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Title: **Literature review on the biological
and logistical aspects of the
transport of perishable roses**

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Flowers are cultivated in different places in the world. Those flowers have to be sold in another place. That place can vary from several kilometers to the other end of the world. For any distance a transport process is necessary. An overview has to be made to get insight in those transport flows.

The transport of flowers is difficult due to the relatively short life of the flowers. During transport the flowers will deteriorate. In this assignment, the deterioration of flowers during transport is taken into account. Influencing factors for deterioration have to be found. Furthermore, the logistic process of roses have to be described. For all these aspects a specific type of flower can be chosen to be part of the literature research.

This literature research can be seen as part of the research to the transport of perishable goods. In that field the PHD-research from X. Lin, MSc is going on. Flowers are a specific group of perishable goods, with specific parameters that define quality. The goal of this research is to gather information from literature to make it possible to optimize the transport of flowers.

The main question of the assignment is defined below:

What is the best strategy to enhance the life of flowers during their transport?

Therefore five sub-questions are defined:

1. What kind of flowers are there to investigate?
2. What is the definition of quality, what factors affect it and what models are present to describe the quality?
3. What are the best ways to handle flowers so that they have the least deterioration and how are they currently handled?
4. What are the handling processes* during the transport of flowers, and how are the flowers gathered and distributed?
5. What control methods can be used by different stakeholders to control the process in the optimal way?

Preface

Logistic operation is about optimization. For any transport process between two points in a network, the fastest, cheapest and/or most sustainable option has to be found. However, for perishable products an extra parameter has to be considered: The quality decay during transport. Variables influencing the quality of the perishable product have to be controlled in an optimal way. Moreover, the logistic chain has to be suitable for the optimal handling of the perishable products.

Most perishable products can be categorized as food. However, more types of products will experience quality depreciation over time. Flowers can be seen as perishable. Flowers have a short lifetime and that lifetime is dependent of certain variables during the lifetime. The first phase of their lifetime, flowers are part of a certain logistic chain. The second phase of the lifetime is the time in the vase of the customer. The flowers have to be in optimal conditions in the beginning of phase two.

Flowers are more and more imported from African and South-American countries. This holds especially for roses, the type of flowers examined in this research. Therefore the logistic chain is long and complicated and quality control has to be done in an optimal way.

This research investigates in literature about the logistic process of roses. The quality of roses has to be defined. Knowing the parameters influencing the quality, optimal handling conditions can be determined. These optimal handling conditions can be helpful to determine the optimal logistic process. In the end the control of the full process can be determined.

I would like to thank Mr. Lin for supervising me during my literature study. The feedback was helpful and steered me into the right direction. I hope that this report will contribute to his PhD research regarding perishable food logistics. Furthermore, I would like to thank the TU Delft for offering me the possibility to learn during this literature review. Sometimes it was hard to stay concentrated and to continue when necessary. For that I would thank my friends for motivating me. Above that, I would like to thank God for helping me through tough times during this research assignment.

Frans de Kok
May 2016

Summary

More and more flowers are grown in African and South-American countries. European countries (especially The Netherlands) cultivate a lot of flowers but their market share decreases. Especially, the cultivation of roses is shifted to African and South-American countries. Many flowers have to be transported to Europe because European people need a lot of flowers. The Netherlands plays an important role in the supply chain of flowers due to the presence of world's biggest flower auction: Royal Flora Holland. A lot of flowers are transported from Africa or South-America to The Netherlands and exported again to other European countries.

Cut flowers deteriorate fast compared to other types of plants (living plants, cut foliage and bulbs). Roses are one of the perishable types of flowers and a lot of roses have to be transported over long distances. Most of the roses are cultivated in Kenya. Therefore the research will zoom in to the logistic chain of roses from Kenya. The transport to Europe is done by aircraft. When the roses arrived in The Netherlands, the roses are transported to several destinations by truck.

The total of all logistical and biological aspects regarding the transportation of flowers is regarded as 'system' during this research. When the system does not behave optimal, the system has to be steered in the good direction. Measurements can give the important information to the controller. The controller determines the necessary actions, executed to the system. This system and control architecture will be the framework of the research.

