distributed to the customers. Currently they use a new logistic system in which the products flow through a few ‘hubs’ instead of all the local distribution centres. The costs of this new system are higher than budgeted beforehand. Therefore it is necessary to find out if improvements in efficiency can be realised in order to reduce costs and attain a high service level.

During the initial phase of our research we are going to identify problems which could have direct or indirect impact on GLASBOER’s distribution costs. We are going to map the causal relationships and choose on which problems our further focus will be. Based on these choices our research questions will be defined to give direction to our research. The next focus will be on attaining data and understanding of the current situation at Glasboer Nederland. Once we have a good and complete view of GLASBOER’s current distribution process we focus on current literature which provides theory and tools that are applicable in the situation of GLASBOER and provide opportunities for improvements. We are going to conduct a simulation study to analyse different scenario’s considering the distribution of glass. After that we come up with a new improved distribution network design based on several optimisation criteria and costs analyses. Based on the outcome of our research we draw our conclusions and come up with recommendations for Glasboer Nederland.

2 PROBLEM IDENTIFICATION

The manager of Glasboer Nederland is concerned about the distribution costs which were higher in 2016 than budgeted beforehand. He has the feeling that the distribution process of GLASBOER does not perform according its potential. Our task is to look critically at the distribution process, identify sub optimisations and come up with recommendations. We can add a certain level of layering in our approach. First, we can solely consider the Glasboer Nederland branch, which consists of the wholesalers who operate as the final link to the customers. Secondly we can also take into account the production facilities GLASBOER has within the Netherlands. Broadening our scope in this perspective might give more opportunities for improvement.

2.1 Problem context

During the first weeks of the project we identified several issues which could have their impact on the current distribution costs and service level. We constructed the problem cluster in Figure 1 on the next page to visualise the causal relationships between these issues. The arrows point from the causes to the effects (upwards), thus the root causes we found are at the bottom of the tree.

When we read this problem cluster we can interpret the following issues. The numbers between brackets correspond with the numbers in the problem cluster.

(1) Employees of GLASBOER stated that the service level delivered to customers is lower than desired. The first reason of this lower service level is based on internal complaints that (2) GLASBOER does not deliver (non)paint orders within a day. This is caused by the fact that (3) these deliveries depend on glass delivery routes with glass rack trucks. (4) Glass deliveries in a certain region are carried out on fixed days depending on these predefined routes. This way (5) customer pools are created and a reduction in daily driven distance by glass rack trucks is realised and thus costs are reduced.

Another mentioned issue is (6) the recurring occurrence of second deliveries, which means that customers are visited twice for a single order. Causes of these are (7) incomplete orders due (8) damages, production delays or other interferences. Another cause is (9) the urge to stick to delivery schedule. (10) Drivers visit more customers on a day than previously and are urged to move on to the next customer when they are unable to deliver the current order on their list. This results in a second visit to this customer.

We also found several problems which possibly cause (11) higher distribution costs than necessary. Employee's experience has told us that (12) there exist parallel flows of glass transportation for different GLASBOER branches within the Netherlands. This is caused by the fact that (13) there are several parties involved with the distribution from producer to hub and customer. There is no common insight in all transportation flows because (14) each branch has contracts with separate transporters and has a separate planning department. At the time of writing this section, (15) there is no common incentive to work towards a collaborative distribution planning. The last issue that is present in the problem cluster is (16) the glass buck utilisation. (17) The volume and weight of glass which is stored on bucks varies a lot. Bucks are carriers for glass for transportation of large volumes. See figure 4 in section 3.2 for an image. (18) Buck utilisation depends on several parameters which consider customer desire, efficiency and safety factors. Another reason for the limited buck utilisation is the fact that (19) the producer is not able to group orders that (20) are placed at the production facilities on different days and thus produced in different runs and therefore end up on different bucks, while they have to be transported to the same location on the same day. We call this order fragmentation. Also, (21) a lot of orders that need to be transported to satellite locations are transported on separate bucks, such that it is not needed to perform extra handlings at the hubs before they are further distributed. These volumes can be pretty small which thus results in lower buck utilisation.

Based on our problem cluster and brainstorming with employees we chose a main problem (in green) which we want to handle and highlighted the root causes (in yellow) that we can influence and thus focus on.

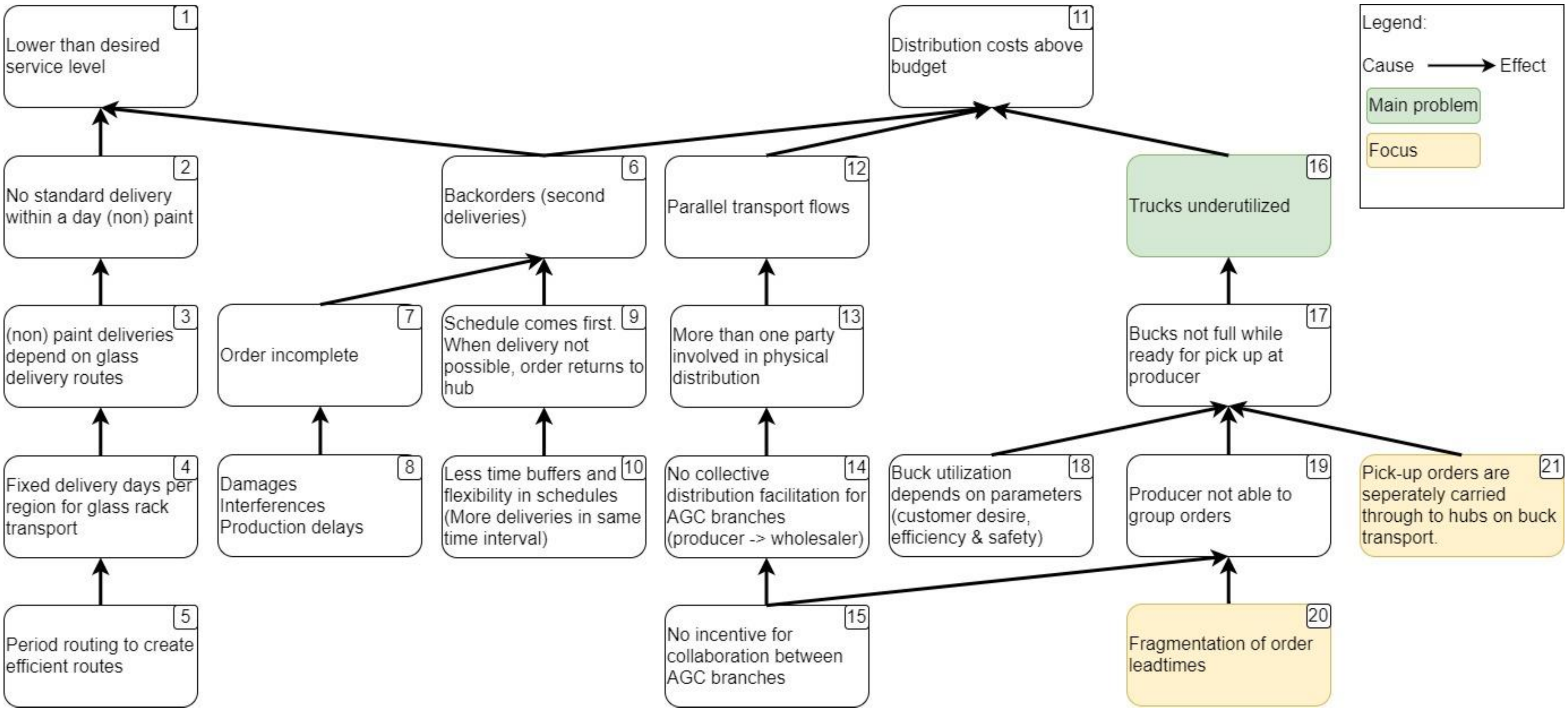


FIGURE 2: PROBLEM CLUSTER

2.2 Main problem

The main problem we focus on is that the trucks for buck transportation are underutilised. The buck utilisation for orders of Glasboer Nederland are significantly lower than the buck utilisation of orders for customers who order directly at the production facility in Roden. The utilisation of bucks that are transported for Glasboer Nederland is below 15m^2 compared to an average volume of 20m^2 glass on bucks for external customers of Glasboer Roden. The management of the production facility claims that the main reason for this is the fragmentation of orders into different site codes and lead times. Similar sited codes are assigned to orders that have the same destination. Orders with different site codes and lead times will be assigned to different bucks. Glasboer Nederland employees claim that the main reason for low buck utilisation is the inability of the production facility to group orders which have different lead times but the same destination and delivery date. We want to quantify the impact of these issues on the buck utilisation. Based on the attained numbers we can do further research and/or make recommendations to the management of Glasboer Nederland.

2.3 Problem approach

To start with we need to image the current situation of the distribution process of GLASBOER within the Netherlands. We will have conversations with several persons that are involved in the relevant processes and try to attain the data we need to make a proper activity profile and attain a deeper understanding of the activities and issues that are related to GLASBOER's distribution process. Next we need to conduct a literature study to find out what research already has been done within our field of interest and which methods and tools we can use in our study. We probably need to learn more about optimising distribution flows, conduct scenario analysis with simulation studies and facilitate collaboration between branches in the supply chain.

2.4 Research questions

Based on the problems we identified during our preliminary research and the opportunities for improvement we identified together with GLASBOER personnel, we defined the following research question:

> *"How can Glasboer Nederland improve their distribution process, by attaining higher efficiency regarding buck utilisation and glass delivery driving distances, whilst maintaining their high service level and minimising costs?"*

In order to find an answer to this research question we defined several sub questions to structure our research. They will also serve as a guide for the rest of this thesis. The numbers of the research questions correspond to the chapters in this thesis that provide answers to these questions.

3) *"What does the current distribution process of GLASBOER (Nederland) look like?"*

   Physical locations

   a) *"Which physical locations/facilities are present within the distribution network?"*
   b) *"What are the main functions of the physical locations within the distribution network?"*

   Goods to be shipped

   c) *"What are the characteristics of the goods to be shipped?"*

   Vehicles

   d) *"Which vehicles are used for shipment of these goods?"*
   e) *"What is the capacity of these vehicles?"*

   Transportation flows

   f) *"What are the current/past transportation flows for the separate GLASBOER branches with the Netherlands?"*

   Activity profile

   g) *"How many orders were received in 2016?"*
   h) *"How many orders were placed at GLASBOER's suppliers?"*
   i) *"What volume has been shipped from the production facilities to the hubs and the customers?"*

j) *"What volume has been shipped with glass rack trucks from the hubs to the customers?"*

k) *"What are the number of goods shipped per region?"*

Costs

l) *"Which costs are associated with GLASBOER's distribution process?"*

To answer the first sub question we start in chapter with attaining a deeper understanding of the distribution process by taking a look at the different processes that are concerned with it and having conversations with as many involved persons as possible. We are going to make several company visits to GLASBOER branches to attain a better view and understanding of their activities. During these conversations we learn about details, doubts, etcetera considering the current logistic processes. Next to that we learn which data is available and who to attend to, to require it. We hope to create a certain degree of goodwill during our visits to gain support from different stakeholders. The main part of the information and data collection process will consist of stakeholder interviews and report analyses. Other information we need will be collected during literature studies.

4) *"What is the most important cause for having a lower buck utilisation than desired?"*
   a) *"What was the realised buck utilisation for buck transport in 2016?"*
   b) *"What buck utilisation could have been realised in different scenarios?"*
   c) *"Which of the scenarios show the largest difference in buck utilisation compared to the current situation?"*
   d) *"Based on our answer to c), where did we identify the largest potential for improvement?"*

To answer this sub question we are going to conduct a simulation study to simulate the effect of different scenarios based on order fragmentation and separation of pick-up orders. Recall from our problem cluster that these were the yellow root causes for having a lower than desired buck utilisation. With order fragmentation we mean that orders with different 'order lead times' end up in different production runs. With order lead times we mean the number of days between placing the order at the production facility and delivering it to Glasboer Nederland. These orders with different order lead times will always end up on different bucks even when they are transported on the same truck and their total volume is small. Separation of pick-up orders means placing the pick-up orders on a separate buck for each destination, such that no further packing handlings are required at the hub. These bucks can stay on the truck, waiting for further transport to the end destination.

We want to quantify which of these causes have the highest impact on the buck utilisation. By creating different scenarios and execute simulation runs for each of them we can make good comparisons of the resulting buck utilisations. We can use the book "Simulation Modelling & Analysis" (Law, 2007) to create a project specification, make design choices and validate & verify our model. Based on the outcomes of this simulation study we are going to draw conclusions and perform further research.

5) *"What does literature tell us about designing and structuring an efficient distribution network?"*
    a) *"What distribution network design concepts are relevant in the situation of Glasboer Nederland?"*
    b) *"How can these concepts contribute to better operations, based on our findings in the previous sub questions?"*
    c) *"Which algorithms and optimisation techniques can be used to evaluate a potential new distribution network?"*
    d) *"What are the pros and cons of these concepts and algorithms?"*

To answer sub question five we will conduct a literature study on several distribution network design concepts from existing literature. Based on the results of our simulation study which is discussed in chapter four, we decided to re-evaluate the current hub network design choices that are made at Glasboer Nederland. Our focus will initially be on distribution network design concepts considering facility locations. Later we will elaborate on optimisation techniques and (local search) algorithms which will help us finding efficient routes and calculating total driving distances and costs for (potential) hub networks.

6) *"Can Glasboer Nederland improve their hub network design, such that they are able to serve their customers more efficient?"*
    a) *"Which alternative distribution network designs should we consider?"*
    b) *"Which differences in costs are expected between the found alternatives?"*
    c) *"Which other benefits are associated by implementing the found alternatives?"*

In order to find as good as possible design alternatives for distribution network models we are going to use the concepts described in our theoretical framework and implement them using Microsoft Excel and Delphi. We are going to compare the design alternatives by doing relevant cost calculations. Based on representative sample data we are going to construct efficient routes for each of the alternatives using the suggested optimisation techniques and algorithms. We calculate driving distances and driving times for these routes to be able to calculate variable costs.

7) *"What organisational changes are needed to work towards collaboration between GLASBOER's branches within the Netherlands?"*
    a) *"What does existing literature tell us about collaboration within a supply chain?"*
    b) *"What are the benefits and difficulties of collaboration between GLASBOER's branches?"*
    c) *"What actions are needed to start incentives for collaboration between GLASBOER's branches?"*

We will provide an overview of existing literature on this topic to emphasize the benefits that a collaboration within a supply chain can have. Based on this literature and past experiences we will make recommendations on this issue for the GLASBOER branches in the Netherlands as one entity.

2.5 Deliverables

After completion of this research we aim to provide Glasboer Nederland with the following deliverables:

- A clear activity profile considering their current situation.
- Substantiation of the most important reasons for having a lower than desired buck utilisation.
- A theoretical framework providing insight in logistic concepts and techniques that are relevant considering GLASBOER's distribution process.
- Proposals for alternative distribution network models (hub network structure) which facilitate higher efficiency levels for buck utilisation, decreased driving distances for glass delivery and eventually decreased costs.
- Recommendations for implementing these distribution network models.
- Recommendations for further development of GLASBOER's Dutch branches.

3 GLASBOER'S CURRENT SITUATION

This section describes the current situation at GLASBOER within the Netherlands. This chapter correspond to the questions which are used to answer the research question "*What does the current distribution process of GLASBOER (Nederland) look like?*".

3.1 Physical locations

GLASBOER has eighteen locations in the Netherlands which can be divided in three separate branches. First they have a production facility in the North of the Netherlands in Roden (Glasboer Roden). They produce standard products in large quantities and provide the main part of the glass sold within the north, east and west regions within the Netherlands. The southern part of the Netherlands receives the standard products from production facilities in Lille, France (GLASBOER Lille) and Charleroi (GLASBOER Charleroi).

