

MASTER

Design of the distribution network for an e-tail scenario in the floricultural sector

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Award date:
2013

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Eindhoven, February 2013

**Design of the Distribution Network
for an E-tail Scenario in the
Floricultural Sector**

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in partial fulfilment of the requirements for the degree of

**Master of Science
in Operations Management and Logistics**

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Series Master Theses Operations Management and Logistics

Subject headings: operations research, logistics, transportation, planning, supply chain management, distribution, electronic commerce.

Abstract

This master thesis describes the design of a transportation network for a future scenario in which the largest part of flower sales in the market will go by an e-tail channel. The analysis of the current market of e-tail channels aimed at flower sales gives a clear benchmark for the performance of the new transportation network. These performance parameters plus models and formulations from scientific literature are the basis for the development of a new logistics distribution network. The objective of the distribution network is to deliver bouquets of flowers in a minimum amount of time against competitive transportation cost while optionally using break-bulk and consolidation hubs across multiple countries, the metro model, multimodal transportation and inventory. Several design scenarios are developed and tested in the mathematical optimization tool, LogicNet, in order to find a new time and cost effective way of transportation from grower till end consumer in an e-tail scenario.

Preface

This report is the result of a six month graduation project executed at the department of Supply Chain Development at FloraHolland and is written in order to complete the Master Operations Management and Logistics at Eindhoven University of Technology. I am very thankful for the opportunity to conduct my research at FloraHolland, it made my research a very dynamic and interesting experience. I would like to grab this opportunity to thank some people who supported me not only during this project, but also throughout my whole study time.

First, I would like to thank my supervisors from the TU/e. I would like to thank Tom van Woensel. During all the short, but efficient meetings we had, you took the time to explain things, gave me solid advice and always provided me a clear set of options for all the problems I encountered. Next, I would like to thank Nico Dellaert, for all his questions that gave me food for thought, which in the end resulted in a more critical view from my side on my own project. Thank you both for your time and critics.

Second, I would like to thank my company supervisors, Rob Koppes and Robert Ossevoort, for answering the tremendous amount of questions I had (live and by e-mail), including all the long discussions about issues and details I encountered, and handling all the problems with the data. Next, thanks to Edwin Wenink for all useful information and feedback. All three, special thanks for providing me the opportunity to execute this project at FloraHolland, the very interesting subject gave me even more motivation to execute the project. Furthermore, there are some people within the company of FloraHolland without whom this project wouldn't have been possible at all. Thank you to Karel van Dijk, Janine Bos and Joost Naber for all the effort you have put into searching data for me.

Third, I would like to thank my mom and dad; thank you for the years of study in which you always supported me in multiple ways. Special thanks for the last months, it was a very hard time, but you always kept me focussed and pushed me to graduate in a fair amount of time while at the same time my study was not always the highest importance for us in these six months. Also thank you to my brother, for always reminding me that students are a weird kind of species, and that books are not that interesting at all. It kept me open minded for all other things in life.

Last, special thanks to Jens, you have always been there for me in the last six years, during all ups and downs. You always supported me in everything I wanted to do, while also being their just to make a lot of fun! Your love and humour makes my life beautiful! Thank you!

Natasha Theeuwen

February 2013

Management Summary

The Netherlands can be seen as the heart of the international floriculture sector, with a historical global trading position. It has a high-end network of companies ranging from breeders and growers to sales experts and export firms, representing every aspect of the business. The Netherlands is the place where worldwide supply and demand comes together.

Although the sector is in a leading position now, it needs to look ahead to stay in this position. At the moment most products still go through the physical auction houses, from (international) growers to (international) customers, which provides the opportunity for physical inspection and control. However, the evolving market requires becoming a more efficient (virtual) network, in which products are delivered to customers taking different routes.

This research is aimed at the future scenario in which e-tail covers 60 percent of the market and thus demands a very different and above all individual, fast, and flexible supply chain network to cover customers 24/7 shopping on the web, where statements such as *'ordered before 17.00, delivered tomorrow'* are not unusual.

This need for a new and improved distribution network has led to the following research question:

What effect has multimodal transportation and the choice of green, fast or cheap transportation on the performance of the transportation network within the e-tail scenario?

This research question can be answered by the content of this report. A short summary of the conclusion and recommendations will be given in this management summary.

The benchmark described in chapter 3 provides important insights in the floricultural e-tail market; worldwide delivery within 24 hours against competitive delivery charges. These findings combined with literature and inputs from the field led to the development of an intended new supply chain design; a long-haul transportation part which can be described by an SND model and a short-haul last mile distribution problem. This design is tested on a case study making use of 13 different scenarios. The results of the 13 scenarios and the calculation for the last mile distribution can be found in Table 1. The main conclusions and recommendations for the floricultural sector are given below, followed by a brief answer on the main research question.

The most important conclusions acquired from this research are:

- Multiple inbound hubs: expanding of the possible inbound hubs from only in the Netherlands to locations across the entire market improves the network tremendously on all aspects. Not only has the lead time to customers decreased by 10 to 30 percent, emission have decreased as well, while simultaneously the cost of the supply chain remain almost equal. This expansion of the supply chain network therefore leads to a faster and greener supply chain. This result is the effect of shortening

the overall distance per customer. It is no longer necessary to make a detour through the Netherlands, you can go directly to your customer;

- Metro model (Figure 1): the design of the network is based on the metro model. In a metro model each hub is connected to at least one other point in the network, in which all points together create an interconnected network in which you can travel from A to B via different routes which can be direct or indirect. From the results can be concluded that the expansion to many more links mainly increases the complexity of the supply chain network and not necessarily performance. From the results it can be seen that lead time (only average) decreases while cost remain equal, however, with a negative effect on emissions. The metro model primarily moves inbound costs for transportation to network costs for transportation. In this, it needs to be mentioned that in case the network transportation would be less efficient due to packing methods, the network cost could increase and the obtained decrease in lead time would possibly be accompanied by higher cost;
- Modalities; time, cost and emissions: faster modalities are more expensive and less environmental friendly. It can be seen as a two way relationship. On the one side cost and emissions, on the other side lead time. To decrease cost, you also decrease emissions, but increase lead time and vice versa. Therefore, a choice needs to be made for the goals of the supply chain network; fast, cheap, and green or a balance in-between. Furthermore, it needs to be decided on whether these goals can be determined by individual customers and what is promised to these customers;
- Last mile distribution: this is the most expensive part of the supply chain caused by the high volume of an individual bouquet, many stops and long tours distances. Pick-up points can make the last mile more efficient, while in essence the burdens of the last mile move from the supplying company to the customers.

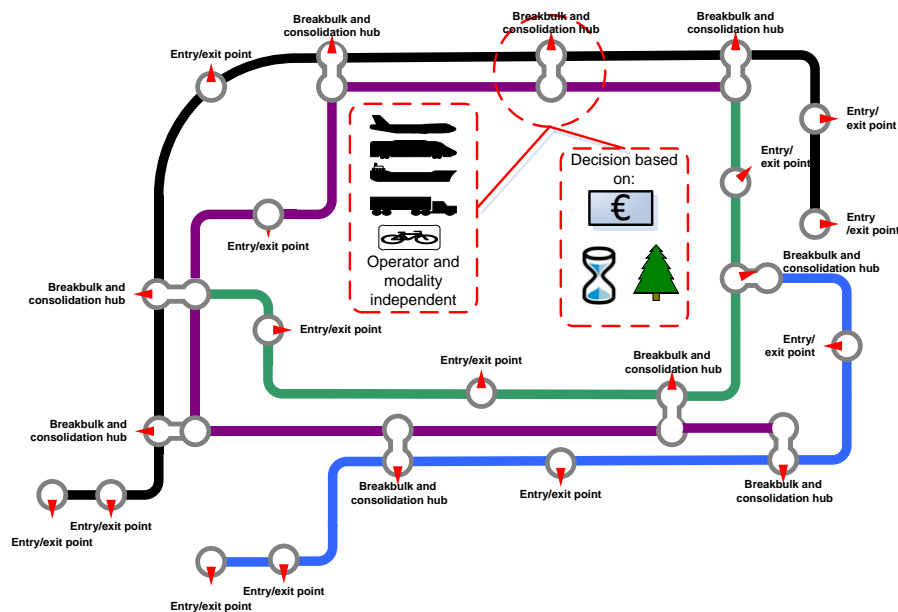


Figure 1: Metro model (Koppes, 2012)

friendly. Therefore it is important to find a good balance between green and cheap transportation, and fast transportation.

Scenarios (MLT)	Current Situation	European Inbound	Metro Model	Inbound Inventory	Clustering Inventory	Cost Competitive
Transportation cost (euro)	0.872	0.889	0.873	0.889	0.873	0.763
Average Lead time (days)	0.406	0.268	0.269	0.268	0.268	0.698
Emissions (gram)	0.446	0.472	0.472	0.470	0.471	0.213

Scenarios (CM)	Adjusted Current Situation	European Inbound	Metro Model	Inbound Inventory	Clustering Inventory	24 Hours Delivery	72 Hours Delivery
Transportation cost (euro)	0.726	0.696	0.696	0.696	0.696	0.701	0.695
Average Lead time (days)	0.414	0.410	0.338	0.410	0.410	0.333	0.367
Emissions (gram)	0.057	0.043	0.045	0.043	0.043	0.047	0.043

Cost	Home delivery	Pickup Points
Cost per flower box (euro)	2.00	0.54
Emission per flower box (gram CO ₂)	8.03	2.59

Table 1: Results from 13 different scenarios and last mile distribution

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1. Introduction

This project is executed as part of the DaVinc³i project from the company FloraHolland. For this purpose a brief description of the company FloraHolland is given in the first section of this chapter. A part of the research of the DaVinc³i project is the investigation of future scenarios in the flower industry for the year 2020. One of these scenarios is E-tail, the subject of this research. Therefore, the DaVinc³i project, future scenarios and especially the e-tail scenario will be discussed in section 1.2. The structure of the report will be outlined in section 1.3.

1.1. Company Background - FloraHolland

The Netherlands can be seen as the heart of the international floriculture sector, with a historical global trading position. The sector has a high-end network of companies ranging from breeders and growers to sales experts and export firms, representing every aspect of business. The Netherlands is the place where worldwide supply and demand comes together.

FloraHolland is a cooperative company owned by its roughly 6000 members, which are primarily from the Netherlands. FloraHolland consists of six auction centres; five in the Netherlands (Aalsmeer, Naaldwijk, Rijnsburg, Bleiswijk and Eelde) and one in Germany (Rhein-maas), which is a joint venture between FloraHolland and Landgard. Next to this there is an intermediary organization FloraHolland Connect which facilitates direct sales between growers and buyers. Each auction has its own unique business, however all auctions together form a single business which are connected by a strong logistical network (FloraHolland, 2012).

The turnover in 2011 totalled €4.2 billion, of which €2.4 billion through clock transactions and €1.8 billion through FloraHolland connect. Which is roughly equal to 9.0 billion units; 8.4 billion units of cut flowers (value €2.4 billion) and 0.6 billion units of plants (value €1.8 billion of plants). FloraHolland is a not-for-profit organization having 4,060 employees (3,218 FTEs) in 2011. The trade of clock transactions is gradually decreasing, but the trade through FloraHolland Connect gradually increases during the last years. Each day, on average 112,297 transactions occur at the auctions clocks between the growers and 2,343 (international) buyers (FloraHolland, 2011).

The vision and mission of FloraHolland is to maintain and increase its strong market position by offering the best and broadest assortment and wishes to tie (international) commerce flows to its marketplaces. FloraHolland offers its members the best sales opportunities at the lowest possible costs and is therefore a service providing not-for-profit company (FloraHolland, 2012).

1.2. DaVinc³i and E-tail

The total horticulture sector in the Netherlands has a large impact on the Dutch economy; it is the largest exporter of fresh products in Europe and the top-3 largest exporter in the world, with even more

growth options. Although the sector is in a leading position now, it needs to look ahead to stay in this position (Figure 2) The evolving market requires becoming a more efficient (virtual) network, in which products are delivered to customers taking different routes. DaVinc³i examines this impact of virtualization on the Dutch horticulture sector to ensure that the sector can continue to be and become the (virtual) horticultural trading hub of Europe, while operating in a market with unique characteristics (many small actors, rapid product quality changes, global-for-global combined with local-for-local flows, high demand and supply uncertainty, etc.) (DaVinc³i, 2010).



Figure 2: Scope and goal of DaVin³i

Scenarios

Within the DaVinc³i project three scenarios are developed for an international virtualized horticultural trade world. These are possible commercial future market situations for the year 2020.

The scenarios are divided among three dimensions (Figure 3): subsector, dominant sales channel and degree of change. Customer wishes become more and more important in the future and creates a demand driven supply. This makes dominant sales channel the most important divider for the scenarios. The three dominant sales channel are: retail, detail and e-tail (web shops). In which the 20-20-60 rule is applied (Figure 4); 60% of sales is allocated to the dominant sales channel in the scenario, the other two both receive 20% of sales. Next to this, there is a division into cut flowers and plants they divide into evolution (normal adjustment) and revolution (extreme adjustment). This leads to twelve options of supply chain structures, which are given with accompanying brief descriptions of retail and detail, in Appendix B (DaVinc³i Kernteam, 2011). A more extensive description of the e-tail scenario, which is the focus of this research, will be discussed in the next paragraph.

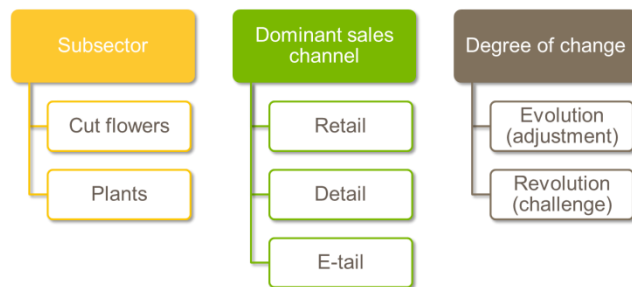


Figure 3: Scenario's according to three dimensions

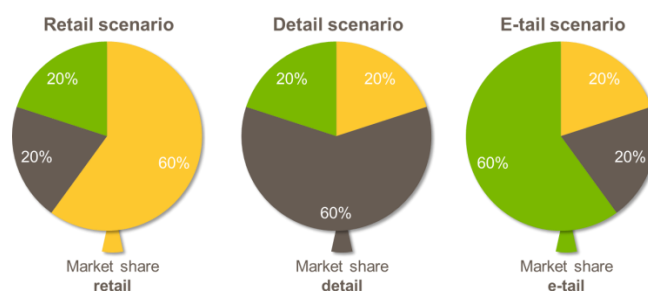


Figure 4: Dominant market shares depending on scenario

E-tail

E-tail is the sales channel in which flowers are sold through the internet, in which the corresponding web shop is not connected to an already existing physical sales channel and the accompanying infrastructure. The consumer can buy the products as a gifts, but also for own consumption. The main reason to buy through this channel is convenience (DaVinc³i Kernteam, 2011).

In this scenario, 60% of sales go through the e-tail channel. This is based on the high level of virtualization and well developed e-tail stores in other sectors. The supply of goods available on the e-tail channel is very broad and deep; even custom made bouquets can be offered according to customer wishes. There is wide price range which is highly dependent on the type of products bought. Logistics is the key to ensure to offer all these products in a timely matter at the customers' home against a competitive price. The strategy is based on customer convenience; one click shopping on a website on a computer, smartphone, or tablet, and the product will be delivered everywhere the customer wants at every moment, now or in the future. Extensive information about the products (origin) and the grower's background on the web shop and guarantees concerning quality and ecological footprint are important. Since there is no physical store present combined with the high 'touch and feel' level of the products. To differentiate themselves, Dutch growers will use a strong own brand and offer mostly high quality and niche products compared to foreign growers who offer more bulk products against a low ecological footprint (DaVinc³i Kernteam, 2011).

