

# Multi-depot distribution planning at Nabuurs : the assessment of efficiencies in complex multi-depot networks

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**eSCF Operations Practices:  
Insights from Science**

**Multi-depot distribution  
planning at Nabuurs**



ir. W.J. Stein



# Multi-depot distribution planning at Nabuurs

## The assessment of efficiencies in complex multi-depot networks

In recent years, the distribution networks of many carriers have grown from a single-depot (SD) network to a complex and dynamic multi-depot (MD) network. Nabuurs is one of the very few carriers that implemented an automated so-called MD planning as one central planning task throughout their organization. Under a SD setting, the deliveries from each depot are planned individually, and drivers return to the starting depot to pick-up a new order. With MD planning, the deliveries from multiple depots can be planned simultaneously, combining all resources and depots efficiently. This allows drivers to go to the nearest DC to pick up a new order. However, it turns the distribution planning into a more complex task.

Nabuurs required clear performance measurements and required more insight into the quantitative factors (e.g. time or KMs travelled) as well as qualitative factors (e.g. flexibility and availability of drivers). This is key during operations, but also during tenders and quotations. These challenges initiated the master thesis project of Marc Close. Many recommendations of Close were followed-up, leading to two important managerial decisions and impressive improvements, both in terms of distribution network efficiency as well as in terms of cost reductions.

### Key terms

Planning, Vehicle Routing Problems, Multi-Depot networks, Transport and Distribution, Operational Planning, Tactical Planning.

### Relevant for

Logistics Service Providers (LSPs) and Manufacturers.

### Nabuurs B.V.

Nabuurs is one of the largest family businesses in the logistics sector in The Netherlands. Nabuurs develops supply chain concepts, especially for the Fast Moving Consumer Goods sector. Nabuurs focuses on the best route for the products of the customers in terms of cost, service and sustainability. Clients are for example H.J. Heinz, FrieslandCampina, SCA Hygiene Products and Refresco.

# Trends

In today's supply chains, many manufacturers have outsourced their logistics activities to Logistics Service Providers (LSPs, or carriers). The rationale is simple: "When carriers exploit large networks of transportation assets, they obtain economies of scale, and perform logistics activities more efficiently. Meanwhile the manufacturer can focus on its core business".

Henceforth, the logistics services business is a highly competitive business with many competitors, large investments and low profit margins. It is no surprise that these networks of assets have become extremely complex<sup>1</sup>. Meanwhile, there are still plenty of inefficiencies in national and international chains. It seems that carriers are less and less able to control these complexities, and it has become increasingly difficult to distribute efficiently. How should carriers approach these challenges?

Nabuurs B.V. is a major logistics service provider in the Netherlands that, prior to its competitors, abandoned the traditional distribution planning methods and implemented a fundamental new planning structure. The Eindhoven University of Technology investigated the impact of this decision and helped improving the visibility of the planning decisions. This ESCF best practice illustrates the efforts at Nabuurs to stay ahead of the competition. First, let's take a look at the distribution planning challenge itself.

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<sup>1</sup> Increased market fragmentation, exploded numbers of product varieties, greying society and upcoming regulations do not make things easier.

# Multi-depot structure determines fixed costs

The structure of a distribution network is primarily dependent on the strategic choice of the number of distributions centers (DCs, or depots). Carriers with few DCs can benefit from shared space, shared equipment utilization, shared safety stocks and spread overhead costs. Furthermore, little primary transportation (to fill the depots itself) is necessary. But when the regions grow wider, the delivering costs always rise sharply, since distances increase exponentially. Carriers with a network of multiple regional DCs, on the other hand, can benefit from smaller delivery distances. So, multiple DC networks have higher warehouse costs, but they have much lower delivery costs. This parabola is illustrated in Figure 1.

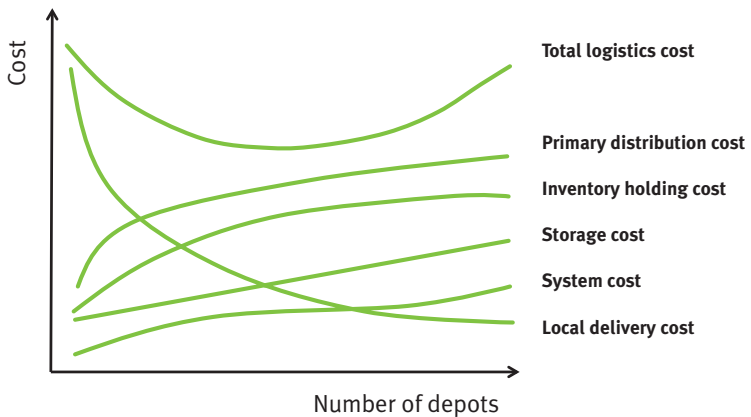


figure 1

The trade-off between total costs and the number of depots (adapted from Rushton et al., 2006)

The physical warehouses determine, more or less, the long-term fixed costs (such as inventory holding costs, storage costs and system costs), since they grow marginally with the number of depots. The delivery costs (such as mileage costs, loading and unloading costs, driver costs and depreciation costs) determine the variable costs to actually deliver the orders. These costs can drop sharply when the carrier operates efficiently.