FIGURE 3

GLASBOER has a second production facility in the Netherlands in Heerlen (Glasboer Maastricht), which is specifically equipped for special orders. They can do a broader set of operations in smaller quantities. Special orders are distributed through the entire country from Heerlen.

The third branch "Glasboer Nederland" consists of sixteen wholesalers that are spread throughout the Netherlands. They consist of three so called "hubs" and thirteen "satellites". The hubs are located in Holten, Amsterdam and Eindhoven. They facilitate the last mile delivery to customers in their region and possess several vehicles which are equipped with glass racks. They can also execute minor operations such as cutting, grinding and sandblasting. The hubs as well as the satellites act as local service points which customers can visit and where they can pick up orders. The satellites can execute minor cutting and grinding operations for local pickup orders. In the current situation the locations in

Bergen Op Zoom and Nieuwegein, which originally intended to serve as satellites in the new distribution system, also have a hub function as delivery routes are also driven from there.

3.2 Goods to be shipped

The type of products that GLASBOER sells and distributes can be divided in two main segments which require different types of handling. The first segment consists of flat glass products, which should be transported vertically on bucks or racks that are specifically designed to safely and conveniently transport flat glass. The other segment consists of paint and paint-related products. Small and easy to handle orders among these can be transported in cartons or baskets and large or heavy orders can be placed on pallets. Our focus will mainly be on the glass segment.

3.3 Vehicles

FIGURE 4: GLASS RACK VEHICLE

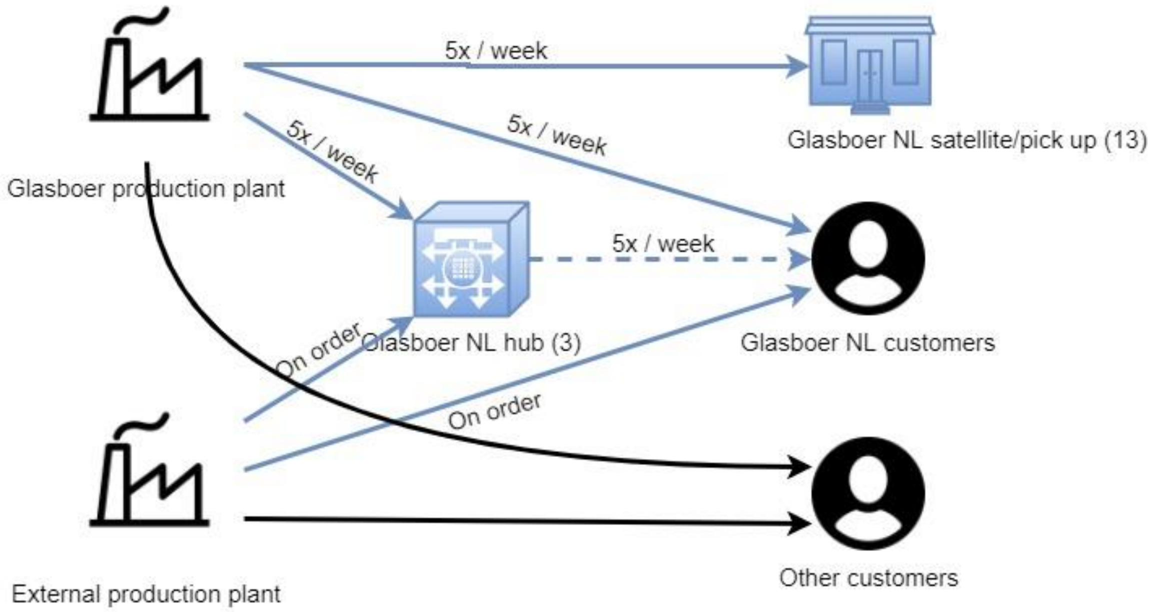
FIGURE 5: GLASS BUCK

Normally there are two alternatives regarding the type of transportation. Small and easily portable customer orders can be transported using vehicles equipped with glass racks. We are going to call these “glass rack vehicles” from now on. These vehicles can also transport cartons, baskets and a few pallets for non-glass and paint (related) orders.

Large and heavy flat glass orders can be transported on bucks which are lifted on trucks. Small cartons can also be transported by vans such as those used by external parcel delivery services like UPS.

3.4 Transportation flows

Glasboer Nederland makes use of cross-channel distribution such that customers can choose whether they pick up their orders themselves on the closest location or let GLASBOER deliver the goods at a chosen address. Figure 6: Transportation Flows illustrates the current transportation flows. The blue arcs show transportation flows for which Glasboer Nederland is responsible. The black arcs show the transportation flows that are facilitated by GLASBOER's production facilities or external suppliers. There is an option of delivering five times per week directly from the GLASBOER production plants with buck transport to the satellites if necessary. Large customer orders can be transported directly from the plant to the customer on bucks based on the routes that will be driven. If a truck for example has a (satellite/hub) delivery near the customer on Wednesday, the customer will also receive his order on Wednesday. Five times per week there is a truck driving from the production facilities to the hubs for regular orders which will be disseminated to the customers with glass rack vehicles. These have to arrive on the hubs before seven AM such that there is enough time to place urgency orders on the glass rack vehicles and deliver them to the customer on that day. The non-urgency orders will be sorted for delivery on the next day. Some orders that cannot be produced by GLASBOER production plants will be ordered by external suppliers. These orders can be transported to hubs or directly to customers. There are no frequencies on the black arcs since these transportation flows are not Glasboer Nederland's responsibility and therefore not known.



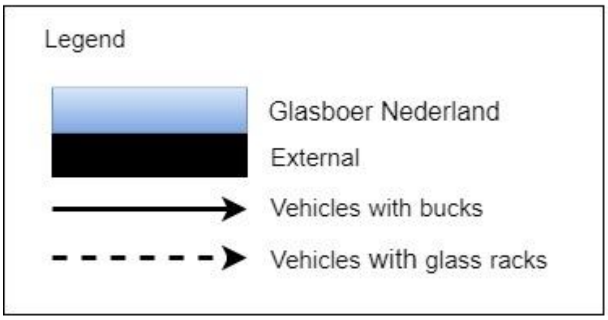


FIGURE 6: TRANSPORTATION FLOWS

3.5 Activity profile

In this section we give a summary of numbers in tables and graphs considering the current activities within the logistic processes of GLASBOER. Table 2 summarises the number of orders sold per GLASBOER establishment and table 3 shows how the orders are dispersed per delivery type. Figure 7 shows how GLASBOER's customers are dispersed within the country based on the number of orders per postal code area. Table 4 shows us what Glasboer Nederland's main suppliers are. Finally, figure 8, table 5 and table 6 show us the number of routes that are driven by glass rack transport from GLASBOER Hubs to customers on a daily basis and the volumes that are concerned with it.

3.5.1 Orders

The order data we received covers the period from the start of June 2016 to the end of February 2017. The data consists of all orders that were booked including customer delivery orders through hubs, pick-up orders and large direct delivery orders from the production facilities. The tables below summarises the amount of orders and volumes per establishment (Glasboer Nederland location) and per delivery type (Glass rack transport, direct buck transport or customer pick-up)

TABLE 2: ORDERDATA PER ESTABLISHMENT

Establishment	**Number of orders**	**Volume in square meters**	**Sales**
Hardenberg	3.138	12.300	-
Zutphen	3.377	15.052	-
Ede	5.036	28.691	-
Amsterdam	5.791	26.816	-
Den Oever	3.744	19.571	-
Varsseveld	3.381	14.119	-
Hengelo	2.338	9.671	-
Holten	2.075	13.543	-
Alkmaar	3.483	15.727	-
Meppel	4.290	17.401	-
Beuningen	5.110	28.170	-
Bergen Op Zoom	5.549	28.802	-
Eindhoven	5.385	73.203	-
Nieuwegein	3.233	17.535	-
Hoorn	4.000	22.708	-
Kampen	3.898	21.550	-
Total	**63.828**	**364.859**	-

TABLE 3

Delivery type	**Number of orders**	**Volume in square meters**	**Volume per order**	**Sales**
Pick-up	16639	49038	2,95	-
Hub delivery (glass rack transport)	38565	145176	3,76	-
Direct delivery (buck transport)	8624	170645	19,79	-

We notice significant differences in the volume per order between the different delivery types. As we would expect the volume per order for direct deliveries are much higher, because their volume is the reason they are transported directly on bucks.

To get a visual of the spread of the customer market of Glasboer Nederland we plotted the postal code areas with more than 10 orders on a map. We can see in Figure 7 that the major hotspots are in North Holland and Gelderland (area around Beuningen and Ede). More orders in a postal code area means a larger circle. The largest circles are represented by postal codes where a pick-up point is established. Pick-up orders also appear on the map on the GLASBOER location where they are picked up.

FIGURE 7: PLOT OF GLASBOER NEDERLAND'S CUSTOMER ORDERS PER POSTAL CODE AREA

3.5.2 Suppliers

The table below shows the top five suppliers of Glasboer Nederland in terms of volume. From the complete dataset we know that Glasboer Roden accounts for more than 50% of the purchased volume and is by far the largest supplier. This is normal since they are the largest producer of standard flat glass within the Netherlands that belongs to the European division of GLASBOER. Besides that, Glasboer Nederland (the wholesalers) are obliged to purchase the gross of their standard flat glass at Glasboer Roden.

TABLE 4: ORDERDATA AT SUPPLIERS

Supplier	**Volume (m^2)**	**Purchases (mln)**	**Sales (mln)**	**Margin (mln)**	**Margin / m^2**	**GPM**
Glasboer Roden	161000	-	-	-	-	28%
GLASBOER Lille	56000	-	-	-	-	20%
GLASBOER Muiden	20000	-	-	-	-	27%
GLASBOER Fabrication	19000	-	-	-	-	25%
Glasboer Maastricht	9000	-	-	-	-	20%

3.5.3 Glass rack truck transport

The following graph shows us the number of routes driven by glass rack trucks per day during 2016. Since Ritplan was put into operation for glass rack truck planning during the spring of 2016, we can see a start-up period in the graph. This does not necessarily mean that there were less routes, because the data from Ritplan might not cover every driven route during this period. We assume the data is complete from the summer holiday onwards. Therefore we consider the period from 29 August 2016 onwards. During this last period the number of driven routes averaged fourteen.

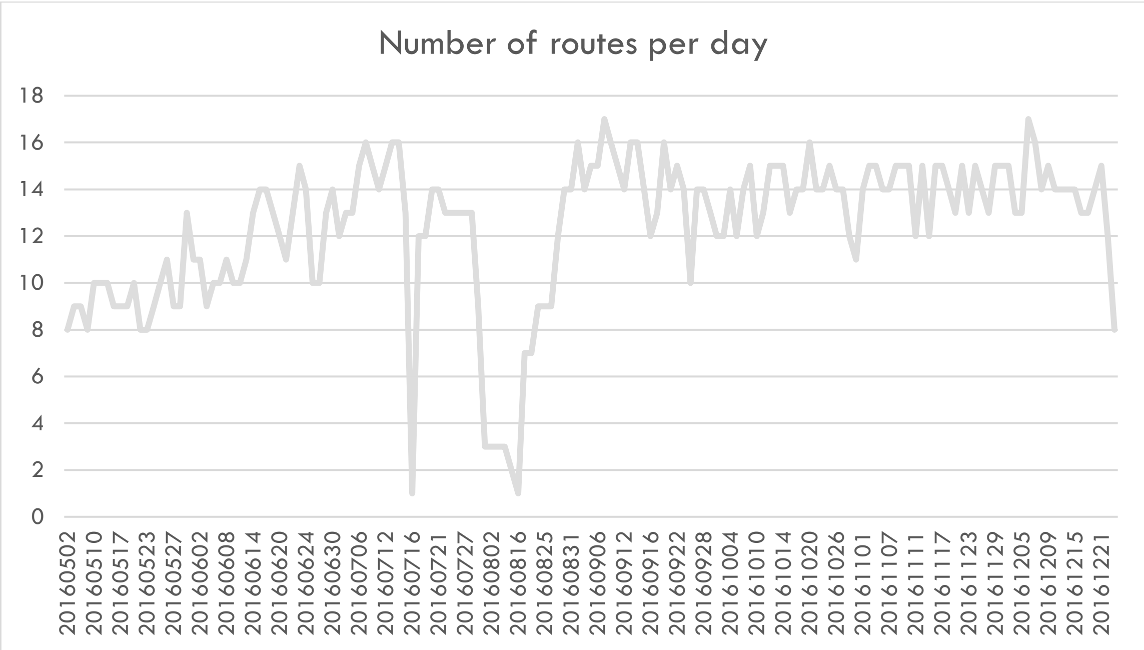


FIGURE 8: NUMBER OF ROUTES PER DAY

The next graph shows us the transported volume per day over the period from 29-08-2016 to 23-12-2016. We can see that the average volume slightly decreases over this period. This is probably caused by seasonality. From the previous graph we can see that the number of routes driven did not significantly decrease over this period. From this we conclude that the utilisation of trucks also decreased due seasonality. We see one outlier in the graph at 13-12-2016. Since this outlier represents an order with a huge unreal volume we assume this is an error in the data. Therefor we will not take into account this data point in the averages calculated below.

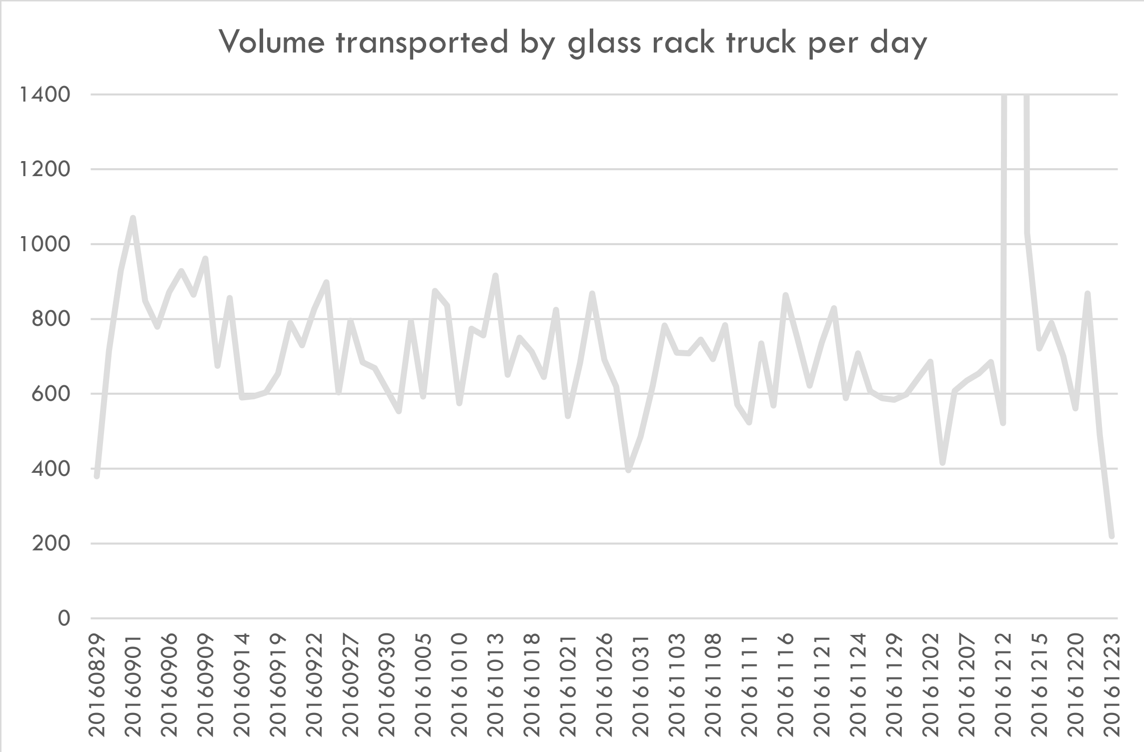


FIGURE 9: VOLUME TRANSPORTED BY GLASS RACK TRUCK PER DAY

For the glass rack truck transport we observed the following numbers:

TABLE 5: GLASS RACK TRANSPORT DATA

Average volume per trip	49.16m^2
Average weight per trip	1015.01kg
Average volume per day	697.70m^2
Average weight per day	14371.87kg

3.6 Costs

The table below summarizes the costs that are concerned with the distribution of glass for Glasboer Nederland. These numbers are fictive for the sake of confidentially.

