

MASTER

The utilization of a multi-depot regarded to a single-depot transport and distribution planning in a complex and dynamic environment

Close, M.J.J.

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Eindhoven, April 2009

**The utilization of a Multi-Depot regarded
to a Single-Depot transport and
distribution planning in a complex and
dynamic environment**

by

M.J.J. Close (Marc)

B.Sc. Industrial Engineering and Management Science - TU/e (2006)
Student identity number 0517512

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in Operations Management and Logistics**

Supervisors:

Dr. T. van Woensel, TU/e, OPAC

Prof. dr. A.G. de Kok, TU/e, OPAC

TUE. School of Industrial Engineering, department of Technology Management

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ABSTRACT

This Master's thesis describes the analysis of a multi-depot regarded to a single-depot planning procedure in a complex, dynamic environment of a logistics service provider. As a result of the analysis phase an evaluation model is developed to calculate and visualize the performance of a desired postcode area within the Ambient transport and distribution network. Furthermore, a simulation model, named SHORTREC, is constructed, which concerns the second part of the design phase. SHORTREC is used to provide insight into the situations in which a multi-depot planning is more advantageous than a single-depot planning, in order to minimize total costs. Besides, the simulation model is able to compare alterations in the network with former and/or future situations.

MANAGEMENT SUMMARY

The logistics activities of logistics service provider Nabuurs have increased strongly. As a result the Ambient transport and distribution network has changed fundamentally, i.e. from a single-depot (SD) towards a multi-depot (MD) planning procedure. On the one hand this growth requires more (technological) developments and integral collaboration with long-term clients, but moreover, this produces a higher density of the network and creates opportunities with regard to efficiency. The before mentioned has led to the following research assignment:

“Analyze and substantiate when the utilization of a multi-depot regarded to a single-depot planning is more advisable and cost-reducing, in order to improve the central routing planning of the Ambient transport flows.”

Based on the initial assignment a literature study has been executed. Thereupon, in order to obtain the required insight into the processes, structure and performances of the current Ambient network, an extensive analysis phase has been performed.

Analysis

A centralized MD planning can benefit from the reduction of labour costs and transport costs, as operations can be planned and controlled more tightly and efficiently. However, increasing pressures on reliability, customization, and flexibility continuously affect the logistics structures. Besides, uncertainty in logistics, i.e. by means of stochastic and dynamic elements, has become an extremely important issue. A composed MDVRP literature review has shown that advances in (information) technology simplifies the solving of objective functions considerably. Thereupon, the Tabu search (TS) algorithm appears to be scoring very well in solving the MDVRP and the best solving methods generally make use of a successively performed constructive and improvement phase.

From the analysis phase it can be concluded that within the Ambient network a MD planning system can be utilized to facilitate routes to be planned simultaneously at one or several central sites rather than separately at individual depots. However, the possibility of advantageously centralizing the execution of operations, i.e. tighter and a more efficient planning and controlling, is heavily dependent on the receipt of orders and arrival of information. Concerning the Ambient network, order arrival times and patterns seem to vary between the different clients. Nevertheless, it is shown that only 15% of the total transport volume has to be delivered within 12 hrs, and 47% within 24 hrs. Therefore, the greater part of the incoming order volumes allow an efficient and proactive execution of the Ambient planning activities.

The current Ambient concerns a dynamic and complex MD network, of which the planning occurs reactive rather than proactive. The planning process is centrally controlled, by means of the planning support system ORTEC Transport and Distribution (OTD). Although the forming of rides and routes can be done semi-automatically, this activity is executed manually, because the implementation of OTD is still in progress. Due to the manual planning procedure, the simulation of alterations in the network is time-consuming and makes the use of a planner necessary. E.g., if the current network is changed through the addition of a new client, the influences on the costs (per client) cannot be indicated. In short, the benefits and cost-savings of a MD regarded to SD planning are largely unknown and not utilized in a desirable way.

Although, the almost total loading volume of the Ambient network can be attributed to around 10 depots (of which DCs Ede, Katwijk and Bodegraven already cover 55%), the delivery locations, and consequently the empty KMs, are spread all over the Ambient Benelux setting. Therefore, the ratio between loaded and empty

KMs of a network area would be a substantial performance indicator, e.g. in order to better balance the network. However, in the current situation management reports are not consistently used to monitor or realize performance improvements. Thereupon, a substantial evaluation model for the performance measurement of a network area is not at hand. In short, there is a lack of goal-oriented performance measurement, despite the fact that this is required for revealing insight into improvements and alterations within the Ambient network.

Design

Based on the observations and in order to comply with the abovementioned findings, the initial research assignment is refined towards the following design assignment formulation:

“Design a model to substantiate if for the current Ambient network a MD operating procedure is cost-reducing compared to a SD procedure, and determine the quantitative impact of the change from a SD setting towards a MD setting. Thereupon, implement the model for calculating the influences of changing volumes and/or clients on the costs of the Ambient network.”

In order to execute the design assignment, Ambient performances have to be measured quantitatively and scenario analyses have to be performed. As a result, the decision is made to focus on a simulation study, through which the entire research scope is handled. However, a simulation model is not suitable to evaluate and visualize the executed Ambient activities. Since an evaluation model is also highly desirable within the Ambient network, the design phase is subdivided into two parts:

1. *The development of a performance evaluation model (PEM):*

An evaluation model is developed to calculate and visualize the performance of desired Ambient network areas. The evaluation tool is a result on the lack of insight into the performance of a particular postcode area in terms of empty vs. loaded KMs. A clearly observable output is realized, by means of the software applications MS Excel, Visual Basic and MS Mappoint. By making use of the PEM it is traceable how many rides and KMs the ratio-result is dependent on. Besides the results can easily be evaluated and/or be used as an input for further scenario analysis. The PEM and results are validated, by means of construct and data validity. However, if future analyses are desired, the tool needs to be adapted in terms of data entry and data correction.

2. *The development and implementation of a simulation model (SHORTREC):*

In order to execute the formulated design assignment a simulation model is constructed, which is named SHORTREC. Next to OTD, SHORTREC is another advanced planning software solution provided by ORTEC. The tactical tool is used to provide insight into the situations in which a MD planning is more advantageous than a SD planning, in order to minimize total costs. Besides, the simulation model is able to optimize the Ambient transport and distribution planning and to compare alterations in the network with former and/or future situations. The solver is based on a two-phase strategy consisted of constructive and improvement algorithms, with a TS included. From the model validation and verification it can be concluded that the model can be utilized for its intended purpose.

Results

From the results it has been concluded that SHORTREC is an appropriate tool for supporting the current Ambient planning, on a tactical rather than operational level. The planning system is able to rapidly produce optimal route combinations and realize quantitative comparisons with future Ambient situations. Through simulation several experiments have been executed from four different perspectives. The main results of the scenario analyses are:

-
- For the benefit of an automatically performed SHORTREC planning compared to a current manual planning of 32 orders, a cost-reduction of 8% is achieved through a decrease of the total amount of KMs and working time. However, the number of vehicles is increased with 10% but the number of rides has remained the same. As regards the main difference, within the manual planning similar rides are planned more frequently, whereas SHORTREC combines the depots, orders and drivers more interchangeable. Although, small reactive changes and adaptations are easier applied to the manual planning, an automatically performed SHORTREC solution takes only a few minutes, instead of several hours for a manual planning.
 - With regard to the main objective of this study, it is indicated what the cost-savings are of a growing Ambient network, while comparing MD to SD. From the results it can be concluded that in general, by switching from a SD towards a MD setting, an increasing cost-reduction is achieved. Thereupon, an increasing cost-saving is gained in case the order volume is growing. However, it is recommendable to re-execute this experiment whenever the network is changed. i.e. changes in the number of long-term clients and/or depots.
 - Within the comparison between an Ambient reactively vs. proactively performed planning, the latter is very well modelled with the help of SHORTREC Multiday, i.e. a different SHORTREC design. For modelling the reactive Ambient planning the following setting is found to be most suitable within this research: a reactive Ambient planning with a free start-location in day one and a free end-location in day two. The results show a cost improvement of 14.77% for the benefit of the proactive planning with a time horizon of 48 hrs and an amount of 100 orders a day (i.e. 200 orders in total). Besides, a reduction of 6 vehicles is achieved and 16% of the total number of combinations is planned to have a night's rest. The latter shows a substantial dissimilarity, since in the actual Ambient situation at least 50% of the drivers overnight in their vehicle.
 - As a basis for the fourth experiment the client FFWE (DC Ede) is assumed to be a new client within the Ambient network. The results show that if the client's 75 orders are executed within the current Ambient network, instead of using its own transport and distribution activities, a cost-reduction is achieved of 9.43% and even 11 vehicles are saved. The latter indicates a huge client's investment that can be avoided by making use of Nabuurs' logistics services.

Recommendations are based on the results and advise Ambient to focus on the following points of interest:

- *Transforming from a reactive to a proactive planning procedure*, to attain improvements in profitably applying night's rest of drivers and correctly determining points of departure of the vehicle fleet.
- *The utilization of automatic planning support*. It is demonstrated that in case a complex and dynamic MD network like Ambient is growing, generally more cost-benefits can be achieved. However, the latter requires more and more calculations and improvements of complex solutions, which is hardly practicable without automatic planning support.
- *Measuring and evaluating Ambient performances*, to continually utilize MD advantages in a best possible way. Since the MD cost-advantages of the Ambient network mainly depend on the multi-use and interchange-ability of vehicles, a cross-docking research would be highly interesting in all probability.
- *Adaptation of invoicing policy*, which is required in order to realize an improved daily Ambient planning. A consistent tariff structure should divide the cost-savings and corresponding profits in a suitable way.
- *Improvement of current procedures*, since many Ambient data files within the database are not correctly stored and/or used. By improving the accuracy and consistency of data all daily Ambient activities, e.g. planning, performance measurements and analyses, can be improved and executed more efficiently.

PREFACE

This Master's thesis is the result of a six-month graduation project undertaken within the Ambient division of Nabuurs. This challenging logistics project marks the end of both the master's programme Operations Management & Logistics and my student days at the Eindhoven University of Technology. The latter, has been characterized by perseverance, development and fun, to put it briefly an unforgettable time. I would like to take this opportunity to show my gratitude to the people who were there for me, not only during this project, but for the entire period I have spent at university.

First of all, I thank my company supervisors, Tjebbe Nabuurs and Kees Menken, for providing me the chance to apply my acquired knowledge to real-life and to experience the ins and outs of this interesting organization. The critical look of Kees, combined with a giving ear and prompt action have led to a progressive project, in which he has given me the right mix of freedom and support for successfully executing the assignment. Besides, I want to thank Lize van Duinkerken of ORTEC and everybody more who helped me executing this project, by providing me the assistance and information on repeated occasions.

Furthermore, I would like to thank my university supervisors. I thank Tom van Woensel for his guidance and support during the past 1.5 year of my master's. It is fantastic to have a supervisor as Tom who shows so much attention and involvement whether it meets his planning or not. The frequent, short meetings and his flexibility in making these appointments have continually helped me to stay focused and follow the right direction. I thank Ton de Kok, for helping me find this interesting graduation project and providing me with the right feedback and structural approach. Working with two scientists like Tom and Ton has been extremely inspiring and stimulating throughout this project.

To conclude this preface, I would like to thank all my friends and fellow students for giving me that wonderful time and pleasant stay in Eindhoven. Last but certainly not least, my parents, sister and family, I am privileged with a family like this and I have you to thank for this all. Denise what can I say more, special thanks, I am sure that you are my prop and stay for life.

Marc Close

April 2009

"Those who speak most of progress measure it by quantity and not by quality."
George Santayana (1863 - 1952)

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CHAPTER 1. INTRODUCTION

In the first section of this introductory chapter a brief description about Nabuurs is given, including its mission in terms of services, its size, and internal structure. In section 2 the company ORTEC is described in short, since ORTEC plays an important role in this project. The initial research assignment is stated in section 3. Finally, in the last two sections the research model and the report structure are presented.

1.1. Nabuurs B.V.

Headquartered in Haps, the Netherlands, Nabuurs B.V. was founded in 1962 by Jacques Nabuurs. Starting with one truck for transporting live poultry, the company has now grown into the number 32 of the 2008 top 50 logistics service providers in the Netherlands (Logistiekkrant, 2008). Nowadays, Nabuurs has an annual turnover of more than 70 million euro and comprises 12 establishments, located in the Netherlands, Belgium, Germany and Poland (Annual report Nabuurs, 2007). The family business, directed by Tjebbe and Ard Nabuurs, employs more than 550 employees and the entire organizational structure is presented in the figure below.

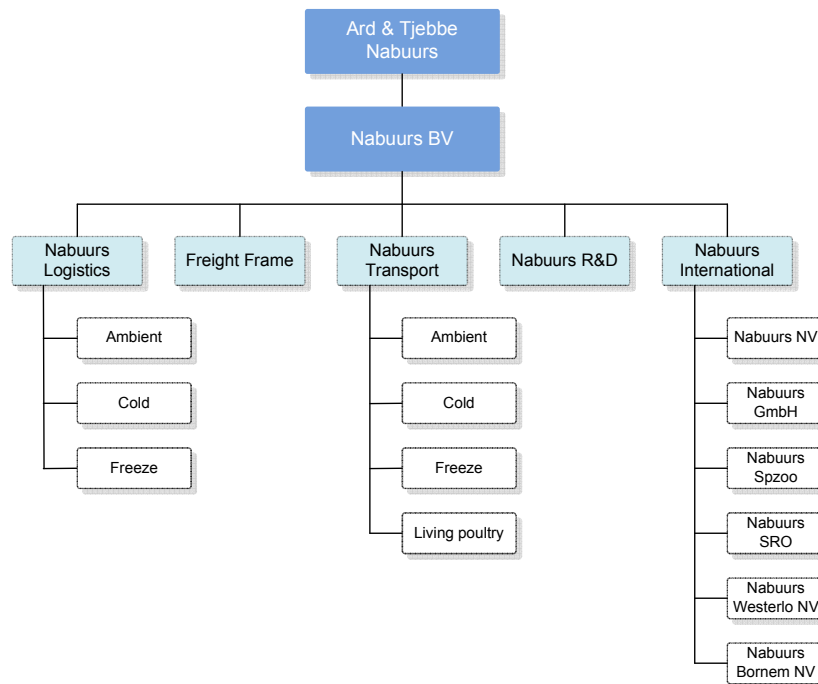


Figure 1.1: Organization chart Nabuurs

The core activity of Nabuurs outside the Netherlands, is transport. Within the Netherlands both transport and warehousing are of great importance. Different distribution centres (DCs) are located in among others Ede, Katwijk aan de Maas, Bodegraven and Breda and from there the number of daily rides¹ are around 75, 35, 25 and 15, respectively. Furthermore, rides are carried out from production locations to different DCs. At the locations Katwijk, Haps, Westerlo, Heijen, Breda and Bodegraven transport as well as warehousing take place. Next to these logistical services, Nabuurs owns a private truck service in order to maintain the fleet. The unit Truck Service is also standing by to serve fleets of colleague-organizations. In addition, a subsidiary of Nabuurs, named Freight Frame, operates as an independent company from within the

¹ Based on the data of August 2008, obtained from the Data Warehouse (DWH).

Nabuurs Group. Freight Frame is specialized in transport between the Benelux, on the one hand, and Finland and the Baltic countries, on the other. Summarizing, Nabuurs currently encompasses Nabuurs Transport, Nabuurs Logistics, Nabuurs Truck Service, Freight Frame and the holding company, Nabuurs Group.

1.1.1. Market segments

The aim of the company's subdivision into the above-mentioned independent operating units is to offer the customers the most effective and efficient service package possible, which is based on four market segments. Below, the four market segments in which Nabuurs provides its services are successively described.

- *Refrigerated*: This market segment concerns refrigerated products, in which Nabuurs offers distribution services for the retail and wholesale sectors. In order to maintain the required product conditions, the trucks and warehouses are fully equipped with temperature control systems.
- *Frozen*: Next to the refrigerated products, Nabuurs is also able to take care of all the distribution, storage and picking requirements in the frozen foods department.
- *Dry*: The Dry market segment covers foodstuff as well as non-food products. However, the emphasis lies on the warehousing and transport of non-conditioned foodstuffs. In reference to Nabuurs' activities the supply chains for the market segments Refrigerated, Frozen and Dry are equivalent, and are shown in Figure 1.2.

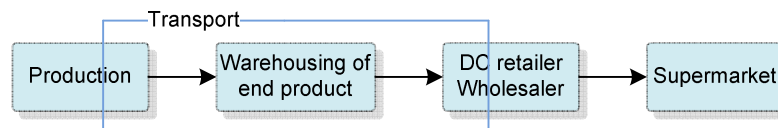


Figure 1.2: Supply Chain for the segments Refrigerated, Frozen and Dry

- *Live*: This market sector includes the transport of poultry from chicken farms to abattoirs. However Nabuurs is able to take over the entire poultry supply, i.e. from catching and transport to just-in-time (JIT) delivery and handling at the factory. Since Nabuurs transports more than 600,000 chickens a day, they are now market leader in the Netherlands. The supply chain which characterizes the market segment Live is presented in Figure 1.3.

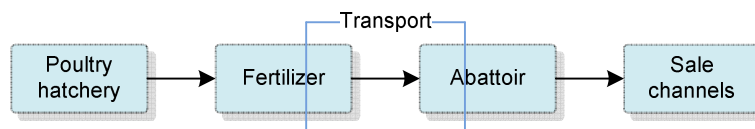


Figure 1.3: Supply Chain for the segment Live (Poultry)

By being active in these four market segments Nabuurs serves customers in various branches. However, the most customers are active in the Fast Moving Consumer Goods (FMCG) industry, and, more specifically, the foodstuffs industry. The relationships between the four market segments and subdivisions of Nabuurs, with corresponding indicators, is presented in Table A.1 of Appendix A. From the data it can be concluded that the market segment Dry provides the largest share of revenues as well as the number of trucks and employees. Furthermore, the Table shows the designation Ambient, which regards the interface between the Dry segment and the provided service activities transport and logistics. Since the Ambient network concerns the research environment throughout this project, it is separately described in the next section.

1.1.2. Ambient

Thanks to centrally located establishments in the Netherlands and Belgium (e.g. Katwijk, Zoetermeer, Bornem) Nabuurs has an effective distribution network in the Benelux. Nowadays the Ambient network

includes the following long-term (direct) clients: Friesland Foods Western Europe (FFWE), Refresco (i.e. Menken & Krings), SCA Tissue, Hero, Heinz, Nutricia, and Hak. The company FFWE is in terms of size and profits the main customer of Nabuurs' Ambient division. Although the headquarters of Nabuurs is located in Haps, the entire Ambient transport and distribution planning is centrally controlled at the office in Ede, which is located besides a production facility of Friesland Foods.

The Ambient division consists of:

- Ambient Transport: Distribution of dry products (i.e. non-conditioned foodstuffs and non-food products, with a few exceptions, e.g. the Coolbest products of FFWE) in the Netherlands, Belgium and Germany towards the retailers, wholesaler and institutional markets (Annual report, 2007).
- Ambient Logistics: The inbound, outbound, storage and transfer activities of dry products in logistic spaces located in among others Katwijk (Annual report, 2007).

The research project is focused on the transport and distribution planning, whereby the warehousing activities (i.e. Ambient Logistics) are left out of consideration. A possible distinction can be made between distribution and transport, which will be discussed in more detail in chapter 3. Despite this distinction, in this report the terms transport and distribution are both used, but in general, aim at the Ambient activities.

As stated by Van den Berg (2006, pp. 30), the problem situation for the Ambient transport flows can be described as a: *"Dynamic Heterogeneous Multi-Vehicle Multi-Depot Pickup and Delivery Problem with Time Windows and Driver's Work Rule Constraints"*. A planning support system, named ORTEC Transport & Distribution (OTD), is implemented for supporting and improving the Ambient transport and distribution activities. Moreover, OTD is supposed to be working according to the above-mentioned problem situation.

1.2. ORTEC B.V.

In 1981 the company ORTEC was established in Rotterdam, whereupon its first automated planning system was launched in 1985. Its mission is to support business and government with strategic and operational decision-making, by means of three core competences: business knowledge, ICT and operations research (OR). Nowadays, the company is comprised of two units, i.e. ORTEC Financial Consultants and ORTEC Logistics Consultants, with more than 700 employees in total and over 800 customers worldwide. In 2007, the total revenues were equal to €52 million.

The headquarters of the Dutch logistics part is located in Gouda. However, offices can be found in Germany, France, Belgium, the United Kingdom, Romania and North America. Since the establishment, ORTEC has developed several decision-supporting systems, and is now one of the largest providers of advanced planning and optimization software solutions and consulting services. The logistic planning solutions are:

- HARMONY: Roster planning
- LOADDESIGNER: Load planning
- OTD / OSP: New generation of trip and route planning
- ORION: Forecasting and inventory planning
- PLANWISE: Production planning
- SHORTREC: Trip and route planning

1.3. Research Assignment

Since Nabuurs started to work for Nutricia in 1968, the logistics activities of non-conditioned foodstuffs have increased strongly. These days, the Ambient network still extends continuously. On the one hand this

requires more (technological) developments and integral collaboration with (long-term) clients, but moreover, this produces a higher density of the network and creates opportunities with regard to efficiency. As a result the Ambient division has changed fundamentally, i.e. from a single-depot (SD) network to a multi-depot (MD) network.

As stated by Eibl (1996), by making use of a MD planning a system facilitates routes to be planned simultaneously at one or several central sites rather than separately at each individual depot. This would significantly reduce labour costs and transport costs, as operations can be planned and controlled more tightly and efficiently than when they are decentralized. Although, Nabuurs has already made the step toward a MD planning, the planning activities still occur manually and the insight into changes and cost-savings is lacking. Therefore, a MD research needs to be executed and changes have to be verified. Together this leads to the research assignment of this project:

“Analyze and substantiate when the utilization of a multi-depot regarded to a single-depot planning is more advisable and cost-reducing, in order to improve the central routing planning of the Ambient transport flows.”

1.4. Methodology

The project is executed according to the solution oriented approach of Kempen and Keizer (2000), which concerns a ten steps methodology that is specifically developed for supporting business problem-solving projects (Van Aken et al., 2007). The solution oriented approach follows the five phases (i.e. problem definition, analysis, design, implementation, and evaluation) of the regulative cycle (Van Strien, 1997). Figure 1.4 summarizes the research model of this project, in which the regulative cycle is interrelated and presented at the top of the model. The research model introduced by Verschuren and Doorewaard (1995), regards the confrontation of theoretical knowledge on the one hand, and practice on the other. The theoretical perspectives and the practical situation of the research subject are compared to come to a further diagnosis of the business problem and exploration of redesign directions. The research model provides the structure of this report.

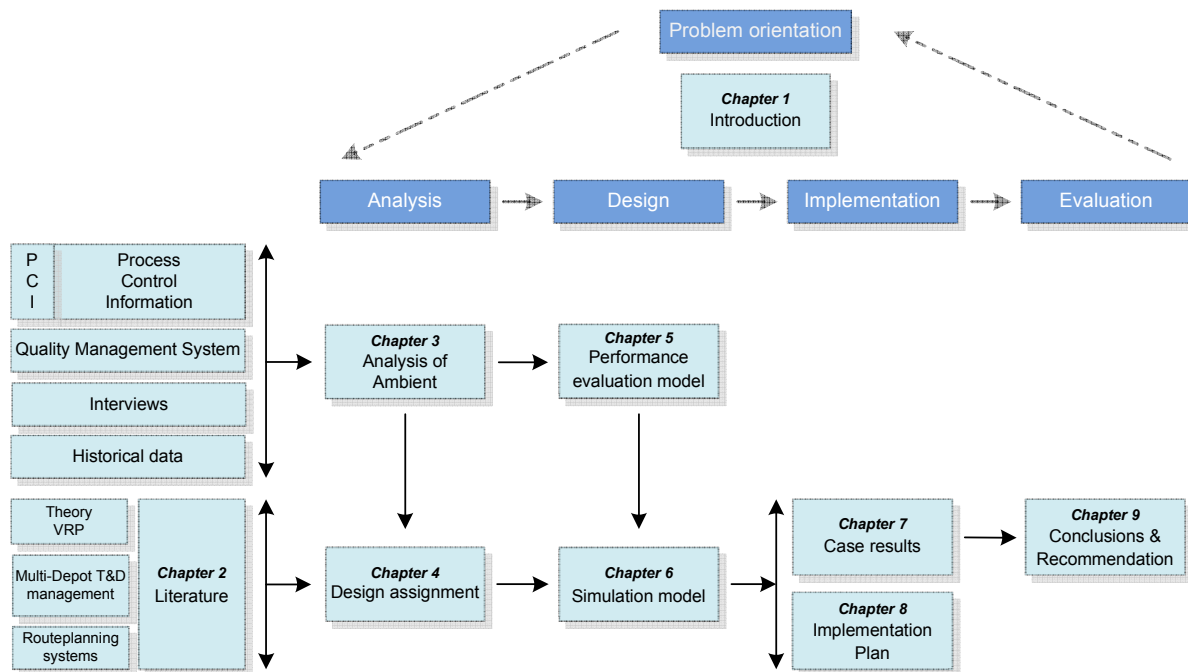


Figure 1.4: Research model

The first phase of the regulative cycle concerns the project orientation, with the aim to become familiar with the organization and to formulate the initial assignment, scope and targets. The achievement of this goal is done by conducting interviews and getting acquainted with systems and processes. In parallel to the orientation phase a literature study is executed to obtain more insight into the research area from a theoretical point of view. Through this, the practical situations are compared to the theoretical perspectives, conformable to the intentions of the research model. The results of the project orientation and the literature research have served as a guiding principle for the following phases.

The second phase includes the analysis phase in which the structure and processes of the current situation are discovered. Besides, in this phase the required insight is gained into the performances of the Ambient network. In order to structure the analyses the PCI model of Bemelmans (1986) is used, in which a distinction is made between the elements process, control and information. Sources of information used for the analyses are interviews with employees at different positions in the organization (at offices in Ede and Haps), discussions with ORTEC consultants and data from the DWH. Furthermore, the quality management system (QMS) of Nabuurs is used in which processes and procedures are formally defined.

Based on the insight and results of the preceding phases (i.e. orientation, literature study and analyses) a final research project is defined. The objective in this stage is the definition of the specific final assignment and key targets, which occupy a central stage in the design phase of the project.

The design phase is started with the development of a performance evaluation model. The analysis phase has revealed that the Ambient division has no insight into the performance per delivery-location (e.g. in terms of empty vs. loaded KMs, ride length relations). The model is able to visualize the desired performance outcome of a particular postcode area. It serves as an extension of the analysis phase and supports subsequent phases of the project.

The second part of the design phase concerns the constructed simulation model so as to demonstrate the final assignment formulation. The simulation model is implemented within a software tool, named SHORTREC, which is a tactical route planning system provided by ORTEC. For future use of SHORTREC, e.g. to simulate and compare changing scenarios, the simulation model is installed on a Nabuurs computer system.

The phases implementation and evaluation together cover the final stage of this project. The implementation phase and design phase are closely interrelated. The experiments have been discussed comprehensively and a simulation plan is formulated. Furthermore, the results have been shared with the stakeholders in order to provide the required insights for its redefinition. To conclude, in the evaluation phase the relevant conclusions are drawn and recommendations are provided for further research activities.

1.5. Structure of report

This report is structured as follows: The next chapter reviews the existing literature on the research area. Chapter 3 presents the analysis phase of the current Ambient network. Thereupon, the final research scope is defined in chapter 4, which results in the formulation of the design assignment. In chapter 5 the developed performance evaluation model is defined with the obtained results. Chapter 6 describes the SHORTREC simulation model. Based on this, the design results are discussed in chapter 7 and the implementation plan is described in chapter 8. Chapter 9 provides the conclusions and recommendations. Finally, the reading guides (i.e. list of Figures, Tables and Abbreviations) and Table of Appendices are shown at the end of this report.

CHAPTER 2. LITERATURE

In order to provide the requisite insight from a theoretical point of view, in this chapter we describe the literature that is related to the initial research scope stated in the previous chapter. First, an introduction is given in section 1. Here it is clarified how in the literature is dealt with the optimization of transport and distribution, by means of the Vehicle Routing Problem (VRP). In section 2, it is described how the number of depots is affected by trends in distribution logistics, and how trade-offs are related to inter-dependent cost factors. Finally, the Multi-Depot VRP (MDVRP) is extensively described in section 4, after which the chapter is concluded in the last section.

2.1. Introduction

As logistics was originally dedicated to the automation of production processes, in order to organize industrial manufacturing as efficiently as possible, the subsequent modernization of logistics can be characterized by an increasing degree of integration (Hesse and Rodrique, 2004). The general trend in logistics is towards a more coordinated and integrated design and control of all of the components, in order to provide goods and services to the customer at low cost and high service levels. In the logistics management literature (Cooper et al., 1991) emphasis is normally placed on the possibility to achieve effectiveness and efficiency simultaneously. Effectiveness aims at the extent to which customer satisfaction is reached and efficiency refers to minimizing logistics costs. *Transportation* occupies a central position in almost every supply chain flow and is therefore a main component of supply chain competitiveness. According to Coyle et al. (1996), transportation costs represent approximately 40% - 50% of total logistics costs and 4% - 10% of the product selling price for many companies. Transportation is regarded as the core of logistic systems and the optimization of transportation costs has appeared in the literature as early as in 1939 (Zhang et al., 2007). According to Toth and Vigo (2002), the *distribution* of goods concerns the customer service by a set of drivers, in a given time period, by making use of vehicles which are located in one or more depots, and which perform their movements by using an appropriate road network.

