MASTER

Design of a decision support tool for driver planning in freight transportation

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Master Thesis

Design of a Decision Support Tool

For Driver Planning in Freight Transportation

by

Bas de Jong

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Abstract

This research project was conducted, to partially fulfill the requirements of the master degree of science in operations management and logistics at the Technical University of Eindhoven and, it took place in the headquarters of Jan de Rijk Company, a Dutch LSP, located in Roosendaal. The target of this research is the development of a decision support model that would provide a quantitative decision or suggestion to the planners at Jan de Rijk Logistics, during the planning of the drivers for long-haul transportation. Problems with the driver planning are at this moment the freshness of the driver, the European regulation and the lack of information. The planning tool will have an interaction with the planners who will use it in their decision making process. It will improve the speed and quality of the planning and will reduce costs and the planning time.

Executive summary

This research study demonstrates that acquiring a Transportation Management System (TMS) which provides access to real time information about fleets is a necessity in today's transportation industry but still it is not sufficient to manage all scheduling operations in an optimal manner.

The planning description will be given in the thesis. However, here below is the planning decisions made at Jan de Rijk Logistics, and who does it at the moment. The main goal of this project is to make a decision support model for the planner to give them a suggestion on which driver they have to pick for the routes. The master thesis concerns the two topics driver allocation and working time considerations. The second item is important because of European regulations on drivers driving and working time. The table below shows the current functional comparison between a planner and Jplexs TMS software.

Planning decisions	Planner	Jplexs
Matching driver(s) with pulled and pulling units		x
Matching pulled and pulling unit		x
Driver allocation	x	
Traveling time considerations	x	
Freight and pulled unit matching assignment	x	
Empty running decisions	x	(x)
Charter hiring decisions	x	(x)
Distribution of pulled units within the network	x	

An extensive literature research was conducted on multiple cases. First all the European regulations on driving, working, breaking and resting times where found, with research studies who already made mathematical models of these regulations. An increasing important item in the transporting industry is the emissions, and as an extension of the final model, multiple emissions calculators were found. This literature was used to compose a model that will give an accurate suggestion of which driver will drive on which route.

With the literature a base model was composed which had the possibility of allocating one driver to one route. This tool looks like a basic planning tool which can work in easy circumstances. The model then was extended with the necessities of the project; the break determination and time windows. The next part of the extensions were extras that give the model more depth and realism for this master thesis. The next extension was that the model could run for infinite weeks. This means that a route can be made that takes a large amount of weeks (more than two) and the model will still give a realistic answer that is correct. The possibility to assign multiple drivers to multiple routes was then added, this is a realistic situation for a large company as Jan de Rijk Logistics. With this extension a second extension is obvious, is that the model will have a driver selection method, that will give a suggestion to the driver, and each driver can only be used once. The final extension added was the emissions calculation.

The results of the model will have influence on the planning decisions at Jan de Rijk Logistics. In the chapter of how the planning works at Jan de Rijk Logistics, a current situation is given. This will change when the model will be implemented. Here the final table is given of the planning decisions. Because this model is a supportive model, the driver allocation and driving and working time considerations are done by the planner and the planning tool Jplexs.

Planning decisions	Planner	Jplexs
Matching driver(s) with pulled and pulling units		x
Matching pulled and pulling unit		x
Driver allocation	x	x
Traveling time considerations	x	x
Freight and pulled unit matching assignment	x	
Empty running decisions	x	(x)
Charter hiring decisions	x	(x)
Distribution of pulled units within the network	x	

The proposed model can consider the followings.

- Multiple routes and multiple drivers,
- An accurate and detailed planning on breaks and rests of drivers.

Therefore, this model covers the (identified) gap in the current planning procedure (lack of attention to costs associated with each decision) which consequently derives to increase the margin for each shipment.

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List of Abbreviations

Abbreviation	Full explanation
3PL	3rd party logistics
4Pl	4th party logistics
APS	Advanced Planning System
BPMN	Business Process Model and Notation
CARGOIMP	Cargo Interchange Massage Procedures
DC	Distribution Centre
EC	European Committee
EDIFACT	Electronic Data Interchange For Administration, Commerce and Transport
EEG	European Economic Community
FTE	Fulltime-equivalent
FTL	Full Truck Load
GET Service	Green European Transportation Service
JdR	Jan de Rijk Logistics
km	Kilometer
KPI	Key Performance Indicator
LSC	Logistic Service Client
LSP	Logistic Servers Provider
LTL	Less than Truck Load
PTV	Planungsbüro Transport und Verkehr
sFTP	SSH File Transfer Protocol
TMS	Transportation Management System
TSP	Transport Service Provider
TU/e	Technical University of Eindhoven
VAP	Vehicle Allocation Problem
VRP	Vehicle Routing Problem
XML	Extensible Markup Language

Chapter 1 Introduction

The Driver-Planning project was initiated by a team from Jan de Rijk Logistics. The team consists of Hans Heeren, Daniel Uijtdewillegen and Albert-Charrel Ernst. The total project is placed within the GET Service project, which is a European supported platform for innovative transportation firms. This introduction will give an insight in the reason why this master thesis is conducted.

1.1 European Commission Regulations

Jan de Rijk Logistics serves multiple countries in Europe. Furthermore, Europe is a free trade zone, no borders and no customs. A result of the Schengen Agreement from 1992, which resulted in free trade between members of the European Economic Community (EEG). For drivers this means no stopping at the borders due to no customs control. Firms are no longer under the obligation to maintain a major distribution center in each country (Crainic & Laporte, 1997). This leads to fewer warehouses and longer traveling distances. Therefore, the European Union requires regulation for the driving hours.

The European Union enforced new driving hours' rules in April 2007. These rules are stated by the European Union, defined in Regulation (EC) No. 561/2006 of the European Union (2006). Furthermore, European drivers also need to abide by the rules regarding their working hours, which include their driving and service hours. The European Union has stated these regulations in Directive 2002/15/EC of the European Union (2002). In this section these rules are mentioned because they will be used in the driver allocation decision algorithm. All these rules restrict the planner as to the allocation of drivers to their trucks and trailers (Prescott-Gagnon, Desaulniers, Drexl, & Rousseau, 2010).

The problem that Jan de Rijk Logistics has at the moment is that drivers are not allowed to drive any further because of regulations set by the European Commission. Planners cannot totally control the planning, so they need a decision support program. This program will contain the EC regulations on driving and working time and will give an advice to the planner. This will reduce the planning time and the amount of re-planning that needs to be done by the planners.

1.2 Research Methodology

From all the aforementioned, it is obvious that diverse parameters had to be considered, thus a stepwise method is needed in order to cite all the stages and results of this study (Figure 1).

The remainder of the this thesis is organized as follows. First a company description will be given, that will show how Jan de Rijk Logistics does their logistical part. The second chapter will be a literature review which is related to the research. This chapter is divided in multiple subjects. The first subject is the description of the difference between short- and long-haul transportation. Then a small explanation will be given of the Vehicle Routing Problem. Different emissions calculators will be explained. Finally the European driver regulations will be given. The next chapter describes the market Jan de Rijks Logistics competes in. Chapter 5 shows the development of the decision support model which is the core of this document. This model is analyzed in the next chapter. The final chapter gives the conclusions and recommendations

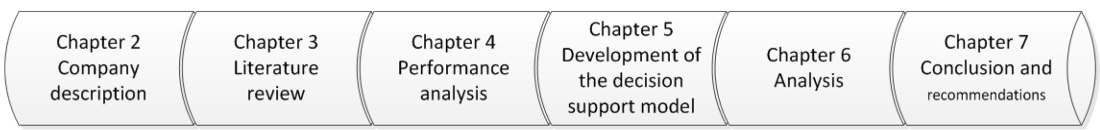

Figure 1 Overview of the Research Methodology

Chapter 2 Jan de Rijk Logistics

This chapter will give a brief introduction of the company Jan de Rijk Logistics with the help of the thesis of Dimarelis (2014).

2.1 Company description

Jan de Rijk Logistics (JdR) is a Dutch company whose headquarters are located in Roosendaal, the Netherlands. They are working as a Logistics Service Provider (LSP) in the transportation and distribution service sector. Jan de Rijk Logistics provides qualitative, reliable, cost-efficient, innovative, sustainable logistics solutions (including 3PL and 4PL solutions) for its customers. The company was founded in 1971 by Jan de Rijk and Jacqueline de Rijk-Heeren, who remain the main shareholders of the group and serve on the Board of Directors. Jan de Rijk Logistics has managed to continue to grow through the years and has expanded their network. Their portfolio has been diversified by acquiring their own warehouse and by developing Benelux distribution and they are also targeting high-end industries. Jan de Rijk Logistics can provide a diversity of transportation options to its customers, like temperature controlled transport, international transport, intermodal solutions, Benelux distribution, warehousing, retail distribution, container transport, event logistics and forwarding. In Table 1 the current figures of Jan de Rijk logistics are given.

Table 1 Figures of Jan de Rijk Logistics (Source: (Rijk, 2015))

Dimension	Numbers
Employees	Approximately 1000 FTE's
Offices	25
Countries	15
Vehicles deployed	Over 1000
Number of owned vehicles	550
Number of owned trailers	750
Warehouse capacity	115.000 m^2
Certifications	ISO 9001, ISO 14001, HACCP, CCQI AEO, TAPA compliance
Revenue	170 million (2014)

2.2 Jan de Rijk Logistics key industries

Since the start in 1972 Jan de Rijk Logistics has expanded its services with providing its customers with tailor-made, reliable, time-critical, innovative solutions. Every sector has its different characteristics and requirements. Jan de Rijk Logistics has worked with many partners in these sectors for many years, specializing themselves into a wide range of industries. Jan de Rijk Logistics has especially excelled in the following industries:

- Tobacco.
- Retail.
- Aerospace (i.e., aircraft engines and components, propulsion units etc.).
- Automotive (i.e., motor vehicle body manufacturing, gasoline engines, vehicular lighting equipment etc.).
- Duty Free (i.e., edibles, luxury commodities, cosmetics etc.).
- General Cargo (customer goods, containers).
- Healthcare.
- High-Tech (i.e., electrical machinery and apparatus, transport equipment etc.).
- Perishables (fresh logistics, pharma).
- Air Cargo.

2.3 Logistics solutions

Jan de Rijk Logistics can provide different solutions to its large field of unique customers. Because of their different solutions, customers can receive dedicated attention and commitment of Jan de Rijk Logistics employees. Jan de Rijk Logistics has all these solutions available so that customers can reduce their supply chain costs. The solutions Jan de Rijk Logistics provide are (Rijk, 2015):

- 4C: cross chain control center; a LLP (lead logistics provider) handling large freight demands together with TSP (transport service providers) in a multi modal way.
- They provide 3PL (offering multiple, bundled services (Selviaridis & Spring, 2007)) and 4PL (advanced contracting arrangements (Selviaridis & Spring, 2007)) solutions.
- Forwarding: Jan de Rijk Logistics has its own forwarding department.
- Special projects: such as sporting events, car and motoring racing events.
- Engineering: Network improvements, design of special trailers, tailor-made solutions.
- Consultancy.
- Intermodal transport.
- Event Logistics.
- Innovative Projects.

2.4 Transportation KPIs

Key performance indicators are quantifiable measures that a company or industry uses to compare performance in order to be able to compare them with performances in the past and to set goals for the future (Velimirovia, Velimirovia, & Stankovi, 2010). Jan de Rijk Logistics has established three important key performance indicators within the company's strategy:

- 80% use of loading meters per vehicle (load factor, loading meters).
- Achieving more than 10,000 km per month per driving unit (running kilometers).
- On-time performances according to the specifications that the customers require (punctuality).

The three previous mentioned KPI's from the company's strategy, are mainly cost driven. From rule operations and planning, a list of other performance indicators can also be defined:

- Empty running operations (%).
- Empty running kilometers (%).
- Operation factor (km/operation).

- Fuel efficiency (liter/km).
- Emission efficiency (gr CO_2e/tkm).
- Vehicle time utilization (%).
- Transport content (km/ton).
- Transport efficiency (ton km/vehicle km).

2.5 Fleet description

Jan de Rijk Logistics owns a large, modern and diversified fleet of assets (vehicles, trailers and semi-trailers, including trailers and road trains, mega- and standard trailers, box- and curtain-sided trailers, roller-bed and flat floor, low-loaders and trailers with slide- and adjustable roof for out of gauge type of cargo). For an LSP provider this is required to provide high levels of efficiency, sustainability and customer satisfaction towards the customers. Jan de Rijk Logistics is still improving their assets by investing in their equipment portfolio. Standardizing the vehicle platforms that comprise a fleet, offers several benefits (i.e., improved maintenance servicing), and therefore the company has chosen a small number of carefully selected suppliers. Moreover, it provides a variety of security solutions with tailor-made equipment, since every action of assets (truck and trailers) is closely monitored to minimize risks and ensures safe transportation (Figure 2) (Dimarelis, 2014).

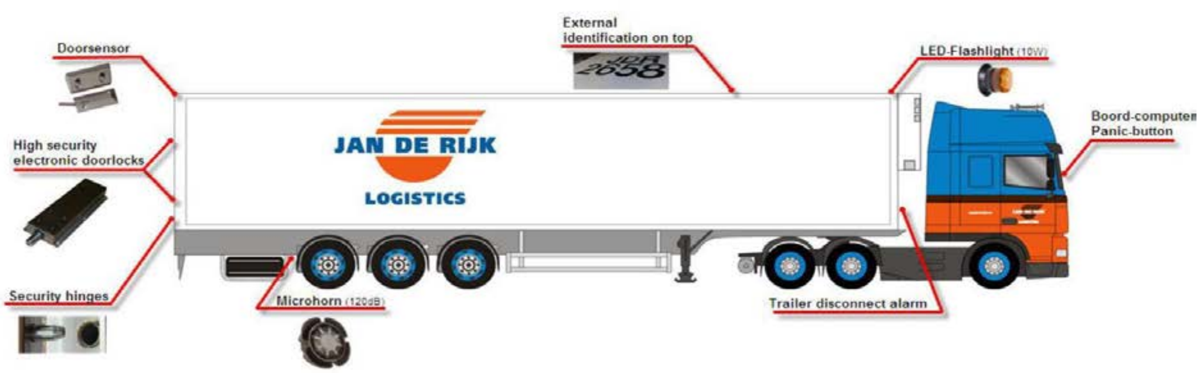

Figure 2 Available tailor made secure equipment of truck

The size of the fleet at Jan de Rijk Logistics already exceeds 550 trucks and 750 trailers and semi-trailers. This fleet serves a variety of customers, who can choose the type of trailer that serves them best. One of the most competitive advantages Jan de Rijk Logistics has is the road feeder services in the emerging air cargo industry in Europe. Jan de Rijk Logistics provides a large fleet of air freight solutions. An overview of the Jan de Rijk Logistics fleet can be seen in Figure 3 (Dimarelis, 2014, Rijk, 2015).

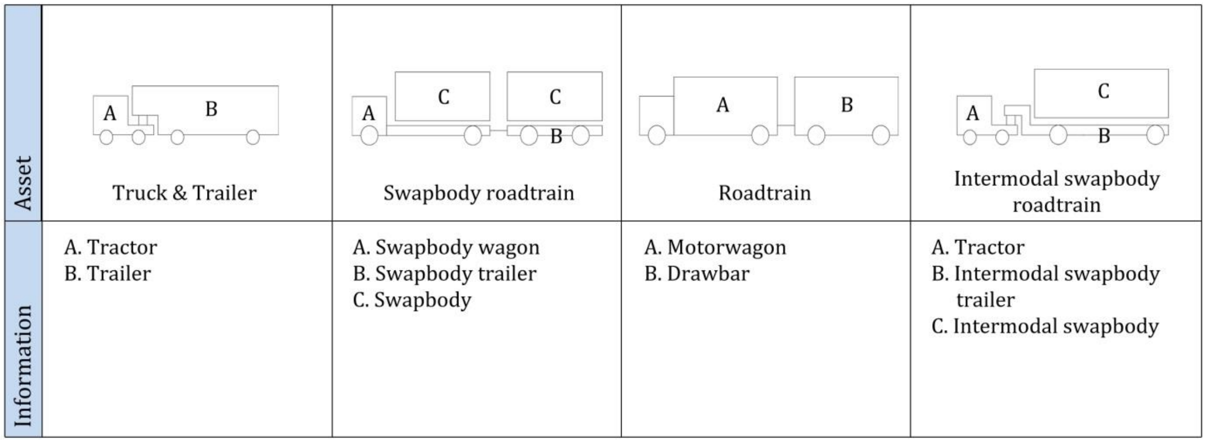

Figure 3 Description of Jan de Rijk Logistics' fleet based on the characters and components of the company's assets

This section will give a brief introduction into the project that will be conducted at Jan de Rijk Logistics.