TABLE 6: DISTRIBUTION COSTS

Glass rack transport (internal transport)	€ 0,175 per kilometre € 20,00 per hour € 2000.00 per month	Fuel costs Driver wage Lease costs
Buck transport (external transport)	€ 0,70 per kilometre € 30,00 per hour	Contract with external transporter
Glass handling (loading/unloading/moving)	€ 1.00 per m^2 glass	Expedition personnel wage
Total fixed costs for GLASBOER hubs and satellites	-	-

The fuel costs for glass rack transport we extracted from data that is held on the account at the gas station, by looking at the average diesel usage of such a truck and recent diesel prices. Costs of the driver's wages and lease contracts for the trucks we received from the financial controller. The agreed prices of the external transporter we received from the technical manager who was responsible for this contract. The glass handling costs are based on measurements within one of GLASBOER's glass factories in France. We are going to do our own measurements later on at the local expedition if we need them. The fixed costs for the establishments are extracted from a management overview with financial key figures. We know that some of the establishments are owned by GLASBOER and some still have some machines at their site which still have maintenance costs, etc.

3.7 Summary

In this chapter we described the current situation of Glasboer Nederland. We showed that there are 16 locations for distribution. 5 of them serve as hub and are responsible for the last mile delivery to the customer. The other locations serve as local service and pick-up points. We showed that there are two modes of transportation. The glass rack trucks for small volumes and final delivery. Secondly the bucks for large volume transport on trailers to the locations that require large volumes such as hubs and customers with large orders. Next we showed which transportation flows are present in GLASBOER's distribution network and which of them are Glasboer Nederland's responsibility. We also provided a summary of data, such as orders, delivery routes, volumes, etcetera that are relevant within this research. Finally we showed costs that are directly related to the logistic activities that are of interest within this research and we most likely need later on.

4 SCENARIO ANALYSIS

Within this chapter we conduct a scenario analysis to investigate what the effect of the agreed order lead times between Glasboer Nederland and their supplier Glasboer Roden is on the average buck utilisation. We focus on the orders that are produced at the production facility in Roden, since they are by far the largest and most important supplier for Glasboer Nederland. We start with composing a project specification which outlines the project problem, goals, expectations and requirements. Then we build our model and discuss the design choices. Thereafter we verify and validate our model to make sure it is a proper representation of the real situation and if there are no errors in the code. We use collected order data as input for the model and analyse the results generated by the simulation runs.

4.1 Project specification

4.1.1 Introduction problem and project goals

We conduct a simulation study to evaluate different scenarios with different order fragmentations. Recall that the average buck utilisation in 2016 was 14,5m^2 for Glasboer Nederland's bucks and 20m^2 for Glasboer Roden's bucks. For simplicity we assume that all bucks have the same capacity and are identical in that perspective. It would not help to differentiate between different types of bucks, since it is nearly impossible to calculate accurate capacity anyway because of the large variety in dimensions of glass. In order to improve the average buck utilisation, it is crucial to know what the main cause is. There are different opinions about this matter.

Some claim that not combining orders with different lead times is the main cause. Recall that an order with a lead time of 4 days that was placed on Monday will be placed on another buck than an order with a lead time of 3 days that was placed on Tuesday, even though they both are transported on Friday. The reason for this is that they are produced during different production runs. Only orders that are produced in the same production run with the same destination can be assigned to the same buck if capacity allows it, because they will be placed on that buck directly after finishing production to minimise the total glass handling time. When the buck is complete it will be stored in the storage area. Imagine that Glasboer Nederland orders everything for Friday on Monday, then this order set will result in a production run at the producer. If

Glasboer Nederland places additional orders at Tuesday that should also be transported on Friday to the same destination, these cannot be assigned to the same production run as the orders placed on Monday.

Others claim that the large amount of destinations are the main reason for a low buck utilisation. Glasboer Nederland chooses to transport most pick-up orders directly on a separate buck for each destination to reduce handling costs at the hubs. Sometimes for example the establishment in Hengelo just needs $2m^2$ of glass. A buck, and thus floor space at a truck, should be reserved for this small volume. If this would have been delivered by glass rack transport via the hub in Holten, it would probably have fitted on one of the other bucks that are transported to Holten for glass rack (delivery) transport. In that case the large truck with bucks does not need to drive to Hengelo, but one of the smaller glass rack trucks should visit Hengelo in their route.

Our simulation model should be able to differentiate between the three different allowed order lead times that Glasboer Nederland and their supplier Glasboer Roden agreed upon and whether satellite establishments can receive pick-up orders also with glass rack transport or solely with direct buck transport. We consider the following options:

- Satellites directly delivered on bucks
    - **Current situation: Urgency, three days lead time, four days lead time (U34):**
      Each of the above will be placed on different bucks, such that for example an order with an order lead time of three days can never be placed on the same buck as an order with an order lead time of four days or an urgency order. Recall that an urgency order can be interpreted as an order with an order lead time of one day. When the urgency order is placed on Monday, it should be transported on Tuesday. This means that production should be finished before the closing time of the production facility on Monday, because transportation happens the next morning around 4AM to arrive at the hubs on time (recall that hubs should be delivered before 7AM, such that glass rack trucks can start their routes on time).
    - **Scenario One: Urgency, three days lead time (U3):**
      Orders with a lead time of four days will be 'remembered' or 'frozen' for one day and are grouped on the next day with orders with a lead time of three days, such that they can be assigned to the same production run and can be combined on the same buck when they have the same destination.

- **Scenario Two: Urgency, four days lead time (U4):**

  Orders with a lead time of three days are ‘remembered’ for two days and will be grouped with urgency orders.
- **Scenario Three: Urgency (U):**

  All orders will be remembered in the system until the day before transportation and are all together handled as urgency orders.

- Satellites can be delivered via glass rack transport

  The scenarios below are based on the four scenarios above, with the addition that pick-up orders can be delivered to the GLASBOER satellite locations with glass rack transport, such that they have the same destination as other orders that are delivered via the closest hub. When an order has a total volume larger than $15m^2$ they will always be transported directly on a separate buck to their final destination (thus not via a hub), since glass rack transport is not suitable for large volumes.
  - **Scenario Four: Urgency, three days lead time, four days lead time (U34R)**
  - **Scenario Five: Urgency, three days lead time (U3R)**
  - **Scenario Six: Urgency, four days lead time (U4R)**
  - **Scenario Seven: Urgency (UR)**

The goal of this simulation study is to quantify the effect of the order fragmentation and choosing to deliver pick-up orders to satellites with direct buck transport. What follows in this research will depend on the outcomes of this simulation study.

4.1.2 Expected contribution and results

We expect to provide the management of GLASBOER with data that could support decisions to be made by them and to concretise the effect of decisions that are made in the past.

4.1.3 Concise model description

The scope of this simulation study will be on the generated (identical) bucks as a result of the flat glass production runs at the production facility in Roden for Glasboer Nederland. All locations of Glasboer Nederland are incorporated in the model, because they all have an effect on the created bucks. We also simulate the different production runs for orders placed on different days, as a consequence of the different order lead times. Production of orders of Glasboer Roden’s own customers, thus not Glasboer Nederland customers, are not within the scope of this simulation study.

We don't use actual production times for the different runs, since we are solely interested in the generated bucks, not other production performance measures. Therefore we choose fixed times on a day for different production runs, because it simplifies the generation of different bucks per run in our model.

As mentioned before we use a few experimental factors including the different allowed order lead times between order placement at Roden and delivery of these orders at the locations of Glasboer Nederland. Next to that we can choose whether pickup orders for different satellites should be placed on different bucks for direct buck transport or they should be grouped for glass rack transport if the size is within the limitations of this type of transport.

The model should create reports containing the created buck per production run (based on the lead time) per day, whether the buck contains pickup or delivery orders and the volume and number of orders per buck.

4.1.4 Data requirements and collection

Our simulation study evaluates a few scenarios over the period between the first of June 2016 and the first of March 2017, because the data that is available to us covers this period. As input for our model we need the following from the data covering this period:

- Order number: The number that is used to identify the customer order.
- Order Date: The date the order is placed at Glasboer Nederland by a customer.
- Delivery Date: The date the order should be delivered to the customer or pick-up location.
- Establishment: The GLASBOER location the customer belongs to.
- Square meters: The total volume of the order in square meters.
- Route: The delivery cluster the customer belongs to, based on his postal code.
- Delivery Type: Glass rack transport to customer, buck transport to pick-up location or direct buck transport to customer.

The controller at GLASBOER Holten can provide us with reports containing the data we require. We should only format the data such that it can be imported into the simulation model.

4.1.5 Time planning and cost estimate

We cannot make a specific time planning in advance, since we are depending on other people to provide us the data we need. They could not give us a proper time indication when the data reports are available. We expect that the data collection and processing would take about a week, building and validating the model would take three to four weeks and executing the simulation runs and interpreting the results would take another week. Thus we expect to need a time frame of plus minus six weeks to complete the simulation study. Since we can use a student license for the simulation software provided by the University of Twente and we don’t need any other payed resources, the simulation study will not cost anything besides time.

4.2 Our Model

Below we discuss the frames and their function that are present in our simulation model. The reader should realise that it is necessary to have some basis knowledge about simulation modelling to be able to interpret the following part of this thesis. This section can be skipped otherwise.

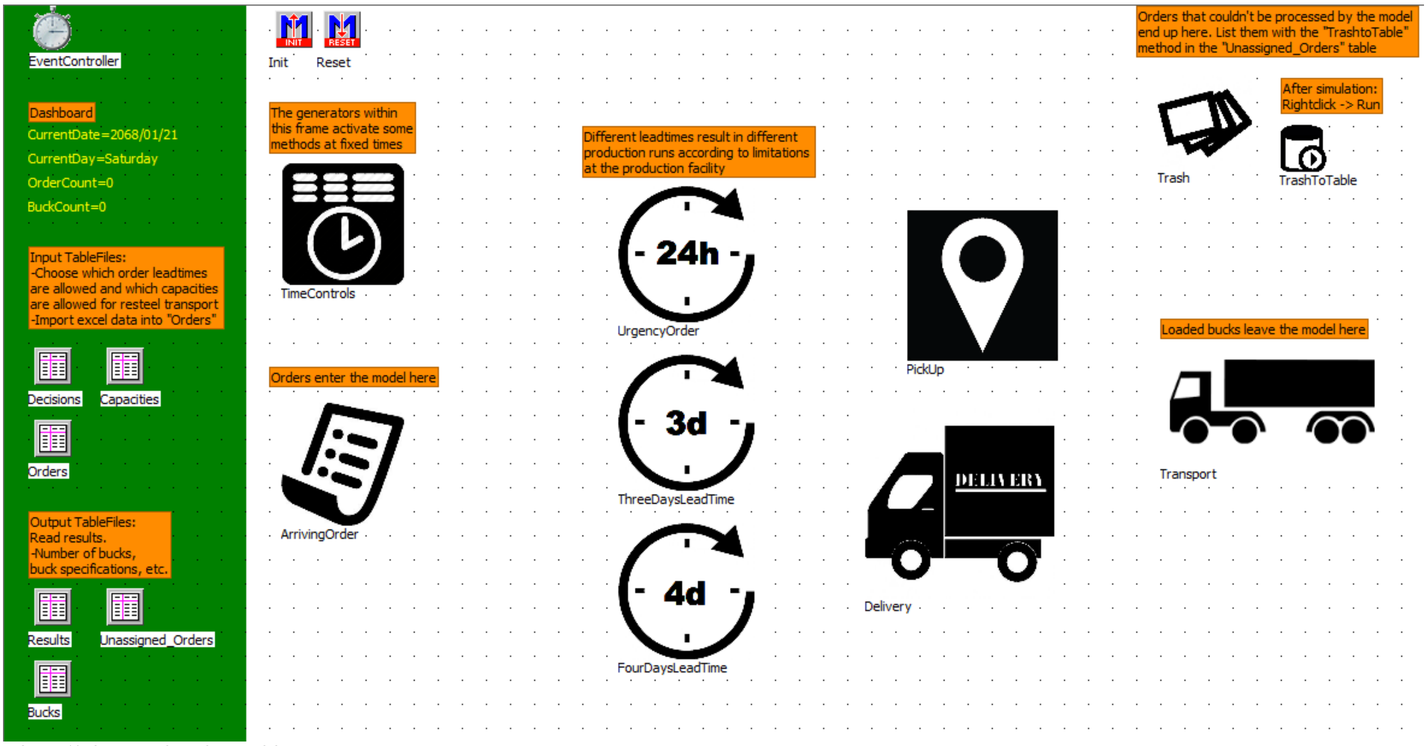


FIGURE 10: SIMULATION MODEL ROOT FRAME

- GLASBOER: This is the root frame which gives an overview of the processes that are described in the model. The figure above shows this frame. We can see the flow of the orders between their arrival and when they are ready to be transported at the expedition of the production facility. This includes the production runs they are assigned to and whether they should be grouped for glass rack transport per hub or they should be grouped per satellite location. We emphasize that this model is not a representation of the actual production process but it represents the factors that influence the construction of bucks during the production process.

- TimeControls: Within this frame several methods are initiated at different times. These are the method for date settings at the start of a day, a method which lets bucks that are ready for transport exit the model, methods which moves loaded bucks after a production run and the method that reads the incoming orders for the current simulated day.
- ArrivingOrder: Within this frame a moving unit (MU) is created for every customer order based on the imported data. Order specifications are assigned to these MU's and the order lead time is determined based on the Order date and the delivery date. We modelled this such that it takes into account that operations are idle during weekends. Based on the lead time the order will be assigned to a production run.
- UrgencyOrder; ThreeyDaysLeadTime; FourDaysLeadTime: These frames represent the production runs for the different lead times where the orders are assigned to. The only difference between these frames is obviously the processing time at the processing stations for the different lead times. If there is weekend between the order date and the delivery date the orders will first inter the WeekendBuffer in this frame. This make sure the order virtually stays in the production facility for two extra days. Finally the order will be sent to the "PickUp" or "Delivery" frame based on whether they have to be grouped for glass rack transport to one of the hubs, or for direct buck transport per satellite or customer.
- PickUp: This frame is able to build bucks for every satellite and place the pickup orders on these bucks such that they are grouped on a buck for direct transport to the satellite. If an order arrives at a satellite and there is no buck, it will be created. After every run the loaded bucks will be sent to the frame "Transport".
- Delivery: This frame basically does the same as the previous one, except it builds bucks per hub for glass rack transport.
- The last frame is "Transport". The loaded bucks will be placed here waiting for transport. Every morning these bucks will be transported and thus leave the system.

Orders that could not be assigned based on the criteria implemented in the model will end up in "Trash". These will not be used by the model, but allows us to evaluate orders that could not be processed by the model. Finally we have the output tables which show us the results of the simulation runs. The flowcharts that show the reasoning of the methods in the model can be found in appendix 9.1.