# Routing determines the operational efficiency

After the strategic decision on the number of depots, the key driver for efficient logistics businesses is related to the tactical/operational 'routing' decisions. Routing is the process to plan and sequence the execution of the deliveries to all geographically dispersed clients in a certain network. The output of the routing process is the distribution planning, combining the shipments with specific trucks and drivers into routes and timetables.

A well-known measure for the network or routing efficiency is the ratio of empty versus loaded kilometers. Decreasing empty kilometers is an efficient way to increase transport efficiency. According to a study in 2010 based on EUROSTAT data, Dutch trucks drive approximately 29% of their inland kilometers unloaded. This illustrates that there is plenty room for improvement when it comes to the routing processes.

Unfortunately, there are a few stringent challenges to routing. Namely, routing deals with:

- Increased customer requirements with respect to timeliness, flexibility and responsiveness of order delivery;
- Time windows set by both retailers and municipalities;
- Traffic congestion and consequently increased uncertainty in travel times (lead-times) and their related waiting times;
- Other unanticipated delays.

# Planning in a multi-depot environment

Moreover, in recent years, the networks of many carriers have grown from a single-depot (SD) network to a complex and dynamic multi-depot (MD) network. Although many LSPs deal with multi-depot structures, only few carriers actually use pure automated MD planning. Several planning programs support automated MD Planning, but (to the best of our knowledge) Nabuurs is one of the very few carriers that implemented an automated so-called multi-day MD planning as one central planning task throughout their organization.

What is the difference? In a SD setting, the deliveries from each depot were planned individually, and drivers would return to the starting depot (see the left-side of Figure 2) to pick-up a new order. With MD planning, the deliveries for multiple clients can be planned simultaneously, combining all resources and depots efficiently. In a MD network, the driver would unload, and then receive an order to load again at the nearest DC. On the right-hand side, the route planning of the same driver is shown in a MD setting. In this example, the amount of empty kilometers drops from 50% to a mere 9%.



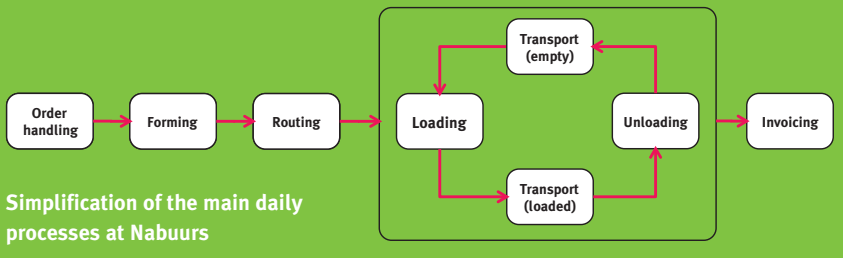
figure 2

When the multiple depots are smartly used, the amount of empty kilometers can drop sharply

Clearly, on a larger scale, the consequences in terms of efficiency opportunities are enormous, especially in a dense network with many long-term clients. But it is also easily understood that planning in MD settings is impossible without proper (IT) support. Due to a staggering complexity, the use of advanced routing methods is pivotal to successful distribution planning.

### The planning and transport process of Nabuurs

The entire ambient transport and distribution planning is centrally controlled at the office in Wijchen. The daily planning and transport processes of Nabuurs go roughly as follows. Firstly, the orders are entered into OTD. The majority of incoming orders are downloaded from the client's systems and uploaded into OTD. The remaining orders are entered manually. Then, Less-Than-Truckload orders are combined to form Full-Truck Loads. The forming process takes locations, volumes, dates, agreements and time-slots into account. Simultaneously, the sequence of loading and unloading is planned. Next, the routing optimization is executed, wherein resources are assigned to the rides. When the routing is finalized, the transportation activities start. The individual rides are communicated to the driver via the board computer or by phone. All activities are centrally monitored and controlled via OTD. At the end of the day, all waybills and receipts are used to create the corresponding invoices.