Delivering goods located at a depot to customers who have placed these orders, is a daily recurrent matter. The goal of these common problems is minimizing the costs of distributing the goods and widely known as the Vehicle Routing Problem (VRP). In brief, VRP is a generic name for problems that deal with the determination of the optimal set of routes for a number of geographically dispersed cities or customers, by making use of a fleet of vehicles based at one or several depots. After the VRP was formulated by Dantzig and Ramser (1959), who called it the truck dispatching problem, many improvements and variants of this heuristic method have been published in the literature. The objectives that can be considered for the classical VRP are:

- Minimization of the (global) transportation costs
- Minimization of the number of vehicles (or drivers) required to serve all the customers
- Minimization of the penalties associated with partial service of the customers
- Balancing of the routes, for travel time and vehicle load

In recent years several new meta-heuristics have been put forward for solving the VRP, which combine a variety of principles including population search, tabu-search (TS) and learning mechanisms (Cordeau et al., 2005). According to the results of "A guide to VRP heuristics" by Cordeau et al. (2002), the classical heuristics do not score well on accuracy and flexibility. However, the Clarke and Wright (1964) heuristic has the distinct advantage of being very quick and simple to implement. Among the tabu search (TS) algorithms, there has been a tendency toward increased speed and simplicity. Besides, among stand-alone heuristics, the unified tabu search algorithm (UTSA) scores very well on all dimensions, i.e. simplicity,

flexibility, accuracy and speed (Cordeau et al., 2002). In Appendix B.1 the basic VRP is described in more detail and an overview is given of the most common VRP variants in literature.

2.2. Number of depots

Although many papers have been published on the classical VRP, only a few have been dealing with the MDVRP. It is therefore not surprising that literature regarding the comparison between SD and MD, is very scarce as well. Although a few researchers (e.g. Nagy and Salhi, 2005; Cordeau et al., 2001) have extended their methods for a SD solution toward a method also applicable for a MD setting, no comparison has been made between the number of depots. In this section the focus lies on how the number of depots is affected by trends in distribution logistics, and how trade-offs are related to inter-dependent cost factors.

2.2.1. Trends

According to Tavasszy et al. (2003), in qualitative terms, long term trends in logistics services indicate a growing degree of product customization and an increased responsiveness in order delivery. New demands on distribution structures can be characterized by an increased pressure on reliability, customization, and flexibility. However, a change in these logistics structures is often linked to the trade-off between transport and inventory costs, which determines the degree of centralization of inventories. Structure with many depots and small and frequent shipments will emerge when firms are primarily service oriented, and will generally be preferred when transport rates are high (Tavasszy et al., 2003).

2.2.2. Cost curve

Following Rushton et al. (2006), larger DCs can benefit from for instance space and equipment utilization or spreading overhead costs over the higher throughput. The latter aims at the economies of scale principle, i.e. cost advantages that a firm obtains due to expansion. By concerning the distribution of goods, a logistic firm might benefit from expanding the number of sites, since the cost of a delivery is essentially dependent on the distance that has to be travelled. According to Rushton et al. (2006), the total transport costs, consisted of both primary and delivery transport, is related to the number of DCs in a distribution network. The total transport costs follow a similar path as the local delivery cost curve shown in Figure 2.1. It can be seen that the total transport costs reduce, as soon as the number of sites increase.

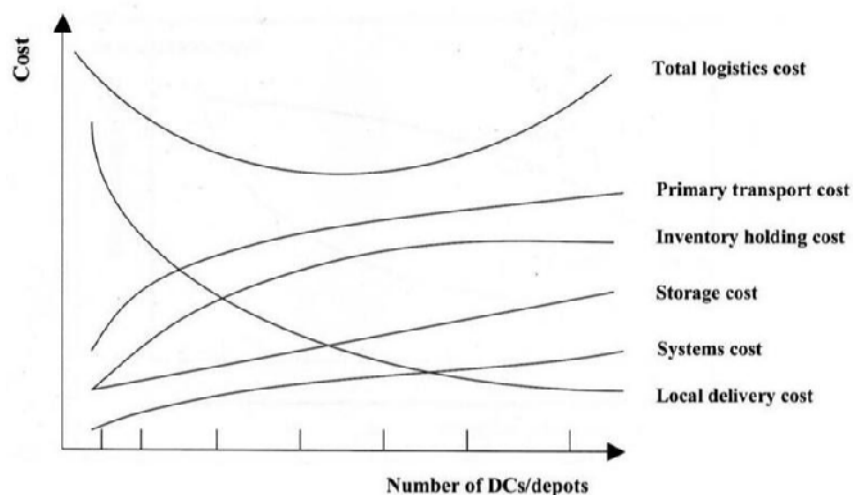


Figure 2.1: The relationship between logistics costs and the nr. of depots (Rushton et al., 2006)

Unfortunately, in addition to these profits the counterparts cannot be avoided, for example the cost of holding inventory. Key costs of holding inventory can be subdivided into four main areas, namely capital costs, service costs, risk costs and storage costs (Rushton et al., 2006). In Tavasszy et al. (2003), an example of a categorization is given with regard to the increase and decrease of transport and handling costs on the one hand, and inventory costs on the other. The categorized overview is shown in Table 2.1 below.

	<i>Transport & handling costs</i>	<i>Inventory costs</i>
<i>Cost increase</i>	<ul style="list-style-type: none"> - Internalization of external costs - Congestion - Unreliability of transport systems and their related waiting times - Reductions in lead time and the responsiveness requirements of demanding 	<ul style="list-style-type: none"> - Value density of products - Interest rates - Focused factories (factories that are specialized on a type of products only) - Product explosion (increase of product varieties)
<i>Cost decrease</i>	<ul style="list-style-type: none"> - The consolidation of freight flows - The design of integrated networks - The improved quality and professional standards of logistics service providers - The implementation of IT systems that improve efficiency 	<ul style="list-style-type: none"> - Reduction of pipeline length - Reduced levels of safety stock - Reduction of inventories through reduction in the nr. of inventory points and levels of safety stocks

Table 2.1: Factors affecting logistics costs (Tavasszy et al., 2003)

It can be observed that a lot of uncertainty and reduction in responsiveness is a major cost-increasing factor for transport and handling. In order to survive in modern economy markets, companies must quickly respond to the encountered growing time pressures and uncertainties (Psaraftis, 1995). In Appendix B.2 the uncertainty variant of the VRP, which can be divided into a stochastic (SVRP) and dynamic (DVRP) approach, is described in more detail. Following Powell et al. (1995), dynamic and stochastic models are playing an increasingly important role if decision making is required before all the information is available, and decisions are modified whenever new information is obtained. It can be concluded that uncertainty in routing planning is being caused by the following three factors: (1) customer demand, (2) travel time, and (3) service time. The problems with a stochastic approach regarding these three factors can, for their part, be solved in two different dynamic approaches. On the one hand, repeatedly solving as new information becomes known. On the other, to develop a model that would consider the anticipated dynamic changes and apply it once at the outset of the period of interest. Moreover, it is shown (e.g. Bertsimas and Simchi-Levi, 1996; Van Woensel et al., 2007) that classical models and techniques have little to say about vehicle routing when stochastic and dynamic elements are included.

By contrast, it is shown that a decrease of transport and handling costs can often be attributed to the design of integrated networks and efficient IT systems. Nevertheless, the total logistics costs are obtained by building up all the individual distribution and logistics costs. The relationships between these total logistics costs and the number of depots in the network, are shown in Figure 2.5. From the figure, it can be concluded that any change in one of the elements is likely to have a significant effect on the costs of both the total system and the remaining elements. Therefore, the concept of trade-off analysis is a key feature of this total cost approach to logistics planning (Rushton et al., 2006).

Since the effects and relationships with regard to the number of depots are clarified above, the next section discusses how in the literature is dealt with the optimization of transport and distribution in a MD setting.

Besides, it provides a description of how the MDVRP is developed in the course of time, and what the recent developments are in solving the MDVRP.

2.3. Multi-Depot Vehicle Routing Problem

As described in the literature, in the case of multiple depots a company has several depots from which it can serve its customers. If the customers are clustered around depots, the distribution problem should be modelled as a set of independent VRPs. However, if the customers and the depots are intermingled then a MDVRP should be solved. As well as the ordinary VRP decisions, a MDVRP requires the assignment of customers to depots. Besides, a fleet of vehicles is based at each depot. The general objective of the MDVRP is to minimize the vehicle fleet and the sum of travel time. Besides, the total demand of commodities must be served from several depots. A solution is feasible if each route satisfies the standard VRP constraints and begins and ends at the same depot.

2.3.1. Literature review

The development of the literature concerning the MDVRP can be typified in a same way as the following statement about the classical VRP: "Since the vehicle scheduling problem was first presented in 1959, the method to solve the problem is developed from an initial C-W heuristic (Clarke and Wright, 1964) to a meta-heuristic algorithm" (Zhang et al., 2007). In order to structure the MDVRP a literature review is constructed and is shown in Table 2.2 below.

Category	Reference	Solving method for the Multi-Depot VRP	# of Depots	# of Customers
Tabu search algorithm	Cordeau et al. (1997) Renaud et al. (1996)	Global optimization meta-heuristic		
Multi-phase heuristic	Chao et al. (1993)	Initialization heuristic combined with an improvement phase	≤ 9	≤ 360
Exact algorithms	Laporte et al. (1988) Laporte et al. (1984)	A branch and bound algorithm which uses a LP relaxation	≤ 3 ≤ 8	≤ 80 ≤ 50
Early heuristics	Raft (1982)	Modular algorithm, clustering, assigning to depot and applying 2-opt exchange procedure	2-5	≤ 249
	Golden et al. (1977)	Two heuristics: 1st a savings method and 2nd assigning customers to depots and solving separate VRP's	≤ 4	≤ 100
	Gillet and Johnson (1976) Wren and Holliday (1972)	Making use of the G-M sweep procedure	2-5 ≤ 2	≤ 249 ≤ 176
	Tillman and Cain (1972) Tillman and Hering (1971) Tillman (1969)	Constructive, using C-W savings criterion and no post-optimization phase		

Table 2.2: Literature review regarding the MDVRP

The classified papers are summarized below, in which the time sequence goes from the past to most recent.

Early heuristics

One of the first methods in order to solve the MDVRP is due to Tillman (1969) and uses the Clarke and Wright (1964) savings criterion. First, each customer is assigned to its nearest depot and then the algorithm constructs back and forward routes between depots and the customers. These routes are gradually merged into larger routes by making use of a savings criterion that takes into account the presence of several depots. In Tillman and Hering (1971) the same idea is used and besides the effect of each potential assignment decision on the next iterations is now considered. Finally, Tillman and Cain (1972) use a partial enumerative scheme that maximizes a savings criterion. All the above heuristics are constructive and do not use a post-optimization phase, which can be seen hereafter.

Exact algorithms

In literature only two algorithms are typified as exact algorithms for the MDVRP. The first was proposed by Laporte et al. (1984) and formulates symmetric problems as integer linear programs with three constraints. After relaxing these constraints (i.e. the sub-tour elimination constraint; chain barring constraint; integrality constraint) the problem is solved by a branch and bound algorithm. In brief, they develop a branch and bound algorithm which uses a LP relaxation, and solve 31 randomly generated test problems that contain up to 25 vertices, including depots and customers. In addition to this, a second exact algorithm was proposed by Laporte et al. (1988) for solving the asymmetric MDVRPs. Still applicable to relatively small instances, but now 80 customers instead of 50 are involved to be solved to optimality. In Laporte et al. (1988) first the problem is transformed into an equivalent constrained assignment problem, after which optimal solutions are found by a branch and bound algorithm.

Multi-phase heuristic

Chao et al. (1993) describe a multi-phase heuristic in which a simple initialization heuristic is combined with an improvement phase that is more powerful than the earlier studies. After the customers are assigned to their closest depot, a VRP is solved for each depot using the modified savings algorithm of Golden et al. (1977). This solution is then improved by moving customers to different depots, and uses the record-to-record meta heuristic by Dueck (1990) to guide the search. The movement of a candidate consists of repositioning a single customer in another route, possibly based at a different depot. The heuristic produces better results than earlier studies on all of the test problems.

Tabu Search algorithm

In 1986 Fred Glover proposed a new approach, named Tabu Search (TS), to allow Local Search (LS) methods to overcome local optima. According to the literature, many elements of this first TS proposal, and some elements of later TS elaborations, were introduced in Glover (1977) in which a short term memory prevents the reversal of recent moves, and longer term frequency memory to reinforce attractive components. In order to avoid cycling, the recently examined solutions were forbidden or declared “tabu” for a certain number of iterations. As mentioned earlier, according to Cordeau et al. (2002), the TS algorithm appears to be well scoring on all dimensions in solving the traditional VRP. Besides, the literature concerning the MDVRP shows a similitude.

Renaud et al. (1996) described a TS heuristic in which the algorithm contains of two parts: (1) construction of an initial solution and (2) tabu search. The initial solution is built by first assigning every customer to its nearest depot. Thereupon, for the solution of the VRP, the “Improved Petal” heuristic developed by the same authors (Renaud et al., 1996) is used. In this petal algorithm a best route selection is made by generating a set of routes that can be supplied by one or two vehicles. Finally, the applied improvement phase is using a

subset of the 4-opt exchange procedure to improve individual routes, swapping customers between routes from the same or different depots, or exchanging customers between three routes.

In Cordeau et al. (1997), an initial solution is again obtained by assigning each customer to its nearest depot. Then, a VRP solution is generated for each depot by means of a sweep algorithm. The initial solution is not necessarily feasible since the number of vehicles available on each day or at each depot is limited. This shows one of the main characteristics of the algorithm: infeasible solutions are allowed throughout the search. Improvements are then performed by transferring a customer between two routes belonging to the same depot, or by relocating a customer in a route belonging to another depot. Continuous diversification is achieved through the penalization of frequent moves. According to Crevier et al. (2007), the TS approach of Cordeau et al. (1997) is probably the best known algorithm for the MDVRP.

2.3.2. Recent literature

Since the literature review shows more or less a path of reaching maturity in solving the MDVRP, the recent literature continues with a more focus towards extensions of the MDVRP. The most relevant variants of the MDVRP, which can be found in the recent literature, are described in Appendix B.3 and are summarized below.

- *MDVRP with Pick-up and Delivery (MDVRPPD)*: In the study of Nagy and Salhi (2005), the aim is to produce a composite heuristic approach, extended to the MD problem, for both the simultaneous and mixed VRPPD. The authors believe that the assumption of delivery-first and pickup-second is unnecessarily restrictive and results in poor quality solutions. Therefore, this model is excluded from their consideration. The objective function of the VRPPD is to minimize the total distance travelled by the vehicles, subject to maximum distance and capacity constraints on the vehicles. The extension to MD problems has not been done before, for the general version of the VRPPD (Nagy and Salhi, 2005).
- *MDVRP with Backhauls (MDVRPB)*: In contrast to Nagy and Salhi (2005), the authors Fan et al. (2007) propose an algorithm with the goal to minimize the total travelling cost instead of total travelling distance. In this article they consider the special case that on each routing the backhauls must be visited after the linehauls. This constraint is motivated by the fact that most vehicles are rearloaded, so it is inconvenient to rearrange onboard delivery loads to accept new pick-up loads (Fan et al., 2007).
- *MDVRP with Time Windows (MDVRPTW)*: According to Cordeau et al. (2004), the MDVRPTW generalizes the VRPTW by considering multiple depots at which the vehicles are based. Important to mention is that in the VRPTW instances, the number of vehicles is not fixed, but instead minimized, as a primary objective. The secondary objective consists of minimizing the total travel time. In this paper new best known solutions are yielded for the MDVRPTW by making use of an improved tabu search algorithm. In this improved TS algorithm again the characteristic of infeasible solutions during the search is allowed, as in the case of Cordeau et al. (1997).
- *MDVRP with Inter-Depot Routes (MDVRPI)*: According to Crevier et al. (2007), the MDVRPI has not received much attention from researchers, and concerns an extension of the MDVRP in which vehicles may be replenished at intermediate depots along their route (Crevier et al., 2007). The algorithmic approach discussed in this paper combines the adaptive memory principle proposed by Rochat and Taillard (1995), a TS method for the solution of sub-problems, and integer programming as well.
- *MDVRP with fixed distribution of vehicles (MDVRPFD)*: One of the remaining extensions is provided by Lim and Wang (2005). They state that the MDVRP is one of the core optimization problems in transportation, logistics, and supply chain management, which minimizes the total travel distance

among a number of given depots. However, the authors state that in real practice, the MDVRP is not reliable because it is assumed that there are unlimited number of vehicles available in each depot. Therefore, the authors propose a new useful variant of the MDVRP, namely the multi-depot vehicle routing problem with fixed distribution of vehicles (MDVRPFD). In order to model this practicable case they make use of both theoretical analysis and heuristic design.

This section has shown the relevant variants of the MDVRP which can be found in the recent literature. However, although it has been concluded before that a lot of uncertainty and reduction in responsiveness is a major cost-increasing factor, unfortunately, no models and solutions for the MDVRP are described yet where uncertainty is taken into account.

2.4. Conclusion

The VRP, formulated by Dantzig and Ramser (1959) who called it the truck dispatching problem, is a generic name for problems that deal with the determination of the optimal set of routes for a number of geographically dispersed cities or customers. Many improvements and variants of the heuristic method are published in the literature. According to Cordeau et al. (2002), none of the classical heuristics scores very well on accuracy and flexibility. Furthermore, with regard to the modernistic methods, among the tabu search algorithms there has been a tendency in recent years toward increased speed and simplicity.

Uncertainty in logistics has become an extremely important issue, because nowadays companies need to focus on timeliness to insure not only their competitiveness, but also their survival. In the case stochastic and dynamic elements are included, classical models and techniques have little to say about vehicle routing (e.g. Bertsimas and Simchi-Levi, 1996; Van Woensel et al., 2007). Besides, in a dynamic setting, the delivery time (wait for service) is often a more appropriate objective instead of minimizing travel distance as the case in the traditional VRP (Bertsimas and Van Ryzin, 1993). It can be concluded that uncertainty in routing planning is possibly caused by (1) customer demands, (2) travel times, and (3) service times. Besides, dynamism can be approached by (1) repeatedly solving as new information becomes known and (2) applying it once at the outset of the period of interest.

A MD situation, in which the company can serve its customers from several depots, is generally described in the literature as the MDVRP. However, here it is assumed that from every depot the distribution of similar types of goods is possible. The review of the existing literature on the MDVRP shows that (1) most existing algorithms for the MDVRP are heuristics, (2) advances in (information) technology simplifies the solving of objective functions considerably and (3) the best solving methods generally make use of a constructive and improvement phase, executed in succession. From the literature the Tabu search algorithm appears to be well scoring on all dimensions in solving both the traditional VRP and the MDVRP. Besides, the TS approach of Cordeau et al. (1997) is probably the best known algorithm for the MDVRP (Crevier et al., 2005).

Trends in logistics services indicate a growing degree of product customization and an increased responsiveness in order delivery. Besides, these increasing pressures on reliability, customization, and flexibility continuously affect the logistics structures. A more service oriented distribution requires for instance a change into a structure with MDs and small and frequent shipments. However, these supply chain management decisions ask for ongoing and appropriate trade-offs regarding total logistics costs.

Although, many papers have been published on the classical VRP, only a few have been dealing with the MDVRP, as well as the comparison between SD and MD. Given the trends and developments in transport and distribution (e.g. globalization and expansion of logistics services), it would be valuable to extend the MDVRP literature with emphasis on uncertainty characteristics.

CHAPTER 3. ANALYSIS OF AMBIENT

This chapter contains the analyses of the current processes, structure and performances regarding the transport and distribution activities within the Ambient network. The aim of this analysis phase is gaining the required detailed insight and creating an overview of the characteristics and problematic nature of the situation as it stands.

In order to achieve the insight in a structured way the PCI-model of Bemelmans (1986) is applied to this analysis phase. This framework provides a structured analysis approach from the perspective of improving the corresponding planning and control structure. Bemelmans supposes that the primary process of an organization determines the required type of control, and thereupon, the information structure regards a result of the adopted control structure. Since Nabuurs performs transport and warehousing activities the main process aims at providing a service. These logistics services affect the objectives and structure of the Ambient division. The Ambient network can be typified as a centrally controlled organizational structure, in which dynamic and uncertain information is involved. In Figure 3.1 the organization of this chapter is outlined by making use of the PCI-model, which is completed with the concepts service, structure and performance. These three key words support the categorization and are applicable to both the PCI-structure and this research project.

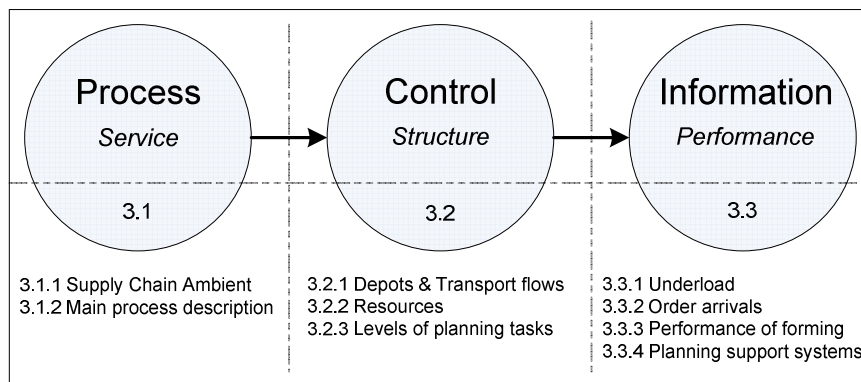


Figure 3.1: Structure of analyses by means of the PCI-model

3.1. Process and service

A process can be defined as a method or system for achieving a commercial result. For Nabuurs, this mainly points to the execution of logistics services, in order to achieve cost-reducing and timely results with regard to transport and distribution. First, the supply chain of the entire Ambient network is depicted in subsection 3.1.1. Second, the main process is described in subsection 3.1.2.

3.1.1. Supply Chain Ambient

In De Kok and Fransoo (2003), the objective of the supply chain operations planning concept is defined as: To coordinate the release of materials and resources in the supply network under consideration such that customer service constraints are met at minimal costs. Logically, a logistics service provider plays a significant role in the realization of this objective, by which often is strived for an integrated supply network. The supply chain is defined as the chain of processes that purchase raw materials, transform them into end-products and distribute these to the end-customers (Lee & Billington, 1993). In order to obtain a clear overview of the network of activities applicable to the Ambient network, the supply chain is pictured and shown in Figure 3.2 below.

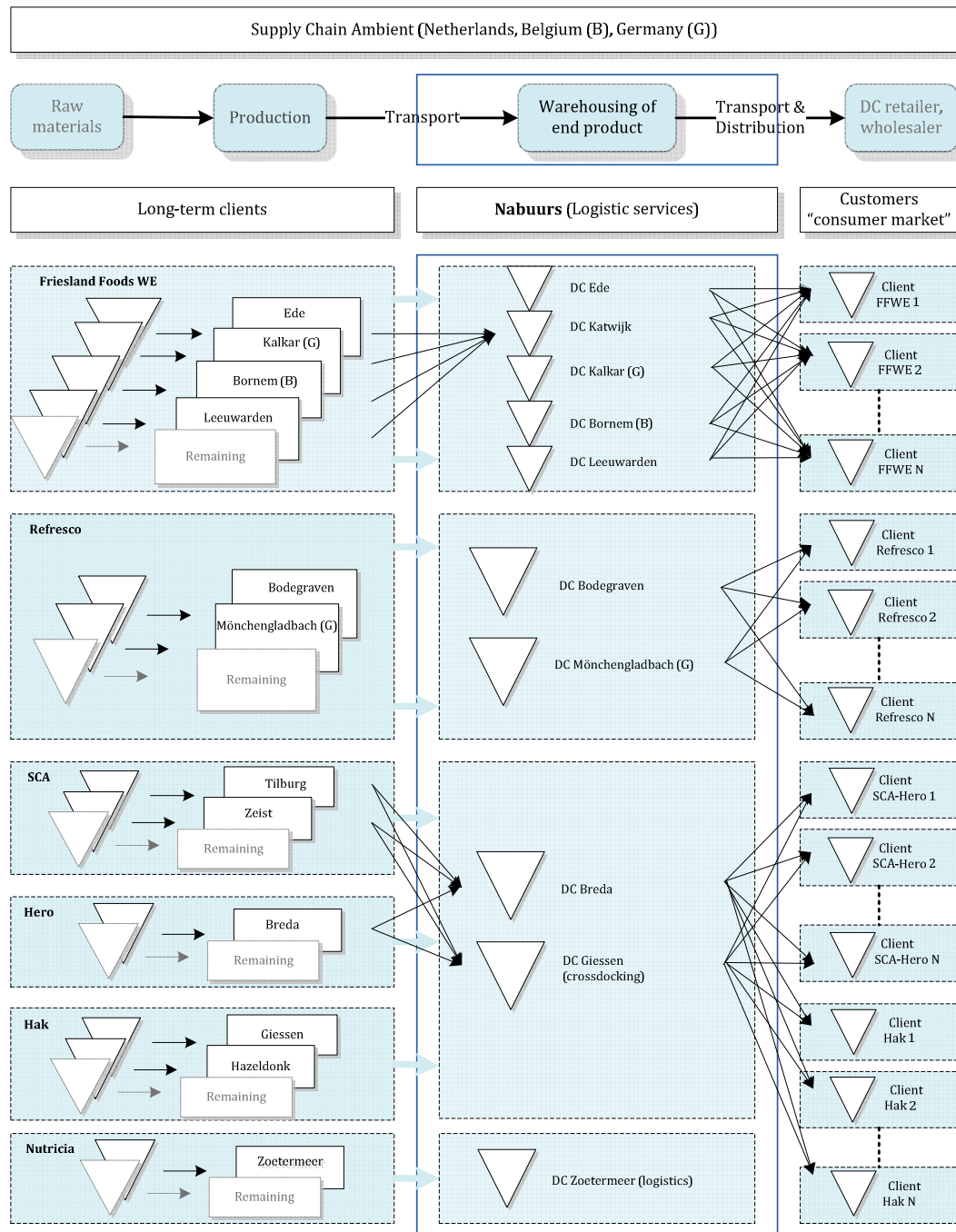


Figure 3.2: Supply chain Ambient

The long-term clients of Nabuurs are the start of the chain and are shown on the left-hand side of the figure, one below the other. These clients concern production companies, which are mainly active in the FMCG market and place transport and distribution orders directly to Nabuurs. The location and size of distribution depots is a strategic issue, but in the case of Nabuurs also dependent on the location of its long-term client. Logically, the orders placed by the clients are dependent on the demand from the consumer market. For that reason, the last customers are the end of the supply chain, which can be seen on the right-hand side of the figure.

Nabuurs is the logistics service provider positioned in the centre of the chain, that broadly speaking, executes three types of services: (1) transport between a production location and/or a DC, (2) warehousing and (3) transport and distribution toward the consumer market. The centrally situated position of Nabuurs can be considered as a dependent position on the supply chain. However, this fact in particular can yield a competitive advantage, by building up and maintaining a long-term relationship with the client. Moreover, a logistics service provider can realize a very strong partnership, by taking over the entire transport and warehousing activities of the client.

3.1.2. Main process description

On the operational level the day-to-day activities take place. In order to obtain a clear picture of the coherent whole of activities, a main process description is desired. Therefore, the main processes are described, which in total comprise the daily Ambient operations. The concerning operational main process is represented schematically in Appendix C, of which each level of activity corresponds to the particular number below.

Commercial (01.1)

Logically, the main process of Nabuurs starts with an agreement between Nabuurs and the client. Both parties, of which Nabuurs in particular, have the advantage to attain a long-term relationship. In this way, systems and procedures can be integrated and more efficiency can be achieved.

Order handling (01.2)

The majority of the incoming orders are downloaded from a client's Warehouse Management System (WMS) and automatically enter the planning system ORTEC Transport & Distribution (OTD). The remaining orders are entered manually, via an OTD order entry. However, deadlines are set for transferring orders, e.g. orders of DC Ede have to be delivered at 11 AM, the day before delivery. Finally, received orders are checked by means of an order list and corrected if required.

Planning (01.3)

After the order handling is finished the planning activities can commence through the system OTD, for which a particular planner is responsible. Orders are combined in a way to strive for a FTL and ideal route, by taking into account the volumes, date and time slots. The sequence of loading and unloading is determined simultaneously. After forming, a ride number is assigned to the ride, by means of a logic. Dependent on specific client and commercial agreements, some rides require feedback because of order picking activities. A ride is handed over to the driver by making use of the board computer, telephone or personally at the counter. Besides, the transport is monitored by making use of OTD, the board computer, and a reporting system. The driver informs the planner when the vehicle becomes empty or in the case a delivery time cannot be met.

Transport (01.4 – 01.8)

After notification a (new) loading location is assigned to the driver, where a transport simply starts and ends with loading and unloading activities. Sometimes a vehicle is pre-loaded, in that case the driver only needs to couple the trailer. An unloading activity starts after arrival at the client, for which the time has to be registered by the driver through the board computer. From a delivery location a return transport can take place as well. However, if there are no more rides available or the working hours of the driver are not permissible anymore, the following possibilities arise: (1) The driver receives a pre-loading task if there is still enough time, (2) the chauffeur drives home, or (3) due to exceeding of working hours the driver is forced to stay the night at the location concerned. In addition, every time a loading and unloading activity is

finished, required waybills and return receipts are exchanged. At the end of a working day waybills have to be handed in at the counter of a DC, on behalf of invoicing processes.

Waybill processing & invoicing (01.9 – 01.10)

At the administration waybills and finished rides are verified. In the case a ride is completed and approved, the information is stored and finally the invoicing procedures are executed from the head office in Haps.