The goal of the report is to search for the best strategy to enhance the life of flowers. Therefore literature is investigated to gather all relevant information. However, 'practical' information is not available in literature. Therefore, three florist are interviewed for receiving this missing information. All information is ordered according to the different aspects and the framework discussed above. Important gaps are pointed out to show where more research is required. This literature review will contribute to a complete picture of the full supply chain of perishable roses. The combination of practical and theoretical information will be part of that complete picture.

For defining the quality of roses, the parameter 'vase life' can be used. Vase life is the time roses can be on the vase displaying good quality. The vase life ends when the rose is visibly deteriorated according to certain quality criteria. Many parameters influence the vase life of roses: temperature, relative humidity, chance of infection by *Botrytis Cinerea*, water balance and the handling of the roses. These conditions have to be optimal to result in a long vase life.

For the temperature two models exist to express the relation between vase life and temperature. The Degree-days model assumes a linear relationship between temperature and deterioration over time. The First order Arrhenius model assumes an exponential relationship between those variables. These models can be used to come to an estimation for the remaining vase life. However, for low temperatures the models differ too much from the actual data. Therefore some adaptations in the Degree-days model can lead to a better prediction for low temperatures.

Temperature is the most important parameter during transport. The temperature has to be kept as low as possible. Therefore, the temperature has to be measured continuously during transport. The temperature has to be adjusted to the desired temperature by several cooling devices. The cooling has to be optimal during storage, during transport and in all intermediate steps.

The logistic process of roses starts at a certain farm where roses are grown. Via several steps of importers, traders, the auction and/or exporters, the roses are sold to a certain retailer. This retailer is responsible for the selling of the roses to the customers.

In these steps several logistic choices have to be made. For the transport between two locations, four modalities can be used. The four modalities are air transport, road transport, sea transport and rail transport. Nowadays air transport is used for long distance transport and road transport is used for short to medium distance transport. However due to sustainability and cost reasons a modality shift to sea and rail transport has to be considered.

The system can be considered at three different levels: Strategic, tactical and operational. These levels differ on level of detail and time horizon. The strategic level can be used for the network design. Due to a different approach of the auction, the price-determining process and the logistic process will be decoupled more and more. The tactical level zooms in on the execution of the chosen network design. The choice for transport modalities is a typical control problem in the tactical level. The operational level is determined for daily choices. The temperature regulation during the full logistic process is part of the operational level.

Samenvatting

Steeds meer bloemen worden geteeld in Afrikaanse en Zuid-Amerikaanse landen. Nog steeds worden er veel bloemen in Nederland en andere Europese landen geteeld, maar hun marktaandeel wordt kleiner. Vooral de teelt van rozen verschuift van Europa naar Afrika en Zuid-Amerika. Veel van deze bloemen moeten wel naar Nederland worden getransporteerd omdat er in Europa veel vraag is naar bloemen. Nederland speelt een belangrijke rol in de keten van bloemen. Dit komt door de aanwezigheid van de grootste bloemenveiling van de wereld: Royal Flora Holland. Veel bloemen uit Afrika of Zuid-Amerika worden getransporteerd naar Nederland en vanuit Nederland weer naar andere Europese landen.

Snijbloemen takelen sneller af dan andere soorten planten (levende planten, snijblad en bollen). Rozen zijn ook bloemen die bederfelijk zijn en veel rozen moeten getransporteerd worden over een lange afstand. Veel van deze rozen worden geteeld in Kenia. Daarom zal dit onderzoek zich focussen op de logistieke keten van rozen uit Kenia. Het transport naar Europa wordt uitgevoerd per vliegtuig. Als de rozen in Nederland arriveren worden ze per vrachtwagen naar verschillende bestemmingen gebracht.

Het totaal van alle logistieke en biologische aspecten van het transport van bloemen wordt beschouwd als systeem in dit onderzoek. Als het systeem niet optimaal opereert moet het bijgestuurd worden in de goede richting. Metingen kunnen belangrijke informatie geven aan de controller. De controller bepaalt de noodzakelijke acties die uitgevoerd moeten worden in het systeem. Het systeem en de controllers zijn de bouwstenen voor dit onderzoek.