In long-haul freight transport, goods are shipped over a relatively large distance, which can vary from some hundreds to some thousands kilometers. Companies that provide long-haul transport services can ship the goods directly or indirectly. Direct shipment means transportation of goods without intermediated transshipments. With indirect shipment, the goods are transported by means of a sequence of multiple different vehicles (Ghiani, Laporte, & Musmanno, 2013).

Short-haul freight transport is the transportation over a relatively small distance, within a city or country. Companies that produce goods for their own home-market have problems getting their goods to the distribution centers and customers. They mostly use their own trucks or local fast couriers who bring the goods from the Distribution Center (DC) to the customers. Examples of short-haul transportation are garbage collection, mail delivery and appliance repair services. The main problems of decision making in short-haul transportation is at strategic level, where to locate the depots, where the trucks start and end, at tactical level the size of the fleet of the company, and at operational level the vehicle routing to have an optimized service route. When a company has multiple customers and multiple requests at the same time, this is called the Vehicle Routing Problem (VRP) and these needs to be solved (Ghiani, Laporte, & Musmanno, 2013).

Jan de Rijk Logistics defines short-haul as Benelux transport. Short-haul transport are trips which can be accomplished within one working day of a driver who can be is back at the home-base the same day. Examples of short-haul transportation done by Jan de Rijk Logistics are Retail and Benelux distribution. Long-haul transportation are trips that take longer than a working day. Hence, the driver has to rest in his truck and abide by European Regulations. Their personal interest goes to the long-haul, because here drivers have to take more breaks than short haul driving. In the short-haul the driver has a limited driving time, coverage in a part of a day or a whole day, as they say, it as a desk job.

When a driver of Jan de Rijk Logistics is on long-haul driving duty, it is even possible that he is on duty for six weeks. Here the driver and planner have to work with the European Regulations on driving and working time for truck drivers (EC No 561/2006). The EC has made distinctions between five different regulation types. These include:

- Regulations on driving.
- Regulations on working.
- Regulations on breaks.
- Regulations on daily rests.
- Regulations on weekly rests.

The detailed regulations can be found in Appendix I. One additional rule has to be invented because this is the desire of Jan de Rijk Logistics. First a fictional scenario will be sketched:

> *'Jan de Rijk Logistics transports to 15 countries in Europe. So most of its transport is called long-haul transport. Their drivers are from different countries. But most of the time the transport starts in Amsterdam, Frankfurt, Charles du Gaulle and London Heathrow. These East-European drivers have to travel a large distance before they are at their trucks. When the driver reaches his truck, he is no longer fresh to drive the full length of his shift. This duration has to be looked at when planning a driver towards a truck. Also when a driver is no longer allowed to drive, he has to travel back to Roosendaal or where his home is.'[subtracted from the interview with Hans Helders]*

This problem is hardly addressed in the literature because of the assumptions most papers make that drivers have their own trucks, or are always near the parking or warehouses. The problem Jan de Rijk Logistics has, is that some drivers have to leave their trucks because they are at the maximum limit of working hours. A new driver has to travel to this truck. This driver will not start fresh at the new truck and so he cannot drive the full predefined time set by the EC regulations. The planners have to acknowledge that they cannot count on a fresh driver. The planners take this into account. However the planning system Jplexs does not. The planning system Jplexs at this moment only counts the drivers on duty and driving time. There is no dynamics in this calculation system of the driving and working hours.

2.6 The description of Jan de Rijk Logistics Planning

There are three main participants in the planning system at Jan de Rijk Logistics. These pools are the Logistic Service Client (LSC), an LSP (Jan de Rijk Logistics) which is also carrying out transportation with its own assets and a third party transport service provider (3PL). The first pool is the customer. Here the customer decides to choose Jan de Rijk Logistics as their transporting company. The customer's request is placed at the customer service desk. They make a first decision if they will accept or refuse the request. If the customer service desk declines the request, this is reported to the customer and the process ends. However, if the request is accepted, the request is entered into the TMS of Jan de Rijk Logistics. The TMS sends a confirmation of the booking back to customer and the service desk employee. Then the request is booked into Jplexs. A small introduction into Jplexs can be found in the interview with Rob Matthijssen. The request is then passed on to the freight planners of Jan de Rijk Logistics. In the future, the planners can use algorithms to help them with the planning of the Full-Truck Load (FTL) or the Less-than-Truck-Load (LTL). When they have decided on the planning of the request, the decision has to be made if the request of the customer will be transported with owned trucks, or with trucks from a charter company. If it is going to be transported with owned trucks, the order is given to the asset planners. The asset planners book a trailer and driving unit. If no driving unit is available, the planners will look for a charter driving unit. If no charter driving unit is available, the trailer unit and driving unit will be hired by the charter planners. However, when both are available, the asset planners will contact the driver and assign him to the order. After the assignment to the order, the paperwork that drivers need for their route is prepared and handed to the driver. The driver now loads his truck and sends a status report to the asset planners. They will check the status and send an update to the customer. The driver will start transporting the goods. During the transportation of the goods the asset planner will look if re-planning is needed. If this is needed the driver will receive the re-planning and will reposition the assets in his truck. If the planner uses real-time data, which is provided by the boardcomputer stationed in the truck, the planner is working on the online planning. However, most re-planning done by the planners is done during offline planning. The planning changes offline when there is a freight shift (cargo is at another location), change of commodity, change of loading meters, or an asset is no longer available.

When the driver arrives at the destination, there will be an exchange of the invoice and the transportation documents. A third party logistics (3PL) will be used if Jan de Rijk Logistics cannot provide the needed transportation with its own trucks. A charter planner will look for a driving unit and trailer if these are needed. The charter planners will book the needed capacity and prepare the documents. Then the same process will run as with own trucks (transport, exchange of documents and unloading). With this complete overview of the planning there is a good understanding of how it is done at Jan de Rijk Logistics.

Resulting from this description of the planning, the following Table 2 can be derived. The following table shows that this moment, the planning system Jplexs only gives support on matching drivers with pulled and pulling units and the matching of a pulled unit with a pulling unit. What this decision support algorithm will improve is that the driver allocation and traveling time considerations will also be supported by Jplexs with additional information.

Table 2 Scheduling planning decision's distribution currently at Jan de Rijk Logistics (Raoufi, 2013)

Planning decisions	Planner	Jplexs
Matching driver(s) with pulled and pulling units		x
Matching pulled and pulling unit		x
Driver allocation	x	
Traveling time considerations	x	
Freight and pulled unit matching assignment	x	
Empty running decisions	x	(x)
Charter hiring decisions	x	(x)
Distribution of pulled units within the network	x	

2.7 Scope of the research

This chapter contains the problem analysis and the main research questions. This is the start of the master thesis project.

2.7.1 Problem analysis and diagnosis

This section of the thesis describes the steps that were done before the research question was prepared. In the previous sections a clear overview was made about Jan de Rijk Logistics and how their planning works. With the problem description that was prepared by Jan de Rijk, had to be made an initial problem statement had to be formulated. From this problem statement a diagnosis was done which resulted in a brainstorm session and a cause and effect diagram. With the results of this diagnosis the research question and sub-questions were prepared. The following steps were subtracted from the course Design Science Methodologies taught at the TU/e.

2.7.1.1 Initial problem statement

Jan de Rijks Logistics fleet has developed into a big organization, with many (European) drivers. With increasing European regulations on driving time, the planners at Jan de Rijk Logistics need to think more if they plan to avoid rescheduling. Literature shows a lot of supporting balancing equations to reduce the costs for the allocation of drivers. With the help of employees at Jan de Rijk Logistics and the project description the following initial problem statement was prepared:

> *“Jan de Rijk Logistics planning department needs a supportive decision algorithm for their driver allocation.”*

2.7.1.2 Diagnosis

With this initial problem statement, a brainstorm session was conducted. Resulting from this session various characteristics were explored regarding the allocation of truck drivers, as can be seen in Appendix II. From this brainstorm session there a cause problem and effect diagram was also prepared.. Multiple problems were then identified that can cause this effect. The causes and problems all came up during the different interviews that were conducted with employees of Jan de Rijk Logistics. The main problems discovered were a combination of the European regulations and long-haul transportation of goods.

Main research question and sub-research questions

From the diagnoses step multiple key words were derived. These keywords will be used in the main research question and sub-research questions. The keywords are planning, decision algorithm and driver allocation.

How does the (re-)planning of the allocation of drivers on long-haul transportation routes using real time data affect Jan de Rijks Logistics performance through transportation network?

2.7.2 Methodology

To fulfill the requirements of this assignment, i.e. the development of a mathematical solution algorithm to support the planning when allocating drivers to trucks to increase the reliability and speed of the planning process, a structured methodology must be used.

The first step of the master thesis is the identification and assessment of the problem stated by Jan de Rijk Logistics. In previous sections most of the issues regarding driver allocation have already been addressed. However, an in-depth understanding of the problem needs to be established standards of Jan de Rijk Logistics. The performance analysis consists of data gathering on the performance of the planners. With this data the constraints planners have regarding driver allocation have to be determined and the Key Performance Indicators (KPI's) are identified which the planners use when establishing the planning. The results from this step, with the insights from the literature study conducted before the start of the project at Jan de Rijk Logistics, will lead to an initial structure (method and variables) of the model that can give the preferred results for Jan de Rijk Logistics. In this initial model the decision variables will be used that are determined to be useful for the planning department. This initial model needs to have an objective function that is aligned with the expected results.

With this initial model, the next step should be the development of the solution algorithm that solves the driver allocation problem to optimality. With the use of old data, simulations have to be done to show the usage of the algorithm. If the algorithm works, the results have to be compared with results of the planning department. KPI's, that have been indicated to be important by the planners, have to be compared with previous results to show the improvement. There will be a lot of revisions on the model during the project; this is done during all the previously mentioned intermediate steps.

Chapter 3 Literature review

An extensive literature review was conducted before and during the master thesis project. This chapter is designed to give a theoretical foundation on the subjects that are relevant to this research. This chapter contains four main parts. The first part is a brief explanation of the difference between short- and long-haul transportation. Next is the Vehicle Routing Problem with and without time windows explained. The third part is the carbon emission calculators. The final part is the explanation of European regulations on driving and working hours.

3.1 Short- and long-haul transportation

In long-haul freight transport, goods are shipped over a relatively large distance, which can vary from some hundreds to some thousands kilometers. Companies that provide long-haul transport services can ship the goods directly or indirectly. Direct shipment means transportation of goods without intermediated transshipments. With indirect shipment, the goods are transported by means of a sequence in multiple different vehicles (Ghiani, Laporte, & Musmanno, 2013).

Short-haul freight transport is the transportation over a relative small distance, within a city or country. Companies that produce goods for their own home-market have problems getting their goods to the distribution centers and customers. They mostly use their own trucks or local fast couriers who bring the goods from the DC to the customers. Examples of short-haul transportation are garbage collection, mail delivery and appliance repair services. The main problems of decision making in short-haul transportation is at strategic level, where to locate the depots, where the trucks start and end, at tactical level the size of the fleet of the company, and at operational level the vehicle routing to have an optimized service route. When a company has multiple customers and multiple requests at the same time, this is called the vehicle routing problem (VRP) and these needs to be solved. (Ghiani, Laporte, & Musmanno, 2013)

3.2 Vehicle Routing Problem and VRPTW

In this chapter there will be a small introduction to the vehicle routing problem. This is done because this is the fundamental basis of the vehicle routing problem with time windows which is needed for the driver regulations. The classical vehicle routing problem (VRP) aims to find an optimal delivery or collection routes from one or more depots, to one or more users. VRPs can be defined in graph $G = (V, A, E)$, where V is number of vehicles, A is a set of arcs and E is a set of edges. A with the vertex 0 is where the depot is, with m number of vehicles. A subset of $U \subseteq V$ of required vehicles and a subset $R \subseteq A \cup E$ of required arcs and required edges. The objective of the vehicle routing problem is to minimize the total routing costs. There are some fundamental operation-related constraints. Some of these constrains are:

- The number of vehicles *m* can be fixed or can be a decision variable;
- The total demand transported cannot exceed the capacity of a vehicle;
- Customers must be served within pre-established time windows;
- Some customers must be served by specific vehicles.

Another constraint is that the duration of a route must not exceed a work-shift duration. Further literature will show that this constraint can be released with the introduction of breaks and rests.

As can been seen from the literature, when introducing the driver regulations, the first extension on the classical vehicle routing problem that has to be made is the VRP with time windows (VRPTW). In the case of VRPTW the service at each individual customer must start between a pre-specified time windows. The objective function of the VPRTW is to minimize the traveling cost. All vehicles must also start and finish at the same depot. There are the two options, soft or hard time windows. For soft time windows no penalty has to be paid when the service is not in the time window. Hard time windows cannot be violated, so when it arrives at the customer too early, the vehicle must wait for the time window to open and it is not allowed to arrive later than the upper bound of the time window. The goal of the VRPTW is to design a route with minimized costs. Constraint of a VRPTW are that a vehicle can only visit a customer once, and a vehicle can only be loaded with its maximum capacity (Kallehauge, Larsen, Madsen, & Solomon, 2005).

3.3 Carbon Emission Calculators

All industrial activity, in particular transportation, produces greenhouse gasses (GHGs). Nowadays it has become more important for companies, governments and costumers to know how much greenhouse gasses (e.g., carbon dioxide CO_2, methane CH_4, nitrous oxide N_2O and chlorofluorocarbons CFC (OECD, 2002)) they produce (Prescott-Gagnon, Desaulniers, Drexl, & Rousseau, 2010). The United Nations has set emission targets to all its members in the Kyoto Protocol. This protocol has led the European Union to set its own targets. The target is to reduce the emissions to 20% less that what they were in 1990. The Kyoto protocol also includes three market-based mechanisms to meet the company's targets. These mechanisms are emissions trading, clean development mechanism and joint implementation. The emission trading is already implemented by the EU for all energy intensive industries. These industries produce almost 50% of Europe's carbon emission (European Commission, 2008). The European Union made emission trading schemes, so that a market has emerged between these companies in trading allowances to produce some maximum amount of carbon and other greenhouse gasses. The market determines the price for the emission allowances.

In the literature review previously made for this Master Thesis, one chapter was the in-depth research of the multiple different carbon emissions calculators. The final model will have an extension for carbon emissions result. From the literature review, three methods were further examined for the possibility to use in the final model. The methods are the EcoTransIT, MEET and the NTM methods. These two were chosen because of their ease to be implemented.

3.3.1 EcoTransIT

EcoTransIT stands for Ecological Transport Information Tool and is developed by the Institut für Energie- und Umweltforschung Heidelberg GmbH and it is initiated and supported by several rail companies from Europe ((EcoTransIT, 2008), (Akker, 2009)). The project was initiated by five large European railway companies in 2000 (DB Schenker Rail, Schweizerische Bundusebahnen SBB, Green Cargo AB, Trentialia S.p.A, Socièté Nationale des Chemins de Fer Francais (SNCF) (Dimarelis, 2014). Their initial tool produced in 2003 has a limited scope to Europe. However, their recent version EcoTransIT World, published in 2010 allows calculations for environmental impacts of worldwide transports. This improved version also has an option for calculating sea and air transportation emissions. The tool uses outsourced resources for their calculation. This tool needs the following factors for the emission calculation: origin and destination, load factor, type of cargo, empty trips and vehicle size. When these factors are present, it compares the emissions and energy consumption between different transport modes. It is primarily used in cargo transport (Hjelle, 2012).

