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Strategic decisions in truck routing for a retail chain

Master thesis report by:

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An analysis of deliveries, return logistics, and backhauls

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Preface

The past six months I have been working on the report that is now in your hands. I hope you enjoy reading the report as much as I enjoyed the moment it was finished.

Although the working atmosphere was great, going through more than fifty pages of report is hard to handle and caused difficulties. I want to thank my supervisors and colleagues at PLUS for their valuable input, but also their jokes and the problems we discussed regarding most varying subjects. This was helpful to stimulate the research.

I highly appreciated the help and the scientific approach of my supervisors from the University of Twente, Marco Schutten and Leo van der Wegen. I want to thank them for their patience and insights, helping me to perform this research.

Last but not least I want to thank my parents and sister for helping me out making this report understandable to people from outside, and for having me picked up at the station many times and the sponsoring of the project called studying.

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Glossary and abbreviations

- Backhaul = the pick-up of goods at a supplier or a LSP after the delivery of groceries to a store
- Consumer = end-customer, customer of the supermarket/store
- Fresh Goods = meat, fresh produce, dairy goods, perishables.
- Dry groceries = Packaged food, non-perishables
- Store = point of sale for the end-customer
- Supermarket = 1 store
- Supermarket chain = the collection of stores and its distribution centers
- Supplier = the direct producer or distributor of the goods sold in the supermarket

Abbreviations

3Ps = People Planet Profit, environmental friendly corporation
3PL = Third Party Logistic provider
AGF = Aardappels groenten en Fruit, Fresh food groceries.
BAS = "Bestel en Afleverings schema": Order and delivery schedule
(R)DC = (Regional) Distribution Centre (Haaksbergen, Ittervoort, Hendrik Ido-Ambacht)
DDC = Frozen goods DC
ERP = Enterprise resource planning
FGP = Factory gate pricing
LDC = Nationwide Distribution Centre (Midden Beemster Location)
LSP = Logistic Service Provider
MF = Manufacturer
MVO = Maatschappelijk verantwoord ondernemen, Corporate Social Responsibility, CSR
p.w. = per week
VDC = Fresh goods DC
VRP = Vehicle Routing Problem

Management summary

In this report we try to minimize transportation costs for PLUS. At the moment four transport flows are the main logistic cost drivers for PLUS:

1. DC to a store (normal deliveries)
2. Store to a DC (returns: such as containers, beer crates, bottles etc.)
3. Supplier to a DC (including cross-dock, backhaul, and normal deliveries)
4. DC to DC (incidentally, low volumes)

In this research we define three scenarios which change the handling of the 2nd and 3th flow:

Scenario 1
In Scenario 1 a truck delivers goods to the store on the traditional way. After store delivery PLUS tries to fit in backhauls within the delivery trucks. The pallets from the supplier are together in the truck with return goods form the stores such as containers and crates. If a backhaul is available, fits in the available truck capacity, and contributes a profit, the backhaul is accepted.

Scenario 2
In Scenario 2 the retrieval of return goods is separated from the deliveries to the store. This way PLUS makes separate trips just for the collection of returns. The second type of routes is the normal deliveries. After the delivery a truck can perform a backhaul at a nearby supplier. Another option is to negotiate with the logistic service provider (LSP) on lower prices for an empty return route. The LSP could for example use the truck for own purposes after delivery, with both LSP and PLUS sharing the benefits.

Scenario 3
PLUS could also retrieve the return goods after the regular delivery at stores. This has an advantage over Scenario 2, since trucks are already present in the regions. For example: A truck first delivers 2 stores and then collects the returns at 3 other stores. The trucks that deliver those 3 stores are empty after delivery. These empty trucks perform a backhaul or may be charged a lower price from the LSP (as in Scenario 2).

Since the transport and routing strategy is a long term choice at PLUS, we analyse the routing on the following aspects: Inter-DC deliveries, location and number of DCs, number of return containers and crates, choice for goods to transport, choice for truck capacity, and choice for the number of delivery moments.

Limitations

We did not consider extra costs or savings in DCs, stores, and at suppliers in this report. Because of the high fill rates in returns at the fresh goods DC (75%) and the daily frequency, those freights are excluded from the scenarios. The already empty trucks of the frozen goods DC are also excluded from the scenario results; A third party already optimizes the transport.

Conclusion and recommendations

The most interesting routing strategy on the short term is Scenario 1 (-2% on total transport costs). However there are more future cost saving possibilities in using Scenario 3 (-18% on total transport costs). At the moment there are not enough backhauls available at PLUS. We propose to gradually increase backhauling using Scenario 1 working towards Scenario 3. The use of Scenario 2 is more expensive than Scenario 3, but routing becomes easier. With the help of routing software the increased complexity in Scenario 3 will be manageable.

Besides the calculated profits and costs by rearranging returns, there are also other advantages and disadvantages of the different scenarios. In Scenario 1 the stores have no changes in the processing of a delivery. Therefore Scenario 2 has a higher acceptance chance. A downside of Scenario 1 compared to the other scenarios is that there is uncertainty in the leftover capacity, not all backhaul orders fit in a truck, and that trucks must dock 2 times. An important advantage for the store is that Scenarios 2 and 3 result in an early empty storage space in the stores. In both scenarios docking with returns at the DC happens left often.

Recommendations on short term (0-2 years):

- Piloting backhauling with suppliers close to stores, far from DCs. After successful piloting PLUS should start extra backhaul routes.
- Gradually implement return goods routing after delivery of stores.
- Deliver stores with the trucks coming from the LDC (Nationwide DC).
- Purchase routing software able to handle the complex situation.
- Try to optimize routing by increasing the number of deliveries to the stores. This way smaller loads are available and more stores fit into one route.
- Investigate the possibility to reduce the number of return materials at stores. Only containers, LDC-crates and beer crates should be returned (no paper, plastic, and bottles).

Recommendations on long term (2-5 years):

- Implement factory gate pricing (FGP).
- Return goods routing after delivery of stores (only with FGP) for a large part of the stores using Scenario 3.
- Build one DC at a central location, for example in the area of Utrecht. PLUS should make sure that it obtains a part of the inbound transport savings (e.g. by FGP).

Options that should not be taken by PLUS:

- NOT: Try to combine VDC (perishables DC) and RDC (Regional DC) flows, due to the high return rate volume of 75% and the daily deliveries.
- NOT: Insert extra goods in the return flow, such as fresh produce waste and residual waste.
- NOT: Increasing the number of inter-DC deliveries.
- NOT: Increase truck-capacity with small steps, this is only feasible with an increase of over 74 containers.
- NOT: Build extra return good hubs.

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Chapter 1: Introduction

This research focusses on the different transportation flows for a supermarket chain in The Netherlands: PLUS. Relevant transport flows exist between PLUS distribution centres, PLUS supermarkets, and PLUS suppliers. We try to minimize the costs, given the current resources and the current service performance that PLUS delivers to their stores.

This chapter sketches the contours of the retail organisation in order to introduce the problem dealt with in this report. Section 1.1 shows locations of distribution centres and stores. The same section also discusses differentiation and organisational aspects. In Section 1.2 we introduce the origin of problem with the various flows of goods present in the supply chain. Section 1.3 presents the problem formulation and how we want to tackle this problem. Section 1.4 gives the research scope.

1.1 Introduction to PLUS

This section describes the environmental aspects in which PLUS operates to understand the organisation and the problem it faces. Section 1.1.1 gives the locations important to PLUS in order to understand the geographical aspects of the situation. Section 1.1.2 discusses the organisational aspects. Section 1.1.3 elaborates the differentiation focus of PLUS towards service. Section 1.1.4 describes the context of the department logistics.

1.1.1 Locations of PLUS DCs and supermarkets

PLUS is a supermarket chain with 256 (June, 2014) supermarkets throughout The Netherlands. The organisation is centrally run from Utrecht and has 6 different distribution centres (DCs). The exact addresses can be found in Appendix 1, and Figure 1 presents the locations on a map.

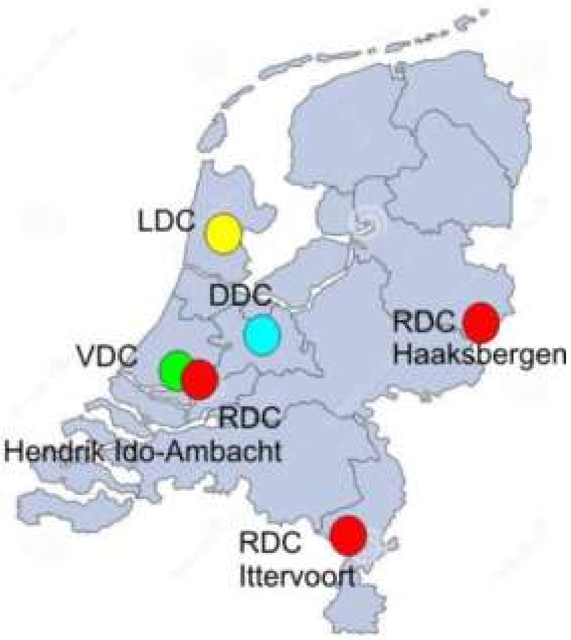


Figure 1: Map of the different DCs

The DCs are categorized according to their different functions. At PLUS there are four types of DCs. Figure 2 presents the functions of each DC.

At the RDCs (Regional Distribution Centres), PLUS stores their fast moving dry-grocery goods. Each RDC has an own regional coordination and delivery responsibility towards their regions stores. Currently there are three similar operations running in Ittervoort, Hendrik Ido-Ambacht, and Haaksbergen.

The Nationwide Distribution Centre (LDC) at Midden-Beemster stores the slow-moving grocery goods. Also this DC has its own coordination and delivery responsibility to the stores and RDCs.

Barendrecht is the DC-location dedicated to all perishables in PLUS-supermarkets (VDC, Fresh-goods DC). In this DC all tactical and operational level operations are performed by Hollander. Hollander is an external supplier with PLUS as its only customer. Therefore the company is fully dedicated to fulfil PLUS' demands. PLUS and Hollander both benefit from improvements in the operations.

The frozen goods operations are run by C. van Heezik in a distribution centre in Utrecht, the DDC. C. van Heezik is an external party not solely dedicated to PLUS. This organisation is a frozen goods supply partner who takes care of warehousing, distribution, and transport.

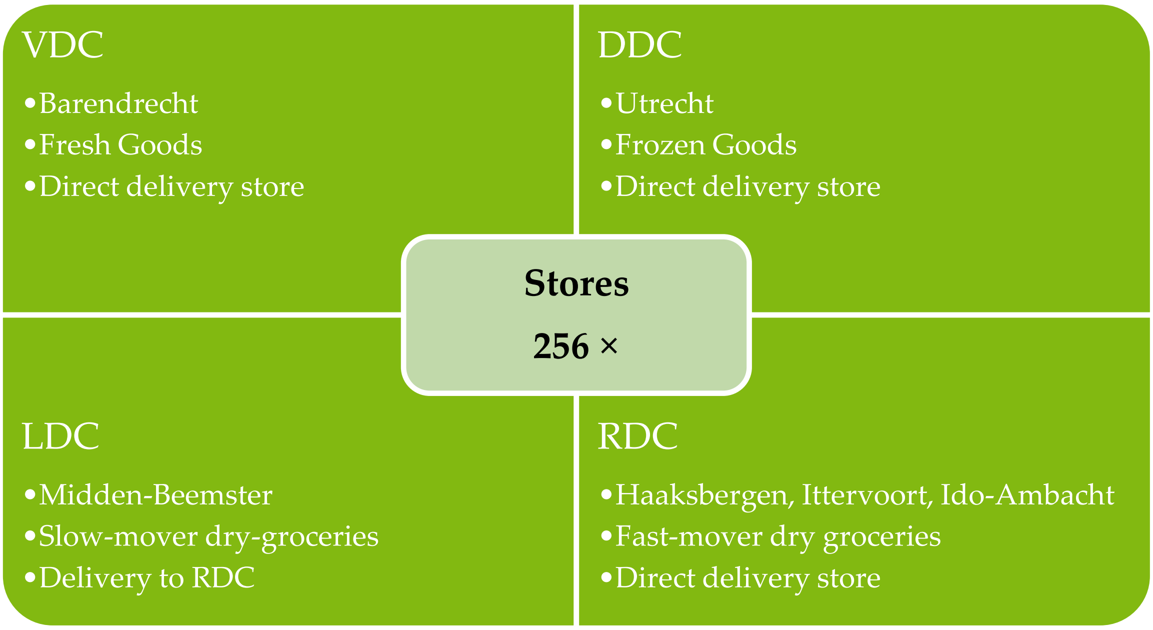


Figure 2: DC function overview

PLUS Supermarkets locations:

The supermarkets of PLUS are divided over the country with no specific focus over regions (See Figure 3). The northern part of The Netherlands is hardly covered, which is among others due to the small population in this areas. A smaller population logically gives less room for the exploitation of stores.

Consumers are also able to order their groceries online at PLUS.nl. Each order is linked to the nearest available store. Those online orders are fullfilled from this store's inventory. There is no special distribution infrastructure for e-commerce present in the form of DCs, hubs, and transportation.

Figure 3: Map of the store locations

1.1.2 Organisation: a cooperative model and "Sperwer groep"

The PLUS organisation is run as a co-operative that is owned by the stores. Although the retail organisation is formed as a private company and is governed by the board of directors, PLUS is owned by the "De Sperwer" Cooperation (See Figure 4). A co-operative is an autonomous organisation that is owned by its members. Those members should benefit from the co-operative's operations. The "De Sperwer" co-operation is owned by the supermarket owners. Those are independent entrepreneurs who run their supermarket(s) with the support of a service facility that functions as a headquarter. The service facility is located in Utrecht.

Since the organisational decision power lies at the entrepreneurs, the office needs to pay special attention to the entrepreneurs and their stores. The service function of the office has a major influence on processes of change within the organisation, since the supermarket owners have a say in those changes. Also in this project the power of entrepreneurs has to be recognized and dealt with.

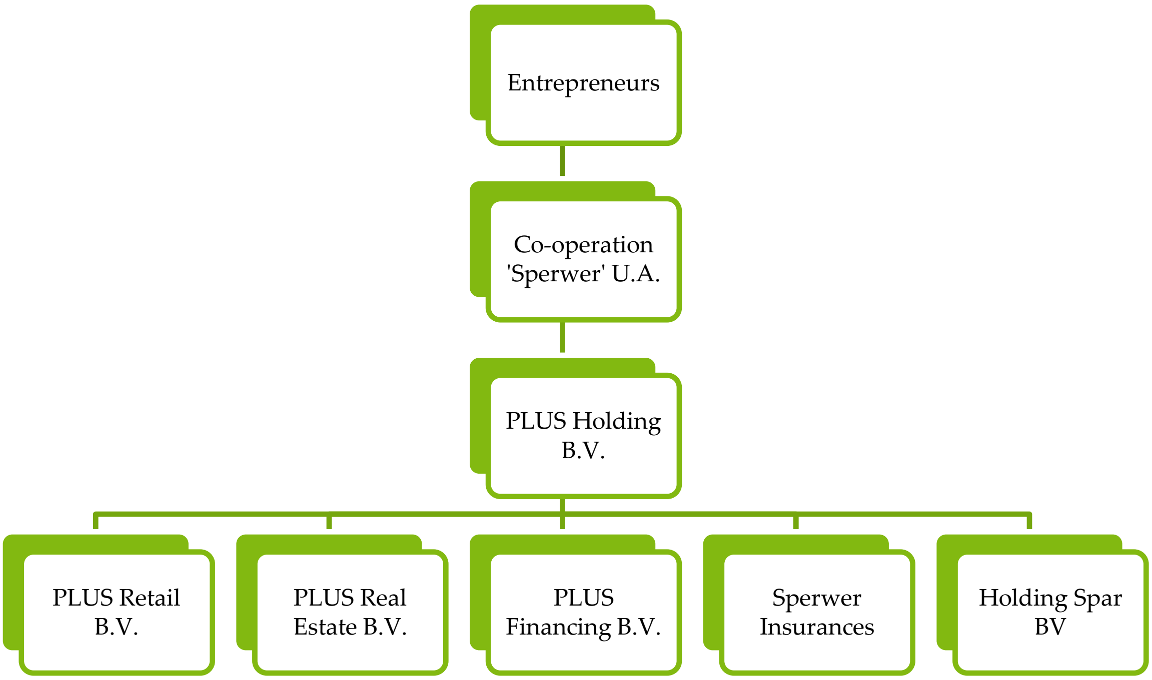


Figure 4: Organisational chart Sperwer groep

Purchasing for the Sperwer groep is done by Superunie, which is a cooperation of a number of supermarket chains. Superunie has a market share of 28.8% (Nielsen, 2013) within The Netherlands. The purchasing organisation has the following retailers as members (% market share from Nielsen 2013):

1. Boni-Markten (<0.3%)
2. Mcd-supermarkten (0.6%)
3. Coop supermarkten (2.8%)
4. Deen Supermarkten (2.0%)
5. Dirk, Bas, Digros and Dekamarkt supermarkets (3.7% + 1.9%)
6. Hoogvliet (2.1%)
7. Jan Linders (1.0%)
8. Nettorama (<0.3%)
9. Poiesz (1.0%)
10. EMTÉ (Sligro) (2.7%)
11. Spar (1.8%), (45% Sligro; 45% PLUS owned)
12. **PLUS (5.8%)**
13. Vomar (1.6%)

The combined purchasing gives PLUS the advantage of large volume purchasing which results in competitive prices for their products. PLUS is the largest partner in Superunie and therefore has more power within the purchasing process.

1.1.3 The added value for a PLUS consumer

"PLUS gives more" (Dutch: "PLUS geeft meer") is the slogan on which the supermarket wants to differentiate itself from its competitors. PLUS wants to give more on: personal attention, quality, local involvement and responsible behaviour to environmental issues (Annual Report PLUS, 2013).

For the logistic operations this means that the focus is not specifically on saving costs, but obtaining a desired service level towards the consumer (end-user). The availability rate of products for consumers needs to be high in order to reach customer satisfaction. Cost savings are however necessary to be able to reach competitive prices in the supermarkets. A balance between costs and service needs to be found in every project.

1.1.4 Logistics department

The logistics department within the PLUS organisation requested this research. The staff logistics is the unit within the Logistics Department that supports the research. At the staff logistics about 5 people work on projects in order to maintain and improve the current logistics infrastructure. The department is located in Utrecht and has close contact to the site-managers in each DC.

The decision power on logistic problems lies with the director of logistics (see also Figure 5), who has a seat in the board of directors of PLUS Retail BV.

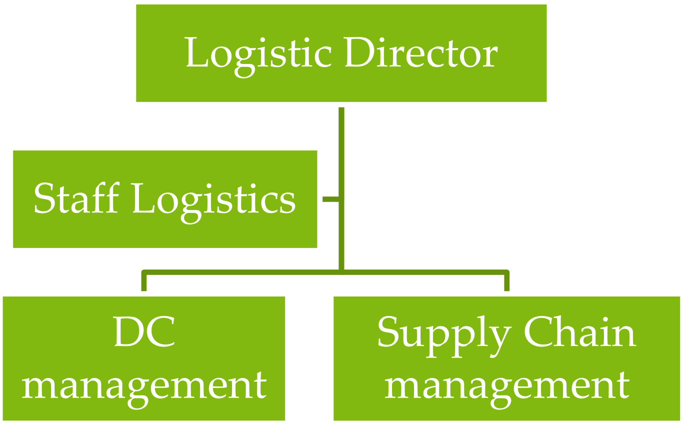


Figure 5: Organizational chart for Logistics

The Supply chain management is responsible for the negotiation with suppliers about transport and deliveries. DC-management focusses on the operations in the DCs. Figure 5 gives an overview of the logistic organisation.

1.2 Origin of the problem

This research originates from three different perspectives: a cost perspective (Section 1.2.1), a service perspective towards stores (Section 1.2.2), and an environmental perspective (Section 1.2.3). The major focus in this research is on cost savings.

1.2.1 Partly empty trucks, potential savings

At PLUS many trucks go almost fully loaded from DCs to the stores. PLUS obtains high truck fill rates on this part of the supply chain (towards 80-95%, depending on the DC). After delivery to the stores, the truck is only partially loaded with the return flow. On this part of the route, the fill rate is rather low (approximately 30%, based on expert opinions from DC-managers and logistic staff). The flows from and towards the stores are interrelated, since carrier materials (containers, crates, etc.) must go back to the sender. The more volume transported towards the stores, the more carrier materials PLUS needs to transport. More goods sent by the DC means more goods received. The returns arrive with some time lag of one or two days.

Besides the (partly) empty trucks from stores to DCs, there are trucks from suppliers heading (partly) empty from the PLUS DC to their own distribution site. So there is a significant loss of capacity in the transportation network from and towards the DCs.

There is structural transport from the LDC towards the RDCs, to cross dock the slow moving goods towards the stores in the delivery truck of the RDC. Only incidentally there are transport flows between the RDCs. These are mainly used to balance out the stocks at different locations. Chapter 2 gives more information about the current situation at PLUS.

Four different flows of goods are relevant for the distribution towards PLUS supermarkets and PLUS DCs (see Figure 6), namely:

1. DC to a store (normal deliveries)
2. Store to a DC (returns: containers, crates, bottles etc.)
3. Supplier to a DC (including cross-dock deliveries towards stores)
4. DC to DC (LDC-RDC and incidentally stock balancing)

External parties deliver waste collection services at the stores and suppliers collect also some goods from the DCs (such as pallets or beer crates). Those are small flows and therefore excluded from the 4 flows.

PLUS sees the possibility to pick-up goods from their suppliers, in order to increase the fill rate of their trucks. Picking up goods leads to extra savings. The retrieval of loads after delivery is known in literature as performing a backhaul.

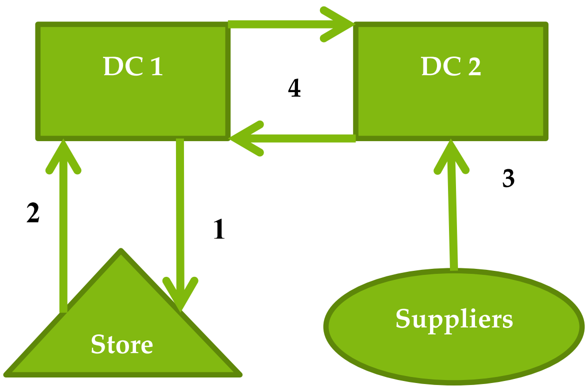


Figure 6: The demand and flow of goods

Some research has already been performed on backhaul and separating returns and combining these flows. The research focussed on The Netherlands and involved all major supermarket chains. The research showed the possibility for achieving significant savings up to 18% (TNO, confidential research, 2013). However this was done with the assumption that there will be cooperation of all supermarket chains in The Netherlands. From the PLUS perspective this would not be a realistic scenario. This situation would lead to giving away too much power about crucial operational aspects. For example PLUS would no longer be able to influence the time between ordering and receiving (lead times) products. In that case also all cost levels and service levels need to be negotiated with external parties.

Albert Heijn, which is the market leader (with about 850 stores) in The Netherlands, already has rearranged the flow of the returns and allows all truck capacity for backhauls. In cooperation with Kuehne & Nagel, they completely outsourced the handling of return goods. The outsourcing includes return good operations at the DC.

PLUS wants to know if it was a wise decision to keep the primary flows to, and return flows from, the stores combined in one truck. Since Albert Heijn has outsourced a part of their operations, PLUS might as well have benefits in rearranging the transportation flows. Although PLUS is about 4 times smaller, there might be significant savings.

1.2.2 Delivering service to stores

The logistic operations at PLUS are focussed on delivering service to the supermarket stores. Currently space in the store's stockroom is occupied with the return goods (Flow 2, Store to DC). The goods are held in the stockroom until the next delivery, which can take one or two days. If return goods are retrieved directly after the stocking of the shelves, the room is available for other purposes. Separating the two flows could be a way to increase service for stores.

1.2.3 Corporate Social Responsibility (MVO)

PLUS has the ambition to be most social responsible supermarket-chain in 2015. In the annual-reports it is highlighted as "Maatschappelijk Verantwoord Ondernemen" (MVO). This stresses the need for environmentally sound processes. In the current situation the supply chain as a whole has a higher than necessary CO2 emission. This is mainly due to the (partly) empty trucks from suppliers and DCs.

The increased truck travelling leads to increased traffic on the already congestion-sensitive roads near the DCs. A decrease of trips travelled by performing backhauls directly leads to less traffic. Less traffic also reduces CO2 emission in the region.

1.3 Problem formulation and approach

Structural changes to the supply chain network have to be addressed from a strategic perspective. Decisions influence the long term situation of the organisation. The strategic choices at PLUS concern the options on handling the transport flows discussed. PLUS wants to know what strategic choices it can and should make in order to improve the current situation. The report should also deliver insights in the consequences for the organisation when implementing the recommended changes.

PLUS expects that the transported volumes remain the same for the coming years. Of course, there are minor changes, but PLUS knows from experience that this does not significantly influence the transport operations. Therefore the problem is mainly related to solutions to handle these flows efficiently. At PLUS efficiently means: high service, low costs.

> The main question for this research is:
>
> *How can PLUS organise the current transportation flows in a more efficient way, to reduce total transportation costs at the same service-level for the stores?*

Here service level is defined as the percentage of the desired products delivered to stores on the desired delivery day.

To solve the main question we divide it into five research questions. First we want to find out how the current transportation flows are running within the PLUS organisation:

> *1.1 How are the transportation flows connected to PLUS currently organised?*

Chapter 2 presents the current situation within the transport network specific for PLUS. For the investigation of the situation, (tacit) knowledge of the direct stakeholders is needed. Interviews are held to obtain this knowledge. First the heads of the DCs, the manager logistics and the director of logistics are being interviewed to give their vision on the transportation flows within PLUS. Based on these interviews we go deeper into the transportation structure and ask for inputs from planners and drivers to clarify the tactical and operational aspects.

Interviews with partners as well as suppliers were considered, but not held since there is enough knowledge within the PLUS organisation to look at their interests. Besides the qualitative inputs from interviews we gather data from the information systems regarding transport schemes, transport volumes, trucks, and other usable data.

A literature search is performed after describing the situation at PLUS, because the research area about optimizing transportation flows is rather big and includes many different topics. If the situation at PLUS is clarified first, this gives insights in what is relevant literature for this research.

> 1.2 *What is known in literature about transport situations as observed at PLUS?*

In Chapter 3 we come up with suitable literature for the problem and situation at PLUS in order to answer Question 1.2. As described in Section 1.3 the problem is more of a strategic nature. This nature asks for a broad approach in investigating the situation and finding literature.

The literature about (retail) logistics is rather broad; in Chapter 3 we focus on the transportation aspects. A division is made between strategic, tactical, and operational aspects.

> *1.3 What different insights from literature and the current situation can PLUS apply to the transportation flows in the PLUS supply chain?*

In Chapter 4 we focus on building a model to obtain quantifiable results regarding transportation costs. In the different sections we come up with different scenarios and options for PLUS to rearrange the transportation flows. For PLUS it is important to have quantifiable results that give an indication of the possible savings. The next research Question, 1.4, addresses possible savings when implementing the different strategic options defined in Chapter 4.

> *1.4 What are the transport costs and consequences for the service level for stores if PLUS applies those insights?*

Question 1.4 is addressed in Chapter 5. We present the computational results with the possible options with a short analysis. Chapter 5 also evaluates the model itself.

> *1.5 What options for transportation and network should PLUS apply if it wants to minimize costs?*

We argue in Chapter 6 what costs and benefits are involved in solving this problem. We discuss the assumptions and conclude on the way the transportation flows should be organised. To implement the conclusions or clarify other parts of the transportation network, further research might be needed. Chapter 6 addresses those recommendations. In Figure 7 we present a short research overview.