At this moment, most web shops are Business-2-Business (B2B) oriented. Web shops in the horticultural sector for consumers (B2C) is a slow emerging market in the Netherlands and Europe. In the US, the market share for the B2C market is higher. However, initial higher prices for horticultural products create a higher acceptance level for the high transportation costs (DaVinc³i Kernteam, 2011).

Evolution and Revolution

Within the DaVinc³i project, two scenarios for potential commercial supply chains are developed; one evolution and one revolution scenario (Figure 5). These scenarios are based on the commercial supply chain configurations for e-tail (Figure 6). This configuration describes the extension of the current market and how the e-tail market should be fitted into this market and corresponding supply chain (DaVinc³i Kernteam, 2011).

The evolution scenario contains a fresh provider in-between the domestic/foreign grower (associations) and the e-tail shop. This fresh provider has a bundling role and international orientation. It bundles the width and deep assortment of products from different growers (associations), domestic and abroad, and offers these to the e-tail shop. The e-tail shop buys the products it needs at different fresh providers to fulfil the demand of European based online customers. These customers are supplied against low cost and in a short time span through the use of a network based on multimodal transportation. The revolution scenario occurs when growers (associations) offer their products directly at the e-tail shop without intervention of a fresh provider (DaVinc³i Kernteam, 2011).

Both scenarios lead to thin product streams because of the high number of scattered suppliers combined with the high number of scattered customers. Therefore information is shared real time between all parties to get an optimal use of the supply chain in which ownership goes along with the parties in the supply chain (DaVinc³i Kernteam, 2011).

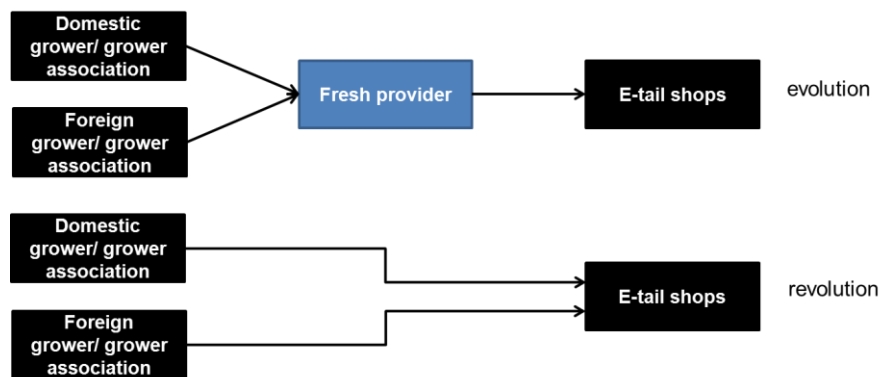


Figure 5: Potential commercial supply chain scenarios for e-tail (DaVinc³i Kernteam, 2011)

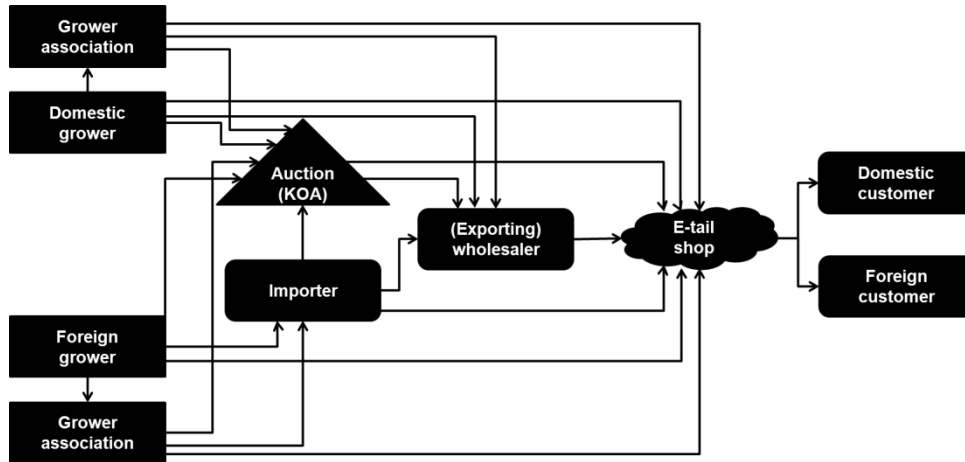


Figure 6: Commercial supply chain configurations for e-tail (DaVinc³i Kernteam, 2011)

1.3. Report Structure

The remainder of this report is outlined as follows. First, the problem definition is described and explained according to the main idea of the research. The second chapter defines the aim of the research and the defined research question. In the third chapter a throughout analysis of the market is provided. Chapter 4 first provides a qualitative and quantitative description of the supply chain. In chapter 5 a case study is described which will be used to test the supply chain design described in chapter 4. Chapter 6 covers the design of the supply chain and accompanying analysis of the results. This report ends with an overall conclusion, recommendations and further research suggestions in chapter 10.

2. Research Design

This chapter contains the research design. In the first section the main idea behind the research is explained accompanied with decisive underlying concept. In the following section the research definition with underlying research question is provided. In the last section a description of the projects scope is given.

2.1. Main idea Research

The aim of this research is the development of the e-tail scenario within the floriculture sector. With the development, a need arises for more individual and flexible logistics. The new situation requires the handling of a large number of orders, which are small and geographically scattered and could be handled via a much shorter supply chain. This in comparison to the old situation in which bulk products were gradually decomposed while going through a more extensive supply chain.

To cope with this new situation, a new type of network is needed; fast, flexible and individually based. The network will be designed as a multimodal network that uses floating breakbulk and consolidation within a metro model (Figure 7). The two scenarios, evolution and revolution, provide two different compositions of involved parties; the evolution scenario involves the domestic/foreign growers (associations), the fresh providers and the e-tail shop, the revolution scenario involves the domestic/foreign growers (associations) and the e-tail shop.

Ordering Online

The whole network is triggered by orders from customers. A customer can order a bouquet of flowers at the web shop. This bouquet may consist of one or more types of flowers. When ordering the flowers the customer has to provide information; the delivery address and the day of delivery, and second the mode of delivery, green, cheap or fast. These options each have their own delivery cost which could be charged to the customer.

Each order creates information on the underlying IT network. All orders are captured at a certain moment during the day (for example: ordered before 17.00, delivered tomorrow). This leads to data on the amount of demand for each type of flower and the corresponding required destinations over a certain consolidated time span. After this information consolidation moment, transportation over the network and the last mile can be planned. All this together creates a situation in which the customer order decoupling point (CODP) is pushed back into the supply chain, so that orders can be made to order (MTO), and inventory is minimized as much as possible. The supply chain is now driven on demand, and not on forecasts.

Multimodal transportation

The new network needs to aim at multimodal transportation. At this moment in the horticulture industry, most transportation is executed through the use of road transportation (trucks). Due to the higher density on roads and importance of doing business greener, this is no longer the best option in

every situation. Therefore the use of different modes of transportation is examined in this research. Alternative transportation modes within Europe are train, barge and short sea. For inbound flows outside of Europe, air cargo and deep sea containerships are considered. Last mile transportation is always performed using a middle sized truck.

Metro Model

The design of the network is based on the metro model (Figure 7). The concept 'metro model' is based on the metro/subways in larger cities across the world. In these cities you can 'jump on and off' the network at every entry/exit point in the network. Each point is connected to at least one other point in the network, all points and connections together create the metro network; an interconnected network in which you can travel from A to B through the use of different routes. While travelling from A to B, you can use a direct line (when available), or go by one or multiple transshipment points before arriving at the end location B.

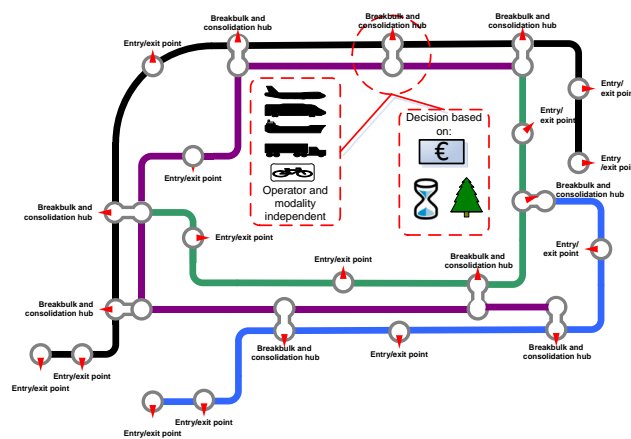


Figure 7: Metro model (Koppes, 2012)

When applying this concept to freight transportation problems, the idea is that the points are hubs in the transportation network. A hub can be a start hub, an end hub or a transshipment hub. Start hubs are growers, end hubs are customers, and transshipment hubs are the hubs in-between which are used to transport the products efficiently from grower to customer. The connections in-between the hubs are transportation links. Each link has its own characteristics: modality, time needed, cost and emissions. It is possible to have no, one or more links between one pair of origin and destination (O-D), the availability of a link between an O-D pair is subject to the availability of transportation modalities in-between. Start hubs can be connected to all transshipment hubs, the links in-between only allow one-way traffic; from the start hubs to the transshipment hubs. End hubs can furthermore only be connected to transshipment hubs and have one-way transportation; from the transshipment hubs to the end hubs. Transshipment hubs can be interconnected to all other transshipment hubs.

Shortening of the supply chain

In the current supply chain (Appendix C) orders are most of the time traded by the use of the auction. At these auctions they are bought by a wholesaler, after which they end up abroad or in detail stores. There are also options to sell directly, without the use of the auction to wholesalers, detail or retail in the domestic market or abroad. All these different steps in the current supply chain require breakbulk and consolidation steps, next to extra (unnecessary) transportation movements. In the new situation (with the two e-tail scenarios) the steps of auction, wholesaler, retailer and detailer are cut out of the supply chain. The growers (associations) deliver directly to the customers by using an e-tail channel and possible with a fresh provider in-between. This shortening of the supply chain makes it possible to design a supply chain without unnecessary breakbulk and consolidation moments and more 'direct' transportation.

Greener/cheaper/faster

An important part of this research is the more conscious customer. Customers get the option when ordering flowers between green, fast or cheap transportation. This choice has profound effects on the planning for the transportation in the network. For example, the choice for green excludes links in the network that have a too high level of CO₂.

Minimizing inventory and next day delivery

It is possible to order bouquets for the next day or upfront. The aim is to get a web shop that distinguishes itself by high quality products. This is only possible when flowers have a long vase life and thus when they are delivered as fast as possible after picking the flowers at the grower. It is probably cheaper and faster to keep some stock closer to the customer, or to already ship pre-ordered products; however this decreases the quality and the lifespan of the products and increases the number of flowers that need to be disposed unnecessary. Therefore, it will be examined what the effect of keeping no stock is, and what cost savings can occur when using a minimum level of stock.

2.2. Research Definition

The need for this research arises from the point of view that the sector wants to be and continue to be the (virtual) horticultural trading hub of Europe, in the ever changing market. The market is becoming more virtual, roads are getting congested, the ecological footprint becomes more and more important, and the market becomes more demand-oriented instead of supply-oriented. These developments, together with the wish to stay the number one horticulture trading hub in Europa, asks for a different view on the currently used logistical concepts.

Within the DaVinc³i project, twelve scenarios for market development are given within the horticulture industry of which six aimed at the floriculture industry. This research will focus at the two e-tail scenario aimed at the floriculture industry.

The idea is to investigate a supply chain network that is designed as a metro model. In this network, there will be certain inbound hubs at which bulk goods can be delivered by suppliers, clustering hubs at which bouquets are made out of the single flowers and where orders are prepared. From these hubs the delivery addresses at which the customers ordered bouquets of flowers need to be served in the end. In-between a hub-and-spoke network rested with multimodal spokes and last mile distribution, takes care of the floating break bulk and consolidation, so that the incoming bulk supplies result in the right deliveries of bouquets (semi-single units) at the delivery address. In this network the difference between green, cheap and fast delivery needs to be examined in combination with the use of multimodal transportation. This leads to the following research question:

What effect has multimodal transportation and the choice of green, fast or cheap transportation on the performance of the transportation network within the e-tail scenario?

Underlying research questions

To answer the main research question stated in paragraph 3.1, several sub-questions are formulated:

1. What is the definition of multimodal transportation, which transportation modes are taken into consideration, and what are the characteristics of these transportation modes?
2. What is the definition of green, fast or cheap and how do these need to be measured?
3. What are key performance indicators for the transportation network?
4. How is an order routed through the network, and how and by whom are these decisions made?
5. How should this transportation network be constructed?
6. How should the performance of the transportation network be measured?
 - a. What is the performance of a basic transportation network (one mode, no transportation criteria)?
 - b. What is the performance of the new extended transportation network?
7. Is there a difference in logistics when using the two different scenarios?

2.3. Scope

The main focus of this research is the performance of the network when using multimodal transportation combined with different criteria for transportation (green/cheap/fast). The whole design and optimization of a newly developed transportation network is a very complex problem. To test the performance of this kind of transportation network, while using parameters like multimodality and transportation criteria, some demarcation on other aspects is necessary.

Sourcing

Sourcing of products is only included from major grower regions worldwide and aggregated on country or region level (when very large or widely scattered). The transportation from grower till inbound hubs and the accompanying cost is incorporated to make an educated decision on the amount of flowers per flower type that need to be delivered at the different inbound hubs at each time period.

Market and end-customers

This research is focused on the cut flower sector; the plant sector will be out of scope. Customers ordering flowers can be situated across Europe. Because the demand in the future scenario (2020) is not known yet and is hard to forecast, demand is estimated on a regional level with as main indicator the number of inhabitants per region divided by the number of inhabitants in the country combined with export numbers.

Number and characteristics of products

Not every product needs to be delivered to each inbound hub; each product is only available on the inbound hub(s) which is a logical extension of the sourcing origin of the product in combination with cost (green) or time efficient transportation between grower and inbound hub.

Customer orders

Customers can order bouquets through a website. There are two categories of bouquets, mono bouquets and mixed bouquets. Mono bouquets consist of only one type of flowers. Mixed bouquets consist of one or more types of flowers combined together with one or two types of green products used as fill up. The assumption is made that the website and the underlying excellent IT system already exist; and that it takes care of real-time information supply for all involved parties.

Inbound hubs

Inbound hubs are chosen according to the origin of the used product combined with transportation possibilities from growers to the inbound hubs. For example, for flowers that arrive from Kenya, the inbound hub can be either an airport or a sea port. Investments for relocation, opening or closing of inbound hubs are out of scope of this research.

Clustering hubs

Bouquets are created at the end of the network at clustering hubs; just before the last mile distribution. The time that is needed to make a bouquet is out of scope of this research. The existence, functionality and design of the clustering warehouses are assumed. Due to this assumption investments in relocation, opening or closing of clustering hubs are out of scope of this research.

Network

In-between the sourcing and clustering hubs there will be a logistic distribution network. This network will be modelled like a hub-and-spoke network. In which the hubs are the grower locations, inbound hubs, or clustering hubs. The spokes will be connections based on present infrastructure for roads, railroads, waterways or flight routes, regardless of how the link is now used. It is furthermore assumed that enough, appropriate, transportation resources are available at each moment in time for all modalities and that facilities for cargo transportation exist on all transportation links. Investments in infrastructure are out of scope of this research.

Last mile

Because of the lack of data on actual end customers, estimations of the average time and costs of the last mile for each customer will be estimated using estimation formulas by Daganzo (2005).