4.3 Verification and Validation

Building and verifying the model was done simultaneously. Each time we have built a new part in the model, we checked the working of the model. For example whether MU's flow through the correct stations by observing the animation of some randomly chosen orders, whether all orders eventually leave the model, whether the amount of orders passed through each production run corresponds to what the data tells us, etc. We validated our model by presenting it to the problem owner at Glasboer Nederland and our mentor at the University of Twente and evaluating with them if our model and associated data represent the real situation at Glasboer Nederland.

4.4 Experimental design

As we specified in the simulation project specification we are going to use the before mentioned experiment setups as you can see below. The number of possible combinations is not large, thus there is no need to evaluate them with for example interaction effects. Since we use historical data as input for our model we only need to perform one simulation run per setup. Every run with the same setup will produce exactly the same outcome, since there is no stochasticity in the model.

- Satellites directly delivered on bucks
    - Current situation: Urgency, three days lead time, four days lead time (U34)
    - Scenario One: Urgency, three days lead time (U3)
    - Scenario Two: Urgency, four days lead time (U4)
    - Scenario Three: Urgency (U)
- Satellites can be delivered via glass rack transport
    - Scenario Four: Urgency, three days lead time, four days lead time (U34R)
    - Scenario Five: Urgency, three days lead time (U3R)
    - Scenario Six: Urgency, four days lead time (U4R)
    - Scenario Seven: Urgency (UR)

In the next section we are going to use the abbreviations as defined between brackets above to denote which results aroused from which setup.

4.5 Results

The tables on the next page show a summary of the results of the simulation study. We assumed that for large volumes in an ideal situation, an average buck utilisation of $30m^2$ could be achieved. This is based on data analysis and expert opinions. There are several hubs and satellites where orders should be transported to and they don't all require large volumes, thus this $30m^2$ is unrealistic in reality. If Ede for example needs $22m^2$ of glass the buck will probably not fully utilised. But if we have a batch of glass with a total volume of for example $50m^2$, we assume that we need two bucks based on the $30m^2$ volume capacity per buck we mentioned above. There are instances where more than $30m^2$ has been placed on a buck, but a lot of factors have influence here. For example a batch of pieces of glass with large dimensions can fill a buck much more efficiently than a lot of small pieces of glass with different shapes and dimensions, if they have the same total volume. Besides, we want to be tentative with our results and not overestimate the improvement.

The first column in the tables denotes which scenario is considered in that row. We denoted the current situation as scenario 0. We should remark that in reality, pick-up orders to satellites are not always delivered on bucks. The buyers of Glasboer Nederland can decide manually how they order and can make different decisions based on which is best in their opinion. Generally they choose to deliver pick-up orders to satellites on buck transport. Even if the total volume for a certain satellite so far is low. They anticipate that extra urgency pick-up orders will be ordered for that satellite, such that the total volume will increase and it would have been a good choice to deliver that satellite on (a) buck(s). In reality these will end up on a separate buck anyway, because the producer does not group these orders with later placed urgency orders since they are produced in another production run. Anyway, in order to be able to simulate the effect of the choice to deliver most pick-up orders on buck transport, scenario 0 (current situation) assumes that all pick-up orders are delivered on bucks. The calculated buck utilisation based on the simulation study is somewhat lower than in reality because of that.

The second and third column in the tables show the volume of glass and number of bucks which are used for urgency orders for each scenario. The columns thereafter show these numbers for orders with three days lead time and four days lead time. The column with the header 'buck utilisation' shows the average volume in square meters over all generated bucks for each scenario. The last column shows the improvement of scenarios 1 to 7 compared to the current situation (scenario 0).

TABLE 7: RESULTS FOR SATELLITES DELIVERED DIRECTLY ON BUCKS

	Urgency		3 Days LT		4 Days LT		Total		Buck	Improvement
	Volume (m^2)	# Bucks	Volume (m^2)	# Bucks	Volume (m^2)	# Bucks	Volume (m^2)	# Bucks	Utilisation	%
0_U34	**8948**	**1675**	**6826**	**1163**	**145680**	**9364**	**161455**	**12202**	**13.2**	0%
1_U3	8948	1675	152506	9749			161455	11424	14.1	7%
2_U4	15774	2281			145680	9364	161455	11645	13.9	5%
3_U	161455	10501					161455	10501	15.4	16%

If the production facility was able to produce all regular final customer orders within three days, an improvement of seven percent in buck utilisation could be realised. Note that the volume of orders with three days lead time for scenario 1 equals the summed volume of orders with three and four days lead time of scenario 0. This is logical since the orders with four days lead time are added to the same production run as the orders with three days lead time. If Glasboer Nederland would order all regular final customer orders four days in advance, this percentage would be five percent. If the production facility was able to produce all orders within a day, the buck utilisation would increase with sixteen percent compared to the current situation.

TABLE 8: RESULTS FOR SATELLITES DELIVERED WITH GLASS RACK TRANSPORT VIA HUB IF $M^2 < 15$

	Urgency		3 Days LT		4 Days LT		Total		Buck	Improvement
	Volume (m^2)	# Bucks	Volume (m^2)	# Bucks	Volume (m^2)	# Bucks	Volume (m^2)	# Bucks	Utilisation	%
4_U34R	8948	631	6826	585	145680	8019	161455	9235	17.5	32%
5_U3R	8948	631	152506	8388			161455	9019	17.9	35%
6_U4R	15774	1008			145680	8019	161455	9027	17.9	35%
7_UR	161455	8817					161455	8817	18.3	38%

When Glasboer Nederland decides to use buck transport solely for destinations that should receive more than 15m^2, an improvement of 32 percent can be realised, based on the results of our simulation study. In this instance (scenario four) we use the same situation as the current situation (scenario zero), with the only difference that satellites will be delivered by glass rack transport when the total volume for that satellite on that date is lower than fifteen square meters. When this is combined with the reduction or groupage of order lead times (scenarios five to seven) larger improvements can be realised, but these are not significant.

4.6 Conclusion

Based on the results of our simulation study we can conclude that fragmentation of production orders based on their destination (delivering pick-up orders to satellites standard with buck transport) has a much more negative impact on buck utilisation than fragmentation of production orders based on their lead times. There are reasons to transport pick-up orders directly on bucks to satellites. Satellites should receive these orders before 10AM, which is not always possible by glass rack transport according to the planner. Based on this information we want to investigate whether Glasboer Nederland can increase its coverage throughout the Netherlands, such that the distance between hubs and customers/satellites are decreased. Because of this it should be easier to deliver pick-up orders to satellites with glass rack transport, since destinations in delivery routes will be closer to the depot (hub) and earlier deliveries are possible when needed. Redesigning the distribution network model will be the main topic of chapter six. New solution alternatives will be created considering different hub network designs.

4.7 Summary

In order to improve the average buck utilisation, it is crucial to know what the main cause is. In this chapter we conducted a simulation study to provide answers. We defined seven scenarios that we wanted to compare to the current situation. The first scenarios were used to simulate the effect of combining orders with different order lead times. The other scenarios were used to simulate the effect of delivering pick-up orders with glass rack transport to satellite locations instead of transporting them separately on (extra) bucks. The results of the simulation study showed that delivering pick-up orders with glass rack transport to satellites within regular customer delivery routes can increase buck utilisation most significantly (with 32 percent). Since this is practically not feasible with the current hub network structure (past experience has shown this) we concluded that the coverage should be increased, such that the average distance from a customer or satellite location to a hub is decreased. To be able to come up with good alternative hub network designs we will first conduct a literature study.

5 THEORETICAL FRAMEWORK

This theoretical framework provides an overview of relevant literature, methods and algorithms which we believe are relevant in our field of research. Based on our research questions and findings during the analysis of the current situation and our simulation study we dived into the rich collection of literature which is available considering distribution network modelling, routing and working towards a collaborative supply chain. We are going to elaborate on the most widely used concepts and compare them where necessary.

5.1 Distribution network model design

For determining the proper hub locations within a distribution network the *p*-median problem is the most applied problem in practical location problems. It aims to minimize the demand weighted average distance between customers and the selected hubs. Our definition is as follows:

We introduce the binary variables X_{ij}, denoting whether orders with postal code i will be served by location j and Y_j denoting whether location j serves as a hub. Furthermore we have parameters p, o_{ij} and d_{ij}. p denotes the number of locations that will serve as hubs. o_i gives the number of historical orders from our dataset with delivery postal code i. d_{ij} gives the Euclidean distance between the centre of gravity of the area with postal code i and location j.

To find the most suitable locations for a distribution network with the chosen number of hubs we want to minimise the following objective function:

$$MIN\ z = \sum_i \sum_j X_{ij} * o_i * d_{ij}$$

By using o_i as a weight based on the number of historical orders with postal code i, we make sure that the determination of the optimal hub locations will be based on the most important areas. To obtain a feasible solution we are subject to the following constraints:

$$\sum_j X_{ij} = 1 \qquad \textit{Every postal code i will be served by exactly one hub}$$

$$\sum_i X_{ij} \le M * Y_j \qquad \textit{A postal code can only be served by a location that serves as a hub}$$

$$\sum_j Y_j = p \qquad p \text{ locations will serve as a hub}$$

$$X_{ij}, Y_j \in (0,1) \qquad \text{All variables are binary}$$

5.2 Route generation

In this part of this theoretical framework we outline a selection of theories and algorithms concerned with route optimisation and improvement heuristics. We first discuss the 'Vehicle Routing Problem' along with some popular path finding algorithms.

5.2.1 Vehicle Routing Problem (VRP)

The vehicle routing problem (VRP) is the general term for the problem of creating (near) optimal routes from one or several depots to a number of geographically dispersed locations. Since a long period, VRPs play an important role within the disciplines of physical distribution and logistics. (Laporte, 1992) Most common in practise is the two-echelon vehicle routing problem. In this instance of the VRP, consolidation of goods takes place at one or a few depots, from where long-haul transportation vehicles ship their goods to a set of 'hubs' (first level). At these hubs the goods can generally be stored for just a short period and are dispersed over smaller transportation vehicles which are responsible for delivery to the final customers (second level). VRPs which considers a limit on capacity of transportation vehicles are called 'capacitated vehicle routing problems' (CVRP).

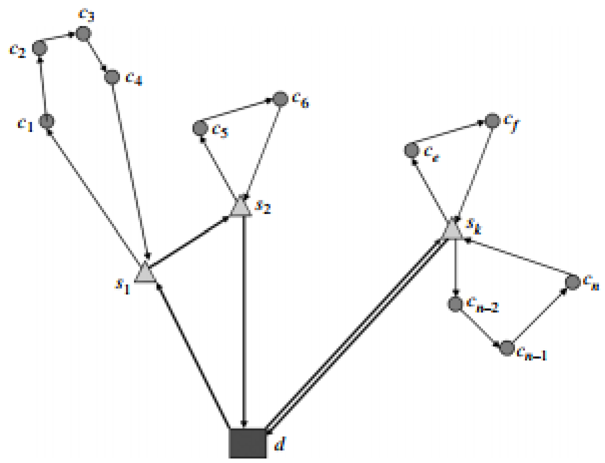


FIGURE 11: EXAMPLE OF TWO-ECHELON CVRP TRANSPORTATION NETWORK (PERBOLI, TADEI, & VIGO, 2011)

Figure 11 illustrates such a two-echelon CVRP, with d as the depot, s_1 to s_3 as the hubs and c_1 to c_n as the customers. Each customers i has a demand d_i, i.e. the quantity of goods that it wishes to receive. Each customers demand cannot be split over several vehicles at this second level. The first level, which indicates the deliveries from the depot to the hubs, can be split over several vehicles. The completion of these vehicles depend on the capacities of these vehicles and the routes to be driven to the hubs. We assume that all vehicles at the same level have the same capacity. The objective is to serve all customers with demand with minimal total transportation costs, while satisfying the capacity constraints of the vehicles. (Perboli, Tadei, & Vigo, 2011) For the CVRP there exist both exact algorithms and heuristic algorithms. The VRP can be defined as follows (Laporte, 1992):

Let G = (V, A) be a graph where V = {1 .... , n} is a set of vertices representing locations with the depot located at vertex 1, and A is the set of arcs. With every arc (i, j) $i \neq j$ is associated a non-negative distance matrix $C = (c_{ij})$. The VRP consists of designing a set of least-cost vehicle routes in such a way that:

1. Each location is visited exactly once by exactly one vehicle;
2. All vehicle routes start and end at the depot;
3. Some side constraints are satisfied, i.e.:
    a. A non-negative weight (or demand) d_i is attached to each location $i > 1$ and the sum of weights of any vehicle route may not exceed the vehicle capacity. (CVRP)
    b. The number of locations on any route is bounded above by q.
    c. The number of routes cannot exceed the number of available vehicles.

The CVRP defined above is NP-hard which means that an exact solution can only be found for small instances. Therefore we only consider heuristic algorithms in the following sections.

THE SWEEP ALGORITHM

The sweep algorithm received its name from Gillett and Miller in 1974. Using this algorithm, destinations are assigned to trucks based on their polar coordinates and angle towards the depot. Laporte(1992) suggests the following implementation of this method:

1. Choose an unused vehicle k.
2. Starting from the unrouted destination having the smallest angle, assign destinations to the vehicle as long as its capacity is not exceeded. If unrouted destinations remain, go to Step 1.
3. Optimize each vehicle route separately by solving the corresponding TSP (exactly or approximately). Perform destination exchanges between adjacent routes if this saves distance. Re-optimize and stop.

The purpose of ‘sweeping’ within this algorithm is to create clusters which can be assigned to a vehicle. So the set of destinations for a vehicle are determined, but an algorithm for solving a traveling salesman problem (TSP) is needed to optimize the sequence in which the locations are visited. We discuss some heuristics for solving a TSP below and compare their solution quality and running times.

NEAREST NEIGHBOUR

This is a very famous but simple heuristic for the TSP. This algorithm is based on the traveller who starts his trip at a depot and will always continue his trip to the nearest unvisited location until he has visited them all. When he has, he will return to the depot.

1. Start at the depot
2. Find the nearest unvisited location and go there.
3. If there are any unvisited locations left, go to step 2
4. Return to the depot

NEAREST INSERTION

This heuristic constructs a route by choosing the location that has the lowest insertion cost of all unassigned locations at each iteration. The insertion cost can be calculated as the extra driving distance of adding a location to the tour. From Figure 12 we can see that adding location C to the subtour Depot – A – B – Depot has an insertion cost of $4 + 3 - 5 = 2$.

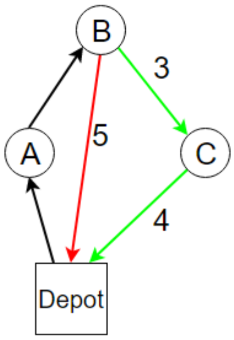


FIGURE 12

1. Start a subtour by adding solely the depot
2. Find the location that is farthest from the depot and add it to the subtour
3. Calculate the insertion cost for all locations that are not in the subtour
4. Add the location with the lowest insertion cost from 3. to the subtour
5. If there are any locations left that are not in the subtour, go to step 3
6. Stop

SAVINGS METHOD

The savings method starts with a solution where the vehicle starts at the depot, visits a location, returns to the depot, visits the next locations, etcetera until all locations are visited. Based on this initial route the savings will be calculated if anywhere within this route the vehicle does not return to the depot, but directly moves on to another location. From Figure 13 we can read that visiting location B directly after location A instead of returnin to the depot in between will save $5 + 2 - 3 = 4$.