Het doel van dit rapport is het zoeken naar de beste strategie om het leven van bloemen te verlengen. Daarvoor is er in de literatuur gezocht naar alle belangrijke informatie. Er mist echter 'praktische' informatie in de literatuur. Daarom zijn er drie bloemisten geïnterviewd. Alle informatie is geordend naar de verschillende aspecten en de hierboven genoemde bouwstenen. Belangrijke gaten zijn aangewezen om te tonen waar meer onderzoek nodig is. Deze literatuurstudie draagt bij aan een compleet beeld van de volledige keten van bederfelijke rozen. De combinatie van praktische en theoretische informatie is onderdeel van dat complete beeld.

Voor de definitie van de kwaliteit van rozen wordt de parameter 'vaasleven' gebruikt. Het vaasleven is de tijd die rozen doorbrengen op de vaas terwijl ze een goede kwaliteit laten zien. Het vaasleven eindigt wanneer de rozen zichtbaar afgetakeld zijn volgens vastgestelde kwaliteitscriteria. Veel parameters beïnvloeden het vaasleven van een roos: Temperatuur, relatieve luchtvochtigheid kans op infectie door *Botrytis Cinerea*, water balans en de manier van behandelen van de rozen. Deze condities moeten optimaal zijn om een lang vaasleven te garanderen.

Voor de temperatuur bestaan twee modellen die de relatie tussen de temperatuur en het vaasleven uitdrukken. Het Graad-Dagen model neemt een lineair verband aan tussen temperatuur en achteruitgang door de tijd. Het Eerste Orde Arrhenius model neemt een exponentieel verband aan tussen deze variabelen. Deze modellen kunnen gebruikt worden om te komen tot een schatting van het resterende vaasleven. Echter, voor lage temperaturen verschillen de modellen te veel van de eigenlijke data. Daarom moet een aanpassing aan het Graad-Dagen model leiden tot een betere voorspelling voor lagere temperaturen.

Temperatuur is de belangrijkste parameter tijdens het transport. De temperatuur moet zo laag mogelijk gehouden worden. Daarom moet de temperatuur ook continu gemeten worden tijdens het transport. De temperatuur moet aangepast worden met behulp van verschillende koelmechanismen. De koeling moet optimaal zijn tijdens opslag, transport en elke stap daartussen.

Het logistieke proces start op de boerderij waar de rozen groeien. Via verschillende stappen van importeurs, handelaren, de veiling en/of exporteurs worden de rozen verkocht naar een kleinhandelaar. Deze kleinhandelaar is verantwoordelijk voor het verkoop van de rozen aan de klanten.

In deze stappen moeten veel logistieke keuzes worden gemaakt. Voor transport tussen twee locaties kunnen vier modaliteiten worden gebruikt. Deze vier modaliteiten zijn luchttransport, wegtransport, zeetransport en railtransport. Tegenwoordig wordt luchttransport gebruikt voor lange afstand transport en wordt wegtransport gebruikt voor medium en korte afstand transport. Echter, vanwege duurzaamheids- en kostentechnische redenen is een modaliteitsverandering naar rail en zee te overwegen.

Het systeem wordt beschouwd op drie niveaus: Strategisch, tactisch en operationeel. Deze niveaus verschillen door niveau van detail en tijdsbestek. Het strategische niveau kan worden gebruikt voor netwerk ontwerp. Vanwege een verschillende aanpak van de veiling wordt het prijsbepalingsproces en het logistieke proces steeds meer losgekoppeld. Het tactische niveau zoomt in op de uitvoering van het netwerk ontwerp. De keuze voor een transport modaliteit is een typische tactische keuze. Het operationele niveau is voor dagelijkse keuzes. De temperatuursturing tijdens het logistieke proces is onderdeel van het operationele niveau.

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1. Overview of global flower trade

The heart of the flower industry is in The Netherlands. However, the cultivation of flowers is done over the entire world. The Netherlands is still leading in the cultivation of flowers, while other countries become more and more important on the flower market. Kenya and Columbia are examples of important exporters on the market. In this section, some key facts are given as overview of the flower market.