3.2. Control and structure

As mentioned before, the entire Ambient transport and distribution planning is centrally controlled from the office in Ede, but supervised by Nabuurs in Haps. The aim of this section is to discover the relevant Ambient structures and control issues. In the first subsection the depots and transport flows within the Ambient network are discussed. Thereupon, in section 3.2.2 an overview is given of the available Ambient resources. Finally, a description is given of the planning and control tasks, applicable to the different levels of the organization.

3.2.1. Depots and transport flows

Transport includes the movement of goods from a loading location to a place of discharge. It depends on the order type whether the loading location or unloading location concerns a depot. Within a single transport ride one or two depots are involved. Regarding the Ambient transport flows two main transport categories can be considered:

- *Outgoing transport:* Transport from a depot towards a (depot of a) client. For the outgoing transport the order volumes differentiate heavily and the transport flows can concern Less-than-Truckload (LTL) or Full-Truck-Load (FTL)².
- *Intra-transport:* The intra-transport orders always regard FTL rides. The loading location and place of discharge often concerns a production location of a long-term client and/or a DC. The latter regards a client's DC or a warehouse location owned by Nabuurs. Moreover, the transport freight includes end-products, raw materials, or packaging.

In order to make an improvement step towards a more desired transport & distribution planning, the consideration of the current loading and unloading locations are of major concern. In Figure 3.3 below, the significant loading locations are shown³.

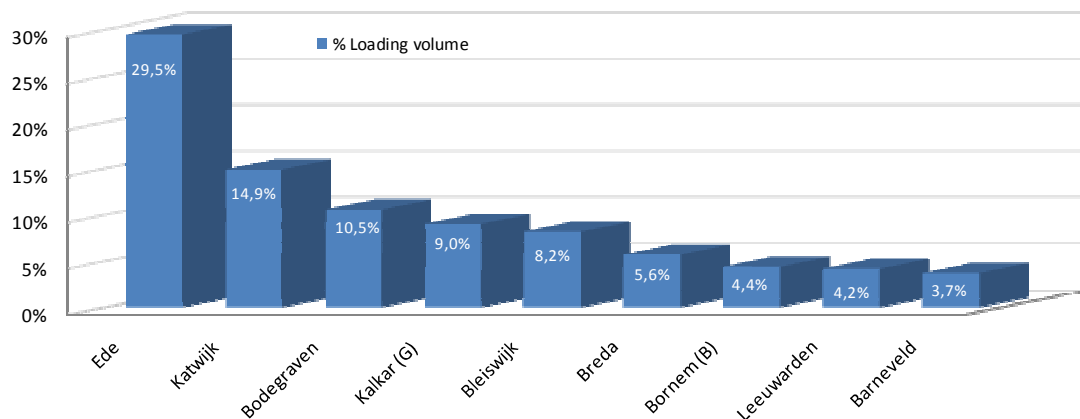


Figure 3.3: Loading locations (together 90% of total loading volume)

² The order volumes are expressed in terms of pallets, with the assumption: $0 < \text{LTL} < 26$ and $\text{FTL} \geq 26$ pallets.

³ The depicted locations cover 90% of the total loading volume. Based on the data of August 2008, obtained from the DWH.

It can be seen that the top three loading locations, i.e. represent the largest portion (55% in total) of the total loading volume, regard the DCs at Ede, Katwijk and Bodegraven. Logically, these locations concern the major clients, FFWE and Menken, of the Ambient network. However, in the current situation the warehousing activities of the Out-of-home (OOH) assortment of FFWE is transferred from Ede to Katwijk. For that reason, regarding the percentage of total loading volume, the locations Katwijk and Ede will probably be switched from position. DC Breda is shown at the sixth position with a result of 5.7 percent of the total loading volume. In Breda and the surrounding area the clients SCA, Hero and Hak are established. From DC Breda and the earlier mentioned DCs Ede, Katwijk and Bodegraven primarily FMCGs are distributed, and therefore belong to the category of outgoing transport. The depicted loading locations Kalkar (Germany), Leeuwarden and Bornem (Belgium) are production locations of FFWE which mainly concern the category of intra-transport (also going by the name of shuttle transport).

The applied data for analyzing the loading locations and depots is also used for discovering the areas for unloading. In Figure 3.4 the ten significant unloading areas are shown, which cover 60% of the total amount of volume being discharged. In this outline the locations are expressed by making use of postcode areas, because not one particular place can be ascribed to every unloading area. However the areas 54, 67 and B28 represent Katwijk, Ede and Bornem (Belgium), respectively.

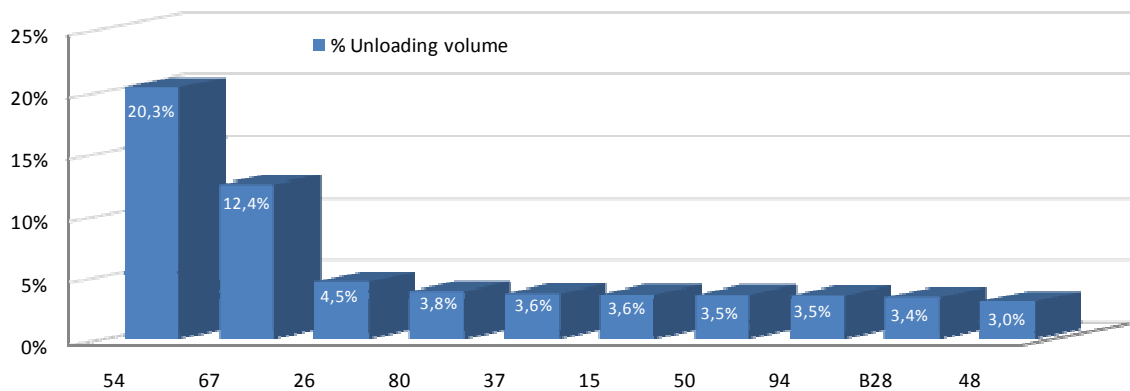


Figure 3.4: Most significant unloading areas

From the figures above it can be concluded that the DCs Ede and Katwijk are playing a significant role within the Ambient network, in the field of both transport and warehousing. Besides, the remaining 40% of the total unloading volume is attributable to many delivery locations.

3.2.2. Resources

An organization's vulnerability to its environment is the result of it needs for resources such as raw materials, labour, capital, equipment, knowledge, and outlets for its products and services (Hatch, 1997). Although the denotation of a resource has a very broad meaning, in this section the meaning of a resource refers to either a driver, or a type of vehicle.

The Ambient fleet of vehicles consists of three different combination types, i.e. the truck and trailer, the refrigerated truck and trailer, and the combination truck and trailer, which together appropriately serve all the clients within the Ambient network. The different types of vehicle combinations are described below (see Appendix D for more details).

-
- *Truck and trailer:* The truck and trailer can be considered as the basic vehicle type. The size of the loading space is 2.5 metre broad and 13.6 metre long. By taking for granted a pallet area of 1.2 m² (i.e. 120 x 100 cm), the available loading space is limited to 26 pallet boards. At the back of the trailer an existing tailgate makes the loading and unloading activities possible. Furthermore, the sidewalls consist of displaceable sails which has two main advantages: first, sideward loading and unloading of cargo is possible, and second, load which is slightly wider in size than the pallet dimension can be transported too (overhang).
 - *Refrigerated truck and trailer:* With regard to the available loading space, loading sizes and volumes, this vehicle is identical to the standard truck and trailer. In order to meet the quality requirements of conditioned freight transport the loading spaces are fully equipped with state-of-the-art equipment and temperature control systems. However, due to climate control the side walls of the trailer are fixed, isolated walls, instead of displaceable sails. Therefore, overhang is not possible and loading and unloading activities can only occur by making use of the tailgate, at the back of the trailer.
 - *Combination truck and trailer:* In the case of a combination the total loading space is divided into a fixed part attached to the truck, and a second part which concerns the trailer. Dependent on the type of vehicle, and again with the assumption of a 1.2 m² pallet area, a combination has space for 28 to 30 pallet boards. As in the case of the standard truck and trailer, the sidewalls consist of displaceable sails, which make both overhang and sideward loading and unloading of cargo possible.

The number of vehicle types owned by Nabuurs within the Ambient network are shown in Table D.1 of appendix D. From the data it can be concluded that the number of active trucks and combination trucks are 51 and 10, respectively. Besides, the total number of trailers amounts to 152, of which 7 concern combination trailers. However, for the daily transport activities Ambient makes use of approximately 100 pre-determined fixed combinations, consisted of a driver and one of the three vehicle combinations as mentioned above. A vehicle is theoretically assigned to a depot which can be seen in the left-hand part of Table D.1, but is allowed to visit different depots. Moreover, based on the collective labour agreements and equipped sleeping facilities in the trucks, Nabuurs can expect the majority of the drivers to stay the night in their vehicle. When a driver is asked to stay the night the chauffeur is disbursed with an additional fee by way of compensation. In actual fact, within the Ambient network approximately 50% of the drivers stay the nights during the entire week, 35% only 2 nights weekly, and 15% return to their starting depot at the end of every working day⁴.

Next to the fact Nabuurs carries out the transport orders by making use of its own resources, a number of fixed charters are deployed as well. Making use of charters regards a planning policy with the intention to firstly occupy the resources of Nabuurs. When the own available resources do not meet the total transport demand, neither do the fixed charters, initially there is sought for more available resources within the Nabuurs organization. If this amount of resources is still insufficient, resources are hired from other external transport companies, but this is an exception rather than a rule.

3.2.3. Levels of planning tasks

From the route planning literature (e.g. Bodin et al., 1983; Rushton et al., 2006) various tasks of vehicle routing and scheduling (VRS) are categorized according to three temporal dimensions, i.e. strategic, tactical

⁴ Based on interviews with the head of Planning.

and operational. The stated planning tasks in the literature are evaluated and the planning tasks which are applicable to the situation at Nabuurs are described below:

- *Long-term planning (1-3 years):* An important strategic task for Nabuurs is the location, size and number of distribution depots, which is also directly and indirectly related to a pre-determined customer service level. Due to the fact that Nabuurs serves as a logistics service provider restrictions exist with regard to the production locations and distribution areas of long-term customers. This affects to a large extent the decision to contract a particular (new) customer within the Ambient network. After all, the size and composition of the vehicle fleet is a major strategic planning task as well. Logically, changes in one of the strategic tasks will often require re-adjustments of lower-level planning tasks.
- *Medium-term planning (> 1 week, < 1 year):* At a tactical level, it is very important for Nabuurs to take into account the planning of distribution sectors, the planning of customer groups and the allocation of these customers to distribution depots. Besides, times and delivery days need to be determined. This directly affects the required planning of fixed or semi-fixed routes, several weeks in advance. Medium-term tasks regarding the resources include the provision of a basis for (1) the driver's payroll, (2) assessing contractors, and (3) decisions on whether to use own vehicles or contract distribution. Finally, reviews of alternative operating procedures have to be considered continuously, e.g. repositioning of vehicles.
- *Short-term planning (1-7 days):* Weekly and daily operations concern the generation of variable routes and the assignment of orders to fixed and semi-fixed routes. Although arrival of last minute customer orders occur, striving for efficiency and optimization of routes is a continuous process. The repositioning of vehicles today with an eye to tomorrow is of major concern, not only on a tactical level but on the short-term as well. Consequently, a thorough insight and immediate calculations of transport and distribution costs are required.

It can be concluded that the relationship between the operational, tactical and strategic level are of great importance throughout this project. Moreover, this research of comparison, between a MD regard to a SD situation, concerns aspects belonging to all planning terms mentioned above.

3.3. Information and performance

Information is not self-producing but serves as a resource for several control and decision processes. Besides, information typifies two perspectives, functional and performance characteristics (Bemelmans, 1986). To support the Ambient activities the flows of information are supported by various IT-systems. Next to the own supportive IT-applications, like Microsoft (MS) Office, DWH and the earlier mentioned OTD, information is also directly linked to the Warehouse Management System (WMS) and Enterprise Resource Planning (ERP) systems of the clients. Thereupon, the performance indicators within the Ambient division determine under what conditions this information has to be produced. This section successfully covers the underload issue of the Ambient network, the order arrival information, the truckload performance and OTD.

3.3.1. Underload

Since in the previous section the unloading areas are depicted (Figure 3.4), this section aims for an additional insight into the delivery of orders and its attendant empty Kilometres (KMs). As mentioned before, two major objectives for a logistics service provider are, the optimal balancing of the routing planning and minimizing total transport costs. Logically, transport costs are directly related to the number of kilometres (KMs), for which often is strived to minimize the empty KMs. Therefore, it can be concluded that a substantial performance measurement for Nabuurs, is the ratio between loaded and empty KMs, in

every particular area within the Ambient network. At the moment, Ambient does not possess an evaluation model for measuring this performance. The major areas coupled with empty KMs are shown in Figure 3.5.

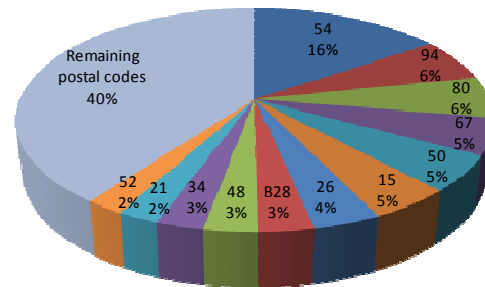


Figure 3.5: The 12 major areas concerning empty KMs (60% of total empty KMs)

From the figure, it can be observed that 16% of the total empty KMs, within the Ambient network, is attributed to postcode area 54 (in this case Katwijk). However, a similar percentage of loaded KMs in that area would indicate a good balance. As mentioned before, a postcode area often regards several unloading locations, which unfortunately is not traceable by means of this pie-chart. Besides, it is not possible to discover the relation to loaded KMs and the frequency of ride lengths, which is of major concern as well. For example, one long ride can comprise the same amount of empty KMs as the case of 10 short rides. Finally, it can be concluded that the percentage of empty KMs is spread all over the Ambient Benelux setting. Therefore, for executing a performance measurement a model has to be developed, which also visualizes the results into a map.

3.3.2. Order arrivals

According to Larsen et al. (2008), in routing applications with time windows (TWs) the reaction time is a very important issue. The reaction time is defined as the temporal distance between the time the request is received and the latest possible time at which the service of the requests should begin. In this section, the order arrivals of the Ambient flows are analyzed. The aim of this analysis is to obtain the relevant information with regard to the order arrival times and patterns, and the dynamism of the incoming orders. However, in this analysis the definition of the reaction time is slightly adapted to, the latest possible time at which the service of the requests should be executed (i.e. latest possible delivery time). Although the number of incoming orders are very important, the (total) transport volume is even more important, from a transport logistics point of view. Moreover, the relationship between the number of orders and the order volumes has to be taken into account as well. The fact is, it can make a great difference whether a late order arrival concerns an FTL or an LTL order.

During the design phase of this project, the order arrival analyses are renewed. In the current situation, the majority of the orders automatically arrive into the planning support system OTD (e.g. via SAP). By combining the creation time (discoverable from the XML-files⁵ created by the client) with the standard order information, the order arrival analyses⁶ are executed for the largest order share of the Ambient network, consisting of the customers FFWE, Menken and HAK. However, it is assumed that the creation time is equal to the order arrival time, because after creation the orders are immediately transferred to Nabuurs, for which the transferring time is negligible. The remaining orders (e.g. SCA, Hero) are still not automatically placed into OTD and are planned with the help of an older planning tool, named TRACC.

⁵ XML (Extensible Markup Language) is a general-purpose specification for creating custom markup languages, used in order to aid information systems in sharing structured data, especially via the Internet.

⁶ Based on the data of week 50 of the year 2008, obtained from the DWH.

Order arrival flows FFWE

The customer orders that arrive from FFWE are subdivided in two categories, i.e. orders from DC Ede and orders from DC Katwijk. Both order flows are described successively and are presented in the figures below. In the figures, both the cumulative percentage of transport volume and the number of orders are plotted, against the time in hours (hrs) between the order arrival and the latest delivery. The blue-coloured area represents the transport volume, next to which the grey line concerns the number of orders, both expressed in a cumulative percentage.

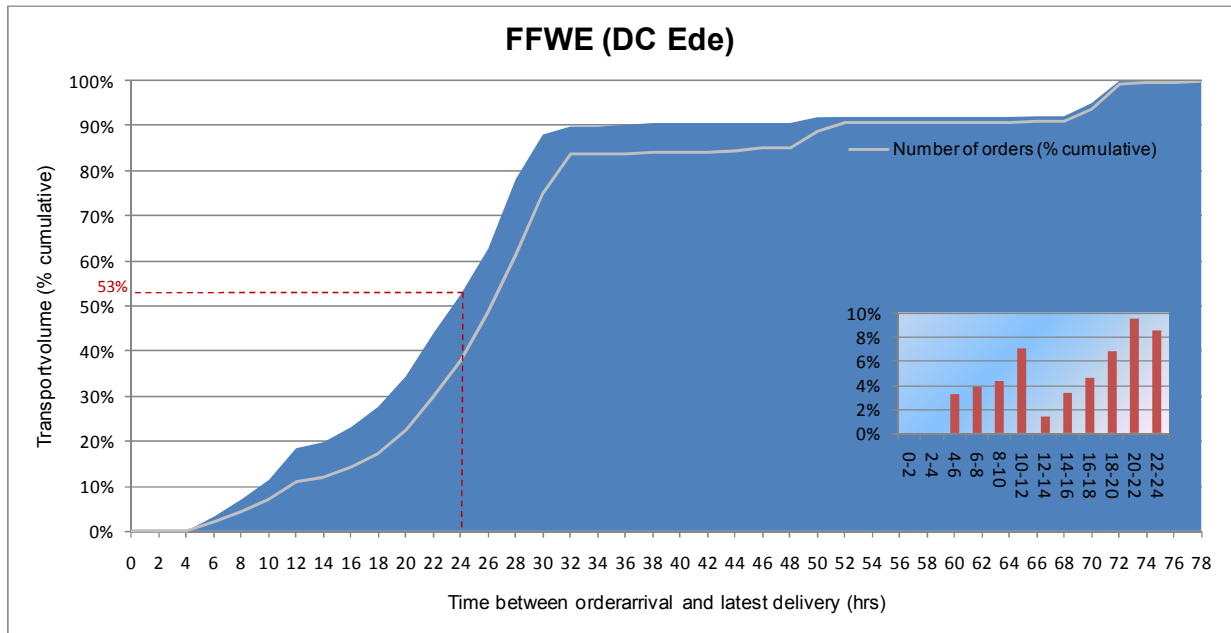


Figure 3.6: Order arrival flows of DC Ede

With regard to the orders from DC Ede the average time available between an order arrival and the latest time of delivery is 28.5 hrs. However, from Figure 3.6 it can be concluded that around 53% of the total transport volume of DC Ede has to be delivered within less than 24 hrs after arrival at Nabuurs. In order to highlight the percentage of transport volume, of which the time-pressure is the highest (i.e. delivery within 24 hrs) a red-coloured line and histogram are added to the figure. However, in this red-coloured histogram the percentage is not expressed cumulatively. From the histogram it can be concluded that approximately 3% of the total transport volume has to be delivered in only 4-6 hrs. For these orders it is notably dependent on the transport distance, whether delivery is achievable within the desired TW. In the area of orders with the highest time-pressure, the order volumes increase relatively faster than the number of orders. Therefore, it can be stated that the Ede orders which have to be delivered relatively fast, concern orders with an order size of more than average or FTL. This is more favourable than LTL orders which first have to be combined to FTL rides, that again is more time-consuming.

In Figure 3.7 below the order arrival pattern of DC Katwijk is visualized. In the case of Katwijk the average time between an order arrival and the latest time of delivery is 43 hrs. Therefore, the average available time for executing an order of DC Katwijk is around 50% more than an order of DC Ede. This dissimilarity is probably due to fact, that DC Katwijk concerns a storage location where no production facility is located. With regard to DC Katwijk, 19% of the total transport volume has to be delivered in less than 24 hrs, instead of 53% in the case of DC Ede. However, the grey line (i.e. number of orders) shows a particular pattern,

which is obviously a weak fit with the transport volumes. In short, the incoming order sizes fluctuate to a larger extent. Logically, this can strongly influence the planning results.

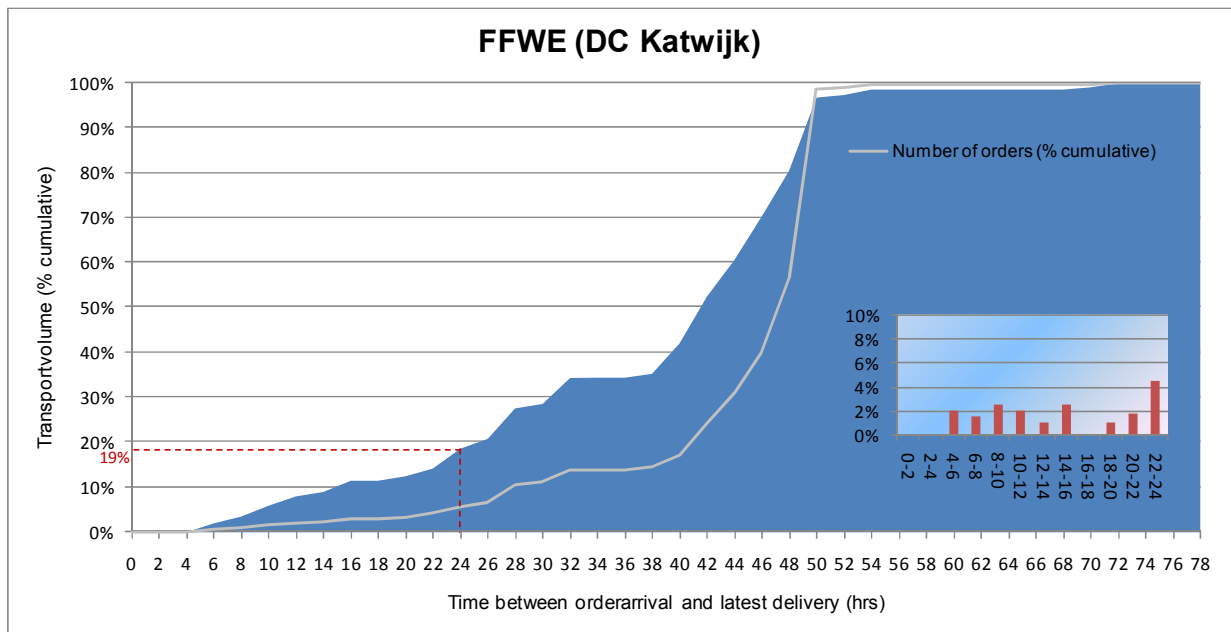


Figure 3.7: Order arrival flows of DC Katwijk

Order arrival flows HAK

In contrast to the order arrival flows of FFWE, the orders originating from Hak are known far before the execution of transport (see Figure 3.8). From the order arrival pattern the conclusion can be drawn, that uncertainty can be excluded with regard to the dynamism of order arrivals, in all probability.

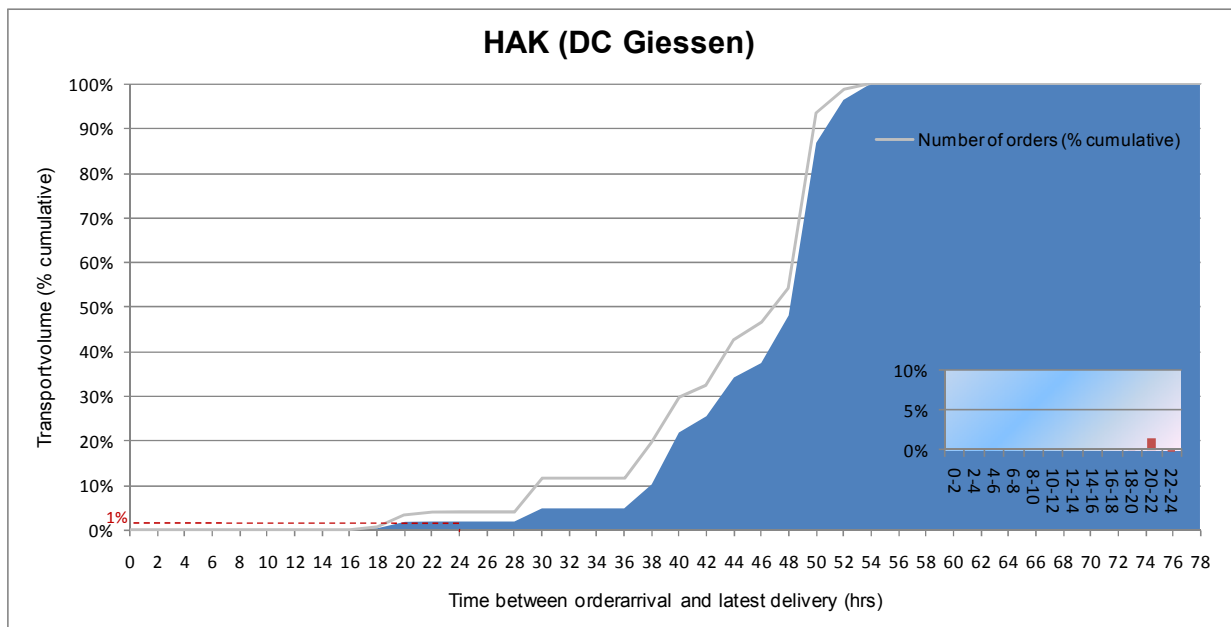


Figure 3.8: Order arrival flows of DC Giessen

Order arrival flows Menken

From Figure 3.9 it can be observed that for DC Bodegraven the percentage of total transport volume that has to be delivered within 24 hrs amounts to 66%. The proportions related to these 24 hrs are again depicted in the red-coloured histogram. Remarkable, is the fact that the number of orders (grey line) fit the transport volumes, very well.

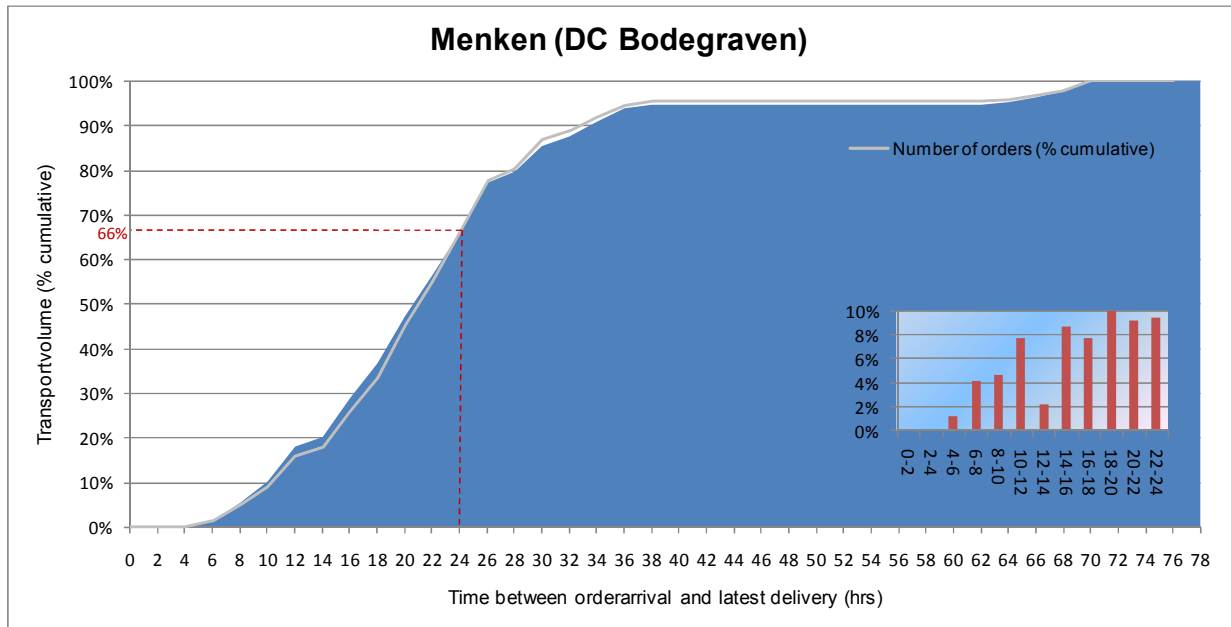


Figure 3.9: Order arrival flows of DC Bodegraven

Since the figures strongly differentiate between the four DCs, the order arrival flows have to be analyzed in further detail. Although the sample mean (μ) is useful it does not convey all of the information. The standard deviation (σ) has the desirable property of measuring variability (Montgomery and Runger, 1999). Thereupon, a reasonable relative measure of the variability is the coefficient of variation (CV), which is the standard deviation divided by the mean (Hopp and Spearman, 2000). In Table 3.1 below an overview is given with the relevant measures of the different arrival flows.

DC	μ	σ	CV (σ/μ)	Variability class	% of total volume	% of total volume < 12 Hrs	% of total volume < 24 Hrs
Ede	15	11	0.73	LV	29%	5%	16%
Katwijk	6.4	8.5	1.33	HV	23%	2%	4%
Giessen	9.3	8.5	0.91	MV	6%	0%	0%
Bodegraven	22.2	7.3	0.33	LV	41%	7%	27%
Total					100%	15%	47%

Table 3.1: Variability and indicators of order arrival flows

The CV values of DC Bodegraven and DC Katwijk, 0.33 and 1.33 respectively, directly clarify the relation between the transport volume (blue area) and the number of orders (grey line). The orders of Menken score very low in variability (LV), which results in the above-illustrated strong fit (Figure 3.9). Conversely, the orders belonging to DC Katwijk show a high variability (HV). This usually requires more time for executing the planning and transport activities (e.g. combining small orders towards a full truck). Although, the orders of DC Giessen are part of the moderate variability (MV) class, no order has to be delivered within

24 hrs. From the order arrival analysis, it can be concluded that 15% of the total transport volume has to be delivered within 12 hrs, and 47% within 24 hrs.