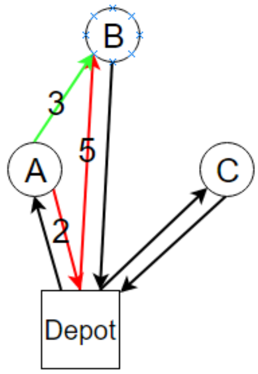


FIGURE 13

1. Form (retour) routes from the depot to each location
2. Calculate all savings for connecting two locations and removing the connections back to the depot
3. Order savings from 2. from largest to smallest
4. Link customers according to saving, taking into account the connections that were formed in a previous iteration
5. If not all locations are on the route, go to 4
6. Stop

COMPARISON

We elaborated on three heuristics for route generation. To make a decision on what heuristic to use in our model we use the attributes of good heuristics by Cordeau, et al (2002). They defined 'accuracy' as the deviation of the heuristic solution value from the optimal solution value, 'speed' as the computation speed after it has been implemented in a procedure, 'simplicity' as the easiness to understand and the robustness of the heuristic to ensure they work as they are meant to do and finally 'flexibility' as the ability to accommodate the side constraints that can be encountered in majority of real-life applications.

Since all three heuristics described above are simple to understand in our opinion and equally flexible, we compare them solely based on running time (C1) and solution quality (C2). Running time will be very important, since we should find a solution in reasonable time and we don't have an extremely fast computer. Solution quality is important, but will also be affected by other factors within this research. In order to calculate route distance between locations we should use Euclidean distances as a rough estimation for actual routing distance, because we don't have the resources to use on-road traffic data available. Since the solution will be an estimate anyway, we decided that running time outweighs solution quality by a factor 1,5. A lot of studies have been done towards determining the solution quality of VRP heuristics. We have used the book of Hoos & Stützle (2004) to find the solution quality for medium sized problems. The solution quality can be defined as the procentual deviation from the optimal solution, thus the lower this deviation the better the solution. The table below shows the values for running time and solution quality for each heuristic and gives them a score based on our motivations above.

TABLE 9: COMPARISON OF ROUTE GENERATION HEURISTICS

Heuristic	Running Time (C1)	C1 Score (1-5)	Solution Quality (C2)	C2 Score (1-5)	Total Score
H1: Nearest Neighbour (NN)	$O(N^2)$	5	20-35	1	5*1,5+1=8,5
H2: Nearest Insertion (NI)	$O(N^2)$	5	13-15	4	5*1,5+4=11,5
H3: Savings Method (SM)	$O(N^2 \log N)$	1	12	5	1*1,5+5=6,5

Based on the scores in the table above and the weights mentioned before we choose Nearest Insertion as the preferred VRP heuristic for route generation.

5.2.2 Simulated Annealing

After an initial solution has been created using the heuristics and algorithms in the previous section we need to improve our solution. We use Simulated Annealing as optimisation algorithm since we have worked with this algorithm before, it has proven its ability to provide very good results since the eighties and it is very suitable in the fields of vehicle routing problems.

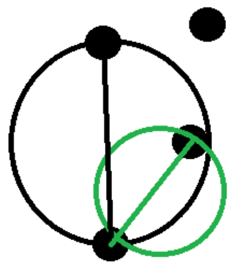
The term Simulated annealing is derived from and inspired by a technique within the field of metal processing. 'Annealing' is a technique which controlled cools down heated metal, to increase the size of the crystals within the metal to reduce the number of defects. As for the SA algorithm, it uses a 'state' to determine the acceptance probability of a solution. This state is based on a so called temperature. The algorithm starts with a chosen starting temperature t_0, which will be decreased over time by a cooling factor c. Based on the current temperature, the algorithm calculates the probability of accepting a worse solution, than the best solution found so far. The lower the temperature, the lower the chance of accepting a worse solution. This method increases the probability of finding a global optimal solution, instead of getting stuck in a local optimum. Local search algorithms often focus on the solution space near the best found solution so far, without looking beyond it. Simulated Annealing tackles this drawback. The following steps should be taken. (Osman, 1993)

1. Generate an initial heuristic solution S by the methods described in the previous sections and store the solution value as the current solution and the best solution found so far.
2. Choose starting temperature $T = t_0$, stopping criteria t_{stop}, decreasing factor c and Markov chain length k. These can be tweaked intuitively based on acceptance ratio's and running time. The algorithm should accept nearly all candidate solutions at the beginning and should reject all of them at the end (since an as good as possible solution should be found). The running time depends on the Markov chain length and the decreasing factor. The Markov chain determines the number of times a new candidate solution will be evaluated before decreasing the temperature.
3. Randomly choose a candidate solution and calculate candidate solution value (according to an evaluation procedure which for example calculates the total distance or total costs).
4. Calculate the difference between the candidate solution value and the current (accepted) solution value and call it Δ.
5. Accept the candidate solution with probability $e^{\frac{-\Delta}{T}}$
6. If the candidate solution is the best so far, store it as best solution.

7. If k < Markov chain length, go to 3.
8. If $T < t_{stop}$, then stop. Else set T = T * c and go to 3.

NEIGHBOURING STRUCTURE

To find a new solution we should make an incremental change to the current solution. In a VRP that can be done by choosing a random location that should be visited and move it from its current route to a neighbouring route. The new solution should not be completely messed up, i.e. that a location will be moved to a route that currently is far away from its location. To ensure that visited locations are moved to routes that are driven nearby, a neighbouring structure can be used. We developed a way to calculate whether the areas of two routes can be considered as neighbours, based on Delaunay triangulations.



When looking at the figure to the right, interpret the black points as centres of gravity of a delivery route. We draw a line between two points and use this as the diameter of the circle connecting these points. Now calculate the distances from the centre of this circle to all other points except those lying on the circle. If there exist a point with a distance smaller than the radius of the circle, then this dot lies inside this circle. This means that the areas with their centres of gravity on the black circle are probably no neighbouring areas, because they are separated by the area which has his centre of gravity inside the black circle. The two points on the green circle show that these points correspond to the centres of gravity of two neighbouring areas, since no point lies inside this green circle.

We should remark that when areas have irregular shapes than two areas can have common borders while another area has its centre of gravity inside the imaginary circle of the two neighbouring areas. However we ignore this possibility to be able to determine neighbours with a procedure in a practically feasible and fast manner. It can be guaranteed that only routes will be found for our neighbouring structure that are close to each other. There is only the risk of not considering a route which can be of interest.

5.3 Collaboration within the supply chain

Within this section we provide an overview of issues and suggestions considering collaboration within the supply chain based on current literature. We are going to discuss why collaboration between vertical chains in the supply chain is essential, where potentials for collaboration exists and which elements are crucial for effective collaborations. (Barratt, Understanding the meaning of collaboration in the supply chain, 2004)

5.3.1 Why is collaboration within the supply chain needed?

Companies continuously strive to improve the efficiency of their internal supply chain activities, such as purchasing, manufacturing and logistics (Ellinger, 2000). From a supply chain wide perspective the results of these can be interpreted as the redistribution of costs and inventory both up and down the supply chain (Ireland & Bruce, 2000). Simatupang & Sridharan (2002) state that potential benefits which could be realised by supply chain partnerships are rarely realised due differences in interests. Chain members are often focused on their own profit instead of the overall chain profit. They often work based on their local perspectives and opportunistic behaviour of maximising their individual profit even though this occurs at the expense of other members and overall profitability.

According to Barratt (2004), the following issues represent opportunities whereby collaboration may provide answers.

Each member within the supply chain has its own plan for its activities and within each organisation other unrelated plans exist. While heavily focussing on planning, organisations fail to consider other internal activities that will also have their impact on the result of a particular plan. This “silo” mentality often results in poor communication.

Responsibilities are often delegated to employees or managers, whilst they have no influence or control over involved activities that are impacted by other departments in the organisation. Personal (informal) relationships between managers and employees across different departments will probably result in dissatisfying or non-optimal outcomes.

Many organisations don’t have the same performance measures across purchasing, manufacturing and logistics. They also don’t share the same performance measures with suppliers and customers. These different measures will most likely produce conflicting behaviour within the supply chain.

Simatupang & Sridharan (2002) categorise sources of differences in interests (or managerial inertia) in (i) inappropiate measures of performance, (ii) outdated policies, (iii) asymmetric information and (iv) incentive misalignment.

The first refers to existing traditional measures of individual performance. Chain members often do not have performance metrics that reflect the performance of the whole chain. While limiting itself to local measures members of the supply chain do not work together as an integrated link and thereby fail to maximise value for end customers. Aiming to improve individual performance without considering the overall chain will likely have an injurious effect on other chain members.

The second source of managerial insertia, outdated policies, refer to decision guides which no longer apply to current practices. These policies can incorporate agreements on capacity utilisation, purchasing quantities, etc. Chain members often take advantage of these outdated policies to fit their own interests. Policies such as minimum order quantity, volume and price discounts, order batching and order quota drive the buying behaviour that often results in demand floors and ceilings that create demand amplification (Lee, Padmanabhan, & Whang, The Bullwhip Effect In Supply Chains, 1997).

Asymmetric information is about different members of the supply chain preserving individual (perceived) private information about demand conditions, products and operations. Services and activities are often not harmonised amongst supply chain members because they lack the required information about each other’s plans, intentions, market needs, etc. This results in sub-optimal decisions to be made and opportunistic behaviour.

Incentive misalignment occurs when only local rewards and penalties are considered, sometimes at the expense of others. Opportunistic behaviour such as forward buying gives a distorted view of customer demand to suppliers as retailers buy larger quantities than needed and stockpile for future selling (Simatupang & Sridharan, 2002).

5.3.2 Elements of collaboration

Barratt (2004) stated that one of the most important elements of collaboration is a “collaborative culture”, which is built upon the cultural elements “trust”, “Mutuality”, “Information Exchange” and “Openness and Communication” as shown in Figure 14: .

Trust and commitment is the foundation of effective coordination of the supply chain (Lee & Billington, 1992) and can contribute significantly to the long-term stability of an organisation (Heide & John, 1990).

Collaborations need to involve mutual benefits. It may not be a situation where "I win, you go and figure out how to win" (Ireland and Bruce, 2000). Risk should be shared and there should be respect for other trading partners (McIvor & McHugh, 2000).

Several authors have emphasised that for supply chains to improve their performance, information sharing is crucial (Barratt, 2004). Intermediation could be a barrier to transparency between partners and is most of the time a non-value adding activity (Popp, 2000). "Information Enrichment" or immediate sharing of marketplace data between partners in the chain is obligatory if we want to move to "seamless" supply chain in which every partner think and acts as one (Mason-Jones & Towill, 1997).

To move towards this seamless supply chain and improve information sharing there should exist clear and passable lines of communication. This is also needed to attain common understanding of each other's necessities and activities. These lines of communication should cross multiple lines of contact to ensure that when someone leaves a partner company, the common understanding will not be threatened. (Barratt, 2004)

Trust, respect and commitment are likely to be the result of improved certainty and reliability (Popp, 2000). This can be developed by openness and honesty about certain issues. If any disturbance will result in for example delays, the receiver should be informed as soon as possible, such that the receiver can adjust their plans to reduce harm as much as possible.

In Figure 14 Mark Barratt(2004) also points out what elements are key for the collaboration to be successful:

8) Cross-functional activities to diminish boundaries and thus information sharing between organisations.
9) Process alignment to resolve differences in partners' processes. It will require senior management support to overcome functional friction.
10) Joint decision making to ensure decisions are made based on collective information. For example variation in demand will collectively be lower than when considered individually per partner.
11) Supply chain metrics to align the directions of chain partners. Most measures are based on internal performance measures of each partner. By focusing on the supply chain as a whole the overall performance can be improved.

All these elements require massive internal and external change which only has a chance if there are change management programs in place. Otherwise internal resistance or secluded employees will prevent the collaboration to develop.

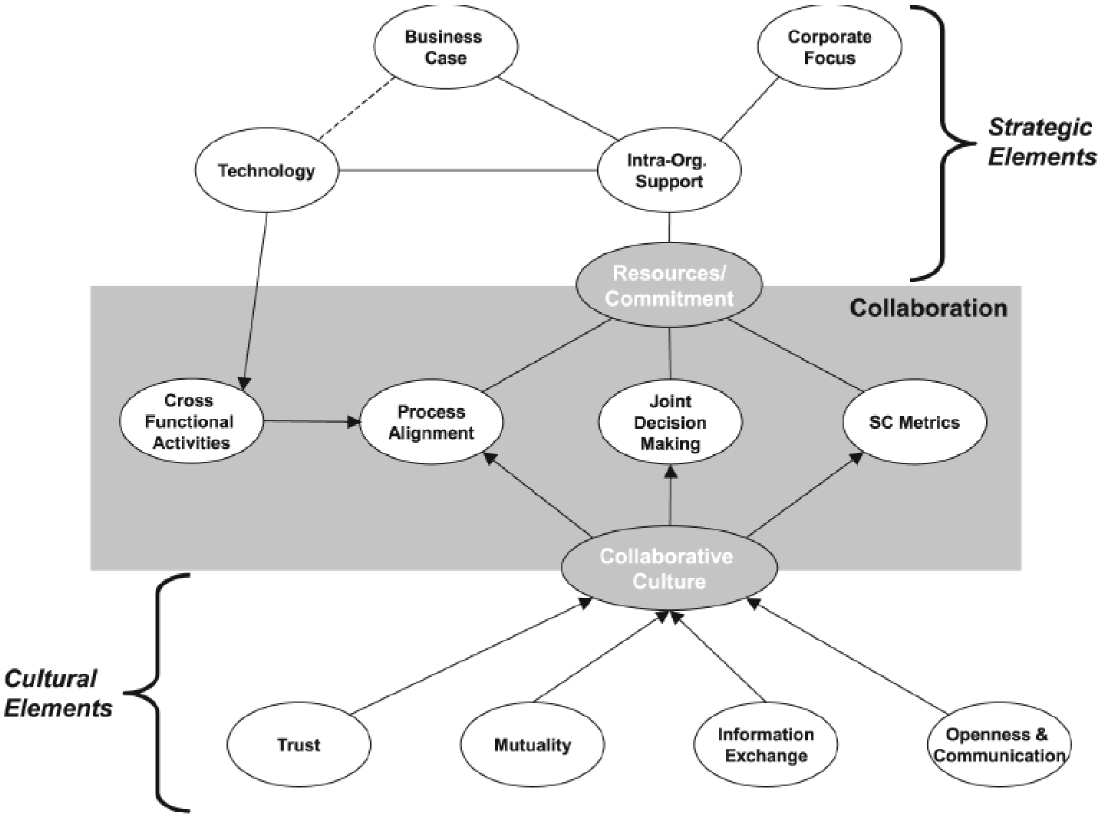


FIGURE 14: (BARRATT, THE "CULTURAL" ELEMENTS OF SUPPLY CHAIN COLLABORATION, 2004)

5.4 Summary

In this theoretical framework we described several logistical concepts that are relevant within the scope of our research. We first elaborated on the p-median problem which is very suitable for designing a proper distribution network. We can use this to decide which locations should act as hubs if GLASBOER decides to open extra, or other hubs. Next we elaborated on concepts and heuristics that we can use to calculate efficiency of distribution networks. The vehicle routing problem describes the problem of constructing efficient routes from delivery orders that are assigned to the closest depot (hubs). Several algorithms can be used to find a good solution for the vehicle routing problem. We described how the sweep algorithm can be used to construct clusters from a large batch of orders that are assigned to a depot. After that we described three heuristics that can be used to construct initial routes from these clusters. We compared these heuristics and prefer the nearest insertion heuristic based on the combination of running time and solution quality. Simulated annealing can be used to improve an initial solution that we can find with the algorithms discussed before. We described the working of simulated annealing and defined a neighbouring structure that we can use to find new, incrementally changed solutions.
Furthermore we provided an overview of issues and suggestions considering collaboration within the supply chain which we can use to provide recommendations for further development of the branches (wholesalers and producers) of GLASBOER within the Netherlands together.