# The challenge

In 2008, Nabuurs implemented the planning system ORTEC Transport and Distribution (OTD), to support the planners with their tasks. Since then, OTD has shown to be very useful in the operational stages of order execution. Especially the ‘forming’ and administrative activities have been well supported by OTD (see also the text box on the planning process at Nabuurs).

However, in 2009, the OTD was not used in the most optimal way due to a few key challenges. Firstly, the planning activities still occurred manually, mainly due to problems with OTD settings regarding truckers who stay the night in the truck. Since a majority of Nabuurs’ drivers only stay overnight between shifts, these problems impeded effective MD planning. Secondly, Nabuurs lacked clear performance measurements and required more insight into the quantitative factors (e.g. time or KMs travelled) as well as qualitative factors (e.g. flexibility and availability of drivers). For example, Nabuurs had no exact information on the performance per delivery (e.g. in terms of empty vs. loaded KMs). Thirdly, it was difficult and time-consuming to make simulations of network changes. For example, during a tender, one would like to calculate additional efficiencies that can be obtained due to the increased routing efficiencies.

These challenges initiated the master thesis project of Marc Close. Supervised by professors Tom van Woensel and Ton de Kok of the Eindhoven University of Technology, Marc Close’s tasks were to:

1. Design a model to substantiate if, for the current Ambient network, a MD operating procedure could be more cost-efficient compared to a SD procedure;
2. Determine the benefits from automatic MD planning versus manual planning;
3. Implement the model for calculating the influences of changing volumes and/or clients on the costs of the Ambient network.

# Model

To answer these interesting research questions, Marc Close developed a simulation model and a performance evaluation model. These models are applied to the Ambient network of Nabuurs. The idea is simplified in Figure 3. Real data from OTD is inserted into the simulation model. The model calculates the output data, which are converted into useful insights by the performance model of Close.

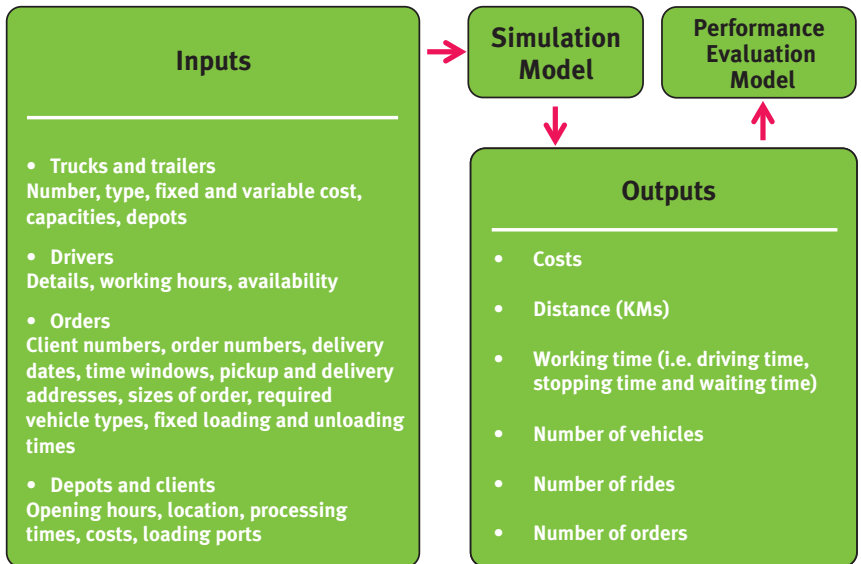


figure 3

The Simulation Model and the Performance Evaluation Model

A major requisite for the simulation model is the availability of a tool, which is able to solve the MD problem of Nabuurs Ambient. Although the current tool OTD is a great tool to support daily operational activities (and a very reliable data source for this research), OTD is inadequate to perform scenario analyses on a tactical level. Another tool had to be selected.

In 2009, there was no (commercial) software available that suited the dynamic planning processes of Nabuurs adequately. The TU/e executed an extended gap-analysis to see which software package would fit best. The planning challenge at Nabuurs has the following characteristics:

1. All demand is met within the time window constraints;
2. Each route starts and ends at the same depot;
3. Vehicles and drivers are not necessarily attached to one client or depot;
4. The total demand of each route does not exceed the vehicle capacity;
5. The total duration of each route (including travel and service times) does not exceed work rule constraints;
6. The drivers can stay overnight at any desired location (currently a majority of Nabuurs drivers are willing to stay overnight at any location);
7. The total routing cost is minimized.

After careful considerations, the software planning support tool Shortrec Multiday was selected for the simulations. The researchers teamed up with the Shortrec provider, ORTEC, to program the simulation model in Shortrec Multiday. Finally, after long days of data selection, collection, converting and uploading the data, the experiments could start.