3.3.2 MEET

Methodology for calculating transportation emissions and energy consumption (MEET) is a publication of the European Commission by Hickman, Hassel, Joumard, Samaras, & Sorenson (1999). It uses real-life data which is produced by actual driving on the road by trucks. The data was generated in 1999, which makes them outdated nowadays. When using this methodology an update of the parameters for eninge fuel consumption and areodynamics should be made. This data is used for the calculation of transporation emissions and energy consumption of heavy vehicles. It differentiates its calculation between the weight of the vehicles. The result that MEET gives is a total CO_2 emission (grams):

A methodology widely used for heavy freight transportation is the Methodology of calculating transportation emissions and energy consumption (MEET). This tool has been developed in Europe for evaluating the impact of transportation on air pollution. The CO_2 emission calculation according to MEET is as followes:

$$F = \varepsilon \cdot GC \cdot LC \cdot Distance$$

This formula makes use of predefined constants for vehicles weights. The rate of emissions ε in (g/km) for an unloaded truck can be calculated with the average speed (km/h) of the truck:

$$\varepsilon = K + av + bv^2 + cv^3 + \frac{d}{v} + \frac{e}{v^2} + \frac{f}{v^3}$$

Here a to f and K are coefficients which are provided by MEET and can be found in (Demir, Bektas, & Laporte, 2014).

Once this estimation of the gas emissions is calculated, the road gradient (GC) calculation and the load factor (LC) can be added.

The road gradient factor:

$$GC = A_6v^6 + A_5v^5 + A_4v^3 + A_2v^2 + A_1v + A_0$$

The given A_0 to A_6 can be found in the Demir et al. (2014) paper to calculate the road gradient factor (GC). These coeffiecients are multiplied with the speed of the truck.

The load factor:

$$LC = k + n\gamma + p\gamma^2 + q\gamma^3 + \frac{r}{v} + \frac{s}{v^2} + \frac{t}{v^3} + \frac{u}{v}$$

The variable coefficients k and n to u are presented in the Demir et al. (2014) paper. With the use of the speed of the truck the load factor (LC) can be calculated.

3.3.3 NTM

Network for Transport and Environment (NTM) is a non-profit organization, started in 1993. Their initial statement was to create a common base of values on how to calculate the environmental performance for various modes of transport. Like the EcoTransIt, they do not collect any data themselves, but use other data sources. Their primary scope is Europe. However, they are also gathering data outside their scope. They developed a calculator that allows (transportation) businesses and consumers to calculate their effect on the environment with their actions. The factors NTM uses for their emission calculation are: number of kilometers; load factors; weight shipment; type of transport mode(different types exists depending on the mode and fuel consumption); positioning; empty return trips; topography and type of road (Dimarelis, 2014) (Hjelle, 2012) (Akker, 2009). NTM calculates the fuel consumption (liter/kilometer) and the total carbon dioxide (kg) at a specific load factor for each type of road. The fuel consumption:

$$f(lf)_i = F(empty) + \big(F(full) - F(empty)\big) \cdot lf$$

Where the $F(empty)$ is the fuel consumption (liters/kilometers) of an empty vehicle and $F(full)$ of a fully loaded vehicle. The lf is a specified load factor. All these constants can be found in NTM Road (2010). The calcultation for the total carbon dioxide (kg) is as follows:

$$E(lf, D_1, D_2, D_3) = \sum_{i=1}^{3} (f(lf)_i \cdot D_i \cdot E_{co_2e})$$

The constant E_{CO_2e} is the emission factor, which is 3.13 kilogram for one liter of diesel fuel. The three $D_i$are the total distances travelled on each of the three different road types.

3.4 Driver regulation

As mentioned in the previous section, Jan de Rijk serves in multiple countries in Europe. Furthermore, Europe is a free trade zone, no borders and no customs, a result of the Schengen Agreement from 1992, which resulted in free trade between members of the European Economic Community (EEG). For drivers this means no stopping at the borders due to no customs control. Firms are no longer under the obligation to maintain a major distribution center in each country (Crainic & Laporte, 1997). This leads to fewer warehouses and longer travelling distances. Therefore, the European Union needed regulation for the driving hours.

The European Union enforced new driving hours' rules in April 2007. These rules were stated by the European Union, defined in Regulation (EC) No. 561/2006 of the European Union (2006). Furthermore, European drivers also need to abide the rules regarding their working hours, which include their driving and service hours. The European Union has stated these regulations in Directive 2002/15/EC of the European Union (2002). In this section these rules will be stated because they will be used in the driver allocation decision algorithm. All these rules restrict the planner for the allocation of drivers to their trucks and trailers (Prescott-Gagnon, Desaulniers, Drexl, & Rousseau, 2010).

The previous rules, set by the European Union, are used to make the following driver regulations definitions. An assumption regarding all the rules is that each of the time periods should be uninterrupted.

- A calendar week begins on Monday at 00:00 and will last until Sunday 24:00
- A driver's *break* is any period of time of at least 15 minutes, but not more than 3 hours where a driver can do non-work related activities. A driver's break can be defined in multiple ways:
    - A *short break* lasts at least 15 minutes but not more than 45 minutes.
    - A *long break* is more than 45 minutes (not exceeding 3 hours) or if the previous break was a short break, then a long break can be at least 30 minutes or rest.
- A drivers *rest* is any time period of at least 3 hours, where a driver can do non-work related activities. A rest is divided into multiple options:
    - A *short rest* is a rest of at least three hours but less than nine hours.
    - A *long rest* is a rest of at least 9 hours but less than 24 hours.
    - A *regular daily rest* can be a long rest of at least 11 hours or a combination of a short rest and a long rest.

- A *reduced daily rest* is a long rest of less than 11 hours and not proceeded by a short rest.
- A *weekly rest* is a rest a driver takes before and after every trip of at least 24 hours.

The European Union also made different regulations on driving and working time periods, which each of them has its own restrictions.

- The time of each driving session must not exceed 4.5 hours. (A1)
- The daily driving time must not exceed 9 hours. This can be extended to 10 hours, but not more than twice a calendar week. (A2)
- The total weekly driving time must not exceed 56 hours. (A3)
- The internal working hours (working hours include driving and servicing hours) must not exceed six hours. (A4)
- The weekly working hours must not exceed sixty hours. (A5)
- The average weekly working time over a period of 4 months must not exceed 48 hours (A6)
- Drivers work only 6 days in a week. (A7)

As stated above, there are European regulations on what defines a rest. There are also regulations on when a driver has to take a rest.

- Within a time span of 24 hours, after the end of the previous daily or weekly rest, a driver must have taken a new daily rest. (B1)
- If the duration of the daily rest period that falls within that 24-hour period is at least 9 hours, but less than 11 hours, then this daily rest period will be regarded as a reduced daily rest (B2)
- When the 24-hour period is over, the rest period does not have to be over. However, the total rest duration, before the end of the 24-hour period, has to be more than 11 (or 9) hours. In other words, a daily rest must start no later than 13 hours after the end of the last one in the case of a regular daily rest or 15 hours in the case of the reduced daily rest. (B3)
- Between two weekly rests, there can be a maximum of only three reduced daily rests. (B4)
- There must be no more than 6 24-hour periods between two weekly rests. This rule takes into account that there is always a weekly rest at the beginning and end after (B5)

each route.

All these rules can be combined into a visualized overview and optimization rules and constraints. Figure 4 shows the schematic overview of a driver's week (Meyer & Kopfer, 2008). This figure is abstracted from the EC Regulation No 561/2006.

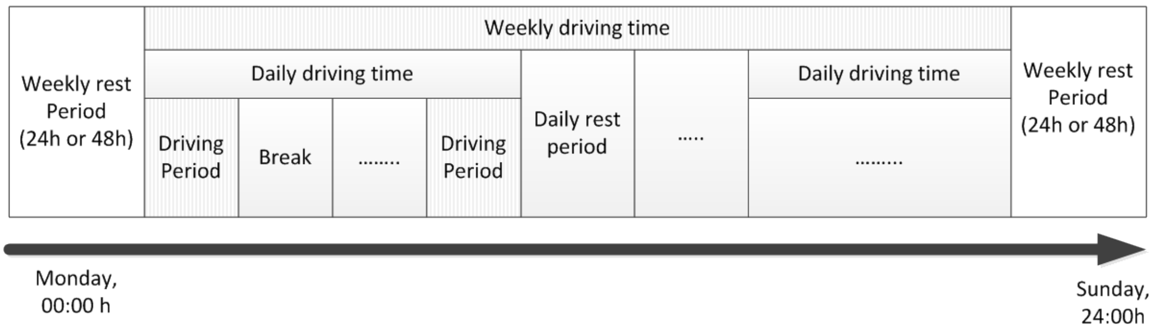

Figure 4 Schematic overview of a driver's week

3.5 Chapter discussion

This chapter starts with a small introduction to the transportation. This is done in order to make the right distinction between short and long haul transportation, for the decision support model is going to be based on long haul transportation issues. Also a small introduction is made into vehicle routing problem with time windows (VRPTW). This is going to be the base of the decision support model that will be introduced at Jan de Rijk Logistics.

The carbon calculations methods shown are both capable of making an estimation of the carbon emission a truck produces during a trip. However, a choice had to be made for the model. Both models have reliable calculations which will give a reliable answer that is comparable with the calculations Jan de Rijk Logistics makes. However, the calculation method MEET has outdated constants which are updated through innovations made in for example engines. The NTM method is an easy to use method with reliable results, matching the calculations at Jan de Rijk Logistics.

As with all the regulations mentioned, most of them are already widely addressed in the literature. However, some regulations are not used because they are not applicable to the Jan de Rijk Logistics situation. With these regulations further literature will be searched. This literature will contain models that will be used in the decision support model.

Not all rules are applicable in the model. A selection was made to have a good and reliable model. A1 to A5 are used in the model. A6 is not used, this is done because the model will not take such a large time span to calculate. At Jan de Rijk Logistics, another department than the planning department regulates this. Because this model will be used by the planning, this will not be included. A7 will be used in the model. B1 and B2 will also be considered in the model.

Chapter 4 Performance analysis

This chapter is dedicated to data analysis of JDR's performance in order to gain sufficient knowledge about the current performance indicators, identifying improvement areas and eventually concluding a decision for the study to be investigated.

4.1 General numbers

The global economy is starting to recover from the impact of the 2007 – 2008 financial crisis, which is considered by financial experts to be as severe as the Great Depression 1929 – 1932. the financial crisis which subsequently turned into an economic crisis, dramatically slowed down the demand for road freight transport services, due to the strong correlation between economic and transport growth (IRU, Impact of the economic crisis on road transport, 2015). The numbers of recent year show that the economies of advanced economies are slowly recovering. The numbers for emerging markets are not increasing as fast as the advanced economies. Figure 5shows the numbers for the more advanced economies with the projects for 2015.

	Real GDP			Consumer Prices[1]			Current Account Balance[2]			Unemployment[3]		
		Projections			Projections			Projections			Projections	
	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015
Advanced Economies	**1.3**	**2.2**	**2.3**	**1.4**	**1.5**	**1.6**	**0.4**	**0.5**	**0.4**	**7.9**	**7.5**	**7.3**
United States	1.9	2.8	3.0	1.5	1.4	1.6	–2.3	–2.2	–2.6	7.4	6.4	6.2
Euro Area[4,5]	–0.5	1.2	1.5	1.3	0.9	1.2	2.3	2.4	2.5	12.1	11.9	11.6
Japan	1.5	1.4	1.0	0.4	2.8	1.7	0.7	1.2	1.3	4.0	3.9	3.9
United Kingdom[4]	1.8	2.9	2.5	2.6	1.9	1.9	–3.3	–2.7	–2.2	7.6	6.9	6.6
Canada	2.0	2.3	2.4	1.0	1.5	1.9	–3.2	–2.6	–2.5	7.1	7.0	6.9
Other Advanced Economies[6]	2.3	3.0	3.2	1.5	1.8	2.4	4.8	4.7	4.3	4.6	4.6	4.5

Note: Data for some countries are based on fiscal years. Please refer to Table F in the Statistical Appendix for a complete list of the reference periods for each country.
[1]Movements in consumer prices are shown as annual averages. Year-end to year-end changes can be found in Table A6 in the Statistical Appendix.
[2]Percent of GDP.
[3]Percent. National definitions of unemployment may differ.
[4]Based on Eurostat's harmonized index of consumer prices.
[5]Excludes Latvia. Current account position corrected for reporting discrepancies in intra-area transactions.
[6]Excludes the G7 (Canada, France, Germany, Italy, Japan, United Kingdom, United States) and euro area countries but includes Latvia.

Figure 5 General Numbers

The economic crisis also hit the road transportation sector hard (IRU, 2015). Figure 6 shows a decline of 12% between the peak in 2007 and the last known figures in 2012. These numbers show the actual driven kilometers done by freight transportation on the road. In comparison, Figure 6 shows the total kilometers goods have been transported in 2012, but for different types of transport.

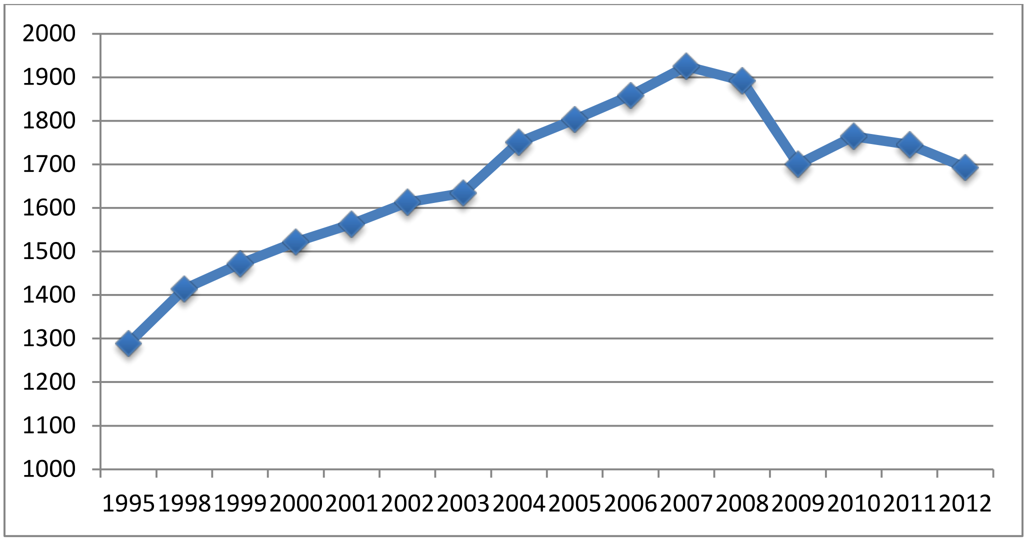

Figure 6 Road Kilometers (billion Ton)

As can be seen in Figure 7 is that road transport is still the largest mode of use in the transportation sector. However, these numbers also show that sea and air are popular ways of freight transport. Road and rail are the modes that are still below the level of which they were pre-crisis. Air and sea have remained on the same levels as they were pre-crisis.