6 HUB NETWORK

Let us now focus on designing an improved hub network for Glasboer Nederland. Recall from our simulation study that pick-up orders which are transported directly from the production facility to satellite establishments on separate bucks are the main cause of a relatively low buck utilisation. These orders are not transported by glass rack transport from the hubs, because early delivery at the satellite cannot be guaranteed. Recall that GLASBOER wants to offer their customer a service degree which allows them to pick up their glass orders after 10AM at their local GLASBOER establishment. In this part of our research we want to find out if we can improve the coverage degree (or average proximity of a delivery address to a hub) of the distribution

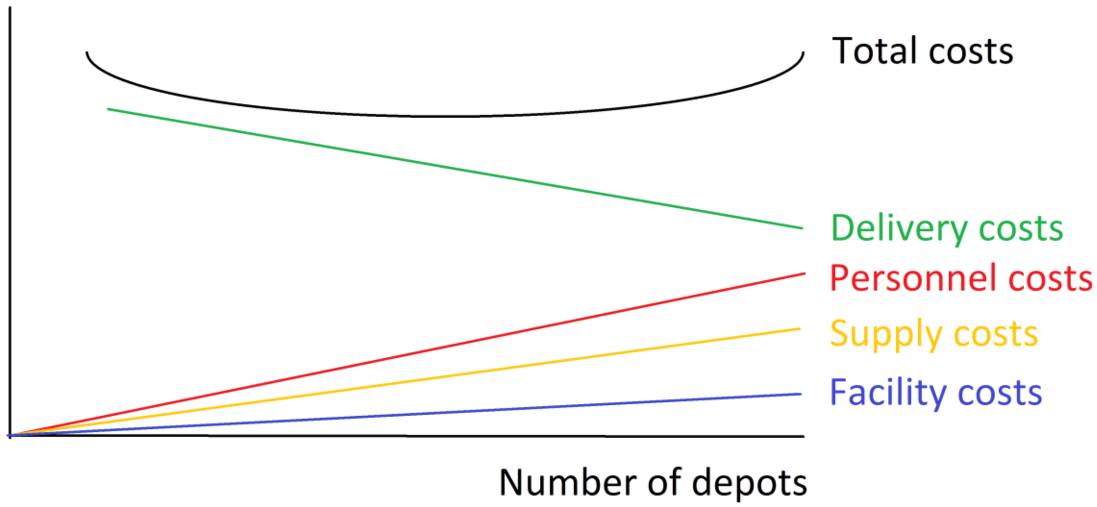


FIGURE 15: BATHTUBE CURVE FOR TOTAL DISTRIBUTION COSTS

network of GLASBOER and decrease the total distribution costs. We can see at the figure below that the distribution costs for different numbers of hubs follow a bathtub curve. This implicates that the distribution

costs are constant for a certain number of hubs around the optimum. Glasboer Nederland uses three hubs at the moment, but we want to investigate what the cost effect will be if we increase this number and thereby increase the geographical coverage.

6.1 Optimal hub locations

We need a well-considered set of locations which should serve as hubs in GLASBOER's distribution network. We focus on their existing locations since they served as individual distributers in the past and are well suited for transhipment of glass. In order to find the best suited hubs for a selected number of hubs we are going to use the *p*-median model. The model should find the best hub locations by minimising the cumulated distances between frequently visited postal codes and the selected hubs.

6.1.1 Model and data

The *p*-median model has been implemented in Excel as described in section 5.1 of the theoretical framework. We created a distance table that contained the distances between every Dutch 4-digit postal code and each of the Glasboer Nederland locations and we added a table containing the number of orders that have been delivered during a period of nine months in 2016 in each of the 4 digit postal codes. The initial setting contained three hubs, Amsterdam, Holten and Eindhoven. These are the most appropriate locations based on location, storage space, expedition space, expedition equipment and outside terrain for unloading and loading vehicles. To accommodate incremental changes that can be achieved in a short period of time we keep these locations as hubs. With the solver in Excel we calculate which form the Glasboer Nederland satellites are the best candidates, if we want to open up to three extra hubs. The following results were obtained for the chosen values of *p* in the *p*-median model.

- *p = 3*: Amsterdam, Holten, Eindhoven
- *p = 4*: Amsterdam, Holten, Eindhoven, Beuningen
- *p = 5*: Amsterdam, Holten, Eindhoven, Beuningen, Meppel
- *p = 6*: Amsterdam, Holten, Eindhoven, Beuningen, Meppel, Hoorn

We have determined the optimal hub networks based on different numbers of hubs and their weighted proximity to the postal codes within the Netherlands that have Glasboer Nederland customers. The next step is to calculate for each of the hub networks the total corresponding distribution costs.

6.2 Route generation

In order to derive the cost curve for each chosen network of hubs we need a model which we can use to estimate the distribution costs for each network. The model should provide us for a given day, as good as possible routes, which we can use to find total driving distances and driving times. To start with the model should be able to assign orders to the selected hubs based on the Euclidean (through the sky) distance between the hubs and the orders' delivery address. For each hub the model should divide their assigned orders in clusters which will be used to create routes later on. For this we use the sweep algorithm, which groups orders based on their angle towards the hub based on their geographical coordinates. After this the model should use a vehicle routing problem (VRP) heuristic to create routes for these clusters to attain a rough approximation of the Euclidean routing distances. These distance will not represent the 'real' driving distances but can be used for optimisation purposes. We did not want to choose a complicated VRP heuristic, since this would have a large impact on the running time of our program. We chose the 'nearest insertion algorithm' since it is easy to implement and does not require intense calculations. In the optimisation part of our model we want to incrementally change the initial solution by moving a random order to a neighbouring route. The model should determine these neighbours using a method based on 'Delaunay triangulations' as described in the theoretical framework. The model should compare the total Euclidean routing distance of the changed routes before and after moving the order. We use 'simulated annealing' (SA) to incrementally improve our solution towards a global optimum. We are going to program our model in Pascal using Delphi.

6.2.1 Variables

In our program we use the following global variables:

- Order: An array containing the orders for a specific Date extracted from the data. with the following specifications:
    - Number: Order ID as used by GLASBOER
    - Volume: Total glass volume in m^2 in order
    - Weight: Total weight in order
    - Amount: Total number of glass plates in order
    - DelDate: Delivery date of order
    - Address: Delivery street and number
    - Postal code: Delivery postal code

    - City: Delivery city
    - InRoute: Denotes which route the order is assigned to
    - Hub: Denotes which hub is responsible for delivering the order
    - Latitude, Longitude: Geographical coordinates of the destination of the order
    - PolarAngle: Denotes the angle of the orders destination towards its assigned hub
- Hub: An array containing the selected hubs with the following specifications:
    - Name: Name of the hub location (String)
    - AssOrders: Array containing all the orders that are assigned to this hub
    - NumOrders: Total number of orders assigned to this hub
    - SumSquareMeters: Total volume glass in m^2 assigned to this hub
    - Latitude, Longitude: Geographical coordinates of the hub
- Route: An array containing the created routes with the following specifications:
    - Number: Route number which will be assigned to the route by the program
    - Hub: Hub from where this route will be driven
    - AssOrders: Array containing all the orders that are assigned to this route
    - NumOrders: Total number of orders assigned to this route
    - Volume: Total volume glass in m^2 assigned to this hub
    - Distance: Total Euclidean distance of this route
    - CentroidLat, CentroidLong: Coördinates of routes centre of gravity
- BestRoute: An array storing the best solution found by the optimising procedure, with the same specifications as Route

6.2.2 Input and parameters

Our model uses a .CSV file with order data as input. For every order the volume, weight, amount, delivery date, delivery address and coordinates of this delivery address should be in the file. A small example of how this file looks like is shown in appendix 9.2.2. To create proper truckloads the model uses the surface volume of the glass. The model can select orders of interest based on their delivery date, such that for a chosen day the routes can be constructed assuming that the data is complete for that date. Sky wide distances between locations can be calculated using the Latitude and Longitude of these orders. We found these coordinates in a Dutch postal code file on the internet and matched our data with it.

Besides the input file we use a few parameters to ensure that space and time capacity restrictions are met. We know from historical data that in most instances a glass rack truck can easily store

$80m^2$ glass. On average a route driven by GLASBOER glass rack trucks stored $50m^2$ of glass in 2016. Based on this knowledge we strive to create routes with total volumes below $80m^2$ and base our initial routes on an average volume of $60m^2$ per glass rack truck. We know that GLASBOER has 19 trucks available, from which some are owned and some are leased. Therefor we want to make sure that no more than 19 routes are created for a given day. Finally we want a maximum of 18 customers per route. The pseudo code of our model can be found in Appendix 9.2.1.

6.3 Using our model

After we finished building, testing, debugging and improving our model, we used our program (for a screenshot we refer to appendix **Error! Reference source not found.**) to create efficient routes for the different alternatives considering the different sets of hubs we defined in section 6.1. Our program is able to create efficient routes based on sky wide (Euclidean) distances. To calculate realistic variable costs for these created routes we need to know road distances and driving times. We used the route planner on www.routexl.nl to acquire these distances and times. This route planner allows us to import up to 20 addresses at a time in batches, considers extra time per visit and is able to deal with time windows. This is a big plus, since GLASBOER's satellite locations need to be visited before 10am to deliver orders on time for pick-up. After an efficient route has been created we were able to read the driving distances and working times on the site. We stored these in Excel and used it to calculate all relevant variable distribution costs for each alternative set of hubs. Since the total capacity that should be transported remains the same for glass rack transport the fixed lease costs, insurance costs, etc. for glass rack trucks are the same for every alternative and we therefore leave them out of our calculations.

6.4 Results

In this section a summary is given of the results found with our distribution model. A more extensive overview of the results can be found in Appendix 9.2.3. Consider the hub network with hubs Amsterdam, Holten, Eindhoven, Beuningen, Meppel. For the hub Amsterdam we plotted the delivery addresses that have received an order on 28-06-2017 on a map in figure 16 to show how they are grouped by our model. Locations with the same colour are in the same route and the red location is the hub at Amsterdam. The route in figure 17 is the same as the yellow plots in figure 16.

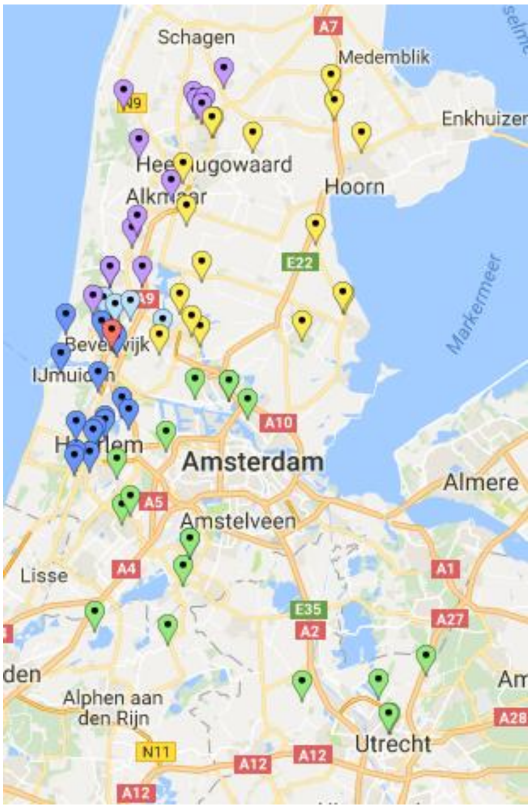


FIGURE 16: PLOTTED ROUTES FOR AMSTERDAM

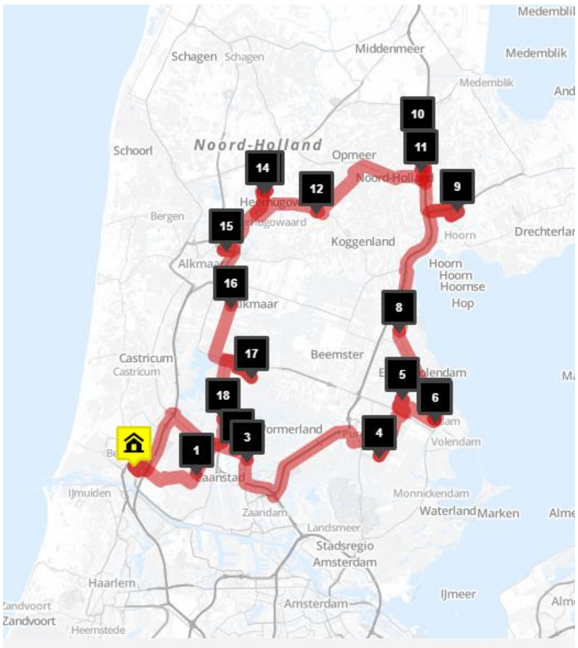


FIGURE 17: ROUTE CREATED ON WWW.ROUTEXL.NL

6.4.1 Costs

Now we elaborate on how we calculated the total costs. The costs can be divided in two parts, the costs for glass rack transport and the costs for buck transport. From our data in the current situation (chapter 0), we know that the glass rack transport costs € 0,175 per kilometre based on fuel usage. Recall that we extracted the fuel usage of the trucks from records of Shell. We used recent Diesel fares to calculate the costs per kilometre. A driver for these trucks costs approximately € 20. As mentioned in the previous section we don't take the lease costs into account, since we want to compare different alternatives solely on how efficient they are, or how efficient the routes are that can be generated within each specific alternative hub network. The facility costs are not relevant here, since Glasboer Nederland already possesses the 16 locations spread through the Netherlands. Using one more of them as hub does not increase costs. Thus we can see these facility costs as sunk costs. Buck transport is outsourced to an external transporter with agreed prices of € 0,70 per kilometre and € 30,00 per hour per truck.

TABLE 10: WEEKLY VARIABLE TRANSPORT COSTS PER ALTERNATIVE

Hub network	**#Hubs**	**Costs glass rack transport (1 week)**	**Costs buck transport (1 week)**	**Total costs (1 week)**
Amsterdam, Holten, Bergen Op Zoom, Eindhoven, Nieuwegein (current)	5	€ 9.550	€ 9.725	€ 19.275
Amsterdam, Holten, Eindhoven (initial plan)	3	€ 9.945	€ 8.374	€ 18.319
Amsterdam, Holten, Eindhoven, Beuningen	4	€ 9.545	€ 8.511	€ 18.056
Amsterdam, Holten, Eindhoven, Beuningen, Meppel	5	€ 9.539	€ 8.575	€ 18.114
Amsterdam, Holten, Eindhoven, Beuningen, Meppel, Hoorn	6	€ 9.335	€ 8.707	€ 18.042

From the results in the table above we can see that our proposed alternative hub networks are very promising regarding variable costs. They all (including the initial plan that has been introduced during Glasboer Nederland's reorganisation) provided better results than the current hub network. We can also see that the total costs are declining when we increase the number of hubs in GLASBOER's network according to our proposed hub network alternatives. There is a slight deviation in this trend at the alternative with 5 hubs (Amsterdam, Holten, Eindhoven, Beuningen, Meppel). This can be explained by minor inaccuracies in our used model. The model does not provide an optimal solution, but tries to find an as good as possible solution in reasonable running time. Sometimes during a run, the model needs more iterations to find a good solution, because it gets stuck in a local optimum.

6.5 Conclusion

Based on our results, which we discussed in the section above, we can conclude that the total variable distribution costs will not increase if Glasboer Nederland decides to appoint up to six locations as hub locations. The costs for buck transport will not increase a lot, since most of the satellites have to be visited with buck transport at least three times per week. If a location has to be visited that often by buck transport, it can as well serve as hub. The costs for glass rack transport are declining significantly by using more hubs, because of the declining distances that have to be driven by glass rack transport routes. The glass rack vehicles will still need to transport the same volumes, thus the fixed costs will not change significantly.