For last mile distribution home delivery is not the only option. Roughly seen in an e-tail channel there are three options: home delivery, pick-up points, or in-store pick up. Home delivery is the most cost and time intensive option; each order needs to be delivered at a separate address with accompanying delays in time and extra kilometres. A pick-up point provides customer the option to pick up their order at a point inside or at the edge of the city; most of the times a postal office, fuel station or shop with long opening hours. The third idea is primarily beneficial when the e-tail shop is part of a clicks and mortar structure. In this, supplying the shop can be combined with the e-tail orders. It has the same characteristics as a pick up point, although the savings on transportation can be higher due to combination. In this research it is assumed that the e-tail shop is not connected to physical shops. Therefore only the difference in cost between home delivery and pick up points will be discussed in section 6.3.

Calculations

In order to test the research question, different scenarios will be tested. The calculations will be executed in LogicNet, a mathematical optimization tool. Approximately 5-15 scenarios will be tested. The scenarios will be tested against a base scenario that resembles the current operations; an objective of minimizing lead time while using trucks for transportation. The other scenarios will be based on choices between the objective of cost minimisations or lead time minimisation, a constraint on cost or lead time, the level of multimodality, the number of inbound hubs, the metro model, and the level of inventory. These chosen scenarios will be explained in chapter 6.

Supply and inventory

It is assumed that there is slightly more supply available to meet demand in time to ensures that all chosen sourcing locations need to be used by the mathematical optimization tool (LogicNet): $\sum demand = 105\% \sum supply$. This supply is early enough available to fulfil demand for 100% while being able to use all modalities.

2.4. Summary Research Design

The aim of the research is to develop more individual and flexible logistics to respond to the fast industry of e-tail which requires handling of large numbers of small orders which have very scattered origins and destinations. The idea behind the new network design is to incorporate multimodality and the metro model. This should ensure that the supply chain is shortened and thus appropriate for the e-tail scenario. This idea has led to the development of the research question, which will be answered while staying inside of the scope.

3. Market Analysis – Current Floricultural E-tail Stores

The overall objective of this chapter is to give an overview of the current activities in already existing e-tail stores selling flowers and will create a clear benchmark for this research and the transportation network that will be designed. At this moment there is no e-tail store owned or managed by FloraHolland that is aimed at selling flowers to end customers, FloraHolland only recently bought a minority interest in Frederique's choice and it is developing a web shop (FloraHolland Exclusief) in which special flower products can be bought by detail shops. Therefore research needs to be done about competitors to get an idea about the current market, important parameters and strategies before getting into this market. The research is executed among 14 Dutch based web stores of which 11 stores operate both in the domestic and abroad market; three stores operate only in the domestic market. More extensive and numerical findings from this analysis can be found in Appendix D, a brief explanation of the findings will be described in this chapter.

First the assortment offered by the different websites is described. Next characteristics about the delivery process are stated. In the third paragraph the three supply strategies from the competitors are explained; florists network, courier service or mixed. In the last paragraph, a summary of the different e-tail strategies is given, and the subsequent implications for FloraHolland. The information in this chapter is extracted from 14 different websites: topbloemen.nl (2012), bloemen.com (2012), fleurop.nl and fleurop.com (2012), frederiqueschoice.com (2012), boeketcadeau.nl (2012), 123bloemenbestellen.nl (2012), euroflorist.nl (2012), bloemenzaak.nl (2012), 123-bloemen.nl (2012), sturbloemen.nl (2012), bloemenbezorging.nl (2012), debloemist.nl (2012), bloemen-bezorgen-buitenland.nl (2012) and zenzi.nl (2012).

3.1. Assortment

In this section the assortment offered on the different websites and the corresponding product prices and guarantees will be discussed

Assortment

The assortment size is classified according to the number of bouquets offered. In most of the shops can be seen that a much wider and different assortment of products is offered for the domestic market than for the foreign market. Only two competitors offered exactly the same assortment for all countries.

Most competitors in the Netherlands offer a deep assortment of products. They often also offer additional gifts next to flowers. Abroad they offer most of the times only a simple assortment, with a small number of different bouquets. Stores offering the similar assortment for both markets mostly use courier services instead of a network of florists. Supply strategies will be discussed in section 3.3. An overview can be seen in Table 2.

	Width		Depth	
	Netherlands	BE/LU/DE/FR/UK	Netherlands	BE/LU/DE/FR/UK
Small/Simple	2	7	2	6
Middle	3	3	2	1
Large	3	1	8	2
Extra large	6	0	2	2

Table 2: Assortment overview; number of shops that offer a particular assortment to a country

Prices

Bouquets for domestic delivery (and sometimes Benelux) start with prices range from €7.95 to €17.95 (excluding delivery charges). Prices can go up to €300 a piece for large mourning pieces. The differences in prices in bouquets are most of the time caused by the number and type of flowers in it. Extras such as vases, wine etc., or flower arrangements made for special occasions additionally increase the selling price.

Flowers meant for abroad are on average more expensive than flowers distributed to the Netherlands; the lower bound of the assortment has increased with a price varying from €3.05 to €28.00 per bouquet, depending on the website. These higher prices are caused by using a network of florists. Flowers in detail shops abroad are most of the times priced higher due to various reasons; this also leads to initial higher prices for bouquets offered on the website for abroad delivery. Websites using courier services offer the same assortment against the same price (different delivery charges) for all countries, however mostly only offer this service in the Benelux.

Unfortunately bouquets cannot be compared one-on-one, so it is hard to determine if the content of the bouquets is significantly better abroad or that other factors increase the price.

Guarantees

Flowers are perishable goods; therefore it is not possible for unsatisfied consumers to return them. Normally with internet orders, you can order a product online, receive it at home, check the product for you preferences and return it when not satisfied. To partly cover this issue, some web shops offer a vase life guarantee; a guarantee on the life of the flowers which varies between 5 and 7 days. When the flowers are in bad quality at the end of this time period, you can file a claim, or even get a whole new bouquet of flowers. In contrast bouquet composition is not guaranteed; it is a product of nature, which gives them the freedom to change the product when necessary.

3.2. Delivery

In this paragraph findings about the delivery will be discussed, the topics are lead times, time window options, pre-orders, delivery days, delivery areas and delivery charges.

Lead Times

Across the sample there are mainly two types of earliest delivery times: same day delivery (only domestic) and next day delivery. For same day delivery the order needs to be filed and paid for before a certain time of the day (varies between 12.00 and 13.00). Next day delivery also requires completion of the order before a certain time of the day (varies between 13.00/15.00 and 18.00)

Time Window Options

Orders are delivered between 9.00 and 18.00 (17.00 for business orders). Sometimes it is possible to indicate a latest time of delivery without any guarantees. A few websites offer time windows (morning, afternoon or evening) against an additional surcharge.

Delivery Date

All web shops offer the option to indicate a delivery date. Most companies offer the option to order for 2-3 months in advance, some offer 1-3 years, and others have an unlimited calendar. But it needs to be said that the web shops with unlimited options probably just did not block their order options in the right way on their website, which makes 2-3 months a plausible time window for possible delivery dates.

Delivery Days

Deliveries are possible from Monday till Saturday, excluding Sunday and national holidays. Web shops using courier services don't deliver on Monday; they can only deliver their packages on a weekday which causes a quality issue for Monday delivery.

Delivery Areas (Countries)

Smaller web shops, and web shops using courier services only deliver in the Netherlands with possible extensions to Belgium, Luxembourg and Germany. Larger web using a network of florists possibly cover up to 150 different countries.

Delivery Charges

Delivery charges for the Netherlands range between €6.95 and €8.80 with an outlier to €13.95. The web shop with a delivery charge of €13.95 is overall more expensive, which is caused by the exclusive aim on the foreign market. Delivery charges for abroad (in which only Belgium, Luxembourg, Germany, France and the United Kingdom are taken into account), range between €9.00 and €17.95 for web shops using a network of florists and for web shops using a courier service between €6.00 and €7.95 (mostly only domestic).

3.3. Supply Strategies

The examined web shops operate under three different supply strategies: network of florists, courier service, or a mixed strategy. Afterwards, the use of green transportation will be discussed.

Network of Florists

Most flower web shops operate using a network of florists. After the order comes in they contact the closest florist to the specified address, and make sure that this florist sends the ordered bouquet to the customer. This has some positive and negative implications for the underlying supply chain and the delivered product: fast delivery; possibility of a wide geographical market; long supply chain; inventory and quality control issues.

A lot of web shops use the network of florist's strategy. The needed parts for the bouquets are already close to the customers, which makes same day delivery possible. This close CODP decreases customer lead time. Furthermore, it is possible to deliver to a very wide geographical area. The only steps necessary after ordering are: contacting the local florist; binding of the bouquet(s); eventual combining of the bouquet with other parts of the order and delivery to the specified address.

However, there are also some negative implications for this strategy. The availability of products at the florists is uncertain (Lack of IT/inventory control), which leads to a small assortment offered and the possibility of delivering bouquets different than initially ordered. The question is therefore: how satisfied is the customer when the delivered bouquet deviates in a certain degree from the ordered bouquet? Another questionable point in this is the quality of delivered products. The partnerships are mainly based on trust and random checks.

As mentioned before, the customer lead time is short, while this does not mean that the whole supply chain is shorter or faster. It is probable that the products follow the total supply chain, which can be seen in Appendix C. They will go from the (international) growers through the auction houses or mediation agencies, to the (exporting) wholesalers after which they get to the (international) florists shops. This can be (unnecessary) time consuming and creates higher prices. This results from all involved parties making money and the many (unnecessary) costly steps in-between such as multiple handling moments, multiple transportation efforts, etc. The time consuming supply chain creates older products; thus a shorter vase life which results in a lower quality level of the web shop.

Courier Service

Web shops using a courier service strategy perform many more steps by themselves. After the order comes in, they collect all the needed parts, bind the bouquets, pack them and finally send them by courier service to the designated addresses.

This strategy makes it hard to deliver orders the same day, while next day delivery is possible; the packages are processed during the night, after which they are delivered during the day. The courier service strategy implies that the orders originate from the same place, which can be a florist, a warehouse, a retailer, a grower etc. Regardless of who manages the web shop, the products come from one place and are controlled by one party, which makes good inventory and quality control easier.

Compared to the strategy with a network of existing florists, the lead time will on average be longer, this due to the fact that the one or few locations of the web store are probably not scattered over the whole distribution region. This means that it is not possible for all regions to receive their goods in one day against a reasonable delivery charge. While it needs to be mentioned that the higher cost for the courier service worldwide may outweigh the higher initial prices for bouquets from foreign florists. Together this creates two options, offering a wide geographical area against high delivery charges, or limiting the delivery area.

Product quality and price is dependent on the position of the web shop in the supply chain, the number of chains and time passing by upstream of the CODP. When the web shop is owned and operated by a grower, a lot of steps in the supply chain will be skipped, which creates lower initial costs for the flowers, but a probably smaller, however fresher assortment (dependent on the size of the grower). On the other hand, when the web shop is owned by a florist, the same longer, more costly and time consuming supply chain lies behind the web shop as in the strategy with a network of florists. In that case a loss in time is made both on the preceding steps (upstream), as on the possible delivery time needed for distribution (downstream). Therefore, how beneficial the courier service strategy is, is dependent on the position of the web shop in the supply chain.

Beneficial in this strategy is that the same flowers and bouquets can be offered to all customers, in which only the delivery charges should be different (in which an average or the real charges can be charged to the customers). A disadvantage of delivery over longer distances can be packaging. Flowers are fragile products, which most of the times need water during transportation. This makes it necessary to transport them in a packing that ensures water for the flowers and protection against all handling activities.

Mixed Strategy

A small part of the web shops uses a mixed strategy: a combination of a courier service with a network of florists, in which the courier service is used for the smaller distances (only the Netherlands, or the Benelux) and the network of florists is used for longer distances and same day delivery.

This strategy can be seen as an extension of the courier service strategy. The courier service strategy can be very appropriate for the shorter distances, but is too time consuming or too expensive for the longer distances. This problem is solved; the more distant and same day ordering customers are served by locally based florists. Still all other (dis)advantages of the two separate strategies remain.

Green Transportation

It is getting more and more important to do business in a green, environmental friendly way; this also concerns transportation. Unfortunately from the 14 examined websites (regardless of the strategy), it is most of the times not directly visible on the website which kind of transportation mode is used. Only in a few cases it is stated which third party takes care of the transportation of the orders in case of use of a

courier service. When a network of florists is used it is not visible which transportation mode is used, this is probably due to the fact that every florist is responsible for its own delivery. Therefore, the level of 'green' of the competitors cannot be extracted from the websites.

3.4. Summary and Implications the Floricultural Sector

4. Supply Chain Description & Mathematical Model

The objective of this chapter is to provide a description of the intended supply chain network for the e-tail scenario. In this scenario, customers can order bouquets at a web site after which they will be delivered the next day or on a later day at the specified address. Therefore a good description needs to be given about the underlying supply chain network, which is responsible for the timely distribution of the bouquets to the customers.

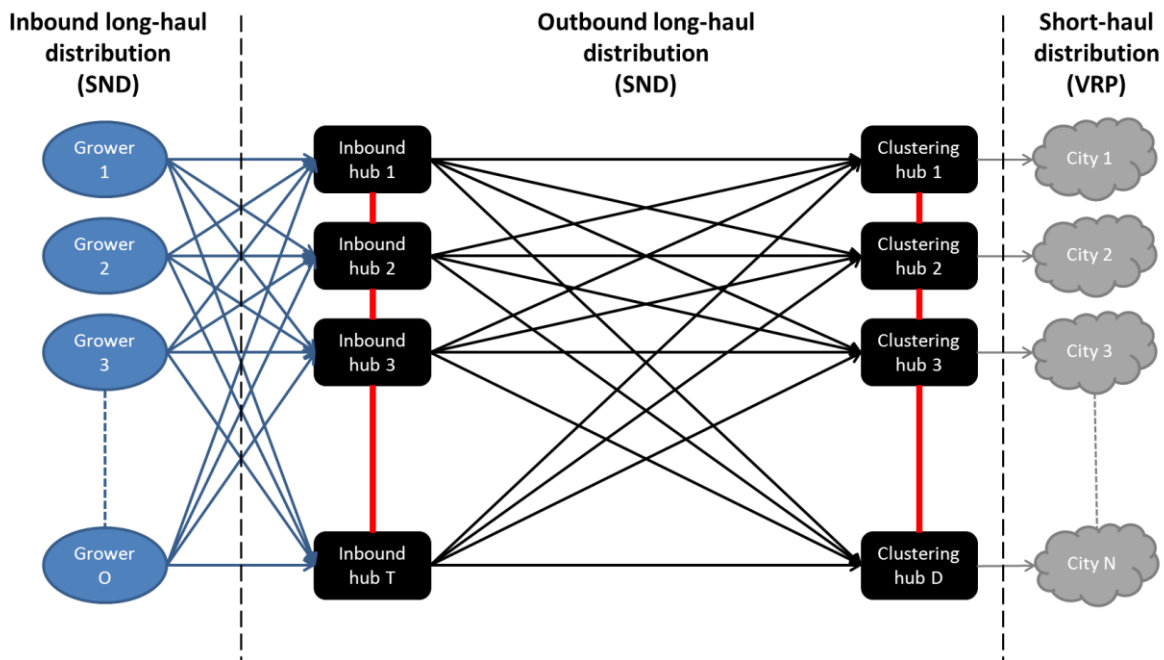


Figure 8: Schematic representation of the intended supply chain for the e-tail scenario

A supply chain is an integrated process in which a number of business entities collaborate to get from raw products to customer ready products, which can be delivered to customers. In this supply chain, transportation planning can be performed at three levels: strategic, tactical and operational. This research is aimed at the tactical level. Tactical planning models are 'a set of interrelated decisions that aim to ensure an optimal allocation and utilization of resources to achieve the economic and customer service goals of the company' (Crainic, 2000, p. 272). Tactical planning models are especially important for less-than-truckload (LTL) trucking, with a lot of consolidation movements. Tactical planning models consider for LTL trucking a service network design (SND) problem and a vehicle routing problem (VRP). The SND problem is aimed at the longer distances over the network and thus covers the logistic distribution network from grower till clustering hub; the VRP covers the scattered customers in the last mile transportation. Tactical planning models cover transportation systems on the level of one vehicle or convoy, which services one or multiple customers and pickup points with possible different origins and

destinations in which consolidation is an important aspect. The aim is to offer the promised service in a cost effective, fast, flexible and reliable way. Therefore the primary objective of tactical planning models is to minimize cost while having a high service level and thus trying to have a good balance between costs and performance (Crainic & Laporte, 1997).