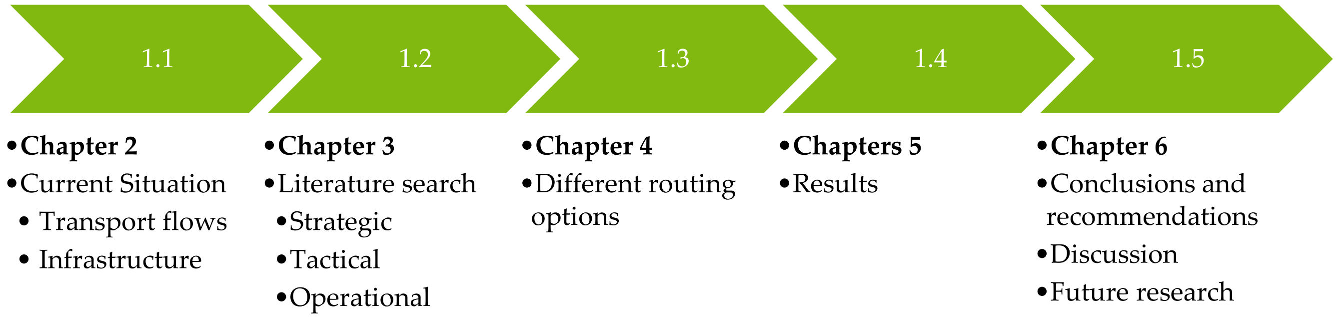


Figure 7: Research overview

1.4 Scoping the research

In order to decrease the complexity of the problem we need to scope the problem. Besides, the time for this research is limited, and therefore stretches the need for achievable research goals. No budget is available to invest in software or in extra resources to support eventual research. However there is permission to ask all stakeholders for their time.

The research is based on a greenfield situation in which we have all possibilities to alter the various current deliveries and delivery times. Although we take a greenfield situation as a starting point, we narrow the research to transport related problems only. The research regards transport flows from and to all DCs.

In Chapter 4 we build scenarios to fill in the greenfield. The scope is further defined in a practical sense. To reduce the complexity we do not include the (financial) consequences for the logistic operations in the DC, the stores, and at suppliers. By doing so some context is lost; this context is further elaborated in the discussion in Chapter 6.

Chapter 2: Current situation

In this chapter we discuss the situation of the delivery of goods towards the stores and DCs. We answer research question 1.1: *"How are the transportation flows connected to PLUS currently organised?"*. First we sketch the current distribution locations and flows in Section 2.1. The transported goods can be divided in two categories: consumer goods and reverse goods. Section 2.2 discusses these two categories. Section 2.3 states how the transport routing from DCs to stores is planned. The day to day routing is made based on the actual demands within a long-term planning. In Section 2.4 we discuss the different aspects of the routing based on three different perspectives: from a DC, a store, and a supplier. Sometimes PLUS needs adaptions to plan the routing, Section 2.5 discusses these adaptions. We define performance measurement in Section 2.6, continuing with the improvement of operations in Section 2.7. Section 2.8 gives a short summary and conclusion of this chapter.

Figure 8 gives a global overview of the decision structure is given on the strategic, tactical, and operational level. Those are linked to the different sections.

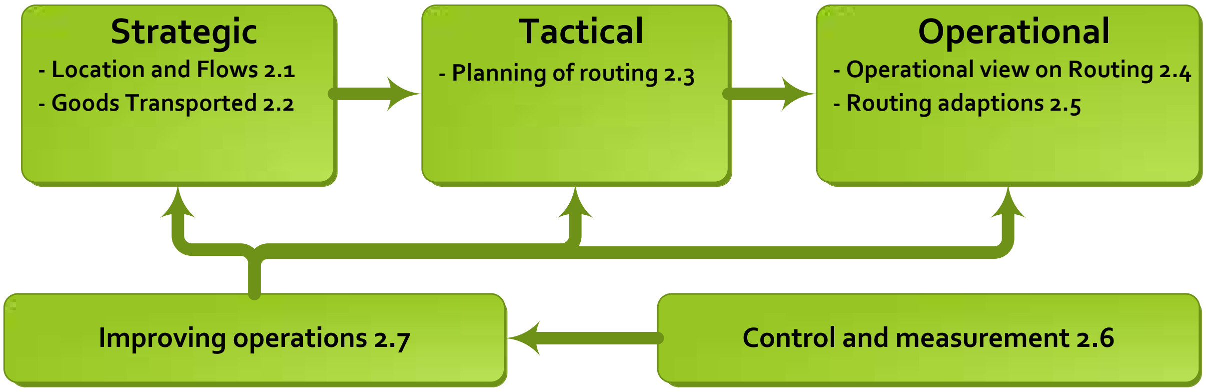


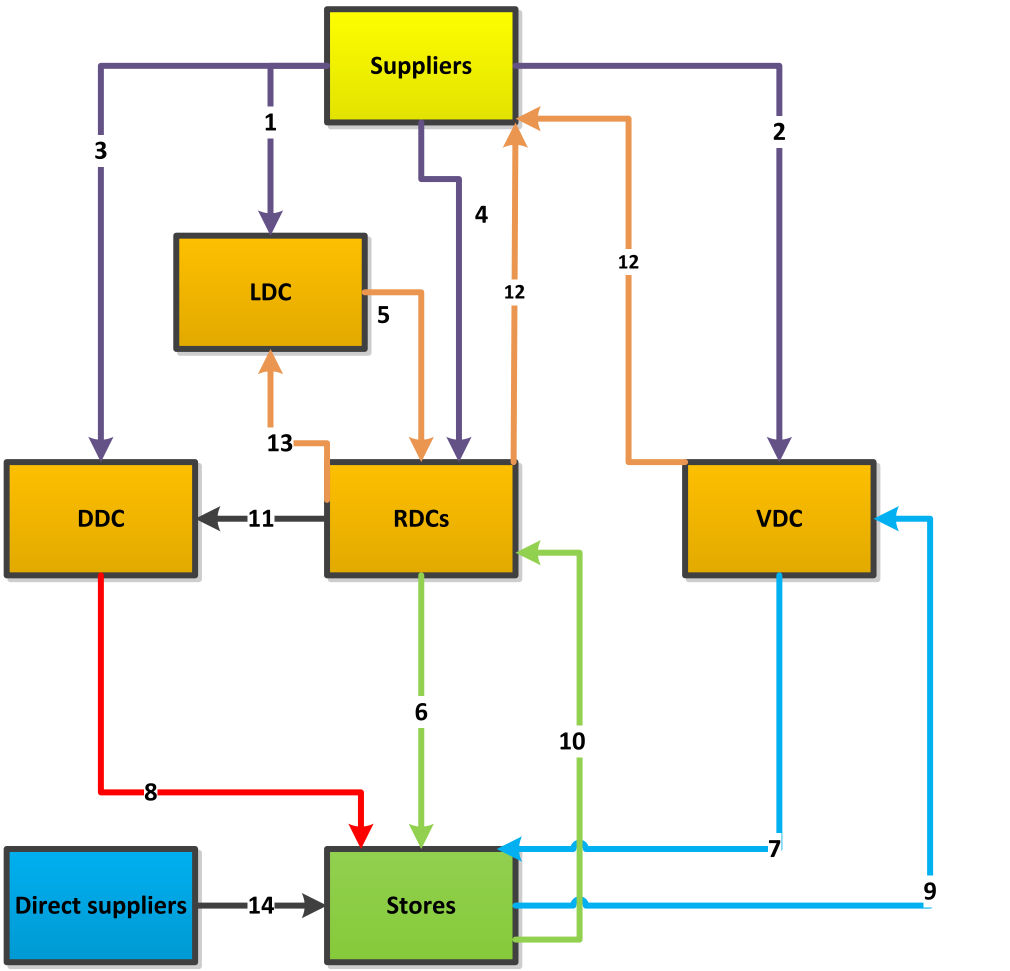
Figure 8: Decision structure overview concerning routing and distribution

2.1 The current distribution system

At PLUS there are four different kinds of distribution centres. The functions are due to the separation of different kind of goods: frozen, fresh, and groceries. In Figure 9 we present an overview of the transport operations towards and from the DCs. In the figure an arrow represents a transport flow and a block represent product locations (DCs, stores, and suppliers).

Goods are produced at suppliers (Yellow) and shipped to the distribution centres (Orange). From there they are consolidated and transported to the different stores (Green).

The LDC acts as a supplier of slow movers towards the RDCs (See 1.2.2 for the explanation). Containers received from the LDC are directly sent to the expedition space for the concerning stores.



1 = Deliveries of groceries (Supplier -> LDC)
2 = Deliveries of fresh goods (Supplier -> VDC)
3 = Deliveries of frozen goods (Supplier -> DDC)
4 = Deliveries of groceries (Supplier -> RDC's)
5 = Deliveries of slow movers (LDC -> RDC's
6 = Deliveries of groceries (RDC's to stores)
7 = Deliveries of fresh goods (VDC to stores)
8 = Deliveries of frozen goods (DDC to stores)

9 = Return of fresh containers and crates (stores to VDC)
10 = Return of containers and crates (stores to RDC's)
11 = Return of containers (RDC's to DDC)
12 = Return of special returns (DC to suppliers)
13 = Return of crates and containers (RDC's -> LDC)
14 = Direct deliveries to shops (Suppliers to Stores)

Figure 9: Supply chain overview

In practice there are also some occasional flows between the different RDCs. These transports are used to balance out the different inventories across the RDCs, especially with the phase out of products. Since the volume is low they are omitted from Figure 9.

Some key figures about the logistics can be found in

Hidden figures, only available at request.

PLUS ideally wants to determine its delivery schedules. The coordination of the supply chain towards the stores may not be given out of hands to another third party. PLUS prefers an increase of their power in the supply chain.

2.2 Goods transported

The logistic flow consists of two kinds of goods: consumer goods (Groceries, fresh-goods, and frozen goods) and reverse goods. Both goods can be subdivided. Consumer goods can be found in the flows 1 to 8 in Figure 9. The reverse goods concern the flows 9 to 13 from Figure 9. The waste deposits (except paper and plastics) are outsourced and not covered by PLUS.

Consumer goods

Consumer goods are the products sold in the PLUS stores. Groceries are dry goods with no cooling required. The groceries generally have a longer shelf life or expiration date. Fresh-goods are dairy products, vegetables, meat, ready meals. Those have a short shelf life and most of them must be cooled or at least conditioned. Frozen-goods are goods that must be stored in a freezer. The goods are transported from the manufacturer to the distribution centre and are then distributed to the supermarkets.

Figure 10: Categories of goods transported

PLUS has 2 different grocery categories, “fast movers” (products sold often) and “slow movers” (products sold less often). The fast movers are stored in the regional DCs and the slow movers in a nationwide DC. Besides the goods delivered by the DCs, there are goods that are directly received from suppliers and sent to the store (Flow 4, Figure 9). These cross-docked goods are already sorted on a store level and directly placed at the outgoing dock. Those docks are the temporary storage space before the goods are placed into the truck. Bread and some minor product categories are directly delivered to the stores (Flow 14, Figure 9).

By keeping one central stock of slow-moving goods PLUS, wants to decrease: 1. transport costs for suppliers, and 2. variability in demand (due to the risk pooling effect). Figure 10 gives an overview of the different (transport) categories.

Groceries and frozen goods are packaged in cartons, crates or plastic. Those packages contain multiple units. The goods are delivered to a DC on pallets, and sent to the store on roll containers. The fresh-goods arrive in crates or cartons and are sent from the DC on fresh-goods containers. There is also a minority of stores (about 70) that receive high volume goods on pallets from the LDC.

Reverse goods

The reverse goods mainly consists of containers with empty crates, paper, plastics, and deposits such as bottles of beer, also there are empty and stacked containers. Those goods are returned to the DC from which they are recycled or reused by PLUS or the supplier. In a previous study by TNO (Confidential report, 2012) the following flows are mentioned which are also relevant to PLUS. In Appendix C there are pictures of containers, a dolly, and a rolly, including their sizes.

1. Pallets for groceries, frozen goods, fresh goods (At DCs).
    a. Negligible < 1%
    b. Figure 5: Flow 12.
2. Roll containers for groceries, frozen goods (At stores and DCs).
    a. About 15% of the total returns.
    b. Figure 5: Flows 10, 11, and 13.
3. Roll containers with: crates (beer), cages, PET bottles (big bags), plastics, paper, and other return goods (such as recalls) (From stores to the RDC).
    a. About 15% of the total returns.
    b. Figure 5: Flows 10.
4. Roll containers fresh goods, dolly, rolly (VDC to stores – Stores to VDC), including packaging crates.
    a. About 70% of the total returns.
    b. By far the largest reverse goods flow.
    c. Figure 5: Flows 9 and 12.
5. Empty beer crates pallets for supplier
    a. Figure 5: Flow 12.

The reverse goods represent a deposit value. Therefore the goods need to be counted and checked when received at the DC or sent from the store. Deposit values are relatively high (from 3.86 euros for a crate to 110 euros per container) which means that good checks are necessary.

Reverse goods make the loading and unloading at stores cost more time. This extra time is increased when multiple stores are delivered in one route. At that moment the truck-driver needs to rearrange the containers in the truck. Return capacity is not exactly known, because the exact number of containers sent back is not announced to the planners. Variation in the number of returns originates mainly from promotions. For example: if there is a beer promotion, this results in many empty beer crates returned at the store. This results in higher fill rates with return goods.

All consumer food products that can no longer be sold are deposited in waste containers. Those containers are separately collected by external parties. The same is true for the residual wastes.

Demand for consumer goods

The demand of the stores varies over time. In practice there is a returning pattern each week, with high demands on Fridays and Saturdays, and low demands at the beginning of the week (See Table 1). Although the products may differ each week, the total transport volume is rather constant.

# containers	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
RDC Demand[1]	29	33	37	40	43	44
RDC St. dev.[1]	2.84	3.06	3.22	3.34	3.58	4.06
VDC Demand[2]	17	18	17	19	23	24
VDC St. dev.[2]	2.76	2.97	2.99	4.14	3.93	3.11

[1]2014 period 1 to 6 excluding Easter weeks, store based
[2] 2014 until week 31, based on total amounts (not store based). A normal distribution and independent data is assumed

Table 1: RDC and VDC demand overview

There is a seasonal pattern in demand in the retailing branch. For the increased demand at Christmas, Easter, et cetera, special forecasts are made to free transport capacity early. Other uncertainties in specific product demand are mainly due to holidays, weather, and promotions. Since many products with this fluctuation in demand are substitutes of each other (e.g. white wine in the summer and red wine in the winter) the transport volume stays rather constant.

The system of PLUS generates an order advise per store based on the store specific forecast. An employee at the store enters extra orders or removes orders from the list generated. Half a day before the shipping of the goods to the store, the DC receives the orders from the stores. The lead-time is equal to the order time plus the delivery time. This lead-time mainly depends on the pre-determined delivery times as set in the planning. Section 2.3 gives more insight in this planning process.

Pricing for the consumer goods

PLUS does not need to negotiate most of the prices at the suppliers. As we mentioned in Section 1.1, PLUS is member of a purchasing cooperation that negotiates supplier contracts for several supermarket chains in The Netherlands: Superunie. In the purchasing contracts paragraphs are dedicated to the logistics. At the moment PLUS receives the products at a place of their desire, with a fixed price. No extra order costs for logistics can be added by the supplier to the purchasing price. The price charged is not made transparent so that the actual logistics costs remain hidden.

2.3 About the planning

Planning of all delivery times is at PLUS almost a strategic task to perform, since it is not done often (once in 3-5 years). This is due to the fact that store entrepreneurs are sceptical towards changes in their delivery times. However, two times a year all requests related to transport times are evaluated. With the requests an adapted order and delivery scheme is made. In this operation PLUS tries to minimize the consequences for the stores.

The planning/routing of the trucks is a difficult task to perform. This is due to the large number of data, parameters, and constraints included in the problem. In order to make a feasible solution one has to take care of the following aspects:

1. Delivery times are fixed with an acceptable deviation of one hour. Each store is delivered daily with fresh goods, 3 to 6 times per week with groceries, and 2 to 4 times per week with frozen goods. This results in a periodic schedule repeated each week.

The periodic schedule is beneficial to PLUS, because of unchanged scheduling of personnel in stores. If there is a fixed delivery time, the shelves can also be filled at a fixed time. This is then known to employees but also to consumers waiting for their desired products to arrive. In this way stores can follow a fixed pattern in their daily operations, which is beneficial for the stores results.

For the planning PLUS assumes 100% of the truck capacity can be used. The capacity for normal trucks 54 containers (Figure 11; left) and 84 for a double-deck trailer (few available, Figure 11; right). There is no buffer capacity in each route although there is some uncertainty in demand (see Section 2.1). PLUS deals with this uncertainty at the operational level.

Figure 11: Example of the trucks at PLUS, left normal truck, right double-deck trailer.

2. There are limited personnel and a limited number of loading docks available. Loading and unloading at the DC is spread by dividing deliveries over the day.

PLUS wants to use its capacity efficiently. Spreading demand leads to lower peaks. If these peaks at DCs are being avoided machine and truck utilization, and storage capacity can be used more efficiently. Therefore deliveries are spread throughout the day.

3. Each store is dedicated to a single RDCs in the different regions (East, South, and West).

This balances out the demand at the various locations, and makes the operations more constant. Stores can communicate with one responsible party in case of problems or incidents.

4. There may not be more than one truck at the same time at one store.

Due to space and personnel constraints it is not possible to unload multiple trucks at the same time. Interference of routes also leads to waiting times and thus extra costs, and higher variability in driving times.

5. At some stores there are time-windows due to municipal restrictions.

These constraints do not lead to the most efficient solution of the routing. The simple conclusion is that every restriction added leads to fewer possible solutions.

BAS-Scheme

Because of the fixed delivery times and the low variety in shipping volume per store, the planning is fixed. The planning is put in the BAS-scheme (**B**estel en **A**fleverSchema; order and delivery scheme). A delivery time is interrelated with the time a store manager has to order his goods. Although the ordering process is automated for most of the goods, changes can and must be made to this advice.

If there is a change in BAS this result in a whole new setting for delivery and (probably) ordering. Since both delivery and order time are fixed, the lead time between the DC and store is also fixed (excluding some minor variation). The BAS is therefore very important in setting the lead times to the stores.

In the case of special promotions or seasonal peaks such as Christmas and Easter, special delivery schedules are made.

The making of the current BAS-scheme

A complete new BAS-scheme was made in 2011. This process was time intensive and took about half a year to design and implement. A software package (Intertour) was used to make the initial routes.

For the organisation it was an expensive process that cannot and should not be repeated often. The costs are due to the meetings, discussions and arrangements that had to be made with the entrepreneurs at the stores. Since 2011 only small, per store, changes were made. Those changes did not have a big impact on the transportation costs.

The number of delivery moments can be reduced for individual stores if the turnover drops at that store. If a store wants an extra delivery, a check is carried out, the so called “leverfrequentiecheck”. The check is based on the current turnover and the number of containers to be transported. Besides turnover, the check looks at the different storage capacities all stores have. This storage constraint is also regarded when determining the number of delivery moments.

2.4 Operational routing

The routing can be viewed from three different perspectives in the supply chain: From DCs, stores, and suppliers. In this section the current routing is approached from those three perspectives.

2.4.1 Distribution Center perspective

Figure 12 gives an example what the current routing can look like. In this simplified example a truck is going from a RDC to one (black arrows results in total 6 drives) or two stores (green arrow + black arrow, results in total 5 drives) and then returns with the return goods.

More than two stores are also allowed, but this (logically) depends on the volume transported. With the current average volumes of at least 29 RDC containers per store it does not happen often. The capacity of 54 (or for some 84) containers per truck leaves not much room for combinations. With the fresh goods there are more stores in a route, since there are lower volumes to transport.

An extensive map of the return flows originating from the stores can be found in Appendix A. In Figure 9, flows 9 to 13 represent the reverse goods.

Besides the flow of goods from the DC to the stores, there is an inbound flow of goods from the manufacturer to the DC, see Figure 12 (blue arrow = in total 4 flows). Those trucks arrive at the DC and go (partly empty) to another DC, or (empty) to the manufacturer's location. Some manufacturers perform a backhaul afterwards. Others take (beer) crates (such as Heineken, Grolsch) or pallets from the DC to their own location**.** The number of incoming trips is about 1.5 times the number of outgoing trips.

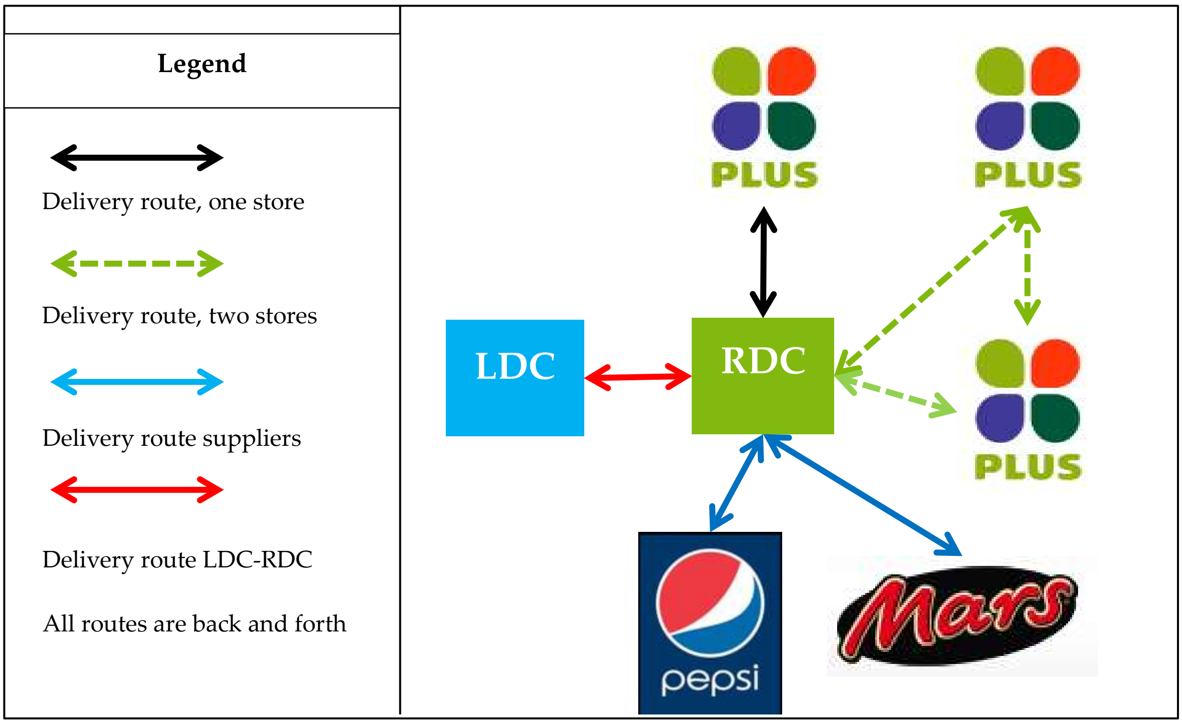


Figure 12: Example, truck routing at PLUS

The regional centres not only receive goods from suppliers, but also from the nationwide distribution centre (LDC). The LDC goods are combined with the shipment from the regional fast mover goods. LDC deliveries are directly placed at the outbound dock in the RDC.

There are no structural inter-depot deliveries between the RDCs. Only a few times a year there are deliveries to balance out the stocks at the RDCs. Transfer of goods between DCs are called inter DC deliveries, the performance of this operation is believed by management to be performed sub-optimal at PLUS.

From a management perspective this sub-optimal performance comes from the fear of going out of stock at one DC and having plenty at another DC. This results in unnecessary loads shipped towards each other, sometimes even having to ship the same load two times between RDCs. Besides those issues the current warehousing software used is not fully equipped to handle this efficiently.

Each store is assigned to one DC based on the smallest distance from the DC to a store and back. Also the spread of turnover across the different DCs is taken into account to balance out the workloads. A delivery route which serves multiple stores is always from stores assigned to the same DC. This results in a fairly simple problem for routing purposes. The assignment of a store to a distinct DC is not necessarily fixed. DCs and stores can be rearranged for routing and planning purposes. However the store can currently only have one RDC assigned which is a constraint for the vehicle routing planning.

2.4.2 Store perspective

From a store perspective, the current schedule is straightforward. A new store negotiates with the headquarters on the number of times it wants to be delivered, including the delivery times. Currently stores can ask for a new "leverfrequentiecheck", which could lead to an increased or decreased number of deliveries. However negotiation is a very important aspect, because of the aforementioned cooperative structure. In Table 2 an example is given of the delivery schedule for three different stores.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Daily
PLUS 104							
1. VDC P.M.							15:33
1. VDC A.M.							6:56
2. DDC	8:53		8:53		14:18		
3. RDC	17:02		16:48		17:34	16:46	
4. LDC	17:02		16:48			16:46	
PLUS 106							
1. VDC P.M.							8:38
2. DDC	9:23		10:08		9:23		
3. RDC		17:23		14:00		14:40	
4. LDC				14:00		14:40	
PLUS 114							
1. VDC P.M.							7:46
2. DDC	9:47			11:26			
3. RDC	7:00		6:30				
4. LDC	7:00		6:30				

Table 2: Examples of a store delivery schedule

Stores prefer to have short lead times, but not necessarily more delivery moments. With short lead times they can decrease their inventory and the needed storage space to cover uncertainty in demand. For each delivery moment a crew is needed to fill the shelves. Therefore costs increase with more frequent, but smaller deliveries. Each store is delivered daily with fresh goods and 2 to 6 times per week with groceries (based on the leverfrequentiecheck, Section 2.2), see Figure 13. Frozen goods are delivered 2 to 4 times per week.

Most stores do not have enough storage space to cover two or more loads of return goods. This means that return goods must be collected before or at the time of delivery. In some stores there is not enough space available to cover all return goods and even separate buildings are rent. Besides return goods also some inventory is kept at the store's storage space. Only promotional goods are sometimes held back directly after delivery in the store storage space.

Figure 13: Number of stores versus delivery days and deliveries per day

2.4.3 Supplier perspective

The times at which a supplier delivers to a DC is, as with stores, based on a fixed schedule with a variable lead time per product. The supplier negotiates about the transport and delivery-schedule with the category-manager (responsible for a specific product range within the supermarkets) and the supply chain department from PLUS. Price and product aspects are already negotiated by the commercial department of PLUS or Superunie (See Section 1.1.2).

Most of the transport is done by an external third party logistic service provider (3PL or LSP). In total about 1350 orders per week are sent towards the RDCs and LDC. The orders consist of about 9 pallets per delivery, which results in a fill rate of 30% (for LSP deliveries with only one PLUS DC). The truck drives (partly) empty back towards the supplier, another DC, or performs a backhaul for the supplier.

Figure 14 gives an illustration of backhauling of goods by PLUS. The backhaul trip is marked as the orange arrow. By doing a backhaul 1 trip is saved (-1 black arrow, -1 blue, +1 orange). At the moment, only a few backhauls are performed. Those backhauls are mostly performed after a delivery from the LDC to the RDC. On that part of the route there is most free capacity left. Backhauling (such as the delivery of products) is done following a regular (weekly) scheme. Suppliers ask for a fixed time when collecting goods from their plant or warehouse.

Currently suppliers deliver goods with a fixed price including transport to the DC. This makes it difficult to calculate the obtainable benefits of a backhaul for the RDCs. Another aspect on backhauling is that a lot of high volume suppliers are having their transport and storage performed by an external party, the 3PL. Negotiation with both 3PL and supplier is needed for the current coordination of the deliveries. At the moment there are fixed prices negotiated for backhauls with 3PLs.

Most strategic discussions are related to a compensation for backhauling by having "*factory gate pricing*" (FGP) for products. The factory gate price is the price for a product without the transport towards the DC of a retailer. In this way logistic costs become more visible throughout the supply chain.