It has been shown that the most promising hub to open next to the three 'main hubs' (Amsterdam, Holten, Eindhoven) is Beuningen. There are a lot of customers in the area Beuningen, Ede and Varsseveld which are not covered well by the current hub network. When opening another extra hub, Meppel will be the best option, since there is also a decent customer market in Drenthe. Besides that Meppel lays on the buck transport route to Holten and will not have a very negative impact on buck transport costs. After Meppel, Hoorn is the best option to appoint as hub. This will significantly reduce the driving distances in the Northern part of North Holland.

Increasing the number of hubs based on the most promising locations, will also improve the reachability of the satellite locations. Our expectation is that it will be easier for the planning department to plan pick-up batches that have a volume of less than 15m^2 into glass rack truck delivery routes respecting the time windows for pick-up orders. It won't be necessary to send an expensive buck transport vehicle that often to a satellite location in that case.

6.6 Summary

The purpose of our research described by this chapter was finding an improved hub network model for Glasboer Nederland. Using the p-median problem we determined (near) optimal hub networks based on different numbers of p (the number of hubs). This resulted in the following alternatives:

- *p = 3*: Amsterdam, Holten, Eindhoven
- *p = 4*: Amsterdam, Holten, Eindhoven, Beuningen
- *p = 5*: Amsterdam, Holten, Eindhoven, Beuningen, Meppel
- *p = 6*: Amsterdam, Holten, Eindhoven, Beuningen, Meppel, Hoorn

For each of these alternatives we calculated the variable distribution costs for one week using efficient routes that we generated based on data from a representative week with the program we created. Based on these costs we concluded that we see a decline in total costs when we increase the number of hubs up to six. We also concluded that the reachability increases significantly at areas such as Ede, Varsseveld and Drenthe that are far away from their closest hub in the current situation, but are visited quite often.

7 FURTHER DEVELOPMENT

During the conversations we had at the orienting phase of this project we noticed that the branches of GLASBOER within the Netherlands are quite distinguished. The manufacturing plants and the wholesalers of GLASBOER operate merely as separate companies, while they all are part of GLASBOER Europe. The wholesaler (Glasboer Nederland) operates as a customer of the manufacturing plants (Glasboer Roden and Glasboer Maastricht), while these plants have their own customers apart from Glasboer Nederland. This means that both the manufacturing plants and the wholesaler have a sales department which is responsible for serving the customers, they both have their own contracts with external transporters, etc. What we also noticed is some restraint to be transparent toward each other. The feeling exists that stakeholders are reserved to share tentative information between branches. Of course this is not strange, considering that the parts of GLASBOER as they are now, were separate companies before they were acquainted by GLASBOER Europe. We believe however, that for GLASBOER as a whole there are major opportunities for improvement if there was more collaboration between the separate branches in the Netherlands. We have done some literature research which we have summarised in the theoretical framework. In this chapter we address the issues and suggestions that the reader can find in the theoretical framework to GLASBOER specifically.

It seems that the different branches of GLASBOER within the Netherlands operate as individual companies. They aim to improve individual performance without considering the overall chain and value for the end customer. To ensure that every decision benefits GLASBOER Europe as a whole, the measured performance of each separate chain should also be directly linked to the overall performance. We advise to hire an external consultant that reviews the performance measurements for GLASBOER in the Netherlands as a whole and introduces a rewarding system that makes sure that made decisions should enhance the end value of products before serving the final customers.

Glasboer Nederland has agreements with their Glasboer supplier about order quantities, volumes, etcetera. This results in demand floors and ceilings that creates demand amplification. An example is that Glasboer Nederland orders extra volumes in advance, when the allowed order volume has not been met for that day. This way, the manufacturer has no idea of the order quantities and volumes that the wholesalers actually need, which might give them a distorted view of short term demand. When there is more transparency regarding customer orders, they can better complement each other on a daily basis.

We recommend Glasboer to conduct further internal research considering the aspects of a collaborative supply chain as explained in our theoretical framework. An independent person or entity should penetrate the organisational functions of the Glasboer branches in the Netherlands and should investigate the possibilities towards a collective department for activities such as sales, production planning and distribution planning between Glasboer branches. This way transparency will be increased, understanding for each other's processes and choices are obtained and mutual trust and commitment will arise. Production and distribution can be based on collective customer demand at both the manufacturer and the wholesaler. This will result in a significant reduction in order variance which will make it easier to meet the total customer demand with the same production capacity. Also distribution will be more efficient because of scale benefits (shorter driving distances for the same volumes). These statements can be quantified if an independent project initiative has access to order information of customers of all Glasboer branches.

8 CONCLUSIONS & RECOMMENDATIONS

8.1 Conclusions

When we started this research the main concern at Glasboer Nederland was a low glass buck utilisation. After conducting a simulation study we concluded that fragmentation of production orders based on their destination are the main cause for this lower than desired buck utilisation. In other words, the small volumes of pick-up orders that are transported directly on bucks to satellite establishments turned out to be the most harmful for the overall buck utilisation. We realised that satellites are too far away from the closest hub, such that on-time delivery of pick-up orders at these satellites via glass rack transport cannot be guaranteed. After constructing alternative hub networks and calculating their variable distribution costs, we came to the conclusion that appointing extra hubs will decrease the total distribution costs. Thus Glasboer Nederland can improve its coverage throughout the Netherlands and thereby reduce the distances to their customers and satellite locations, whilst at the same time decreasing costs.
Based on what we experienced during our time at GLASBOER and what current literature tells us, we can conclude that there is huge potential for improvement if GLASBOER emphasizes on collaboration between its branches within the Netherlands. Unfortunately we could not demonstrate this with numbers, since we did not have access to all the data we needed.

8.2 Recommendations

Our recommendations for the management of Glasboer Nederland are:

- Change the current hub network incrementally to the hub network proposed in chapter six, by first moving the hub function from Nieuwegein to Beuningen. Then moving the hub function from Bergen Op Zoom to Meppel. Finally opening a new hub in Hoorn.
  - We advise the management team of Glasboer Nederland to take this action first. We expect that this will fetch the largest benefits and it can be realised in a short period.
- Since increasing the number of hubs will decrease the risk pooling effect, the variation in number of orders per area will increase. To cope with this variation we recommend to the distribution planning department to make a pre-planning in advance of placing a production order at the factory. Based on the orders that are already known just before

the moment of placing an order at the factory, a route planning should be made. For each route a buffer should be incorporated to cope with urgency orders. Keep track of the number of urgency orders per day and per area (for example 2-digit postal code) to be able to forecast the number of urgency orders on a specific day. Discuss the possibilities of making a pre-planning with for example a consultant of the supplier of the routing software Ritplan.

    - We suggest it would be best if the distribution planners are prepared to make pre-plans as soon as the number of hubs are increased, since the variation in the amount of orders per area will probably increase immediately.

- Decrease facility costs by downsizing satellite locations that are not considered to be used as a hub in the near future. They can retain their function as paint shop and reserve some floor space for a few bucks for pick-up glass orders.
    - This recommendation is less urgent than the previous two. As soon as the hub network proves itself as efficient and cost effective, the management of Glasboer Nederland can make their decision about downsizing satellite locations.

We also have a number of recommendations for the management of GLASBOER that oversees all branches of GLASBOER in the Netherlands. Since these require a large mental change amongst a lot of employees, these will take a lot of time to achieve. We sorted them in decreasing order of urgency based on our opinion.

- Promote transparency and mutual trust amongst GLASBOER branches, such that all of them are encouraged to work according mutual benefits and understand the impacts of certain decisions on the operations of another part of the company.
- Reconsider the performance measurements that are in use for all GLASBOER branches within the Netherlands. These measurements should promote all branches to operate for the mutual benefit of delivering the highest value for the end customer. Care must be taken that performance measurements do not induce the temptation to work in the interest of their local ‘part’ of the company.
- Let an independent person or project group quantify the effect of merging the customer orders of Glasboer Nederland, Glasboer Roden and Glasboer Maastricht in one order pool. This will have benefits for production planning because of risk pooling (reducing variation by aggregation of orders). Distribution of customer orders of all branches should also follow the same channels. Simultaneous deliveries of different GLASBOER

branches in the same area can be avoided this way and again the variation in the number of deliveries per geographical area will be reduced because of risk pooling.

REFERENCES

Barratt, M. (2004). The "cultural" elements of supply chain collaboration. *Understanding the meaning of collaboration in the supply chain.*

Barratt, M. (2004). Understanding the meaning of collaboration in the supply chain. *Supply Chain Management: An International Journal, 9*(1), 30-42.

Cordeau, J. F., Gendreau, M., Laporte, G., Potvin, J. Y., & Semet, F. (2002, May). A guide to vehicle routing heuristics. *Journal of the Operation Research Society, 53*(5), 512-522.

Ellinger, A. E. (2000). Improving Marketing/Logistics Cross-Functional Collaboration in the Supply Chain. *Industrial Marketing Management, 29*(1), 85-96.

Heide, J. B., & John, G. (1990). Alliances in Industrial Purchasing: Determinants of Joint Action in Buyer-Supplier Relationships. *Journal of Marketing Research, 27*(1), 24-36.

Hoos, H. H., & Stützle, T. (2004). *Stochastic Local Search: Foundations and Applications.* San Francisco, CA: Morgan Kaufmann Publishers Inc.

Ireland, R., & Bruce, R. (2000). CPFR: only the beginning of collaboration. *Supply Chain Management Review, 4*(4), 80-88.

Laporte, G. (1992). The Vehicle Routing Problem: An overview of exact and approximate algorithms. *European Journal of Operational Research, 59*(3), 345-358.

Law, A. M. (2007). *Simulation Modeling & Analysis* (4th ed.). McGraw-Hill.

Lee, H. L., & Billington, C. (1992). Managing supply chain inventory: pitfals and opportunities. *Sloan Management Review, 33*(3), 65-73.

Lee, H. L., Padmanabhan, V., & Whang, S. (1997). The Bullwhip Effect In Supply Chains. *Sloan Management Review, 38*(3), 93-102.

Mason-Jones, R., & Towill, D. R. (1997). Information Enrichment: Designing the Supply Chain for Competitive Advantage. *Supply Chain Management, 2*(4), 137-148.

McIvor, R., & McHugh, M. (2000). Partnership Sourcing: An Organisation Change Management Perspective. *The Journal of Supply Chain Management, 36*(3), 12-20.

Osman, I. H. (1993, December). Metastrategy simulated annealing and tabu search algorithms for the vehicle routing problem. *Annals of Operations Research, 41*(4), 421-451.

Perboli, G., Tadei, R., & Vigo, D. (2011, June 16). The Two-Echelon Capacitated Vehicle Routing Problem: Models and Math-Based Heuristics. *Transportation Science, 45*(3), 364-380.

Popp, A. (2000). Swamped in Information, but Starved of Data: Information and Intermediaries in Clothing Supply Chains. *Supply Chain Management, 5*(3), 28-36.

Resende, M. G., & Werneck, R. F. (2004). A Hybrid Heuristic for the p-Median Problem*. *Journal of heuristics, 10*(1), 59-88.

Simatupang, T. M., & Sridharan, R. (2002). The Collaborative Supply Chain. *The International Journal of Logistics Management, 13*(1), 15-30.

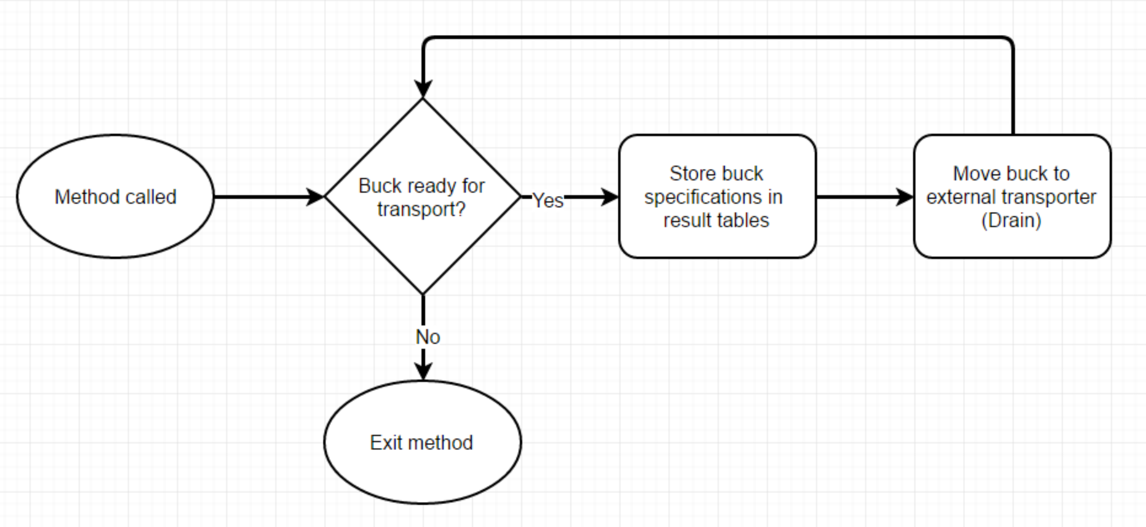
Snelste route naar meerdere adressen. (2009-2017). Retrieved from RouteXL: https://www.routexl.com/

van Lokven, S., & Blom, Y. (2013, April 4). *Inrichten distributienetwerk vraagt tweeledige aanpak*. Retrieved from Logistiek: http://www.logistiek.nl/supply-chain/blog/2013/4/inrichten-distributienetwerk-vraagt-tweeledige-aanpak-101130711