A schematic representation of the intended supply chain can be seen in Figure 8. In this figure there are three main parts of the supply chain; inbound long-haul transportation (sourcing), outbound long-haul transportation and short-haul transportation. The long-haul transportation part is covered by a service network design (SND). The short-haul transportation is covered by a vehicle routing problem (VRP).

Demand and order characteristics

The whole supply chain will be designed as make-to-order (MTO); therefore the demand is especially in this research very important. The demand by customers and the order characteristics determine the functioning of the whole supply chain upstream. When using an e-tail scenario, you are not delivering anymore to a limited set of customers with a (relatively) large demand, but to a lot of single, widely scattered customers. These customers order especially in the case of flowers mostly one or maybe a few products per order. These widely scattered customers create many different O-D pairs.

That the supply chain is driven by demand means that at one or several moments during a day all orders at the website are aggregated to a total demand over a certain time span. This gives information about a total demand for a certain time span for the network. After this aggregation step, the needed flowers and green products are selected and consolidated according to delivery regions at the different inbound hubs. Next, these consolidated flows are transported directly or indirectly to the associated clustering hubs where the bouquets are made and the orders are packed, after which the orders are ready for the last mile distribution.

The choice to produce MTO instead of make-to-stock (MTS) is made because of the high perishability of flowers, the wide range of choices between bouquets on the website and the probable high fluctuations in demand; not only in total number, but also in the distribution between the different types of bouquets. Therefore after an order comes in, the needed flowers and eventual green product are selected at the different inbound hubs, after which they need to be transported to a clustering hub near the delivery address.

A customer order consists of a few customer characteristics which are specified by the customer at the moment of ordering (Figure 9). A customer needs to choose a certain bouquet (or more) from a predetermined collection. Each bouquet consists of a certain number of flowers which are from one or more types which can be complemented by one or two green products. Next, a delivery date and address needs to be specified, so that is clear where and when the order needs to be delivered. Finally, a choice can be made between green, cheap or fast delivery with associated delivery charges.

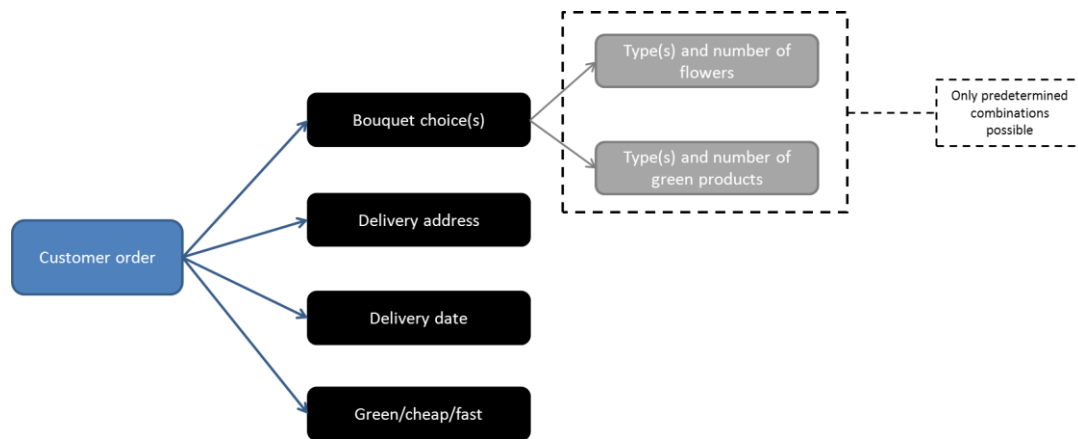


Figure 9: Customer order characteristics

Bouquets can only be made later on in the supply chain due to the fact that not all flowers and green products are available in the right combinations at each inbound hub. The individual flowers and green products therefore need to be transported to a selected clustering hub first, where the products can be combined into a bouquet; the end-product.

Chapter structure

In the first section a qualitative and quantitative description of the long-haul distribution part will be discussed. The second section covers the qualitative and quantitative description of the short-haul transportation. The third section covers issues while solving the mathematical SND model and calculating the last mile approximations. The last section covers the model inputs and outputs. Variables used in this chapter and their accompanying definitions can be found in Appendix E.

4.1. Long-haul Distribution

The long-haul distribution covers the logistic distribution network from grower till clustering hub which can be described by a SND model. First, a qualitative description is given in which sourcing, long-haul distribution and consolidation and clustering is discussed. Second a quantitative description is given which covers the SND model.

4.1.1. Qualitative Description Long-haul Distribution

This section explains the characteristics of the long-haul distribution part of the supply chain. This part needs to take care that all individual flowers and green products necessary to cover the customer orders are transported from the sourcing locations to the clustering hubs where they can be merged into bouquets and packed for transportation. The long-haul distribution is mainly driven by customer demand, because of the e-tail scenario and the use of minimal or no inventory at the clustering and inbound hubs. After aggregation of demand over a certain time span, the planning for the transportation network can be made and transportation can start. It is due to the e-tail characteristics and the very low to zero inventory levels that the long-haul part of the supply chain operates

accordingly, so that the orders are delivered at the right place in a timely matter; within a short time frame combined with a high customer service level.

It is assumed in this case that the locations of the sourcing locations, inbound hubs, clustering hubs and the cities for delivery are known, which makes this a service network design problem. In a service network design are, as previously mentioned, the terminals already present, These cover the consolidation of freight, grouping of products and cross-docking of freights and are connected with each other by physical or conceptual links. Demand is then grouped according to origin and destinations and transported over the network on specified routes by multiple vehicles. The network consists of end-of-line and break bulk terminals, where goods are inserted into the network and rearranged (Crainic & Laporte, 1997).

Sourcing

Flowers and green products are sourced from growers all over the world, main supplying countries are the Netherlands, Kenya, Ethiopia, Israel and Ecuador. At the moment these flowers are still transported to the Netherlands so that they can be sold at the auction houses after which they are further transported to worldwide destinations. In the future e-tail scenario of FloraHolland the sourced products are delivered at one or more inbound hubs. Each grower delivers to the most cost and/or time efficient inbound hub, which is not necessarily located in the Netherlands. In this the cost and/or time efficiency is also influenced by the location of end customers.

Long-haul Distribution and Consolidation

In-between the sourcing locations, inbound hubs and clustering hubs long-haul transportation is necessary to bring the products in a cost efficient, green or fast way to the clustering hubs. This can be done by direct or indirect distribution and is covered by a service network design. This transportation has three aims: first to bridge the longest part of the distance between the origin and destination of orders, second to rearrange all individual flowers so that the right flowers arrive at the right clustering hub and third to deliver them in a green, fast and/or cost efficient way.

At least one breakbulk and consolidation step is needed in the second part of the supply chain; when using direct distribution from each inbound hub to each clustering hub, the individual products that are meant for one clustering hub can be consolidated into one load. When using trans-shipment hubs and thus also indirect transportation, multiple break bulk and consolidation steps are needed at the different hubs.

Transportation over this service network can be done using different modalities. Dependent on the presence of multiple physical and/or conceptual links on each arc, different modes can be used. Physical links are available infrastructure such as railroads; conceptual links are connections between airports, waterways and the road infrastructure (Crainic, 2000). For example, when there is a rail road and a normal road available between hub 1 and hub 2, both truck and rail transportation is possible. Each

transportation mode has its own characteristics: speed (time needed to bridge the link), cost (fixed and variable), and CO2 emission. Combining the use of these characteristics with customer preferences about transportation, a choice can be made about the preferred mode of transportation.

Clustering

At the end of the transportation network, a few steps need to be taken before the orders are ready for the last mile distribution. The products need to be unloaded from the transportation vehicle, the individual products need to be combined (searched, selected and moved), after which the bouquets can be made according to the customer orders, the bouquets need to be packed and loaded into the assigned truck for the last mile distribution. In this research is assumed that these facilities already exist.

4.1.2. Quantitative Description SND Model

In this section the associated model for the service network design is given. A service network design is a network of transportation services which is based on a given set of terminals in which decisions need to be made on route characteristics (like frequencies, number of intermediate stops etc.), on the traffic assignment along these routes and the operating rules at each terminal (Ghiani et al. 2003).

Ghiani et al. (2003) propose a model for a fixed-charge network design (FCND). It is a general network flow model in which a fixed cost needs to be paid for using a certain arc. This model can be used for the determination of which arcs need to be employed in a network and to determine on which arcs which products need to be transported. In this research multimodality and transhipments hubs occur, therefore the given model by Ghiani et al. (2003) is extended to give a model that represents the description in the previous section. Additionally, the lead time is important in this research because of the high perishability of flowers and the fast pace of the e-tail market. Therefore, in some scenarios only arcs in combination with certain modalities are going to be considered in the model that take less than the maximum allowed lead time. This means that the following condition must hold before a certain arc in combination with a modality is included in the set of possible arcs. This condition is:

After the adjustment for multimodality and transhipment hubs, the model that represents the researches subject is:

Minimize

Subject to

The objective of this model is to minimize transportation costs; which consist of the sum of the cost for transporting q_{ij} flow units of commodity k on arc ij while using modality m plus the sum of the fixed cost for use of arc ij when using modality m . Under the following constraints: (1) the flow conservations holding at each vertex i and for each commodity k ; (2) that the flow of each commodity k is not larger than the capacity C_{ij} on every arc ij ; (3) that for each ij the total flow on arc ij is 0 if the arc is not used, and not larger than the capacity C_{ij} otherwise.

Also emissions are an important factor to FloraHolland, because of the importance on greener transportation. However compared to the lead time and multimodality, emissions are indirectly already incorporated in the cost function, and thus in the variable C_{ij} . C_{ij} are costs that are dependent on the flow of commodities. Emissions are also dependent on the volume of flow of commodities. Therefore while minimizing C_{ij} , also indirectly emissions are minimized.

With the transshipment hubs included in the model, the model can be used for the whole long-haul distribution; otherwise it is only appropriate for the outbound long-haul distribution part of the supply chain without intermediate transshipment hubs.

4.2. Short-haul Distribution

The short-haul distribution covers the last mile distribution from clustering hub to customer. First a qualitative description of the last mile distribution is given, which can be seen as a VRP problem. Second the approximation formulas for distances and cost for this described last mile distribution are stated.

4.2.1. Qualitative Description Last mile Distribution

After merging of the individual products, making of the bouquets, packaging and eventual combination of bouquets for one order, the orders need to be loaded into trucks after which the last mile distribution can start. The last mile distribution is the distribution to the specified delivery address, which can be a home addresses; company addresses etc. The last mile distribution covers mostly short distances at local or regional level. In the case of this research the distribution from one of the clustering hubs into one of the cities. This kind of distribution problem can be characterized as a vehicle routing problem (VRP); VRP

is defined as: 'the design of pick-up or delivery routes from one or more central depots to a set of geographically scattered customers' (Crainic & Laporte, 1997, p. 425).

A VRP problem can be solved in two ways, implicit or explicit. Explicit solving methods are used when actual data on delivery addresses is known. This is not the case in this research; this research is about a future scenario, which means that actual delivery addresses are not known. Therefore an implicit method needs to be used which makes approximations of the expected distances (per order or total) and the associated expected cost. This implicit method will be obtained from the book Logistic Systems Analysis from Daganzo (2005), and will be discussed in the subsequent sub-section.

In the case of this e-tail scenario the VRP is the design of delivery routes from the clustering hubs to customers scattered all over a city. Each clustering depot is dedicated to one city. Assuming that multiple routes are needed to cover the whole city, each route consists of an area within this city, in which a middle sized truck drives by all the assigned delivery addresses where he delivers the associated order(s). After finishing one route, the truck returns to the clustering hub after which the next route can start which will be on the same day, or another day dependent on the remaining time available in one work shift and the quantity of orders that still need to be delivered.

4.2.2. Mathematical Formulations Last Mile Distribution

In this section the approximation formulas for the last mile distribution will be discussed. In this research the exact locations of customers are not known. Next to that the delivery points are not a few fixed locations, but varying locations (in number and location) scattered over a wide area. But, there is always delivery from one clustering hubs to many delivery addresses in one city. Therefore it can be characterized by short-haul, one-to-many distribution (Ghiani et al., 2003) for which approximation formulas are given by Daganzo (2005).

According to Daganzo (2005, p. 93), one-to-many distribution is a 'physical distribution problem where items produced at a single origin are to be taken, without transshipments, to a set of scattered destinations over a service region'. In which the objective is to obtain simple guidelines for the development of delivery schedules and sets of routes while minimizing the total cost per unit time. First approximation formulas for the travelled distance will be next the associated cost will be added.

Distances

Daganzo (2005) gives approximation formulas to estimate distances for this one-to-many distribution problem. These approximations are feasible for situations in which data is not (yet) available, but where the characteristics of the problem vary slowly over both space and time. The approximations apply to situations in which a large number of destinations/customers (delivery addresses) are distributed over a certain region in a form that can be described by a slow varying continuous density function of point coordinates within a region.

Non-detailed near optimal vehicle routing strategies

The main aim of vehicle routing models is to minimize the total distance travelled over all routes. The total distance is a key indicator of cost, therefore indirectly the total cost are minimized. It is assumed in this chapter that identical vehicles are used, which are capable of carrying v_{max} items. In which v_{max} can be a unit of volume or weight of an item or of the whole vehicle. In this, each destination requires a certain number of unit's volume (or weight) which contains the required products (Daganzo, 2005). In the case of this research one unit can be seen as one bouquet.

Vehicles leave the origin (depot) at t_ρ on service routes to a particular subset of customers. The aim is to find a delivery schedule which covers all customers while minimizing transportation costs at each t_ρ . The cost of transportation of one vehicle route is approximated by a linear function of the total size of the shipment, the number of stops and the total distance travelled. It is assumed that the different costs of vehicle routes are additive, which gives a total cost on t_ρ which is equal to the sum of the costs on each route; the total number of routes, the total volume shipped, the total number of stops, and the total distance (Daganzo, 2005).

The strategy is to minimize the number of vehicle routes and with that the total distance, part of this strategy is that the number of delivery stops at one customer needs to be minimized and thus that load-splitting among vehicles is avoided. This not always provides the most optimal solution, but the possible improvements are according to Daganzo (2005) negligible. With this strategy (only aiming at minimizing distance), routes can be designed without knowing cost coefficients.

The formulas are developed for distance estimations (and so transportation cost) using the following parameters: numbers of customers to be served at time t_ρ ; their spatial distribution over the region; and the number of stops for each vehicle, $S = \left\lceil \frac{v_{max}}{v} \right\rceil$. This operates under the assumption of equal lot sizes for each customer; which gives an equal S for all vehicles (Daganzo, 2005). This is an acceptable assumption in this research; bouquets are approximately of the same size, and most customers only order one bouquet at a time.