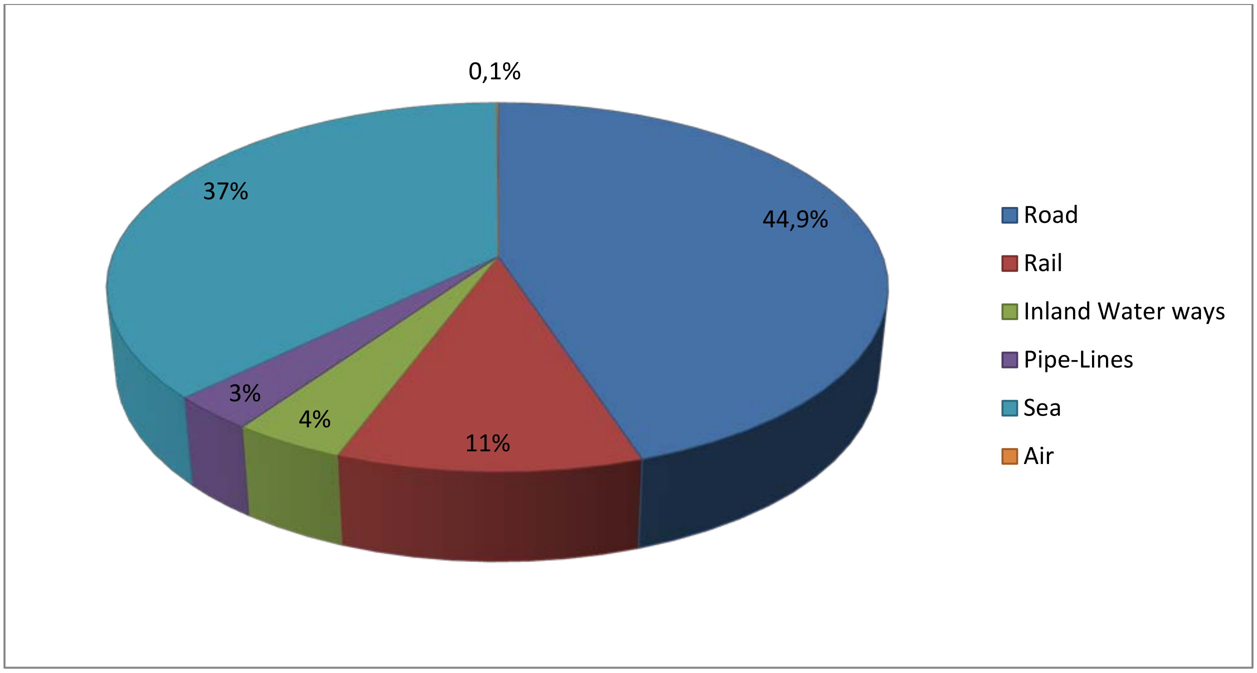

Figure 7 Transportation per mode

As can be seen in figure 8, road transportation is almost 50% of the kilometers. However, from the CO_2e emission perspective, road transportation, with 72% is the largest contributor to the GHGs.

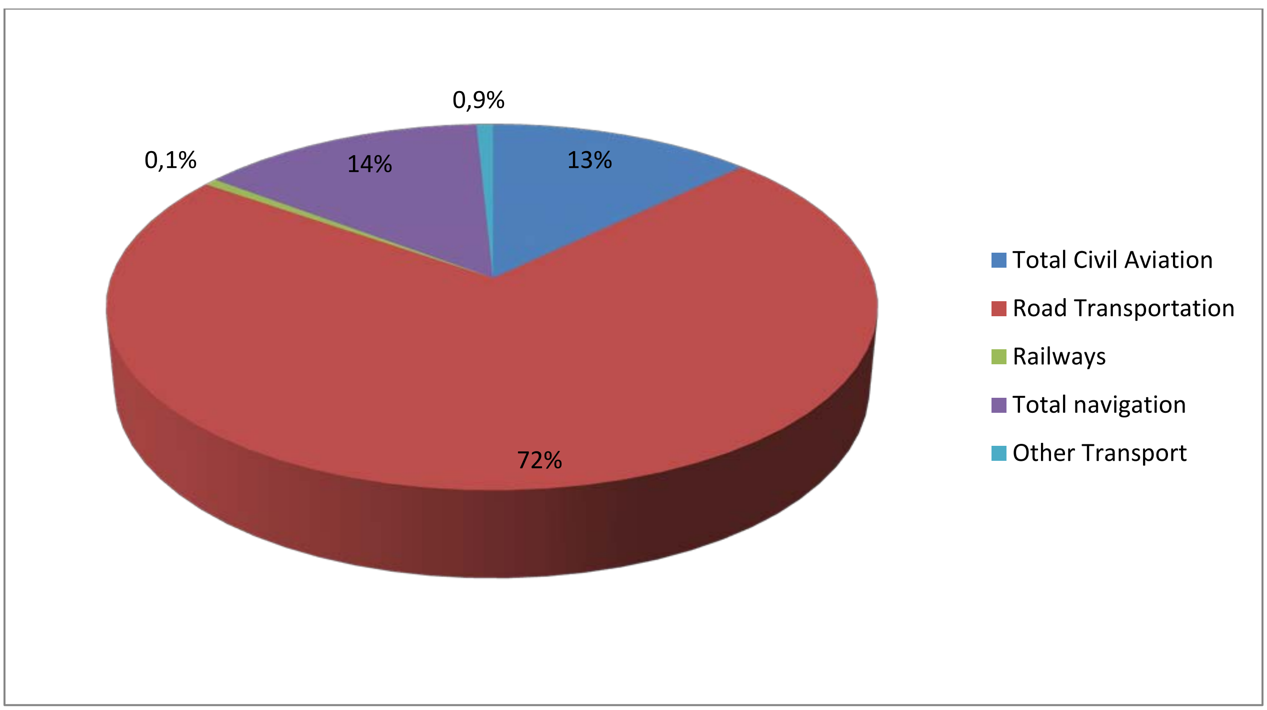

Figure 8 CO_2e Emissions per Mode

The road transportation sector will also be the largest contributor for the GHGs in the future.

4.1.1Freight shift

In logistics terms freight shift means that when the original plan of a pick-up and/or drop off location of a freight request changes, the focus on freight shift is mostly on the commodity air-freight. Freight shift in the air-shift happens because of two main reasons:

- An airplane is rerouted to another airport, due to i.e. weather conditions, technical defects or a strike, resulting in that the freight has to be picked up at a (different) airport.

- The airline changes the way in which it decides to load the airplanes due to efficiency in their own planning. As a consequence, different transportation orders are placed on different airplanes at different airports causing a shift in the freight demand towards JdR. This freight then needs to be dropped off at a different airport..

4.2 Re-planning characteristics

During the completion of the research proposal, characteristics of making the planning at Jan de Rijk Logistics were shown. A large problem at the moment is the large amount of re-planning that needs to be done by the planners. There are a lot of activities that can occur which will result in re-planning. There five main reasons are demand characteristics, low planning quality, assets, planners and delay events. Re-planning can occur when demand characteristics have an influence on the planning of assets and drivers. Demand characteristics are a highly dynamic demand, the behavior of clients, cargo type and non-standardized demand. The planning quality can decline when the complexity of the planning increases, if not all key performance indicators are taking into account and if there is no supporting decision algorithm. Re-planning can also occur when there are problems with the assets. Some of these problems are that no optical rule or policy is defined, not supported by the system or that the distribution of the assets is based on experience. Also the performance of the planner can lead to re-planning activities. The flaws of a planner can be the poor decisions based on their experience, that they are not supported by a decision support algorithm or poor allocation of resources. The last problem that can lead to re-planning is delay events. These can be categorized into two sub-categories, these are in control delay events, and out of control delay events. In control events are events where an employee of Jan de Rijk Logistics (planner, driver) or an external personnel is in control of delaying the planning. Out of control events are events resulting from weather, traffic jams, and road blockage.

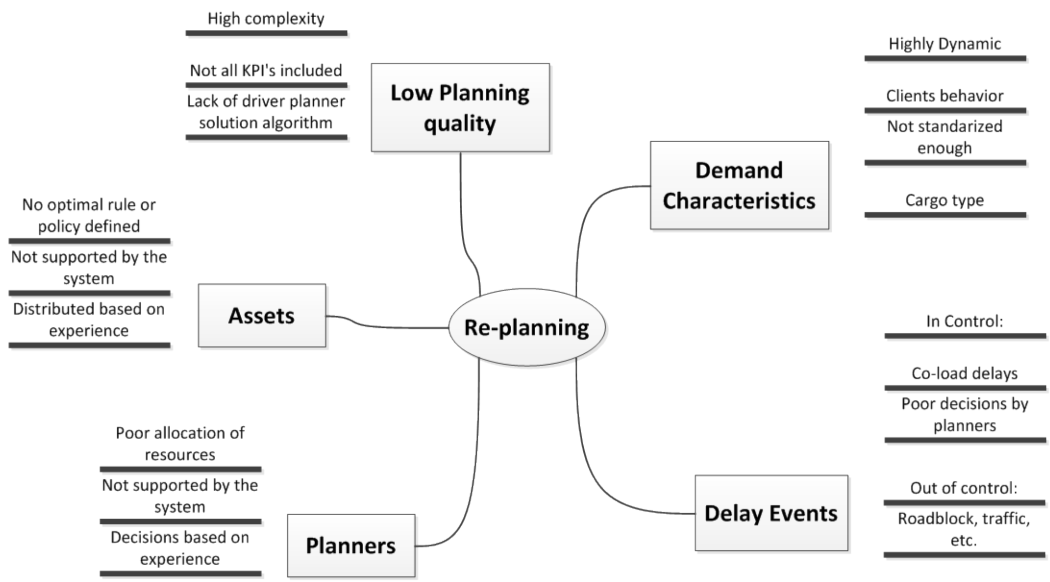

Figure 9 Re-planning factors

With the supportive decision algorithm that is going to be developed, the following aspects will be improved for the re-planning. The quality of the planning will increase, because the algorithm should support every type of complexity and include all the KPI's. The allocation of drivers and assets will give lower costs. The planners will also plan better, because their decision is not only based on experience.

4.3 Delay events

Delay events cause a lot of the planners' time to be lost regarding the re-planning. By having an interview the main delay events were found. During this interview the following delay events were considered the most important ones:

- Co-load
- Long loading
- Bad weather
- Traffic problems
- Late report for loading
- Delay un/loading previous address
- Freight not ready
- Police check

All these delay events were recorded in Jplexs with specific codes. With these codes a quantitative analysis could be performed on which delay event occurs more often. Conclusion from the interviews conducted with employees at Jan de Rijk Logistics proves that most of the delays are results of poor planning quality. This is due to the fact that planners plan without a supporting tool in Jplexs.

4.4 Planning of the drivers

In regard of the planning of the drives, Jan de Rijk Logistics works as follows. Planners at Jan de Rijk logistics have defined some fixed jobs, which holds the same route. For instance, one freight line that is always been driven is the line from London Heathrow through Roosendaal and finishes in Frankfurt. These lines have a more or less known duration, capacity, demand and time window. With this information the lines get a number of trucks assigned. With this number of trucks and duration of the line another group op planners start to plan enough drivers with their trucks to meet this capacity without delay of break time. When these drivers are available, the first group of planners can assign the available drivers towards the trucks. The planners who make enough drivers available work with a Gantt-chart to have a clear overview.

4.5 Time windows

A key part of the Jan de Rijk Logistics service is to satisfy the customers' time windows. Time windows are the moments that the customers are open to load and unload the goods carried by the trucks from Jan de Rijk logistics. However, not all the time windows provided by the customers of Jan de Rijk Logistics have hard restrictions, this gives flexibility to meet the time windows at the customer planned by the planning department.

Each commodity group has delays. The commodity with the most delays is the air freight commodity. This is due to the handling at the airports, this has a low standardization level and there is a huge delay in loading and subsequently on delivery as well. The average delay for each shipment is approximately 9 hours.

4.5.1 Loading meters

One of Jan de Rijk Logistics most important KPI is the loading meter. The aim of the planners is to load each commodity type to at least 80%.

It can be seen that in Jplex that there is a high frequency of zero loading meter and utilization shown, this is due to the fact that within each location there are a lot of small movements happening without being registered into Jplex. For instance; mounting and dismounting, maintenance check. Furthermore, in each city there are some dedicated pulling units that are only responsible for operations inside the terminal and never load any trailer. Together this results in initial high frequency in both utilization and loading meter graphs.

4.5.2 Re-allocation of foreign drivers and assets

One of the items that were discussed with employees at Jan de Rijk Logistics were the re-allocation of drivers and trucks when a driver reaches his long breaks. It is possible that the load of a truck needs to reach its destination before a due date (freshness, high importance load or security load). The problem with this is that there extra costs are involved when a driver has to be flown to the truck to make sure that the truck keeps driving. However, this problem only occurs a couple of times a year. So this KPI is not regarded as an important measurement of the quality of the planning.

4.5.3 Distribution of drivers towards Roosendaal

One of the measures Jan de Rijk Logistics took to prevent delays of trucks, is that they have a Jan de Rijk Logistics Hotel near their HQ in Roosendaal. When interviewing multiple employees at the planning department, it has become clear that nearly all long haul shipments come through Roosendaal. With this they have the ability to store, but also change drivers at this location. This reduces the amount of drivers that have to take their long breaks when they are on route. For example, the route London Heathrow – Roosendaal – Frankfurt am Main is driven daily multiple times. The idea to keep this line open all the time is to have two drivers on this route for a week, one driver keeps driving between London and Roosendaal, while the other driver drives between Roosendaal and Frankfurt am Main.

Another problem for the planning department is that drivers do not arrive fresh at Roosendaal. Not fresh means that this driver has already driven that week, or that he has driven a significant amount of time towards its truck. Jan de Rijk Logistics has a large amount of employees from Eastern Europe, like Poland. These drivers drive together in a van to Roosendaal to get there to start working. These drivers have already worked and get paid for this trip. However, this is not seen in the planning tool Jplexs at Jan de Rijk Logistics.

4.6 Analysis of green indicators

Jan de Rijk Logistics' goals for the future are to have a sustainable fleet of trucks and trains. As discussed before, road freight transportation is the largest contributor to the global warming. As can be seen in Table 3, transportation scores high on many factors comparing to other modes of transportation (Demir, Huang, Scholts, & Woensel, 2015). Demir et al. (2015) state that Air pollution and GHGs have been extensively studied as road transportation externalities for two main reasons. The first reason is that research on air pollution confirms that road transportation is by far the most polluting freight transportation mode for all pollutants. The second reason is that the most of the emissions can be predicted fairly accurate provided that the amount of energy consumption is known.

Table 3 Relevance of the negative externalities per transportation mode

Negative externalities	*Road transportation*	*Rail transportation*	*Maritime transportation*	*Air transportation*	*Pipeline transportation*
Air pollution	***	**	**	**	*
Greenhouse gases	***	**	**	**	*
Noise pollution	***	**	**	**	*
Water pollution	*	*	***	*	*
Congestion	***	*	*	*	*
Accidents	**	*	*	*	*
Land use	**	**	*	*	*

*: Low; **: Medium; ***: High

The European Union, the Dutch government and also Jan de Rijk Logistics have sharpened the rules around the emissions the trucks make. For all vehicle types, the following emissions are regulated: nitrogen oxides (NO_x), total hydro carbonation (THC), carbon monoxide (CO) and particle matter. The total transportation sector contributes for a significant amount to the global CO_2 emissions, primarily from the combustion of fuel for its transporting activities, it is the second most contribution domain after energy in Europe (European Union, 2014).

Like other companies in the transportation sector, Jan de Rijk Logistics also makes attempts towards sustainable mobility. A good example is the GET service project that is currently running at Jan de Rijk Logistics, to aforementioned target. Other activities are estimating fuel consumption and CO_2 emissions of the assets, as well as transforming, acquiring and operating more sustainable vehicles. Example for this is the new engines (Euro 6) which produce 80% less nitrogen oxides and particle matter compared to the Euro 5 engine (Scania, 2013). Since one of the targets of the present project is also to extend the VAPCI algorithm (Raoufi, 2013), considering minimization of fuel consumption and consequent CO_2 emissions, it was found interesting to investigate the environmental performance of the company using the two above aspects (fuel consumption and CO_2 emissions generated by the assets).

Jan de Rijk Logistics cooperates with Shell to collect and analyze all the data regarding the fuel consumption and CO_2 emissions of each week and for all the assets of the company. This is useful information and creates insights for Jan de Rijk Logistics, who want to achieve a transparent but also a greener company. The method used to calculate the fuel consumption at Jan de Rijk is that they use the weighted average for each asset. This is an approved method to use, because the fuel consumption of the engine is hard to estimate due to the fact that it depends on many factors. Factors like driving behavior, outside temperature, truck load, type of engine, average radiant of the road and road resistance (Demir, Bektas, & Laporte, 2014) (Demir, Bektas, & Laporte, 2011). Using the weighted averages of each week (which have already been estimated by the company and Shell) the average prices of fuel consumption and CO_2 emissions for each asset were estimated and, histograms were created to examine the frequency of these values, during the four months. Obviously the utilization of an asset during a week was taken into account, thus the weeks that have no data for specific assets were excluded.