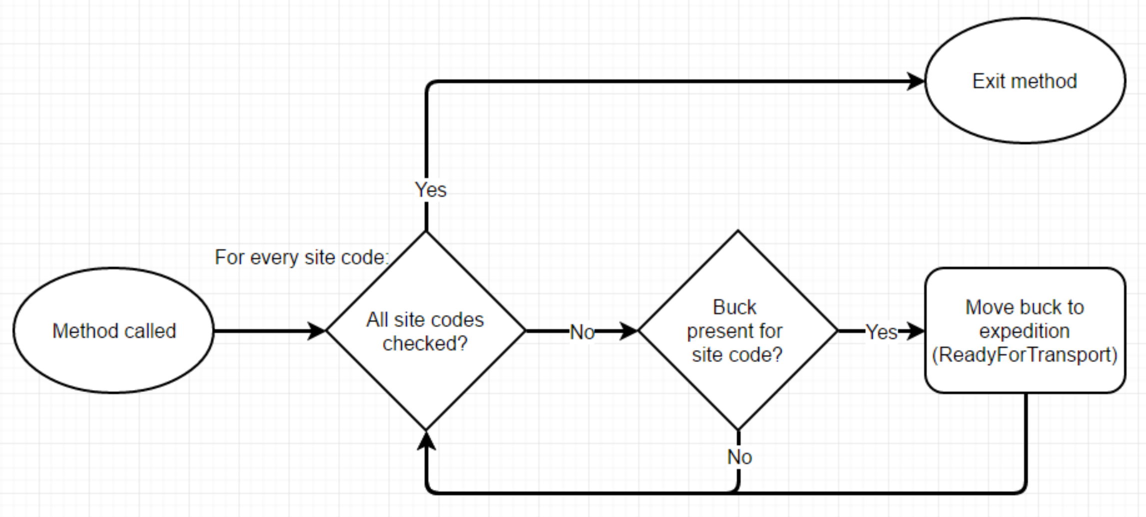
9 APPENDICES

9.1 Flowcharts for methods in simulation model

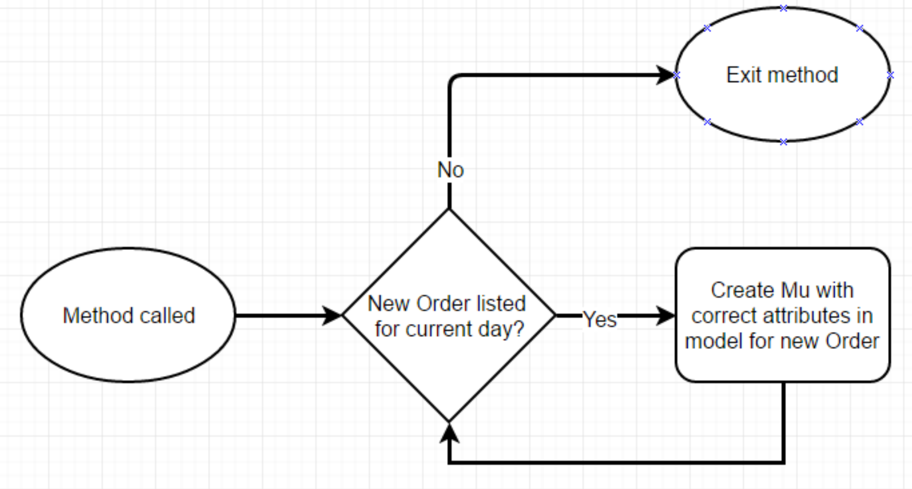
9.1.1 Method LoadTruck



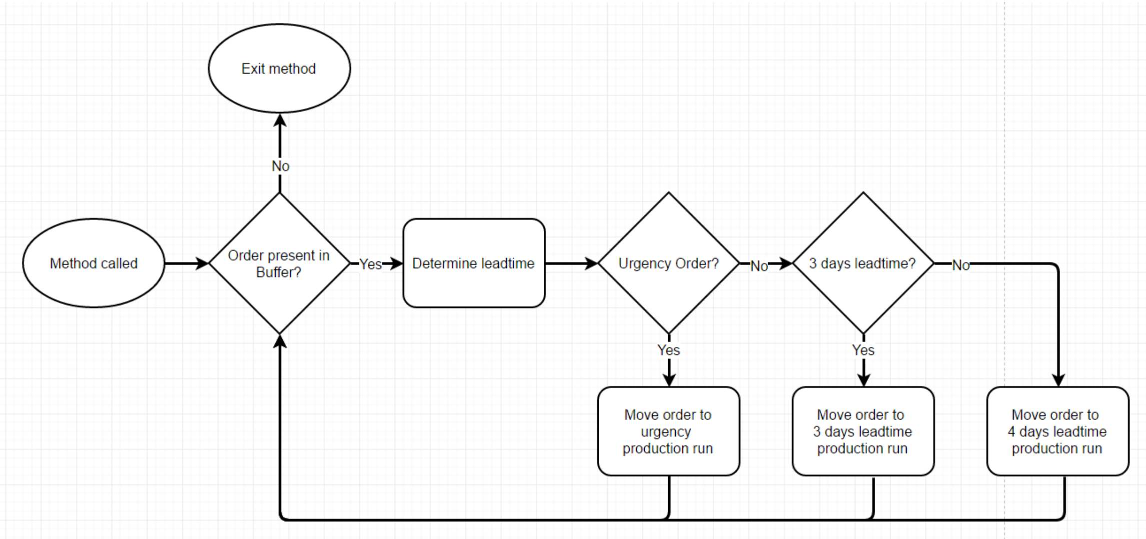
9.1.2 Method MoveBucks



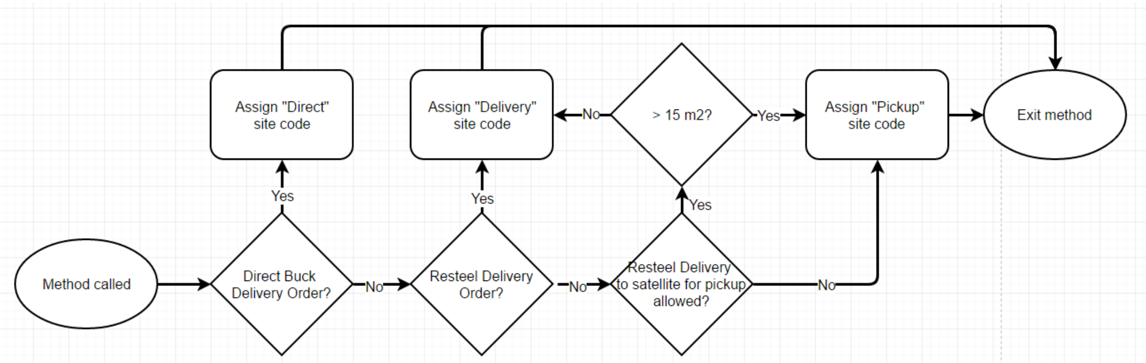
9.1.3 Method IncomingOrder



9.1.4 Method DetermineLeadTime

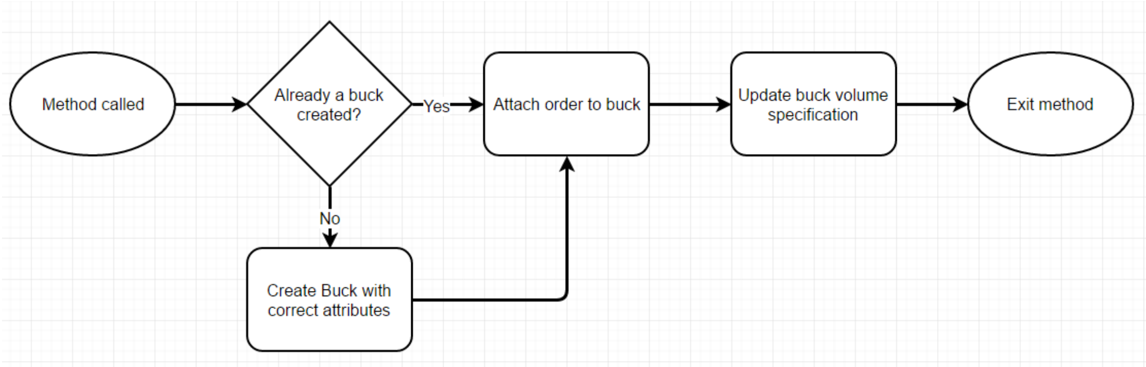


9.1.5 Method Destination



NB.: This method is the same for Urgency_Destination, three_days_lead_time_Destination and four_days_lead_time_destination.

9.1.6 Method Attach



9.2 Distribution network model

9.2.1 Pseudo code

We can split our model in several parts. We write their workings separately in words below. The first parts following below are for creating an initial solution:

- Assign Orders to Hubs: AssOrd2Hub

  Loop over all orders

    Loop over all hubs

      If Distance to this hub is shortest

        Then Assign order to this hub

- Create Truckloads: AssTruckLoad

  Loop over all hubs

    Loop over all orders

      If order belongs to current hub

        Then Pick order and add volume to total of picked orders for this hub

    Determine number of trucks needed based on total volume

    Calculate exact average volume per truck

    Execute SweepAlgorithm

- SweepAlgorithm: Sweep(CurrentHub, ord, numtrucks, LSeed)

  Loop over all selected orders

    Calculate polar angle to hub for every order

  Use bubble sort to sort orders on polar angle

  Initialise first route for selected hub

  Loop over all sorted orders assigned to this hub

    If Total volume in route so far is lower than seed value

      Then Add order to route

    Else Initialise new route and add order to this new route

- Vehicle Routing Problem: VRP(SelRoute)

  Loop over all orders in selected route

    Store orders in temporary array 'unassigned'

    Remember farthest order destination

  Assign farthest order first to route, adjust route distance and remove from unassigned array

  Loop over all orders that are stored in the unassigned array behind the farthest order

Move them one place to left one by one in the unassigned array

While there are unassigned orders left

Loop over all unassigned orders

Calculate which order has the lowest insertion cost based on additional distance

Move order with lowest insertion cost to best position in route

Update route distance

- Optimise initial solution: SimulatedAnnealing

While temp is higher than stopping temp

Choose order randomly

Loop over all possible neighbour solutions for selected order

Store total distance of old solution

Move order to neighbouring route

Reproduce routes for both concerned routes using VRP heuristic

Compare total distance of new solution with old solution

If Total distance of new solution is lower than that of old solution

Then Keep new solution with probability = 1

If New solution is lower than best solution

Then Store new solution as best solution

If Total distance of new solution is higher than of old solution

Then Keep new solution with probability = exp((Old distance – new distance)/ temp)

Decrease temp by factor alpha

9.2.2 Example of input file for Delphi model

Order	M2	KG	Aantal	Leverdatum	Delivery Adress	DeliveryPostalCode	Delivery City	Latitude	Longitude
790350	0.5	9.68	2	02-05-17	Adress Number	Postal code 6PP	Hengelo	52.21555	6.820523
790351	0.9	11.35	2	01-05-17	Adress Number	Postal code 6PP	Sint Pancras	52.66008	4.780449
790352	0.5	2.25	2	04-05-17	Adress Number	Postal code 6PP	Schijndel	51.61194	5.464487
790353	1.25	26.1	3	02-05-17	Adress Number	Postal code 6PP	Hoorndijk West	52.67464	5.05669
790354	1.07	32.98	2	02-05-17	Adress Number	Postal code 6PP	Alkmaar	52.38683	4.657076
790355	2.75	61.21	4	02-05-17	Adress Number	Postal code 6PP	Hengelo	52.21555	6.820523
790357	1.5	27.45	6	02-05-17	Adress Number	Postal code 6PP	Hardenberg	52.37108	6.643609
790358	7	100.36	14	03-05-17	Adress Number	Postal code 6PP	NUENEN	51.44535	5.56138
790359	1.84	40.73	4	02-05-17	Adress Number	Postal code 6PP	Enkhuizen	52.6942	5.265869
790361	2.23	68.42	1	09-05-17	Adress Number	Postal code 6PP	Den Oever	52.94432	4.774131
790362	1.35	27.9	1	03-05-17	Adress Number	Postal code 6PP	NUENEN	51.44535	5.56138
790363	0	0	1	05-05-17	Adress Number	Postal code 6PP	Den Oever	52.94432	4.774131
790365	0	0	2	05-05-17	Adress Number	Postal code 6PP	Den Oever	52.94432	4.774131
790366	0.66	14.4	2	02-05-17	Adress Number	Postal code 6PP	Eibergen	52.09046	6.639123
790367	2.59	13.5	6	22-05-17	Adress Number	Postal code 6PP	Eindhoven	51.45768	5.395856
790368	27	324.54	54	05-05-17	Adress Number	Postal code 6PP	Oudenbosch	51.60879	4.522246
790369	2.36	48.3	2	05-05-17	Adress Number	Postal code 6PP	Sprundel	51.53831	4.583629
790370	3.3	84.68	2	03-05-17	Adress Number	Postal code 6PP	Eindhoven	51.58754	5.062692
790372	2.62	65.56	4	02-05-17	Adress Number	Postal code 6PP	Nunspeet	52.37406	5.777844
…	…	…	…	…	…	…	…	…	…

9.2.3 Results

EXAMPLE PER ROUTE

Route	Order	Adress	Postal code	City	Volume
		Street + Number	6PP	Amsterdam	
1	799270	Street + Number	6PP	Alkmaar	5.26
1	802679	Street + Number	6PP	Wijk aan zee	6.18
1	802701	Street + Number	6PP	Castricum	1.64
1	804772	Street + Number	6PP	Obdam	7.83
1	802664	Street + Number	6PP	Hoorn	2.66
1	790983	Street + Number	6PP	Hoorn	0.6
1	804206	Street + Number	6PP	Enkhuizen	1
1	797359	Street + Number	6PP	Kwadijk	10.2
1	794204	Street + Number	6PP	Monnickendam	7.09
1	794947	Street + Number	6PP	Weesp	4.56
1	799189	Street + Number	6PP	Schiphol Noord	2.5
1	805236	Street + Number	6PP	Zaandam	0.5
1	797413	Street + Number	6PP	Wormerveer	3
1	802728	Street + Number	6PP	Wormerveer	9.47
1	804768	Street + Number	6PP	Amsterdam	0.5
		Street + Number	6PP	Amsterdam	

EXAMPLE PER DAY

						19 tot 30				Driving				
						Jun		Distances		Time		Costs		
Scenario Nr			Hubs			Date	#Routes	Glass Rack	Buck	Glass Rack	Buck	Glass Rack	Buck	Total
5	Ams	Hol	Ber	Ein	Nie	26-06-17	9	1628	1401	60.2	30.3	1481.26	1946.24875	3427.50875
6	Ams	Hol	Ber	Ein	Nie	27-06-17	12	2195	1436	85.3	34.7	2079.15	2117.55125	4196.70125
7	Ams	Hol	Ber	Ein	Nie	28-06-17	13	2327	1373	89.4	30.3	2184.09	1927.195	4111.285
8	Ams	Hol	Ber	Ein	Nie	29-06-17	11	2151	1333	80.1	29.2	1967.17	1864.48375	3831.65375
9	Ams	Hol	Ber	Ein	Nie	30-06-17	11	1936	1347	75.5	29.1	1838.12	1869.315	3707.435
15	Ams	Hol	Ein			26-06-17	9	1946	1401	62.9	30.0	1587.82	1933.4425	3521.2625
16	Ams	Hol	Ein			27-06-17	11	2315	1138	86.2	26.7	2116.55	1649.7975	3766.3475
17	Ams	Hol	Ein			28-06-17	12	2436	1373	91.7	29.6	2247.12	1901.5825	4148.7025
18	Ams	Hol	Ein			29-06-17	10	2341	864	83.4	20.3	2064.97	1253.1375	3318.1075
19	Ams	Hol	Ein			30-06-17	11	2123	1176	78.4	25.5	1928.91	1636.07875	3564.98875
25	Ams	Hol	Beu	Ein		26-06-17	8	1736	1401	58.8	30.0	1471.12	1933.4425	3404.5625
26	Ams	Hol	Beu	Ein		27-06-17	11	2150	1138	83.0	27.0	2026	1662.60375	3688.60375
27	Ams	Hol	Beu	Ein		28-06-17	12	2290	1373	88.6	29.9	2161.3	1914.38875	4075.68875
28	Ams	Hol	Beu	Ein		29-06-17	10	2255	919	81.9	22.1	2020.35	1352.065	3372.415
29	Ams	Hol	Beu	Ein		30-06-17	10	1970	1176	76.6	25.9	1865.9	1648.885	3514.785
35	Ams	Hol	Mep	Beu	Ein	26-06-17	8	1697	1401	58.7	30.3	1462.49	1946.24875	3408.73875
36	Ams	Hol	Mep	Beu	Ein	27-06-17	10	2129	1138	83.0	27.4	2021.93	1675.41	3697.34
37	Ams	Hol	Mep	Beu	Ein	28-06-17	13	2258	1373	87.4	30.3	2132.36	1927.195	4059.555
38	Ams	Hol	Mep	Beu	Ein	29-06-17	10	2179	919	80.4	22.5	1978.43	1364.87125	3343.30125
39	Ams	Hol	Mep	Beu	Ein	30-06-17	12	2075	1176	79.6	26.3	1943.75	1661.69125	3605.44125

45	Ams	Hol	Mep	Beu	Ein	Hoo	26-06-17	9	1598	1420	57.3	31.3	1417.16	1992.74875	3409.90875
46	Ams	Hol	Mep	Beu	Ein	Hoo	27-06-17	10	2110	1138	83.5	27.8	2028.2	1688.21625	3716.41625
47	Ams	Hol	Mep	Beu	Ein	Hoo	28-06-17	13	2228	1373	87.7	30.7	2132.26	1940.00125	4072.26125
48	Ams	Hol	Mep	Beu	Ein	Hoo	29-06-17	10	1995	919	78.7	22.9	1912.65	1377.6775	3290.3275
49	Ams	Hol	Mep	Beu	Ein	Hoo	30-06-17	11	1947	1195	75.7	27.3	1844.99	1708.19125	3553.18125