Many vehicle tours ($N \gg S^2$)

This research is designed based on the assumption that 60 percent of all flower sales go through an e-tail channel. This ensures that there is enough demand to have $N \gg S^2$, multiple more customer destinations than stops. It needs to be mentioned that each vehicle should be used to the fullest, and that there will be maximally one vehicle that is not used to the fullest and thus makes less than S stops. The routing strategy by Daganzo (2005) is cluster-first, route second; the service region is therefore divided into non-overlapping zones containing S customers; each zone should therefore be visited by a separate vehicle route. The routes will be constructed by minimizing the total distance, which is done by designing the zones according to specific shapes and orientations, dictated by the relative magnitude of N and S^2 (Daganzo, 2005).

The total distance travelled within one of these zones, when visiting S points in a zone containing point x_0 is then approximated by (Daganzo, 2005):

$$\text{tour distance} \approx 2r + \left[z\delta^{-\frac{1}{2}}(x_0) \right] S$$

The first term represents the line-haul distance from the depot to the centre of gravity of the points in the zone. The second term represents the local distance travelled to cover all points in the area. z is the dimensionless constant that depends on the used metric; its value is 0.57 for the Euclidean metric and 0.82 for the L_1 metric (Daganzo, 2005).

Costs

Cost of transportation can be approximated in relation to distance. According to Daganzo (2005), rate books reveal that fixed and variable cost are mainly dependent on distance, which makes it possible to get a good approximation of total transportation cost. Approximations of the distance are already given in the previous section. These approximations can then be used for the cost calculations.

The formula given by Daganzo (2005), for transportation cost approximations for one-to-many distribution is:

$$\text{cost for } n \text{ shipments} \approx c_s(1 + n_s)n + c_dnl + c'_sV$$

The first component, $c_s(1 + n_s)n$, represents the cost for stopping. It includes the fixed cost of the initial stop in which the vehicle waits until it is loaded and unloaded and the fixed cost for each additional stop at individual customers in which the vehicle needs to wait until the package is taken out of the vehicle and delivered at the delivery address. The second component, c_dnl , is the cost for each incremental vehicle-km; it is the cost charges for each km travelled, regardless of the vehicle's content. The last component, c'_sV , are the additional cost when carrying an additional item; a penalty for delaying the vehicle at stops for loading and unloading, and a penalty for handling the item within the vehicle (Daganzo, 2005).

The previous formula can also be written as the cost per shipment and the cost per item:

$$\text{cost per shipment} \approx c_s(1 + n_s) + c_d l + c'_s \bar{v}$$

$$\text{cost per item} \approx c_s \frac{1 + n_s}{\bar{v}} + c_d \frac{l}{\bar{v}} + c'_s$$

In which $V = \bar{v}n$.

4.3. Solving the mathematical model and Last Mile Approximations

After explaining this mathematical model and the approximation formulas, these can be applied to the e-tail scenario. The application will be discussed in this paragraph.

Service Network Design Model

The SND model described in paragraph 4.1.2 can be seen as a Mixed Integer Linear Programming model (MILP). The next step after formulating the mathematical model is applying this model to the cut flower sector and solving it to (near) optimality. Solving the model can be done in an exact way, or by use of heuristics. For this linear fixed-charge network design (LFCND), which is NP hard, small instances of a few hundreds of arcs and tens of commodities can be solved by branch-and-bound algorithms to an exact solution, otherwise heuristics need to be used (Giani et al., 2003). Because of the large problem, with many instances, solving exact is not an option in this situation, it would take too much computational resources. Therefore a small version of the model with a few instances is modelled in GAMS to test the model. This indicated that the designed model from paragraph 4.1.2 is a working model. But, to do calculations on the situation with many instances in this research, another more sophisticated program is needed. Therefore a larger model will later be tested in the mathematical optimization tool LogicNet.

Last Mile Approximations

The approximation formulas for the last mile distribution can be used in the upcoming chapters to make approximations for the distances and costs. To do this in an appropriate way, reasonable reliable data is needed to make good approximations.

4.4. Model Inputs and Outputs

In the previous sections both the SND model as the approximation formulas are described. Certain inputs are needed for the approximation formulas and for testing the SND model in LogicNet. Also certain outputs are desired from the approximation formulas and the model in LogicNet. Both the inputs and the desired outputs are stated in Table 3. The inputs are carefully compiled to the best of knowledge from sources and expert opinions within FloraHolland combines with external sources. Further detail can therefore be found in Appendix F, next to more extensive explanations concerning the outputs.

Input	Output (KPIs)
<i>General:</i>	<i>Transportation cost:</i>
Product details	Total cost
Sourcing locations	Total inbound cost
Inbound hub locations	Total network cost
Clustering hub locations	Total last mile cost
	Total cost per bouquet

Customer locations on city level Demand aggregated on a daily basis per product type per city over a time span of one year Supply aggregated on a daily basis per product type per sourcing location over a time span of one year	Inbound cost per bouquet Network cost per bouquet Last mile cost per bouquet
<i>SND:</i> Transportation cost per modality for all transportation links Inventory holding cost Transportation time per modality for all transportation links Capacity constraints of modalities Emissions per ton/km per modality	<i>Lead time:</i> Average lead time per bouquet Maximum lead time per bouquet
<i>Last mile:</i> Cost parameters: Cost per stop Cost per vehicle km Cost per additional item Customer density Flower box details Medium truck capacity constraints	<i>Emissions:</i> Total emissions supply chain SND emissions Last mile emissions Average emissions per bouquet

Table 3: Model inputs and outputs

The key determinants for the model are lead time, transportation cost and emissions which will be calculated and compared in the scenarios defined in the subsequent chapter.

4.5. Summary Supply Chain Description

The supply chain can be characterised by a network in which bulk products are delivered by growers (associations) or fresh providers at certain inbound hubs of the network. The destination, composition of the product and the required mode of transportation are decided on by the many individual customers, which demand bouquets instead of single products and are widely scattered over a large region. This creates many different O-D pairs and necessary breakbulk and consolidation steps.

This transportation network can be characterized by a SND model for the long-haul transportation part and a VRP problem for the last mile distribution. Mathematical formulations are given for both; the formulas for the last mile distribution will be used to approximate last mile distances and cost; for the SND model the mathematical optimization tool LogicNet will be used to test different scenarios.

5. Case Study

A case study is designed to test the proposed supply chain description provided in chapter 4. To test the case study certain choices are made which proceed on the scope described in section 3.3. Therefore consecutively the following choices are briefly outlined: countries, cities and clustering hubs, products, sourcing, inbound hubs and green/cheap/fast. Extensive explanations can be found in Appendix G.

5.1. Choices

The choices in the case study are briefly outlined in this section.

Countries

The market is defined as six countries; the Netherlands, Belgium, Luxembourg, Germany, France and the United Kingdom. Together they form a connected chain of countries which represent the key markets for cut flowers for FloraHolland. Together they represent approximately 76% of the turnover of FloraHolland. Both inbound hubs, the transportation network, clustering hubs and the end customers are present in these six countries.

Cities and clustering hubs

Ten cities are chosen scattered over the six countries in which customers can order bouquets from the e-tail channel. The cities are chosen according to three criteria: the size of population, the accessibility with different transportation modes and the spacing in-between the different cities. This ensured that there is enough distance in-between the cities to use cost (green) and time efficient multimodal transportation; cities are accessible with at least two different transportation modalities; and they are large enough to create a substantial demand of bouquets each day. The chosen cities are: Amsterdam, Brussels, Luxembourg, Munich, Berlin, Hamburg, Marseille, Bordeaux, Paris en London. The borders and 'size' of these cities is determined by use of the definition of NUTS 3 regions by the European Union (European Commission, 2012).

Customers in the cities are supplied using last mile distribution starting from a clustering hub. Because of the widely scattered cities across the six countries, each city gets its own clustering hub. A clustering hub is located at the edge of the city and has next to road access, access to one or two other transportation modalities. This means that next to having road access it needs to be close to a cross docking place for inland barges (short sea) and/or close to an intermodal train terminal.

Products

Bouquets ordered at the e-tail channel in the six countries consist out of a subset of 10 products. These 10 products are 8 different kinds of flowers and 2 sorts of green products. The flowers are chosen from the top 15 flowers in the six countries. Not every flower has the same level of popularity in each country, but a selection is made based on a weighted popularity over the six countries. For green products, the two most sold products by FloraHolland are chosen. All 8 types of flowers are highly

aggregated cut flower types. Normally each type can consist out of large assortment of different subtypes; different colour, size, quality etc., but only products at a high aggregation level are taken into account in this research.

Together the 8 flower groups represent 69.7% of the turnover of FloraHolland ((FloraHolland, 2011)). The resulting list of products can be found in (Table 4). The Latin names will be used throughout the chapters.

At the e-tail channel it is possible to order mono and mixed bouquets. A mono bouquet consists of one type of flower without green products; a mixed bouquet consists of 2-4 different kinds of flowers and one or two types of green products. Both types of bouquets contain 15 flowers in total; additionally the mixed bouquets are complemented with 8 green products. This makes these bouquets more high-end with a selling prices around 12.00-15.00 euro.

English name	Latin name	Dutch name	Origin
Rose	Rosa	Roos	Aalsmeer, Naaldwijk, Ecuador, Ethiopia, Kenya
Tulip	Tulipa	Tulp	Aalsmeer, Naaldwijk
Chrysanthemum (spray)	Chrysanthemum (spray)	Chrysant (tros)	Aalsmeer, Naaldwijk
African Daisy	Gerbera	Gerbera	Aalsmeer, Naaldwijk
Freesia	Freesia	Freesia	Aalsmeer, Naaldwijk
Carnation	Dianthus	Anjer	Aalsmeer, Naaldwijk, Colombia, Ethiopia, Sicily (IT), Naples (IT), Kenya, Portugal, Almeria (SP), Jerez de la Fronterra (SP)
Lely	Lilium	Lelie	Aalsmeer, Naaldwijk, Ethiopia, Israel, Spain, Tanzania
Peruvian Lily	Alstroemeria	Alstroemeria	Aalsmeer, Naaldwijk
Ruscus	Ruscus	Ruscus	Israel
Pittosporum	Pittosporum	Pittosporum	Israel

Table 4: Chosen products and country of origin

Sourcing (growers)

The 10 products are sourced from 13 locations across the World; Aalsmeer, Naaldwijk, Colombia, Ecuador, Ethiopia, Tanzania, Israel, Kenya, Sicily (IT), Naples (IT), Portugal, Almeria (SP) and Jerez de la Fronterra (SP). These locations are selected based on the amount of products per product type they supply on a yearly basis. From the 10 products, 5 products are only sourced from the Netherlands; the other 5 products are sourced from multiple locations across the world. Product and sourcing location combinations can be seen in Table 4.

Inbound hubs

Products from the different sourcing locations can be delivered at 10 inbound hubs across the six countries. These inbound hubs are chosen according to most likely arrival points of supplies in the network. For this five airports and five sea ports are chosen which are a logical extension of worldwide sourcing; they have the possibility of receiving airplanes or containerships from all over the world, to good access to other modalities. The airports and sea ports represent the largest cargo airports and sea ports across the six countries or are already in use for receiving flowers. The airports are: Schiphol Airport, Liege Airport, Frankfurt am Main, Charles de Gaulle and Heathrow Airport. The sea ports are: Port of Rotterdam, Port of Antwerp, Port of Hamburg, Port of Marseille and Port of Tilbury.

Logistic distribution network

An explanation of the metro model is provided in section 2.1. Although for this case study a small adjustment needs to be made to the possible links in the metro model. The start hubs are the sourcing locations (growers), these can be linked (one-way) to all inbound and clustering hubs to which transportation is possible with one or more modalities. Cities are only connected to the clustering hub dedicated to the city.

Green/Cheap/Fast

As stated in section 2.1, customers can declare with their order if they want it delivered in a green, cheap or fast way. This would mean that each individual order has its own constraints on possible transportation routes and modalities. When, for example, a maximum is set on transportation cost, or on emissions for that specific order. In this case study the customer's choice is translated to one objective function for the whole supply chain; minimize lead time or minimize cost (emissions), to test the model described in chapter 4. In this, cheap and green can be seen as the same objective; cheaper modalities are also more environmental friendly.

5.2. Summary Case Study

In this chapter the case study used to test the model provided in the previous chapter is described. The previous led to a case in which 10 products can be sourced from 13 worldwide locations and need to be transported to customers in 10 different cities scattered over six countries by using a transportation network consisting of 10 inbound hubs and 10 clustering hubs. This case description makes it possible to test different network design scenarios that will be defined in chapter 6.

6. Design

For the design of the supply chain network, different scenarios will be taken under consideration in order to find an appropriate design for the distribution network for the e-tail scenario in the floricultural industry. In the first section the structure of the different scenarios will be discussed. In the second section the chosen scenarios will be explained and analysed. Sub-section 6.2.1 contains the analysis of the base scenario (Current Situation) and the adjusted base scenario (Adjusted Current Situation). Sub-section 6.2.2 contains the analysis of the alternative scenarios. Last mile calculations are provided in the third section, concluding with a brief summary in the last section.

The analysis and numbers from section 6.2 only contain costs, time and emissions for the long-haul distribution part of the supply chain. The cost, time and emissions for the last mile distribution are analysed in section 6.3.

6.1. Structure Scenarios

Each scenario will be defined using one objective function and a set of constraints and options. The possible choices in objective function, constraints and options can be seen in Figure 10.

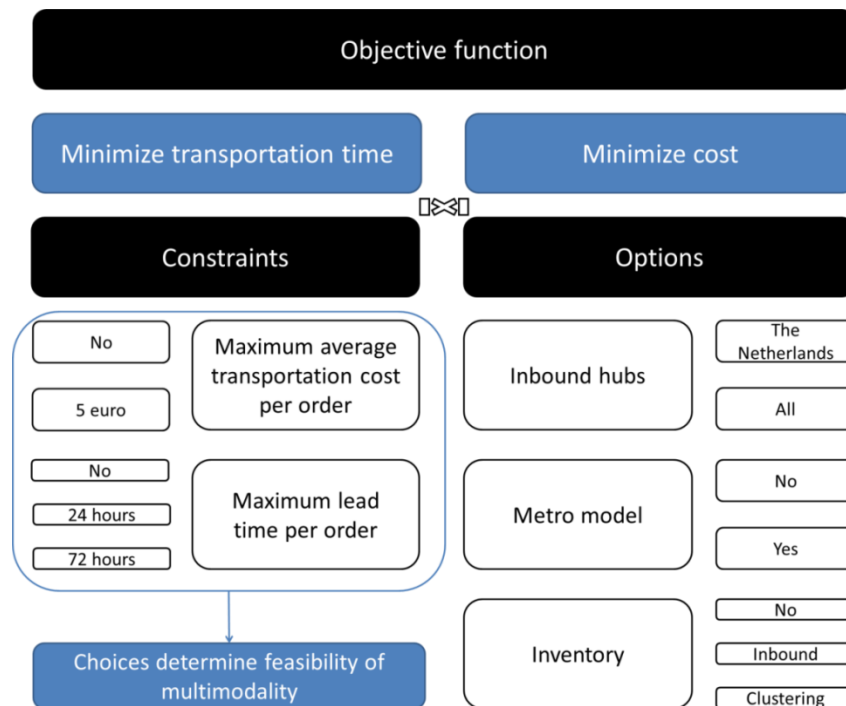


Figure 10: Set of criteria used to construct the scenarios



Figure 11: Outline chosen scenario with accompanying legend

Objective Functions

The two objective functions come from the possible company objectives: minimize cost or minimize lead time. The objective function minimize lead time comes from the e-tail character of the sales channel and the high perishability of cut flowers. Customers ordering online want their order within an acceptable time limit (preferably 24 hours) and want to enjoy a long as possible vase life of their bouquet. The constraint minimize lead time means therefore that the time from the moment of ordering until the time of receiving the order needs to be minimized. The objective to minimize costs aims at the cost of transportation from grower till consumer and is based on three aspect: competition, outsourcing and customer willingness to pay. First, you do not want to be more expensive than competitors offering the same or similar products on the web; it could make you lose customers. Second, when it is cheaper to outsource the transportation to a specialized third party, you would consider this option. Third, if a customer is not willing to pay the shipping cost, they simple don't buy it or buy it somewhere else. The constraint to minimize costs means therefore that the transportation costs over the whole logistic distribution network are minimized.