Chapter 5 The development of the Decision support models

The methodology of the development process of the decision support model is descripted in this chapter. It starts with the planning priorities at Jan de Rijk Logistics. Then it continues with the description of the cost or revenue driven model. The gaps are identified in the literature and the gaps at Jan de Rijk Logistics. Multiple models were considered, the most important ones are descripted in the next section. The base model with all it extensions are given in the final part.

5.1 Planning and its priorities in Jan de Rijk Logistics

Each day thousands of shipments are released in JPLEXS and being planned by the planners in which over 70% of them are full truck load (or EXC) requests. The planning department thus has a 24/7 job on keeping all trucks moving and satisfying customers. Jan de Rijk logistics and other similar companies have a continuous operation on keeping the planning department able to do their job. Planners have to take their decisions quickly and accurately to make a quality planning and to reduce the amount of re-planning. If the planning is of high quality, this will ensure for Jan de Rijk Logistics the profitability of the business. The planner makes his decisions on the company's KPI's and customer service agreements. One of the KPI's at Jan de Rijk Logistics is to reduce the re-planning of the driver allocation.

However there are other performance indicators which play an important role in the (cost driven indicators) final profit of each shipment. The regulations at Jan de Rijk Logistics are that if a shipment is released in the system (Jplexs) the shipment cannot be rejected. If the order cannot be fulfilled with own assets (driver and pulled unit and pulling unit), the shipment will be sold to a charter company which will execute the order. Selling orders to charter companies can be profitable for Jan de Rijk Logistics, because if an order is not on-route for the planning, extra expenses can be saved by selling the order to the charter company. In the case of the driver assignment model, the decision of selling the order to a charter company has to be made already. This is because the decision model only uses the drivers employed at Jan de Rijk Logistics.

Planners typically deal with these situations relying on their experience and ad hoc decision aids, though the competitive nature of the freight industry calls for more systematic and efficient procedures that can take advantage of real time information on vehicle positions and their status (Raoufi, 2013). The main goal of the previous decision models on LTL and FTL ((Raoufi, 2013) and (Dimarelis, 2014)) was to give the planner a tool to support them in their decisions. The continuation of these models is to improve the driver planning. Therefore, when all the models are added to the planning, the planner has all the necessary information to consider all associated costs and future outcomes for the company. Jan de Rijk Logistics have to increase their revenue because of the small margins in the industry.

To increase their position in the market as a competitor in the transportation industry, they have to cut as many costs (fixed and variable) as possible. Currently the philosophy is to maximize turnover per asset in a specific time period (revenue driven strategy). The gain on their variable costs, specific to drivers, is to decrease the allocation of drivers among Europe and reduce the long (24 to 48 hours) rests that drivers must legally take after a workweek. These indicators are not yet KPI's of the planning. At the moment Jplexs is not designed on the driver's rests and breaks, more on allocation and other assets.

5.2 Cost or a revenue algorithm

Based on the discussion in the previous chapters, a planner has to make the planning decision based on either revenue or costs. For a planner who needs to make his decisions in short periods of time, it is hard to take the decision on revenue. Transportation rates on markets are highly dynamic and are exogenous to Jan de Rijk Logistics so it is impossible to decide on them for the driver planning. Market rates are not structured enough to be analyzed accurately (margins are not fixed due to market situations).

The operations cost at Jan de Rijk Logistics get revised periodically. However, they are more stable and reliable, stable and specific than the revenue rates. The revenue can change dramatically every other day, this is not with the operational costs. The costs for each kilometer (driver, fuel and emission) are transparent and known for the employees at Jan de Rijk Logistics. Therefore the conclusion is to use the costs as result of the decisions support model rather than the revenue rates.

At the moment, Jan de Rijk Logistics is a revenue driven company. Meaning that all planning KPI's (productivity factor for each asset, loading meters, and kilometers driven by truck) are revenue driven.

5.3 Identified gaps in the literature

As mentioned in the literature review, there are some gaps concerning driver allocation algorithms. Nearly all found literature starts with the Vehicle Routing Problem (VRP). For this model, the VRP is not needed, because all routes are known in advance. The first gap in the literature that is found is that mostly all models are an addition to the VRP problem and have an objective function that only adds the extra costs that resting and breaks give to the route. There are no calculations and discussions on the possibility of allocating (multiple) drivers to (multiple) routes.

The second gap that is found in the literature is the traveling of drivers towards the departure location. However, there are some companies that are already working on this item that it can be committed to the European Union to become law. The meaning of traveling is that a driver has to travel a certain amount of distance towards its truck to start the route. Most companies do not consider this travel time as work time and there are no regulations on this regarding rest and breaks. It is possible that a driver needs to travel more than 8 hours and can, regarding the law, start his route immediately because these are not needed to be recorded by the law.

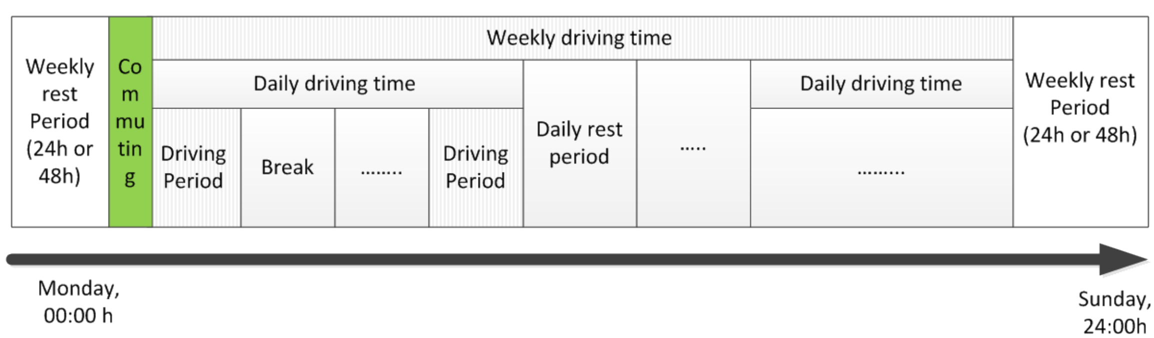

Figure 10 Schematic overview of a driver's week with Commuting

5.4 Identified gaps at Jan de Rijk Logistics

A fourth gap can be found at Jan de Rijk Logistics. This gap concerns the information available of the drivers. The proposed model can give a very detailed planning of the drivers which can be used to have a better planning. However, driver information is needed to make this qualitative high planning. Information like, what was the last type of break the driver had, how long it has been since a rest period, how many days has this driver has been working. If these information types become available to the planner, the suggestion of driver the model gives becomes of higher quality.

The model will need this information to perform correctly. When the model is implemented in Jplexs, a large number of calculations will be done automatically. Therefore, before the implementation phase the missing driver information has to be obtained.

5.5 Models considered

First multiple models were considered before the final model was composed. Hence, the models are all about driver scheduling and vehicle routing. The main reason multiple models were considered is due to the fact that none of models completely connected with the problem at Jan de Rijk Logistics. Mostly because there is no routing problem at Jan de Rijk Logistics, just an allocation problem of the right drivers to the existing routes. Therefore, most of the models have an objective function with a minimizing distance and minimizing cost function.

5.5.1 Model 1

The first model considered was the Wen, Krapper, Larsen, & Stidsen (2009). This paper was the first paper with relevant information for the problem at Jan de Rijk Logistics. In this paper, a Multi-Period Vehicle Routing and Crew Scheduling problem was considerd. The main advantages of this model were the capacity constraints, volume and traveltime constraints. The model has been adjusted to the known route situation, which leads to the following model of Wen, Krapper, Larsen, & Stidsen (2009):

Notation:

Set:

T The set of workdays in the planning horizon,

D_l The set of internal drivers,

T_l The set of workdays for driver l ∈ D,

K The set of vehicles,

N The set of customers,

N_0 The set of customers and depot N_0 = {0, n + 1} ∪ N,

K_i The set of preferable vehicles for customer i ∈ N,

T_i The set of days on which customer i ∈ N orders, Parameter:

Q_k The weight capacity of vehicle k ∈ K,

c_{ij} The travel time from node i ∈ N0 to node j ∈ N0,

$[a_i, b_i]$ The earliest and the latest visit time at node i ∈ N,

D_i^t The service time of node i ∈ N0 on day t ∈ Ti,

H The maximum working duration for each internal driver over the planning horizon,

F The maximum elapsed driving time without break,

G The duration of the break for drivers,

A The cost factor on the total travel time of internal drivers,

B The cost factor on the total working duration of the external drivers,

Variables:

v_{ik}^t The time at which vehicle k ∈ K starts service at node i ∈ N0 on day t ∈ T,

z_{ik}^t Binary variable indicating whether vehicle k∈K takes break after serving node i ∈N0 on day t ∈ T,

u_{ik}^t The elapsed driving time of vehicle k ∈ K at node i ∈ N0 after the previous break on day t ∈ T,

y_{ik}^t Binary variable indicating whether vehicle k ∈ K is assigned to driver l ∈ D on day t ∈ T,

r_l^t The total working duration of driver l ∈ D on day t ∈ T,

s_l^t The total travel distance of driver l ∈ D on day t ∈ T.

Objective function:

$$\min A \cdot \left(\sum_{l \in D_I} \sum_{t \in T_l} s_l^t \right) + B \cdot \sum_{l \in D_I} \sum_{t \in T_l} r_l^t$$

Elapsed driving time:

$$u_{jk}^t \geq u_{ik}^t + c_{ij} - M z_{ik}^t$$

$$u_{jk}^t \geq c_{ij}$$

Travel time calculation:

$$c_{ij} = \frac{d_{ij}}{m_{ij}}$$

Upper limit elapsed driving time:

$$u_{ik}^t + \sum_{j \in N_o} c_{ij} - F \le M z_{ik}^t$$

Determination of the service start time at each customer

$$v_{jk}^t \ge v_{ik}^t + d_i^t + c_{ij} + G \cdot z_{ik}^t$$

Time window constraint:

$$b_i \ge v_{ik}^t \ge a_i$$

Calculation of the total driving time of each internal driver

$$s_l^t \ge \sum_{i \in N_0} \sum_{j \in N_0} c_{ij}$$

Calculation of the working durations

$$r_l^t \ge v_{n+1,k}^t - g_l^t$$

Definition of the binary variables

$$z_{ik}^t \in \{0,1\}$$

$$v_{ik}^t, u_{ik}^t, r_l^t, s_l^t \ge 0.$$

As can be seen from the constraints this model already holds the time window constraint, working hours. However, good, detailed constraints are missing about the break determination. For the composed model, the constraints for time windows, elapsed driving time and the determination of the service start time at each customer are used.

5.5.2 Model 2

According to Goel & Gruhn (2006), the vehicle routing with drivers' working hours is an extension of the vehicle routing problem with time windows (VRPTW). The consideration of drivers' working hours in vehicle routing and scheduling is of extraordinary importance to increase safety and punctuality in road freight transport (Goel & Gruhn, 2006). Goel & Gruhn (2006) describes the regulations stated by the European Union on working and driving hours. They also propose a Large

Neighborhood Search algorithm capable of handling drivers' working hours. The idea of using a recursive function for the final model was considered here, because this would make the model usable for Jan de Rijk Logistics. A down side of this paper is that they do not use all the constraints set by the European Commission. Therefore, it was not used totally for the composition of the final model.

Goel proposed in a later paper (Goel A. , 2009) the use of all the regulations in a recursive function. He starts with a naïve Method for Scheduling Driving Periods, Breaks, and Rest periods. With this naive method he enlarges it with all the regulations to a full recursive function. The recursive function is used in the final model. Recursive functions are easily used with the use of VBA in Excel. However, these functions are not used in detail for the final model.

5.5.3 Model 3

The last paper that was used to build the model was the paper of Dabia, Woensel, Dellaert, & Steadieseifi (2014). In this paper all the European regulations are mentioned, with mathematical formulation. As is shown in the previous papers, this paper considers an unknown route, with a number of vehicles and drivers, and vehicle capacity. The constraint which regards the routes are eliminated and not shown below.

This model proposed by Dabia, Woensel, Dellaert, & Steadieseifi (2014) is an Integer linear Programming (ILP) form of the Vehicle Routing Problem with Time Windows (TSPTW) and extended with the Driving and Working Hour Regulations (DWR). The main advantage of this paper is that the rules proposed are very strict and based on the European Regulations. However, if it is needed, the rules are flexible to be modified for other regulations as well.

There are some differences with the previous papers that were discussed. The objective function is to minimize the total travel times. Where in previous discussed papers the cost had to be minimized. For the final model this objective function is not going to be used. Because of the known routes, the costs are going to be minimized. The calculation of the accumulated driving time will be used in the final model, however, in a other form that shown here. The constraints that determine the points where a vehicle crosses each of the 4.5 hour intervals are used because of the regulations on the drivers. To make sure that the drivers do not drive more that the allowed weekly driving and working time limits the formulas where used as well.

i,j Node indexes

k Vehicle index

g Index of the day of the week

n Number of customers

K Set of drivers

tt_{ij} Driving time between nodes i and j

ts_i Service time at node i

$[e_i, l_i]$ Time window of node i

th Time interval (threshold) for limiting driving hours in a day, equal to 4.5 hours

tb Minimum break time, equal to 0.75 hours

tr Minimum rest time limit, equal to 11 hours

td Daily driving time limit, equal to 9 hours

tw Daily working time limit, equal to 13 hours

p_{ik}^{g} Binary variable, equal to 1 if driver k has exceeded driving hour interval of th hours at node i on day g, and equal to 0 if not

r_{ik}^{g} Binary variable equal to 1, if driver k has exceeded maximum daily driving time of td hours at node i on day g, equal to 0 if not

d_{ik} Accumulated driving time up to node i by driver k

w_{ik} Arrival time at node i by driver k

r Route number

r_{ij} In Route r, there are nodes i and j

Objective function

$$\sum_{(i,j)\in R} \sum_{r\in R} t_{ij} x_{ijk}$$

Accumulated driving times

$$d_{ik} + t_{ijk} - d_{jk} \le M(1 - x_{ijk})$$

By considering the accumulated driving time, the logical constraint which determines the points where the vehicle crosses the 4.5 hour driving intervals during the week:

$$th\sum_{g=1}^{6} p_{jk}^{g} + th\sum_{g=1}^{5} r_{jk}^{g} \leq d_{ik}$$

$$d_{ik} - \left(th\sum_{g=1}^{6} p_{jk}^{g} + th\sum_{g=1}^{5} r_{jk}^{g} \right) \leq th$$

Weekly driving bounds:

$$0 \leq d_{n+1,k} \leq 6 \times td \sum x_{ijk}$$

This constraint ensures that the driver does not drives more than allowed

Working hour bounds:

$$0 \leq w_{n+1,k} \leq 6 \times tw \sum x_{ijk}$$

This constraint ensures that the driver does not work more than allowed.

Break type

$$p_{ik}^{g} \geq r_{ik}^{g}$$

$$r_{ik}^{g} \geq p_{ik}^{g+1}$$

These final two constraints make sure that the model gives the driver the right break type.

5.6 Base model

The following variables were used for the model:

i, j	Node indexes
k	Vehicle index
g	Index of the day of the week
n	Number of customers
K	Set of drivers
tt_{ij}	Driving time between nodes *i* and *j*
ts_i	Service time at node *i*
$[e_i, l_i]$	Time window of node *i*
th	Time interval (threshold) for limiting driving hours in a day, equal to 4.5 hours
tb	Minimum break time, equal to 0.75 hours
tr	Minimum rest time limit, equal to 11 hours
td	Daily driving time limit, equal to 9 hours
tw	Daily working time limit, equal to 13 hours
p_{ik}^{g}	Binary variable, equal to 1 if driver *k* has exceeded driving hour interval of *th* hours at node *i* on day *g,* and equal to 0 if not
r_{ik}^{g}	Binary variable equal to 1, if driver k has exceeded maximum daily driving time of *td* hours at node *i* on day g, equal to 0 if not
d_{ik}	Accumulated driving time up to node *i* by driver *k*
w_{ik}	Arrival time at node *i* by driver *k*
r	Route number
r_{ij}	In Route *r*, there are nodes i and j

The start of the model was with just one driver and one route. With this model, the requirements of Jan de Rijk Logistics were met. In appendix A, a visualization of the base model is shown. Here can be seen that the model already applies all the European regulations. It also holds the basic planning tools, like arrival and departure time and date, service time. The use of the mathematical model in Excel with the use of VBA will be explained in appendix A.