3.3.3. Performance of forming process

After order arrival, as described in the previous section, the initial planning activities occur. The first activity concerns striving for a full truck by combining small orders, which mainly applies to outgoing transport. Then, in order to create routes the rides are assigned to resources. This first stage of the planning process is called forming. The forming process of a routing planning in general can be done manually, automatically, or semi-automatically. Although, the planning system OTD is supposed to be operative in automatic support, the forming process is still executed manually by a planner (see Appendix E). Next to the earlier-stated ratio between loaded and empty KMs, the achieved average truckload in the forming process can be considered as another important Ambient performance measurement. Generally, a higher average of truckload results into less required rides and KMs for delivering the same amount of orders.

An FTL refers to freight for one destination, but in the Ambient forming process trucks can be filled with small orders belonging to different customers. However, in section 3.2.1 the FTL and LTL volumes applicable to Ambient are defined based on the vehicle capacities. Therefore, the current Ambient forming process is analyzed⁷ by means of a ratio between a truckload of 26 pallets or more, and a formed truckload of less than 26 pallets (see Figure 3.10). Although one-third of the truckloads after forming are filled with less than 26 pallets, the realized average truckload amounts to 24.8 pallets. However, this average is based on all the formed transport and distribution rides, of which a great part of the incoming orders already encloses intra-transport (FTL) orders.

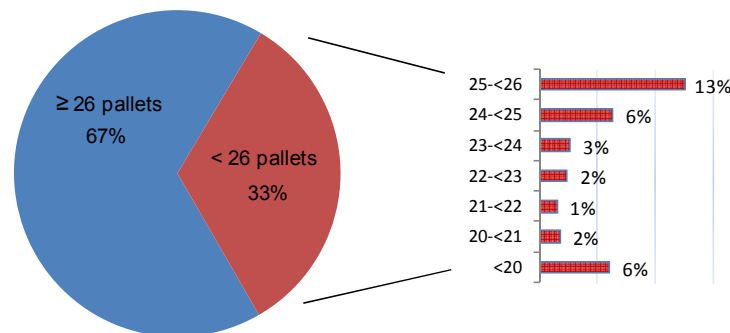


Figure 3.10: Performance of forming process

The histogram on the right-hand side of the figure shows the decomposition of the 33% formed truckloads. It can be concluded that the majority (51.5%) of this one-third scores a truckload of 24 pallets or higher, which partially clarifies the good average of almost 25 pallets. Nevertheless, it should be evaluated in the (near) future, whether semi-automatically forming of rides regards an improvement or not.

3.3.4. Planning support system

ORTEC Transport & Distribution (OTD) regards the main Ambient planning support system, which is able to streamline transport and distribution processes. By proper use of a planning support system like OTD cost-savings and an increase in service levels, can be achieved. OTD takes into account all the factors and pre-conditions that are important within the specific organization or branch. However, the planning tool has to be considered as an addition to an ERP or Transport Management System (TMS), which supports a planner with the following functionalities:

⁷ Based on the data of week 32-35 of year 2008.

-
- Automatic insight into missed delivery deadlines, working hours, loading capacity, etcetera.
 - Insight into alternatives to avoid planning conflicts and the capacity to deal with urgent orders.
 - The insight into the financial and logistical consequences and the possibility to make online reports.
 - Organization of efficient vehicle fleet management and a call centre interface for order reception.
 - An automated planning board with a card function for the desired level of detail.

In short, through advanced optimization methods, OTD is able to support for the optimal completion of orders. Thereupon, it can be integrated into other company's processes and systems, e.g. WMS and Mobile Communication platforms.

The implementation of OTD at Nabuurs is still in progress. The next OTD implementation phase concerns the transition from manually executed planning activities towards semi-automatic activities, which is described in Appendix E. Therefore, the current OTD is incapable of automatically generating an optimized route planning. Since the system cannot be characterized as solid, it is not recommendable to become dependent on this system during the execution of further steps in this research project.

3.4. Conclusion

This section contains the main conclusions of the Ambient analysis. The goal of this chapter is to analyse the Ambient network in terms of processes, structure and performances, with an eye on the initial research assignment stated in the first chapter of this report.

With regard to the network structure, Ambient can be characterized as a heterogeneous MD planning. The diversity characteristic of the depots partially conflicts with the MDVRP, as described in the literature. However, the various clients within the Ambient network are all served by means of the Ambient fleet of vehicles consisted of only three different combination types. The resources are not necessarily attached to one client or depot, which makes combining of orders and clients possible. Besides, a great part of the drivers can stay the night at any desired location within the network. Therefore, it can be concluded that a planning system is utilizable to facilitate routes to be planned simultaneously at one or several central sites rather than separately at individual depots.

However, the possibility of advantageously centralizing the execution of operations, i.e. planning and controlling more tightly and efficiently, is heavily dependent on the receipt of orders and arrival of information. Concerning the Ambient network, order arrival times and patterns seem to vary between the different clients. Nevertheless, it is shown that only 15% of the total transport volume has to be delivered within 12 hrs, and 47% within 24 hrs. Therefore, the greater part of the incoming order volumes allow an efficient and proactive execution of the Ambient planning activities.

Despite performance measurement is a necessity for gaining improvements, it has revealed that purposive performance measurement is not executed consistently within the Ambient network. Although, the almost total loading volume of the Ambient network can be attributed to around 10 depots (of which DCs Ede, Katwijk and Bodegraven already cover 55%), the delivery locations, and consequently the empty KMs, are spread all over the Ambient Benelux setting. Therefore, the ratio between loaded and empty KMs of every particular network area would be a substantial performance measurement. Based on these types of evaluations the network can be more balanced and improved significantly.

Finally, since the current OTD implementation is still in progress, therefore cannot be characterized as solid, it is not recommendable to become dependent on this system during the execution of further steps in this research project.

CHAPTER 4. DESIGN ASSIGNMENT

Based on the results of the preceding project phases, in this chapter the design assignment is formulated. In the first section the relevant issues related to the current situation are described. By using this description, in section 2 the research areas are outlined and clustered into a final cause-and-effect diagram, which represents the final research scope. Finally, in the last section the design assignment formulation and the approach of the design phase are covered.

4.1. Current situation

As mentioned before, the main planning processes of the Ambient network are centrally controlled, by means of the planning support system OTD. OTD is supposed to be operative and supportive following three subdivided parts of functional specifications: (1) the start of the planning process, with the forming of rides (i.e. combining the LTL orders towards FTL rides) and routes (i.e. assigning resources to rides), (2) the execution of rides, where the planner follows and surveys the planning, and (3) the translation to functionalities with regard to invoicing and management reports. Although, the forming of rides and routes can be done (semi-) automatically, this activity is still executed manually. Moreover, the implementation of OTD is still in progress.

The current Ambient concerns a dynamic and complex network, of which the planning occurs reactive rather than proactive. Nevertheless, Nabuurs has already abandoned the SD situation, in which a driver after delivery simply returns to the starting depot. In order to save the number of KMs, in the current situation after a delivery the driver is requested by a planner to go on to the nearest DC. However, this is just a starting point towards a MD planning in which more clients and DCs are advantageously combined. In the case of a proactive approach all the orders are planned simultaneously, whereby an improved MD planning can be realized. The latter aims at the reduction of labour costs and transport costs, as operations can be planned and controlled more tightly and efficiently than when they are decentralized (Eibl, 1996). From the previous chapter it can be concluded that only 15% of the total transport volume has to be delivered within 12 hrs. Therefore, on condition that the generation of a near-optimal MD planning solution is achievable within a reasonable time, an improved (semi-)automatic MD planning is possible, in all probability.

Furthermore, it can be concluded that the insight is lacking with regard to the effects, when changes occur in the Ambient network. For instance, if the current network is changed through the addition of a new client, the influences on the costs (per client) cannot be indicated. The simulation of alterations in the network is time-consuming and makes the use of a planner necessary. In short, the benefits of a MD regard to SD planning are largely unknown and not utilized in a desirable way. At the moment, the management reports are not consistently used to monitor or realize performance improvements. Thereupon, from the previous chapter it can be concluded that, a substantial evaluation model for the performance measurement of a network area is not at hand. In short, there is a lack of goal-oriented performance measurement.

With reference to the invoicing policy, Nabuurs uses a KM/hour rate, based on a distance and a time component. Currently, the client is charged the empty KMs for the ride after delivery towards a DC or other loading location. Suppose, more clients are combined successively in one route before an “empty” ride to a DC is necessary. Then, a consistent cost allocation system is required, which is not existing in the current situation. To conclude, there is a need for a different invoicing policy, i.e. a tariff structure that determines who pays for which part, in case more clients and/or DCs are combined within a MD planning. Logically, in order to make well-founded decisions on this subject an insight into all the cost factors is required.

4.2. Research scope

The aforementioned current issues can be translated into possible research areas for this report. From the research areas in question, the final research scope is determined on which the design phase is based. In the figure below, the current research areas are clustered in an outline. The outline concerns a derivation of the cause-and-effect diagram by Ishikawa (1990), and presents a clear overview of all interconnections.

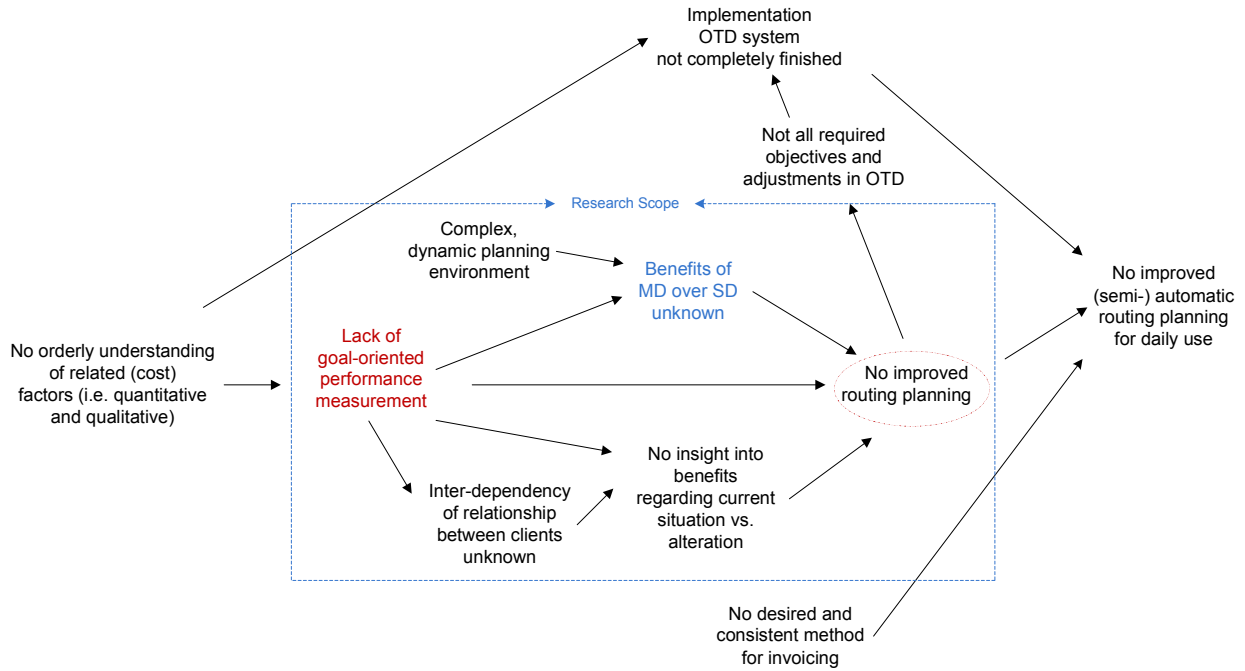


Figure 4.1: Cluster of research areas

In the first chapter the research assignment of this project is formulated as follows:

“Analyze and substantiate when the utilization of a multi-depot regarded to a single-depot planning is more advisable and cost-reducing, in order to improve the central routing planning of the Ambient transport flows.”

In order to realize an improved routing planning, further reduction of logistics costs through a more efficient execution of processes is a continuous objective. The very right side of Figure 4.1 above refers to the main objective, an improved (semi-) automatic routing planning for daily use. The latter is feasible on condition that the following three requirements are met: (1) the implementation and adjustments of OTD are completely finished, (2) the current Ambient planning is improved and (3) a consistent invoicing policy is adopted. Since, the first requirement is dependent on external factors, this part cannot be involved in the research project. Thereupon, the research area concerning the invoicing policy is out of scope, because this is based on profits rather than costs.

As a result, the final objective of this research project has become the improvement of the current routing planning, circled by the red, dotted line in Figure 4.1. The achievement of this improvement step is directly related to the main research area included in the research assignment, i.e. the benefits of MD over SD. This research area aims at the insight into the situations in which a MD planning is more advantageous than a SD planning. Since this research area is highly important, it is indicated in the figure by the blue lettering. Next to this main research area two remaining links to an improved routing planning can be observed. From these interconnections, it can be concluded that without purposefully measuring the performances of the Ambient network, the required insight and improvements remain unknown. Therefore, the lack of goal-

oriented performance measurement (red-coloured research area) is regarded as the main cause within this research scope. Through the abovementioned the entire research scope is defined and indicated by the blue-dotted square in Figure 4.1.

4.3. Design assignment

In order to start the initial assignment, a literature study and an analysis phase have been executed. Based on these results the current situation is clarified and a research scope is determined, discussed in section 4.1 and 4.2 respectively. From the preceding project phases it can be concluded, that there is a lack of goal-oriented performance measurement, which is required for revealing insight into improvements and alterations within the Ambient network. However, an understanding of related (cost) factors is again a necessity for measuring the right performances. Withal, related factors include quantitative factors (e.g. time or distance travelled) as well as qualitative factors (e.g. flexibility and availability of drivers). In order to fulfil the above-mentioned findings, the initial research assignment is refined towards the following design assignment formulation:

“Design a model to substantiate if for the current Ambient network a MD operating procedure is cost-reducing compared to a SD procedure, and determine the quantitative impact of the change from a SD setting towards a MD setting. Thereupon, implement the model for calculating the influences of changing volumes and/or clients on the costs of the Ambient network.”

For executing the design assignment, Ambient performances have to be measured quantitatively and the comparisons of different scenarios have to be performed. Scenario comparison by means of a pilot, e.g. based on (qualitative) expectations and case studies, is costly and hardly practicable. Thereupon, since quantitative comparisons are required, the decision is made to focus on a simulation study instead of a (theoretical) feasibility study. By implementing a constructed simulation model, that is capable of correctly modelling the complex and dynamic Ambient network, the entire research scope (see Figure 4.1) can be handled. Possible improvements can be discovered by simulating the adaptation towards a proactive and/or an automatic Ambient planning procedure.

Furthermore, the preceding project phases (e.g. by means of interviews and discussions) revealed that an evaluation model is highly desirable within the Ambient network. However, since the proposed simulation model is not suitable to evaluate and visualize the executed Ambient activities, an evaluation model is required as well. As a result, the design phase is subdivided into two parts, for which the design approach is described below:

1. *The development of a performance evaluation model (PEM):*

An evaluation model is developed to calculate and visualize the performance of desired Ambient network areas. The evaluation tool is a result on the lack of insight into the performance of a particular post code area in terms of empty vs. loaded KMs. This first part of the design phase is comprehensively described in chapter 5.

2. *The development and implementation of a simulation model (SHORTREC):*

In order to execute the formulated design assignment a simulation model is constructed, which is named SHORTREC. This tactical tool is used to provide insight into the situations in which a MD planning is more advantageous than a SD planning, in order to minimize total costs. Besides, the simulation model is able to compare alterations in the network with former and/or future situations. This last part of the design phase is fully described in three chapters: First, the construction of the simulation model (chapter 6), second, the results of the scenario analyses (chapter 7), third, the implementation plan (chapter 8).

CHAPTER 5. PERFORMANCE EVALUATION MODEL

In the previous chapter the design assignment has been defined. This chapter is based on the first part of the design phase and describes the developed performance evaluation model (PEM). First, the model description is given in section 1. Then, in section 2, the main results are presented. Finally, the chapter ends with a conclusion.

5.1. Construction of model

In the analysis phase it has been shown that it is imperative to measure the performance, in terms of loaded against empty KMs, within the Ambient network. Besides, it has been pointed out that (1) Ambient does not utilize this substantial performance measurement and (2) an evaluation tool, for visualizing the proposed performance, does not exist. Based on these findings, the following objective is defined.

5.1.1. Objective

The objective regards the development of a PEM in order to:

1. Measure the performance of a desired postcode area within the Ambient network. The performance measurement is subdivided into a ratio between empty and loaded KMs per postcode area and a frequency of ride lengths per postcode area.
2. Realize a clearly observable output through visualization of the results, where the frequency of ride lengths is visualized into a frequency table and the ratio of KMs is visualized into an EU-map. The latter is preferably pictured by means of colour indication.

5.1.2. Model description

To solve the objectives as stated in the previous section a PEM⁸ is developed, which has resulted in two desired outputs. A schematic overview of the model, with the input, process and output variables is shown in Figure 5.1 below.

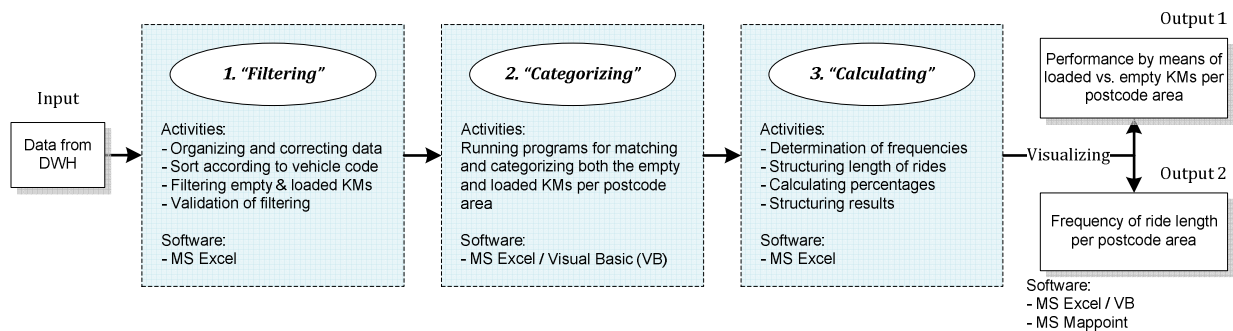


Figure 5.1: Overview of the performance evaluation model (PEM)

Figure 5.1 shows that the program consists of three building blocks, namely filtering of the input data, running of a VB program for categorization, and the execution of calculations in order to visualize the desired output. The phases that represent the PEM are successively described below.

Input

Since evaluating is the main objective of the PEM, the input regards registered data from the DWH. Therefore, the model is constructed based on a real data file⁹, which is selected from the Ambient

⁸ The PEM is based on the MS Excel file <<PEM_Ambient.xls>> (approximately 90MB) which is linked to MS Mappoint.

⁹ Based on the complete data record of August 2008.

database¹⁰. The data record includes all the drivers' activities, of which the main activities concern: Couple, decouple, travel, pickup, deliver, and home base. Furthermore, the major input parameters concern the vehicle codes, the distance (KMs) per activity, and the location (i.e. postcode) per activity.

Filtering (1)

After data entry the data file is filtered, which is referred to building block 1. The filtering process starts with structuring the data columns that are relevant for the subsequent steps. Hereafter, the relevant data (i.e. consisted of the above-mentioned input parameters) is checked and corrected if necessary.

Quality is a main factor of determining the usefulness of information (Alter, 2002). Four possible issues that can create a lot of difficulties for users and designers of a database are: missing data about an entity type; unnecessary or inappropriate attributes; ambiguity in the meaning of various attributes; appearance of attributes in two places.

The last-mentioned problem has recurred several times during the initial development phase of the PEM. Client records sometimes show up twice and address files are imported by means of a non-consistent character input (e.g. varied use of capitals or spaces). In order to realize a usable input, postcodes are adjusted to a consistent notation and for instance a "B" is added if it concerns a Belgian address. Unfortunately, these initial steps are executed (semi-)manually. However, if the Ambient database is cleaned and consistently organized, then there is no need for data correction. Besides, if the PEM is directly linked to the DWH the data entry process can become automated. The sorting process, which concerns the following step, creates data columns with all the activities in chronologically performed order. The final phase in the first building block is filtering out all the empty and loaded KMs, which is done automatically through Excel. The last is validated by means of a built-in check.

Categorizing (2)

The second building block includes the categorization of all the distances belonging to a particular postcode area. This process is programmed in Visual Basic (VB) and can be executed by using the created buttons. By running the program every distance, that was filtered in the previous building block, is copied and placed in the matching postcode column. In order to distinguish between loaded and empty KMs, two data sheets and two programs are constructed in the PEM. The result of a performed program regards a data sheet, with a complete overview of every distance travelled, categorized per postcode area.

Calculating (3)

Third, the created overviews from the previous phase are the input for all the required calculations. The calculations are programmed in Excel and hardly need any manual assistance. The major calculations concern the determination of frequencies with regard to the categorization of ride lengths and the amount of empty vs. loaded KMs expressed in numbers and percentages. Particular results are structured, as in the case of output 1, for which two datasheets are added in order to link MS Excel with MS Mappoint.

Output

The results of the PEM are the visualization of the two outcomes, that are shown on the right-hand side of Figure 5.1. In order to visualize output 1, the software tool MS Mappoint is required. For output 2 an arbitrary postcode area can be selected from a drop-down list on the datasheet in question and can be visualized by running the visualization program. In Appendix F.2, a manual is presented for supporting the required activation. In the next section the results of the outcomes are discussed in more detail.

¹⁰ A database is a structured collection of data items, stored, controlled and accessed through a computer, which is based on predefined relationships between predefined types of data items (Alter, 2002).

5.1.3. Validity

With regard to the PEM the adequacy of the evaluation results is of major concern. Therefore, the construct validity is assessed, which is defined as the extent to which a measuring instrument measures what it is intended to measure (De Groot, 1969). Especially in the automatic filtering process it is important that a correct selection is made between empty and loaded KMs. Two steps are undertaken to achieve construct validity, (1) the filtering scenarios and results are discussed with members of the Ambient division and (2) an automatic check is built in Excel, to verify if the filtered KMs are placed in one of the two columns in question (i.e. column of empty KMs or column of loaded KMs), instead of both columns or none. The check indicates an error if the requirement is not met.

Data validity is ensuring that the data, necessary for model building, model evaluation and testing, is adequate and correct (Sargent, 2003). As regards the data validity, the data used for the model is real data obtained from the DWH, which concerns the data list that in reality is used for invoicing. Although, data adaptations have been made in order to realize a consistent and reliable data entry, the data with respect to content is not changed. Therefore, it can be concluded that the PEM is also valid in terms of data validity.

5.2. Results

As shown in the previous section the results of the PEM are bifurcated. In this section the two different outcomes of the PEM are discussed in succession. Besides, it is described how to consider the implementation of the evaluation model.

5.2.1. Output 1: Ratio between empty and loaded KMs

The first PEM output concerns the ratio between empty and loaded KMs, of which the corresponding measurements for every postcode area can be found in Appendix F.1. From all postcode areas a selection is made, based on the highest ratio of empty vs. loaded KMs and the restriction of at least 50 executed rides. The resulting 20 significant postcode areas (i.e. “worst-case” regions) are shown in the table below.

Postcode area	Empty KMs	Loaded KMs	Ratio empty KMs/ loaded KMs	% empty KMs/ total KMs	# of rides
			0.87	46.52	307
			0.80	44.53	78
			0.78	44.03	333
			0.76	43.38	254
			0.76	43.30	352
			0.74	42.67	136
			0.68	40.56	370
			0.65	39.64	247
			0.65	39.60	134
			0.65	39.54	70
			0.63	38.82	86
			0.62	38.42	87
			0.62	38.28	54
			0.58	36.90	221
			0.58	36.76	175
			0.57	36.61	243
			0.57	36.56	130
			0.53	34.80	67
			0.52	34.63	178
			0.52	34.32	144

Table 5.1: 20 significant postcode areas of PEM output 1

As mentioned before, in order to visualize the ratio between the empty and loaded KMs, the software tool Mappoint is linked to the PEM. In Figure 5.2, a result of the Ambient network is shown in a map, by means of MS Mappoint. In the figure the performance is shown for every postcode area, where Ambient transport and distribution activities have taken place. The postcodes are intentionally combined toward two-numbered postcode areas aiming for improving the observability. When the postcode area turns darker the more empty KMs are concerned, compared to the total KMs (i.e. total empty and loaded KMs) in that area.



Figure 5.2: An example of output 1 created by the PEM

From the results it can be observed that, for instance the postcode areas 34, 97 and 16 ask for more attention in order to possibly improve the overall performance. Thereupon, the North-Holland region is coloured somewhat darker and could be evaluated in more depth if desired. However it is important to

know how many rides and KMs the ratio-result is dependent on. Logically, it is not sensible to generalize the result if only a few rides have been executed in the region concerned. The last-mentioned is verifiable by making use of the frequency table (output 2) which is discussed hereafter.

In case a region continuously includes much more empty KMs than loaded KMs, the area is probably accompanied with many places of discharge rather than loading locations. E.g. seeking for cross-dock possibilities or finding a new long-term client, with a loading location in this region, could possibly more balance this network area. Moreover, a simulation model is utilizable for calculating these changing scenarios. The latter will be discussed in the subsequent chapters. To conclude, the aim is to focus on the less-performing areas (see Table 5.1) in order to improve the overall performance of the Ambient network.

5.2.2. Output 2: Frequency of ride lengths

The second output of the PEM regards the frequency of ride lengths, belonging to a desired postcode area. As an example, the frequency table of postcode 67 is shown in Figure 5.3 below. From the visualization it can easily be observed how many rides have occurred in a particular ride length category. As the legend indicates, both the loaded (blue coloured) and empty (red coloured) KMs are presented. Based on this figure, the chosen postcode area can be evaluated on the proportion between the empty and loaded KMs in terms of ride lengths. Besides, It can be discovered whether there have been executed desirable or undesirable rides.

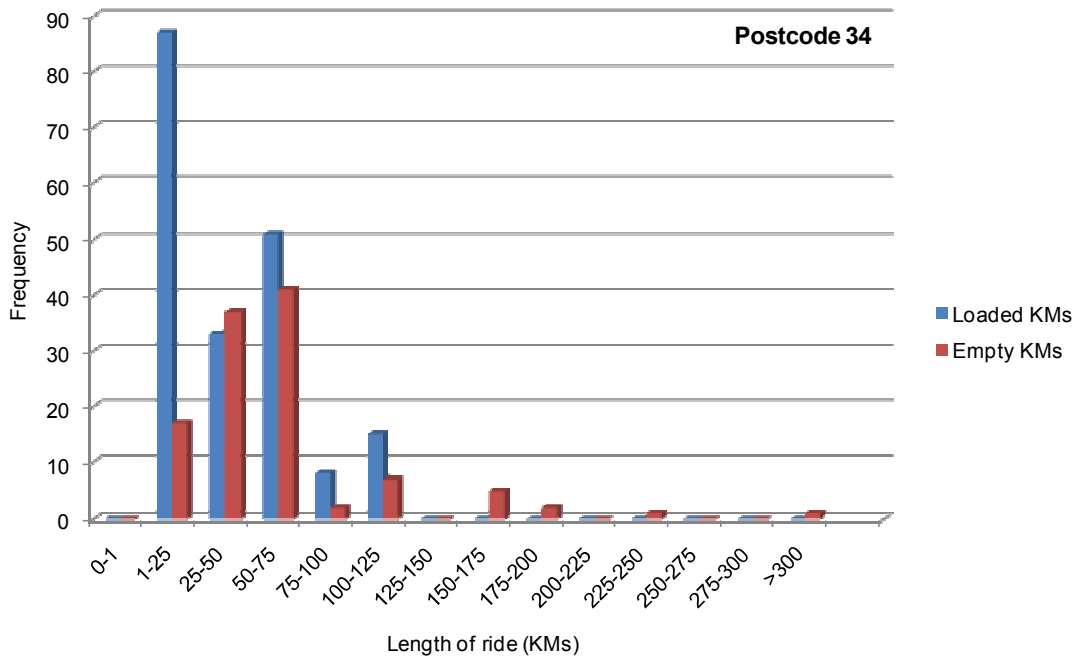


Figure 5.3: An example of output 2 created by the PEM

5.2.3. Implementation

Due to the data correction problems in the first building block of the model (see Figure 5.1), the utilization of the PEM in future settings requires certain adjustments. As mentioned before, these issues can mainly be solved through database improvements. The major adjustment that has to be considered regards the postcode correction. Nevertheless, several parts of the PEM are already ready for use. Besides, the Mappoint visualization can be applied to many monitoring practices.

5.3. Conclusion

In this chapter the PEM has been described. The evaluation tool is a response to the lack of insight into the performance of a particular postcode area, in terms of empty vs. loaded KMs. The developed PEM serves the purpose of evaluating realized activities, for which a clearly observable output is realized through:

1. The visualization of ratios into an EU-map with colour-indication, by means of the linked software tool MS Mappoint.
2. The visualization of ride lengths into a frequency table, by means of MS Excel and Visual Basic.

Moreover, thanks to the PEM it is verifiable how many rides and KMs the ratio-result is dependent on, since it is not sensible to generalize result if only a few rides have been executed in the region concerned. The depicted results can easily be evaluated and/or be used as an input for further scenario analyses.