Constraints

Two constraints are possible: a maximum average transportation cost per item or a maximum lead time per order. These constraints are in line with the objective functions and can be used in combination with the opposite objective function to put a cap on lead time or cost. This way, both objectives can be integrated in the model. Maximum lead time can be, for example, that all orders need to be delivered within 24 hours. Maximum average transportation cost per item is, for example, that on average you do not want to spend more than €3.00 on transportation per bouquet.

Options

The options to the model are add on options to the base model, the choices are: inbound hubs, metro model and inventory. The option 'inbound hubs' means that products can only be delivered at inbound hubs in the Netherlands (Port of Rotterdam or Schiphol Airport), or that the products can be delivered at all of the 10 inbound hubs across the six countries. Metro model means as explained in section 2.1 that not only shipments between inbound and clustering hubs are possible, but also among inbound hubs, among clustering hubs and from European sourcing locations directly to clustering hubs. So, when metro model is not used as an option, it is only possible to deliver from the sourcing locations to the inbound hubs, from the inbound hubs to the clustering hubs and from the clustering hubs into the cities. Inventory is the choice between allowing no inventory or a minimum amount of inventory at the hubs in which also a location for inventory needs to be picked; at the inbound hubs, the clustering hubs or both.

Multimodality

Multimodality means that in addition to using one modality (trucks) for transportation movements across Europe, also trains and barge can be used. The inbound streams from sourcing locations outside

of Europe till inbound hubs are by air cargo and/or container sea freight. The last mile distribution is always executed by a middle sized truck.

For the scenarios discussed in the following paragraphs, choices will be made between the previously mentioned objective functions, constraints and model options. The combination of these will determine the possibility of multimodality.

6.2. Scenarios

The scenarios used in this section are built upon the components mentioned in section 6.1. First a base scenario (Current Situation) is created, having the aim to approach reality as much as possible. All other scenarios are extensions of this base scenario in which one or two extra constructs are added to the base case and/or the objective function is changed. Only minor changes are made for the sake of analysis; it makes it possible to examine the effect of each component individually. Finally a new extensive transportation network will be examined. This network contains multiple components and represents the final design of the future e-tail scenario. The chosen scenarios for analysis can be seen in Figure 11, an extensive explanation per scenario is provided in the subsequent section.

6.2.1. Current Situation Scenario (A0) and Alternative Current Situation Scenario (B0)

The current situation scenario (A0) is designed as reference point to reality for all alternative scenarios. This makes it possible to analyse the different scenarios with possible network improvements on the basis of the key performance indicators: lead time, cost and emissions.

The current situation scenario (A0) is based on the current operations in the floricultural sector as visually can be seen in Appendix C. An analysis of this current supply chain can be found in Dat (2010) or even more extensively in Jonkman (2010). A short abstract description which is the basis for the current situation scenario (A0) is given below:

In the current situation (only from a transportation point of view) products are sourced from a very large number of growers all over the world. This can be aggregated to locations based in the Netherlands, Africa, Southern America, Southern Europe and Israel. Products are transported from the sourcing locations to the FloraHolland auctions in the Netherlands. Products originating from outside of Europe are mainly transported by air cargo arriving at Schiphol Airport and sometimes by sea container arriving at the Port of Rotterdam. Products originating from inside of Europe are mainly transported by truck and arrive at the different auctions. After the auction products are rearranged according to their buyer and transported to their end location/customer. These customers are mainly detail and retail sales channels; however in this case it is assumed that the customers buy through the use of the e-tail channel.

The sector mostly emphasises on speed for quality reasons. Cut flowers are highly perishable goods and conditioning of these goods is not yet practiced that much. Inventory is minimized as far as possible; estimates are that products lose 10-15 percent of their value within 24 hours (Experts FloraHolland, 2012 - 2013).

Therefore the current situation scenario (A0) is based on the objective function: minimize lead time. Only the inbound hubs in the Netherlands are used; Schiphol Airport and the Port of Rotterdam. There is no inventory, no metro model and no cap on the transportation cost or the lead time per item. The transportation modalities used are air cargo, sea container and truck.

An alternative current situation scenario (B0) is designed to see the differences in objective function. It is the same scenario except that the objective function is now minimizing cost. In practice, the main aim is minimizing lead time, but not against all costs. Therefore a counterpart is designed to see the effect on performance.

Current Situation scenario (A0) performance (Table 5):

The base scenario fulfils 100% of demand for a cost of € 24,308,957 on a yearly basis. This is divided in € 22,694,695 on inbound streams (from sourcing locations to inbound hubs) and € 1,614,263 on network streams (from inbound hubs and clustering hubs).

According to experts in the field, inbound cost per single products sourced from the Netherlands is approximately 4.0 eurocents, sourced from Kenya 7.0 eurocents. Taking into account that over 70% of the products are sourced from the Netherlands, makes 4.0 eurocents per single product a bit low, but acceptable price. Network streams contribute only for 0.3 eurocents per single item. This is mainly so low due to high efficiency levels and chosen packing methods. Together this results in a total transportation price of 87.2 eurocents per bouquet and 4.3 eurocents per single product.

The average lead time in the base scenario is 0.41 days; so almost 10 hours, with a maximum of 0.88 days (21 hours). When recalling that this scenario only takes trucking into account as modality and that all products go by inbound hubs in the Netherlands, then an average lead time of 0.41 days is a good representation of reality.

Emissions are 12,436,400 grams a year; this is 0.45 grams per bouquet. There is no clear reference point for this value. Therefore emissions will only be compared in relation to each other.

Verification

Verification and validation of the results is important to ensure that results obtained are reliable and represent reality.

Verification is covered by use of the software tool IBM LogicNet XE 7.2. LogicNet is a mathematical optimization tool developed by IBM. As LogicNet is a broadly used software tool in business and the

academic world and developed by the representative company IBM. It is assumed that verification is already covered for by IBM. Therefore it is assumed that the software works properly and gives reliable results; that algorithms are implemented correctly and that the software works without errors or bugs.

Validation

Validation needs to be done to ensure that the model is a good representation of reality. According to Van Aken et al. (2007) model validity is divided into three sorts: construct validity, internal validity and external validity.

Construct validity is ensured in this research due to the extensive qualitative supply chain and problem description in chapter 4. Next to this, the cost based results are discussed with people from FloraHolland. Data on prices is not known exactly, but is created by people, having expert knowledge. Therefore construct validity is not fully substantiated. Internal validity is ensured by the quantitative description in chapter 4. The model used is well recognized among professionals, which ensures that the model is internally valid. External validity needs to ensure that the model is applicable to a broad set of situations. The model in this research is based on an e-tail scenario in the floricultural industry. However, the model could easily be applied to situation outside of the floricultural industry or on other market segments. As long as it implies transportation of multiple products from sourcing location to customers with in-between possible breakbulk and consolidation hubs, and use of multimodal transportation, it can be used. Only the parameter values need to be changed. The high applicability to other situation ensures high external validity. Together these three aspects of validity partly ensure model validity.

Performance Alternative Current Situation scenario (B0) (Table 5):

The alternative scenario is in total 16.8 percent cheaper than the current situation scenario; with a total cost of €20,236,830 which is 72.6 eurocents per bouquet and 3.6 eurocents per individual product. This result is expected due to the difference in objective function. When examining the results closer, it shows that the gains are made at the inbound transportation, with a slight loss at the network transportation. This effect is mainly caused by trading air cargo for container transportation which in turn creates that the inbound hub Schiphol is traded for the inbound hubs Port of Rotterdam which creates a small difference in cost.

The lead time performance is as expected. Due to the objective function the lead time is slightly worse than in the current situation scenario; 0.41 days (+2.0%). But it needs to be mentioned that a tiny increase in lead time can yield large improvements in cost.

The decrease in emissions compared to the base scenario is tremendously, especially when looking again at the tiny loss in lead time; a decrease of 87.2%.

Scenario		A0	B0	A0	B0
<i>Transportation cost (euro):</i>	Total Inbound	22694695	18592192	100	81.9
	Total Network	1614263	1644638	100	101.9
	Total transportation cost	24308957	20236830	100	83.2
	Inbound per bouquet	0.814	0.667	100	81.9
	Network per bouquet	0.058	0.059	100	101.9
	Total per bouquet	0.872	0.726	100	83.2
	Inbound cost per single product	0.040	0.033	100	81.9
	Network cost per single product	0.003	0.003	100	101.9
	Total per single product	0.043	0.036	100	83.2
<i>Lead time (days)</i>	Average	0.41	0.41	100	102.0
	Maximum	0.88	0.85	100	96.4
<i>Emissions (gram)</i>	Total	12436400	1595688	100	12.8
	Per bouquet	0.446	0.057	100	12.8

Table 5: Performance current situation scenario (A0) and adjusted current situation scenario (B0)

6.2.2. Alternative Scenarios

The alternative scenarios are extensions of the current situation scenario (A0), in which the objective function can be changed, and constraints and options can be added. So every scenario is the current situation scenario (A0) with a possible change in objective function and possible additions in terms of constraints or options. All alternative scenarios allow the use of multimodality; though the constraints on lead time, cost and emissions determine which modalities on which links can actually be used.

For every (group of) scenario(s) a description of the scenario(s) is given before the expected results are discussed. Afterwards, the performance of the scenario(s) is discussed and compared to the (alternative) current situation scenarios. A comparison is made against the scenario (A0 or B0) with the same objective function. For scenarios which use the option all inbound hubs combined with others options or constraints, a comparison will be made in relation to either the European inbound MIT (A1) or MC (B1) scenario. The chosen scenarios will be discussed in the following sections.

European Inbound MLT (A1) and European Inbound MC scenarios (B1)¹

These scenarios contain the extension: all inbound hubs. This means that products from sourcing locations can be delivered at the inbound hubs in the Netherlands (Schiphol Airport and Port of Rotterdam), as well as be delivered at 8 other inbound hubs across the six countries (Port of Antwerp, Liege Airport, Port of Tilbury, London Heathrow, Port of Hamburg, Frankfurt am Main Port of Marseille and Charles de Gaulle).

¹ MLT = Minimize Lead Time, MC = Minimize Cost

Instead of sending all products through a detour via the Netherlands, they can now directly be delivered at inbound hubs that are more time and/or cost efficient in relation to the location of the customer. For example, roses bought by customers in Munich now go from Kenya to Frankfurt am Main to Munich instead of via Schiphol Airport or the Port of Rotterdam. This would hopefully create savings in time, costs and emissions. Time savings can be achieved by decreasing transportation time from inbound hubs to clustering hubs. Cost and emission savings can be caused by decreasing the distance and time needed for transportation. The expected results are that products can get faster, cheaper and greener to their customers. Unfortunately there is a possibility of more expensive transportation due to thinner products streams.

Performance European Inbound MLT scenario (A1) (Table 6):

The European inbound MLT scenario is compared to the current situation scenario (A0). There is a slight increase in cost of 2 percent, which is mainly caused by inbound transportation. This can be explained by thinner product streams caused by 10 instead of 2 'end' locations for inbound transportation, which causes that the containers are less occupied. However improvements are made at the network transportation cost (-3.8%), this is caused by the delivery of products at inbound hubs closer to the customers, so that the distance travelled after the inbound hubs gets shorter. Together this leads to a total price of 88.9 eurocents per bouquet, which is 4.4 cents per single product.

This shorter distance also results in a shorter average lead time of 0.27 days (-34.1%), the maximum lead time remains the same. The increase in emissions (+5.8%) is caused by the less efficient use of inbound transportation. More air cargo and less occupied containers is used, which both cause an increase in emissions.

Performance European Inbound MC scenario (B1) (Table 6):

The results of this scenario are as expected. Costs decrease (-4.1%) both on inbound transportation (-1.3%) as on network transportation (-35.4%). Again savings are made on network transportation due to the delivery at inbound hubs closer to customers. Together this leads to a price of 72.6 eurocents per bouquet, which is equal to 3.6 eurocents per single product.

These savings due to shorter distances between inbound hubs and clustering hubs also appears in the average lead time; 0.41 days (-1.1%). It needs to be said that the average decreases, but that there are outliers with a maximum of 1.74 days. This is caused by choosing a (slower) train on the longest distances above a fast truck.

Emissions again decrease drastically compared to the alternative current situation scenario (-24.3%). This is caused due to prioritizing cheaper and thus greener transportation modes both on inbound as on network transportation.

A remarkable point when comparing scenario A1 with B1 is that scenario A1 only uses trucks for the network transportation, while scenario B1 uses all modalities.

From now on, scenarios will be compared to the European inbound scenarios (A1 and B1), as all further scenarios incorporate the construct 'All inbound hubs'.

Scenario		A0	A1	A0	A1	B0	B1	B0	B1
<i>Transportation cost (euro):</i>	Total Inbound	22694695	23236784	100	102.4	18592192	18342973	100	98.7
	Total Network	1614263	1553470	100	96.2	1644638	1063175	100	64.6
	Total transportation cost	24308957	24790254	100	102.0	20236830	19406148	100	95.9
	Total per bouquet	0.872	0.889	100	102.0	0.726	0.696	100	95.9
	Total per single product	0.043	0.044	100	102.0	0.036	0.034	100	95.9
<i>Lead time (days)</i>	Average	0.41	0.27	100	65.9	0.41	0.41	100	98.9
	Maximum	0.88	0.88	100	100.0	0.85	1.47	100	174.2
<i>Emissions (gram)</i>	Total	12436400	13153973	100	105.8	1595688	1208361	100	75.7
	Per bouquet	0.446	0.472	100	105.8	0.057	0.043	100	75.7

Table 6: Performance European Inbound Scenarios (A1 & B1)

Metro Model MLT (A2) and Metro Model MC Scenarios (B2)

These scenarios contain the extension All inbound hubs and Metro model. The extension All inbound hubs is already explained with the A1 and B1 scenarios. Metro model means that next to the normal transportation links it is allowed to have transportation in-between inbound hubs, in-between clustering hubs and from European sourcing location directly to clustering hubs. So, for example roses arrived at Schiphol Airport go via Frankfurt am Main to the clustering hub Munich. Or, products from Italy are directly delivered at the clustering hub in Munich instead of going first to an inbound hub. An extensive explanation about the concept metro model can be found in section 2.1.

The results aimed for with the metro model are savings in time, cost and emissions. Every individual product can choose its own most time and/or cost (green) efficient route between its origin and destination which creates a very flexible system. However, it can be the case that the occupancy of the vehicles is not high enough to be more cost efficient and greener with the metro model than without.

Performance Metro Model MLT scenario (A2) (Table 7):

The performance of the Metro model MLT scenario (A2) is not as good as expected. The average lead time compared to the European Inbound MLT scenario increased by 0.4 percent. In costs, positive results are achieved (+1.9%). The cost decrease is mainly caused by a decrease in total network costs; products are now directly shipped to the clustering hubs, which creates a smaller need of transportation movements over the network. In total, this results in a price of 87.3 eurocents per bouquet, which is equal to 4.3 eurocents per single product. Emissions remain almost the same (+0.1%).