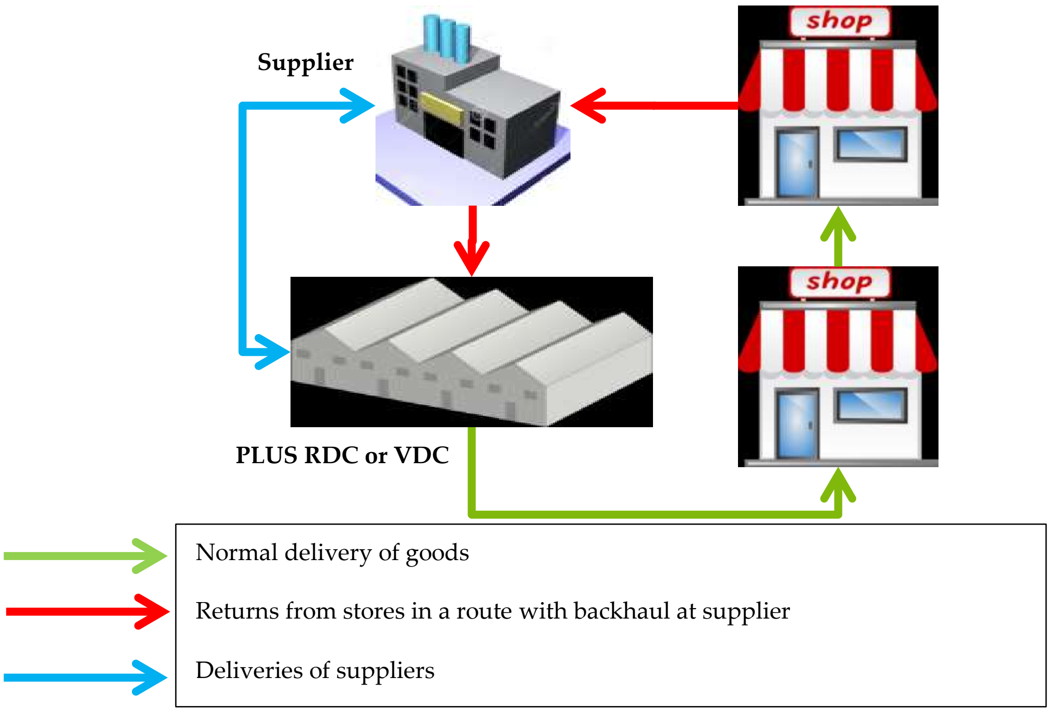


Figure 14: Transportation flows with backhauls

In order to perform a backhaul, space is needed in the truck after delivery to the stores. A backhaul order currently has been about 40% of a full truck load, with a high variance depending on the supplier. Loads are ranging from 5 pallets to a full truck load. However, there are also reverse goods coming from the stores which result in less opportunities for a feasible backhaul. Most backhauling is currently performed on the route RDC to LDC, because the low fill rate gives plenty of room for performing a backhaul.

Backhauls are currently not consolidated at the nearest DC to have inter-depot deliveries. A short example of what is meant by consolidation and inter-depot deliveries: PLUS picks up all the “MARS” in 1 full truck and “Pepsi” in 1 full truck in the area of Ittervoort. After receiving the goods, Ittervoort sends one truck with both “MARS” and “Pepsi” to Haaksbergen. The same can be done in Haaksbergen for example with “Bolletje” which can be consolidated in Haaksbergen and sent in a truck towards Ittervoort. For an illustration see Figure 15.

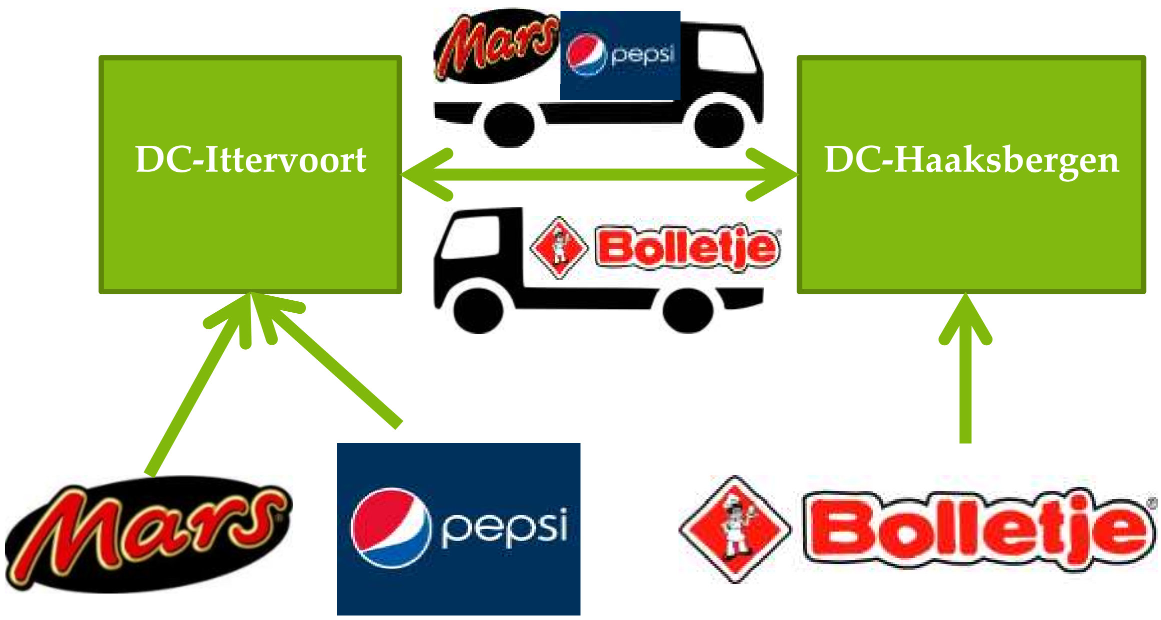


Figure 15: Illustration of consolidation of backhauls

2.5 The day to day routing

In each DC there are planners who make a daily plan for all tours from that DC. The planners check if there are violations of truck capacity, driver times, or distances. In 2011 after implementing the new BAS, software was used for the day to day routing of the trucks. However there was no support from the operational organisation to implement the package. The lack of support is believed to be caused by the lack of (early) involvement of stakeholders (drivers, planners) in the choice and set-up of the software.

The current day to day routing is based on the number of containers to be shipped. This data is retrieved from the *Locus* software. *Locus* is the warehouse software package PLUS has implemented for its RDCs and LDC.

Depending on the number of containers on a day (given by Locus), most of the time the same schedules are repeated. Most changes are related to trucks and drivers. If there is a violation of the constraints adaptions are made or an extra route is created. This operational planning leads to the schedule that is handed over to the truck drivers. The estimated time of arrival at a store is also communicated towards the store. When there are changes in the regular schedule, the store is informed via email or telephone.

PLUS plans to centralize the operational route planning towards one location, most likely one RDC. A benefit would be that information can be shared more easily amongst planners. With this information about the operation, PLUS obtains more integration and coordination of transport activities. This aspect makes improvement projects that concern the whole supply chain (such as this project) easier to implement.

2.6 Routing and delivery performance

Since PLUS is focussed on quality and service, on time delivery is crucial to obtain high availability of products. Each period a report with the performance of the logistics is made.

Cost focus for transport is expressed in kilometres travelled or in total transportation costs per stock keeping unit. Vehicle utilisation is used to express the efficiency of the trucks deployed. Those are important indicators of the logistic performance, the figures are also presented in the Confidential Appendix.

Service levels are measured in on-time deliveries and on-shelve availability at stores. The logistics staff is not responsible for the service levels. The service levels are accounted for by the commercial department and supply chain management. The DC-managers are accounted for operational costs occurred at the DC. Furthermore the quality of delivery (delivery times, broken products, handling etc.) is measured at the DCs (see also Section 1.1.4 for the organisational aspects).

2.7 Improvement for transport flows

PLUS management currently has a few ideas on how to improve transport flows and what the ideal situation would look like. From a cost perspective the most preferred situation is that a truck travels full from a DC to the stores. The truck is fully unloaded after the last store. The best option would be to return fully loaded to a DC. At the moment only small improvements are made one the tactical/operational level to increase fill rates.

In this report we will contribute to this improvement on transportation flows on a strategic level.

The PLUS routing problem

In order to determine what kind of routing PLUS has to deal with we need to specify the constraints encountered by the company.

Constraints

As mentioned earlier the constraints PLUS faces in their routing (Section 2.1):

1. All return goods need to be retrieved from the stores before a delivery can take place.
2. There are time-windows for delivery of stores: so time is blocked for delivery.
3. Limited truck capacity: may not be exceeded.
4. Limited time a truck can drive: may not be exceeded.
5. Split delivery is not permitted.

Ad. 1 and 2. This means there are two different sets of time windows which depend on each other. The reverse good must be retrieved before, or at, the normal delivery. The normal delivery depends on the same store time window.

Features of the PLUS routing

There are several aspects that need to be considered when selecting a good routing algorithm for PLUS.

- Multiple Depots
    - PLUS has multiple depots from which RDCs are partly interchangeable.
- Backhauls

    - PLUS needs to be able to include backhauls, trucks must be able to retrieve goods at the supplier's depots.
- Combined delivery and pick-up points
    - Not only the store should be delivered, but also empty goods should be retrieved at the same spot. The demand and supply of these goods are also interrelated, with one period time difference. The volume of the returns is equal to the previous demand multiplied with a return goods factor.
- A weekly repeating schedule (as researched in Section 3.2.1)
- Able to deal with over 250 stores, 6 depots, over 300 suppliers with different or the same (depot) locations.

Now we defined the routing problem at PLUS, we continue with selecting and explaining the applicable literature for PLUS in Chapter 3. Chapter 4 presents the model based on the input from the literature and the current situation at PLUS.

2.8 Conclusion

In this chapter the research question *"1.1 How are the transportation flows connected to PLUS currently organised?"* was answered. The four transportation flows, 1. DC to a store, 2. Store to a DC 3, Supplier to a DC, 4. DC to DC, are hand planned without the help of software. This is caused by the fixed time schedules from stores, suppliers, and DCs. The schedules are negotiated within the supply chain and therefore schedules are time intensive to alter.

Only flows towards the stores are currently included in planning the routes at PLUS. Planning complexity in the current situation is therefore rather low. There are possibilities to perform backhauls at suppliers, but those are hardly used. However PLUS has some ideas on how to increase fill rates for the trucks returning to the DCs such as separating the second from the first flow.

Chapter 3: Literature review

In this chapter we solve research question 1.2: "*What is known in literature about transport situations as observed at PLUS?*". The chapter describes the transportation problem from three decision levels: Strategic, tactical, and operational. Although the research question is from strategic nature, attention is given to all different decision levels, because a choice for an appropriate transportation infrastructure depends on the results on the tactical and operational level (Dethloff, 2001) (Le Blanc et al. 2004) (Fisher and Gaur, 2004).

Section 3.1 starts by sketching the strategic aspects, continuing with the tactical aspects in Section 3.2. The tactical section is the most extensive. This is due to the fact that the strategic and tactical levels are strongly interrelated for decisional purposes. Section 3.3 is about routing aspects on an operational level, which mainly concerns adaptions to the planned routes. Section 3.4 presents a short conclusion about the literature in this chapter.

3.1 Characteristics of retail transportation logistics on the strategic level

The strategic decisions presented in this section are split into the influenced work-/transport- flows. Section 3.1.1 introduces a short history on supply chain choices by supermarket chains. In Section 3.1.2 we discuss the flows from DCs to stores, in Section 3.1.3 from store to the DCs and in Section 3.1.4 the inter-DC flows. The focus in Section 3.1.4 is on the backhauling of goods from suppliers and factory gate pricing. Section 3.1.5 addresses the inter-DC deliveries.

3.1.1 Historical shifting strategic focus for supermarket chains

Consumers take for granted that each product in a supermarket is available every day at a relatively low price. The profit margins for supermarkets currently are between 1 and 2%. This makes a cost efficient and service focussed logistic system necessary to meet the consumers demand for a low price (Fernie and Sparks, 2009). Given the competitiveness of the market, supermarkets need to be pro-active in cost savings and improving service levels in order to survive. This relates directly to the logistic operations, which are core business in the branch.

Strategic choices in retail logistics mostly concern infrastructure questions. Sparks (1998) states that management should decide on: Storage facilities (DC-network, locations and type), Inventory, Transportation, Unitization & Packaging (handling materials), Communications (IT-structure). The factors that retailers try to improve are either the service level (availability of products to the end customer) or the incurred logistic costs.

In the early 70s and 80s a lot of effort was put into the consolidations of orders within the supermarket chain, by setting up DCs. Deliveries were no longer made directly towards the stores, but from the DCs. This development brought savings by reducing lead time and decreasing inventory levels.

In order to reach a new (lower) cost level, increased fill rates (# containers in trucks) and decreased lead times (time between placing and receiving an order), new projects were started. Transport for supermarkets increasingly involved cooperation of the supply chain partners such as suppliers, LSPs, DCs, and stores. In order to create a network of logistic partners, even competition is involved (Fernie and Sparks, 2009). Focus in retail has shifted towards an overall approach to integrate and come to an end to end supply chain.

A supply chain party has two options to increase or decrease power within the chain. By having horizontal integration, this would mean cooperation or purchasing with companies on the same level. For example: At PLUS this is done by cooperating with Superunie-members. The other option is vertical integration which means cooperation with up or downstream partners. In the supermarket this could mean transporting towards customers or picking up goods at suppliers. In extreme circumstances it could mean to even acquire suppliers.

If a supermarket wants to increase horizontal and vertical integration of the supply chain, it must build external relations that rely on trust and commitment. The company needs to feel safe to give away power and increase dependence. Ideally in effective relationships one has interdependence (Kumar, 1996).

The choice for each retailer is whether to do logistic operations in-house or outsource (parts of) the operations. For each part of the operation the retailer can make a different decision. Relations must be maintained and built in both scenarios, savings can be achieved by building (cooperative) networks, but issues such as giving away power must be taken. In practice those issues were too high to lead to direct cooperation within the food retailing (Stephens, 2006).

Only if one dives deeper into a specific operation, a well-informed choice can be made on whether or not to outsource/integrate/self-organise it. This basically results in a make or buy decision (Fernie and Sparks, 2009). If the choice between "buying" or "making" is made, the organisation can build its network depending on the choice to buy or make it (Stephens, 2006). The same is true for each of the different transportation flows discussed in Sections 3.1.1 to 3.1.3.

If a balance is made for the strategic overview for retail logistics, the balancing act as in Figure 16 can be observed (Fernie and Sparks, 1998). The focus in this report is on the strategic choices that concern transportation. This means that strategic choices for storage, inventory, and communications are not researched. Packaging is included since it has high influence on the return goods volume. Those return goods highly influence the transport network between stores and DCs.

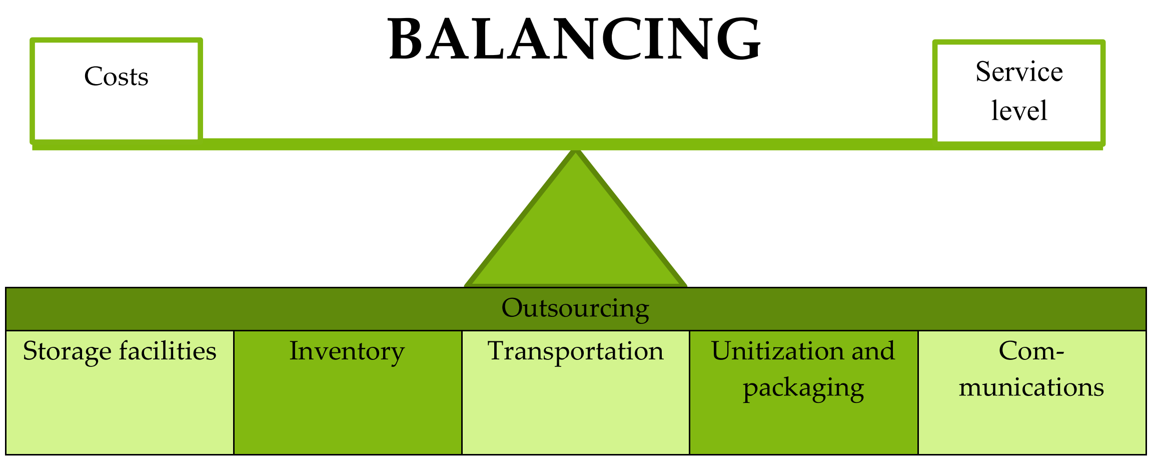


Figure 16: Balance of costs and service level

3.1.2 DC to store: primary flow for supermarkets

The flow from DCs to stores is the primary flow in the supermarket chains. Before the time of supermarket owned DCs, direct deliveries from the supplier to the store were common. No strategic choices on DC to store were needed since there where none. Having direct transport gave advantage to stores which could create high sales volumes in their stores. A full truck load was faster obtained and discounts could be made. In the UK this led to the rapid growth of Tesco (Smith and Sparks, 2009) and in The Netherlands for Albert Heijn.

Currently the focus is set on on-time delivery, low lead times, and fill rates of trucks. This means: getting the right product to the right place at the right time, as stated in many articles. To do so is not as easy as it sounds. The most important choice to achieve this is the decision on the number of deliveries per time instance. This decision also highly determines the costs of the logistic operation.

During the 90s a lot of effort was put in optimizing the flow from the DC to the store. The stores demand more frequent deliveries. More deliveries results in a decrease of the number of full truckloads towards one store. Therefore it is feasible to visit multiple stores in one route (Fernie and Sparks, 2009). The impacts of increasing the number of deliveries stressed the need for expert trip planning. This adds extra complexity to the tactical and operational levels as described in Sections 3.2 and 3.3.

3.1.3 Store to DC: Reverse goods

This transport flow concerns the reverse goods as outlined in Section 2.1. Since the 90s the focus on recycling and reuse of materials is strongly increased (Kroon and Vrijens, 1994) (Fernie and Sparks, 2009). This trend is reinforced by European packaging laws.

Reverse logistics is essential in the reuse of materials. The complexity increases with this second flow in the network, especially when using multiple containers, crates, and a diversification of deposit goods (Kroon and Vrijens, 1994). The use of same transportation materials in the network helps to reduce the complexity. Those returnable materials are from a non-competitive nature, and could be shared across the supply chain (Stephens, 2006).

Lützebauer (1993) describes three different systems for reverse logistics: Switch pool systems, System with return logistics, and systems without return logistics.

1. Switch pool system: Only the store and the DC have allotted goods. The DC sends the goods towards the store and receives the empty containers and maintains the goods.

2. System with return logistics: In this system the containers are owned by a central agency (LSP), which also retrieves and maintains the containers. It is essential that containers are accumulated at the stores for cost effective collection. There are two different systems within the return logistics (Lützebauer, 1993): A book system and a deposit system.

> A book system is controlled by the LSP. The LSP keeps track of the containers delivered to the stores and the number retrieved. There is a debit/credit account for each store, which is altered after every delivery or return trip.
>
> A deposit system works with a payment to the LSP for each container. The agency refunds the containers after collecting the containers from a store or DC. Tracking and tracing is not necessary in this case. Deposits stimulate the quick return of containers (Kroon and Vrijens, 1995).

3. Systems without return logistics. Here the containers are rented when needed for the term the DCs need the containers. Afterward the lending period they are collected by the LSP.

The choice which system is suitable for an organisation relies on the goods and quantities transported, but also on available storage space and the size of the organisation. A returnable container or crate system is only feasible with a large scale implementation (Kroon and Vrijens, 1995). The extra use of an external partner or cooperation, gives the opportunity to create standardized containers. This gives an extra saving in transport and handling costs (IGD, 2006).

De Koster et al. (2002) state the following hypothesis: “For retailers that supply stores it is most efficient to collect the returned material to the DC with the same truck that delivers the products”. This seems logical since the truck has to go there anyway. They argue that this is not necessarily true, due to: Multiple stores in one route and the need for reshuffling goods within the truck. They do not argue the not fully loaded truck returning to the DC. To guarantee the savings made on the collection of return materials the scheduling of trucks should be done internally.

De Koster et al. (2002) examined the reverse logistics of nine retailers. Among these nine retailers there are three different supermarket chains, one nationwide, and two regional chains (called chain 1, 2, and 3). The downside of this scope (10% of the market) is that it does not give a complete picture of the market. De Koster et al. (2002) state that there is not enough attention paid to reverse logistics and that there are savings to be made. They found the following important aspects:

- Contextual factors
    - Type of goods returned
    - Return policies and volume
- The process
    - Transport
    - Receipt of goods
    - Storage
- Manpower, space, and associated costs

The return crate flow is on average 35% of the outgoing flow (de Koster et al., 2002). The rest is paper/plastics/waste (about 20%). The flow for returning unused goods is negligible.

Viewed from a process perspective the supermarket chains differ from one another (de Koster et al., 2002). For so called ‘Chain 1’ of the different supermarkets the return goods are directly taken in the same truck. For ‘Chain 2’ the goods are only collected 2 times a week when it is the last supermarket on the route. Both chains outsource their waste collection. At ‘Chain 3’ stores pay for their waste disposal, this results in a low volume since stores outsource it themselves.

Supermarket chains can optimize their reverse logistics very well since there is low uncertainty in demand and supply. Also there is much room for standardization, because the goods returned are very alike (De Koster et al. , 2002).

The costs for transport and handling the goods at the DC are between 5.8% (without waste disposal) and 12.0%. The space used is approximately 10%. The receipt is separated, since the reserve flow is, different than a forward flow (de Koster et al. , 2002).

De Koster et al. (2002) also argue that for more efficient handling of reverse goods, volume/stores should be increased. The more goods the lower the cost per container will be. This leads to the necessity of cooperation on return flows since (only) then volume can be increased volume on short term.

Collaboration and consolidation of flows

The past years was a discussion going on in literature about whether or not to collaborate with different retailers (Le Blanc et al. , 2004) (Involvation, 2004) (TNO, 2013). The same discussion is still held at the practical side: collaboration between the supermarket chains. The end goal could be to set-up a joint network of handling returns. This would mean a complete separation of return logistics from the primary flow. The collaboration gives room to pick up goods at each other's DCs, stores, and plants. Some flows might be handled in a consolidated return goods DC. By picking up each other's returns costs could be reduced (Le Blanc et al. , 2004). The savings could be up to 26% of the supply chain costs for specific types of products (Le Blanc et al. , 2004). To look into this strategic problem they used only a simple routing algorithm to assess the differences.

3.1.4 DC to DC: Inter-depot or consolidation of backhauls

These transport flows are the so called transit deliveries. Not much research is addressed to this problem in the context of transportation. This is mainly due to the fact that the choice for transit deliveries is influenced by lower inventory costs and extra handling costs. Those are mostly operations based on warehouse management, not transport management.

The consolidation of backhauls at one DC which delivers to other DCs is called a hub-situation. A hub is a terminal in which trucks arrive with their goods that are (directly) transferred to other trucks and shipped to another hub or to the end destination. If a hub is used, transportation cost can be reduced due to the economies of scale (Moon et al. , 2011). Using a hub for retrieving goods for multiple DCs automatically results in higher truckloads for backhauls. This situation is sketched in Figure 15 (Section 2.4.1).

3.1.5 Supplier to DC: Direct delivery or backhauling goods

In order to perform a backhaul, two cooperating parties are needed. First, suppliers are needed who are willing to give away power over their outbound logistics towards the LSPs or supermarkets. Second, supermarkets must prove capable to meet the logistic demands of the supplier, but also to meet their internal demands. Both aspects merely rely on good relations and coordination. Hingley et al. (2005) discuss the relationship between retailers and suppliers within the UK. Due to the high volumes and low margins, the relationships are under pressure and suppliers do not feel there is room for sustainable relationships.

Besides a lack of trust in the relationship with the retailers, the relationship from the supplier with their logistic service provider might be very good. There is also a good chance for the supplier having a fixed contract with a LSP. This leaves (almost) no space at this supplier to perform a backhaul (Le Blanc et al. , 2004).

The most interesting backhaul goods are those not sufficient to fill a whole truck (Involvation report, 2004). This is mainly due to the fact that those loads come from smaller suppliers, and that they are more costly per unit to ship for the supplier.

Backhaul savings, two methods: Factory gate pricing or "Lump sum"

When a retailer performs a backhaul, this does not automatically lead to cost-savings. Actually total transport costs will rise for the retailer. The supplier saves money by no longer having to transport goods to the retailer. This gain from the supplier is to be negotiated with all partners. In the current literature there are two options given to collect the savings: Suppliers charge a lower price for products (Factory gate pricing) or they give a fixed amount per load collected ("Lump sum"). Both policies are widely used by Tesco and Sainsbury in the UK.

Factory gate pricing (FGP) in The Netherlands is discussed by Le Blanc et al. (2004). A factory gate price is the price for a product without the transport towards the retailer's DC. Le Blanc et al. (2004) present a case study for Superunie members; data was delivered by Coop, Dekamarkt, and Jumbo. At the time they represented about 6% of the total market share, see also Section 1.1.2.

During the past years, the focus in retailing was on the reduction of inventory at the DCs and stores. This trend led to lower volumes shipped from the supplier and thus more deliveries. More deliveries lead to extra costs for the suppliers, resulting in hidden supply chain costs not visible to the retailer. In the end the extra transport costs are accumulated in the product price. The higher product price might waste all the savings that were obtained by having lower inventory.

With FGP the retailer collects goods from the supplier which results in a more integrated supply chain (Le Blanc et al., 2004) (Van der Vlist, 2007). The integrated chain, from manufacturer to store, provides more insights in the cost structure. Those insights can be used for further optimization in terms of smaller or larger order quantities which result in lower inventory costs or lower transport/replenishment costs.

In 2007 van der Vlist, published that about 40% of the logistic cost for dry groceries originate at the supplier and 60% at the retailer. In total 42% are transport costs, from which: 9% from plant to a warehouse; 14% from the supplier to the retailer's warehouse and 19% distribution to the stores. Van der Vlist (2007) argues that by this rule negotiations can start for a correct Factory Gate Price.

The increase of order quantities could be feasible, and increased numbers of full truckloads (van der Vlist, 2007). The balancing is between replenishment costs and inventory costs. If the retailer balances these costs using factory gate pricing a better order quantity can be found. According to Le Blanc et al. (2004) this leads to savings in the supply chain of up to 7.5%. An important note to make is that Le Blanc et al. (2004) include cooperation benefits from multiple retailers (see Section 3.2.2). If a small group of retailers would cooperate the savings from backhaul would be about 2.5% and results in slightly higher costs (1-2%) for other non-participating retailers.

3.1.6 Strategic transport problem analysed at tactical and operational level

The strategic choices a retailer makes rely on the way the retailer can handle the transportation in practice, on a tactical and operational level. The benefits can only be monitored and estimated at the operational or tactical level, as proposed by Le Blanc et al. (2004). The operational level is researched in Section 3.3. Before describing the operational level, the tactical level is addressed in Section 3.2. Since the tactical choices are essential in the development of efficient transport systems it will be discussed extensively. The focus in Section 3.2 is on the development of good routing tactics.

3.2 Retail transportation logistics on the tactical level

The tactical level within the strategic framework mainly focuses on long term planning and allocation for several periods. Most routing problems are described from an operational level. This is due to the day to day planning made at most transport corporations. Supermarket chains however work with periodic schedules which are fixed for a long(er) time. In this way planning and scheduling coincide, except for some necessary adaptions. On the operational level only minor changes are made due to the fluctuations in demand (le Blanc et al. 2004), see also Section 3.3.

For routing purposes there are dynamic and static routing options. If routing is dynamic, the routes can be altered at any time. If a routing is static this means that "part or all input is unknown beforehand" and that "routes are set a-priori". Pillac et al. (2012) define the kind of routing problems at supermarkets as static and deterministic. Section 3.2.1 clarifies the static and deterministic aspects of periodic schedules. Section 3.2.2 describes how to solve a static and deterministic vehicle routing problem.

3.2.1 Making periodic schedules

The fixed delivery times within a periodic schedule are due to the organisational structure and work processes that retailers are used to (Gaur and Fisher, 2004). The organisation relies on fixed times in order to create a workable environment on the store floor. The workable environment can be defined as: fixed working hours, fixed time to place orders, on time delivery of goods, one delivery at the time, limited floor space required.

A periodic schedule also provides advantages to the DCs. The DC can then perform cross-docking and preparing deliveries in advance. Balancing workflows based on the periodic schedule has improved because, one can see what personnel, equipment, and trucks are needed. Eventually the routing is adapted to smoothen or relax the operations at the DC.

After the planning is made, most of the transportation costs are fixed for the next period until a new periodic schedule is made. Those costs are lower for a periodic schedule, a supermarket can than enter long term (fixed) arrangements with LSPs (Gaur and Fisher, 2004).

A periodic schedule or an indication on what happens can be approximated or determined by solving a routing problem. The solving of the routing problem is discussed in Section 3.2.2.

3.2.2 Solving vehicle routing problems

In Section 1.3 we state that it is necessary to report the possible savings for a new routing network. In this section we perform a literature research on the various versions of the vehicle routing problem (VRP). In Chapter 2 we already analyzed the situation at PLUS. Since we have clarified the situation we can continue with the appropriate VRP-literature to solve the specific PLUS routing problem.

Introduction to the vehicle routing problem

The routing problem in this report is a Vehicle Routing Problem (VRP). The VRP category deals with pickup (and delivery) points that need to be visited by one or multiple vehicles with a limited capacity. The objective of solving the problem is mostly linked to minimizing total route costs, time, or distance. The VRP formulation is first mentioned by Dantzig and Ramser (1959).