Furthermore, the PEM and results are validated, by means of construct and data validity. However, if future analyses are desired, then the tool needs to be adapted in terms of data entry and data correction. Two main causes are ascribable to this required adaptation, (1) the Ambient database is not consistently organized and (2) the PEM is not directly linked to the DWH.

CHAPTER 6. SIMULATION MODEL

In the previous chapter the PEM has been described, which concerns the first part of the design phase. This chapter describes the constructed simulation model. Simulation is used to describe and analyze the behaviour of a system, ask “what if” questions about the real system, and aid in the design of real systems (Banks, 2000). In Robinson (1994) it is shown that there are four main phases in a simulation project: Problem definition, model building and testing, experimentation and project completion. Besides, a simulation study is an iterative process rather than a simple sequential process. By Law and Kelton (2000), ten steps are defined that compose a typical, sound simulation study. However, several steps show an overlap with the former mentioned phases. Therefore, the proposed phases and steps relevant for this simulation project are summarized and depicted in Figure 6.1. This overview also provides the structure that encompasses the remainder of this report.

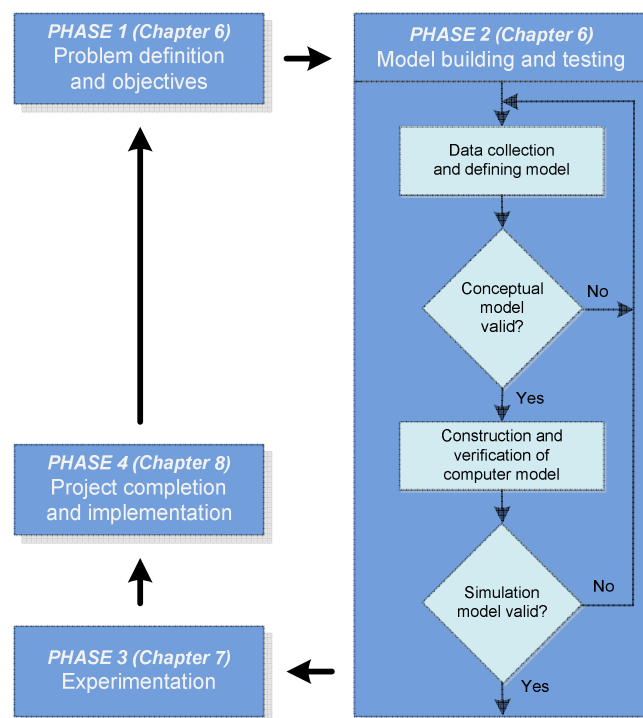


Figure 6.1: An overview of the simulation project

The first two phases are presented in this chapter. First, in section 6.1 the objectives of the simulation model are defined. Section 6.2 describes the composition of the simulation model. Thereupon, the simulation model is assessed on its validity in section 6.3. Finally, the conclusions are drawn in the last section. The phases experimentation and implementation are described in chapter 7 and 8, respectively.

6.1. Problem definition and objectives

With regard to the design assignment stated in chapter 4, the simulation model has to be constructed in order to (1) obtain insight into the situations in which a MD planning is more advantageous than a SD planning and (2) compare alterations in the network with former and/or future situations. The design assignment is translated into three initial simulation scenarios which are required for demonstrating the research project.

-
1. Current MD Ambient planning vs. SD Ambient planning, to substantiate what the amount of cost savings are in the current operating procedure.
 2. Current Ambient planning vs. changes within the network (e.g. addition of a new client), to quantitatively indicate what the effects and results are.
 3. An Ambient planning per day vs. 48 hrs, to show the effects on the planning and costs if the planning occurs proactive rather than reactive.

In order to use simulation as a tool within this research project, the simulation model must at least be able to fulfil the above mentioned requirements. However, one major requisite for realizing the requirements in question is the ability to perform a MD Ambient transport and distribution planning. For that reason, the simulation model should be suitable for solving a *Dynamic Heterogeneous Multi-Vehicle Multi-Depot Pickup and Delivery Problem with Time Windows and Driver's Work Rule Constraints*, as stated in the first chapter. Besides, from the literature review in chapter 2 it has been concluded that the TS approach of Cordeau et al. (1997) is probably the best known algorithm for the MDVRP. Therefore, in consideration of this MD research, it is desirable to obtain reliable results by means of an optimization tool that includes a TS algorithm.

6.2. Model building

Since the desired simulation model serves the purpose to meet the objectives mentioned before, a model cannot be fully constructed from scratch, within the amount of time planned for this project. For that reason there has been chosen to make use of an existing software tool, which is both applicable and adaptable for executing this assignment. Although, the current Ambient planning support system OTD is largely able to meet the formulated objectives, OTD is not fully implemented (see section 3.3.4) and not an adequate tool for simulating and performing scenario analyses. However, before the acquisition of OTD, among others, a decision was made between OTD and a tactical tool, named SHORTREC. Both planning tools are offered by ORTEC, but OTD has been found more suitable for the Ambient daily activities, i.e. a more operational rather than a tactical application. SHORTREC, by contrast, is perfectly applicable for simulation purposes on a tactical level, and is described in more detail below.

6.2.1. Software tool: SHORTREC

SHORTREC is an automated trip routing and scheduling system, that is able to optimize a transport and distribution planning. The planning system is able to find an optimum allocation of the vehicle fleet by efficiently filling in trips, combined with the fastest routes. The obtained plan can be looked at in various ways and can be adapted if desired. Within SHORTREC it is possible to see all the vehicles, drivers and corresponding trips, which can be displayed on a digital map. The scenario-analysis option enables a user to draw up various plans and to compare them with each other. SHORTREC is built in a modular structure and is therefore configurable to a specific situation. Some examples of (extra) modules are: plans for one or for several days; pick-up and deliveries; traffic-jam issues; processing status reports from board computers, PDAs and GPS positions; single or multi-depot; multi-user or multi-site; single or multi-compartments; national & international transport; time windows, such as opening hours and waiting times; charter and subcontracting issues; breaks and regulations governing driving hours.

SHORTREC is designed to minimize overall costs, for which a two-phase strategy is followed:

1. *A basic solution:* A rule based strategy to build initial routes which only adds unassigned orders to existing or new routes. A feasible solution is created with the target to assign as many orders as possible. This initial phase provides a quick insight in how many vehicles and hours are needed at most, without a direct focus on costs.

2. *Optimization routines*: In the second phase several heuristics are executed to minimize costs and reduce miles, hrs, overtime, routes, etc. Logically, this is more time intensive, especially when there are a large number of exchange alternatives.

Based on the above-mentioned two-phase strategy the solver of SHORTREC consists of two types of algorithms, namely construction and improvement algorithms. This phenomenon is comparable to the multi-phase heuristics shown in the literature review of chapter 2. All the algorithms included in SHORTREC are enumerated and shortly clarified in Appendix G. The list of SHORTREC algorithms contains many well-known algorithms and indicates the versatility in optimization possibilities. Thereupon, the improvement phase contains the most important, present-day algorithms, i.e. the Opt and TS algorithms, which are again recognizable from the literature study in chapter 2. In conclusion, SHORTREC is able to meet the objectives and requirements as stated in the beginning of this chapter. Besides it is an appropriate tool for executing the assignment by means of scenario analysis.

6.2.2. Inputs and outputs

By making use of a simulation model (see figure below), experiments can be performed by changing the input parameters and predicting the response (Robinson, 1994). Robinson states that it is important to recognize that simulation is primarily a decision support tool and does not directly seek optimum solutions.

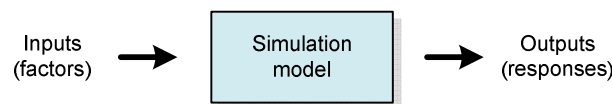


Figure 6.2: Simulation modelling (Robinson, 1994)

Although the optimization strength of SHORTREC is not required, the system shall function as the simulation model presented in Figure 6.2. The solver can be considered as a “black box”, because it does not visualize anything while solving the algorithms (see Appendix G). Nevertheless, the SHORTREC solver is interruptible and manual changes can be made, which then can be included in subsequent solving solutions.

As in the previous subsection an overview is given of the extra SHORTREC modules, these modules play a significant part in obtaining the desired results. The adaptation of SHORTREC, e.g. toward a MD setting with required import definitions, makes the model capable of correctly modelling the Ambient network.

Model	Inputs (factors)	Outputs (responses)
- SHORTREC automated trip routing and scheduling system	<ul style="list-style-type: none"> - Combinations (i.e. resources): Trucks and trailers (e.g. number, type, fixed and variable cost, capacities, depots) Drivers (e.g. details, working hours, availability) - Orders Client (number), ordernumber, delivery date, time window, pickup and delivery address, size of order, required vehicle type (e.g. cooler), fixed loading and unloading time - Depots and clients Opening hours, location, processing times, costs, loading ports 	<ul style="list-style-type: none"> - Costs - Distance (KMs) - Working time (i.e. driving time, stopping time and waiting time) - Number of vehicles - Number of rides - Number of orders

Table 6.1: SHORTREC simulation model with inputs and outputs

Due to the SHORTREC construction all the required inputs can be entered and applied to the solver, which results in consistent and reliable outputs. In Table 6.1 an overview is given of the inputs and outputs concerned.

Input 1: Combinations

A more convenient way of importing the resources is by making use of the import definition, named Combinations. Instead of importing the resources separately (i.e. vehicle types and drivers) a combination can be composed and used for the transport activities. The Ambient vehicle types are described in Appendix D. Since Ambient makes use of combinations as well and applies a tariff structure consisted of a cost/hour and cost/KM rate (see Table 6.2), this import definition exactly fits the reality.

<i>Distance rate (KMs)</i>	<i>Time rate (Hours)</i>
Fuel consumption	Hourly wage driver
Variable costs vehicle	Fixed costs vehicle
Costs per KM	Costs per Hour

Table 6.2: Ambient tariff structure

As mentioned before, charters are used within the Ambient network, for which a higher cost tariff is charged. Logically, different cost tariffs are also used for the three vehicle types: standard truck and trailer (tr.), combination truck and trailer (ck.) and refrigerated truck and trailer (K.). With regard to the drivers the most input parameters (e.g. working hours) are held equally, because for simulation purposes the input parameters have to be consistent and adjusted as realistic as possible.

Input 2: Orders

The order import definition is adapted to an Excel format (i.e. CSV-files). On condition that the orders contain the required data (see Table 6.1) positioned in the correct, assigned columns, SHORTREC is able to read-in the complete data list, after which the program starts constructing a matrix (see also Appendix J.1). This matrix contains the order locations with the in-between calculated distances, which is later used for solving the routing problem. If the pickup location of an order concerns a pre-defined depot, the order data should correspond to the assigned depot name in SHORTREC.

Input 3: Depots and clients

By making use of this third input, the MD setting type can be suitably adjusted to the realistic situation. Since Ambient concerns a heterogeneous MD setting, it is not possible to pick up a particular product at different locations within the network. Except for DC Katwijk, every depot in the Ambient network concerns a depot where unique products are stored, i.e. that every single product is attributed to only one depot. Although, this means that a MDVRP as described in the literature is not entirely applicable, the Ambient network has the characteristic that the vehicle types and combinations can be deployed for serving all clients. Therefore, orders belonging to different clients can be combined and vehicles can be utilized throughout the Ambient network. As regard the depot input in SHORTREC, with this option every client's depot can be entered, with the matching parameter settings (e.g. opening hours and processing times).

Outputs

The outputs of SHORTREC are listed on the right-hand side of Table 6.1. The cost output can be regarded as (1) the main objective which is minimized for optimizing the route planning and (2) the major quantitative standard for analyzing the scenario comparisons. However, the total costs are directly or indirectly related to the remaining outputs. In Van den Berg (2006, pp. 94-96), a similar mathematical formulation is described, that is applicable to the Ambient optimization problem, which is solved by SHORTREC in this

research project. In the case a scenario comparison is executed, it is of major concern that the number of orders are equivalent in both scenarios. Then, the solver of SHORTREC strives to minimize the costs, KMs and working time and indirectly the number of vehicles and rides are diminished. However, the last two outputs are not necessarily minimized for achieving the lowest total costs.

6.2.3. Data collection

After the model is constructed, information and data should be collected for the system of interest. The inputs, as described in the previous subsection, mainly concern the data items that need to be collected. As mentioned in the previous chapter, quality is a main factor of determining the usefulness of information (Alter, 2002). In order to accurately model the real-life Ambient network, the most reliable and proper data is recommendable. For that reason, the data is collected from various sources, of which an overview is presented in the table below.

Data type	Source
Combinations:	
Vehicle types, capacities and numbers	Recent Ambient vehicle fleet documents
Variable costs of combinations	OTD and Ambient costs-construction document
Fixed costs of combinations	Planning department
Depot assignment	Planning department
Driver information (e.g. working hours)	OTD and Planning department
Orders:	
e.g. order/client number, delivery date, pickup and delivery address, required vehicle type, size, etc.	DWH (Filtered real order arrivals as XML-files converted to CSV-files with the help of ORTEC)
Depots and clients:	
e.g. opening hours, locations, processing times, costs, number of loading ports	OTD and Planning department

Table 6.3: Data collection overview

As can be observed from the table, the order data is based on real order arrivals, because this data is validated and contains all the required information. However, the real orders, which are currently planned by means of OTD, arrive in separate XML-files. Due to this, different conversion steps are required in order to obtain one correct Excel import file that fits the import definition. Logically, this affects the SHORTREC implementation, which is comprehensively discussed in chapter 8.

If data changes are required for a particular SHORTREC planning, this can easily be adapted within the mutation screens. A copy of this planning (and adjustments) can again be used for a new planning format, so that recurrent adaptations of the default can be avoided.

6.2.4. Assumptions and limitations

A few assumptions are applied to SHORTREC in order to utilize the model and match the Ambient network in a best possible way. The general assumptions applicable to the model are described below. Additional assumptions with regard to the experiments are defined in the next chapter.

1. *Fixed cost of vehicle:* With regard to the Ambient operating procedure, in real-life the costs of a vehicle is mainly based on variable factors. The fixed cost per vehicle used for invoicing amounts a fourth part of the hour tariff in question. In order to minimize the number of trucks in SHORTREC during a simulation, the system has a need for an adjustment that disables the fact that combinations can be brought into action unlimited. Therefore, a fixed vehicle tariff of €100 is

assumed and used in SHORTREC. After running the solver a cost correction is made in order to obtain reliable results.

2. *Time adjustment*: If SHORTREC is used for a day planning, as it is in the initial state, the parameter settings of delivery times and timeslots are slightly adjusted in order to make a correct night schedule. Therefore, if today a planning is made for the coming night, which actually already concerns the next day, the delivery times are adjusted by continued counting, e.g. the time of 3:00AM is assumed to be 27:00 hr. See also the rolling horizon issue below.

The limitations of SHORTREC that have to be considered are described below:

- *Rolling horizon issue*: The starting state of SHORTREC is only able to model a day planning, i.e. 24 hrs. This means that in order to model a planning for several days, a complete different SHORTREC design is required, next to the standard adjustments for modelling a particular branch. This design is called Multiday and is also applied to this research project.
- *Pre-loading issue*: In case the setting is adjusted that a combination is pre-loaded at the beginning of a day a problem comes into being for the SD situation, i.e. no depot-check is executed anymore. In the SD situation a combination is ascribed to one single depot. If a combination is pre-loaded SHORTREC sometimes (i.e. if desired) allows a pre-loaded combination to start from a different depot than the assigned depot. In this case the depot-check is overruled. However, pre-loading is necessary, because without pre-loading several time-slots are not achievable, by taking into account the correct opening hours of depots and working hours of drivers. Moreover, pre-loading is also the case in real-life, if needful.
- *Cost per client issue*: SHORTREC is not able to provide insight into the costs per client. A laborious solution to this limitation is to manually filter the results reported in Excel. Logically, ORTEC recommends the purchase of their provided invoicing system which can be attached to SHORTREC.
- *Generality issue of additional options*: If additional options, i.e. night's rest, free end-location, free-start location, is chosen, it is not possible to apply the option on only a section of the order list (e.g. by means of a percentage).

6.3. Verification and validation

This section successively describes the verification and validation of the SHORTREC model. These steps have to be executed to make sure that the tool can be applied to the Ambient network.

6.3.1. Verification

Verification of a (computerized) model is defined as assuring that the computer programming and implementation of the conceptual model is correct (Sargent, 2003). The verification step checks if the model has been built right and the program functions as it should. This report makes use of the software tool SHORTREC, which is a much-used route planning system applied to companies world-wide. The application of SHORTREC at companies like Coca Cola, Campina and Albert Heijn (Albert.nl) are reliable references of verified implementations. Besides, with regard to this project the construction of SHORTREC is executed in collaboration with ORTEC. Because of this, several verification checks have been performed.

6.3.2. Validation

The assessment of the quality of the proposed model is an important aspect of the design phase. In Van Aken et al. (2007) three quality criteria are defined in relation to business problem-solving projects: controllability, reliability and validity. Controllability is a prerequisite for the evaluation of reliability and validity. In order to make research results controllable, it has to be revealed how the study is executed. Thereupon, the results of a study are reliable when they are independent of the particular characteristics of

that study (Swanborn, 1996). Both controllability and reliability are inherent to the methodology (section 1.4) used within this research project. Validity refers to the adequacy and verity of the generated research results and can be decomposed into construct, internal and external validity.

As stated in the previous chapter, construct validity refers to the quality of the operationalization of the model, in this case SHORTREC. Since SHORTREC is mainly used for simulation purposes an appropriate model validation is executed. In Goossenaerts and Pels (2009), model validation is defined as the determination whether an executable simulation model is an accurate representation of the real system. Validation of the model should be performed upon completion of the model and can be done in various ways (Goossenaerts and Pels, 2009):

1. If there is an existing system, call it the base system, then an ideal way to validate the model is to compare its output to that of the base system.
2. An idea of the validity of the model can be obtained by demonstrating it to experts or people who know the system. The results produced by the model can be compared to historical data.
3. The model produced could also be compared to other models, e.g. mathematical models, deterministic models, and other simulation models (Mehta, 2000).

The three recommended validation checks have all (partly) been used for validation. After the construction of SHORTREC, the model has been applied to a real-life Ambient problem: the production of an optimized route planning of a night schedule for the client Albert Heijn. This schedule is performed by taking into account the new orders, delivery times and timeslots. After fine-tuning the adjustments, SHORTREC has been made suitable for creating results that fit the reality. Results have been validated and discussed within the planning department, whereby also comparisons could be made with former results. The recommended night schedule produced by SHORTREC is shown in Appendix H.

In the methodological approach of the regulative cycle (see section 1.4) the concept of internal validity refers both to the adequacy and the completeness of suggested relationships. In the diagnostic phase (see chapter 4) the main causes are translated into proper research areas and clustered in a diagram. Based on the justified conclusions for which multiple perspectives are considered, it can be concluded that the study is internally valid. External validity refers to the generality of research results to for example other situations and organizations. However, external validity is often less important in business problem-solving projects, since these projects focus on one specific problem (Van Aken et al., 2007). The last-mentioned is also applicable to this project, since SHORTREC is completely adapted to the Ambient characteristics.

6.4. Conclusion

Based on the actual Ambient network, the modelling structure and parameter settings of the SHORTREC simulation model have been gained. SHORTREC meets the objectives and requirements as stated in the beginning of this chapter (section 6.1) and is found to be a perfect application for the required simulation purposes (on a more tactical level). Besides it is an appropriate tool for executing the assignment by means of scenario analysis.

Furthermore, a few assumptions are applied to SHORTREC in order to utilize the model and match the Ambient network in a best possible way. At the same time, a number of discovered SHORTREC limitations are described, in order to deal with these issues in subsequent phases. Finally, the model has been validated in terms of construct, internal and external validity.

CHAPTER 7. CASE RESULTS

In the previous chapter the SHORTREC model has been defined. The model has been applied to the scenarios that have been established. In this chapter the results of the scenario analysis are discussed. First, in section 7.1 an overview of the experiments is presented with regard to the base case. Thereupon, four subsections are devoted to the main comparisons that comprise the scenario analysis of section 7.2. Finally, the chapter is concluded in section 7.3.

7.1. Base case

The base case refers to the default of the constructed SHORTREC model, that is adjusted to the characteristics of the current Ambient network. The base case scenario is used as the basic principle that is prepared for an experiment and compared with other scenarios. The preparation includes for instance, reading-in orders and determining the number of active combinations (i.e. vehicles and drivers). An overview of the experiments is visualized in the figure below, of which the base case of every experiment is shown in the centrally positioned rectangle.

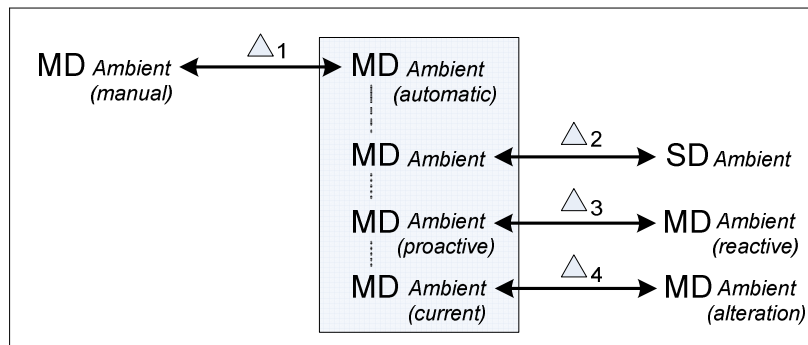


Figure 7.1: Overview of experiments

It is relevant to note that the base case named *MD Ambient (proactive)* is the only one from the figure which is based on a different default, compared to the other three base cases. As described in the previous chapter, in order to model a planning for several days a Multiday SHORTREC design is required due to the rolling horizon issue (section 6.2.4). To conclude, the third experiment (i.e. proactive vs. reactive) is executed by means of SHORTREC Multiday and is based on the Multiday default. However, the other three base cases are based on the standard SHORTREC default, but differentiate for each specific experiment. To maintain the surveyability the four base cases are named differently (see Figure 7.1). Finally, although the main model assumptions are described in the previous chapter, in the next section additional assumptions are defined for correctly executing the experiments.

7.2. Scenario analysis

A simulation model is a dynamic model that is meant to be solved by means of experimentation (Kleijnen, 2008). To find out whether the changes in the network affect the performances in a positive or negative way, various experiments have been performed, which are subdivided into four main comparisons. The scenario analyses related to the comparisons are successively discussed in the subsections below.

7.2.1. Comparison 1: MD Ambient (manual) vs. MD Ambient (automatic)

The first scenario analysis regards the comparison between the current manually performed Ambient planning on the one hand, and an automatically performed Ambient planning on the other. This comparison also demonstrates the validation of applying SHORTREC to the real Ambient environment. The total results

are shown in Appendix I.1 and the results in terms of KPIs (Key Performance Indicators) are shown in Table 7.1 below.

SCENARIO	Costs (€)	KMs driven	Number of vehicles	Number of rides	Number of orders	Working time	Driving time	Stopping time	Waiting time
Manual	5643,28*	5083	10	32	32	132:25	NA	NA	NA
SHORTREC	5191,27	4451	11	32	32	109:27	65:33	40:45	3:09
Difference	-8,01%	-12,43%	10,00%	0,00%	0,00%	-17,34%			

Table 7.1: KPI results of comparison 1

The total costs of the manual planning is the budgeted sum that is charged to the client minus the profit margin¹¹. However, whether the executed planning is resulted in higher or lower costs is unknown. Nevertheless, the comparison focuses on the different planning methods (i.e. manual vs. automatic) instead of the execution of the planning, because the latter is very difficult to measure due to data noise (see also section 2.2.2). From the KPI results in the table it can be concluded that:

- A cost-reduction of 8 percent is achieved through a decrease of the KMs and working time.
- The number of vehicles is increased but the number of rides is remained the same.
- A SHORTREC solution with less than 11 vehicles is not attainable according to the experimental requirements.

The cost saving is primarily due to less KMs, which is mainly a result of smart combining order rides for drivers. Within the manual planning a driver performs similar rides more frequently (e.g. four times a ride Bodegraven - Delfgauw), where SHORTREC combines the depots, orders and drivers more interchangeable. In case the adjustment of SHORTREC is realized, the execution of a SHORTREC solution for this small amount of orders takes only a few minutes, instead of several hours for a manual planning. However, small reactive changes and adaptations (e.g. a slight TW exceeding) are easy applicable to the manual planning, compared to the need for an anew entire SHORTREC planning if requirements are changed. This also refers to the fact that in the manual planning ten vehicles are used, which according to the restrictions is not possible in any SHORTREC solution. Finally, it can be concluded that SHORTREC is a utilizable tool for providing insight into optimally produced route combinations. Therefore, SHORTREC is extremely appropriate for supporting the current Ambient planning procedure.

7.2.2. Comparison 2: MD Ambient vs. SD Ambient

The second scenario analysis concerns the main objective of this study, i.e. the comparison between a SD and a MD planning procedure, with regard to the Ambient network. The aim of this study is to substantiate what the quantitative savings are in the current MD operating procedure regarded to a SD Ambient planning. By representing the performed route planning of a particular driver, a validated insight can be achieved between the SD and MD setting. In the left-hand side of Figure 7.2, it can be clearly observed that the driver executes two rides in a SD setting, by which in both rides the driver returns to its starting depot. On the right-hand side of Figure 7.2, the route planning of the same driver is shown in a MD setting.

The comparison is started by considering different scenario settings in order to discover the corresponding effects. A one day's data list of real orders¹² is used that initially contains 174 orders. The first change in settings regards the reduction of orders.

¹¹ With regard to the * in Table 7.1 a profit margin of 7.35% is subtracted from €6058.06 in order to reliably execute this comparison.

¹² Based on the order entry of Tuesday 9-12-2008 (week 50).



Figure 7.2: Route planning of a driver in a SD (left-hand side) and MD setting

Moreover, scenarios are compared by deleting 74 largest volume orders and 74 smallest volume orders. The remaining changes in settings concern the number of available pre-loaded vehicles and the fixed vehicle price used in SHORTREC. The latter is required with reference to the first model assumption described in subsection 6.2.4. An overview of the applied settings and KPI results are shown in Table 7.2 below.

SCENARIO				PERFORMANCE AND COMPARISON							
Setting	Number of orders	Smallest or largest volume orders deleted	Nr. of available pre-loaded vehicles	Costs after correction (€)	KMs driven	Number of vehicles	Nr. of rides	Working time	Driving time	Stopping time	Waiting time
SD	174	0	25	27693	21803	57	116	573:12	315:32	238:00	22:19
MD	174	0	25	25267	19287	54	119	530:36	284:57	238:00	3:19
DIFFERENCE:				-8,76%	-11,54%	-5,26%	2,59%	-7,43%	-9,69%	0,00%	-85,14%
SD	100	-74 large	25	11292	8856	34	49	230:38	131:27	98:00	1:11
MD	100	-74 large	25	11229	8595	30	50	230:42	128:10	99:00	3:32
DIFFERENCE:				-0,56%	-2,95%	-11,76%	2,04%	0,03%	-2,50%	1,02%	198,59%
SD	100	-74 large	10	12853	9919	30	48	259:36	144:17	112:00	3:19
MD	100	-74 large	10	12802	9868	28	50	260:43	143:43	114:00	3:00
DIFFERENCE:				-0,40%	-0,51%	-6,67%	4,17%	0,43%	-0,39%	1,79%	-9,55%
SD	100	-74 small	25	19183	15206	46	96	401:36	220:37	169:00	11:59
MD	100	-74 small	25	18404	14465	41	96	384:35	211:37	169:00	3:58
DIFFERENCE:				-4,06%	-4,87%	-10,87%	0,00%	-4,24%	-4,08%	0,00%	-66,90%
SD	100	-74 small	10	21252	17173	47	96	431:23	246:03	184:00	1:20
MD	100	-74 small	10	19892	15563	43	96	418:01	226:07	185:00	6:54
DIFFERENCE:				-6,40%	-9,38%	-8,51%	0,00%	-3,10%	-8,10%	0,54%	417,50%

Table 7.2: KPI results of comparison 2

First of all, from the table above it can be concluded that the amount of cost-saving diminishes in case the number of planned orders decreases. Secondly, although the required cost correction is consistently taken into account, in all cases the increase of a fixed vehicle price results in a worse SHORTREC solver outcome. Therefore, a fixed vehicle price adjustment of €100 (based on assumption 1, subsection 6.2.4), for which a

cost correction is made afterwards, is emerged to be a good approach for obtaining better results with SHORTREC. Furthermore, it is revealed that the number of available pre-loaded vehicles affects the comparison between a SD and MD Ambient planning. Therefore, based on these findings and the earlier-mentioned pre-loading SHORTREC limitation (see subsection 6.2.4), the use of a minimum required amount of pre-loading vehicles is founded to be an appropriate standard. This criterion is tantamount to approximately one seventh of the total number of planned orders. Finally, by comparing a MD with a SD planning, it can be observed that deletion of the smallest orders results in a higher cost-saving than deletion of the largest orders. The explanation to this is probably based on the following statement: Ten small orders gain a smaller effect on the total order volume than ten large orders. Thereupon, as mentioned before a larger order volume in the planning yields a higher cost-saving than a small order volume.

Based on these findings, a second computation is performed for reliably indicating what the cost-savings are of a growing Ambient network, when comparing a MD setting with a SD setting. In figure 7.3 below, this comparison is pictured by means of the following assumed scenario settings:

1. The deletion of orders regards an amount of small orders equivalent to the amount of large orders.
2. The number of available pre-loaded vehicles is adjusted to the number of orders planned as described above, i.e. one seventh of the total number of planned orders.

The graph is based on the scenario calculations and KPI results shown in Table I.3 of Appendix I.2.