### **The Vehicle Routing Problem**

The challenge to determine the optimal set of routes for a number of geographically dispersed clients is called the Vehicle Routing Problem (VRP). In the previous fifty years, many researchers have devoted their time and efforts to elaborate upon VRP heuristics, and there is a vast amount of academic literature on VRPs with all kinds of extensions and variations. For example, extensions exist for multiple-vehicles, backhauling, time windows, distance constraints, capacity constraints, etc. One of these extensions on VRP heuristics is the Multi-Depot situation (MDVRP). The transport flows at Nabuurs can be described as a “Dynamic Heterogeneous Multi-Vehicle Multi-Depot Pickup and Delivery Problem with Time Windows and Driver’s Rule Constraints”.

Although uncertainty can be a major concern and cost-factor, no models and solutions for MDVRP were found that concern uncertainty. For example, time delay perturbations have only recently been subject to thorough research in single-depot settings. For the Eindhoven University of Technology, the impact of uncertainty will remain an important research field in the upcoming years.

# The findings part 1: MD versus SD planning

For the first experiment, the research team hypothesized that when the number of orders increases the benefit from using MD planning should also increase. In order to test this in a reliable fashion, scenario analyses were executed on a dataset of real orders. A dataset of 174 orders of an arbitrary day in 2009 were used to resemble a rather large network.

In initial experiments, a cost reduction of nearly 9% was found. As observed from Table 1, the amount of rides slightly increased, but all others costs factors decreased. Note that the outputs “KMs driven” and “Working time” have both dropped significantly.

Scenario	Number of orders	Nr. Of available pre-loaded vehicles	Costs (€) after correction	KMs driven	Number of vehicles	Number of rides	Working time <sup>2</sup>
<b>SD planning</b>	174	25	€ 27.693	21.803	57	116	573:12
<b>MD planning</b>	174	25	€ 25.267	19.287	54	119	530:36
<b>Difference</b>			-8.76 %	-11.5 %	-5.2 %	2.6 %	-7.4 %

table 1

The performance model shows that MD planning is 9% more cost efficient than SD planning

To analyze the impact of size of the network, parts of the dataset were removed to simulate smaller networks. Small and large orders were deleted simultaneously<sup>3</sup>, to keep the simulations balanced. It turned out that, indeed, smaller datasets lead to smaller cost reductions. An example of the results is shown in Figure 4. The pattern of the graph clearly shows that cost-savings increase when the amount of orders grows.

<sup>2</sup> Working time consists of driving, stopping and waiting times.

<sup>3</sup> The deletion of the smallest volume orders resulted in a higher cost saving than deletion of the largest volume orders. This is most likely caused by the fact that small orders gain smaller effects on the total order volume than ten large orders.



figure 4

Scenario analyses reveal that cost reductions (gained from using MD planning as opposed to SD planning) increase when the network becomes larger.

During additional scenario analyses with other data samples, different shapes and scales were found. This means that the cost-reduction is dependent on the specific orders within the network. This is unfortunate, because this makes it impossible to develop easy guidelines or rules of thumb.

It was concluded that MD planning generally outperforms SD planning when the network increases, but the precise effect depends on the orders. In terms of managerial implications, this means that the potential benefits per additional potential client differ. Automated MD scenario planning is therefore highly recommendable during each tender.

## The findings part 2: Manual versus automatic

In a second experiment, the research team compared a manually performed Ambient planning with a computer generated Ambient planning. From this experiment, three findings are worth mentioning.

Firstly, Shortrec clearly outperforms manual planning in terms of speed. The execution of a computer generated Shortrec solution for this small amount of orders takes only a few minutes, instead of several hours manually. Also, small reactive changes and adaptations are more easily applied to the manual planning. Secondly, the computer generated planning achieves a cost-reduction of 8% on a set of just 32 orders. This is achieved through a 12.4% reduction of KMs driven and 17.3% reduction of the working time. It turned out that planners plan recurring rides with a certain pattern, whereas Shortrec combines the depots, orders and drivers more interchangeable.

Scenario	Number of orders	Number of rides	Number of vehicles	KMs driven	Working time	Costs (€)
<b>Manual planning</b>	32	32	10	5.083	132:25	€ 5.463
<b>Shortrec</b>	32	32	11	4.451	109:27	€ 5.191
<b>Difference</b>	0.0 %	0.0 %	10.0 %	-12.4 %	-17.3 %	-8.0 %

table 2

### Manual planning versus automatic planning in Shortrec

Thirdly, note that (although Shortrec found a better solution with less kilometers and less working time) the number of vehicles increased by 10%. This is intriguing. Would it be more cost efficient to use additional vehicles? Or did something else happen? Further examination of this finding revealed that, for Shortrec, it was impossible to use less than 11 vehicles due to planning restrictions. Yet, the planner apparently found another solution that uses only 10 vehicles. It turned out that planners sometimes exceed some restrictions. In this case, a specific time window was exceeded. Such operational insight and tacit knowledge cannot be programmed. If Shortrec would have been able to figure this out, the total cost reduction would have been between the upper and lower bound of 12.4 and 17.3%. So, in terms of operational execution, the planners outperform the system.