However, from all previous papers, none of the objective functions were applicable in this model. As mentioned before, all of these objective functions were cost or time based for a not known route. This is not the case for this model, therefore, an objective function has to be formed which will result in the best results for Jan de Rijk Logistics. As mentioned before, the model will be cost driven. The reduction of the distance is also not of use here, because of the known route. Therefore, the objective function will have a driving cost factor.

This is done because of the possibility that individual drivers have different wages and daily pays (based on age and nationality). Drivers are paid according to the payment regulations in their home country. It is well known that Eastern Europe employees are less expensive than the employees from Western Europe. This results in a large amount of drivers working at Jan de Rijk Logistics from Eastern Europe.

The second part of the objective function is the arrival time for each individual driver. In the first few models this is not used because it only applies one driver and one route. However, in later versions of the model there will be the possibility to have multiple drivers. These drivers could have different statuses. This means that a driver could have worked already that week and has already driven time of his maximum allowed driving hours per week. This could result that a driver who is cheaper, but has already had driven sometime, costs more because of rests and breaks regulations. The final objective function is:

$$\sum_{k \in K} \sum_{n \in N} w_{n+1}^{k} \cdot c^{k} \qquad [1]$$

In this function the w_{n+1}^{k} is the minimization for the arrival time at the customers and at the depot for individual drivers. Hence, the c^{k} are the costs for the individual drivers. These costs contain hourly costs and daily costs. A driver gets a daily pay, even when they are at rest. They also get an hourly payment for working and driving hours.

With the objective function set, the constraints can be composed to get the model into a Linear Program form. In the first few models the constraints are for the planning, like calculating driving times, accumulated driving times, weekly driving and working limits. In this model the following mathematical formulas and constraints where used, composed were the previous papers:

Travel time calculation:

$$c_{ij} = \frac{d_{ij}}{m_{ij}} \qquad [2]$$

Accumulated driving times

$$d_{ik} + t_{ijk} - d_{jk} \leq M\left(1 - x_{ijk}\right) \quad [3]$$

$$d_{ik} + t_{ijk} \leq d_{jk} \qquad [4]$$

Constraint [3] and [4] make sure that each node is visited. However, constraint [3] is not needed for the model because the routes are known. It is mentioned here because the variables have to be defined.

Weekly driving bounds:

$$0 \leq d_{n+1,k} \leq 6 \times td \sum x_{ijk} \quad [5]$$

Working hour bounds:

$$0 \leq w_{n+1,k} \leq 6 \times tw \sum x_{ijk} \quad [6]$$

Constraint [5] makes sure that de driver does not exceed the daily driving time of 9 hours and constraint [6] makes sure that the driver does not exceed the daily working time.

Appendix A shows was the first model looked like when these previous constraints was put in Excel VBA. Hence, the model shows an early start of a planning model. However, in this model an early start was made on the break determination. At this moment it was an very simple calculation of when the driver passed the 4,5 hours barrier and then only the break time (45 minutes or 11 hours) was added to the total break time.

For this base model, a number of extensions was made. The first extension which will be explained next is the break determination. To make sure that the planning is as realistic as possible, and that a planner has more information on when the breaks are, and what the status of the driver is, more information is needed from the drivers to make a quantitative high planning. A second extension is the time window extension. This extension is made to make the planning of the routes more realistic. The next extension is that the model can plan for an infinite amount of weeks. With all the previous extensions, the model can be extended to a multiple drivers, multiple routes model. To make the model easy to understand for a planner, a driver selection is added to the summary of all the routes. The final extension is to calculate the emissions of each route. Also one considered extension is discussed because of a later use of Jan de Rijk Logistics of the speed optimization.

5.6.1 Extension 1: Break determination

The first extension to the model is the break determination. This extension has four constraints added to the base model. Constraint [7] and [8] are there to make sure that a driver does not exceed the 4,5 hours driving time. This forces the driver to take the break according to the constraint [9] and [10]. These make sure that the model takes the right type of break. If a driver starts his work fresh for that day, after the first 4,5 hour he has to take the 45 minutes break (p_{ik}^{g}) and after the second 4,5 driving a 11 hour rest period (r_{ik}^{g}).

$$th \cdot \sum_{g=1}^{6} p_{jk}^{g} + th \cdot \sum_{g=1}^{5} r_{jk}^{g} \leq d_{ik} \qquad [7]$$

$$d_{ik} - \left(th \sum_{g=1}^{6} p_{jk}^{g} + th \sum_{g=1}^{5} r_{jk}^{g} \right) \leq th \quad [8]$$

$$p_{ik}^{g} \geq r_{ik}^{g} \qquad [9]$$

$$r_{ik}^{g} \geq p_{ik}^{g+1} \quad [10]$$

In the excel model some extensions were made to make sure that a driver drove his 4,5 hours. The variable in the model called “remaining time” is the time a driver has left after he visited a customer. For example, if a driver visits customer 1, which is a 3,5 hours’ drive, he has 1 hour left until he has to take a break. With this addition, this model is now capable of handling short and long-haul route planning simultaneously.

5.6.2 Extension 2: Time windows

The second extension to this model is the time window extension. With this extension the model becomes more realistic because most customers have a hard time window which has to be met. The time window constraint [11] is a basic constraint found in most VRPTW problems:

$$b_i \geq v_{ik}^{t} \geq a_i \quad [11]$$

For the model this was more difficult to realize. As can be seen in the appendix B the time window can be different on multiple days.

5.6.3 Extension 3: Infinite weeks

The model can now handle time windows and breaks. However, this is only for two weeks. This is due to the fact the model cannot reset after the large break. As shown in the literature, when a driver starts fresh (fresh is after a 48h break), the next large rest period a driver has to take after 6 days of work is a 24 h break. In the second week, after this 24 hour break, the next rest period is the 48 break. So after two weeks a driver is fresh again.

With the use of VBA this was modelled in Excel. However, VBA has some shortcomings on this. For this to model, VBA has to "remember" some results. VBA is not able to do this, so everything has to be written in the excel sheet. This makes the excel sheet less easy to work with for a planner.

First, the model has to recognize which type of break the drive had last, a small break of 45 minutes or a large break of 11 hours. With this the model knows how much the driver had worked for that week. The next thing the model does, is getting the drivers' information on his previous work of that week. In the model this is called the cumulative R, because it uses the information of the large breaks to know when a day is over. Finally the model calculates the result of a driver. When this is done, the model adds the time that is needed for the breaks and rests to the arrival time. With this calculation the model can run for infinite weeks because the model recognizes the types of rests.

5.6.4 Extension 4: Multiple drivers, multiple routes

With all the previous extensions, the decision can be improved significantly if it can handle multiple drivers with multiple routes. First, the model has to be adjusted to handle multiple routes. A form was made that the model was able to duplicate the route planning forms (to work with this form, instructions can be found in Appendix A. This form also allows deleting routes and keeping the sheets but deleting the content. This form is added to a new sheet, the summary sheet which has been added to give a clear view of all the routes and results of the calculations.

The second part that has to be added is an advanced driver information sheet. At the moment at Jan de Rijk Logistics only limited information is available in Jplexs about the drivers. To make full use of this decision model, the availability of driver information has to be improved. The sheet allows entering the "Cumulative R", which is explained above. With this, the model knows when the driver has to take his next break. The remaining time is also needed for each driver. In combination with the "Cumulative R" the model can make the planning accurate, so the supportive decision to the planner is very reliable. What is needed next from the drivers is their costs. The model is based on minimization of the arrival time with the associated cost for each driver. The hourly costs and the daily pay are needed for this model to give the planner a supportive decision on which driver he has to choose. To give the planner an easier overview, the summary sheet was introduced. The management of the routes button has already been explained. The button “give me the best driver” will start the calculation of the multiple driver multiple route. In the results it will give for each driver his or hers trip time, total gate waiting time, arrival time back at the depot and approximate costs. The list is sorted on trip time (from low to high) and costs (from low to high). For each route it will give the total trip distance, and the approximate emissions. The model roughly works as follows, the drivers information about his previous activities are filled in each route, the model recalculates with the new information and gives the results in the summary page. The costs are calculated afterwards, when all the driving information is known. In the following extension it is going to be easier for the planner, the drivers will be shown which will be needed for each route.

5.6.5 Extension 5: Driver selection

The summary shows an organized overview of the routes and drivers. However, to make it easier for the planner, the model will give suggestions on the driver selection. It is possible to select the driver on what is most important. However, the summary now shows the shortest and cheapest first. Hence like the objective function says. To make sure the model does not choose a drive multiple times, this selection objective function [12] is used. This is needed because it is not possible to drive two routes at the same time.

$$Min \sum_{r} P_{rk} \cdot x_{rk} \quad \forall (r,k) \quad [12]$$

Subjected to

$$\sum_{r} x_{rk} = 1 \; \forall \, r \qquad [13]$$

$$\sum_{r} x_{rk} \leq 1 \; \forall \, r \qquad [14]$$

The objective function is bounded by the constraints [13] and [14].The binary constraint [13] makes sure that each driver can be picked once, and constraint [14] is the binary constraint that holds that a driver does not have to be picked.

5.6.6 Extension 6: Emissions

With the use of NTM emission calculator the emissions of each route are calculated. This was done to compare the calculations with the emission calculation at Jan de Rijk Logistics. This result was added to the summary, to be able to compare different routes with each other.

$$E(lf, D_1, D_2, D_3) = \sum_{i=1}^{3} (f(lf)_i \cdot D_i \cdot E_{co_2e}) \ [15]$$

5.6.7 Extension considered 1: Speed optimization

As another extension, speed optimization was considered to be part of the model. After some calculations and thought this was rejected. When routes are known in advance and therefore also the breaks for each driver, the results of speed optimization will always be to go as fast as that is allowed. However, the part where speed optimization would work is on the time windows. When a driver is just short of meeting the last time window, driving faster will result in meeting the customer. However, for the model an already high average speed was chosen because of the type of trips this is model will be used, for mostly on long-haul trips (mostly high ways). The formulas for the speed optimization formula that was going to be used in the model is shown below (Demir, Bektas, & Laporte, 2012).

Speed optimization

$$min \sum_{i=0}^{n} f_c F_i(v_i) + f_d e_{n+1} \ [16]$$

Subjected to:

$$e_{i+1} = e_i + w_i + t_i + \frac{d_i}{v_i} \ i = 0, \dots, n \ [17]$$

$$a_i \leq e_i + w_i \leq b_i \ i = 1, \dots, n \qquad [18]$$

$$v_i^l \leq v_i \leq v_i^u \ i = 0, \dots, n \qquad [19]$$

$$w_i, e_i, v_i \geq 0 \quad [20]$$

$$w_0 = e_0 = t_0 = 0 \ [21]$$

5.7 Chapter discussion

In this final paragraph of the development of the decision support model chapter, an overview will be given of the mathematical model (base model, extensions and considered extensions) as how it was implemented in the Excel VBA model. A stepwise method was used for both, describing the extensions that were implemented. The contribution of the two models to the general research is summarized as follows:

The mathematical model starts with the base model. This base model provides a basic planning tool. However, it needs a lot of extensions to be helpful for the driver planning problems at Jan de Rijk Logistics. With this base model, a good foundation is laid where the final model has to be improved. With this base model there is also a first start on the Excel programmed model with Excel VBA as programming tool.

When the base model was finished, the extensions were composted from the literature. With these extensions, the decision support model will have a more realistic result and to be more useful for the planners. The extensions are break determination, time windows, infinite number of weeks, multiple drivers and multiple routes, driver selection and emissions. The extensions are then implemented in the Excel VBA model to give the tool more body.

An extra extension was considered for the model, which was the speed optimization. This can be used in later research at Jan de Rijk Logistics. However, for this research it is not feasible to implement this extension because it will not result in reduction of the costs.

The final model now has a good base model with multiple extensions. This model is implemented in Excel to give a decision support tool to Jan de Rijk Logistics' planners. The model has been explained in detail in the beginning of this chapter. It is a good foundation to continue with the case study and draw conclusions based on the model.

As an addition to the research, the model has been implemented in Excel with the use of Visual Basic for Applications. This makes the model comprehensible to planners and other users.

With all these constraints, a lot of the European regulations are met. All the regulations on the driving and working hours are used to have a reliable model. Constraints A1 to A5, of the previous chapter therefore used in the model. The break determination constraints are derive from A1, A2 and B1, B2.

Chapter 6 Analysis

This paragraph regards the different case studies that are going to be conducted at Jan de Rijk Logistics to test the model proposed in the methodology. As proposed in the methodology, the model was built in different stages (single driver, single route, multiple drivers, and multiple routes). The case studies will follow a similar testing sequence. The cases are a realistic representation of the daily operations of Jan de Rijk Logistics. Two types of results are expected of the case studies. The first result is the decision making of the planner in comparison what the model gives as the best choice of driver. The second result is the time a planner takes to make a decision for multiple drivers and/or multiple routes. Both are an improved to quality of the planning and will reduce extra costs on re-planning.

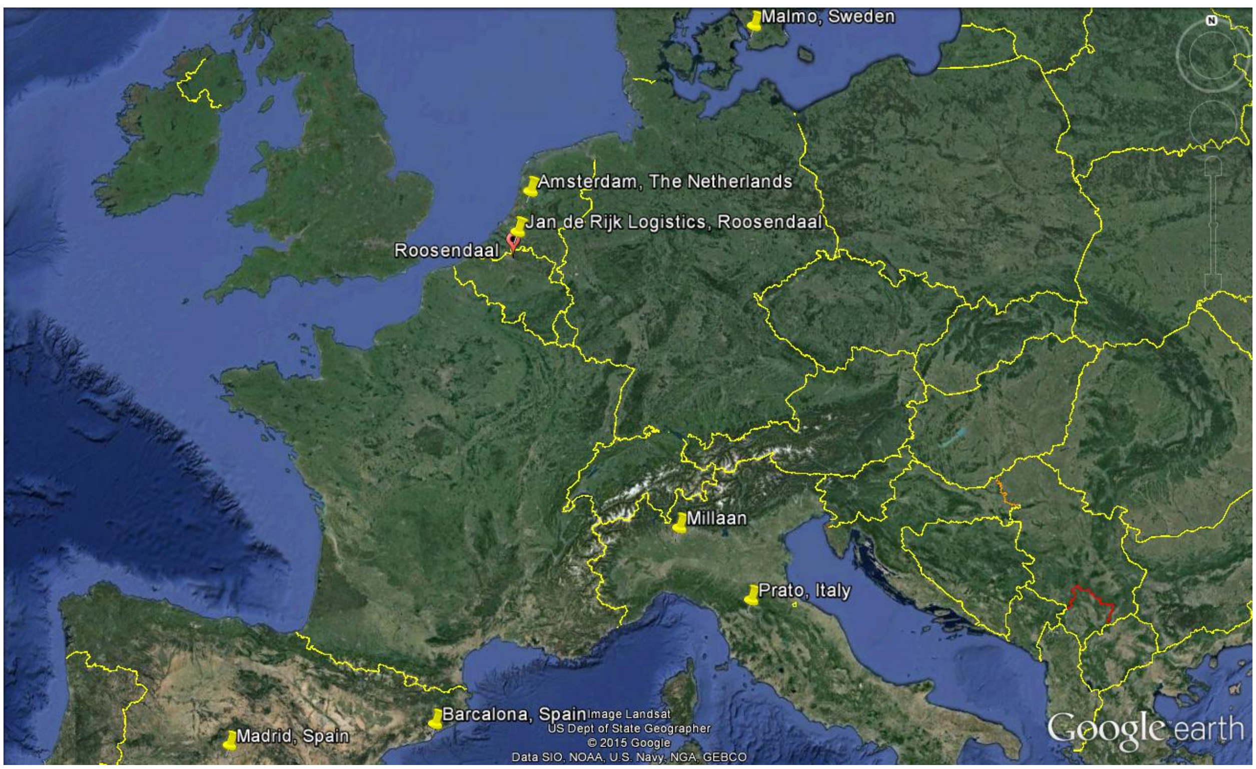

Figure 11 Map of places considered in the case study

The last test is to test the speed of the model with large amounts of data. Here a large number of drivers, with all different history, and a lot of different routes will be run in the model to show the speed and accuracy of the model with planning types not realistic for Jan de Rijk. This test will show that the model will run and always gives a solution to the planner. However, here there is one restriction to the excel model that can be improved by implementing the model into Jplexs. The model makes use of google to calculate the distances between locations. The model can only run 100 elements per query, 100 elements per 10 seconds and only 2500 elements per 24 hour period (Analystcave, 2014).