A VRP is comparable with a Travelling Salesman Problem (TSP), but must not be confused with each other. The TSP is a subset of a VRP. The difference is in the constraints. A VRP can have multiple vehicles with a certain capacity and also multiple depots, whereas in a TSP can have only one tour from one starting and ending point.

Although there are easy VRPs, most of the VRPs are NP-hard (Non-deterministic Polynomial-time) problems in combinatorial optimization. Non-deterministic meaning the computation and solution can be different in different runs using specific algorithms. NP-hard problems result in a large numbers of possible solutions. Only for small instances those solutions can be computed by computers in reasonable time (Polynomial-time). In practice for most VRPs it cannot be solved in polynomial-time.

In practice, heuristics are used to find good, if not optimal, solutions for a VRP. Searching through VRP literature a trend can be observed towards meta-heuristics and increased computation power of algorithms. The meta-heuristics do also well apply to the supermarket cases, so extra focus is placed on that subject.

VRP Literature and abbreviations

VRP studies use abbreviations to clarify about what problem they write. The abbreviation starts with VRP and adds letters for the specific problem.

For backhauls a B is added to the abbreviation. With a simultaneously Pick-up and Delivery Problem a SPD/SDP is added, if it is not simultaneous the S is omitted. In the case of Time Window TW is added and for a Multi-Depot problem, MD. For example: a problem with Multi-Depot and Time-Windows gets the following abbreviation: MDVRPTW.

The review of the literature is divided into categories. Selection and orderings are based on VRPs such as the routing problem observed at PLUS. To prevent double or long explanation, referrals are made to other sections in this chapter and a basic knowledge level in routing literature is expected.

VRP and the use of simulation studies

On a strategic level, simulation studies are widely applied. Businesses use simulations to minimize the resources used in their operations. Making simulation model is effective for example in minimizing the number of trucks, relocating DCs, testing capacities etcetera. A simulation model is capable to deal with fluctuations in demand and create statistics by doing experiments (Carson and Maria, 1997).

In the case of truck routing, simulation is used to tests the solutions on robustness. Most companies want to see if the number of trucks used, service levels, costs, et cetera fluctuate when demands and supply change over time. This simulation is especially important where if the fluctuations in demands are high (Hu et al., 2008).

Kökten (2011) used a simulation model on fixed solutions computed by a combinatorial optimization method. By running the simulations Kökten (2011) is able to obtain information about the routing's robustness of multiple solutions.

VRP with (simultaneous) delivery and pick-up (VRPSDP)

In the case of a pick-up and delivery problem there are two different options concerning deliveries and pick-ups. There are unpaired and paired deliveries/pick-ups (Parragh et al. 2008). A delivery is called an unpaired delivery if the delivered good is the same product, and can be sent from each pick-up location to any delivery location. These situations are found in VRPs with homogenous goods such as oil. Within the supermarket branch there are only paired deliveries and pick-ups possible. This is since pick-ups must be sent to a (specific) DC and all the store deliveries are assigned to a specific store. In literature the Paired Delivery and Pick-up (PDP) is mentioned by Parragh et al. (2008), they also present a mathematical formulation. Parragh et al. (2008) find two options to solve this PDP: by exact methods or by heuristics.

Exact methods

Most exact methods are based on the branch and bound algorithm, column generation and dynamical programming (DP). The branch and bound algorithm dates back to Little (1963) and Kalanantari (1985) who first used it to solve a VRP. By branching, an upper or a lower bound is set at the start of the algorithm. One then selects a node and splits the branch into different sub-problems. The bad solutions, higher or lower than the bounds set, are excluded for further computations. This saves computation time, however for large instances the exact methods take a lot of time. In 1995, Gelinas described a branching strategy for time constrained and backhauling VRPs. The computation time is acceptable, but the problem instance that is used has not the complexity dealt with in current day to day problems.

With column generation a linear problem is split into different solution spaces (so called columns) which can be solved separately. The master problem is solved by adding the columns together so that the optimal point (e.g. the minimum or maximum) can be reached. Those added columns are computed as a sub-problem. The column generation increases the speed of calculation by excluding columns with a negative objective value.

Within dynamic programming all options are evaluated using a break down into (simpler) sub-problems. In the PLUS-case this leads too long computation times before getting an optimal solution. Since there are many solutions possible with multiple DCs, multiple stores, and multiple suppliers.

Heuristics

In the domain of the heuristics there are many different suggestions on how to find a good solution to the VRPs. Two different heuristic categories can be found in literature: Construction and improvement heuristics. Construction heuristics are built on selection rules in which they build route(s) towards a feasible end solution. Each step one delivery is added to a route. An improvement heuristic starts with a feasible solution obtained for example from a construction heuristic. The ways to obtain a better solution vary. Figure 17 presents an overview of the different categories.

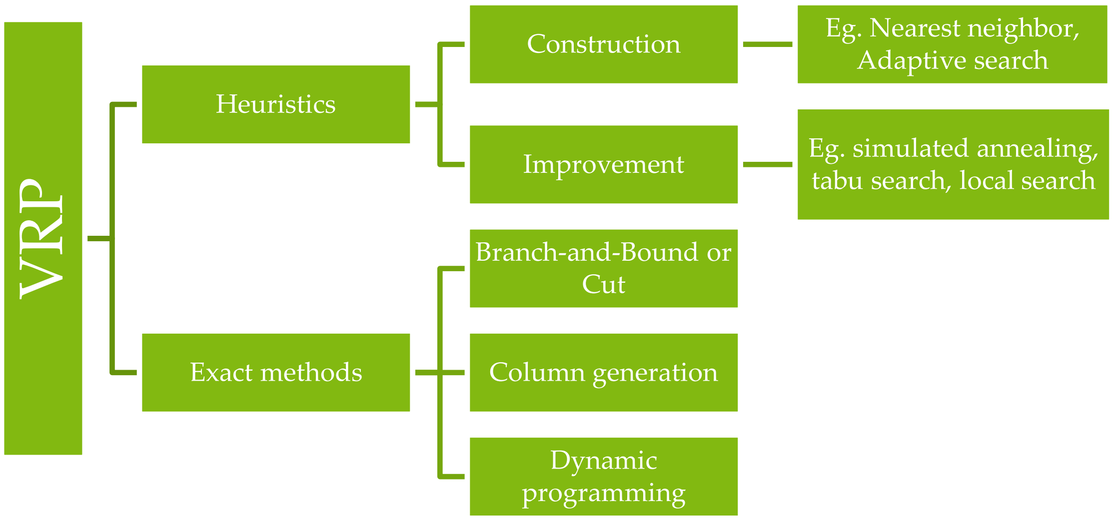


Figure 17: VRP overview

A construction heuristic that is rather easy is the nearest neighbor (NN) heuristic. Although this algorithm was developed for the TSP it can be adapted to solve a VRP problem. Below the steps for the NN heuristic build in a sequential procedure, so first finishing a route before starting a new one.

1. Start from the starting point (storage point, DC) with the full vehicle capacity available.
2. Select the delivery point that is nearest to the storage point and makes a trip, limited by the given restrictions, and mark the point as visited. Update the available capacity in a truck. The first store in a route is the seed store.
3. Find out the shortest option connecting the current route with a delivery not yet performed, limited by the given restrictions. If there is no option available close the route towards the DC and go to step 1 (start a new route).
4. Mark the delivery point as visited.

5. Go to step 2.

A short example is given based on the nearest neighbor principle: Consider the scenario as presented in Figure 18 with 4 stores with demands (Table 4) from the DCs, and travel distances (Table 3). The capacity for one truck is set at 20 containers.

Figure 18: Nearest neighbor example overview

Distance km	DC	Store 1	Store 2	Store 3	Store 4
DC	-	6	12	18	15
Store 1	6	-	10	22	25
Store 2	12	10	-	13	14
Store 3	18	22	13	-	20
Store 4	15	25	14	20	-

Table 3: Distance nearest neighbor example

Store ID	Demand # containers
Store 1	12
Store 2	11
Store 3	8
Store 4	9

Table 4: Demand nearest neighbor example

In the nearest neighbor heuristic first the nearest store from the starting point (DC) is selected. In this example it is based on kilometers, but this could also be costs, time et cetera.

1. The nearest store is store 1. This store is added to the first route. The so called seed is store 1. The truck is now at store 1, with a capacity left of only 8 containers (20 capacity – 12 containers).
2. The next step is to search the nearest neighbor of store 1. This is store 2 with only 10 km distance. However the demand (11) exceeds capacity (8), so continue to the next available store, store 3 with a distance of 22. This store can actually fit in, making the route complete since no capacity is left (8 capacity – 8 demand = 0 capacity).
3. Start a new route with the first available nearest store from the DC, in this case store 2.
4. Fit in the last available store, store 4.
5. End result: 2 routes (store 1, 3 and store 2, 4) see Figure 19.

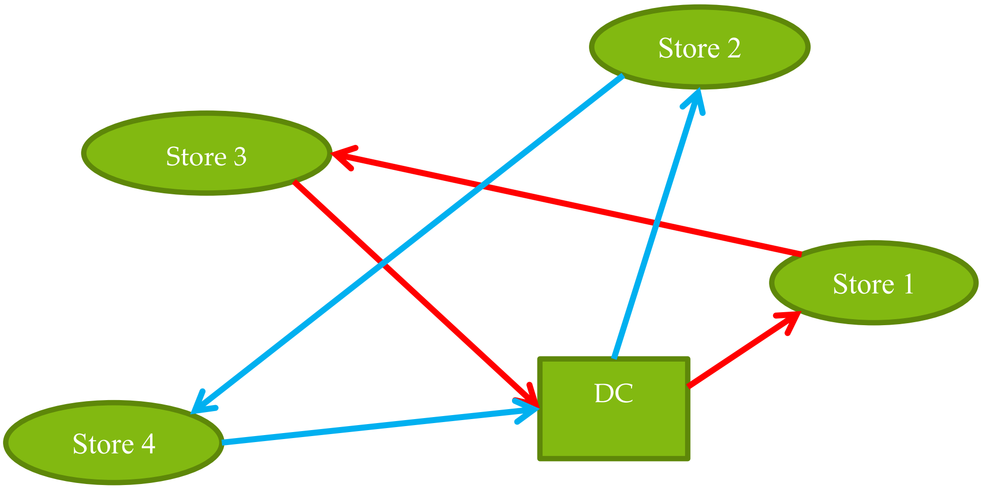


Figure 19: End solution nearest neighbor

The next heuristics we describe become more complex. We choose to only slightly introduce the literature and the proposed solutions in order to be able to give a broad overview of the possibilities to solve the VRP at PLUS.

Parragh et al. (2008) found in a survey 6 different heuristics for solving a PDP with multiple vehicles. Two of them they discuss in the paper, a column generation based heuristic from Xu et al. (2003) and a construction heuristic from Lu and Dessouky (2006).

Lu and Dessouky (2006) suggest an interesting solution, because they add the possibility to include distance into the evaluation criteria. They propose to use time windows for which they add extra time. This results in larger time windows with left over time (so called slack). If they succeed in reducing the slack the routing will become more efficient. This is important since costs for trucks are largely based on time travelled.

Dethloff (2001) proposes to use an insertion algorithm for a pickup and delivery. The insertion chooses one initial customer. The best insertion criterion they propose is the "radial distance surcharge". A distance is then weighted by a multiplier that relies on the "*late and unfavorable insertion of remotely located customers*". This is method is repeated until all stores are routed. The retrieved solution could be good to select as initial solution for further optimization by local search procedures. Dethloff (2001) tested the model on a case with only 22 customers resulting in a computation time of less than 1 second. Unfortunately Dethloff (2001) was not able to include time-windows.

Xu et al. (2003) investigated a more complex model considering the constraints they are able to include: Time windows, loading restrictions, compatibility of goods, and driving hours. The solution is based on a column generation master problem solved by linear programming. They solve sub-problems, by using two heuristics based on merging trips and insertion of trips. Within a few seconds 200 deliveries or pick-ups can be handled and 500 within a reasonable time instance.

Meta-heuristics

Most of the meta-heuristics set-up an initial route and then use improvement methods to make a final solution. The difference between meta-heuristics (MHs) and heuristics lies in the following aspects. MHs try to select strategies that steer search to good solutions. A MH is not dedicated to one problem i.e., not problem specific. The MHs want to efficiently explore the problem space to find better solutions. There is a wide range of local and global procedures which include learning while solving the VRP (Blum and Roli, 2003). Since an MH is not problem specific, solutions are proposed that not only solve the pickup and delivery problem. MHs also include Multi-depots and Time Windows.

The area of research for MHs is rapidly expanding. Most of current VRP research is focused on this topic. Parragh et al. (2008) find twelve different procedures to evaluate the VRP with delivery and pick-ups (which also include time windows). The authors use various kinds of improvement selections, such as evolutionary algorithms with local search, adaptive search, randomized search, tabu search, adapted neighborhood. The options below give a good overview of the different options suitable to the multi-depot and time window situation at PLUS.

Cho and Wang (2005) recommend to use a meta-heuristic based on modified nearest neighbor with some extras. The initial solution is based on the nearest neighbor algorithm for which different options are tested in order to come up with a good algorithm. They conclude that a neighbor selected on the minimal waiting time is the best candidate. Afterwards they use a threshold accepting heuristic in which they make swaps of locations between and in routes. This so called inter-route exchange procedure is effective and reduced the driving time with over 15%.

Thangiah et al. (1996) find a well performing route construction heuristic with improvement heuristics. The solutions are on average within 2.5% of the optimal solution. For the construction, a seed store is selected by a combination of time window, distance, and the previous routed store location. After the seed selection, stores are added and selected by the lowest insertion costs. Those costs depend on the weighted sum of the new travel time and on the driving time of a route. If the insertion is not feasible the insertion costs are set to infinity, the store will never be selected for this route. The insertion costs for that store are always to higher than other available stores. In this heuristic all deliveries must be made before performing a backhaul, and time-windows can be set.

The most interesting meta-heuristic is discussed by Ropke and Pisinger (2006). They solve a PDP with TW using a large neighborhood search. This procedure can be used as a general heuristic for the VRP. The main model is applicable to all kind of VRPs and it is one of the best performing so far (Parragh et al. 2008). This makes the heuristic very interesting.

Periodic Pick-up and Delivery Problem PVRPDP

Le Blanc et al. (2004) solve a periodic pick-up and delivery problem for a combination with all supermarkets located in The Netherlands. The interesting aspect is the periodic aspect in this sub category of the PDP, with a meta-heuristics approach. First Le Blanc et al. make a regression model with clusters for different stores based on their geographical location. This way they use a simple model to approximate the first savings in phase one of their investigation. Time-windows are not included. In the article they do not state the exact meta-heuristics used for phase two of their research. For the first analysis on high level no exact complex methods are needed to make a high level observation (Le Blanc et al., 2004).

A general heuristic for vehicle routing problems

Pisinger and Ropke (2007) describe a general heuristic in order to solve multiple of the above mentioned VRPs such as the VRPTW and the MDVRP. Backhauls (VRPB and VRPDP) have been discussed earlier by Ropke and Pisinger (2006) using the same concept (See also meta-heuristics).

Pisinger and Ropke (2007) construct a framework with an Adaptive Large Neighborhood Search (ALNS). The most important aspect in ALNS is that it can be applied to a large set of optimization problems. They suggest multiple ways on how to design components for the heuristic. ALNS is a type of "Hyper-heuristic" as described by Burke et al. (2013). This means that ALNS selects a heuristic that improves the initial solution. The way ALNS selects the heuristics and varies in them during the iterations depends on scores the heuristic gets from past iterations.

Evaluating heuristics

There are many possibilities for developing a model that could suit to the situation at PLUS (Section 3.2). What to choose is not really clear and all of these models are quite time intensive to implement. Trying them all is not an option. Cordeau et al. (2002) use the following attributes to score a heuristic in order to be able to select one for the VRP faced:

1. Accuracy: deviation of heuristic from optimal solution.
2. Speed: response time, usually trade-off with accuracy.
3. Simplicity: relation with planner's confidence on having a good routing.
4. Flexibility: side constraints will often change within some years in practice, flexibility to alter the heuristic could be necessary.

In Table 5 we present a short overview on the applicable literature in this section. [1]Since the complexity and the speed of the PLUS problem all exact methods are omitted, because of their irrelevance to the current situation.

	Time windows	Pickup and delivery	Periodic routing[4]	Multi-depot
Heuristics				
Nearest neighbor[1]	Yes	Yes	No	Yes
Dethloff (2001)	No	Yes	No	No
Lu and Dessouky (2006)	Yes	Yes	No	No
Xu et al. (2003)	Yes	Yes	No	No
Meta-heuristics				
Ropke and Pisinger (2006) [2]	Yes	Yes	No	No
Le Blanc et al. (2004)	No	Yes	Yes	Yes
Gaur and Fisher (2004)	Yes	No	Yes	Yes
Cho and Wang (2005)	Yes	Yes	No	No
Thangiah et al. (1996)	Yes	Yes	No	No
Hyper heuristics				
Pisinger and Ropke (2007) [3]	Yes	Yes	No	Yes

[1] First author not clear.
[2] First definition of the ALNS.
[3] Flexible version of the ALNS.
[4] All methods can be used to develop a periodic routing but those are specially developed to do so.

Table 5: Overview of VRP-methods

3.3 Transportation problems on the operational level

In Section 3.1 we refer to the make or buy decision in transporting operations. Insights in the tactical level are needed to assess the variability on the operational level. Since at the operational level, planners execute the predetermined tactical day to day planning. This tactical planning however does not always sufficiently includes daily differences such as peak demand, weather, employee absence, or traffic. In the case of an excess of certain restrictions or specific demands other routes are made for that day. Most of these are only slight adaptions to the tactical planning.

Software packages are available for the support of the operational process. In some branches algorithms are used to determine a routing only on an operational level. The purchased capacity within the transport network is then the main decision on tactical routing. This is not the case at retailers, who ask for a periodic schedule. The daily rerouting is therefore not as important as the tactical level in this research.

Making day to day routes

On the operational level planners are the decision makers for the dispatching and routing of the trucks. Poot et al. (1999) researched what planners see as important measures for a properly constructed route. Poot et al. (1999) argue that not only costs are important, but also the visual attractiveness of a route. Planners may use visual tools to prove if the solution obtained is logical. They propose to use four measures:

1. Center of gravity (# of stores closer to another centre of gravity of a next trip).
2. Convex hull (average # of stores contained in the convex hull of another trip).
3. Average distances.
4. Crossings (number of times parts of trips are crossing each other).

During the operational phase those measures are used to evaluate the changes made to any routing. Of course the same measures apply on the tactical level when determining the periodic schedule. However if the situation gets more complicated the routes will be less visual attractive due to the high number of stores and senders present (Poot et al. , 1999).

3.4 Conclusion

This chapter answered research question 1.2 “What is known in literature about transport situations as observed at PLUS?”. We conclude that the literature is clear about the strategic problem PLUS is facing. A strategic decision should be supported by a tactical model that is tested. Based on the tactical model the organisation can find the costs for each different strategic scenario on whether or not outsource the transport flow.

Currently flexible VRP models are gaining more interest. The models score high on all of the four different aspects mentioned by Cordeau et al. (2002). Their simplicity is arguable since the combination of multiple (simple) learning heuristics makes the model difficult to explain. From the flexible models the ALNS model by Pisinger and Ropke (2007) is very applicable to the VRP of PLUS. A disadvantage of ALNS could be that it is not yet tested in practical routing software or at any retailer (as far as known).

For strategic purposes no complicated routing algorithm is necessary (Le Blanc et al., 2004). A simple algorithm is sufficient to plan routes based on different scenarios.

Chapter 4: Strategic transport scenarios and options

In Section 3.1 we state that PLUS can only asses the costs and impacts on a tactical/operational level. This is done by constructing routes and perform calculations on these constructed routes. In this chapter we answer research question 1.3: *What different insights from literature and the current situation can PLUS apply to the transportation flows in the PLUS supply chain?*.

Section 4.1 suggests scenarios for the model to investigate. Section 4.2 discusses the model and its construction. Section 4.3 presents the assumptions and limitations. Section 4.4 gives insight on the calculation of costs. The routing algorithm used for PLUS is presented in Section 4.5. We propose in Section 4.6 options on the scenarios that influence the strategic decision on the long term.

4.1 Scenarios for return logistics at PLUS

To enable PLUS to make a wise comparison on their transportation network, the research needs to account on what to model and which different scenarios to compute. Remember the following four flows:

1.	DC to a store	(delivery of goods)
2.	Store to a DC	(collecting returns)
3.	Supplier to a DC	(backhauls, including cross-dock deliveries for stores)
4.	DC to DC	(LDC-RDC deliveries; incidentally stock balancing, low volumes)

The objective for this report is to minimize costs given a minimum service level (current). Most choices for different handling of goods can be made in the flows 2, 3, and 4. This is due to the high fill rate, the fixed service level, and the necessity of performing the deliveries in flow 1. The opportunities for performing a backhaul (flow 3) are linked to the collection of returns from stores (flow 2). Since we only accept backhauls when they are profitable, backhauling is always incorporated. This policy is always in line with our objective to reduce costs. If we take these circumstances into account we can only vary rigorously in the returns; the 2nd flow. That is why we build the scenarios around the handling of returns.

A truck can perform three realistic routing scenarios within the current PLUS DC-store-supplier network for flow 2 and 3. Those scenarios form the framework on which we built a transport analysis for PLUS. All backhauling in the 3 scenarios is an optional addition to the constructed routes. If there is no feasible backhaul, for example due to higher costs than profits, the truck travels directly back to the DC. All researched scenarios (1, 2, and 3) include backhaul operations.

Scenario 1: Fit in backhauls within current routing

In Scenario 1 the transport operation is performed on the traditional way (see also Figure 20). After the delivery backhauls can be collected if there is one near, it fits within the available capacity, and is profitable. The Scenario 1 route is:

1. Deliver the goods from a DC to the store(s),
2. take the returns along,
3. and eventually perform a backhaul if this is feasible for revenues and costs (as in Figure 20).

If PLUS would exclude backhauls it results in the current situation. Due to the fact that there are returns in the trucks, we expect to have low backhauling profits. Not all backhaul freights can fit in the same truck with the returns.

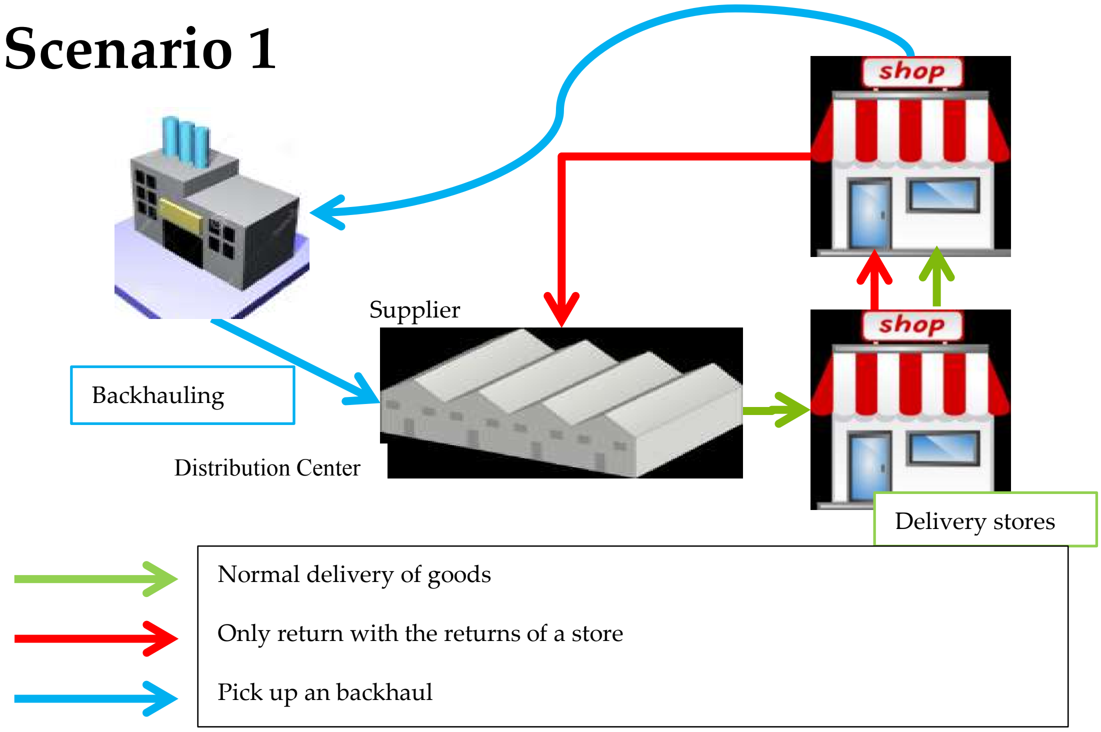


Figure 20: Scenario 1 overview; delivery of trucks with returns and backhauls

Scenario 2: Separate route for returns, more backhaul capacity

In Scenario 2 the trucks first collect all returns in a separate route. This is done because all returns must be collected before or at delivery of goods (Figure 21, red). After the collection of the returns goods, the stores are delivered in another route (Figure 21, green and blue). The truck can perform a backhaul with an empty truck after the delivery, since all returns were already collected at the stores (Flow 3).

With Scenario 2 we expect a higher probability of backhaul opportunities, since there are many empty trucks available after the delivery to stores. On the other hand PLUS obtains extra costs for the separate return routes.

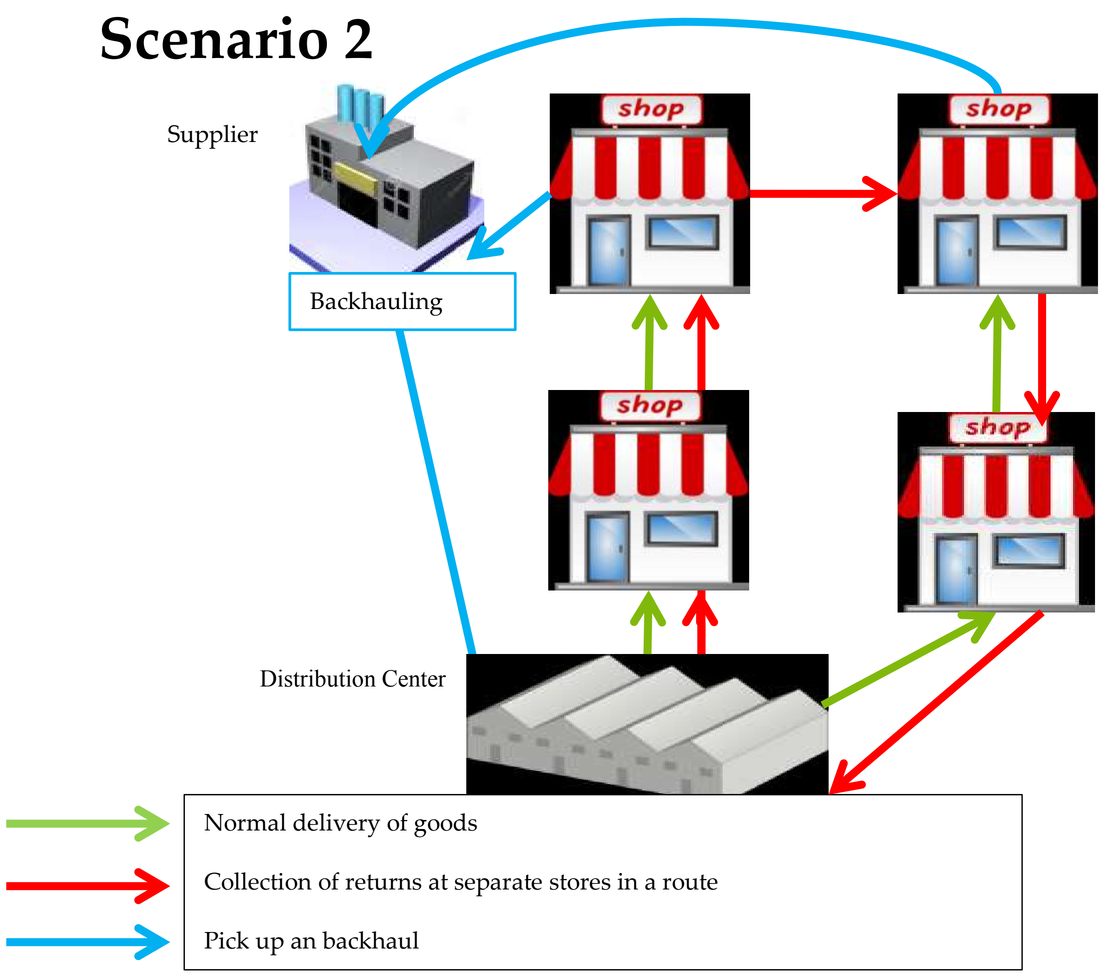


Figure 21: Scenario 2 routing overview; separate return and delivery routes.