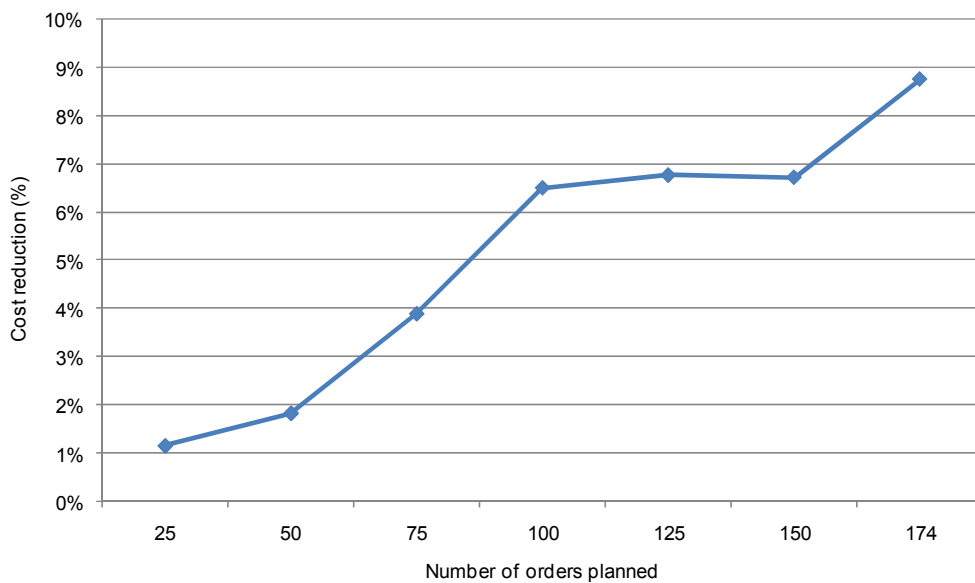


Figure 7.3: Comparison between MD (Ambient) vs. SD planning

The pattern of the graph clearly shows an increasing cost-saving in case the number of orders is growing. Although it is not statistically grounded, it can be concluded that in general, by switching from a SD towards a MD setting, an increasing cost-reduction is achieved if there are more orders involved in the planning. However, the slope of the line changes continually and by switching from 100 to 150 orders the percentage of cost-reduction almost remains constant. To conclude, the path of the cost-reduction increase is dependent on the specific order data within the network and the slope is not directly an applicable guideline for all order data lists. It is recommendable to re-execute this experiment whenever the network is changed. i.e. changes in the number of long-term clients and/or depots.

7.2.3. Comparison 3: Proactive vs. reactive MD Ambient

In this subsection the third comparison is computed and concerns the planning per day vs. the planning of several days, i.e. 48 hrs (see rolling horizon issue in subsection 6.2.4). This comparison shows the difference between a proactively performed planning and a reactively performed planning. A proactive planning can yield benefits (e.g. by changing the points of departure of the vehicle fleet) but is only possible if order information is received in time. Therefore, in this case study it is assumed that the order information is available two days beforehand. A minor part of the Ambient order arrival volume meets this requirement (see subsection 3.3.2). The fact, that a depot within the Ambient network contains its own type of products, makes the current planning process that is manually performed per single DC perceptible. This more reactive planning procedure in the current situation is a logical method for dealing with the complex and uncertain environment. Notwithstanding the fact that an entire proactive planning would be a much more desirable approach, for both the planning and the drivers.

As mentioned in the previous section, for executing this planning comparison the Multiday construction of SHORTREC is used. Due to this, it is very important to consider the additional scenario settings which can be used for this experiment. The experiments are again executed by taking into account the two assumptions defined in the previous subsection (7.2.2) and the entire overview of KPI results is shown in Appendix I.3. Within this experiment three important scenario options are discoverable (see also the generality limitation in subsection 6.2.4), which are explained below:

1. *Night's rest*: The planning option to enforce the driver a night's rest of 8 hrs in the vehicle, whereupon the driver continues the transport activities. However, this option is only available in the SHORTREC Multiday adjustment and not eligible if a reactive day planning is made.
2. *Free end-location*: The planning option that enables the choice for a free end-location, instead of a driver's return to its home depot. However, this option is indirectly linked to the night's rest option mentioned above, because due to a free end-location a driver is generally not able to go home after work. Therefore, if this option is chosen within a reactive planning, which is possible in SHORTREC, the additional costs of the night's rests are not taken into account, i.e. the outcome is too beneficial for the reactive planning.
3. *Free start-location*: The planning option that enables the choice for a free start-location. However, if a reactive day planning is produced, i.e. planning lacks the insight into the next-day's orders, a start location may be random, but the planning does not have the advantage of choosing a desirable start-location. This is the case because the point of departure of the vehicle fleet is a fixed given in a reactive planning. Therefore, if this option is chosen within a reactive planning, which is also possible in SHORTREC, the results are again too favourable.

To conclude, the proactive planning is very well modelled with the help of SHORTREC Multiday. The result of the Ambient 48 hrs planning is shown at the bottom of Table 7.4. From the table it can be observed that the total costs amount to €20,447 and 9 drivers are planned with a night's rest, which results in a total break time of 72 hrs. Nevertheless, in order to reliably execute the comparison an appropriate modelling for the reactive planning has to be chosen.

Since Ambient has the possibility to request the majority of the drivers to have a night's rest within the vehicle (see subsection 3.2.2) two scenarios can be defined as the upper and lower bound solutions for modelling the reactive Ambient planning. The upper and lower bound solutions are shown in Table 7.3 below, and are based on a reactive planning of two days with 100 orders a day, i.e. 48 hrs and 200 orders in total.

Reactive planning: 2 days separately (i.e. 2x 24 hrs and 2x 100 orders)											
Option for night's rest in vehicle	Option for free end-location	Option for free start-location	Costs after correction (€)	KMs driven	Number of vehicles	Number of rides	Working time	Driving time	Stopping time	Waiting time	Break time
No	No	No	31589	25063	66	131	620:26	366:12	228:00	26:14	0:00
No	Yes	Yes	20349	13442	55	128	440:12	197:48	212:00	30:24	0:00

Table 7.3: Upper and lower bound solution of reactive Ambient planning

Although the first solution is the most correctly modelled reactive planning, it does not take into account any Ambient night's rest advantage. The second solution includes all the advantages, i.e. free start and end-location without getting charged any night's rest working hours. Therefore, based on the descriptions above, the following scenario setting for modelling the reactive Ambient planning is found to be most valuable within this research: A reactive Ambient planning with a free start-location* in day one and a free end-location** in day two¹³. This solution precludes the night's rest issue and includes the advantages of a free start and end-location. However, compared to an actual reactive planning this scenario setting is again too beneficial. The KPI results of the proactive and reactive Ambient comparison are shown in Table 7.4 below.

SCENARIO					PERFORMANCE AND COMPARISON								
Horizon of 48hrs or 2x24hrs	Nr. of orders	Option for night's rest	Option for free end-location	Option for free start-location	Costs after correction (€)	KMs driven	Nr. of vehicles	Nr. of rides	Working time	Driving time	Stopping time	Waiting time	Break time
48 (2x24)	200	No	Yes*	Yes**	23989	17155	62	133	495:52	255:17	216:45	23:50	0:00
48	200	Yes	Yes	Yes	20447	13399	56	130	448:17	197:07	284:00	39:10	72:00
DIFFERENCE:					-14,77%	-21,89%	-9,68%	-2,26%	-9,60%	-22,79%	31,03%	64,34%	

Table 7.4: KPI results of comparison 3

The results show a cost improvement of 14.77% for a planning with a time horizon of 48 hrs and an amount of 100 orders a day (i.e. 200 orders in total). Besides, there are 6 less vehicles needed in this proactive planning. By considering the fact that Ambient generally executes more than 150 orders a day, the cost-savings resulting from a proactive planning procedure are large on a yearly basis, in all probability. However, from the table it can be observed that only 9 drivers are planned to have a night's rest, which is tantamount to 16% of the total number of combinations (i.e. 56 vehicles with drivers). It can be concluded that based on these results, the 50% of drivers that overnight in the actual Ambient (see subsection 3.2.2) are too many to be profitable.

7.2.4. Comparison 4: MD Ambient vs. alteration

As stated in the design assignment, the SHORTREC model has to be implemented for calculating the influences of volumes and/or clients on the costs of the Ambient network. The SHORTREC implementation assures the possibility to perform comparisons in future situations and is comprehensively described in the next chapter.

In this subsection a fourth comparison is discussed, in which the effects are calculated in case a new client is added to the Ambient network. Therefore, the aim is to indicate what the influence is, on the costs of a client by comparing the current Ambient planning with the addition of a new client (see also the cost per client issue in subsection 6.2.4). As a basis for this scenario analysis the client FFWE (DC Ede) is assumed to be a

¹³ The symbols * and ** refer to Table 7.4.

new client within the Ambient network. Three scenarios are solved through SHORTREC, of which the results in KPIs are shown in Table 7.5 below.

SCENARIO	Costs (€)	KMs driven	Number of vehicles	Number of rides	Number of orders	Working time	Driving time	Stopping time	Waiting time
Total Ambient network	21496	16466	44	92	143	454:16	239:49	206:00	8:27
Ambient without FFWE (Ede)	11140	8528	26	49	68	240:07	126:38	110:00	3:29
FFWE (Ede) seperately	11434	8925	29	42	75	229:06	128:12	99:00	1:54
<i>Impact client</i>									
FFWE (Ede) seperately	11434	8925	29	42	75	229:06	128:12	99:00	1:54
FFWE (Ede) within Ambient	10356	7938	18	43	75	214:09	113:11	96:00	4:58
<i>Difference</i>	-9,43%	-11,06%	-37,93%	2,38%	0,00%	-6,53%	-11,71%	-3,03%	161,40%

Table 7.5: KPI results of comparison 4

From the table it can be observed that if the client FFWE (Ede) performs its own transport and distribution activities, the costs amount to €11,434 and 29 vehicles are required. By contrast, in case the same 75 orders of FFWE (Ede) are added to the Ambient network, a cost-reduction is achieved of 9.43%. Besides, as much as 11 vehicles are saved, which indicates a huge client's investment that can be avoided by making use of Nabuurs' logistics services. It can be concluded that SHORTREC is extremely suitable for performing fast and quantitative comparisons in future Ambient situations, e.g. in favour of a cost quotation for a new client.

7.3. Conclusion

In this chapter four main experiments have been executed. As a result of the scenario analyses the following conclusion can be drawn:

Manual vs. automatic

For the benefit of the automatically performed SHORTREC planning compared to the manual planning, a cost-reduction of 8% is achieved through a decrease of the total amount of KMs and working time. However, the number of vehicles is increased with 10% but the number of rides has remained the same. As regards the main difference, within the manual planning similar rides are planned more frequently, whereas SHORTREC combines the depots, orders and drivers more interchangeable. Although, small reactive changes and adaptations are more easily applied to the manual planning, the execution of an automatic SHORTREC solution for this small amount of orders takes only a few minutes, instead of several hours for a manual planning. From this experiment it can be concluded that SHORTREC is a utilizable tool for providing good insight and for obtaining rapid, optimally produced route combinations, which makes it an extremely appropriate tool for supporting the current Ambient planning, i.e. on a tactical rather than operational level.

Multi-Depot vs. Single-Depot

The second experiment covers the main objective of this study, i.e. the comparison between a MD and SD planning procedure, within the Ambient network. It is indicated what the cost-savings are of a growing Ambient network, when an Ambient MD setting is compared to an Ambient SD setting. In order to reliably execute the experiment, the computation is based on two main assumptions: (1) order deletion within the planning regards a same amount for both the small and large orders and (2) the number of available pre-loaded vehicles is adjusted constantly, according to a pre-determined standard. From the Ambient results it can be concluded that in general, by switching from a SD towards a MD setting, an increasing cost-reduction is achieved. Thereupon, an increasing cost-saving is gained in case the order volume is growing. However, the path of the cost-reduction increase is dependent on the specific order data. Therefore, it is

commendable to re-execute this experiment whenever the network is changed. i.e. changes in the number of long-term clients and/or depots.

Proactive vs. reactive

The third experiment shows the comparison between a proactively performed planning and a reactively performed planning. The proactive planning is very well modelled with the help of SHORTREC Multiday. For modelling the reactive Ambient planning the following setting is found to be most suitable within this research: A reactive Ambient planning with a free start-location in day one and a free end-location in day two. However, compared to an actual reactive planning this scenario setting is slightly too beneficial, but fits the Ambient reactive planning more. The results show a cost improvement of 14.77% for the benefit of the proactive planning with a time horizon of 48 hrs and an amount of 100 orders a day (i.e. 200 orders in total). Besides, a reduction of 6 vehicles is achieved and 16% of the total number of combinations is planned to have a night's rest. The latter shows a substantial dissimilarity, since in the actual Ambient situation at least 50% of the drivers overnight in their vehicle.

Ambient vs. alteration

From the last comparison it can be concluded that SHORTREC is extremely suitable for performing fast and quantitative comparisons in future Ambient situations, e.g. in favour of a cost quotation for a new client. As a basis for the executed experiment the client FFWE (DC Ede) is assumed to be a new client within the Ambient network. The results show that if the client's 75 orders are executed within the current Ambient network, instead of using its own transport and distribution activities, a cost-reduction is achieved of 9.43% and even 11 vehicles are saved. The latter indicates a huge client's investment that can be avoided by making use of Nabuurs' logistics services.

CHAPTER 8. IMPLEMENTATION PLAN

In the previous chapter the SHORTREC case results have been discussed. This chapter covers the implementation plan by describing how SHORTREC should be implemented within the Ambient division. However, to fully implement the program a simplification of the order entry and a structured manual for preparing the model are desirable, which are described in Appendix J.1 and J.2 respectively.

To implement the SHORTREC system, it is required that there is support for the program and willingness to use the program within the Ambient environment. During the project, several actions have been executed to gain support for this study. Besides, an implementation session has taken place in order to teach the future main user about the implementation and utilization of SHORTREC. To create more support for the program and the implementation, the following actions should be considered:

- The first important step is to show that SHORTREC really improves the Ambient activities. In this case, Ambient improvements do not only refer to reducing transport and distribution costs, but also obtaining insight in current and future situations. The results mentioned in this report show (1) the validation and applicability of SHORTREC within the Ambient network and (2) the performance improvements that are achievable for already a small number of orders, by means of four different perspectives of experiments. Therefore, the first implementation step is covered by this report and it is demonstrated that it is in Ambient's interest to use SHORTREC.
- A following step is to determine how SHORTREC is going to be used. In the previous chapter, it has been shown that SHORTREC is a utilizable tool for providing good insight, for obtaining rapid, optimally produced route combinations and for performing fast and quantitative comparisons in (future) Ambient situations. However, it concerns an appropriate system for supporting the current Ambient activities on a tactical rather than operational level. Due to this, it is recommendable to start using SHORTREC for these tactical purposes (e.g. analyses and performance measurements) and make it accessible for those who are operating on this level (e.g. managers, supervisors and internal consultants). Since the constructed simulation model is suitable for calculating the influences and results of a new client, a SHORTREC application should be installed on a notebook. Making use of a notebook extends the mobility and makes appraisals and cost-savings presentable at any desired location.
- A definite factor for the utilization of SHORTREC, is the required time to use the system and generate outputs. The latter has already been indicated to be absolutely acceptable, by means of the performed experiments. E.g. for creating an optimized solution with 200 orders included, the solver never exceeds a running time of 10 minutes. Conversely, for frequent use of SHORTREC one important step is required, namely the simplification of the order entry. At any time, it should be possible and easy to read-in a desired data list of orders, e.g. orders of a particular day or week. In Appendix J.1 a description is given of this implementation step accompanied with a time and cost estimation.
- SHORTREC users must be able to understand the basics and results of the program. It is not required to understand every detail, but essential is the understanding to a certain extent, i.e. important characteristics, adjustments and preparations and how the program responds to changing parameters. This report is the starting point for this required insight, of which the preceding two chapters in particular. In sum, in chapter 6 the SHORTREC model has been defined, e.g. in terms of data collection, assumptions and limitations, next to which in chapter 7 the experiments and scenario analyses have been discussed from four different perspectives. However, although it is stated in section 7.1 that the base case scenario is used as a basic principle for

preparing an experiment, the model preparation is not explained in great detail. Therefore, Appendix J.2 is devoted to the preparation of SHORTREC and includes the required information for simplifying this implementation step.

The results obtained from the SHORTREC simulations, reveal substantial improvements for the benefit of an automatically and proactively performed planning procedure. However, SHORTREC is not an appropriate planning support system for executing the daily Ambient planning activities. Therefore, a pilot project is recommendable to find out what savings can be achieved by a proactive planning in real-life.

For this purpose SHORTREC can play a significant supportive role in further investigation. Besides SHORTREC should be used to indicate what the requirements are for an applicable planning tool that is capable of proactively executing the daily Ambient activities. If OTD is able to comply with these requirements the supportive function of SHORTREC should accelerate the OTD implementation, otherwise the further use of OTD should be reconsidered.

CHAPTER 9. CONCLUSIONS & RECOMMENDATIONS

In the previous chapter the SHORTREC implementation plan has been discussed. This chapter concludes this thesis by describing the most important conclusions and recommendations. First, the most important conclusions are summarized in section 1. Thereupon, the recommendations are presented in section 2. Finally, the areas for further research are defined in the last section.

9.1. Conclusions

The logistics activities of Nabuurs' Ambient division have increased strongly. As a result the Ambient network has changed fundamentally, i.e. from a SD towards a MD planning procedure. On the one hand this requires more (technological) developments and integral collaboration with long-term clients, but moreover, this produces a higher density of the network and creates opportunities with regard to efficiency. Therefore, the intention of this research has led to the following research assignment:

"Analyze and substantiate when the utilization of a multi-depot regarded to a single-depot planning is more advisable and cost-reducing, in order to improve the central routing planning of the Ambient transport flows."

Increasing pressures on reliability, customization, and flexibility continuously affect the logistics structures. Besides, uncertainty in logistics, i.e. by means of stochastic and dynamic elements, has become an extremely important issue. Although, many papers have been published on the classical VRP, not many have been dealing with the MDVRP, nor with the comparison between SD and MD. The MDVRP literature review shows that (1) advances in (information) technology simplifies the solving of objective functions considerably, (2) the best solving methods generally make use of a constructive and improvement phase and (3) the TS algorithm appears to be very well scoring in solving both the traditional VRP and the MDVRP.

From the analysis phase it can be concluded that within the Ambient network a MD planning system is utilizable, to facilitate routes to be planned simultaneously at one or several central sites rather than separately at individual depots. However, the possibility of advantageously centralizing the execution of operations, i.e. planning and controlling more tightly and efficiently, is heavily dependent on the receipt of orders and arrival of information. Concerning the Ambient network, order arrival times and patterns seem to vary between the different clients. Nevertheless, it is shown that only 15% of the total transport volume has to be delivered within 12 hrs, and 47% within 24 hrs. Therefore, the greater part of the incoming order volumes allow an efficient and proactive execution of the Ambient planning activities.

Although, Ambient has already made the step towards a MD planning, the planning activities mainly occur reactive and manually and the insight into changes and cost-savings is lacking. Simulation of changes in the network is time-consuming and makes the use of a planner necessary. In short, the benefits of a MD regarded to SD planning are largely unknown and not utilized in a desirable way. Despite performance measurement is a necessity for gaining improvements, it has revealed that goal-oriented performance measurement is not executed consistently within the Ambient network. Although, the almost total loading volume of the Ambient network can be attributed to around 10 depots (of which DCs Ede, Katwijk and Bodegraven already cover 55%), the delivery locations, and consequently the empty KMs, are spread all over the Ambient Benelux setting. Therefore, the ratio between loaded and empty KMs of a network area would be a substantial performance measurement. However, an evaluation model for the performance measurement of a network area is not on hand, while by using these types of evaluations the network can be more balanced and improved significantly.

Based on the observations it is concluded that there is a lack of goal-oriented performance measurement, which is required for revealing insight into improvements and alterations within the Ambient network. Therefore, the initial research assignment is refined towards the following design assignment formulation:

“Design a model to substantiate if for the current Ambient network a MD operating procedure is cost-reducing compared to a SD procedure, and determine the quantitative impact of the change from a SD setting towards a MD setting. Thereupon, implement the model for calculating the influences of changing volumes and/or clients on the costs of the Ambient network.”

In order to execute the design assignment, Ambient performances have to be measured quantitatively and the comparisons of different scenarios have to be performed. As a result, the decision is made to focus on a simulation study, through which the entire research scope is handled. However, a simulation model is not suitable to evaluate and visualize the executed Ambient activities. Since an evaluation model is also highly desirable within the Ambient network, the design phase is subdivided into two parts: (1) *The development of a performance evaluation model (PEM)*, to evaluate the performance of a desired Ambient network area and (2) *The development and implementation of a simulation model (SHORTREC)*. The latter, concerns an automated trip routing and scheduling system, that is able to optimize the Ambient transport and distribution planning. Through simulation, several experiments have been executed, from four different perspectives. The main results of the scenario analyses are:

- For the benefit of an automatically performed SHORTREC planning compared to a current manual planning of 32 orders, a cost-reduction of 8% is achieved through mainly combining depots, orders and drivers more interchangeable. Although, small reactive changes and adaptations are easier applied to the manual planning, an automatically performed SHORTREC solution for this small amount of orders takes only a few minutes, instead of several hours for a manual planning.
- In all executed Ambient cases, by switching from a SD towards a MD setting, an increasing cost-reduction is achieved, for which an increasing cost-saving is gained in case the order volume is growing.
- The comparison between an Ambient proactively vs. reactively performed planning, with a time horizon of 48 hrs and an amount of 200 orders, shows: A cost improvement of 14.77% and a reduction of 6 vehicles, for the benefit of the proactive planning. Besides, only 16% of the total number of combinations is planned to have a night's rest, which is a considerable difference with the current situation, that amounts to more than 50%.
- In case FFWE (DC Ede) is assumed to be a new client within the Ambient network, the results show that when 75 orders of DC Ede are executed within the current Ambient network instead of executing its own transport and distribution, a cost-reduction is achieved of 9.43%. Thereupon, even 11 vehicles are saved, which indicates a huge client's investment that can be avoided by making use of Nabuurs' logistics services.
- SHORTREC is an extremely appropriate tool for supporting the current Ambient planning, on a tactical rather than operational level. The planning system is able to realize rapid, optimally produced route combinations and quantitative comparisons with future Ambient situations.

9.2. Recommendations

Recommendations are based on the results obtained throughout this project and advise Ambient to focus on the following points of interest:

- *Transforming from a reactive to a proactive planning procedure*
To realize substantial cost-reductions Ambient should adopt a proactive planning policy, since the majority of the incoming order volume allows a proactive planning. Through this, improvements are

attainable in profitably applying night's rest of drivers and correctly determining points of departure of the vehicle fleet. However, automatic planning support and insistence of timely and correct order receipts are advisable in order to achieve this goal.

- *Utilization of automatic planning support*

Automatic planning support has repeatedly proven its benefits throughout this research, in terms of costs and time for calculating. It is demonstrated that in case a complex and dynamic MD network like Ambient is growing, generally more cost-benefits can be achieved. However, the latter requires more and more calculations and improvements of complex solutions, which is hardly practicable without automatic planning support. This also directly applies to the first mentioned recommendation. Ambient should benefit from an automatically performed route planning. Whether it is utilized for daily planning purposes or merely aims for performance measurement and scenario analysis. If these two recommendations are not performable within OTD, the implementation of OTD should be reconsidered.

- *Measuring and evaluating Ambient performances*

In order to improve logistics activities, further reduction of logistics costs through a more efficient execution of processes is a continuous objective. Therefore, Ambient should continually utilize its MD advantages in the best possible way by evaluating and measuring performances. It is recommendable to re-execute scenario analysis whenever the network is changed, e.g. alterations in the number of long-term clients and/or depots. Although the evaluation of the Ambient network areas, is stated as a significant matter for improving the Ambient network, other performance measurements might be important to consider as well. Since the MD cost-advantages of the Ambient network mainly depend on the multi-use and interchange-ability of vehicles, a cross-docking research would be highly interesting in all probability. Therefore, it should be determined what kind of performance measurements are useful for improving the Ambient planning.

- *Adaptation of invoicing policy*

In order to realize an improved daily Ambient planning a different invoicing policy is required. Ambient should implement a consistent tariff structure that determines who pays for which part and divides the cost-savings and corresponding profits in a suitable way. Therefore, a tariff structure research is a matter of great interest.

- *Improvement of current procedures*

Since many Ambient data files within the database are not correctly stored and/or used, Ambient should improve the accuracy and consistency of data. By means of a clean, organized database all daily Ambient activities, i.e. planning, communication, administration etc., as well as performance measurements and analyses, can be improved and executed more efficiently.

9.3. Further research

Although, many papers have been published on the classical VRP, only a few have been dealing with the MDVRP, as well as the comparison between SD and MD. Given the trends and developments in transport and distribution (e.g. globalization and expansion of logistics services), it would be valuable to extend the literature concerning the MDVRP, e.g. by taking into account both dynamic and stochastic factors.

Furthermore, as a continuation of this research project it could be statistically supported whether the "number of orders" and "type of orders" (e.g. size, timeslots) are significant variables of the cost-reduction, in the case the Ambient planning is switched from a SD towards a MD setting. Besides, an optimum could be found by taking into consideration the law of diminishing returns.

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READING GUIDES

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List of Abbreviations

<i>Concept</i>	<i>Definition</i>
C-W	Clarke and Wright
DC	Distribution Center
DVRP	Dynamic Vehicle Routing Problem
DWH	Data Warehouse
ERP	Enterprise Resource Planning
FFWE	Friesland Foods Western Europe
FMCG	Fast Moving Consumer Goods
FTL	Full-Truck-Load
G-M	Gillet and Miller
JIT	Just-In-Time
KM	Kilometer
KPI	Key Performance Indicator
LRP	Location-Routing Problem
LS	Local Search
LTL	Less-than-Truckload
MD	Multi-Depot
MDVRP	Multi-Depot Vehicle Routing Problem
OOH	Out-Of-Home
OR	Operations Research
OTD	ORTEC Transport & Distribution
PCI	Process, Control and Information
PEM	Performance Evaluation Model
QMS	Quality Management System
SD	Single-Depot
TMS	Transport Management System
TS	Tabu Search
TW	Time Window
UTSA	Unified Tabu Search Algorithm
VRP	Vehicle Routing Problem
VRPPD	Vehicle Routing Problem with Pick-Up and Delivery
VRPTW	Vehicle Routing Problem with Time Windows
VRS	Vehcile Routing and Scheduling
WMS	Warehouse Management System

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APPENDIX A. OVERVIEW OF CONCEPTS & INDICATORS

CONCEPTS	Refrigerated	Frozen	Dry	Live	
Transport	Transport refrigerated/frozen (NL) Transport refrigerated/frozen (B) Transport Sligro Foodservice		Transport Ambient (NL) Transport Ambient (Belgium) Transport Trucking	Transport live poultry	
Logistics	Warehousing Superunie		Warehousing Ambient Katwijk Warehousing SCA Gennep Warehousing Refresco Bodegraven Consumer Goods Consolidation Center		
Sundries			Freight Frame		
INDICATORS					Total
Revenues	€ 7.087.000	€ 3.150.000	€ 56.900.000	€ 7.863.000	€ 75.000.000
% of Nabuurs	10%	4%	76%	10%	100%
# of Employees	80	25	446	51	602
# of Trucks	31	20	270	42	363

Table A.1: An overview of Nabuurs' concepts and indicators

APPENDIX B. STUDY OF LITERATURE

B.1. Vehicle Routing Problem and variants

This section concentrates on the basic version of the Vehicle Routing Problem (VRP), in order to provide a requisite insight with regard to the objectives and extensions of the VRP.

Definition

According to Solomon (1987), the solution of a Vehicle Routing Problem (VRP) calls for the design of a set of minimum-cost vehicle routes, originating and terminating at a central depot, for a fleet of vehicles that services a set of customers with known demand. Each customer is serviced exactly once and, furthermore, all the customers must be assigned to vehicles without exceeding vehicle capacities. The Classical VRP can be formally defined as follows (Díaz, 2007).

- Let $G = (V, A)$ be a graph where $V = \{v_0, v_1, \dots, v_n\}$ is a vertex set, and $A = \{(v_i, v_j) / v_i, v_j \in V; i \neq j\}$ is an arc set. Vertex v_0 represents a depot, while the remaining vertices correspond to customers.
- C is a matrix of non-negative costs or distances c_{ij} between customers v_i and v_j
- Each customer has a demand of q_i and a service duration of d_i
- Besides, the vertex v_0 represents the depot at which are based m vehicles of capacity Q
- When $c_{ij} = c_{ji}$ for all $(v_i, v_j) \in A$ the problem is said to be symmetric. It is then common to replace A with the edge set $E = \{(v_i, v_j) / v_i, v_j \in V; i < j\}$.

With each vertex v_i in V' is associated a quantity q_i of some goods to be delivered by a vehicle. The VRP thus consists of determining a set of m vehicle routes of minimal total costs, starting and ending at a depot, such that every vertex in V' is visited exactly once by one vehicle. The objectives that can be considered for the classical VRP are:

- Minimization of the global transportation costs
- Minimization of the number of vehicles (or drivers) required to serve all the customers
- Minimization of the penalties associated with partial service of the customers
- Balancing of the routes, for travel time and vehicle load

In recent years several new meta-heuristics have been put forward for solving the VRP, which combine a variety of principles including population search, tabu-search (TS) and learning mechanisms (Cordeau et al., 2005). According to the results of "A guide to VRP heuristics" by Cordeau et al. (2002), the classical heuristics do not score well on accuracy and flexibility. However, the Clarke and Wright (1964) heuristic has the distinct advantage of being very quick and simple to implement. Among the tabu search (TS) algorithms, there has been a tendency toward increased speed and simplicity. Besides, among stand-alone heuristics, the unified tabu search algorithm (UTSA) scores very well on all dimensions, i.e. simplicity, flexibility, accuracy and speed (Cordeau et al., 2002).