These facts show what kind of flowers are necessary to investigate and what kind of transport modes are used. This can determine the subject of the research to flower perishability during transport. The research goal and direction are given to show the direction of the report. In the end the control cycle is shown that will function as a framework for describing the perishable flower logistics.

1.1. Import and export statistics

Below the top 10 of the countries that export flowers and the top 10 of countries that import flowers are shown [1]. The results are given in billion USD.

Table 1: Flower export top 10 (billion USD)

	2011	2015
Total	21.5	19.5
The Netherlands	11.1	9.2
Colombia	1.3	1.3
Germany	1.1	0.9
Ecuador	0.7	0.8
Italy	0.9	0.8
Ethiopia	0.2	0.7
Kenya	0.5	0.7
Belgium	0.9	0.6
Denmark	0.7	0.5
USA	0.4	0.4

Table 2: Flower import (billion USD)

	2011	2015
Total	20.3	17.7
Germany	3.9	3.0
The Netherlands	1.8	2.2
USA	1.8	2.0
United Kingdom	1.8	1.6
France	1.4	1.1
Russia	0.9	0.7
Italy	0.8	0.6
Japan	0.7	0.6
Switzerland	0.6	0.5
Austria	0.5	0.4

Some remarks can be made according to the tables above.

- The flower trade over the world is decreasing in the period between 2011 and 2015. However, the decrease is small compared to the increase of the import and export in the period 2001 – 2011. In 2001, the total export was 8 billion USD [2].
- The Netherlands is the most important country in the world of the flowers. The Netherlands are famous due to their cultivation of flowers. Another important factor is the presence of the greatest flower auction house in the world, Royal Flora Holland [3]. Royal Flora Holland has a turnover of 4.6 billion euros in 2015 [4].
- The countries can roughly be split into three categories:
 - o Countries where the export is high and the import is low. Examples of those countries are Colombia, Ecuador, Ethiopia, and Kenya. Those countries can cultivate flowers for a low price. The export of those (more developing) countries is increasing in the years between 2011 and 2015.
 - o Countries where the import is high and the export low. Examples of those countries are the United Kingdom, France, Russia and Japan. Those countries rely on the cultivation of flowers in other countries. The import of those countries is decreased in the examined period.
 - o Countries that have both high import and export. In those countries, the trade of flowers is important. The Netherlands are the best example of such a country. However, Germany and Italy are also part of this group.
- According to the categories above, the main logistic flows of flowers are from the exporting countries (Africa, South America) towards the more importing countries (Mostly Europe). Another option is the transport of flowers through a third country, like the Netherlands.

1.2. Flower types

Flowers can be distinguished in four distinct categories [1].

- Cut flowers. The most well-known group of flowers are the cut flowers. Cut flowers are cut from the plant to use for decoration. The flower contains (in most cases) a colorful part. The cut flowers are sold in a bouquet or loose. Cut flowers are an important symbol of appreciation and love. Therefore, cut flowers are common used as a present.

- Living plants. This group considers the trade of the full plant, including the roots. They are mostly sold in pots. When a customer buys a living plant, the plant can grow further in the environment determined by the customer.
- Bulbs. A bulb is a resting stage of a plant [5]. The customer can plant the bulb and if the conditions are good, a plant can start to grow.
- Cut foliage. Cut foliage can consist of cut leaves and other parts of the plant (except roots and cut flowers). It can be used in a bouquet or for ornamental purposes.

The total export value of all flowers is 19.5 million USD in 2015 [1]. The following table shows the division over the different categories for 2011 and 2015 [1]. The results are given in billion USD.

Table 3: Division of the export over type of flower (billion USD)

	2011	2015
Cut flowers	9.1	8.6
Living plants	9.0	8.1
Bulbs	1.9	1.6
Cut foliage	1.4	1.1

1.3. Research necessity

Above the four different categories are given. The research is about the logistics of perishable flowers. For perishable flowers a research to the logistics and transport environment can be beneficial to the ultimate product for the customer. Therefore, the examined flower has to be perishable. Another demand for the research of the logistics of perishable flowers is the complexity and length of the logistic process. More benefits can be obtained by investigate in a flower, that has an extended, long logistic process.