Scenario 3: Combined returns, less expected costs.

In Scenario 3 a truck has two options after the delivery of a store:

1. Collect returns at the stores in the area and then return to the DC (Figure 22: Red arrows).

2. Obtain a backhaul at a nearby manufacturer, if there is one available that is profitable (Figure 22: Blue arrows).

These two options results in two routes. We expect less costs compared to Scenario 2 due to the availability of the trucks in the region to pick up returns after delivery. However fewer trucks are available to perform backhauling, which should result in less profits compared to Scenario 2.

Scenario 3

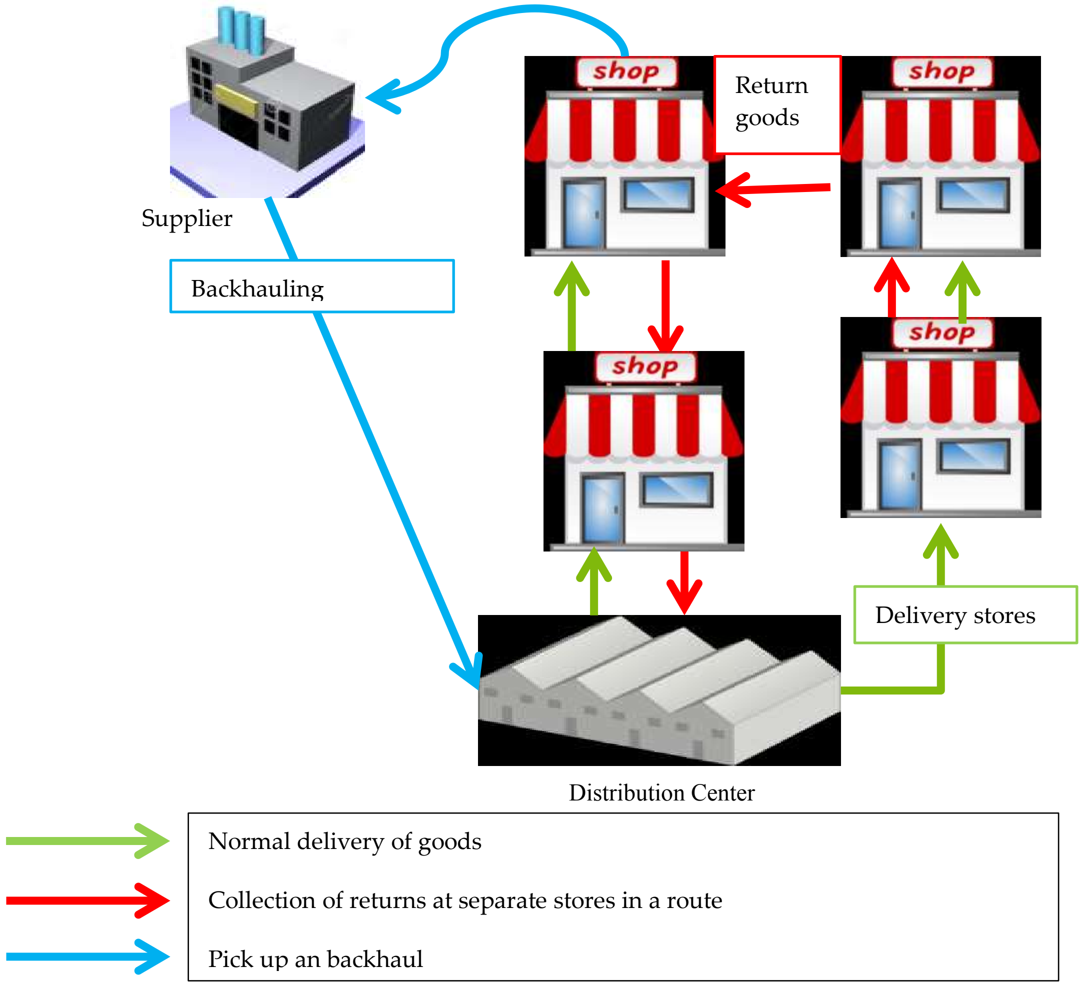


Figure 22: Scenario 3 routing; return goods retrieval after delivery of a store

4.2 Tactical routing model building for PLUS

Based on the VRP literature in Chapter 3 we conclude that the best option for this research is to build just a simple routing model (see Section 4.5). Eventually we can further improve the method, if this is necessary for decision making. This is like the method Le Blanc et al. (2004) used in their Factory Gate Pricing study for the Superunie supermarkets.

4.2.1 Selection of the model

The routing made for PLUS is used for a decision at the strategic level. Based on the output of the model a decision should be made. This leads to the following consequence:

If significant savings from the simple model (such as a nearest neighbour approach) are found, new solutions proposed by the optimization techniques are only improvements. Therefore a simple heuristic based on nearest neighbour is used first, with an option to include an optimization technique afterwards. We expect that changes from the optimization technique are in percentage equal per solution. This is due to the high number of routes and few combinations per route. How the routing is made can be viewed in Section 4.5.

4.2.2 Collecting and selecting data

In this section we sketch the four different datasets we used: Time windows, travel distances/time (locations), delivery demands, and the store's returns.

1. **Time windows for stores**

Mostly time windows are due to store closings and city areas with a regulatory time window for delivery. Stores without a legal city area restriction have time windows from 07:00 hours until 20:00 hours. Since those time windows are only set for a few stores at PLUS they are less relevant for this research. The number of trucks is also not limited, so we do not need to take time windows into the model. In this research we assume a greenfield scenario and expect the delivery times (hours, not days) to be negotiable with entrepreneurs. Besides in a strategic study, the choices made on a long term, may not be limited by the choices of some entrepreneurs not willing to negotiate about delivery times.

2. **Travel distance matrix from stores, suppliers, and DCs**

Travel and routing data is retrieved from a company that sells routing data. The matrix includes all distances between each location to be visited by the trucks. In total there are 319 locations from stores, suppliers, LSPs, and DCs included in the distance matrix.

3. **Demand and returns from DCs and stores.**

All demands are translated to physical container spots in a truck. By doing so all demands can be equally matched and capacity can be reduced to a single numerical constraint.

There are different kinds of demand matrices for each flow:

- Demand from stores to the RDCs and LDC (# Containers)
- Demand from stores to the VDC (# Containers)
- Demand from stores to the DDC (# Containers)
- Returns from stores to the RDCs and VDC (# Containers spots)
- Demand from RDCs and LDC to the suppliers (# pallets)

For the current deposit system it is not relevant to keep track of the number of container locations used for returns in a truck (volume in a truck). Therefore the demand data from the returns is not available within PLUS. PLUS can only estimate the locations used by retrieving historical data using deposit receipts. The lack of information is due to the variety of returns and the way that the goods are sent to the DCs. It is not always true that five containers fill in one container spot. For example: Sometimes there are only 2 containers in one spot. Plastic, beer and crates can be mixed on one container and therefore might they be wrongly counted as separate containers.

We estimate the volume of the returns based on empirical data regarding regular deliveries. We counted the number of container spots at the DCs and related those to the store demands of the previous delivery. We estimate the return percentage on 35% of the previous delivery for RDC. For the VDC we find a return percentage of 75% of the previous delivery.

4. **Safety buffers**

Since this research deals with static data and routes will be fixed for some time, variation of demand and supply may be included in the data or restrictions. If this is done in the tactical process, a safety buffer could be included for scheduling the loads in the trucks. At the moment there is no safety buffer used in the planning of the routes at PLUS.

We decide to not use safety buffers. At the moment there is still room for volume variation due to the truck fill rate of about 80%. Volume variation for each delivery day in each supermarket is relatively low, and can sometimes be managed by timing/postponing large volume orders. The variation in demands has relatively low influence on the choice for a scenario since the number of dispatched trucks and costs would increase for each scenario.

4.2.3 Constraints (not) modelled

We model three different constraints in this research:

1. Maximum duration of a route:
    a. Max. 9 hours, due to the regulations (Rij-en rusttijden bepalingen, 2014)
2. Time for break drivers:
    a. 45 minutes within 9 hours at least before 4 hours of driving.
3. Truck capacity:
    a. Fixed at 54 container spots (720 x 810).
    b. One euro pallets (1200 x 800) counts as 2 containers, maximum of 27 per truck.

Not modelled is the capacity of the stores and distribution centres. The current deliveries can be handled correctly. Since the model is built on historical data we assume that no big difficulties will occur on this operational level. Another point is that most of the stores can handle only one truck at the time. This is due to the parking space and capacity (storage, personnel) constraints at the stores. To reduce complexity this constraint is omitted from the model. In practice we will not to use the routing we compute with this model, so we find this acceptable.

4.2.4 Parameters

Loading and unloading time

In the model we relate the (un)loading times to the number of containers, with a fixed amount due to the parking and reporting at the store. At the DC, 1 minute for each container is used to approximate the loading time. The unloading time at a store is assumed by planners to be 10 minutes and about 1.3 minutes extra per container. These figures are based on the experiences in RDC-West. Although these costs are fixed we include them in the model. This way the actual driving times and costs will match the actual routing costs better. Also the opportunity to express figures compared in a percentage increase for transport cost become more realistic. This is since we compare to all of the expedition costs.

For cost parameters we refer to Section 4.3 where the translation is made for the objective function and decision variables in order to minimize total transport costs.

Distance matrix

All cost parameters are linked to distances and time travelled (Section 4.2.2).

4.3 Assumptions and limitations of the model

The model presented in Section 4.2 has some underlying limitations due to the current and desired situation. Section 4.3.1 discusses the assumptions and Section 4.3.2 gives the limitations found in this research.

4.3.1 Assumptions

Volume of containers remains stable over time

It is not reasonable to expect a sharp decline (over 5%) or increase of transportation materials (containers/crates) that have to be returned to the senders such as DCs or suppliers. The current operations in the stores and at the DCs are completely dedicated to the current way of handling the containers. Therefore we excluded reduction of materials of the options in order to reduce the transportation costs. We do include in the research the exclusion of return flows like paper, plastics, bottles, and crates.

No building of separate return good DC(s)

It is not realistic to build new DCs just for the return goods at PLUS, so called hubs. There is enough free storage capacity in the RDCs. Therefore a saving here would not directly contribute to cost savings or growth possibilities on these locations. Besides transports between those hubs and DCs would be needed, including extra loading and unloading. This is believed to be sub-optimal.

All trucks have the same capacity

To be able to make a general routing in which variables can be altered easily, a similar truck capacity is needed. In the scenarios we use a capacity of 54 containers per truck, which is the same as the most used truck (over 90%). This assumption leads to better performance for the nearest neighbour heuristic we propose in Section 4.5. Since no choice on vehicle capacity is needed within the algorithm. Also limited numbers of trucks are available with different capacity. Besides not all PLUS stores can be served with larger trucks.

One backhaul order represents one truck at the DC

We assume one separate truck for one order. It could be that in one truck there are multiple orders from different suppliers. It is time intensive to investigate how many and which delivery, and thus a truck, is coupled to one or more orders. Since each order is about 9.4 pallets, given 26-30 pallets per truck we find this acceptable (35% fill rate per truck for PLUS).

4.3.2 Limitations

Dedication of stores to DCs

In the model we choose to have no longer stores dedicated to a DC. So a store in the eastern region of the country may be served by another DC than the eastern DC (Haaksbergen). This gives the possibility to backhaul goods for other DCs with trucks originally located in another DC. The option is not allowed in the current software PLUS is working with. The stores must be assigned only to one DC.

The need to keep the current delivery days

Although the delivery times must be met, the schedule might change in this greenfield situation. PLUS wants to maintain the same delivery days for stores. This has also advantages for modelling purposes; historical data can be used for our model, besides that it gives more opportunities for the schedule to be implemented. This is since the (non-monetary) costs due to alteration of the delivery schedule will be lower.

Fixed pick-up day for the return goods

In order to reduce complexity the pick-up days for the return goods are fixed at the day that a delivery takes place. This means a store that receives freight on Monday, Wednesday and Friday sends back on Monday the return goods arose on the Friday before.

Maximum driving time

In the scenarios we defined in Section 4.1 the routes will become significant longer. This is due to the additions of a return goods pick-up or a backhaul. This could cause difficulties with the maximum driving time of 9 hours. If routes become too long the extra capacity for backhauling cannot be used efficient. In the evaluation of the results we will mention eventual consequences for too long routing in terms of unused capacity.

4.4 Definition of savings and costs

There are different perspectives on how to state goal functions for routing models. We need to clarify the objectives for PLUS and how to fairly measure them in this specific situation. PLUS receives profits (from backhauling) as well as obtains costs (from deliveries).

Transport costs

In this research the objective is to minimize logistic costs for PLUS. Costs can be matched to kilometres travelled or time travelled. We explain two options:

Option 1: Total kilometres travelled.

This is a clear and easy way of comparing the different routes. Distances are computed and displayed in a matrix. The distance measurement is of less discussion than the travel time. Since the travel time depends on two factors: distance and (average) speed.

Option 2: Total travel time (including loading and unloading and waiting time).

The total travel time is available from a matrix model PLUS has obtained from a professional routing partner. Trucks are largely paid per hour and not per kilometre, we believe this is a more realistic cost approach. For most part, the costs are incurred by labour costs. Another argument is that in the west of The Netherlands kilometres to travel could take significant more time than in for example the North of the country. We choose to use the second option since the travel time is more linked to the costs per hour than to the costs per kilometre.

Converting kilometres and hours to costs

To translate transport kilometres to costs the following rules of thumb are used: A truck travels about 35 kilometres per hour. In total a truck costs about 48 euros per hour to operate. This means an average of 1.4 euros per kilometre or 0.8 euros per minute. Since we use a time based computation method we only need the costs per hour of 48 euros.

Savings from backhaul

Not much research is performed on the best way to calculate the profit retailers can gain by performing backhauls at their suppliers. Most articles use the kilometres travelled and multiply it with the market rate for transport (e.g. 1.4). But with backhauling this assumption is often not correct. A negotiation in which three parties have to benefit takes place. If the numbers of pallets per delivery increase, the transport costs per pallet decrease. This due to the cost sharing over multiple pallets in one truck. As a mathematical formulation: $\frac{cost\ per\ trip}{number\ of\ pallets}$. The costs per trip are fluctuating. If there is only one pallet in a truck this gives the opportunity for the LSP to load other orders in the same truck. This reduces the costs per order for both parties.

The best way to calculate backhaul benefits should lie somewhere in between a kilometre price and a lump sum per pallet. In the model we use quantity prices, related to the number of pallets transported. This price is linked to the number of kilometres a supplier used to travel between their site and the PLUS DCs.

Table 6 states the price range used. This is a simplified approximation on rates currently received at PLUS from Kuehne + Nagel. PLUS receives a fixed rate for a trips from Kuehne DCs to PLUS DCs, regardless of the number of pallets. If we would extrapolate these figures we expect a rates between €0.25 and € 0.08 per pallet kilometre. Branch expert estimate the current received fee as 10 euro on average per pallet. Based on these figures we expect Table 6 to give a fair indication of backhaul prices per pallet per kilometer.

# of pallets	Income per pallet per kilometre
1 to 5 (small loads)	€ 0.25
6 to 12 (medium loads)	€ 0.15
Up to 26 (large loads)	€ 0.10

Table 6: Income from backhauling

4.5 Model and calculations used

For each scenario we model a flowchart, this flowchart represents the algorithm used for the routing. First of all Scenario 1 in Figure 23; second Scenario 2 in Figure 24 and then Scenario 3 in Figure 25. Before starting the routing all parameters and limitations must be fixed. In Section 4.6 we discuss why they can be altered. For the three scenarios the pre-set parameters are:

1. Capacity, (standard 54) with delivery demands of the stores. Only one type of truck can be used.
2. Return percentage of containers (standard 35%).
3. Profits from backhauled pallets, 1-5 pallets (€ 0.25, 5-10 pallets €0.15, >pallets € 0.1).
4. Number and location of the DCs.
5. Driving, loading and unloading times.

The first part for all scenarios is the construction of delivery routes. This is done following the nearest neighbour structure as explained in Section 3.2. The first store (1) is based on the nearest store from the DC (in km). The next store (2) in the route is the nearest store from store 1 that fits within the leftover capacity after the delivery of store 1.

We model separate return routes after modelling the deliveries. The return routes start from the DCs, the same way as the delivery of the goods. This action is only needed for Scenario 2. In the Scenario 3 we do not start at the DCs, but we attach the return route to a store that has been delivered. This start store for the return route is selected with the most reduced costs for a route as compared to the Scenario 2 routing for the same route. After planning the stores in the routes they are made unavailable to be attached to other routes.

For the backhauling part we review all backhauls available on that day. We couple the backhaul to the store with the least insertion costs (in km). The store must be still available in case of Scenario 3, or in case of

Scenario 1 the backhaul must fit within the leftover truck capacity (due to the loaded returns). If the insertion costs are lower than the estimated profit by picking up the load the backhaul is accepted. The store is made unavailable for next iterations.

We perform the programming and running of the model in VBA within Microsoft Excel. This is because of the availability throughout PLUS and no added cost of the software.

The cost function of the model

The actual computation of the costs in the model is based on the travel time. In this research we minimize costs (following from the research question). The routing and therefore the cost start with the delivery of goods from DC. This process is performed sequentially for each route. So first minimize transport costs to destination 1. Given the truck location we minimize transport costs to destination 2.

In the scenarios trucks can collect either returns (extra costs), or obtain a backhaul (profits, and extra costs). After the return route, backhaul, or delivery there are costs to return to the starting point, the DC.

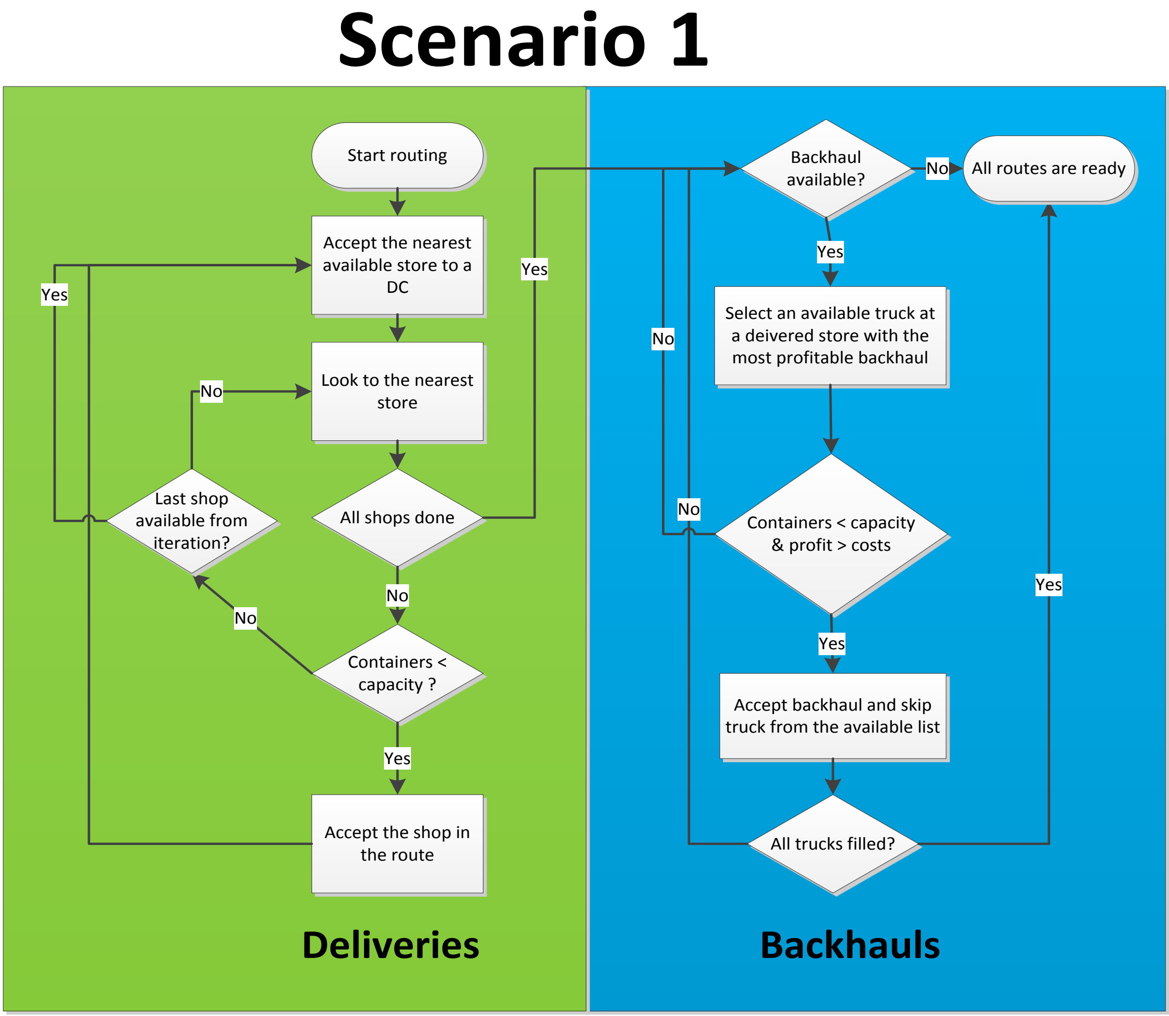
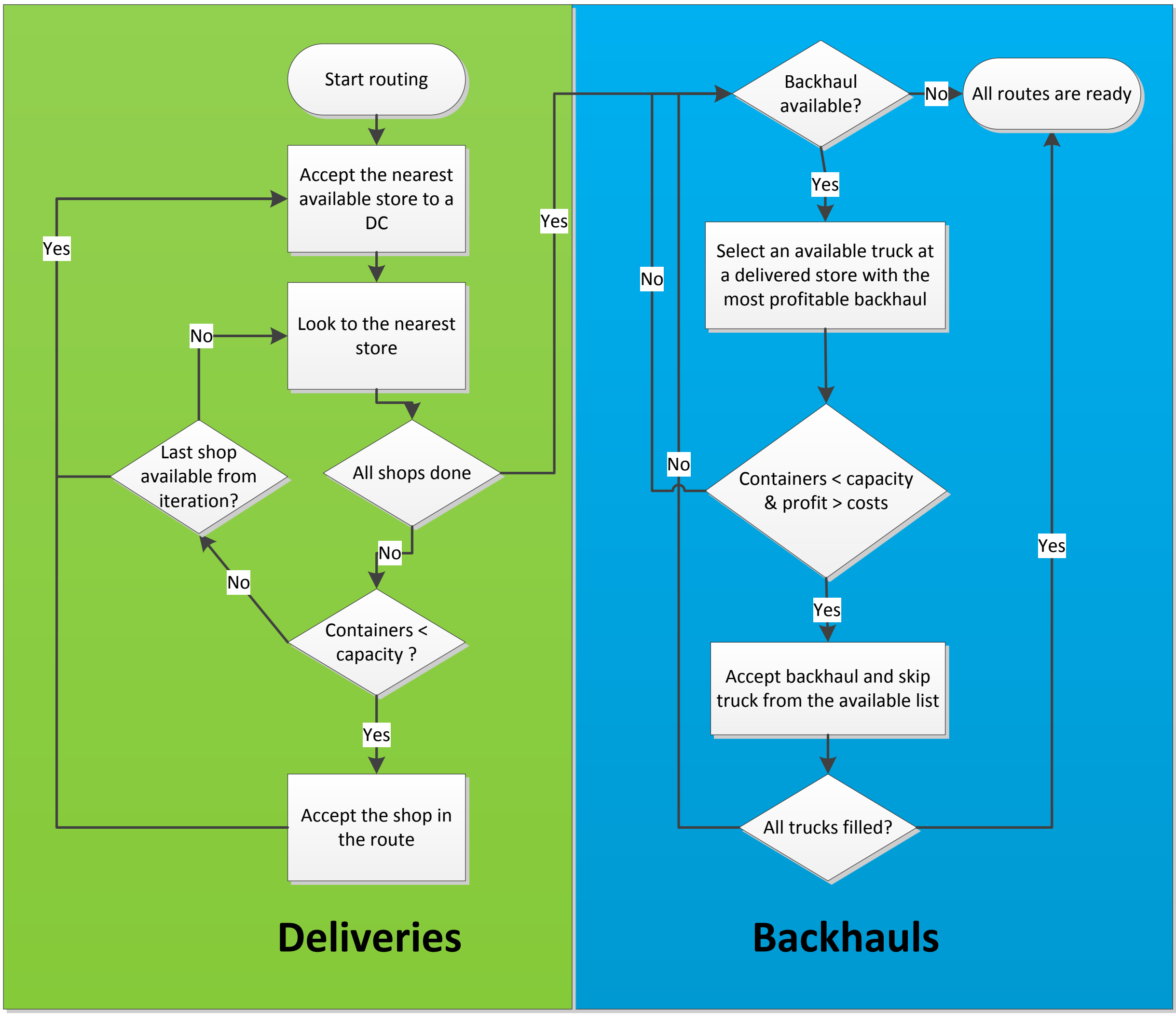


Figure 23: Flowchart of the computational model for Scenario 1

Scenario 2

Delivery routes



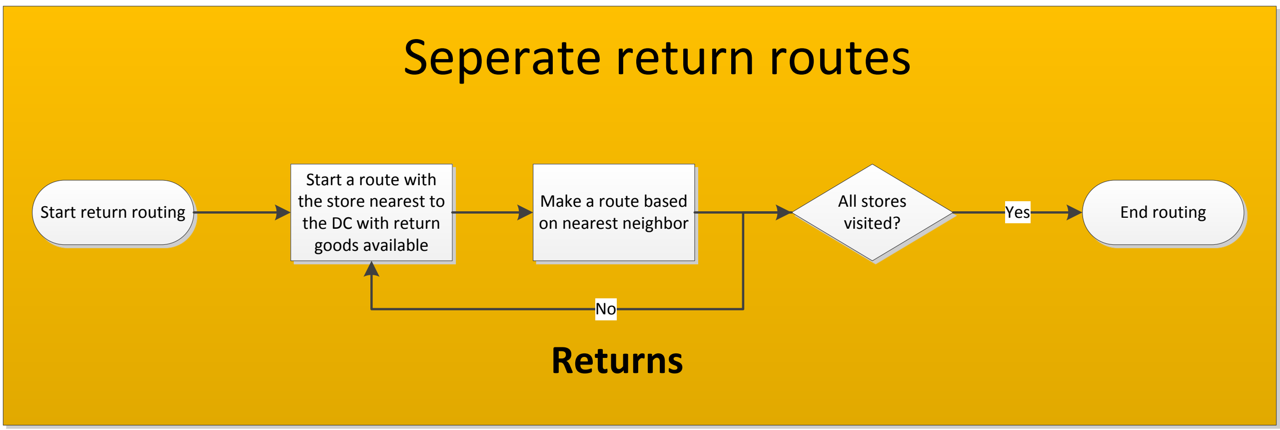


Figure 24: Flowchart of the computational model for Scenario 2

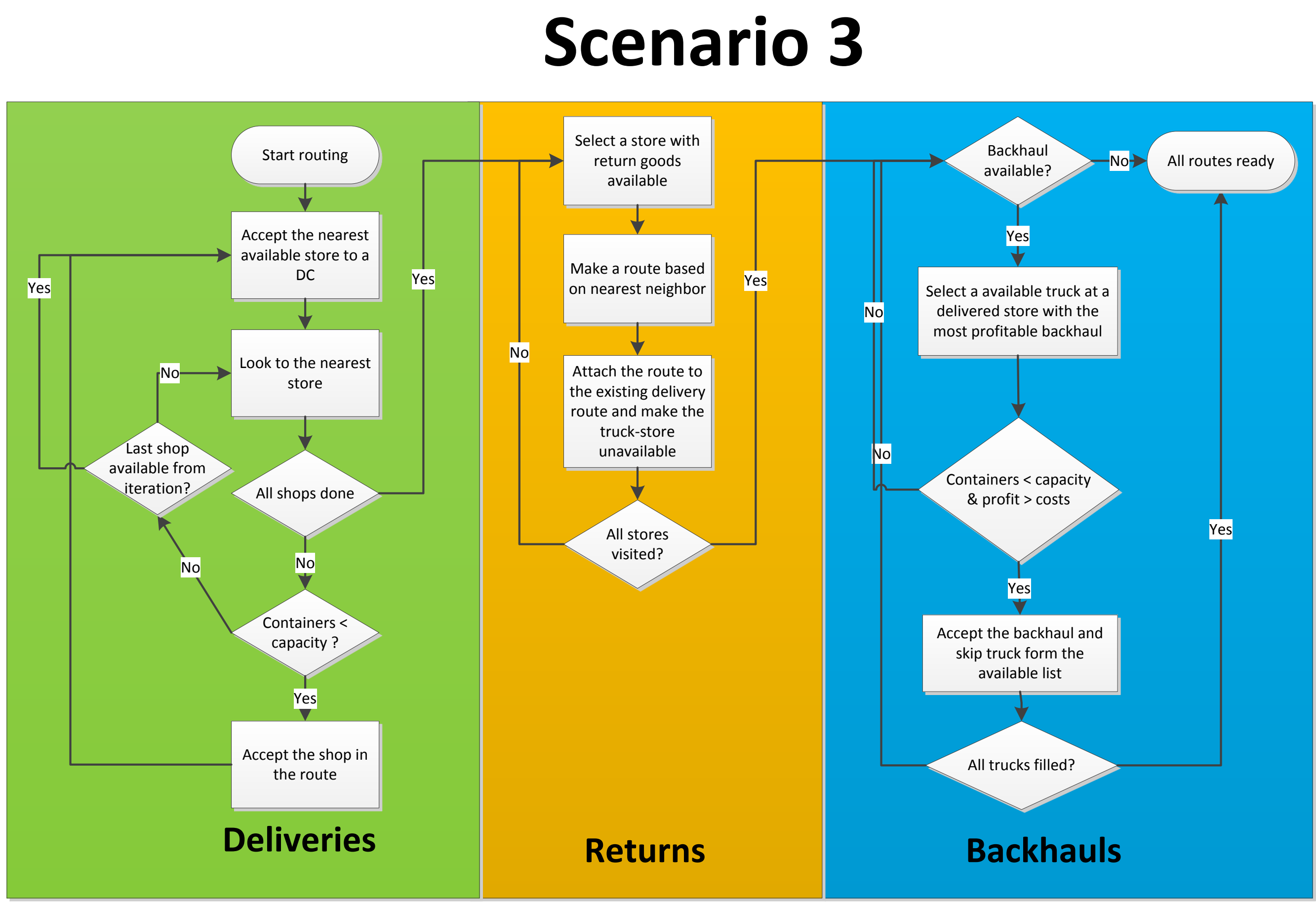


Figure 25: Flowchart of the computational model for Scenario 3

4.6 Options and variations on the PLUS logistic network

This section gives different options for the three scenarios defined in Section 4.1. The use of these options makes the research applicable in future situations and provides context to a long term (strategic) decision. The strategic nature of the study recommends insights in what route changes do to the network, but also the other way around.