Performance Metro Model MC Scenario (B2) (Table 7):

The performance of this scenario is better than the performance of its counterpart; costs remain the same, but lead time is improved at the expense of emissions. The costs are moved from the inbound transportation costs to network transportation costs, with a very large increase in total network costs (+5.1%). This is explained by the metro model, where extra transportation movements in-between inbound hubs and in-between clustering hubs are made. Together this leads to a price of 69.6 eurocents per bouquet, which is equal to 3.4 eurocents per single product.

Savings on the lead time are large (-18.5% compared to scenario B0, -17.6% to scenario B1), but on the contrary there is an increase in emissions, probably due to more transportation movements inside the network

Scenario		A1	A2	A1	A2	B1	B2	B1	B2
<i>Transportation cost (euro):</i>	Total Inbound	23236784	23195787	100	99.8	18342973	18313846	100	99.8
	Total Network	1553470	1134583	100	73.0	1063175	1116983	100	105.1
	Total transportation cost	24790254	24330371	100	98.1	19406148	19406148	100	100.0
	Total per bouquet	0.889	0.873	100	98.1	0.696	0.696	100	100.0
	Total per single product	0.044	0.043	100	98.1	0.034	0.034	100	100.0
<i>Lead time (days)</i>	Average	0.27	0.27	100	100.4	0.41	0.34	100	82.4
	Maximum	0.88	0.88	100	100.0	1.47	1.42	100	96.1
<i>Emissions (gram)</i>	Total	13153973	13161701	100	100.1	1208361	1260225	100	104.3
	Per bouquet	0.472	0.472	100	100.1	0.043	0.045	100	104.3

Table 7: Performance Metro Model scenarios (A2 & B2)

Inbound Inventory MLT (A3) and Inbound Inventory CM Scenarios (B3)

These scenarios contain the extensions All inbound hubs and Inventory at inbound hubs. The extension All inbound hubs is already explained. Inventory means that it is allowed to keep a minimum amount of inventory; in these scenarios this inventory is allowed to be kept at the inbound hubs.

Conditioning is at this moment not common practice in the floricultural industry. At this moment there are tests with container transportation of cut flowers in which these flowers are conditioned. Therefore it will probably be easier to keep cut flowers for longer periods and still have qualitative good products in the year 2020, which makes transportation with slower modalities attractive in cost and environmental friendliness.

Gains are hopefully made in these scenarios because of higher utilization of transportation; products are allowed to be kept in inventory for a little while so that transportation capacity can be utilized to the fullest. This will increase the time that a products needs in the supply chain, but decreases transportation costs and emissions. It needs to be mentioned that keeping inventory is not for free, the gains in transportation should therefore outweigh the cost for inventory.

The inventory is kept at the inbound hubs in these scenarios. This makes it possible for growers to deliver their products more in bulk after which the products can be moved to the customers on demand. Gains will therefore be made on inbound transportation in costs and emissions.

Performance Inbound Inventory MLT scenario (A3) (Table 8):

The performance of this scenario is not really different from the European Inbound MLT scenario. When looking very close, it can be seen that the total transportation cost are decreased a tiny bit (-€2139). Emissions vary a bit (-0.3%), which is probably caused by a slight change in choice of modalities.

Performance Inbound Inventory MC scenario (B3) (Table 8):

The performance of this scenario is also not really different from the European Inbound CM scenario. Only emissions vary a bit (+0.2%), which is probably caused by a slight change in choice of modalities or routes.

Scenario		A1	A3	A1	A3	B1	B3	B1	B3
<i>Transportation cost (euro):</i>	Total Inbound	23236784	23234657	100	100.0	18342973	18342973	100	100.0
	Total Network	1553470	1553457	100	100.0	1063175	1063175	100	100.0
	Total transportation cost	24790254	24788115	100	100.0	19406148	19406148	100	100.0
	Total per bouquet	0.889	0.889	100	100.0	0.696	0.696	100	100.0
	Total per single product	0.044	0.044	100	100.0	0.034	0.034	100	100.0
<i>Lead time (days)</i>	Average	0.27	0.27	100	100.0	0.41	0.41	100	100.0
	Maximum	0.88	0.88	100	100.0	1.47	1.47	100	100.0
<i>Emissions (gram)</i>	Total	13153973	13118382	100	99.7	1208361	1210269	100	100.2
	Per bouquet	0.472	0.470	100	99.7	0.043	0.043	100	100.2

Table 8: Performance Inbound Inventory scenarios (A3 & B3)

Clustering Inventory MLT (A4) and Clustering Inventory CM Scenarios (B4)

These scenarios have the extension All inbound hubs and Inventory at clustering hubs. The difference with the previous scenarios is the location of the inventory; it is now located closer to the customer at the clustering hubs. Expected advantages of this strategy would be that customers could be supplied very fast from inventory and that long-haul transportation (from sourcing locations to inbound hubs and from inbound to clustering hubs) can be better utilized, with use of cheaper and greener modalities while the lead time remains acceptable due to a more downstream CODP.

Performance Clustering Inventory MLT scenario (A4) (Table 9):

This scenario differs slightly compared to the European inbound scenario (A1) in cost (-1.8%). The benefits are mostly gained in the network transportation costs. The decrease in transportation cost is unfortunately not really enough to cover the inventory holding cost. All this together leads to a total transportation price of 87.3 eurocents per bouquet, which is equal to 4.3 eurocents per single product.

Lead time remains equal to scenario A1. There is a slight improvement on emissions which is probably caused by the higher occupancy of the network distribution.

Performance Clustering Inventory MC scenario (B4) (Table 9):

The performance of scenario B4 is again different from the base scenario, but not different from scenario B1, not at any of the KPIs. This is caused by the possible decrease in transportation costs made possible due to the option of inventory holding cannot cover the inventory holding cost.

Scenario		A1	A4	A1	A4	B1	B4	B1	B4
<i>Transportation cost (euro):</i>	Total Inbound	23236784	23211775	100	99.9	18342973	18342973	100	100.0
	Total Network	1553470	1140514	100	73.4	1063175	1063175	100	100.0
	Total transportation cost	24790254	24352290	100	98.2	19406148	19406148	100	100.0
	Total per bouquet	0.889	0.873	100	98.2	0.696	0.696	100	100.0
	Total per single product	0.044	0.043	100	98.2	0.034	0.034	100	100.0
<i>Lead time (days)</i>	Average	0.27	0.27	100	100.0	0.41	0.41	100	100.0
	Maximum	0.88	0.88	100	100.0	1.47	1.47	100	100.0
<i>Emissions (gram)</i>	Total	13153973	13134082	100	99.8	1208361	1208587	100	100.0
	Per bouquet	0.472	0.471	100	99.8	0.043	0.043	100	100.0

Table 9: Performance Clustering Inventory scenarios (A4 & B4)

Sensitivity analysis

A sensitivity analysis is conducted on inventory; both on allowed time for inventory as on the inventory holding cost. Even with very low inventory holding cost and allowing it to stay for a very long time, the model still chooses to transport in the same way as in model A1 and B1. This is probably caused by two reasons. First, the transportation of one single unit is so cheap that inventory holding needs to be almost for free to make inventory attractive. Second, due to the very high volume in the network it is possible to have high occupancy rates every day which makes it unnecessary to keep inventory.

Cost Competitive MLT (A5) Scenario

This scenario is an extension of the current situation scenario with the extensions All inbound hubs and Maximum average transportation cost per item. This scenario is created to get a view on what the minimal lead time feasible is while delivering against a competitive price. As stated in section 6.1, if you are too expensive, the possibility exists to lose customers.

The intended effect of this scenario is to find a balance between lead time and cost (and thus emissions). Cheaper and greener transportation should lead to longer lead times and vice versa.

Performance Cost Competitive MLT scenario (A5) (Table 10):

This scenario is, as expected, an improvement on cost on the European inbound MLT scenario. A maximum cost of 77 cents is used for transportation cost. This leads to a decrease in total costs; -14.2%.

The counterpart is the increase in time of 72% compared to the base scenario and even an increase of 160.7% to scenario A1. It needs to be mentioned that this should be taken in perspective, since the lead time is now 0.7 days, which is still within one day. Another beneficial point of the maximum cost per item is the decrease in emissions (-54.8%). Together this leads to total transportation costs of 88.9 eurocents per bouquet, which is equal to 4.4 eurocents per single product.

Scenario		A1	A5	A1	A5
<i>Transportation cost (euro):</i>	Total Inbound	23236784	20616657	100	88.7
	Total Network	1553470	662169.6	100	42.6
	Total transportation cost	24790254	21278826	100	85.8
	Total per bouquet	0.889	0.763	100	85.8
	Total per single product	0.044	0.038	100	85.8
<i>Lead time (days)</i>	Average	0.27	0.70	100	260.7
	Maximum	0.88	10.30	100	1172.8
<i>Emissions (gram)</i>	Total	13153973	5945761	100	45.2
	Per bouquet	0.472	0.213	100	45.2

Table 10: Performance Cost Competitive MLT Scenario (A5)

24 Hours Delivery (B5) and 72 Hours Delivery Scenarios (B6)

These scenarios are both based on the alternative current situation scenario in which the extensions All inbound hubs and Maximum lead time are used. Within the e-tail market and in comparison to competitors, as described in chapter 3, it is necessary to deliver flowers within 24 hours. Scenario B24 Hours delivery (B5) is therefore created to see at what cost it is possible to deliver a bouquet of flowers within 24 hours of lead time (thus from inbound hub to customer).

The constraint of 24 hours of lead time probably forces the model to only or mostly use the fastest and at the same time also the most expensive and least environmental friendly modality truck. Therefore the constraint is weakened to 72 hours in the 72 Hours of delivery scenario to see if other modalities are used when given a wider time window and what effect this would have on cost and emissions.

The intended result is therefore that with a constraint of 24 hours on lead time, cost and emissions will increase because of the use of mostly fast modalities. While with a 72 hour constraint the cost and emissions will decrease and all modalities are feasible to use within the given time window.

Performance 24 Hours Delivery scenario (B5) (Table 11):

This scenario shows very impressive results. It is only 0.8% (6.8% on the transportation network) more expensive than the B1 scenario, while the average lead time is decreased by 18.7% and the maximum lead time even by 43.6%. What needs to be mentioned is the increase in emissions (+8.4%). An inevitable result when the transportation on the network is forced to cover demand within 24 hours. In this situation almost always train and barge need to be replaced by trucking. Only on small distances it

remains feasible to use greener modalities. All this together provides that within 24 hours all bouquets are delivered for a transportation price of 70.1 eurocents.

Performance 72 Hours Delivery scenario (B6) (Table 11):

This scenario is the soft variant of 24 Hours Delivery scenario and only tops of the really time consuming links. These links are mainly short sea and really cost and time intensive due to a large detour around Europe. But still, compared to the European Inbound MC scenario there are improvements. Cost are almost equal (-0.1%) and there is a slight decrease in emissions (-0.8%). The biggest achievement of this scenario is that it managed to decrease the average lead time by 10.6% while only slightly increasing costs or emissions. This makes the 72 hour variant an attractive scenario when you want to promise your customers a maximum lead time, but still want to keep the benefits of cost efficiency and you want to operate in an environmental friendly way. All together this provides the result that within 72 hours (even 48) all bouquets can be delivered against a transportation cost of 69.5 eurocents per bouquet.

Scenario		B1	B5	B6	B1	B5	B6
<i>Transportation cost (euro):</i>	Total Inbound	18342973	18422040	18374015	100	100.4	100.2
	Total Network	1063175	1135990	1007593	100	106.8	94.8
	Total transportation cost	19406148	19558030	19381608	100	100.8	99.9
	Total per bouquet	0.696	0.701	0.695	100	100.8	99.9
	Total per single product	0.034	0.035	0.034	100	100.8	99.9
<i>Lead time (days)</i>	Average	0.41	0.33	0.37	100	81.3	89.4
	Maximum	1.47	0.85	1.38	100	57.4	93.5
<i>Emissions (gram)</i>	Total	1208361	1309449	1198230	100	108.4	99.2
	Per bouquet	0.043	0.047	0.043	100	108.4	99.2

Table 11: Performance 24/72 Hours Delivery scenarios (B5 & B6)

6.3. Last Mile Calculations

After arrival of the individual flowers at the clustering hubs and packing into flower boxes, the boxes still need to be transported to the individual customers who ordered them online. As mentioned in section 2.3 home delivery and pick up points are options for the last mile. The differences and performance of these two options will be discussed in this section. Calculations in this section are based on the approximation formulas from Daganzo (2005).

Home Delivery

Home delivery is the variant of last mile distribution in which every package is delivered to the specified address (probably home address) of the customers by use of a middle sized truck.

Performance Home Delivery:

Results of home delivery can be seen in Table 12. The average cost for delivery of one flower box is €2.00 and causes an emission of 8.03 gram CO₂ per box. As can be seen the cost and emissions vary per

city. This is mainly caused by the factor customer density (number of customers per m²); cities as Bordeaux, Marseille and Luxembourg have lower demand in combination with a more rural area and thus a lower number of customers per m². This leads to longer tour distances and thus higher costs and emissions.

The performance in time is not measured while using approximation formulas. For an e-tail scenario it is common to deliver orders in a time window between 9.00 and 17.00. Therefore it is assumed in this research that the last mile delivery needs 8 hours of time. This time is of course not spend on the delivery of one order, but it is the time taken to deliver all orders of one day in which it is not known if an order is first or last in line. This assumption provides the freedom to make an efficient planning for the already so expensive home delivery. However, the 8 hours needs to be taken into account when using constraints as delivery within 24 hours.

City	Home Delivery		Pickup Points	
	Cost per flower box (euro)	Emission per flower box (gram CO ₂)	Cost per flower box (euro)	Emission per flower box (gram CO ₂)
Amsterdam	1.97	5.95	0.52	1.97
Brussels	1.96	5.48	0.55	2.28
Luxembourg	2.19	23.24	0.57	4.28
Munich	1.97	5.82	0.54	2.24
Berlin	1.97	6.02	0.51	2.26
Hamburg	1.98	7.20	0.54	2.37
Bordeaux	2.32	33.33	0.63	7.22
Marseille	2.16	21.06	0.60	5.13
Paris	1.95	4.45	0.57	2.3
London	1.97	6.27	0.55	2.37
Weighted average	2.00	8.03	0.54	2.59

Table 12: Costs and emissions for home delivery and pickup points

Pick-up Points

When using pick-up points, customers need to pick-up their package at a pick up point somewhere nearby. This implies that per stop more packages can be dropped which makes the last mile distribution cheaper and more environmental friendly.

Performance Pick-up Points:

The performance of the pick-up point's strategy can also be seen in Table 12. It is in this situation assumed that there is one pick-up point for every 15,000 inhabitants of a city. Results with other amounts of inhabitants per pick-up point can be seen in Appendix H. As can be seen are pick-up points a lot cheaper and greener than home delivery. This is caused by a higher amount of drops per stop, which leads to fewer stops per tour and thus a shorter distance per tour. The emissions are decreased due to

this decrease in distance. The cost decrease faster due to the decrease in distance plus the decrease in number of stops.

6.4. Summary Design Supply Chain Network

In this section different scenarios are compiled and tested, from which different results are obtained. The first result is that the objective function has a large impact on the performance of the network. This can best be characterized by a balance between lead time on one side and costs and green on the other side. When emphasizing speed, cost and emissions will go up and vice versa. Second, the biggest improvement is made with the incorporation of the construct All inbound hubs. Other constructs created differences; however this meant always an improvement at one aspect with deterioration on another aspect.