Below the different categories are evaluated, regarding to the two aspects mentioned above. Therefore, the perishability and the transport flows over the world are discussed [1].

Cut flowers: Cut flowers are well-known for their perishable nature. The reason for their perishable nature is the fact that the flowers are cut from their natural environment and placed in a new environment. The stem has to adapt to the new situation. It cannot receive its nutrient and water from the main plant anymore. From the time of the cut from the plant, the deterioration process will start.

The export and import of cut flowers is high. Columbia, Ecuador, Ethiopia and Kenya export only cut flowers (No living plants, bulbs and cut foliage). Those countries are in the top-5 of the export of cut flowers (together with the Netherlands). The most important import countries of cut flowers are European countries. A lot of cut flowers are subject to a long trip from Africa or South America to Europe.

Living plants: Living plants deteriorate less than cut flowers. The reason is the fact that, the living plants are kept in a more natural environment (for example a pot with ground). The logistics of living plants is more short-distance transport. According to trademap.org [1], both import and export countries are European countries. Due to that fact, the transport is more intracontinental.

Bulbs: Bulbs are in a stage before the growing of flowers. In that stage temperature and environment is not very important. The deterioration of bulbs is therefore neglectable. The top of the export countries is formed by European countries, but also Egypt, Chile and New Zealand are in the top of the export of bulbs. Transport of bulbs can be intercontinental.

Cut foliage: The shelf life of cut foliage is relatively long compared to cut flowers [2]. Cut foliage has a relatively low amount of import and export. Most importing and exporting countries are European countries. However, flows from and to the United States, China and Japan are present.

Summarizing the four categories above results in a very clear conclusion. Research to the transport of cut flowers is most promising. Cut flowers deteriorate more compared to other types of plants/flowers. A relatively large number of cut flowers have a long transport distance. Some cut flowers can be transported from the country of cultivation (South America, Africa) to a European country. In many cases a large auction like Royal Flora Holland imports the cut flowers from those countries and re-exports those to another (European) country [4].

A very large flow of cut flowers is the flow of cut roses. For Royal Flora Holland roses are (by far) the most imported type of flowers. The total import of cut roses is 451 million euros. The total turnover of roses is 735 million euros. The roses are sold in the Dutch market but also re-exported to Germany, the UK and to France

[6]. One of the biggest exporters of roses is Kenya [6]. The logistic process starting from the cultivation in Kenya via the auction in the Netherlands towards several destinations in Europe is worthy to investigate.

After a rose is cut, its life is limited. Tests result in vase lives varying between 1 and 13 days [7]. The rose has a perishable nature and several factors can affect the vase life [8].

1.4. Transport modes

For intercontinental transport of cut flowers, air transport is the most used option. Due to the perishability of the flowers, fast transport is important. That is the reason air is the most used option. For intercontinental transport, sea and air are the only possible options. In the figure below, the transport of flowers by sea is visible. The number of shipped flowers is low compared to the total number of transported flowers. For example, the export of flowers from Columbia is done for only 15% by sea transport. For other countries, that percentage is lower [2]. For the transport of roses from Kenya to the Netherlands, 98% is transported by air and 2% is transported by sea [9].