Most of the options cannot be coupled to a certain flow, specifically because they influence multiple levels of the transportation network. Therefore we divided them in 4 different categories. The categories are linked to the transport flows and to the network overview: network, deliveries, returns, and suppliers. Options are selected by input from PLUS-employees and literature discussed in Chapter 3.

4.6.1 Network options

Location and number of DCs

Currently PLUS has three RDCs and one LDC. Those DCs might be closed or replaced in the course of time. It is helpful for the decision makers to observe what happens to the transport costs if there are changes in the DC network.

Choice for truck capacity

Currently there are two types of trucks driving for PLUS. The model must be capable to alter capacities and calculate the differences in the total transport costs in case that transport capacities alter.

Inter-DC deliveries

The situation at PLUS with four grocery DCs may be interesting for inter-DC deliveries with backhauls. This although there are not many case studies on backhauling combined with consolidating inter-DC deliveries (see Figure 15). PLUS can assign one DC for all incoming deliveries of suppliers. All incoming goods from this DC are then consolidated towards the different RDCs. This option saves trips on the incoming goods side (flow 3).

4.6.2 Delivery options

Choice for number of delivery moments

In the future it might happen that the current stores desire more frequent deliveries. This results in smaller deliveries. Assuming that the current demand remains the same the number trips to stores would increase, and thus higher costs occur. However PLUS might get a more efficient delivery and return flow. The fill rates of trucks will rise since there are more possible combinations. A decrease of deliveries is not possible since our promise to keep the service level towards the store on an equal level.

Choice concerning rush-orders

Currently all uncertainty between two deliveries and the chance of going out-of-stock is buffered using storage capacity at the stores. For PLUS it is interesting to see the impact on the on-shelf availability by implement rush-orders. The impact on costs must also be assessed since this research is on minimizing costs.

4.6.3 Return flow options

Return containers and crates

PLUS could experience changes in the volume of the return goods received at the DC. Currently not all goods are efficiently transported; the goods are not always stacked to smallest units. Also a part of the return goods might be retrieved from other parties of the stores. In the near future this could happen for flows such as paper, plastic, bottles, and crates. Besides these changes the elimination of the returnable bottles is currently discussed. If investments (time, money) are made there are opportunities to reduce the number of return goods.

Inclusion or exclusion of VDC return goods

In the current network there are two types of return flows: the VDC and the RDC flow. There is a choice on whether or not include the fresh return goods in the RDC trucks. The other way around is also possible: RDC returns in the VDC trucks. One of the DCs could then perform backhauling after deliveries.

Selling the trucks back to the LSP after store delivery

PLUS can try to negotiate monetization of the value of the empty trucks to the LSP. This option would be feasible since an LSP can use a truck to transport other goods from the stores, also it does not have to return to the PLUS DC.

If on the operational level a choice can be made to sell an empty part of the trip after delivery, this might lead to extra savings. This way it is possible to easier obtain the break-even point. It gives also the opportunity to gradually increase backhauling since there are more trucks available.

4.6.4 Suppliers – DC flow options

The number of suppliers involved in backhauling

The potential profit depends on the number of freights PLUS is able to pick-up. To decide upon the different scenarios it is helpful to know what percentage to pick-up is necessary to get break-even.

Choice for goods to transport with backhauling

It is not realistic to try and influence the size of the flows towards the stores. Consumers and suppliers largely decide on the goods supplied and demanded. The choice to transport other goods towards the stores is out of the scope of this research.

PLUS can however influence the goods on the trip back from the stores, the backhauled goods. PLUS might want to enter partnerships with distributers or manufactures close to their DCs, in order to pick-up loads for them. This way the numbers of backhauls are increased.

4.7 Summary

This chapter presents the outline for the PLUS transport model. There are three different scenarios defined for collecting the returns from the stores. Scenario 1 only tries to fit in backhauls within the existing routes. Scenario 2 makes separate routes for returns; Scenario 3 collects the returns after the last delivery. We come up with various options besides the scenarios which could influence the strategic decision on the three scenarios:

Network options

1. Inter-DC deliveries.
2. Location and number of DCs.
3. Choice for truck capacity.

Delivery options

4. Choice for number of delivery moments.
5. Choice concerning rush-orders.

Return flow options

6. Return containers and crates.
7. Inclusion of waste in the RDC trucks.
8. Inclusion or exclusion of VDC return goods.
9. Selling the trucks back to the LSP from PLUS.

Backhauling options

10. The number of suppliers involved in backhauling.
11. Choice for goods to transport in a backhaul.

The costs for those options consist of delivery and collection costs which are related to time travelled by a truck. Besides costs there are savings from backhauling, as a profit per pallet per kilometre. We propose a nearest neighbour heuristic to calculate and construct routes. The heuristic is able to provide a simple and fast solution accurate enough for decision making. In the Chapter 5 we continue with the results based on the input given in this chapter.

Chapter 5: Results and analysis

In this chapter we present the outcomes of the quantitative routing model defined in Chapter 4. By doing so we answer research question 1.4: *What are the transport costs and consequences for the service level for stores if PLUS applies those insights?*. Section 5.1 discusses the three scenarios related to the four transport flows. In Section 5.2 we analyse the options stated in Section 4.1.2. Section 5.3 gives a conclusion on the subjects discussed in this chapter.

5.1 Results for the scenarios

After programming and running the model we obtain results for the various scenarios. The computation with the nearest neighbour model only takes about 2 minutes for three scenarios. To compute an optimal location for section 5.2.1 with one or two DCs it takes 1.5 hour computation time. Compared to the actual average of kilometres per week we have an acceptable deviation of only 2.5%.

Each scenario includes three of the four different transport flows namely: 1, 2, and 3 (remember from Chapter 2, as stated below). Flow 4 will be discussed in Section 5.2. Table 7 shows the results for each flow.

1. DC to a store (delivery of goods)
2. Store to a DC (collecting returns)
3. Supplier to a DC (backhauls, including cross-dock deliveries for stores)
4. DC to DC (incidentally, low volumes)

These flows are linked to the three scenarios explained in Section 4.1.1. Figure 28, Figure 29, and Figure 30 present a graphical representation of costs for these routes in the scenarios. The next subsections deal with remarks and detailed information on the four flows.

	Current	Scenario 1	Scenario 2	Scenario 3
Total Trips	1000[4]	1000[4]	1308[4]	1000[4]
1. RDC to a store	**From DC-truck**	**From DC-truck**	**From DC-truck**	**From DC-truck**
# delivery trips	1000 trips[4]	1000 trips[4]	1000 trips[4]	1000 trips[4]
2. Store to a DC	**In delivery truck at delivery**	**In delivery truck at delivery**	**Special return goods trucks**	**Fill delivery trucks**
Return goods: **Extra stops:** **Costs for collection of returns:**	Included in all trips No extra costs	In all trips No extra costs	308 trips extra[4] Extra stops 902 Extra costs 44%[3]	308 from 1000 trips[24] Extra stops 658 Extra costs 23%[3]
3. Supplier to a DC	**In separate LDC truck**	**Fit in, in delivery trucks**	**In delivery trucks**	**In delivery trucks**
Trucks available for backhaul	Some	793 trucks with 74% capacity	793 trucks	549 trucks[2]
# of backhauls accepted	0	36	107	99
Savings by current backhaul opportunities	Negligible	2% Savings[3]	10% Savings[3]	7% Savings[3]
Extra costs[1]	-	- 2%[3]	+ 34%[3]	+ 16%[3]

[1] Based on a fill rate of returns 35%.
[2] Needed from 793 trips that have performed an delivery
[3] Extra cost related to the current total RDC transport costs
[4] trips are set to a standard of 1000 due to confidentiality reasons. But are put in balance to make comparisons

Table 7: Overview of scenario results

5.1.1 DC to a Store

This transport flow remains the same compared to the current way PLUS performs their routing (see flowcharts Appendix D). Therefore we can make a good comparison to the current figures. We try to explain on how to relate the current costs to the costs computed in this model. The management can then relate the figures stated in this report.

The expedition costs include 3 different costs:

1. LDC-RDC transport
2. RDC-Store-RDC transport
3. Handling: (un)loading of the trucks.

In the logistic report the costs for transport from the LDC to the RDCs account for 18% of the total expedition. The handling costs make up 12% of total transport costs per year. This results in the fact that only 70% of the costs originate from the time a truck is driving between the RDCs and stores.

In the model we have a 20% difference compared to the current routing costs for RDC transport. This difference can be found in the sub-optimality of the current used routing due to constraints not regarded in this research. In the model also extra costs that are normally added due to public holidays, peak demands, and store remodelling are not included. The average weekly kilometres from the model do match with the current regular routing there is only a small percentage difference.

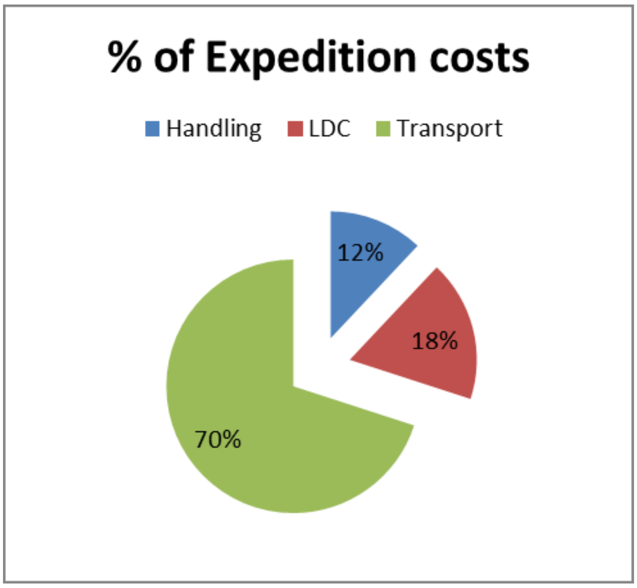


Figure 26: Expedition costs related to transport costs

5.1.2 Store to a DC

In this flow there are three different options. In Scenario 1 nothing happens to the costs since the return goods are directly picked up in the same truck and delivered to the DC.

Scenario 2: Separated returns:

Figure 29 gives an overview of Scenario 2. To summarize:

- About 42% extra transportation costs to pick up the returns.
- 308 trucks needed to pick up all return goods at the stores.

- 1000 trucks available for backhauling per week.
- Number of extra stops 902.

Scenario 3: Combined returns

In Figure 30 a complete overview with the routing including costs and revenues is given for Scenario 3. In the summation below the relevant aspects in Scenario 3:

- 21% extra transportation costs to collect the returns.
- 308 filled trucks with returns from the 1000 trucks driving.
- Results in 692 empty trucks after delivery per week, those are available for backhauling
- Number of extra stops 658.

5.1.3 Supplier to a DC

For the current computation only the known available freights are included. In Section 5.2 a more complete insight is given in the future possibilities for extra profits by backhauling. The profits are related to the current costs of transport, not to future costs. One remark must be made to the number of orders available. In practice it might be that multiple orders are combined in one truck.

Scenario 1: Fit in backhauls in existing routes

- Savings of 1.5% on total transport costs.
- 36 orders backhauled per week.

Scenario 2: Total separated returns

- Most trucks available for backhaul logically resulting in more profits.
- Savings of 10% on total transport costs.
- 107 backhauls per week (see Figure 27 for a division of the loads per backhaul).

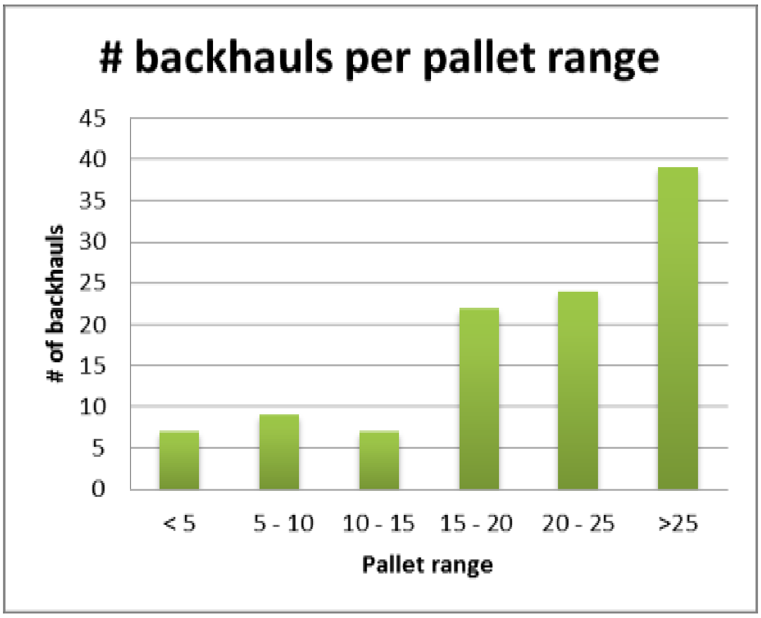


Figure 27: Number of backhauls in pallet range

Scenario 3: Combined returns

- Savings of 7% on total transport costs.
- 99 backhauls per week.

The potential for backhauling is high if it is related to the current numbers of orders per week. At the moment there arrive weekly 1389 orders. Those loads are divided over 349 suppliers. The higher number of orders compared to the number of suppliers is mainly due to the 4 DCs which all need to be delivered. The number is high although some suppliers only deliver to the LDC.

Currently there are 184 orders available for backhauling. To obtain an estimation of the number of backhauls possible in the futures orders can be extrapolated from the current figures. The extrapolation is related to the number of available backhauls by the following formula:

$$\frac{\text{current backhaul}}{\text{current orders available}} \times \text{total orders} = \text{numberof future backhauls}$$

If we extrapolate the orders following this formula there should be about 99 / 184 * 1389 = 747 feasible backhauls in Scenario 3 and 109 / 184 * 1389 = 822 feasible backhauls in Scenario 2. If this is enough to fill all available trucks after the delivery of the stores we can except them all. Otherwise we need to select the most profitable ones.

With those figures we can extrapolate the profits from backhaul. Table 8 gives the calculation and results for future benefits.

$$Estimated\ profit = Current\ backhaul\ profit \times \frac{MIN(Availble\ truck, number\ of\ future\ backhauls)}{Current\ orders\ accepted}$$

	1 Current backhaul Profit	2 Current orders accepted	3 Current orders available	4 Trucks available	5 Total orders available	6 Orders feasible*	7 Estimated profit**
Scenario 1	1.5%	36	184	1000	1389	272	12 %
Scenario 2	10 %	109	184	1000	1389	822	73 %
Scenario 3	7 %	99	184	658	1389	747	39 %
*** 6 = 2 / 3 x 5** **** 7 = MINIMUM(4, 6) / 2 x 1**							

Table 8: Estimation future benefits backhaul

Scenario 1

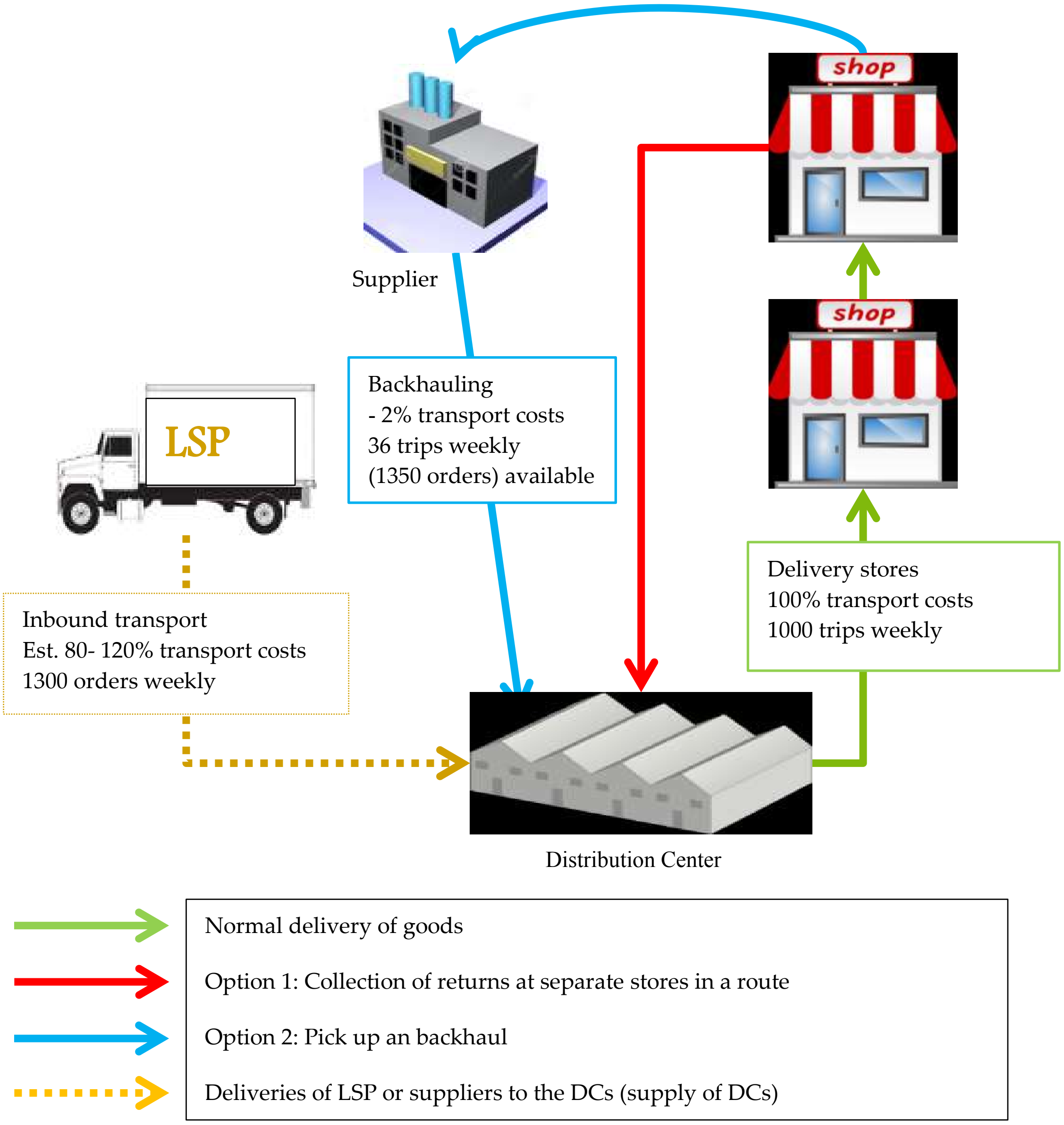


Figure 28: Overview Scenario 1

Scenario 2

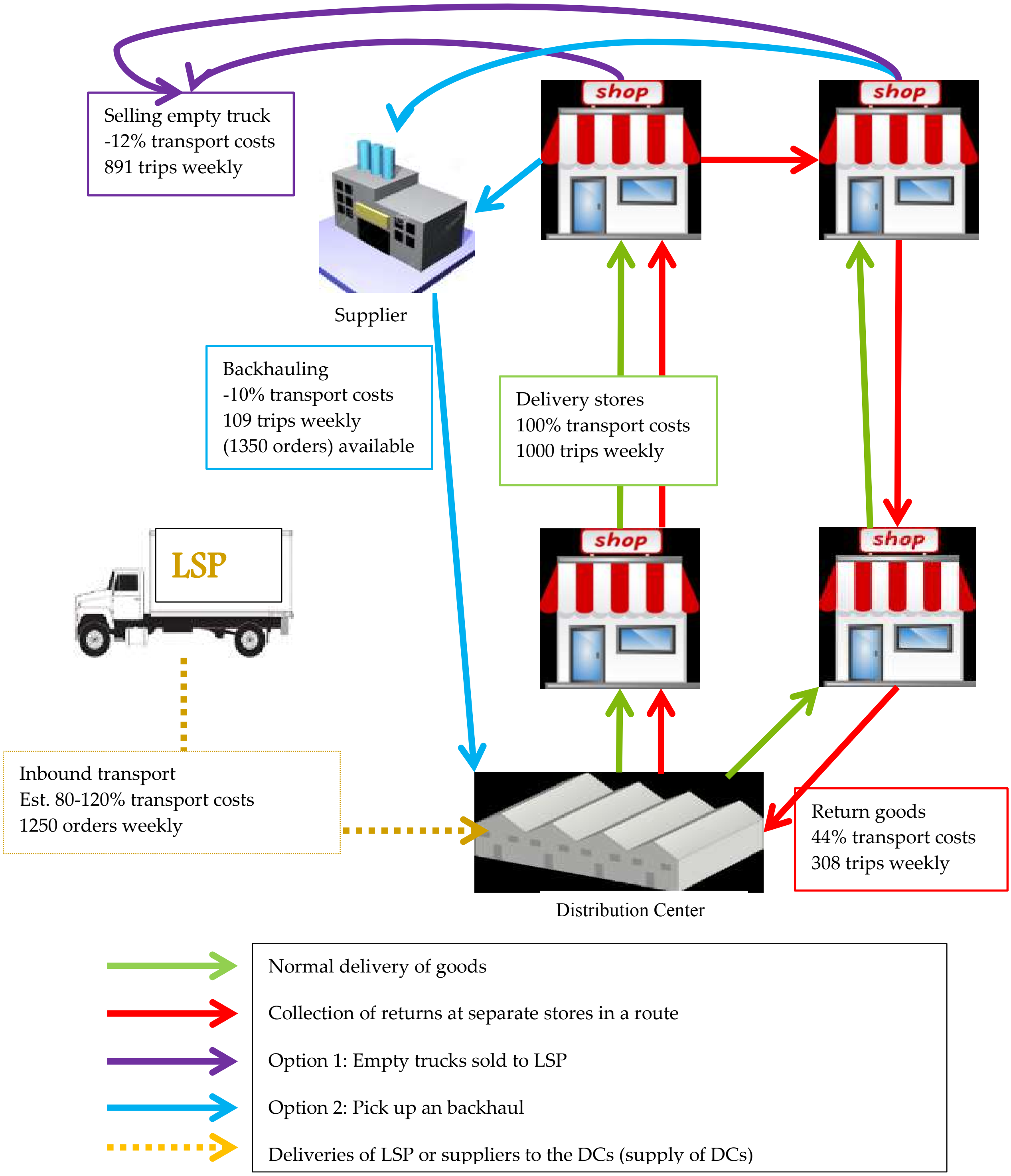


Figure 29: Overview Scenario 2

Scenario 3

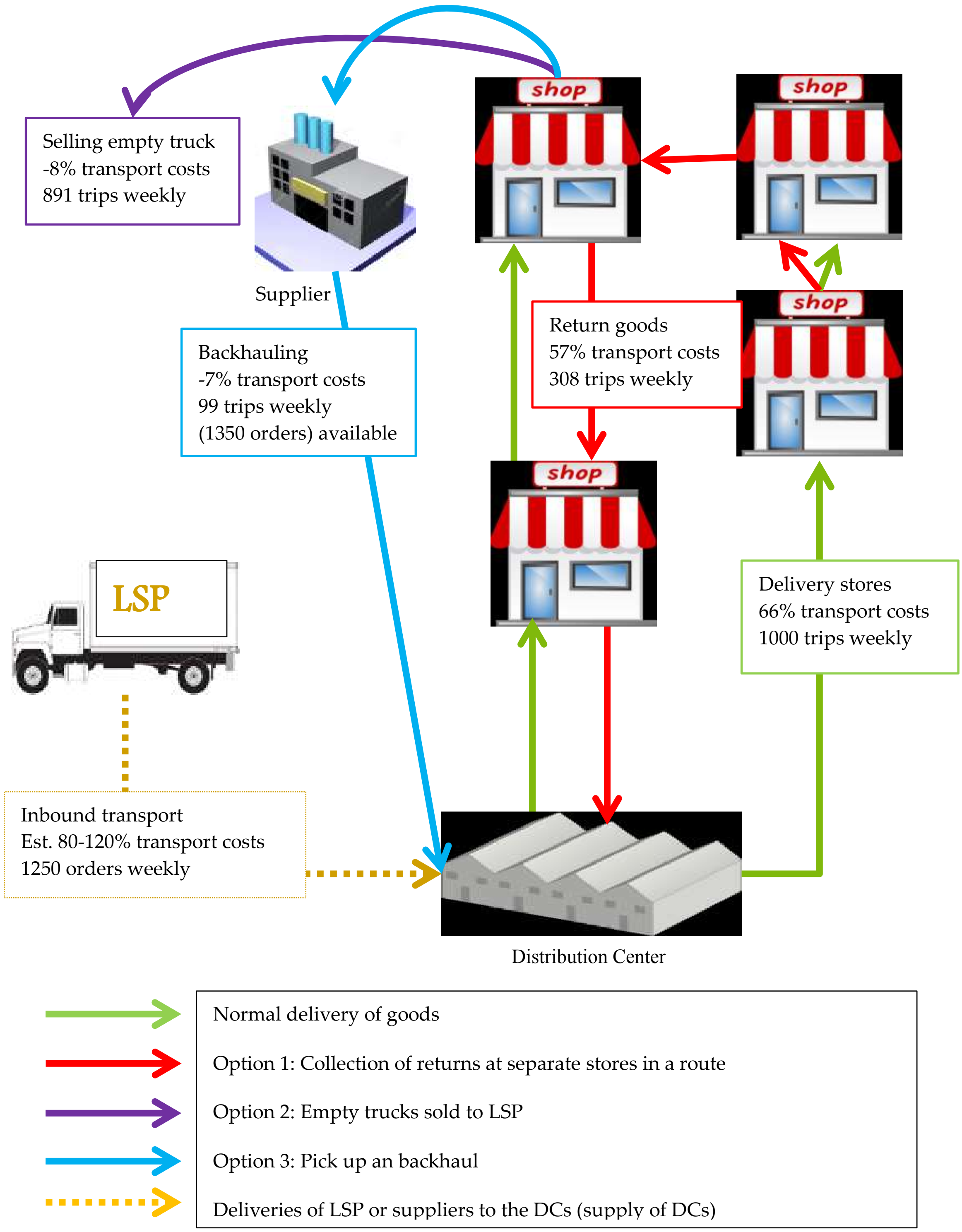


Figure 30: Overview of Scenario 3

5.2 Options on the scenarios

Although three scenarios are already evaluated this section gives insights into variation on the different options as proposed in Section 4.6. It is hard to couple them directly to all scenarios, since the effect can be different for each option on each scenario. Therefore we view all options separately for each scenario. In Table 9 we give a short overview what happens with an increase or a decrease of this factor. This can help to understand the different options. We give exact figures for the options 1.1, 1.3, 2.1, 3.1 since those make the biggest difference to the scenarios.