## The findings part 3: The impact of an additional client in the network

In the third experiment, the research team calculated the effects of adding a new client unto the network. Understanding these effects are critical in tender phases. Calculating the effects of an additional customer is difficult, time-consuming and risky: any under- or overestimation of the required investments leads to additional costs without benefits.

For this scenario analysis, one large Nabuurs client was assumed to be a new client within the Ambient network. A selection of 143 orders is used for this experiment. In separate networks, the client would use its own transport and distribution assets to distribute 75 orders and Nabuurs would distribute the remaining 68 orders for their other clients.

The performance measures of this analysis are shown in Table 3. The results show that if these orders are executed within the current Ambient network the costs are reduced by 9.4%. Moreover, it can be observed that Nabuurs has to add just 18 vehicles to their distribution network to distribute the client's goods. The client would actually use 29 vehicles. This saves the client a huge investment, and this allows Nabuurs to increase the efficiency of the current trucks. Obviously, these assessments are an important differentiator during a quotation and/or negotiation phase.

Scenario	Number of orders	Number of rides	Number of vehicles	KMs driven	Working time	Costs (€)
<b>Separate networks</b>						
• Client by itself (A)	75	42	29	8.925	€ 11.434	229:06
• Ambient network without client (B)	68	49	26	8.528	€ 11.140	240:07
<b>Client in the Ambient network</b>						
• Client' share in the network (C)	75	43	18	7.938	€ 10.356	214:09
• Total network with 'client' (B +C)	143	92	44	16.466	€ 21.496	454:16
<b>Difference</b>						
• A versus C	0.0 %	2.4%	-37.9 %	-11.1 %	-9.4 %	-6.5 %

table 3

One additional client has significant advantages for both the carrier and the manufacturer

# Conclusions

The aim of the master thesis project of Close was to provide a quantitative model to gain insight into the internal performance of operations, i.e. transport planning. The installed performance model is able to visualize many desired performance outcomes. For example, it displays the empty vs. loaded KMs ratio on a map per particular postcode area. Also the relations between loaded KMs and the frequency of rides can clearly be analyzed.

But the gains for Nabuurs were even more substantial. Our research convinced the Nabuurs management to make two important investments:

- Firstly, based on Close's recommendations concerning manual versus automatic planning, the management of Nabuurs has decided to upgrade the operational planning tool OTD. With the upgraded support, the planners can quickly create an automatic daily planning, and easily make manual adjustments when unforeseen situations arise. This combines the skills of the planners with the speed of the program, providing Nabuurs with efficient and effective planning operations. This will also further enhance the use of MD planning, promising significant future cost reductions and substantial sustainability improvements.
- Secondly, the recommendations of Close persuaded Nabuurs to implement the tactical planning tool Shortrec. The desire to utilize advanced network analyses had been around at Nabuurs for quite some time, because this had always been too much time-consuming. During this research, it turned out that Shortrec is very suitable for performing fast and exact quantitative comparisons for network changes. Shortrec, accompanied by the implemented simulation model of Close, provides Nabuurs with a useful system for tactical planning activities, such as advanced analyses on different distribution and transportation scenarios. Nowadays, Shortrec is used as an important tool during tenders, to successfully perform valuable scenario analysis.



An intense collaboration between Nabuurs and the university has resulted in this very successful project. The Nabuurs network is now more balanced and the planning department is well equipped, allowing for continuous improvements at Nabuurs.



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### *Editorial*

Author: Walter Stein ([www.walterstein.nl](http://www.walterstein.nl) and [w.j.stein@tue.nl](mailto:w.j.stein@tue.nl))

Editors: prof.dr. A. van Weele and prof.dr.ir. G.J. van Houtum, prof.dr. T. van Woensel, Eindhoven University of Technology, European Supply Chain Forum.

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Technische Universiteit  
**Eindhoven**  
University of Technology

**Visiting address**

Den Dolech 2  
5612 AZ Eindhoven  
The Netherlands

**Postal address**

P.O.Box 513  
5600 MB Eindhoven  
The Netherlands

Tel. +31 40 247 39 83  
escf@tue.nl  
<http://escf.ieis.tue.nl>