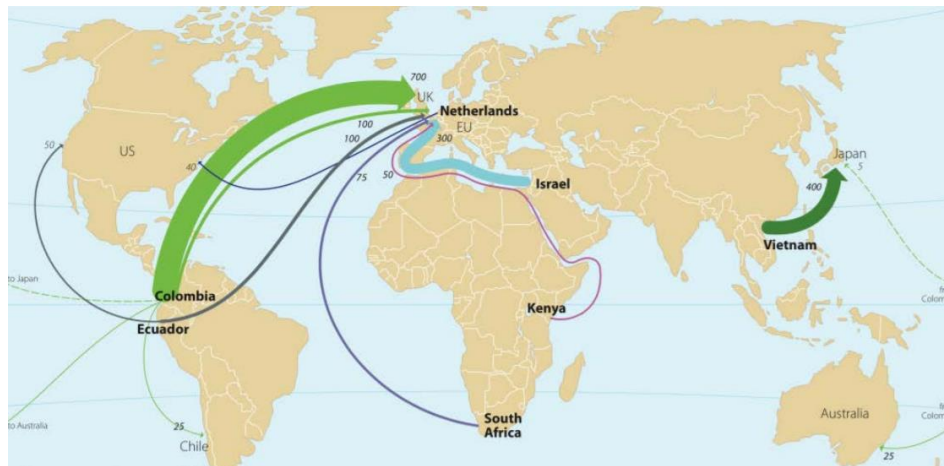


Figure 1: Flower transport by sea [2]

In the case of intracontinental transport, truck is the most used option. Only a small part of the flower logistics is done by train. Nowadays, flower transport from the Netherlands to Milan is possible by train and new initiatives for the transport of flowers by train from the Netherlands to Spain are introduced [10]. The use of a truck to transport flowers from one place to another is the standard option for intracontinental transport.

1.5. Research goal

The research is to the perishability of flowers during transport. Roses have a perishable nature, long transport distances and a complex, diverse logistic process. Therefore roses are examined in more detail in this report. However, most of the research will hold for all flowers and can be useful for the knowledge of perishability logistics for flowers in general. This research will investigate in literature to collect important information and will denote the gaps where information is missing.

For this research the following main question is defined:

What is the best strategy to enhance the life of flowers during their transport?

To answer the main question, five sub-questions are defined:

1. What kind of flowers are there to investigate?
2. What is the definition of quality, what factors affect it and what models are present to describe the quality?
3. What are the best ways to handle flowers so that they have the least deterioration and how are they currently handled?
4. What are the handling processes during the transport of flowers, and how are the flowers gathered and distributed?
5. What control methods can be used by different stakeholders to control the process in the optimal way?

The first question gives an overview of the flowers. This question is answered in the first (introductory) chapter. Question two and question three will more focus on the biological aspects of perishable flower transport. Question four will discuss mainly the logistical aspects. Question five will discuss the different control methods for the system. Each question is discussed in a corresponding chapter. However, some of the biological aspects of question four are discussed in chapter three.

1.6. Framework

This research is about investigating in the transportation of perishable flowers. The transportation can be considered as a 'system'. The system is the total of all logistical and biological aspects regarding the transportation of the flowers. In more detail, the subject of the system will be roses. The supply chain will start in Kenya and will continue via Holland and will end in one of the destination countries of the roses. For this supply chain the logistical and biological aspects will be discussed. The main part of this report is focussing on the description of the system. Especially chapter two and three describe the biological aspects. Chapter 4 describes the logistical aspects.

However, this report will not only contain a description of the current system. The system is part of a certain framework shown below.

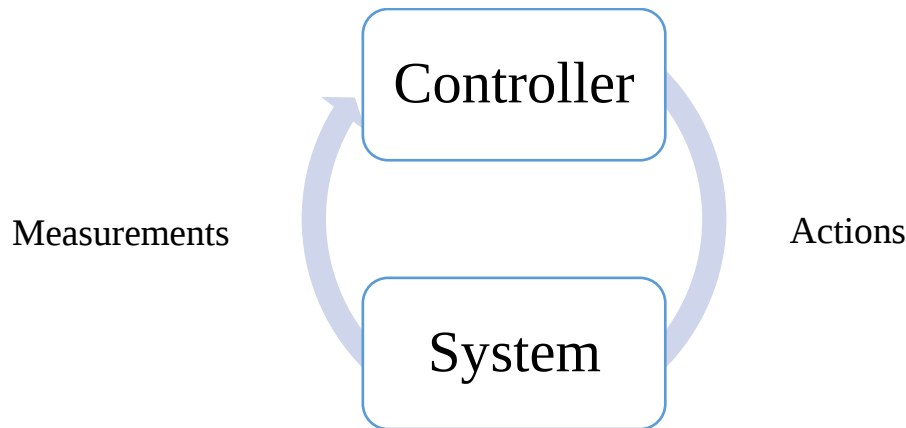


Figure 2: System and controller interaction [11]

The system contains a lot of parameters regarding the performance of the system. These parameters can vary from temperature measurements to effectivity measurements of the supply chain. These parameters can be fed to the controller.