During the case study, some new insights were found. The model presented in the previous chapters will be used to increase the information flow of the driver to the planner and so increase of the quality of the work done by the planners. What needs to be change at Jan de Rijk Logistics is the information known of the driver. At the moment the only information available for planners is the small break (24 hours) and large break (48 hours).

From all the interviews with the employees at the planning department and comparison with the current way of driver planning, the model resulted in a good addition to the planning decisions. First a small summary will be given with the positive and negative parts of the model. The special part that was needed for Jan de Rijk Logistics with the freshness will be explained i.e., the feasibility of the model, the actual time of the driver, the complexity and a speed test were conducted for the case study.

The first actual result of this model is that the information flow of the drivers will increase. This will have a positive influence on the planning, because the planning can now be made with the accuracy of half a day. This can be improved by having it accurate to the minute. However, this will add a large amount of time which has a negative effect on the planning. Another positive part the models shows is the ease with which the regulations can be changed. When these are changed overtime, for example, European Regulations. However, this is easily changed in the model. This model is also able to conduct planning activities for short-haul transportation and large routes. The main advantage of this model is the multiple drivers and multiple routes planning. This is makes it possible for a planner to get supporting decision from the model for the multiple drivers to multiple routes.

There are also some downsides on this model, which were discussed with the planners. The first is that this model gives a good inside into on how planning can work and how it is taught at the TU/e. However, at Jan de Rijk Logistics the planning works different. This is a downside on the comparison of the model with the planning tools at Jan de Rijk Logistics.

What this model proves, is that the information flow of the drivers is lacking at the moment at Jan de Rijk Logistics. The model has a need for information to work and to give the planner a good suggestion on the drivers. The information lacking at Jan de Rijk Logistics is the small breaks positioning.

If the information is available, the planning department will have a better insight into the status of the driver. This will result in a better estimation of the arrival time, which gives a more accurate planning tool.

6.1 Freshness and lack of freshness

One part of the model that needed to be included was the ability to add the freshness of a driver to the calculation. At the moment at Jan de Rijk Logistics it is the rule is, that when a driver , who has made a long trip, arrives at Jan de Rijk Logistics with a van that he goes to the "Jan de Rijk Hotel" (a house owned by the company) and rests here. This driver had a trip for several hours, but these are not working hours (he is not driving a truck). This is not mentioned in the system. However, at the moment there is no regulation on this part. It is possible that when a driver arrived too late, or he is needed immediately, the driver can be put to work without the system knowing he has already driven and/or has been awake for a large amount of hours. This is included in the model at the driver's page. Here the planner can add how many days the driver had "worked" already before he starts his shift. This day will be recognized by the model as a working day, so the drive towards Jan de Rijk Logistics is included in the system. It is also possible not to add a full day but to add a half day. The planner has to enter a time in minutes to the "remaining time" where the model will recognize this as the time towards his next break.

6.2 Feasibility

The results of the model does not increase a better time estimation of the drivers, because all the routes have the same group of drivers. The only part where a planner will increase his time and quality if his has to make a choice between two or more drivers. However, this is mostly not the case because the planner who is involved with the availability of the drivers makes sure that the amount of drivers is conform the need of the planner who is involved to the long-haul shipments. Here the model will have little to small influence on the final outcome.

6.3 Complexity

The complexity can increase in two ways. The complexity of the routes can increase, in the amount of routes and in the length of a route. If the amount of routes increases, the planner also has to be able to choose from more drivers. This is the second complexity level. The length of the route will create an increase in the complexity because the planner has to watch more factors. One factor is that the planner has to watch the break times of the driver. If the driver has already worked 6 days in a row and he needs to take his 24 or 48 hour break soon, this will extend his arrival time at the customer. This will decrease the quality of the planning.

So when the complexity increases, the model will have multiple advantages over regular planning as long as all the necessary information is provided correctly. If this is not, so the model will not give the correct suggestion, as mentioned in the methodology.

6.4 Model capability

To prove the models capability, the code has to be examined in detail. The code uses a lot of recursive functions. Normally this reduces the speed of the model. However, when coding this model, the recursive functions were kept very small, so this will not decrease the speed of the model.

As the capability of making routes, the model has a drop-down menu for each customer that needs to be added for the route. This keeps the model fast regarding entering each customer for each route. It is possible to enter all the customers in one sheet. The planners has only to choose from a drop-down menu that to enter a route. When a planner has to delete a customer in a route, the planners simply has to press delete and add another customer. It is also possibly to enter or delete a customer in the middle of route. The model will ask if you want to delete that entire row or add another customer. When a customer is deleted from a route, the model will then move all the customers below this customer one line upwards.

The maximum number of customers per route is now set on 20 customers. The model is made for the long-haul problems. This assumption was made in consultation with the planning department. The average number of customers for an individual route is four.

6.4.1 Speed test

To prove the capability of the model, a speed-test was conducted to prove this. An unrealistic situation was created to prove the reliability and speed of the model. This was needed to have it to prove that the model could conduct large calculations within a certain time. The test is unrealistic because it will contain a large number of routes and a large number of drivers.

50 routes and 50 drivers will be used to test the model. This will never occur at Jan de Rijk Logistics because this is not in line with their daily long-haul planning.

It takes the model 27.60 seconds to calculate for all the drivers the time and costs for each individual route and give a summary of each driver to show the allocation of the drivers to each route.

6.5 Chapter discussion

Within this case study, the results are mentioned and explained of the usages of the model. These were done in collaboration with the planners. These results will be used to conclude this chapter and will have influence on the implementation of the model into the planning tool Jplexs.

From all previous parts Table 4 is the result of the analysis part. This table shows the results when the model will be implemented at Jan de Rijk Logistics. The driver planning is obviously working at the moment. However, when the model will be implement this will enhance the planning significantly. At the moment the only traveling time considerations that are regarded are the large breaks (24 and 48 hours). The model will improve the awareness of the time drivers are taking their brakes and rests. This will improve the planning by becoming more detailed. Commuting is now only considered by the driver planners who make sure that there is enough driver capacity. The model will have this embedded so that the model will give its suggestions with regard to the planning. Finally the model will have an increased information flow of the status of the drivers. This will have a positive effect on the drivers planning.

Table 4 Analysis results

	Without model	With Decision Support model
Driver Planning	+	++
Traveling Time Considerations	-	+++
Commuting	--	+++
Information flow	+	+++

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Chapter 7. Conclusions and recommendations

After analyzing the results of the case study with the planners, the time has come to finalize this report by mentioning conclusions, limitations, recommendations, discussions, recommendations and future research fields that resulted from and were associated with this research. In the first section, the conclusions are drawn and the research question, which was mentioned in the introduction, will be answered. The second section contains the limitations of the project and the model and after that the recommendation will be given. The final part of this chapter contains suggestions for future research.

7.1 Results

The target of this chapter was to focus solely on the problems with the driver planning regarding the European regulations. The start of the project was with a research study, which was pointed at defining the company, gathering information, defining the problem and the composing of the research question. As a result of these the conclusion was that there is a lack of information flow through the planning departments of Jan de Rijk Logistics regarding the breaking and resting time. Here the planning tool can get an improvement. Although, Jan de Rijks Logistics planning department already works with the large breaking regulations (24 and 48 hours), an improvement can be made in the small breaking regulations (45 minutes and 11 hours). Another conclusion that was drawn from the research project was that emissions are becoming more important for logistics companies. Multiple emission calculators were examined, the NTM calculator is the one implemented in the final model. Resulting from this is the main research question that goes as follows: *How does the (re-)planning of the allocation of drivers on long-haul transportation routes using real time data affect Jan de Rijks Logistics performance through their transportation network?*

From this research project, a model was composed from existing literature. The first conclusion that was drawn while composing this model, was that all the literature was about one non-existing route with one driver. The case at Jan de Rijk Logistics is multiple existing routes with multiple drivers compared with each other. The model that has been developed has the purpose of providing the planning with a decision based on time and trip costs. Therefore the objective function will be minimizing the costs for each driver for each different route.

The model performance has been explained and analyzed in the methodology and the case study parts. The results were that the model gives a good impression on how the model works and how it will be used at Jan de Rijk Logistics. However, the model is no match to the current planning tool Jplexs, which did not give comparing results.

The results of the model will have an influence on the planning decisions at Jan de Rijk Logistics. In the chapter of how the planning works at Jan de Rijk Logistics, a current situation was given. This will change if the model will be implemented. Here the final table is given of the planning decisions. Because this model is a supportive model, the driver allocation and traveling time considerations are done by the planner and the planning tool Jplexs.

Table 5 Planning decisions with the model implemented

Planning decisions	Planner	Jplexs
Matching driver(s) with pulled and pulling units		x
Matching pulled and pulling unit		x
Driver allocation	x	x
Traveling time considerations	x	x
Freight and pulled unit matching assignment	x	
Empty running decisions	x	(x)
Charter hiring decisions	x	(x)
Distribution of pulled units within the network	x	

7.2 Limitations

The project also has some limitations regarding the extensiveness of the model. For a good working model, the model needs a lot of information regarding the drivers. This will take a lot of time but will result in a qualitative good model. The model is also developed for long-haul transportation. However it is possible to use it on short-haul but this has not been tested in this project.

One large limitation is that the model needs a large amount of information, from different departments to work properly. This information is not easily extracted from all the different operating systems at Jan de Rijk Logistics. Therefore, someone has to extract all the information frequently to have the model up-to-date for the planning department.

7.3 Recommendation

Based on different analysis and discussions about the model and its variables and parameters that planners need to decide about, also examining the way that planners interact on a daily basis in order to plan shipments, the following recommendations can be made:

The different departments will have to improve their information feed about the drivers. If this is done, the planning will significantly be improved regarding breaking and resting times. One of the programs available at Jan de Rijk Logistics, Trimble, which holds all the information for the model. However, it was not possible to easily extract this information. Therefore, this model was created which shows when and which types of breaks a driver takes.

With this model, the awareness of when the drivers rest becomes higher. This will have a positive influence on the drivers planning. It will improve the planning on when drivers rest . The

The planners should have visibility on the costs of choosing one driver over another. Age, nationality and gender have different influences on the costs.

Transformation of the way executed shipments are stored in TMS is needed since, historic data can offer valuable information regarding the performance of the company and the way shipments were handled as well as, more precise decisions about the availability of trailers in each location (future visibility).

7.4 Future research

This last paragraph provides suggestions for future research which can result in improvement regarding the planning of drivers at Jan de Rijk Logistics. For implementation at Jan de Rijk Logistics, a further research will have to be conducted on the information gathering topic. At this moment all the regulations and planning tools only work if the information flow is correct and complete. At the moment all the different departments only use their own information.

Another part of the future research is to implement this model into Jplexs that it is a helpful tool for the planners. Parts of the model (planning part) are already in Jplexs, but not the break determination of the drivers.

This is a very static model. However, when during the planning phase updates enter this model regarding traffic jams, congestions or other sorts of delay, this will improve the model to be more realistic.

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Appendix A Guidelines of the proposed model

To have a good use of the model, a manual is made for Jan de Rijk Logistics. This manual contains different parts. The first part is the explanation of all the different sheets in Excel that are needed to run the model. Here are some parts that need to be filled by a planner, or automatically with Jplexs.

- Excel sheets explained in detail
    - Regulations

The first sheet in the Excel model is the regulations sheet. Here all different regulations are mentioned that are used in the model. Each regulation can be changed manually when these change over time. These regulations are used in each of the models constraints and the planning tool.

The average speed is set on 80 km/h. This is a high average for trucks. However, the planning tool is made for long haul transportation, which is mostly on highways. The average speed here is higher than on short haul transportation routes.

The maximum driving and working time are also set as variables so that when these European Regulation changes in the years coming, these are easily changed.

Than the variable “to late allowing”. This variable is made with two intensions. The first one is to make all the time windows soft. Here it means that a driver is 60 minutes after the closing time, still allowed to enter the customer. When this is set to 0, it means that it is a hard time window. The second intension is that there was extension with speed optimization. This was not entered in the model, because it would not have influence on the objective function. That is why this variable was also used to be able to stretch the time window. When a driver was able to drive faster than the average, with the speed optimization, this will decreased the costs.

	A	B	C
1	Average Speed	80	km/h
2	Max Driving time	9	h
3	Max Working time	13	h
4	To late allowens	60	min
5	CO2 emisions	0,867036	gr/km
6			
7			

- Locations

The second sheet in the Excel model is the location sheet. In this sheet, all the locations that are visited by Jan de Rijk Logistics can be added. Here it is possible to have multiple locations in the same city. In the first column the name of the location has to be filled. This can be the name of the city, but when multiple locations in one city, it is possible to have the name of the customer here. The second column is the address of the customer. This address has to be in English and does not have to be specific, which means a city and country are sufficient. However, to have a qualitative planning tool, the street name, ZIP code, city and country are the best to be filled in. The model uses a plug-in from Google Maps and calculates the routes in less than seconds. The third column is the service time column. Here the service time at each customer can be added. It is possible to have different values here. The last two columns are the time windows columns. The first one is the opening time and the second is the closing time. The notation will now be explained in detail. As can be seen in, the notation has starts (*), stripes (-), numbers (0900) and backslashes (/). The backslashes are the separation between days. So the first position, before the first backslash, is Monday. After the first backslash is Tuesday. This goes on until the last backslash, after this one it is Sunday. So now we have the separation of the days, for early due dates and late due dates. The stars (*) mean that a customer is open the whole day, so from 00:00 – 23:59 for that day. The stripes (-) mean that the customer is closed for that day. It is also possible to have a customer that is only open during office hours and the working week. So then in the first column of the time window the opening time has be filled in, and then closing time in the second column. See Luxemburg for example which is only open from 0900 till 1200 and closed on Saturday and Sunday.