Options	
1 Network	
1.1	Number of DCs
1.2	Inter-DC delivery
1.3	Truck capacity
2 Delivery	
2.1	Number of deliveries
2.2	Rush-orders
3 Returns	
3.1	Number of return loads
3.2	Inclusion of different wastes in return goods
3.3	Inclusion or exclusion of VDC return goods
3.4	Selling the trucks back to the LSP from PLUS
4 Backhauling	
4.1	The number of suppliers involved in backhauling
4.2	Goods to transport

Table 9: Overview of options

NETWORK

Option 1.1: Number of DCs in the network

In the future there might be changes in the DC network. This section gives results for the return goods routing with one, two or the current four DCs based on 35% return rate. The model only presents the outbound transport costs with returns. This is due to high uncertainty of the reachable profit for backhauls and inbound transport. With one DC the inbound transport movements can decrease with over 60% (see Section 5.1, DC to DC). The decrease of DC-deliveries results in less backhaul opportunities (Table 10).

To compute a good location for one RDC we use all stores and supplier locations in the matrix. We dispatch all trucks from each location and make a complete routing schedule from that point on. This complete routing schedule is made for each location. In the results we found Utrecht, Smaragdplein as the best location present in our model. The area of Utrecht near a highway should therefore be a good point to build on.

For two DCs the optimal location is computational very extensive, since many options arise. We make the choice for Hendrik Ido-Ambacht (current RDC) and Arnhem. Compared to some other options (e.g. Haaksbergen, Ittervoort, Apeldoorn, Deventer) this is a better solution. The choice for Hendrik Ido-Ambacht prevents extra costs for closing one DC, therefore we expect his as the most practical scenario. Table 10 gives an overview of the results for each of the scenarios, percentages can be coupled to the RDC expedition costs on the current 3 RDCs.

	1.1 Number of DCs			
Scenario 1	Current	2DCs	1 DC	Remarks
RDC Transport costs	100%	117%	128%	Those figures exclude the benefits of the inbound transport or backhauling operations. And only relate to the LDC and RDC transport.
LDC Transport costs	22%	9%	0	
Total outbound transport	122%	126%	128%	
# Delivery trips p.w.	1000	999	999	
# Max Backhaulorders p.w.	1349	800	500	
# kms p.w.	150,000	207,476	237,334	
Scenario 2	Current	2DC	1 DC	Remarks
RDC Transport costs	144%	177%	179%	One DC results in extra outbound costs for transport
LDC Transport costs	22%	9%	0	
Total outbound transport	166%	186%	179%	
# Return trips p.w.	308	309	308	
# Max Backhaulorders p.w.	1349	800	500	
# kms p.w.	213,102	307,325	327,288	
Scenario 3	Current	2DC	1 DC	Remarks
RDC Transport costs	123%	147%	150%	Kilometers are adapted due to the confidentiality reasons, however they are equally scaled.
LDC Transport costs	22%	9%	0	
Total outbound transport	145%	156%	150%	
# Return trips p.w.	308	309	308	
# Max Backhaulorders p.w.	1349	800	500	
# kms p.w.	163,827	239,323	253,302	

Table 10: Overview DC analysis

With one DC and the current routing manner (or Scenario 3) extra transportation costs arise of 28% (Table 11). If the closure of the LDC is included, already 22% LDC-RDC-LDC transportation costs are saved, resulting in only 6% extra for outbound DC transport. Having only one PLUS DC could be very lucrative, already from the outbound transport side. Although routes become longer with 1 DC in the longest (return) routes in Scenario 3 this only incidentally causes problems.

Two DCs give relatively high costs, due to the geographical separation of the PLUS stores. The current three regions are clearly recognizable in the map from Figure 3. Transportation costs rise towards almost the same level of 1DC (8.5% difference). PLUS does also not have the full advantage of the closure of the LDC. This makes one DC cheaper than 2DCs from a transport perspective. In Appendix D we give a geographic representation of the problem.

1DC	Scenario 1	Scenario 2	Scenario 3
Extra costs delivery	28%	28%	28%
Extra costs returns	-	51%	22%
Total extra costs	**28%**	**79%**	**50%**
Savings LDC	- 22%	- 22%	- 22%
Result Transport costs	**6%**	**57%**	**28%**

Table 11: Overview 1 DC transport costs and result excluding backhaul profits

Option 1.2: Inter-DC delivery

The performance of Inter-DC deliveries does not contribute to outbound cost savings, but can highly reduce the number of inbound deliveries by consolidating orders.

There can be a reduction of 68% of incoming orders if we assume that all pallets can be consolidated to one DC. The number of external trips reduces from 1389 to 440. There will however also be an increase of inter DC travel. This results in a reduction of the number of total incoming trips of 36%. Since the rates calculated for transport from suppliers are not really clear it is hard to estimate the monetary value of this option.

Besides the incoming trips from the RDCs there are trips between the RDC and LDC. These trips from the RDC back to the LDC could be altered to reduce costs. Currently only empty containers and crates are transported to be filled again at the LDC. If the containers could be collected at the stores, this results in a saving for about 3% on total transport costs. Per week about 75 trucks at maximum could be used, disregarding the use of some special trucks for LDC-RDC deliveries.

Option 1.3: Truck capacity and loads

	1.3 More truck capacity			
Scenario 1	54 containers	70 containers	84 containers	Remarks
Transport costs	100%	95%	90%	The transport costs are based on the assumption that the rates for the trucks stay equal.
Backhauling profits	2%	2%	3%	
Total costs transport	98%	93%	87%	
# Delivery trips p.w.	1000	792	636	
# kms p.w.	150,000	139,654	117,602	
Scenario 2	54 containers	70 containers	84 containers	Remarks
Transport costs	144%	140%	134%	
Backhauling profits	10%	10%	10%	
Total costs transport	134%	130%	124%	
# Return trips p.w.	308	235	193	
# kms p.w.	213,102	198,954	176,870	
Scenario 3	54 containers	70 containers	84 containers	Remarks
Transport costs	123%	120%	105%	
Backhauling profits	7%	8%	8%	
Total costs transport	116%	112%	97%	
# Return trips p.w.	308	235	193	
# kms p.w.	163,827	152,151	131,302	

Table 12: Overview truck capacity, adapted in scale to hide private information

The trucks generally have a capacity of 54 containers however a few double decker trailers with a capacity of 84 containers are available. An increased capacity means that more stores can fit in one route. Due to the assumption of no variability the truck can be filled rather efficiently in this model. If the truck capacity increases with 20% the costs will decline about 2% for Scenario 2 and 3% for scenario 1. An increase of 35% capacity leads to decrease of about 6% in Scenario 2 and 7% in Scenario 1. The trend observed is not linear, but slightly increasing between 60 and 72 containers. So an increase towards 70 containers delivers more value for money than a slight increase to 60 containers. This is due to the fact that more delivery combinations are possible with 70 containers.

At the moment loads are close to a full truckload. With some extra capacity PLUS can only fit in a few extra stores in existing routes. The average loads of about 29 containers on Monday and 43 on Friday, coupled to a capacity of 54 containers.

Capacity containers	54 (current)	60	66	72	78	84
Costs (% to current)	100%	99%	97%	94%	91%	90%
# **Delivery trips**	1000	919	846	758	686	536

Table 13: Truck capacity related to delivery trips in Scenario 1

In this situation backhauling opportunities are strongly reduced, since less (lucrative) positions of stores become available. The routes become much longer and therefore tend to go over or near the maximum driving time. This means that some of the extra capacity cannot be used efficiently, since a truck needs to return to the DC within 9 hours driving time (See also Section 4.3.2 with the "Rijtijdenwet"). This is mainly the case for Scenario 3 with the return routes. Besides the driving time, not all stores can be delivered with the double decker, and the loading of goods is more time extensive, especially for loading pallets. Increasing capacity is related towards the decline of demand; more stores will fit in one truck. The same effects will then occur.

DELIVERIES

Option 2.1: Spreading deliveries throughout the week

In the future PLUS might increase the number of delivery moments. This should for example result in reduced lead times between RDC and the stores, increased fill rates, or lower inventory costs. To test this option the demand is evenly spread over 6 week days (excluding Sunday), resulting in a decrease of number of containers per delivery. Table 14 gives an overview of the results.

% of total transport costs	Current deliveries RDC transport costs	Spreading deliveries (6x a week) RDC transport costs
Scenario 1	100% (current)	130%
Scenario 2	144%	224%
Scenario 3	123%	198%

Table 14: Overview costs maximum delivery moments

Costs compared to the current routing will increase about 30%; However fill rates increase from 82% to 90%. Retrieving the return goods in Scenarios 1 and 2 however becomes even more expensive. This is due to the fact that returns need to be picked up before each delivery and the size of the delivery is decreased. This leads to fewer returns per store per delivery, in one route fit about 7 or 8 stores. This leads to too long routes, so the number of stores needs in a route need to be reduced. The fill rate of the return route is therefore lower than with the current delivery frequencies.

Option 2.2: The use of rush-orders

PLUS currently not needs rush orders since the service level in the stores is high (+99.0%) and out of stocks due to deliveries to stores lower than 0.5%. Most of the out of stocks occur due to bad sales forecasts. Therefore it is considered as not relevant for strategic purposes; decisions must be made on an operational level when rush-orders are needed. If inventory costs would be included in this research the choice might become relevant. With rush orders there is a reduction possible of inventory costs since PLUS needs lower safety stock levels.

RETURNS

Option 3.1: Return loads volume changes

For the pick-up volume of VDC return goods 75% of the previous delivery volume is used. This is higher than the number of returns at the RDCs due to the delivery in returnable crates and non-stackable containers.

If PLUS includes the VDC returns in the RDC-truck costs increase significantly in all scenarios. This is due to the daily delivery of the VDC, which is not common for the RDC. The option results in extra RDC transport costs of about 90% for all return goods. Scenario 2 is no longer possible since there are too much return goods to pick up in existing trucks and have to be combined with separate return routes. We limit the research on returns is therefore to the RDCs.

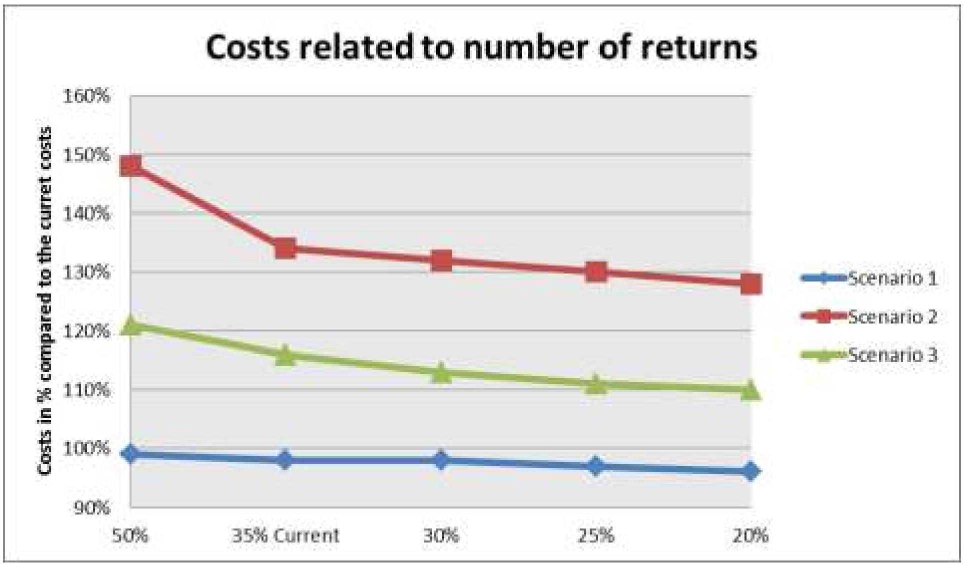


Figure 31: Graphical view on transport costs with varying returns

In Figure 31 a declining trend in costs can be observed if returns decrease. This is due to the number stores which can fit in one truck for a return route. If return goods decline from 50% to 35% only one store extra can be visited (2 -> 3, approximately), however for the same reduction from 35% to 20%, 5 stores can be visited. This results in a better truck utilization and also significant less kilometres travelled since most of the costs occur from travelling from a DC to a store. The inter store trips are relatively cheap.

From a certain point trips become too long and violate driver constraints. The return volume should therefore not be reduced below 20 % in Scenarios 1 and 2 if costs are necessary to achieve this. For scenario 3 this is not the case since they are included in the delivery routes which do not change.

In Table 15 the overview of total costs per scenario linked to the return rates is presented. The background figures can be found in Appendix E.

	3.1 Less return loads				
Scenario 1	50%	35% Current	30%	25%	20%
Transport costs	100%	100%	100%	100%	100%
Backhauling profits	1%	2%	2%	3%	4%
Total costs transport	99%	98%	98%	97%	96%
# Delivery trips p.w.	1000	1000	1000	1000	1000
# kms p.w.	150,000	150,000	150,000	150,000	150,000
Scenario 2	50%	35% Current	30%	25%	20%
Transport costs	158%	144%	142%	140%	138%
Backhauling profits	10%	10%	10%	10%	10%
Total costs transport	148%	134%	132%	130%	128%
# Return trips p.w.	438	308	265	225	199
# kms p.w.	242,491	213,102	207,812	200,976	197,383
Scenario 3	50%	35% Current	30%	25%	20%
Transport costs	127%	123%	121%	119%	118%
Backhauling profits	6%	7%	8%	8%	8%
Total costs transport	121%	116%	113%	111%	110%
# Return trips p.w.	438	308	265	225	199
# kms p.w.	171,186	163,827	163,855	162,074	158,404

Table 15: Overview of the return volumes and the influence on costs

Option 3.2: Inclusion of different wastes in return goods

PLUS can reduce the percentage of returns by no longer servicing the collection of wastes such as paper and plastic. The flow can also increase by taking residual wastes into the trucks. The inclusion of fresh produce wastes in supply trucks is partly prohibited by law. Recycling experts advise PLUS to have wastes such as food products, and residual waste not collected using PLUS trucks. Although it might be feasible this process is believed to be not hygienic.

An overview linked to costs is presented in Table 16; the costs are linked to Scenario 2, and formed from separate removal out of the transport. This means that savings cannot be added up.

	Paper	Plastic	Residual waste (estimated)
Average weight or volume per container spot	91 kg	27 kg	240 litre
Weight or volume per million € turnover	5.3 tons	0.32 tons	2573 litre
Container spots per million € turnover	58	12	11
Container spots per store per week	8.9	1.8	1.9
Increase flow to stores	0	0	1.9
Contribution to the return flow %	15%	4%	4%
Savings or costs	5% Savings	2% Savings	2% Extra Costs

Table 16: Overview of waste materials

At the moment residual waste is collected separate with low cost of about 4% of related to the total RDC transport. Those costs for residual waste are for 60% allocated to landfillrates and the rest to transport, collection, lease of containers, administration. What means that at maximum PLUS can save at maximum 1.5% on transport costs by performing the waste collection themselves.

At the moment there are negotiations going on for the elimination of deposits on bottles and maybe beer crates. This could lead to even more savings on return routes, see Table 17, the costs are linked to Scenario 2.

	Bottles	Beer crates
Container spots per truck	1.8	7.6
Contribution to the return flow %	15%	40%
Extra costs	5%	8%

Table 17: Overview savings on deposits bottles and beer

Option 3.3: Inclusion or exclusion of VDC return goods

The current figures of the VDC prove that it is efficient in fitting in backhauls with returns loaded compared to the available capacity. Currently 13% of the total expedition costs are regained by backhauling, although the current return flow is estimated at 75%. This flow arises daily since there is a delivery each day. The fill rates on this part of the supply chain are relatively high. That means that no optimization in the fresh (cooled) transport is currently possible.

If the return flow from the VDC would decrease to 50% the total transport costs rise with still 74%, this compared to 42% if only separate routes would be made for the RDC goods. The costs exclude the travel from the RDCs to the VDC, and increased handling costs.

Option 3.4: Selling empty trucks to the LSP (one-way paying)

In the current contract negotiations for transport there are possibilities discussed to sell empty drives back to the logistic service provider. The trips per year returning to the DC costs PLUS 31% of total transport expenses. For example if the LSP only invoices half of those costs there is a saving of 14% of those costs in Scenario 2. In Scenario 3 the saving would be 9%, since there are fewer trucks empty at the stores.

BACKHAULING

Option 4.1: The number of suppliers involved in backhauling

In order to break-even on the different scenarios more backhauling revenues are needed. To achieve this more backhaul possibilities at suppliers are needed. In Scenario 3, PLUS needs about four times as many backhauling opportunities to realise the current costs.

This would result in performing about 350 backhauls orders per week with 549 trucks available. In total there are 1.083 orders available per week that could be feasible. From these orders about 35% needs to be backhauled to get break-even with the extra costs that originate from the return goods. If PLUS would combine it with selling trucks back to the LSP at 50%, the needed backhaul percentage is 30%.

Total costs for transport on the supplier side however are bigger than the savings calculated at PLUS. Implementing Factory Gate Pricing gives a total other perspective on the case: If a discount of about 0.5% is possible by picking up goods, purchasing benefits up to 120% exist for PLUS (related to RDC-transport costs). The 0.5% is an estimated figure from purchasers at Superunie and should be regarded with some caution. PLUS expects that the actual percentage is lower. Literature already states that supplier and retailer transport costs do match 23 to 19% in total logistic costs (Van der Vlist, 2007).

Important to note is that breweries take their empty crates back in the trucks. It is useless to implement FGP or backhauls for this category.

Option 4.2: **Goods to transport with backhauling**

This option is actually comparable to Option 4.1, except that the orders must be delivered to another destination than the PLUS DC. The option to backhaul goods for other companies can therefore only be profitable if there are companies to cooperate with in the neighbourhood of the RDCs. The number of backhaul orders needed for breakeven would be slightly higher if the expected transport price for a non-food pallet is equal to a food pallet. This is because the extra transport costs from the external location to the PLUS DC. Basically this result in the same individual decision per backhaul opportunity: If there is a profit: Accept it, else reject.

5.3 Conclusion

Chapter 5 discussed many different figures and options and the most relevant inputs for decision makers were tested. The current model we proposed in Chapter 4 can perform one calculation of the three scenarios within one minute. We observed real differences between the scenarios.

We found that Scenario 1 results in 2% savings per year on the total transport costs. In Scenario 2 transport costs rise with 34% and in Scenario 3 with 23%.

Also the options presented in Chapter 4 gave difference in some of the results. We see that costs outbound transport costs rise with 6% having only one DC. We found that the best location for such a DC would be in the area of Utrecht. The number of suppliers needed to break even must also increase with at least 300% in order to reach the breakeven point for Scenario 2 or 3. Other options only gave a slight difference to the transport costs.

These differences give PLUS choices to make. In Chapter 6 we give conclusions and recommendations for PLUS to make good choices regarding their transport. Since the current model is only used as an efficient route construction method, further improvement of the solution with other (improvement) heuristics is possible.

Chapter 6: Conclusions and recommendations

In this chapter we state our conclusion and recommendations for PLUS based on the main research questions posed in Chapter 1: *"How can PLUS organise the current transportation flows in a more efficient way, to reduce total transportation costs at the same service-level?"*.

Section 6.1 presents the conclusions on the research question 1.5: *"What options for transportation and network should PLUS apply if it wants to minimize costs?"*. Section 6.2 gives recommendations for improving the logistics at PLUS. The same section also discusses qualitative aspects that need to be addressed. We states some remarks and points for discussion in Section 6.3. Section 6.4 makes several suggestions for future research.

6.1 Conclusions

In Chapter 5 we found some remarkable and non-remarkable results. First we give an insight in the conclusions from literature in Section 6.1.1. Section 6.1.2 gives a short conclusion on the scenarios introduced in Section 4.1. Although there is overlap between Section 6.1.2 and Section 6.1.3 the first section gives a short and more overall view on the situation.

1. Scenario 1: Perform a routing from DCs to stores and include the returns. After the delivery a supplier can be visited to pick-up an order at a supplier.
2. Scenario 2: Separate routes for picking up the returns. And a route for the delivery of stores with afterwards the pick-up of an order at a supplier.
3. Scenario 3: The trucks delivering the stores can either pick-up the returns at the stores or pick-up a backhaul at the suppliers. Afterwards the truck returns to the DC.

Section 6.1.3 discusses the routing of trucks at PLUS in the transport flows as stated in Chapter 1 and Chapter 2 extensively:

1. DC to a Store
2. Store to a DC
3. Supplier to a DC
4. DC to DC

6.1.1 Concluding from literature and previous studies

Literature proposes several ways to deal with the four transport flows. We found that the current way of solving the routing problem by hand with some minor software support is not feasible if complexity increases. This is increase is due to the networking aspects created in the proposed scenarios. Literature states that the best way to solve this is by using meta-heuristics. The ALNS model proposed by Pisinger and Ropke (2007) is very applicable to the problem PLUS faces. ALNS is not incorporated in this research, since the model is only used for a strategic analysis and not for the actual routing. Besides the model is time intensive to implement for which was no time during this research. For this reasons we used a nearest neighbour approach.

Professional software is required for PLUS. This means the heuristic or algorithm is determined by the software choice. Models are pre-programmed in each software package; the software choice should be influenced by the available algorithm(s) in the software package.

6.1.2 Concluding on the different scenarios

With the current backhaul possibilities the best way to operate the PLUS transport flows is to create some stores served with Scenario 3. Those stores must be in the area of a structural backhauled supplier. The rest of the stores can be served using Scenario 1 or the current routing. The best way to achieve this cost efficient is to set pilot projects and make changes to the tactical level. Separate routing for returns is not yet effective.

If PLUS can rapidly increase backhaul possibilities we recommend to implement a combined routing of return routes and backhaul routes (Scenario 3). Scenario 3 can be run cost neutral for all regions if the number of available backhauls will be about 3 times as large as the current set of 180 orders. This also depends on the profits PLUS achieves by selling back the return ride to the DCs. This could result in 9% transport cost savings extra.

This combination of Scenarios 1 and 3 is long term the most efficient from a cost perspective. From an organisational view a choice could be made for Scenario 3 only. This way PLUS to reduces complexity for planners and stores, and PLUS makes a uniform routing choice.

6.1.3 Concluding on the separate flows

1. DC to a store

We conclude that there are not much savings possible on the transport from DC to a store by PLUS. The current fill-rates are good (80-90%), unfortunately only on Mondays, Tuesdays, and Wednesdays delivery combinations between stores are possible. We advise to keep the current flows of VDC and DDC separated from the RDC/LDC. Currently they are well organized. Besides, the return flow coming from VDC is rather high, 75%. Fill rates at the VDC are already high (86%), and trucks from the DDC have excellent backhaul opportunities since they already drive empty from the store.

This is given by the current demands, which are mostly too high to combine. A suggestion would be to look to the order sizes and increase the delivery moments to the store, in order to come up with more stores combined in one truck. Some further improvements in the current routing are possible if the preferred algorithm could be used, and stores would be assigned to the cost optimal RDCs. The optimal DC could vary from shortest distance to the store, due to backhauling profits or more efficient return flows.

Concluding:

- No changes needed, increase of the number of deliveries lead to higher truck fill rates.
- Keep fresh-goods, frozen goods (returns) separated from the dry groceries.
- Assign stores towards the most suitable RDC, depending on backhaul and return route.

2. Store to a DC

From a cost perspective the most desirable is to handle the returns with a combination of Scenario 1 and Scenario 3. This means that backhauls are fit in the truck, or if full capacity is needed, another delivery truck collects the returns. A separate return collection route (Scenario 2) is far less complicated to plan compared to the 1st and 3th Scenario. We expect this increased complexity in the 1st and 3th Scenario is manageable. Perceived difficulties at the start of the implementation would disappear over time. Scenario 3 is preferred above Scenario 2 since the high cost differences.

The current way PLUS uses materials and goods that need to be returned is relatively up to the standards in the market. The reduction of containers and crates to transport seems to be unlikely. The conclusion from the various interviews is the same. However with some (mainly time) investments, reductions in flows such as empty bottles, plastics, paper can be made. Only a small reduction would lead to between 1 and 2% savings on total costs. The maximum reduction is 20% due to the fixed container stacking (5 containers = 1 stacked container). This cost relation only occurs if backhauls are performed or return good routes are made, not in the current routing without backhauls.

PLUS should not implement the retrieval of residual wastes at stores from a cost perspective (since there are no savings possible). We advise to keep wastes separately collected by recyclers. This is also due to qualitative aspects as tidiness of the trucks and the increased complexity at the DC. PLUS should make up a scenario for the stores in which all wastes (plastic, AGF, paper, residual wastes) can be collected at lowest costs by an external party.

Outsourcing of all return flows originating from the stores would always costs more than in Scenario 2. This is because the truck is at minimum distance at the latest store (0 km to a store). The truck from the LSP must come from a depot, which should take a certain distance. Only if there is cooperation in the sourcing of return goods at stores trips can become smaller. The cost for a third party could be smaller and the involvement of at third party would be preferred.

The most important store aspect regarding the return goods is owners preferring an empty storage room. If PLUS performs the collections of the returns early as possible, or within desired time windows, this leads to emptier storage rooms. In this case less storage space is needed and working space is created.

PLUS requires routing planning software to reach this flexibility in returns. The software should be linked with historical data regarding return goods sent from each store each day.

Concluding:

- Combine return-flow with the delivery of goods.
- Combine Scenarios 1 and 3 in the beginning, resulting in growing complexity in routing.
- Decrease of the number of return goods at stores, resulting in significant less cost for returns.
- Early (or late) delivery for some stores needed, rescheduling is necessary.
- Store-owners happy with emptied storage room, so return pick-ups as early as possible.
- Flexible planning software required in all scenarios with increased backhauling.
- Hubs not necessary in current DC-network.
- Outsourcing cost higher than observed in Scenario 3, but lower than Scenario 2. Therefore outsourcing not preferred.

3. Supplier to a DC

The supplier to DC part of the transportation flow is the hardest to arrange. This flow involves two extra stakeholders (the supplier and their LSP). From interviews with management we find that suppliers are not keen on increased complexity of their operations. Besides they are not always willing to negotiate on factory gate pricing or a lump sum compensation of transport costs. Superunie is a key-player to negotiate the terms to perform backhauls based on a factory gate price.

We find that the current number of inbound transports mainly originate from reduced inventory costs at the retailer and not for overall logistic costs. If PLUS can coordinate the deliveries in a synchronized way over the supply chain, savings of over 5% on total logistic costs can be achieved (Le Blanc et al., 2006) (Van der Vlist, 2007).

Performing backhauls is not only preferred for transportation aspects, but also from a DC-organisational point of view. If a load arrives on backhaul basis this gives the DC more time to vary in the unloading time thus the workloads can be balanced out. The freedom is created by late arriving trucks at DCs that (possibly) do not need to leave before the next day.

Concluding:

- Coordination and negotiation in the supply chain is very important.
- Results in difficult organizational aspects.
- The current infrastructure of 4 DCs and geographical situation is not good.
- LDC Backhauling difficult due to different capacities of trucks
- Factory Gate Pricing is necessary to fairly identify transport costs. The role of Superunie is from an inbound perspective essential. This is a long term project, but can result in large transport costs savings.