VRP extensions

In order to better model real world applications, a number of extensions to the basic VRP have been considered by researchers. These VRP variants are mainly originated due to the addition of constraints like for example mixing decisions, including fleet size, or allowing different forms of routes. A survey with a brief explanation of well-known VRP variants in literature is given below:

- *Capacitated VRP (CVRP)*: In the Capacitated VRP, all the customers correspond to deliveries and the demands are deterministic and known in advance. The vehicles are identical and based at a single

central depot. Besides, only the capacity restriction for the vehicles are imposed (Toth and Vigo, 2002).

- *Distance-Constrained VRP (DCVRP)*: Here both the vehicle capacity and the maximum distance constraints are taken into account (Toth and Vigo, 2002).
- *Split Delivery VRP (SDVRP)*: In the Split Delivery VRP the restriction that each customer is visited once is removed. Therefore, a fleet of homogeneous vehicles has to serve a set of customers and no constraint on the number of available vehicles is considered (Archetti et al., 2006).
- *Periodic VRP (PVRP)*: Delivery routes are constructed for a period of time, for example deliveries in some days (Cordeau et al., 1997).
- *Stochastic VRP (SVRP)*: The stochastic VRP arises when elements of the VRP are stochastic, the set of customers visited, the demands at the vertices, or the travel times. In brief, If any component has a random behavior (Gendreau et al., 1996).
- *Dynamic VRP (DVRP)*: In contrast to the static traditional VRP, the Dynamic VRP deals with real-life applications in which the information often tends to be uncertain or unknown at the time of the planning (Psaraftis, 1988).
- *VRP with Multiple use of Vehicles (VRPM)*: In some contexts, one can assign more than one route to a vehicle. For example, when the vehicle fleet is small or when the length of the day is large (Fleischmann, 1990).
- *VRP with Backhauls (VRPB)*: The VRP with backhauls is the extension of the CVRP in which the customer set contains linehaul customers and backhaul customers as well. Linehaul customers require a given quantity of products to be delivered and backhaul customers from where a given quantity of inbound products must be picked up. VRP with Backhauls and Time Windows (VRPBTW) has been studied in literature as well and is the VRPB in which time windows are present (Toth and Vigo, 2002).
- *VRP with Pick-Up and Delivery (VRPPD)*: The Pick-Up and Delivery variant extends the VRP by allowing customers to both send and receive goods (Desaulniers et al., 2002).
- *VRP with Satellite Facilities (VRPSF)*: In the Satellite Facilities variant a satellite replenishment allows the drivers to continue making deliveries without necessarily returning to the central depot, until the end of the shift (Bard et al., 1998).
- *VRP with Time Windows (VRPTW)*: The VRP with Time Windows is the extension of the CVRP in which capacity constraints are imposed and each customer is associated with a time interval (time window). The delivery locations have time windows within which the deliveries or visits must be made (Solomon, 1987).
- *Multiple Depots VRP (MDVRP)*: The Multiple Depot VRP is a generalization of the single depot VRP in which multiple vehicles start from multiple depots and return to their original depots at the end of their assigned tours (Laporte et al., 1984).

B.2. Uncertainty in the VRP

In order to survive in modern economy markets, companies must quickly respond to the encountered growing time pressures and uncertainties. “Dynamic scenarios have become more common in distribution logistics recently, and are likely to become even more so in the future” (Psaraftis, 1995). Following Powell et al. (1995), dynamic and stochastic models are playing an increasingly important role if decision making is required before all the information is available, and decisions are modified whenever new information is obtained. Below, both the Dynamic VRP and Stochastic VRP are discussed in succession. It provides the insight in the types of uncertainty and how there is dealt with uncertainty in VRPs.

Dynamic approach

Psaraftis (1988) was among the first to consider the dynamic extension of the traditional static VRP, which is called the Dynamic Vehicle Routing Problem (DVRP). In Psaraftis (1988), dynamic vehicle routing is described as the dispatching of vehicles to satisfy multiple demands for service that evolve in a real-time dynamic fashion. In Figure B.1 this extension is visualized with respect to the static, basic VRP.

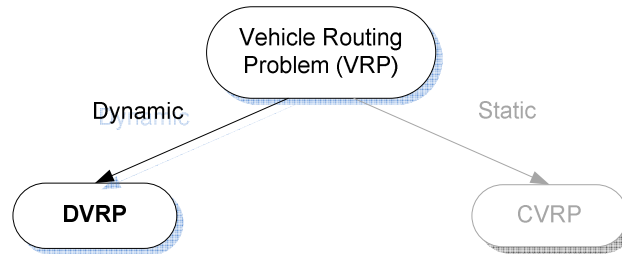


Figure B.1: Dynamic extension of the basic VRP

As stated in Psaraftis (1988), little work was done to combine congestion (queuing) and vehicle routing theory, although both concerned very rich subjects. In Van Woensel et al. (2007), by modelling the traffic congestion component through a queuing approach, it is shown that static (or time-independent) solutions for routing problems within a congested traffic environment are often infeasible. Shortly, the best solution of a static problem applied in a dynamic context is in general sub-optimal (Van Woensel et al., 2007).

In order to give a dynamic application of a static model, in Powell et al. (1995), two types of dynamic problems are covered:

1. Problems with dynamic data: Problems characterized by constantly changing information, e.g. data that might include real-time customer demands, traffic conditions, or driver statuses.
2. Problems with time-dependent data: Problems for which all the information is known in advance, but where the data is a known function of time (e.g. customer demands or travel times if assumed to be known functions of time).

Related to this division, following Larsen et al. (2008), in the DVRP vehicles must service two types of requests: advance requests (i.e. placed before the routing process is started) and immediate requests (i.e. arisen in real-time during the day of operations). In Larsen et al. (2008), the importance of the *degree of dynamism* (DOD) in dynamic vehicle routing systems is emphasized. The concept of DOD, introduced by Lund et al. (1996), is the ratio of the number of immediate requests relative to the total number of requests. Logically, the level of DOD might influence the solution quality with respect to the objective of minimizing the total distance driven.

Conversely, according to Bertsimas and Van Ryzin (1993), “the objective of minimizing travel distance as the case in the traditional VRP, is not necessarily paramount. In a dynamic setting, the delivery time (wait

for service) is often a more appropriate objective". In the literature (e.g. Bertsimas and Van Ryzin, 1993; Van Woensel et al., 2007; Larsen et al., 2007) the objectives seem to differ from one application to the other. Nevertheless, as stated by Larsen et al. (2008), a few measures are almost always relevant to consider, namely travel costs, service level, and throughput maximization.

Stochastic approach

In the case of a stochastic approach one or more parameters of the problem are not exactly known before a routing planning is made. The figure below, shows the connection regarding the Stochastic Vehicle Routing Problem (SVRP), again with respect to the basic VRP (which is deterministic by nature).

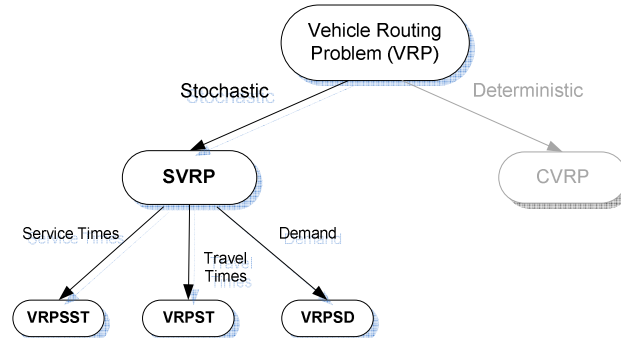


Figure B.2: Stochastic extension of the basic VRP with underlying variants

The literature shows the following three variants of the SVRP:

- VRP with Stochastic Service Times (VRPSST). Herein the service times are followed by a specific distribution of probability. In Hadjiconstantinou and Roberts (2002), an algorithm, referred to as the Paired Tree Search Algorithm (PTSA) is used to solve the VRPSST with variable costs of recourse (that generates a cost or a saving). In their study optimal schedules of jobs are identified by taking into account stochastic service times and reactive call-outs.
- VRP with Stochastic Travel Times (VRPST). Uncertainty in travel times, through for instance unexpected traffic-jams, causes a need for the forecasting of an expected travel time. The unexpected queues might deviate the real travel times from the planned travel times. Stochastic travel times are described in among others the papers of Laporte et al. (1992) and Gendreau et al. (1996). Hadjiconstantinou and Roberts (2002), state that Laporte, Louveaux, and Mercure were the first to consider an alternative objective for the VRPST. They presented exact results for VRPSTs up to 20 customers by making use of a three-index simple recourse model and a two-index recourse model, based on finding a minimum cost a priori solution.
- VRP with Stochastic Demands (VRPSD). In this case the demands of the customers are random variables. The VRPSD is according to Gendreau et al. (1996) the most studied of the stochastic VRPs. Nevertheless, the few studies that have been completed on the VRPSD focused on heuristic methods (Hadjiconstantinou and Roberts, 2002). According to Larsen (2008), the SVRPs are usually two-stage recourse problems, i.e. in the first stage a planned or a-priori route is designed and in the second stage a recourse is used to accommodate problems. Gendreau illustrates this two-stage methodology by considering the VRP with stochastic demands.

B.3. Multi-Depot Vehicle Routing Problem

The recent literature with regard to the MDVRP is shown in the left-hand part of the figure below.

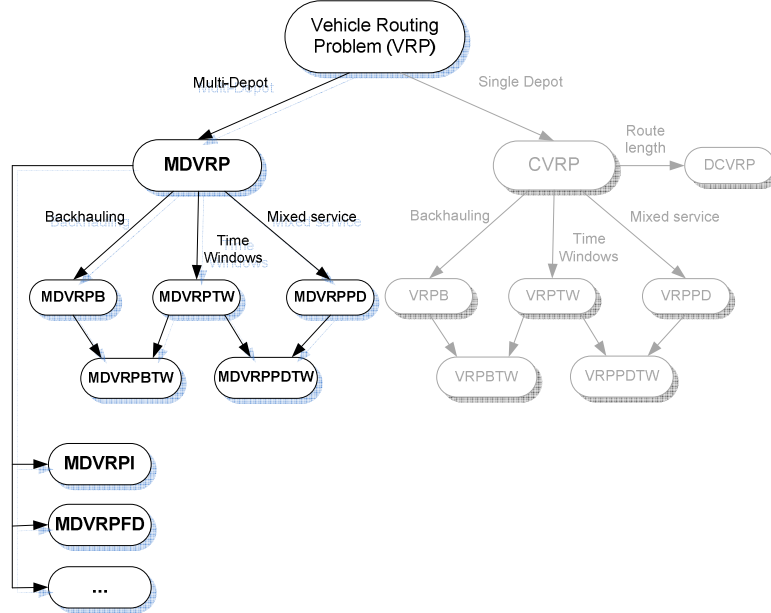


Figure B.3: Interconnected framework with the MDVRP extension

The combinatorial extensions of the MDVRP presented in the framework above are successively discussed in more details below.

- *MDVRP with Pick-up and Delivery (MDVRPPD)*

According to Nagy and Salhi (2005), the following three important VRPPD models may be distinguished in the literature:

1. Delivery-first, pickup-second. A model in which most authors assume customers to be divided into linehauls (receiving goods customers) and backhauls (sending goods). Besides the vehicles can only pick up goods after they have finished delivering all their load.
2. Mixed pickups and deliveries. In this case linehauls and backhauls can occur in an arbitrary sequence.
3. Simultaneous pickups and deliveries. A VRPPD where customers simultaneously send and receive goods.

The first two models, *delivery-first pickup-second* and *mixed pickups and deliveries*, are jointly referred to as the VRP with Backhauling (VRPB). In the study of Nagy and Salhi (2005), the aim is to produce a composite heuristic approach, extended to the MD problem, for both the simultaneous and mixed VRPPD. The authors believe that the assumption of delivery-first and pickup-second is unnecessarily restrictive and results in poor quality solutions. Therefore, this model is excluded from their consideration. Besides, the extension to MD problems has not been done before, for the general version of the VRPPD (Nagy and Salhi, 2005). The objective function of the VRPPD is to minimize the total distance travelled by the vehicles, subject to maximum distance and capacity constraints on the vehicles. The integrated heuristic consists of the following phases: The construction of a weakly feasible initial solution and an improvement of this solution, while maintaining weak feasibility. Subsequently, the same two steps but now for strong feasibility.

- *MDVRP with Backhauls (MDVRPB)*

In contrast to Nagy and Salhi (2005), the authors Fan et al. (2007) propose an algorithm with the goal to minimize the total travelling cost instead of total travelling distance. For the algorithm mixed vehicle routings with both linehauls and backhauls are needed, to serve the set of customers. In this article they consider the special case that on each routing the backhauls must be visited after the linehauls. This constraint is in accordance with the before mentioned first model of Nagy and Salhi (2005). The cited reason by Nagy and Salhi for not using this model because of poor quality solutions is not mentioned in the article of Fan et al. (2007). Conversely, this constraint is motivated by the fact that most vehicles are rear-loaded, so it is inconvenient to rearrange onboard delivery loads to accept new pick-up loads (Fan et al., 2007).

The main idea of the algorithm for the MDVRPB of this paper is according to the following steps: Firstly, borderline customers are determined, which means that the customers are divided into borderline customers and non borderline customers. The borderline customers are left unassigned, whereas each non borderline customer is assigned to the nearest depot. Secondly, in each depot, initial routings are constructed conformable to the constraints to serve the customers assigned to the depot. Next, each borderline customer is then inserted into an existing routing or an empty routing. Finally, all the initial routings are improved by making use of a post-optimization procedure (Fan et al., 2007). An important limitation of the approach is that different types of vehicles are not taken into account.

- *MDVRP with Time Windows (MDVRPTW)*

In the paper of Cordeau et al. (2001), the authors provide the unified tabu search algorithm (UTSA) that was initially designed for the periodic VRP and the multi-depot VRP, and later slightly modified and extended to the single depot, multi-depot and periodic VRP with time windows. Here they also explain that a same solution approach can be used to address all three variants, because the MDVRPTW and the SDVRPTW can be seen as special cases of the PVRPTW.

Important to mention is that in the VRPTW instances, the number of vehicles is not fixed, but instead minimized, as a primary objective. The secondary objective consists of minimizing the total travel time. In Cordeau et al. (2001), the heuristic is not designed to minimize the number of vehicles, but the number of available vehicles is set equal to the number of routes of the best solution reported in the literature. In addition, the reported results only include methods in which the feasibility and cost of the solutions are computed using a sufficient degree of precision (Cordeau et al., 2001).

According to Cordeau et al. (2004), the MDVRPTW generalizes the VRPTW by considering multiple depots at which the vehicles are based. In this paper new best known solutions are yielded for the MDVRPTW by making use of an improved tabu search algorithm. In this improved TS algorithm again the characteristic of infeasible solutions during the search is allowed, as in the case of Cordeau et al. (1997) mentioned in the previous chapter. Besides, the reported results are anew compared to each other through the cost of the solution, which has taken into account the following constraints:

1. Every route starts and ends at the depot
2. Every customer belongs to exactly one route
3. The total load and duration of a route do not exceed a certain value
4. The service at a customer and the departure of every vehicle belongs to a time interval
5. The total travel time of all vehicles is minimized

The heuristic moves at each iteration from the current solution to the best non-tabu solution. In brief, the algorithm first constructs a random initial solution within the search space, and then sets a solution that minimizes the cost of a best non-tabu solution.

- *MDVRP with Inter-Depot Routes (MDVRPI)*

According to Crevier et al. (2007), the Multi-Depot VRP with Inter-Depot Routes (MDVRPI) has not received much attention from researchers. The MDVRPI is an extension of the MDVRP in which vehicles may be replenished at intermediate depots along their route (Crevier et al., 2007). Noticeable, the algorithmic approach discussed in this paper combines the adaptive memory principle proposed by Rochat and Taillard (1995), a TS method for the solution of sub problems, and integer programming as well.

The adaptive memory principle creates solutions by combining elements of previously obtained solutions. The decomposition of the MDVRPI takes place, into an MDVRP, VRPs and inter-depot sub problems, resulting into three types of problems. Thereupon, a TS heuristic is applied to these three types of problems and the underlying single-depot and inter-depot routes will be extracted and inserted in a so-called solution pool. Finally, an MDVRPI solution is created by a set partitioning algorithm and a post-optimization phase will be performed in an attempt to improve the solution. In short, the five components of their methodology are: (1) the tabu search heuristic; (2) the procedure applied for the generation of a solution pool; (3) the route generation algorithm; (4) the set partitioning algorithm, and (5) the post-optimization phase.

- *MDVRP with fixed distribution of vehicles (MDVRPFD)*

One of the remaining extensions of the Multi-Depot VRP in the recent literature is provided by Lim and Wang (2005). According to Lim and Wang (2005), the MDVRP is one of the core optimization problems in transportation, logistics, and supply chain management, which minimizes the total travel distance (the major factor of total transportation cost) among a number of given depots. However, in real practice, the MDVRP is not reliable because it is assumed that there are unlimited number of vehicles available in each depot. Therefore, the authors propose a new useful variant of the MDVRP, namely the multi-depot vehicle routing problem with fixed distribution of vehicles (MDVRPFD). In order to model this practicable case they explore the notion of minimizing the maximal length of a tour in a MDVRP ("min-max MDVRP") by making use of both theoretical analysis and heuristic design.

In practice, many companies in the transport sector make use of a charter service. Therefore, in case the number of vehicles are inadequate in a certain time-period (e.g. caused by a peak demand), charters can be used to meet the deficiency. In that way, the assumption of unlimited number of vehicles available in each depot, can be made properly.

APPENDIX C. OPERATIONAL PROCESS STRUCTURE

In this appendix the main process and planning procedure of the Ambient division are presented.

C.1. Main process Nabuurs

Responsibility	Procedure main process Nabuurs	Description
	<pre> graph TD Start([Start main process Nabuurs]) --> 01.1[01.1 Commercial] 01.1 --> 01.2[01.2 Order handling] 01.2 --> 01.3[01.3 Planning] 01.3 --> 01.4[01.4 Loading] 01.4 --> 01.5[01.5 Transport] 01.5 --> 01.6[01.6 Unloading] 01.6 --> 01.7{01.7 Next ride?} 01.7 -- Yes --> 01.8[01.8 Transport] 01.8 --> 01.4 01.7 -- No --> 01.9[01.9 Waybill processing] 01.9 --> 01.10[01.10 Invoicing] 01.10 --> End([End of main process Nabuurs]) </pre>	
01.1 Commercial director	01.1 Commercial	01.1 Agreement with client and enter into contract.
01.2 Order entry	01.2 Order handling	01.2 Incoming orders are handled.
01.3 Planner	01.3 Planning	01.3 Incoming orders are planned for transportation.
01.4 Chauffeur / sender	01.4 Loading	01.4 The vehicle is loaded for transport, by the driver or sender.
01.5 Chauffeur	01.5 Transport	01.5 Executing of ride according to schedule.
01.6 Chauffeur / receiver	01.6 Unloading	01.6 After arrival at the client's destination the goods are unloaded.
01.7 Planner	01.7 Next ride?	01.7 Next ride that needs to be executed.
01.8 Chauffeur	01.8 Transport	01.8 Driving towards loading location.
01.9 Administration	01.9 Waybill processing	01.9 After finishing ride, handing in waybill on behalf of administration and invoicing.
01.10 Administration	01.10 Invoicing	01.10 Invoicing process
	End of main process Nabuurs	

Figure C.1: Main process Nabuurs

C.2. Planning procedure

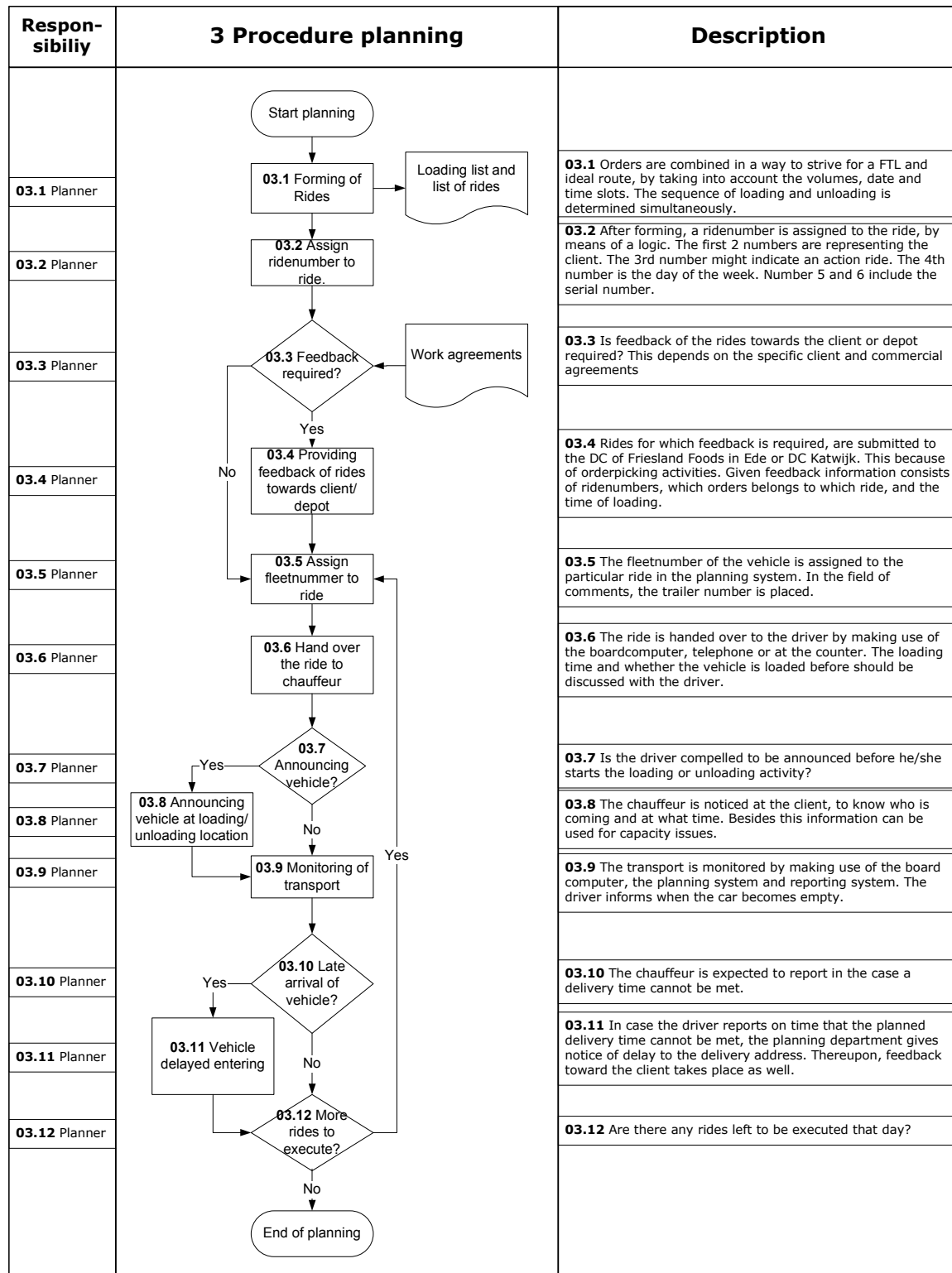


Figure C.2: Planning procedure Nabuurs

APPENDIX D. FLEET OF VEHICLES

In the Ambient network three types of vehicle combinations are used, which are explained in detail below.

- *Truck and trailer:* The truck and trailer can be considered as the basic vehicle type. The size of the loading space is 2.5 metre broad and 13.6 metre long. By taking for granted a pallet area of 1.2 m² (i.e. 120 x 100 cm), the available loading space is limited to 26 pallet boards. At the back of the trailer an existing tailgate makes the loading and unloading activities possible. Furthermore, the sidewalls consist of displaceable sails which has two main advantageous: first, sideward loading and unloading of cargo is possible, and second, load which is slightly broader in size than the pallet dimension can be transported too (overhang).



- *Refrigerated truck and trailer:* With regard to the available loading space, loading sizes and volumes, this vehicle is identical to the standard truck and trailer. In order to meet the quality requirements of conditioned freight transport the loading spaces are fully equipped with state-of-the-art equipment and temperature control systems. However, due to climate control the side walls of the trailer are fixed, isolated walls, instead of displaceable sails. Therefore, overhang is not possible and loading and unloading activities can only occur by making use of the tailgate, at the back of the trailer.
- *Combination:* In the case of a combination the total loading space is divided into a fixed part attached to the truck, and a second part which concerns the trailer. Dependent on the type of vehicle, and again with the assumption of a 1.2 m² pallet area, a combination has space for 28 to 30 pallet boards. As in the case of the standard truck and trailer, the sidewalls consist of displaceable sails, which make both overhang and sideward loading and unloading of cargo possible.



In the table¹⁴ below the number of vehicle types within the Ambient network are given. The number between brackets indicates the status of active per specific vehicle type.

Ambient Fleet	Truck (Active)	Trailer (Active)	Combination Truck (Active)	Combination Trailer (Active)
DC Bodegraven	5 (1)	50 (20)	0 (0)	0 (0)
DC Bornem	3 (1)	5 (2)	11 (5)	6 (3)
DC Breda	7 (6)	17 (16)	0 (0)	0 (0)
DC Ede	41 (29)	166 (86)	6 (2)	7 (4)
DC Zoetermeer	24 (14)	30 (20)	3 (3)	0 (0)
Total (Active)	80 (51)	268 (144)	20 (10)	13 (7)

Table D.1: Ambient fleet of which combinations are made

In reality Ambient makes use of fixed combinations which are made up of a driver and a truck and trailer combination. Approximately 100 combination are active in order to execute the daily transports.

¹⁴ Based on the fleet data of November 2008

APPENDIX E. OTD PLAN PHASES

The OTD plan phases, which are formulated on 1-10-2008, are described below.

Semi-automatic planning

The system proposes a combination, for which the planner needs to agree with yes or no. If the answer is *yes* the proposal is automatically planned, if the answer is *no* the planning occurs manually. The system's expectations regarding the semi-automatic planning are:

1. Forming of rides; the order data received from a client will be, if desirable, combined to Full Truck Loads (FTLs), by taking into account the loading volumes, resource capacities, equipment, time-windows and geography.
2. Taking the restrictions into consideration, e.g. regulations governing driving hours.
3. Providing of indications whether a delivery is according to plan. A colour indication for *OK* (order delivered); *OK* (no retarding noticed); *ATTENTION* (departure of preceding ride too late); *CRITICAL* (lack of an unloading sign while 15 minutes before expiring time-window); *TOO LATE* (time-window exceeded).
4. Composing of a planning concerning the first rides and deliveries for the proximate working day. Again by taking into account the restriction and requirements.
5. Continuation of current planning; if a ride is finished and confirmed (by board computer or planner) a proposal is given for the most suitable match between the resources concerned and a to be executed ride.

Principles:

- The planning system optimizes through total costs minimization, by taking into account time-windows, regulations governing driving hours, and (legal) preconditions.
- If a *no* is reported in a particular step this decision only concerns the present, proposed ride. For the remaining rides still an unchanged proposal is given by the system.
- If all the proposals are finalized by the system (interruptible by planner) the planner continuous manually.

Automatic planning

The system makes a planning automatically, with the steps conformable to semi-automatic planning. Nevertheless, the planner is able to overrule the system.

APPENDIX F. PERFORMANCE EVALUATION MODEL

F.1. PEM Output 1

Table F.1: Total overview of measurements PEM output 1

F.2. PEM Output 2

Output 2 of the PEM concerns the performance measurement in terms of a ride lengths frequency. The desired results can be visualized in a frequency table by means of the following two actions (see red-coloured number 1 and 2 below):

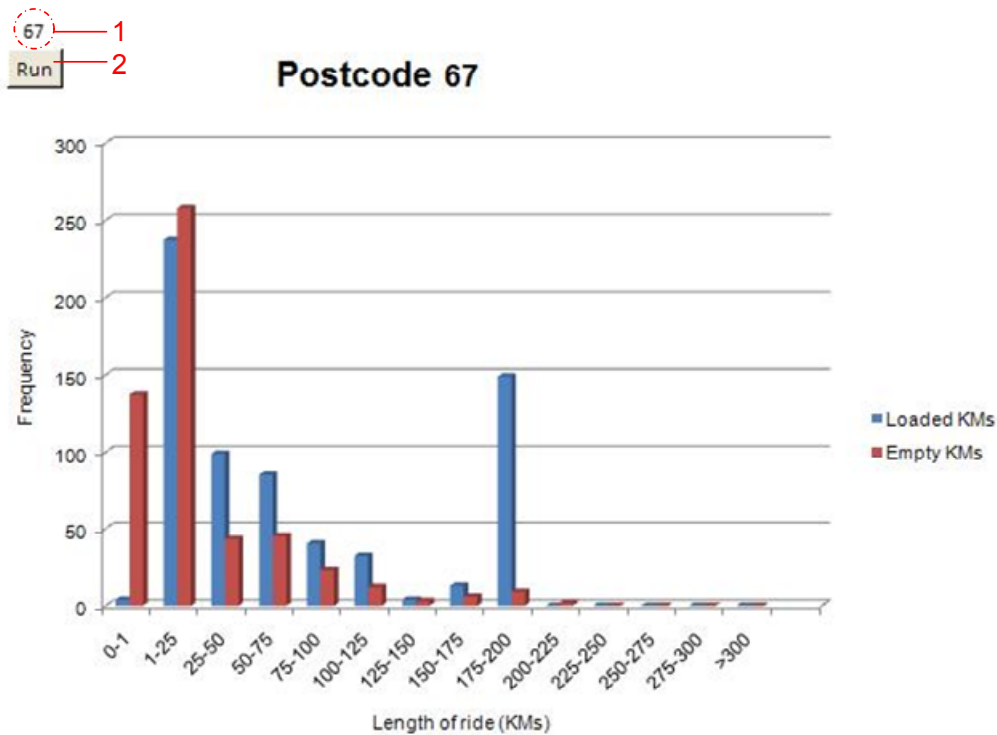


Figure F.2: Manual of the PEM

APPENDIX G. SHORTREC ALGORITHMS

In this appendix the SHORTREC algorithms are presented, of which the information is originating from ORTEC documents and presentations. As mentioned before, SHORTREC is designed to minimize overall costs. Costs can be adjusted by bonuses or penalties to influence the algorithm and achieve or avoid certain outcomes. The SHORTREC algorithm follows the following two-phase strategy:

1. *Basic Solution*: Rule based strategy to build initial routes which only adds unassigned orders to existing or new routes. A feasible solution is created with the target to assign as many orders as possible.
2. *Optimization Routines*: Heuristics to minimize costs (reduce miles, hrs, overtime, routes, etc). This second phase is more time intensive, especially when there are a large number of exchange alternatives.