	A	B	C	D	E
1	Amsterdam	Hellenburg 35, Amsterdam, The Netherlands	3	*/*/*/*/*/-/-	*/*/*/*/*/-/-
2	Barcelona	Barcelona, Spain	2	*/*/*/*/*/*/*	*/*/*/*/*/*/*
3	Bavel	Seminarieweg 12, Bavel, The Netherlands	2	*/*/*/*/*/*/*	*/*/*/*/*/*/*
4	Breda	Nieuwe Inslag 97, Breda, The Netherlands	3	*/*/*/*/*/*/*	*/*/*/*/*/*/*
5	Eindhoven	De Lismortel, Eindhoven, The Netherlands	0	*/*/*/*/*/*/*	*/*/*/*/*/*/*
6	Frankfurt	Frankfurt am Main, Duitsland	1	*/*/*/*/*/*/*	*/*/*/*/*/*/*
7	London	Longford,Hounslow, Greater London TW6,Verenigd Koninkrijk	1	*/*/*/*/*/*/*	*/*/*/*/*/*/*
8	Luxemburg	Luxembourg, Luxembourg	3	0900/0900/0900/0900/0900/-/-	1200/1200/1200/1200/1200/-/-
9	Madrid	Madrid, Spain	2	*/*/*/*/*/*/*	*/*/*/*/*/*/*
10	Malmo	Malmo, Sweden	2	*/*/*/*/*/*/*	*/*/*/*/*/*/*
11	Milaan	Milaan, Italy	2	*/*/*/*/*/*/*	*/*/*/*/*/*/*
12	Moskou	Moscow, Russia	3	*/*/*/*/*/*/*	*/*/*/*/*/*/*
13	Parijs	Paris, France	1	*/*/*/*/*/*/*	*/*/*/*/*/*/*
14	Prato	Prato, Italy	2	*/*/*/*/*/*/*	*/*/*/*/*/*/*
15	Roosendaal	Leemstraat 15, Zegge, The Netherlands	0	*/*/*/*/*/*/*	*/*/*/*/*/*/*
16	Rottedam	Voorschoterlaan 134, Rotterdam, The Netherlands	1	*/*/*/*/*/*/*	*/*/*/*/*/*/*

- Drivers

The next sheet is the driver sheet. When the first name and last name are filled in, the history of a driver can be added. The “cumulative R” is to show the history of the driver. The variable contains a number and a letter, separated by a vertical bar (|) or it can be left blank. The first number means how many days the driver has already worked that week. When this number is for example 2, the driver has worked for two days. It does not matter if the driver starts his workweek on a Wednesday, the two means than that he worked Wednesday and Thursday. The letter that comes next after the vertical bar, is which large break the driver has to take first. A “S” stands for short, this means that his next large break has to be 24 hours (after 6 days of work). It is also possible that he is working in his 2nd week, then a “L” means that his next break will be the large break of 48 hours. The next column is when the planning goes into detail of that day. Here it can be stated how much time the drive has left till his next small rest (the 45 minutes or 9 hour). The number that has to be stated here is the time remaining until the driver is forced to take a break. This means that his 4,5 hour trip are finished. The final two columns are the costs columns. The hourly wage is the fee the driver gets for driving and working. The DayPay is the amount of allowance the driver gets for his day’s work. The driver also gets this when he does not drive or works, so when he is resting.

	A	B	E	F	G	H
1	Name	Surname	Cumulative R	Remaining time	Hourly wage	DayPay
2	Roelf	ten Brink			15	46
3	Zarah	Ligtenberg		75	12	46
4	Bas	de Jong	1|S	30	11	46
5	Marchelle	ten Brink			13	46
6	Nickey	Schakelaar	3|S	170	10	46
7	Lonneke	de Jong			14,5	46
8	Jan	Verhaart		60	15	46
9	Maarten	Verhaart	1|S	100	14,5	46
10	Amber	Kors	2|S		13,65	46
11	Suzan	Logger	1|S	120	12	46

- Route planner [1 … n]

Up next is the planning sheet. This is a regular VRP planning sheet with time window, rest and break extensions. As can be seen in the figure below it starts with the locations. When click on a cell in this column, a dropdown menu comes up with all the locations that are present in the locations sheet previous explained. When multiple locations are entered, the model automatically calculates the distance (column D), accumulated distance (column E), break types p and r (column F and G), hidden cells "Last Break and "Cumulated R" (column H and I), service time of that location (column J), the driving time calculated with the distance and average speed (column K), accumulated driving time (column L), remaining time (column M), the arriving time and departure time at that location calculated with the driving time and service time (column N and O) and the wait time is the time a driver has to wait at a customer before it reaches its early due date. The sheets starts with all the variables on 0. This means that it fills the form with a fresh driver who has no history of driving.

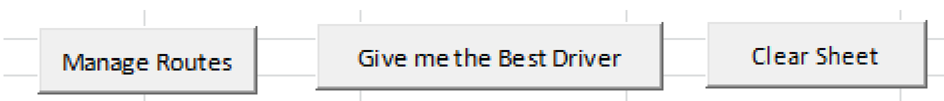
The only thing that has to be changed manually by the driver, next to the locations, is the "Manual Departure Time". This variable can be manually set to the needed departure time for a specific route. This can differ when multiple routes (explained in the next paragraph). When the route is calculated for each driver specific, his information is entered in the top row.

#	Location	Manual Departure Time	Distance (km)	Accumulated Distance (km)	p	r	Last Break	Cumulative R	Service Time (h)	Driving Time (min)	Accumulated Driving Time (min)	Remaining Time (min)	Arrival Time	Departure Time	Wait Time (h)
1	Roosendaal	18-12-15 9:00	-	0	0	0			-	-	0	0	-	-	
2	London		474,2	474,2	1	0	p	0|5	1	356	356	86	18-12-2015 15:41	18-12-2015 16:41	0
3	Roosendaal		471,8	946	0	1	r	1|5	0	354	710	170	19-12-2015 9:35	19-12-2015 9:35	0
4	Frankfurt		421,7	1367,7	1	0	p	1|5	1	316	1026	216	19-12-2015 15:36	19-12-2015 16:36	0
5	Roosendaal		421,7	1789,4	0	1	r	2|5	0	316	1342	262	20-12-2015 8:52	20-12-2015 8:52	0
6	London		474,2	2263,6	1	1	r	3|5	1	356	1698	78	21-12-2015 2:33	21-12-2015 3:33	0
7															
8															
9															

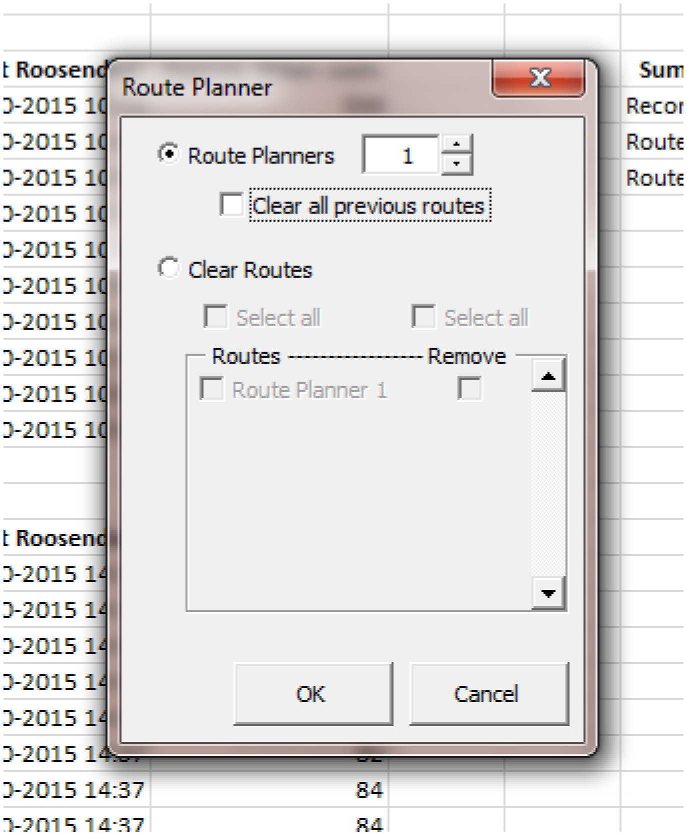
- Driver choice

The final sheet of the decision support model is the “driver choice” sheet. This sheet is built in a couple of different stages. These stages will be explained in detail in logical order.

First, at the top of the sheet, three buttons appear. The first button is the “Manage Routes” button. When this button is pressed, the Route Planner form, as shown below, appears. This form has two options. The first option is the possibility to add more routes. This can be done to add a number. It is also possible to clear all routes, if this box is not checked, than it will copy the previous route. The second option is to



First, at the top of the sheet, three buttons appear. The first button is the “Manage Routes” button. When this button is pressed, the Route Planner form, as shown below, appears. This form has two options. The first option is the possibility to add more routes. This can be done to add a number. It is also possible to clear all routes, if this box is not checked, than it will copy the previous route. The second option is to remove sheets, when less routes are needed for the calculation. It is also possible to only clear the already available sheets.



The second button is the “give me the best driver”. When this button is pressed, the calculation starts with all the available drivers and available routes. The result of the calculation is shown below. The table is sorted on costs and trip time. Both can have different outcomes for each driver because of his history. Other information given is the total kilometers and CO_2 produced in grams for each route.

Route 1		3312,7 Km	2872 Gr		
Name	**Surname**	**Trip Time (dd:hh:mm)**	**Total gate waiting time**	**Arrival date at Roosendaal**	**Approx. driver costs**
Nickey	Schakelaar	4:12:09	0	16-10-2015 10:09	598
Bas	de Jong	4:12:09	0	16-10-2015 10:09	639
Zarah	Ligtenberg	4:12:09	0	16-10-2015 10:09	681
Suzan	Logger	4:12:09	0	16-10-2015 10:09	681
Marchelle	ten Brink	4:12:09	0	16-10-2015 10:09	722
Amber	Kors	4:12:09	0	16-10-2015 10:09	749
Lonneke	de Jong	4:12:09	0	16-10-2015 10:09	784
Maarten	Verhaart	4:12:09	0	16-10-2015 10:09	784
Roelf	ten Brink	4:12:09	0	16-10-2015 10:09	805
Jan	Verhaart	4:12:09	0	16-10-2015 10:09	805
Route 2		209 Km	181 Gr		
Name	**Surname**	**Trip Time (dd:hh:mm)**	**Total gate waiting time**	**Arrival date at Roosendaal**	**Approx. driver costs**
Nickey	Schakelaar	0:12:37	0	12-10-2015 14:37	72
Bas	de Jong	0:12:37	0	12-10-2015 14:37	75
Zarah	Ligtenberg	0:12:37	0	12-10-2015 14:37	77
Suzan	Logger	0:12:37	0	12-10-2015 14:37	77
Marchelle	ten Brink	0:12:37	0	12-10-2015 14:37	80
Amber	Kors	0:12:37	0	12-10-2015 14:37	82
Lonneke	de Jong	0:12:37	0	12-10-2015 14:37	84
Maarten	Verhaart	0:12:37	0	12-10-2015 14:37	84
Roelf	ten Brink	0:12:37	0	12-10-2015 14:37	85
Jan	Verhaart	0:12:37	0	12-10-2015 14:37	85

The last part of the "Drivers Choice" sheet is the summary part. This gives of all the routes the best driver. It has an selection algorithm behind it so that it cannot select the same driver twice. Here the planner can get his information.

Summary	
Recommanded drivers	
Route 1	Nickey Schakelaar
Route 2	Bas de Jong

- Usage explained

Above, all the different sheets are explained. In this paragraph a small step-by-step guide will explain what the planner should do when he would like to use this decision support model. However, first a couple of requirements are stated that needed which have to be filled before the planner could start.

The regulations sheet has to be updated for the current regulations. This will not change that often but this has to kept in mind when changes are made by the European Union. As well as the $C0_2$ emissions change over time due to more economical engines. All the possible customers have to be added with their updated time window information. The service time is mostly standardized to 1 hour, however, when this changes it has to be changed accordantly to the customer. The drivers sheet has to have all the possible drivers and their updated driving history of that week. The costs of drivers also changes overtime so this can be updated as well. Now that all the information is correct, the planner can start with his planning activities.

When the planner activates the driver decision suggestion program, the planner first gets the form that asks for how many routes does the planner wants to make. Here he can also decide if he wants to clear previous usages. When the sheets are created for the planner, he can start with the actual compile of the routes. When he is finished with compiling of all the routes, the planner goes to the “Drivers Choice” sheet and presses the “give me the best driver” button. The model starts to run. When the model is finished, the summary is shown and the planner can see what the model suggests. When the planner is not pleased with the result, he can also look in the results of each route if a second driver is more applicable for the route.

Appendix B Methodology

- Base model

#	Location	Distance (km)	p	r	Duration	Service Time (h)	Driving Time (min)	Accumulated Driving time (min)	Arrival Time	Departure Time
1	Roosendaal	-	-	-	-	-	-	0	-	-
2	Luxemburg	316				3	237	237		
3	Bavel	309	1			2	232	469		
4	Luxemburg	315		1		3	236	705		
5	Breda	310				2	232	937		
6	Eindhoven	61	1			1	46	983		

Average Speed	80	km/h	
Driving period	4,5	h	p
Driving period	270	min	
Driving day	9	h	r
Driving day	540	min	
Break	45	min	
Rest	11	h	
Rest	660	min	

Amsterdam	Hellenburg 35, Amsterdam, The Netherlands	3
Bavel	Seminarieweg 12, Bavel, The Netherlands	2
Breda	Nieuwe Inslag 97, Breda, The Netherlands	2
Eindhoven	De Lismortel, Eindhoven, The Netherlands	1
Luxemburg	Luxembourg, Luxembourg	3
Oosterhout	Wilhelminakanaal Zuid, Oosterhout, The Netherlands	5
Roosendaal	Leemstraat 15, Zegge, The Netherlands	2
Rottedam	Voorschoterlaan 134, Rotterdam, The Netherlands	4

- Break determination

#	Location	StartTime	Distance (km)	p	r		0	Duration	Service Time (h)	Driving Time (min)	Accumulated Driving time (min)	Remaining Time (min)	Arrival Time	Departure Time
1	Roosendaal	2-10-15 12:00	-	0	0	0	0	-	-	-	0	0	-	-
2	Breda		26,44						3	20	20		2-10-2015 12:20	2-10-2015 15:20
3														
4														

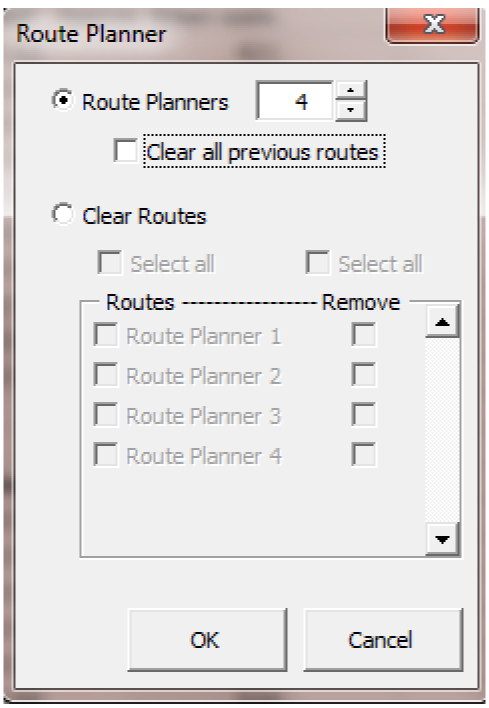
- Time windows

Amsterdam	Hellenburg 35, Amsterdam, The Netherlands	3	*/*/*/*/*/-/-	*/*/*/*/*/-/-
Bavel	Seminarieweg 12, Bavel, The Netherlands	2	*/*/*/*/*/*/*	*/*/*/*/*/*/*
Breda	Nieuwe Inslag 97, Breda, The Netherlands	3	*/*/*/*/*/*/*	*/*/*/*/*/*/*
Luxemburg	Luxembourg, Luxembourg	3	0900/0900/0900/0900/0900/-/-	1200/1200/1200/1200/1200/-/-
Moskou	Moscow, Russia	3	*/*/*/*/*/*/*	*/*/*/*/*/*/*
Parijs	Paris, France	1	*/*/*/*/*/*/*	*/*/*/*/*/*/*
Roosendaal	Leemstraat 15, Zegge, The Netherlands	2	*/*/*/*/*/*/*	*/*/*/*/*/*/*
Rottedam	Voorschoterlaan 134, Rotterdam, The Netherlands	1	*/*/*/*/*/*/*	*/*/*/*/*/*/*

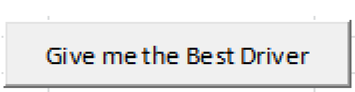
- Inifinte weeks

#	Location	Manual Departure Time	Distance (km)	p	r	Last Break	Cumulative R	Service Time (h)	Driving Time (min)	Accumulated Driving time (min)	Remaining Time (min)	Arrival Time	Departure Time	Wait Time (h)
1	Roosendaal	12-10-15 9:00	-	0	0		0	-	-	0	0	-	-	
2														
3														
4														
5														
6														

- Multiple routes



- Multiple drivers



- Driver selection

Summary	
Recommanded drivers	
Route 1	Nickey Schakelaar
Route 2	Bas de Jong
Route 3	Zarah Ligtenberg
Route 4	Suzan Logger

- Emissions

Route 1	2263,6 Km	1963 Gr