4. DC to DC

Figure 32: Geographical triangle for Inter-DC deliveries

The position of the PLUS DCs (borders of The Netherlands), and the more central location for the suppliers, makes it relatively unattractive to implement inter-DC flows for all suppliers. However the suppliers outside the geographical triangle of the combined three RDCs could be backhauled and then shipped inter-DC (See Figure 32). From a cost perspective, choosing to build one DC would be a more feasible option.

Between the RDC and LDC there must be made room for deliveries which result in a significant higher added value than the current backhauls or selling back of the truck to the LSP.

Concluding:

- LDC-RDC and RDC-LDC, remains the same.
- Backhauling possible after delivery from LDC to the RDC.
- LDC-RDC: Better to perform a return good route towards the stores and deliver goods. Eventually take the returns back to the LDC.
- Since loading times at DCs are rather high inter-DC, low volumes are the most interesting to consolidate.

6.2 Recommendations

In this report we divide the transport aspects into the strategic, tactical, and operational level decisions. We continue this approach by providing recommendations for each level. Those recommendations form an extra addition to the answering of the main question in Section 6.1. The most attention is paid to the strategic aspect (Section 6.2.1) because the research is intended to make recommendation at this level. However, we make small remarks on the tactical (Section 6.2.2) and the operation level (6.2.3).

6.2.1 Strategic level

On the strategic level we use the model from Fernie and Sparks (1998) as discussed in Section 3.1 to give guidance on what different work levels at PLUS are influenced. This section places the focus on the transport and storage, since those fit best to the scope of the research.

Storage facilities

PLUS should consider the centralization of the storage in one location. In that case the outbound transportation costs rise only about 6% (including LDC saving). If PLUS includes the Scenario 3 backhauling this gives about 28% extra costs. Most savings are made by reduction of trips from suppliers towards the RDC. The number trips from suppliers to the RDCs currently are about twice the size of the outbound transport at the RDCs. It is hard to find a good way to approximate these savings, but a reduction of over 50% on the number of trips is possible. The monetization of the less inbound trips is an important aspect.

The DC-operations are not part of this research, but operations on site can be improved. Currently trip/resource planning and dispatching is performed separate at each DC. In one DC the planning and routing can (for example) easily be centralized.

If a balance is made, one DC is certainly advised from a cost perspective. We recognize however that there are major social aspects to be considered. Therefore we propose to build a central DC to replace the current LDC and (slowly) phase out operations at the RDCs.

Inventory

PLUS should implement factory gate pricing. According to literature this leads to price transparency. Savings from 8 to 20% on transport costs for the food supply chain are possible (Involvation, 2004) (Le Blanc et al. , 2006).

Interesting is that order sizes increases with over 40%, because a drive from the supplier to the DC then results in less costs per pallet. The increased volume leads to less (reduction of trips) and bigger DCs, since those bigger volumes must be stored.

Transportation

The operations are not yet ready for a transformation into a networking model. A model with trucks driving to multiple locations picking up returns at stores and goods at suppliers always returning to the DCs. If PLUS would implement the complete network model this increases complexity in a large extend. Good routing software that can handle these complex situations is required.

Also the number of transportation trips available need to be included from a backhaul perspective. The current number of suppliers of backhauls needs to be increased to get a profitable business case of collecting separate returns.

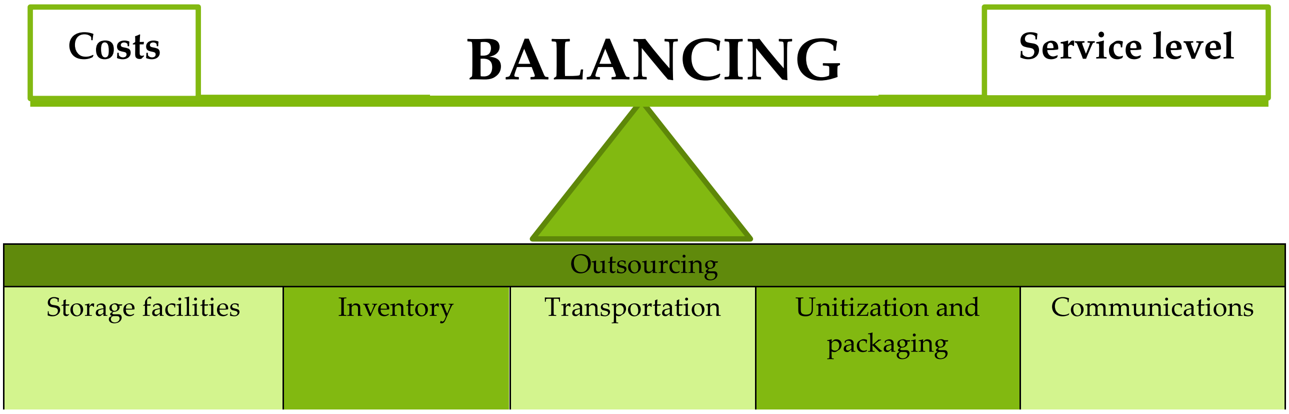
If PLUS has a uniform transport capacity backhauling is less complex. PLUS must prefer backhauling and deliveries with the normal 54 containers truck if they want a good networking scenario. The high capacity trucks should then be send to regions with low backhaul possibilities.

Unitization and packaging

No changes are needed for the current scenario. If return goods can be reduced, for example by selling more canned beer, using fewer crates or no longer using deposits, this has to be considered.

Communications

With the implementation and development of the routing, the improvement of IT (Software) communications becomes more important. The meetings with suppliers, entrepreneurs, and DCs, would involve discussions about pricing and restrictions. If those aspects are clearly defined this means that less communication is needed to discuss operational aspects such as truck-drivers, time, number of trucks/trips, and etcetera. Since the dispatching and the trip and resource planning is automated to a high degree with the routing software.



All these recommendations result in the conclusion that PLUS needs to invest in the complete network, to optimize costs for the truck routing. However if those investment are made, not only the transportation costs will decrease. Total supply chain costs would be influenced, since an insight in operations gives the opportunity for improvement. Besides the insights it could lead to significant savings by improving processes and eliminating part of the operations.

6.2.2 Tactical

This decision level mainly concerns loads routing and trip planning. Although the strategic choice might be set in cooperation with store owners, the tactical routing will cause a lot of discussion in the operation. This is due to the alteration on delivery times or even delivery days. PLUS can solve this by paying less attention to this level of making a BAS with the concerning routes. With the correct restrictions in a routing and transportation schedule making efficient routes on an operational level could lead to cost savings. The restrictions could be set to the current BAS-times, however more freedom in delivery times results in better solutions. The downside of this is that one might overlook possible savings by relaxing certain restrictions. Therefore the relaxation of time windows is important to monitor. A more relaxed arrival time for trucks results in more possibilities for truck routing, and therefore lower (or equal) costs.

Piloting

If PLUS starts with a few suppliers in the middle of the country (most attractive backhauls) and select appropriate stores, a new BAS-schedule for that region can be locally made. We advise to use a combination of Scenario 1 and 3 for the routing. With pilot projects running on Scenario 3. Like this example (see Figure 33): Region West could deliver on Wednesday to two PLUS stores in Utrecht, say Smaragdplein (1) and van Ostadelaan (2), and then pick-up returns at the other two stores, Voorstraat (3) and Plantage (4). The truck delivering Voorstraat and Plantage could continue to Kuehne Nagel (K&N DC) in Utrecht picking up the Douwe Egberts or Pepsi. This is a local adaption to the BAS that could function as a pilot project.

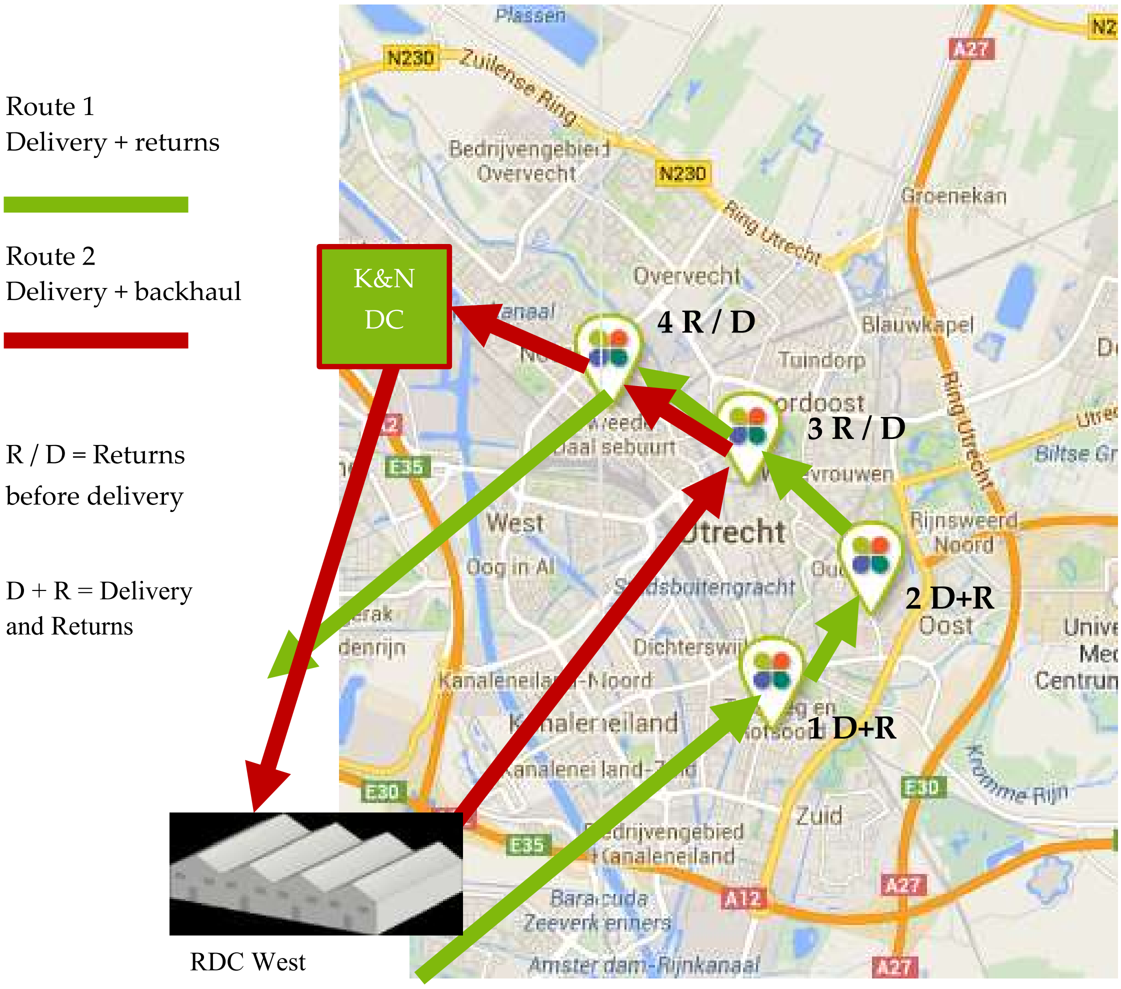


Figure 33: Example on piloting Scenario 3

6.2.3 Operational

Concerns at planners about a new resource planning, different dispatching of trucks, and increased routing complexity is logical. However the result of the tactical planning with backhauling still could give a fixed schedule for the operations. Adaptions to the schedule due to temporary disruptions are however harder to repair, mostly at higher extra costs. Therefore the suggestion is to invest also in operational routing software to assist planners. A time ago a routing system was already implemented, but failed due to the lack of the planners' commitment to the project. We suggest an early involvement of the planners in order to increase support.

Cooperation with the LSPs in the routing process is needed in order to coordinate the loading at the supplier or the docking at the PLUS DCs.

6.3 Discussion

In this research we make many assumptions and we face limitations and constraints. For example, we did not incorporate time windows. The option to create a total network scenario, such as transporting RDC freight in LDC or VDC trucks, is also not researched thoroughly. This is because we expect no feasible profits from combining these flows in the current DC structure. If those are all concentrated on one place this could give other insights.

We compared the options to a basic scenario. This basic scenario was calculated following the same assumptions. This must provide enough information to decision makers on how big the impact of a certain decision would be to the transport costs. Therefore we can state that with this research PLUS is able to make a good decision on what to do with their transport operations.

Otherwise PLUS could also relax the limitation we set to the delivery days. In other researches it proofed helpful to cluster nearby stores and give them the same delivery days for RDC deliveries. The objective to obtain the same service level and keep a "similar" schedule prevented us from doing so.

The view in the report is narrowed to only the costs for transport, whereas other parts could be essential for some parts of decision making. Most of the DC processes however remains the same. Cost could from our perspective only differ by not balancing out the demand. In the current situation this is still possible so we expect no big cost impact. In Section 6.4 we recommend further research on the impact of rerouting on other (DC) operations.

In the current DC network of PLUS backhauling is difficult. The geographical spread of the suppliers' locations does not really match the PLUS network. It is hard to find all supplier warehouse locations, from the locations we identified most are in the center of The Netherlands. In Figure 34 we show this geographical spread. We only see a few stores in the area of the supplier warehouses. For the current number of backhauls this is not a problem. It is uncertain what profits can be obtained if the number of backhauls increases.

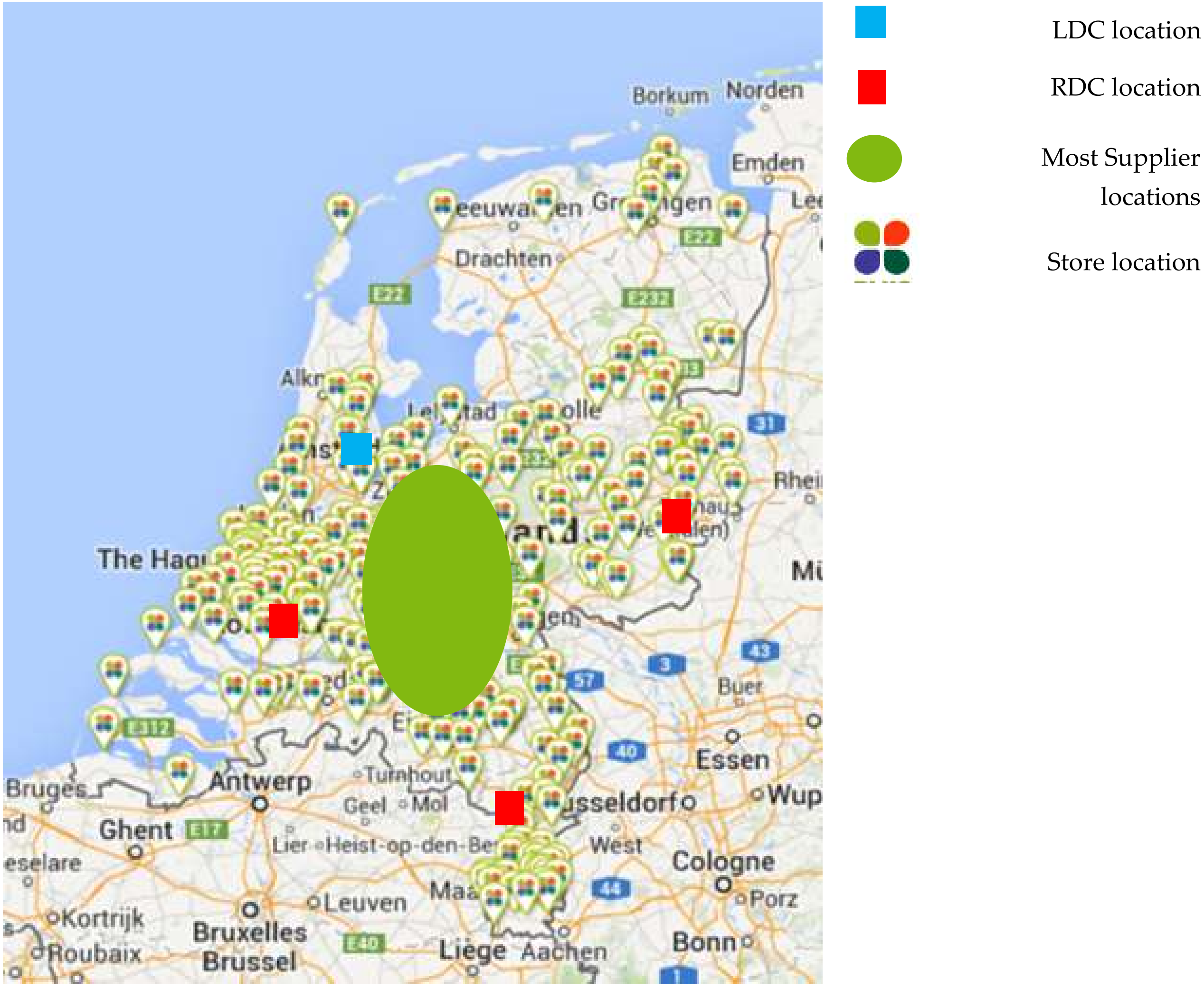


Figure 34: Locations of suppliers, RDC and Stores

When PLUS build a DC in the center of The Netherlands it helps achieving a better scale for the backhauling, with fuller truckloads. With a single DC more trucks pass the suppliers' locations and supplier demand is combined.

We tried to make this research less time dependent by including the different options (see Section 5.2). This way we hope that the input is still relevant for over a few years. This is important since the implementation of some of the recommendations and conclusions take time. During this implementation the environment and/or the network changes.

6.4 Further research

This section states different suggestions for research on the implementation of the new routing. Also we propose researching further information about the new routing. The future researches should address software, suppliers and DC operations in order to make a new routing possible.

The purchase of capable routing software

Routing software is needed when PLUS transforms the transportation network towards Scenario 3. Only a few well known software suppliers are capable of handling this kind of problems (multi depot, suppliers, and stores). PLUS should start conversations and negotiations in order to get the right package. In a first rough search we find companies such as Ortec, Paragon, Descartes, and modules from SAP, Oracle and other enterprise resource planning systems suitable for the current situation at PLUS.

Research the input of suppliers

In this research we did not investigate the inputs from suppliers regarding factory gate pricing and the opportunities for backhauling. We advise to have a research or project on the large scale implementation of FGP. This investment should mainly be addressed to the supplier since they are sellers, which determine the FGP. Suppliers have to negotiate with their LSPs on the conditions for having a pick-up at an external warehouse. A good partner to initiate this project is Superunie since they are the negotiating party. The goal of the project should be to encourage suppliers to set a Factory Gate Price.

Research the influence of the routing on the DC operations

In order to reduce complexity this report does not take DC operations into account. Now it is clear there are (future) benefits in changing the routing, PLUS should take steps to research the influence on the DC operations. For example on loading and unloading trucks, increased or decreased handling, timing of transport, and etcetera. Important is the cooperation of the supply chain department in the coordination of the order and delivery times at the DC-level.

Delivery of stores by external LSPs or suppliers

Instead of PLUS backhauling the orders from their suppliers PLUS could "outsource" store deliveries to suppliers/LSPs that visit the DC. PLUS should use a Scenario 3 approach for its deliveries. PLUS needs pick-up the returns at the stores whereas the supplier delivers them with groceries. The LSP then has an empty truck after the delivery of the stores, and not necessarily has to return to the PLUS DC.

A main advantage of this model would be the decrease of negotiation time with the supplier or their LSPs about the compensation for the backhauls. A downside is that PLUS decreases its power over the supply chain.

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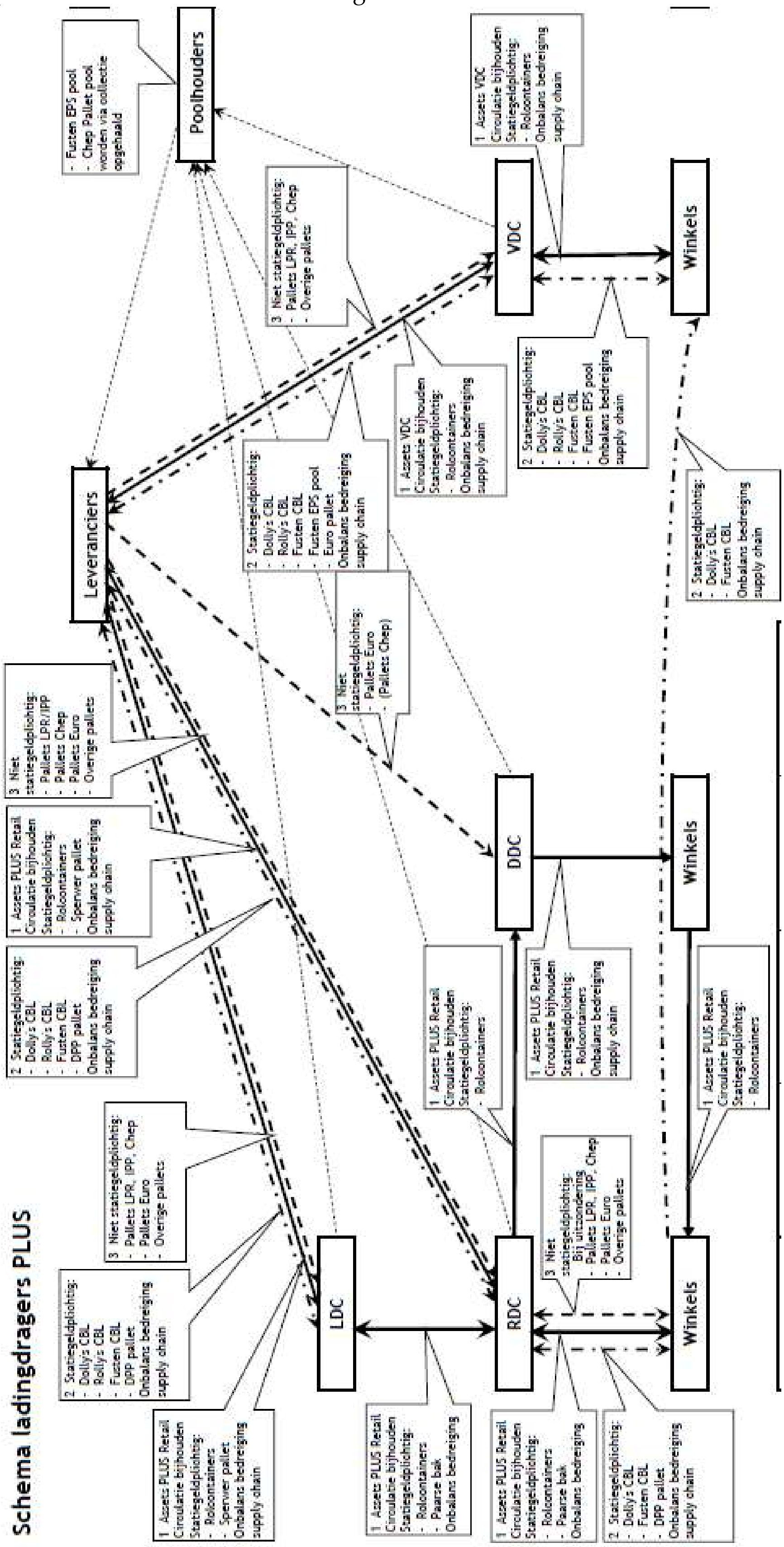
Appendices

Appendix A: Scheme for the reverse goods and their flows.



Appendix B

The DCs are located in:

Regional DC (RDC): PLUS Retail | East
Industriestraat 67, 7482 EW HAAKSBERGEN

Regional DC (RDC): PLUS Retail | West
Nijverheidsweg 61, 3341 LJ HENDRIK-IDO-AMBACHT

Regional DC (RDC): PLUS Retail | South
Afrikastraat 10, 6014 CG ITTERVOORT

Nationwide DC (LDC): PLUS Retail | Beemster
Insulindeweg 1, 1462 MJ MIDDENBEEMSTER

Nationwide DC (VDC) Fresh goods, Hollander, Greenery, PLUS
Dierensteinweg 30, 2991 XJ BARENDRECHT

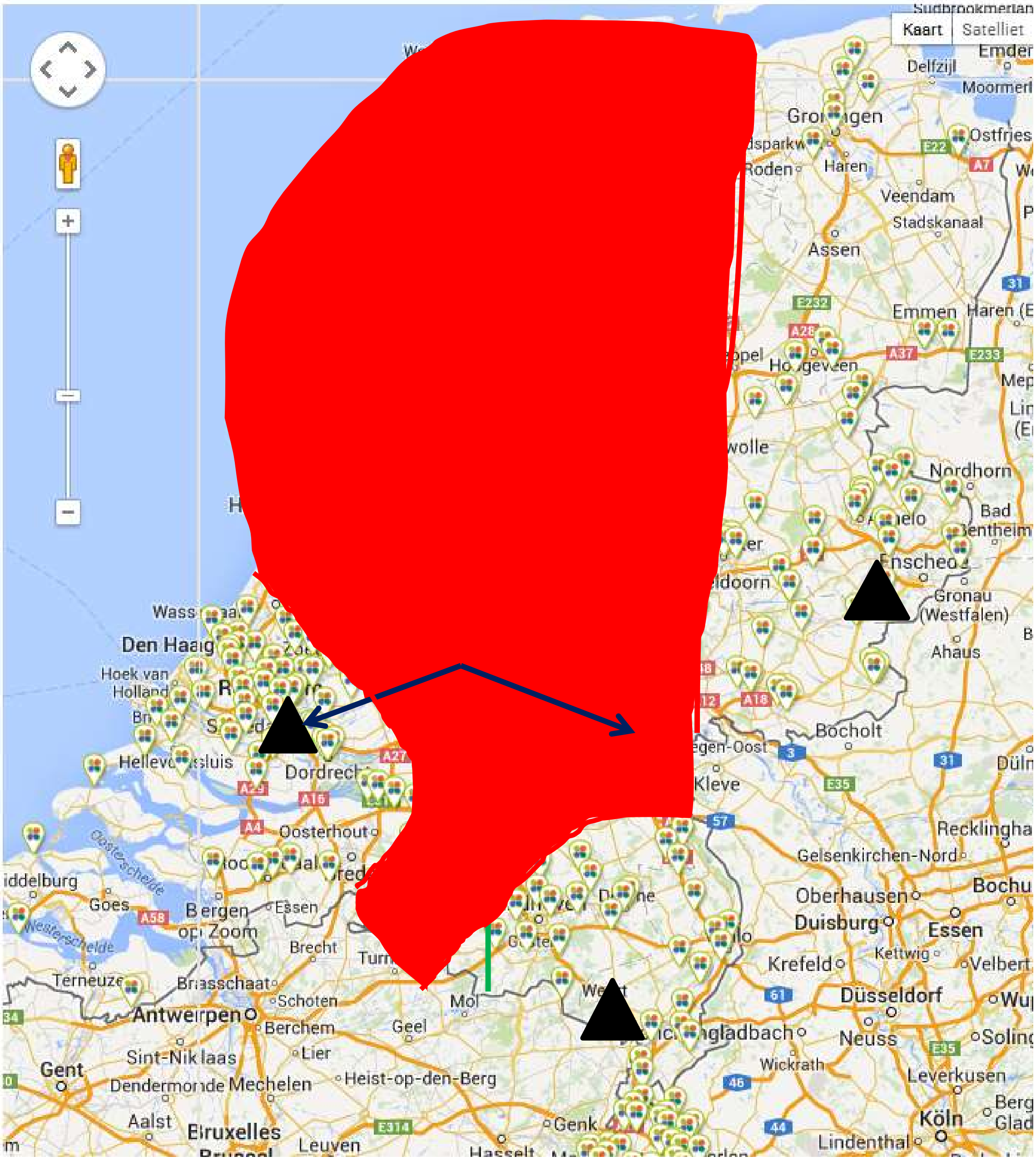
Frozen goods DC (DDC) Frozen goods, Van Heezik PLUS
Neutronweg 5, 3542 AH UTRECHT

Appendix C: pictures for material handling

 **Roll Container** 810 x 720	 **Dolly** 603 x 403 x 152 mm (1/4 pallet)
 **Fresh Roll Container Hollander** 855 x 600 x 1554 mm	 **Rolly** 811 x 605 x 182 mm (1/2 pallet)

Appendix D:

Map for the DC analysis



1DC Utrecht

Current RDCs

2DCs Arnhem

Max. extra distance 1 vs. 2 DCs DCs

Stores near 1 central DC

Division of stores with 2DCs