The biggest differences above the improvements from the incorporation of All inbound hubs can be seen in the scenarios with the objective minimize cost while using metro model or the constraint on lead time. The incorporation of Metro model mainly provides improvements on the average lead time while accompanied with only minor increases in costs or emissions. It still needs to be mentioned that there is a high increase of network transportation costs which are offset by a decrease in inbound transportation costs. At this moment with this data the total network cost are much smaller than the total inbound costs. This can cause that the result appear to be better than they are in reality. The incorporation of a cap on lead time provides good results. The results of the 24 hours cap are similar to the results of the metro model; a decrease in time, with only a small increase in cost (which is created due to higher network cost offset by lower inbound cost) and an increase in emissions. The 72 hours cap gives a more balanced result; it rules out the most time consuming (and thus not cost efficient and green) transportation links. This results in slightly lower transportation costs, while still having a good improvement on lead time compared to the European Inbound scenario while only marginally increasing the emissions.

All the above leads to the decision on the new extended transportation network. After testing a large amount of different construct combinations the conclusion is that the already tested 24 Hours Delivery scenario provides the best results when taking into account the e-tail constraints (delivery within 24 hours). This model has a good balance between costs, lead time and emissions, while having large improvements compared to the (alternative) current situation scenarios and avoiding the complexity of the implementation of a metro model. A visualisation of this new extended transportation network can be seen in (Figure 12), visualisations of other scenarios can be seen in Appendix I.

The last mile is the most expensive part of the supply chain. This is caused by a few reasons. First, the high volume per bouquet compared to the volume needed for the same amount of single products in the long-haul transportation. Second, the extensive number of stops in one tour; not only increase the tour distance, but also takes time. Last mile distribution can be more efficient when using pick-up points. This decreases the cost and emissions in total and per bouquet which are attributed to the e-

tail/transportation company. However, it needs to be mentioned that every single customer in that situation would need to travel to the pick-up point which in the end costs probably more in terms of money, time and emissions (when not combined with already planned trips).

The combination of the whole transportation network from grower till consumer through the use of home delivery leads to the following end results: transportation costs of € 2.70 per bouquet under the condition of delivery within 24 hours while having an emission of 8.08 gram CO₂ per bouquet.

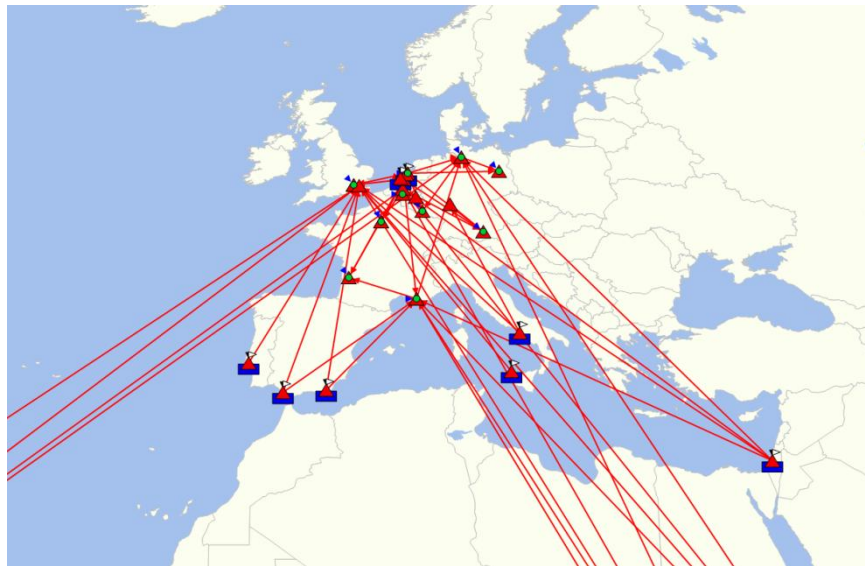


Figure 12: Results New Extended Transportation Network (B5) (LogicNet)

7. Conclusion & Recommendations

This chapter concludes the report by giving the main conclusions next to some recommendations for the floricultural sector next to a set of implications for further research.

7.1. Conclusion

This research is based on an emerging market segment: e-tail. In some sectors already well developed, in the floricultural industry still in its infancy. For this sector it is important to keep up with the competition and to focus on future developments to ensure and maintain its leading position in the floricultural market. E-tail is very different from the current activities of the sector, it is driven by convenience, 24/7 shopping and is characterized by a supply chain with individual, fast and flexible logistics. This combined with the general developments in transportation such as high road density and emphasising on a low ecologic footprint creates the need to look at the future and look at the possibilities to change the distribution network to keep up with the ever changing market.

This all has led to the following research question:

What effect has multimodal transportation and the choice of green, fast or cheap transportation on the performance of the transportation network within the e-tail scenario?

This research question can be answered by the contents of this report and will be answered in conclusion in this section.

A market analysis has led to important insights especially about fast delivery, shipping fees and used supply strategies. To keep up with the competition you need to be able to deliver high quality goods, worldwide within 24 hours against a delivery charge of approximately €7.50. These valuable insights from the market analysis combined with ideas from the field and input from literature about e-commerce strategies, hub-and-spoke networks and multimodal transportation led to an intended supply chain design described both quantitatively as qualitatively in chapter 4. The supply chain design is tested using the mathematical optimization tool LogicNet in which different scenarios build from various constructs are implemented in order to answer the overall research question. The scenarios are implemented on a case study; a simplified representation of reality. Together this has led to the following results:

- *Multiple inbound hubs*: expansion of the possible inbound hubs from the Netherlands to locations across the market improves the network tremendously on all aspects. Not only has the lead time to customers decreased by 10 to 30 percent, emission are decreased as well while the cost of the supply chain remain almost the same. This expansion of the supply chain network therefore leads to a faster and greener supply chain. This result is the effect of shortening the overall distance per customer. It is no longer necessary to make a detour to the Netherlands; you can deliver directly to your customer;

- *Metro model*: the expansion towards numerous more links mainly increases complexity of the supply chain network and not necessarily performance. As seen in the results, lead time (only average) decreases while costs remain steady, while having a negative effect on emissions. The metro model primarily moves inbound costs for transportation to network costs for transportation. In which it needs to be mentioned that when the network transportation would be less efficient due to packing methods, the network cost could increase and the obtained decrease in lead time could possibly be accompanied by higher costs;
- *Inventory*: normally inventory is used to capture fluctuations in demand and with that to cover demand faster from stock. This implies at the level of transportation costs that vehicles would be used more efficiently. In the case of this research the effects of inventory are tiny which is caused by two reasons. First, the transportation of one unit over the network is so cheap that inventory holding needs to be almost for free to make inventory holding attractive. Second, due to the high volume in the network it is possible to have relatively high occupancy rates every day without the use of inventory. It would become interesting if the assumption of 60% of the market is sold through e-tail would be loosened, and a significant smaller volume would be captured by the transportation network while using very low inventory holding costs;
- *Maximum lead time*: when using a tight maximum lead time, like 24 hours, the network is forced to use fast, non-environmental friendly modalities. This increases costs and emissions, especially on the product flows within the transportation network. When loosening the constraint to 72 hours, more modalities can be used which provides a more beneficial balance on costs, time and emissions. However, to keep up with the competitors it is probably a necessity to deliver within 24 hours;
- *Maximum average cost per item*: when using a constraint on the maximum cost per item while minimizing lead time, the lead time will increase compared to the situation in which there is no constraint. To stay a competitive e-tail channel, you need to offer competitive shipping rates and assortment prices, otherwise, especially in e-tail, you will lose customers;
- *Last mile distribution*: this is the most expensive part of the supply chain caused by the high volume of one bouquet, many stops and long tours distances. Pick-up points can make the last mile more efficient, while essentially moving the burdens of the last mile from the supplying company to the customers;
- *Fresh provider*: The role of this fresh provider can be described such that in the evolution scenario the fresh provider manages the supply chain and logistics from sourcing till delivery, while in the revolution scenario the e-tail shop is responsible for these steps. This does not necessarily create a difference in logistics, however it creates definitely a difference in ownership.

An answer to the research question can therefore be given as follows:

Multimodal transportation makes it possible to execute transportation in a cheaper and greener way; however it definitely has its impact on transportation time. When taking into account the e-tail scenario, in which it is important to deliver within a short time frame against an acceptable delivery charge, some

greener and cheaper transportation links will be excluded from the transportation network. These are mainly very long distance links which need a truck or at least a train to cover demand within an acceptable time frame, however against an increase in cost and emissions.

Customer choices for green, cheap or fast transportation therefore definitely have an influence on the possibility of multimodality and the impact on the networks performance. Green delivery can be executed by mainly barge, supplemented with train transportation or eventual truck transportation on links with bad facilities. However, it can take some time (up-to 10 days), especially for distant locations like Munich or Bordeaux. Greener modalities are also cheaper; this provides the customer with the choice for green or cheap results in the same transportation paths. The choice for fast delivery will result in mainly truck transportation, thus fast transportation and at the same time higher costs (+25-30%) and higher emissions.

Last mile delivery and the choice for green, cheap or fast has no clear implications. Although pick-up points are cheaper, greener and faster for the supplying company; essentially the costs, time and emissions are moved from the supplying company to the customer. In this, the total effects are hard to determine.

Therefore multimodality and the choice for green, cheap and fast has definitely influence on the performance of the supply chain. Choices need to be made or a balance needs to be found which is in line with the sector and the e-tail objectives.

7.2. Recommendations

There are several recommendations which are mainly intended for the floricultural sector. These recommendations are explained below:

- *Model:*

;

- *Data:*

;

- *Level of detail:*

-

- ;
- *Perishability and conditioning:* ;
- *Start-up scenario:* ;
- *Hub locations:* ;

7.3. Further Research

There are some implications for further research which will be discussed below:

- ;
- ;
- ?

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List of Abbreviations

B2B	Business to Business
B2C	Business to Consumer
CODP	Customer Order Decoupling Point
DaVinc ³ⁱ	Dutch Agricultural Virtualized International Network with Coordination, Consolidation, Collaboration and Information Availability
JIT	Just in Time
KPI	Key Performance Indicator
LFCND	Linear fixed-charged Network Design
LTL	Less-than-truckload
MILP	Mixed Integer Linear Programming
MTO	Make To Order
O-D	Origin – Destination
SND	Service Network Design
VRP	Vehicle Routing Problem

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Mathematical model:

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Modelling

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Transportation

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Appendix B: Retail and Detail Scenarios Further Explained (DaVinc³i Kernteam, 2011)

Retail

Detail

Figure 13: Six different supply chains depending on scenario (same scenarios for cut flowers and plants)

Appendix C: Current Supply Chain

Figure 14: Current supply chain (EVO Bedrijfsadvies, 2009)

Appendix D: Results Market Analysis

Table 13: Findings 14 flower e-tail shops

Definitions:

Appendix E: Glossary of Symbols

Appendix F: Model Inputs and Outputs

This appendix provides an explanation of the supply chain characteristics and KPIs. It contains a description how the data is established and the choices that are made considering this data, parameters and output variables. First the supply chain characteristics are discussed, second the drivers from the SND model are discussed, third the variables used in the last mile calculations are explained, after which in section 4 the model outputs and KPIs are discussed.

Supply Chain Characteristics

In this section the characteristics of the supply chain are discussed. First the aggregation level of demand is discussed with the accompanying calculations. Second the sourcing of this demand from the 13 sourcing locations is explained. Third and fourth the capacity and emissions of the different vehicles used is outlined.

Demand

Table 14: Export values and demand percentage countries (HBAG, 2011)

Table 15: Number of products per product type per city per year

Table 16: Daily demand pattern for the six countries (Tuinbouw, 2012)

Sourcing

Capacity

Table 17: Volume of containers (BrinkBox, 2012) (shortsea.nl, 2012)

Table 18: Capacity AA box (WvdPlas, 2012)

Table 19: volume individual products (WvdPlas, 2012)

Emission

Table 20: CO₂- emissions modalities (Boer et al. 2008) (NTM, 2010)

Service Network Design

Five different modalities are used: air cargo, container sea freight, truck, barge (incl. short sea) and train. Each modality has its own combination of cost, time, capacity, emissions and availability. The costs, time and emissions are aggregated on the level of modality and are therefore the same for every vehicle in a mode category, but differs in cost and emissions dependent on time and/or distance.

Transportation cost

Transportation time

Availability

Last mile

For the last mile distribution approximation formulas from Daganzo (2005) are used as mentioned and explained in section 6.2. These formulas require input for the variables used. This input is discussed below.

Cost parameters

Table 21: Extracted numbers from Connekt (2012) and corresponding variable values

Transportation time

Customer density

Flower boxes and Truck capacity

Table 22: Dimensions and capacity of a flower box and last mile truck (Mercedes-Benz, 2012)

Figure 15: Mercedes Benz Sprinter Complete lightweight small version (Mercedes-Benz, 2012)

Figure 16: Example of a flower box (Frederiqueschoice.com, 2012)

Model outputs

The model outputs need to ensure that the main research question can be answered. Therefore first green, fast and cheap will be defined and how these will be measured. These together will also be the key performance indicators of the transportation network; customers need to be supplied within a minimum amount of time (preferably 24 hours) after ordering against a competitive transportation price while using a multimodal transportation network. The key performance indicators are therefore: lead time per item, average transportation cost per item and CO₂-emissions per item. The three performance criteria will be measured in different scenarios. Therefore first the three KPIs will be discussed in the following sections.

Lead time

Transportation cost

Emissions

Green, cheap and fast

Appendix G: Case Study

In this appendix more extensive explanation can be found of the choices made that are already stated in chapter 5. Therefore the same topics as in chapter 5 will be discussed subsequently.

Countries

Cities and clustering hubs

Table 23: Mutual distances between cities (by truck, source maps.google.nl)

Figure 17: Graphical representation of chosen cities, one circle has a diameter of approximately 8 km's

Table 24: Cities with corresponding NUTS 3 names and codes and available modalities (EuroStat, 2012)

Clustering hubs

Products

Table 25: Top 15 cut flowers among six countries (FloraHolland, 2010)

Table 26: Top 7 green products sold by FloraHolland (FloraHolland, 2010)



Rosa



Tulipa



Chrysanthemum tros



Gerbera



Freesia



Dianthus



Lilium



Alstroemeria



Ruscus



Pittosporum

Figure 18: Pictures of the 10 chosen products

Sourcing

Table 27: Sourcing location with accompanying products (FloraHolland, 2010)

Inbound hubs

Figure 19: Map of inbound and clustering hubs

Appendix H: Pick-up Points

In **Error! Not a valid bookmark self-reference.** the differences in cost and emissions can be found when increasing or decreasing the number of pickup points per inhabitant.

Table 28: Cost and emissions per bouquet with pickup points

Appendix I: Visualisations LogicNet

This appendix gives a selection of visualisations from LogicNet. First two figures are given which show the starting solution. The first with only Dutch inbound hubs (Figure 20), the second with all 10 inbound hubs (Figure 21) used. The other figures represent solutions for different scenarios and can be seen in Figure 22, 23, 24 and 25. Figure 22 gives the solutions for the current situation scenarios. Figure 23 gives the solutions for the European Inbound scenarios. Figure 24 shows the results of the Metro Model scenarios and Figure 25 shows the results of the 24 and 27 Hours Delivery scenarios.

Figure 20: Current situation with only Dutch inbound hubs

Figure 21: Adjusted situation with 10 inbound hubs

Figure 22: Solution of Current Situation scenario & Adjusted Current Situation Scenario

Figure 23: Solution of European Inbound MLT scenario & European Inbound MC scenario

Figure 24: Solution Metro Model MLT scenario & Metro Model MC scenario

Figure 25: Solution 24 Hours Delivery scenario & 72 Hours Delivery Scenario