Based on the above-mentioned two-phase strategy the solver of SHORTREC consists of two types of algorithms, namely Construction and Improvement algorithms. All the algorithms included in SHORTREC are enumerated below and clarified by means of a small summary.

Construction Algorithms

The construction algorithms build initial feasible solutions without trying to optimize. In construction algorithms two criteria play a central role: (1) The Selection criterion, i.e. which order should be selected given the current solution. (2) The Insertion criterion, i.e. where should the selected order be inserted. The goal of construction methods is to produce fast a feasible initial solution that can be improved upon later by means of the so-called improvement methods.

- The Sequential Insertion Algorithm

In the Sequential Insertion algorithm trips are constructed sequentially, where initially all vehicles are empty. The most important step of the algorithm is the selection of the first order (seed) in a vehicle. As the seed usually the order farthest from the depot is chosen. Other possibilities for the seed are the largest order and the order with the smallest time-window. When the seed is selected, orders are added to the vehicle until the vehicle is full. Therefore, first a vehicle is selected and filled with orders until no more orders can be feasibly added. Next, a second empty vehicle is selected and the procedure is repeated, and so on. The algorithm consists of four steps. The advantages of the algorithm are that it is easily understood and implemented and that it generally provides a good initial solution in little calculation time. A disadvantage is that the resulting trips may be visually unattractive, for example due to trip crossings or poor clustering.

- The Savings Algorithm

Probably the most widely known heuristic is the savings method by Clark and Wright (1964). The algorithm starts with a solution in which every order is supplied by a separate trip and each trip by a separate vehicle. Then the savings in for example distance from combining trips are calculated and the feasible trips with maximum savings are iteratively selected to form the initial solution. Since in the Savings algorithm the trips are constructed simultaneously, trip crossings hardly occur and clustering is very good. Some disadvantages of the algorithm are the following. Since the savings calculation is only based on distance, the difference in delivery times between two orders may be very large, resulting in large waiting times. Because in the algorithm orders cannot be inserted between the two orders, this waiting time cannot be reduced. Moreover, when the algorithm terminates possible remaining orders cannot be assigned to the remaining vehicles and capacity may not be used efficiently.

- The Priority Based Parallel Insertion Algorithm

The Priority Based Parallel Insertion algorithm groups orders based on restrictions between orders and vehicles. The algorithm starts by constructing a matrix, the so-called difficulty matrix, storing feasible

vehicles for each order and the row and column totals of the matrix. In each step of the algorithm a group of orders and vehicles is selected that should be scheduled together. In other words, in each step of the algorithm small sub-problems are constructed and solved by means of the Sequential Insertion algorithm. A disadvantage of the algorithm is that the resulting trips may be visually unattractive due to trip crossings and poor clustering. However, situations in which the algorithm outperforms the alternative construction algorithms are when there are several groups of orders and vehicles that overlap.

- The Cluster Based Insertion Algorithm

The steps of the Cluster Based Insertion algorithm are similar to the steps of the Sequential Insertion algorithm and can be summarized as follows: (1) Select the seed order. (2) Find a vehicle for the seed. (3) Add orders to selected vehicle until the vehicle is full. (4) Find a cheaper vehicle. (5) If remaining orders, go to step 1. The algorithm starts by determining the difficulty and the cluster size of the orders. The difficulty of an order is determined by the number of allowed vehicles and depots. The cluster size is the number of orders within a pre-specified radius from each other.

- The Multi-Depot Insertion Algorithm

In the first step of the algorithm amongst others the sort method should be selected, there are five possibilities. After all necessary data is initialized, in step 2 the seed order is selected based on difficulty. That is, based on the number of admitted depots and admitted vehicles. In step 3 the largest remaining empty vehicle is selected and in step 4 orders are added to the vehicle based on the selected sort method. If no more orders can feasibly be added to the vehicle and there are remaining orders, the procedure is repeated from step 2.

- The Group Based Insertion Algorithm

In this construction algorithm the orders are planned group by group. These groups are determined by the vehicle size and the order size. The steps of the algorithm are the following: (1) Assign the vehicle to groups based on vehicle capacity. (2) Assign the orders to groups based on order size. (3) Apply the Sequential Insertion or the Savings method per group. This construction method can be used in situations where certain orders should be given priority in the scheduling process. The orders within the group with the highest priority are scheduled first. Then the second group is scheduled and so on.

- The Pickup-and-Delivery Insertion Algorithm

When both pickup and delivery orders are to be scheduled, the Pickup-and-Delivery Insertion algorithm should be used. The algorithm consists of the following steps: (1) Select the seed order, i.e. from a set of orders with earliest pickup times, the order with the largest distance between pickup and delivery location is selected as the seed order. (2) Select the vehicle with start location closest to the pickup location that is allowed for the seed. (3) Find a cheaper vehicle. (4) Add orders to vehicle until the vehicle is full, i.e. for all unplanned orders, determine the best place in the trip for both the pickup and the delivery order. (5) Repeat step 4 until the vehicle is full, then go to step 1.

Improvement Algorithms

Iterative improvement procedures are based on a very well known and old optimization idea: the neighbourhood search. In general, the procedure is searching for a better solution, starting from an initial feasible solution. If a better solution is found, the procedure is repeated on the new solution. This process continues until no more improvements are found and a (local) optimum is obtained.

- The Opt Algorithms

After an initial solution is generated by means of one of the construction algorithms, several iterative improvement algorithms can be called to improve this solution. These algorithms can be executed

successively to find improvements. The implementation is such that the user can specify which algorithms to apply and the order in which they are applied. Also the maximum amount of time each algorithm is allowed to run can be specified. Each of these options attempts to reduce the costs of the current planning. Since application of a certain improvement method may lead to the possibility of improvement by another improvement method, the methods can be called repeatedly. In the figure below, the SHORTREC screen is presented in which the sequence of the improvement procedures can be specified

Option	Maximum calculation time (Minutes)
1. Basic solution	
2. Optimize within trip	5
3. Replacing of orders	5
4. Optimize between trips	5
5. Equalize workload	5
6. Choose cheapest vehicles	5
7. Change trips	5
8. Change stops	5
11. Replace trips	5
15. Flip trips	5
16. Optimise between several trips	5
17. Optimize within trip (advanced)	5
19. Savings basic solution	5
Total maximum calculation time	30

SR. Start repeat cycle.
ER. End repeat cycle.

Sequence in total solution
1,2,SR,3,4,1,2,15,ER,6,2

Figure G.1: SHORTREC screen for modifying the total solution

The first option calculates the basic (initial) solution by means of the Sequential Insertion method. In option 2 the sequence of the orders is changed so as to improve the current solution. The third option attempts to move orders between trips to obtain a better solution, while option 4 improves the sequence in which the trips are executed. This option is actually a combination of the options 7 and 8. Option 5 tries to equalize the workload over the available vehicles by fictitiously penalizing the amount of time a vehicle exceeds the average working time per vehicle. Applying this option will lead to an increase of the costs of the planning due to an increase in distance travelled and in working hours, but the work will be divided more evenly over the vehicles. Option 6 tries to find the cheapest vehicle for the complete workload of each vehicle. This is necessary since the construction algorithm only checks on capacity and availability and does not take the costs of vehicles into account. In option 7 trips are exchanged between vehicles and in option 8 orders are exchanged between trips so as to find a better solution. Option 11 reduces the costs of the planning by moving, for each combination of two vehicles, every trip from one vehicle to the other. In option 15 for each

trip the order within the trip is reversed. Option 16 is similar to option 4 except now orders are exchanged between several trips simultaneously. Like option 2, option 17 optimizes the sequence of the orders within a trip, but a different approach is used. First a Nearest Neighbour method is applied and then an Insertion method. In the Nearest Neighbour method, for each trip the order closest to the last order in the trip is determined and the trip is reordered such that each order has minimum distance to the last order in the trip. The Insertion method determines for each trip the order that causes the least extra distance and sorts the trips based on this criterion. Finally option 19 gives an initial solution by means of the Savings method.

- The Cyclic Transfer Algorithm

The Cyclic Transfer algorithm makes it possible to optimize by moving string of (consecutive) orders between more than two different trips. The idea is to iteratively transfer k orders among b trips in a cyclic manner in order to improve a given solution.

- Tabu Search Algorithm

By means of the Tabu Search algorithm the current solution is optimized by searching in the neighbourhood of the solution for a better solution. A solution is characterized by the planned trips and the sequence of the orders within the trips. Therefore the neighbourhood of a solution can be defined as a set of solution with almost identical trips. The elements of this set are called neighbours. From the set of neighbours, the Tabu Search algorithm selects the best as the new solution even if this solution is worse than the current solution unless this solution is on the tabu list, a list of forbidden solutions. Accepting a solution worse than the current one makes it possible to move away from a local optimum and by using a tabu list searching in a cycle is prevented. In the tabu list information about the most recent solutions is stored. The length of the tabu list is the number of iterations for which a solution is forbidden, so after this number a solution from the tabu list can be revisited. A solution from the tabu list can also be revisited if certain criteria, the so-called aspiration criteria, are satisfied. For example when the costs of a solution are lower than the costs of all previously found solutions, this solution will be accepted even though it is on the tabu list.

The implementation of this method is as follows. First, an initial solution is generated by one the construction methods from the previous section. The next step is, after initializing all necessary parameters such as the tabu list length, to iteratively search the neighbourhood of the solution for a better solution. In every iteration orders are moved within and/or between trips. For each possible solution the corresponding costs are calculated and the tabu list is checked. If a new solution is not on the tabu list and is better than the current solution, this solution is stored and the procedure is continued. If the new solution is on the tabu list, but satisfies the specified aspiration criterion, the solution is stored and the procedure continued. At the end of each iteration the best solution is stored on the tabu list unless no improvement has been found. The algorithm stops if no improvement is found for a maximum number of iterations.

APPENDIX I. SCENARIO COMPARISON

I.1. Comparison 1: MD Ambient (manual) vs. MD Ambient (SHORTREC)

In the tables below, the results are presented of the scenario comparison between the manual planning (Table I.1) and the SHORTREC planning (Table I.2) of the MD Ambient network.

Table I.1: Results manual planning MD Ambient

Table I.2: Results SHORTREC planning MD Ambient

I.2. Comparison 2: MD Ambient vs. SD Ambient

Table I.3: SHORTREC simulation results

I.3. Comparison 3: Proactive vs. reactive Ambient

Table I.4: Total results comparison 3

APPENDIX J. IMPLEMENTATION PLAN

J.1. Order entry implementation step

A definite factor for the utilization of SHORTREC, is the required time to use the system. For frequent use of SHORTREC one important step is required, namely the simplification of the order entry. In this appendix a description is given of the required SHORTREC implementation step with regard to easily reading-in orders, whenever this is desired. Besides, an estimation is given of the time and costs involved for realizing this purpose.

Since the majority of the incoming orders automatically arrive into the planning support system OTD (e.g. via SAP), all required order information is already available for SHORTREC purposes. In the Table below an example overview is given of the most important order information.

1	2	3	4	5	6	7	10	15	16	17	21	22	23	24	25	26	37
ORDNR	KLNR	DUMCHAR1	NAAM	ADRES1	POSTKD	PLAATS	AFLDATUM	START TIJD	END TIJD	SIZE	WGTYP _00	WGTYP _01	WGTYP _02	SIZE(Pal)	LAND	ORD _ACT	DEPOT_1
9122	1037	Ord Bod	Menken		2411	BODEGRAVEN	20081209	0700	2200	26308	1	1	1	26	NL	1	4-TIEL
9123	1038	Ord Bod	Menken		2411	BODEGRAVEN	20081209	0700	2200	26308	1	1	1	26	NL	1	4-TIEL
9124	1039	Ord Ede	Albert Heijn	Laan Van Ru	2645 EE	DELFGAUW	20081209	0700	2200	27040	1	1	1	26	NL	1	2-EDE
9125	1040	Ord Ede	FFWE	Havenlaan 6	5433 NK	Katwijk	20081209	1100	1200	127	1	1	1	1	NL	1	2-EDE
9126	1041	Ord Katwijk	Albert Heijn	Hoofdtocht 1	1507 CJ	ZAANDAM	20081209	1200	1300	22353	1	1	1	25	NL	1	1-KATWIJK
9127	1042	Ord Katwijk	de Rooy	Coenecoop 3	2741 PN	WADDINXVEEN	20081209	1500	1600	106	1	1	1	1	NL	1	1-KATWIJK
9128	1043	Ord Ede	FFWE	Havenlaan 6	5433 NK	Katwijk	20081209	1000	1100	8320	1	1	1	8	NL	1	2-EDE
9129	1044	Ord Ede	Boni Vers DC	Edisonstraat	3861 NE	NIJKERK	20081209	1400	1500	17247	1	0	0	16	NL	1	2-EDE
9130	1045	Ord Ede	V & S	Handelscent	2991 LD	BARENDRECHT	20081209	0830	0930	2501	1	0	0	4	NL	1	2-EDE

Table J.1: Example of order entry information

The numbers at the top of the table represent the required column positions within MS Excel for matching the constructed Ambient import definition. However, as mentioned in the report every single order with accompanying order information arrives as a separate XML-file. An XML (Extensible Markup Language) is defined as a general-purpose specification for creating custom markup languages, used in order to aid information systems in sharing structured data, especially via the Internet. It is possible to directly open XML-files within Excel, but this is not the favourable format. See table below for an example.

id	order_number	order_date	id2	code	name	id3	code4	name5	code6	name7	unit_code
812200801	812200801	8-12-2008	5038	5038	Friesland Foods	default	default	default	default	default	NettoKG
812200801	812200801	8-12-2008	5038	5038	Friesland Foods	default	default	default	default	default	Volume
812200801	812200801	8-12-2008	5038	5038	Friesland Foods	default	default	default	default	default	BrutoKG
812200801	812200801	8-12-2008	5038	5038	Friesland Foods	default	default	default	default	default	Stellpl

Table J.2: Example of XML-file

For realizing the desired automatic order entry, a complete list of separate XML-files have to be converted into one XLS or CSV-file, which can be opened with Excel. A converting tool has already been made for converting an incoming XML-file to a correct CSV-format. However, this constantly concerns only one order, through which an entire order list has to be composed by manually adding all the separate order files. This is too time-consuming and requires an automatic composing tool.

The construction of this desired composing-converter tool approximately takes a half working day. ORTEC is able to realize this step in all probability, which amounts to the costs of one consulting day at most.

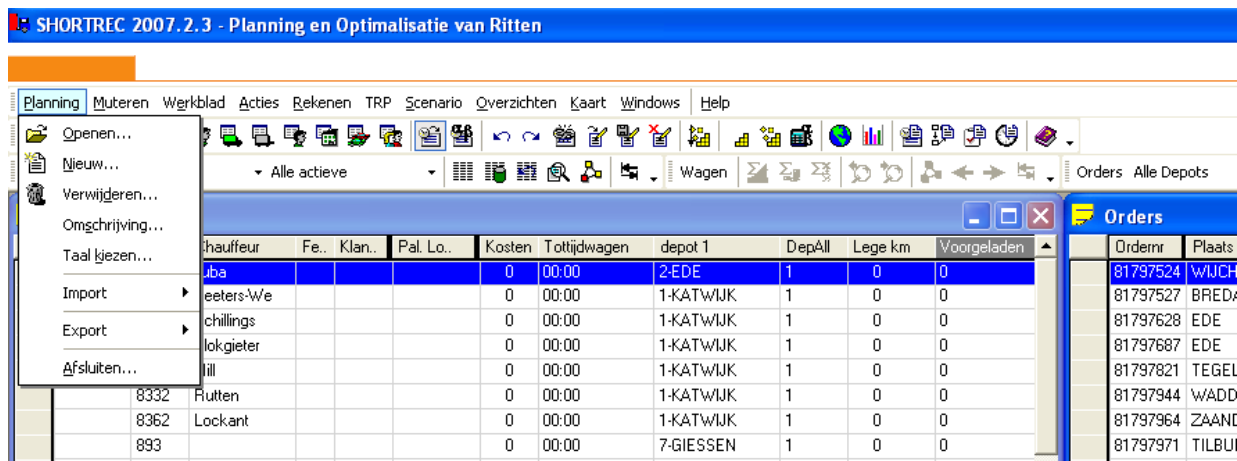
J.2.Preparing SHORTREC for Ambient planning

Below the most important steps are described for preparing an Ambient planning within SHORTREC.

1. Opening a planning

After having been launched, SHORTREC automatically loads a planning. The currently loaded planning is called the active planning. The name of the active planning is always displayed in the bottom left corner of the application window. If you have not created a planning yet, the DEFAULT planning will be open. This planning contains only general data, and can only be used as a template to base actual plannings on. To plan with SHORTREC, you will need to either create a new planning from scratch, or open an existing planning.

A running SHORTREC always keeps a planning opened. This planning is called the active planning. If you want to work on a different planning, an existing planning must be loaded from disc, or a new one can be created. SHORTREC automatically saves the active planning before activating a different one. Choose the Openen entry from the Planning menu:



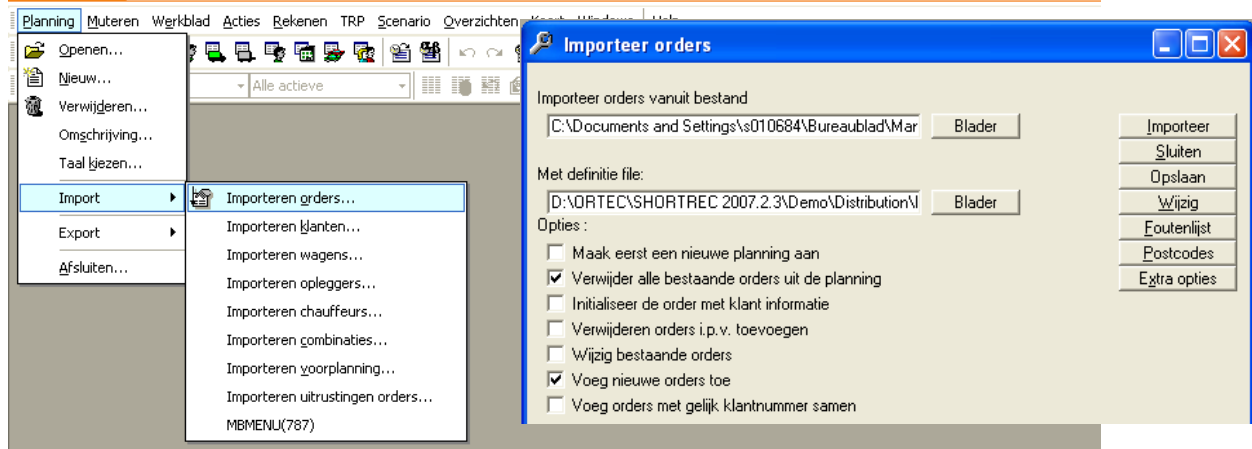
Available plannings are listed at the bottom of the dialog. If no planning has been created yet, only the DEFAULT planning will be available. Details concerning the currently selected planning are displayed in the boxes at the top. To select a different planning, *double-click* its list entry. The name, description and path of the planning will appear in the detail boxes. New plannings are always based on an existing planning: either the DEFAULT planning or one created earlier:

- Copy of default planning: To be chosen when orders vary greatly over plannings. You will create a clean planning, containing only general data.
- Copy of existing planning: To be chosen if the new planning's orders largely correspond with an older planning's orders. This option perfect for small adjustments and scenario analysis.

2. Importing orders

In Appendix J.1 a description is given of the reading-in process of orders. If the import definition is correctly followed, it is easy to import the entire data file. The import of this order data file should be a .CSV file originating from MS Excel. In the figure below it is shown how to import the orders via the planning menu (see also figure above). In the planning menu Import and Importeren orders can be chosen, one after the other.

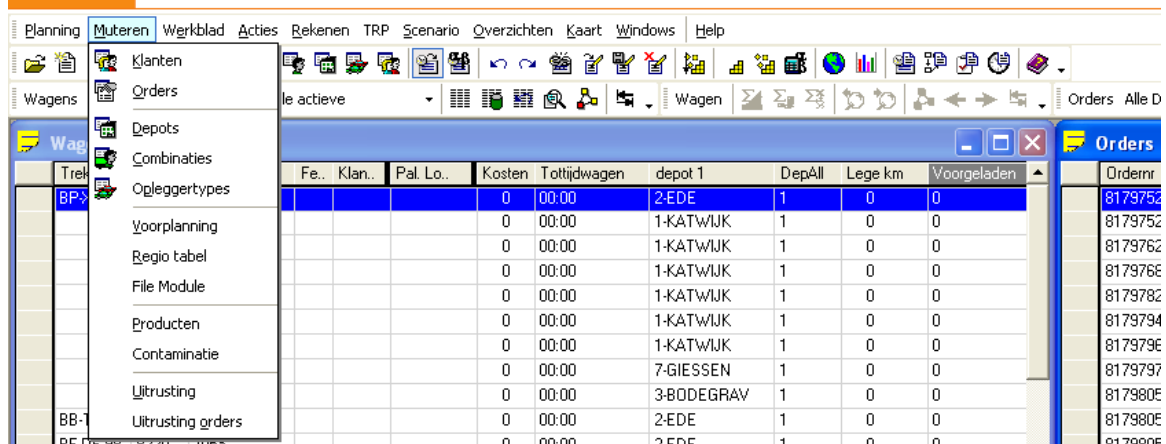
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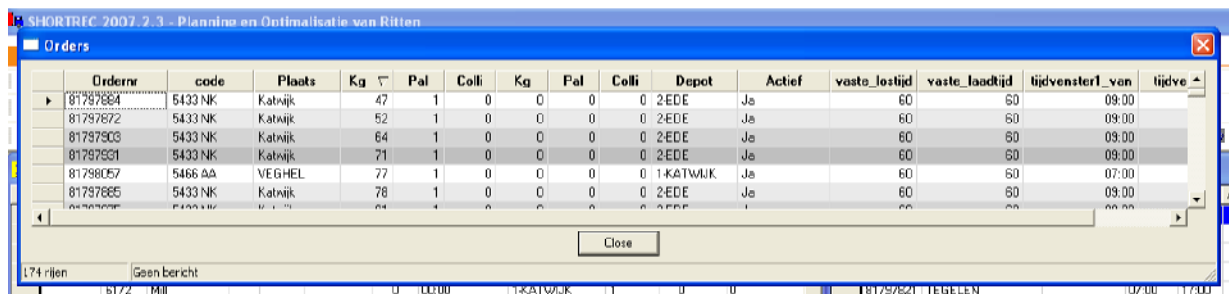
3. Altering Ambient data

SHORTREC stores most planning data in a database. Records are easily altered, added, or removed using the Muteren menu.

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From this menu, choose the appropriate entry to have an edit window appear. Use the popup menu for any changes to the data. Alterations can be made with regard to the Orders:



Combinations:

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Wagens

Wagen Nr	Naam	Kg	Pal	Colli	Actief	Wagentype	voorgeladen o.h. begin /	voor volge	Alle depots toegelaten?	Depot_1	Depot_2	Kr
BJ-HJ-44	BJ-HJ-44	30000	30	0	Ja	c.k.	Nee	Nee	Ja	2-EDE		
BJ-JS-36	BJ-JS-36	30000	26	0	Ja	tr	Nee	Nee	Ja	2-EDE		
BJ-NL-33	BJ-NL-33	30000	26	0	Ja	tr	Nee	Nee	Ja	1-KATWUK		
BJ-RJ-66	BJ-RJ-66	30000	30	0	Ja	c.k.	Nee	Nee	Ja	2-EDE		
BJ-FX-04	BJ-FX-04	30000	26	0	Ja	tr	Nee	Nee	Ja	1-KATWUK		
BJ-FX-05	BJ-FX-05	30000	26	0	Ja	tr	Nee	Nee	Ja	1-KATWUK		

106 rijen Geen bericht

8332 Ruten 0 00.00 1-KATWUK 1 0 0 81797944 WADDIN-YEEN 07.00 16.00

and Depots:

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Depots

Depot	Plaats	code	Van	Tot
1-KATWUK	Katwijk	5433 NK	06.00	22.00
2-EDE	Ede	6717 AG	00.01	23.59
3-BODEGRAV	Bodegraven	2411 NE	00.01	23.59
4-TIEL	Tiel	4004 JP	06.00	22.00
5-EDE2	Ede	6717 AH	07.00	16.00

The right mouse button and the scroll bar allow you to view the contents of the table, and to alter, add or remove records. Double-clicking a record in the list view will bring up that record's detail view, which allows you to view the data in more detail.

4. Settings and parameters for calculating solution

Choosing the Rekenen menu will open a list view for changing Parameters of the solver which are used during calculation of the planning. Through this list view also the Basisoplossing and Totaaloplossing can be activated. See figures below:

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Planning Mutenen Werkblad Acties **Rekenen** TRP Scenario Overzicht

Voorplanning
Basisoplossing
Totaaloplossing
Parameters...
Werken met markering

Wagens

Trekker	Ople.	Chaufeur
BPXS-54	8218	Juba
6118	Peeters-We	

Complete Solution

Costs	16637	17141
Kilometers	3522	3635
Working hours	314:38	319:00
Number of vehicles	27	27
Number of trips	29	29
Number of orders	257	

Time point: 3:01

Current optimization step: Optimize between trips
Next optimization step: Replacing of orders
Current action: Optimizing between trips: trip 12

Reken parameters

Algemene parameters

- ☒ Alleen werken met gemarkeerde orders en wagens
- ☒ Rekening houden met lurchtijden
- ☐ Overwerk toegestaan
- ☐ Gebruik kapstok ritten planning
- ☐ Dezelfde lokaties verplicht in dezelfde rit

Maximaal aantal ritten in een wagen: 9999
Maximaal aantal orders in een wagen: 9999
Maximaal aantal orders in een rit: 9999
Maximum aantal kilometer per rit: 9999
Inplannen stops tot en met groepnummer: 0

Algemene correctiefactor sneheid: 1.00
Correctie voor afstand binnen hetzelfde Geocode ID: 0 Km.
Correctie voor tijd binnen hetzelfde Geocode ID: 0 Min.
Datum planning: 29/01/2009

Andere parameters

Totaal oplossing: Tidenberekening:
Algoritme:
Restrictie parameters:
Flexibele restricties:

Orders

Ordernr	Plaats
81798057	VEGHEN
81797944	WADDIN
81798063	VEGHEN
81798070	MILL
81798062	VEGHEN
81797821	TEGELE
81798060	VEGHEN
81798058	GIETEN
81797527	BREDA
81797524	WIJCHE
81798065	VEGHEN

SHORTREC needs a starting point for optimization. The Rekenen menu's Basisoplossing entry creates such an initial assignment of orders to vehicles. Although SHORTREC will make sure no restrictions are violated, the basic solution is usually not the best one. Further optimization usually yields great improvement. A basic solution assigns orders to vehicles until all orders are planned, or until no further orders can be assigned to vehicles. Note that optimization often generates new "space" for orders to be planned into. A new basic solution can then add orders which previously remained unplanned. SHORTREC displays a status dialog while calculating a basic solution.

The Rekenen menu's Totaaloplossing entry optimizes the planning, attempting to reduce cost and increase the number of deliver orders. A dialog keeps you informed of the optimization progress: The boxed values represent the planning's current state of affairs. For comparison, the unoptimized values are displayed to the right. The bottom part of the dialog displays the optimization sequence's progress, and information on the optimization routine being applied. The sequence of optimization routines can be changed using the before mentioned Parameters entry. When optimization is complete, a dialog will display the number of planned orders, trips, and vehicles. Clicking OK will take you back to SHORTREC's workspace.

5. Scenario analysis

For the execution of experiments and scenario analysis the Scenario menu should be chosen. In this menu you are able to make a new, save a open a scenario, of which the results can be loaded in the KPI table.

6. Reports

The Overzichten menu (see figure below) offers six different overviews of SHORTREC's planning. After creation, reports are first displayed on-screen in a text editor such as WordPad, or in Excel. The reports can then be sent to the printer from these applications. The Complete Solution report contains all data concerning the planning and planned resources. The report consists of: an overview of the entire planning; an overview of committed resources; detailed trip information per vehicle. The report includes the planning's total costs and distance, the number of regular hours and afterhours, and the number of committed vehicles. The Complete Solution report is sent to a third-party application. From this application, the report may be printed or saved as a regular file.