The controller can operate on various levels. Some control signals can result in immediate actions like the changing of the set point of the temperature in the storage room. Some control signals can result in the proposal of a different network design. These control actions are determined for the long term.

Figure 2 shows a continuous process of evaluating the system according to measurements and determining the appropriate actions. These actions are determined by the controller. This framework is available for various levels. These levels can differ in scale (truck cargo compartment versus complete transportation network), time horizon (real time versus several years) and execution of the controller (automated temperature regulation vs decision of the management board).

This control framework will be the basis of this report. First the biological system is described and possible measurement and actions are proposed (Chapter two and three). Then the logistical system is described and evaluation criteria (measurements) and possible adaptations (actions) are proposed (chapter 4). In the last chapter (chapter 5) three examples of controllers are worked out.

1.7. Discussion

In this chapter, the international flower market is being investigated. More and more flowers are grown in the African and South-American countries. Especially the cultivation of roses is shifted more from the traditional cultivation in The Netherlands and other parts of Europe to Kenya, Ethiopia, Columbia en Ecuador.

This shift involves long distance transport. For long-distance transport, an aircraft is the most used option. For short- to medium distance transport a truck is the most used option for transport of flowers. Transport per train and transport per ship are other possible options. However, these transport modalities are not used often. These transport modalities can play an important role in the future due to sustainability reasons. One of the challenges of this research is to examine the options to replace air and road transport by rail and sea transport.

Cut flowers will deteriorate fast compared to other types of plants (living plants, cut foliage, bulbs). Therefore, the research to cut flowers is most promising. It is important to investigate in the causes for deterioration. When these causes are known, improvements can be suggested for better transport. The ultimate challenge is to deliver flowers of a high quality to the customer.

The goal of the report is to search for a best strategy to enhance the life of flowers. This strategy will be explored by searching for literature regarding the biological and logistical aspects of flowers. The report will be based on the control framework: A system, measurements, a control structure and appropriate actions.

The transport process of flowers is important for keeping the quality. But the question arises: What is 'good quality' regarding flowers. That will be discussed in the next chapter.

2. Quality of flowers

A lot of flowers are transported all over the world. In the end, the flowers end in the customers home. For customers of flowers, the quality of a flower is very important. Flower quality can be evaluated according to exterior aspects of a flower (like wilting of the leaves) and to interior aspects (like the appearance of some bacteria). Within the distribution of exterior and interior aspects a wide range of options to assess the quality are possible. In this section, the different parameters are discussed that describe the quality of a flower.

The quality of a flower can be influenced by different parameters. Those parameters should be discussed to come to proper handling methods of flowers. The different parameters and the influence on the quality can be described. For this influence models will be proposed that describe the relation between the parameters and the quality.

To come to proper conclusions about the quality of roses, three florists are interviewed. Florists are practical experts in the field of cut flowers. Therefore the interview can give practical information next to the theoretical information from literature. When they buy new flowers, they should judge them according to quality. In their shop, they have to care for them and keep them in a good quality. In appendix A, the results of the interview are visible. These results, combined with existing literature will result in a description of the quality and the different parameters affecting it.

2.1. Quality criteria

Customers have one important question: How long can a rose be on the vase displaying good quality? In literature, the parameter vase life is used. The vase life is always expressed in days. Florists use the vase life to guarantee the time, they can be in good quality on the vase. 'The remaining vase life of cut flowers is defined as the time that flowers can be kept on the vase at room temperature, which is regularly assumed to be 20 °C. Vase life ends according to predefined quality criteria [7]' According to literature, the remainder conditions during vase life can be regarded as a relative humidity of 60% and each day 12 hours of light ($12 \mu\text{mol m}^{-2} \text{s}^{-1}$) and 12 hours of darkness [12].

The main criteria of a rose is the opening of a rose. The picture below shows the different phases a rose can have.

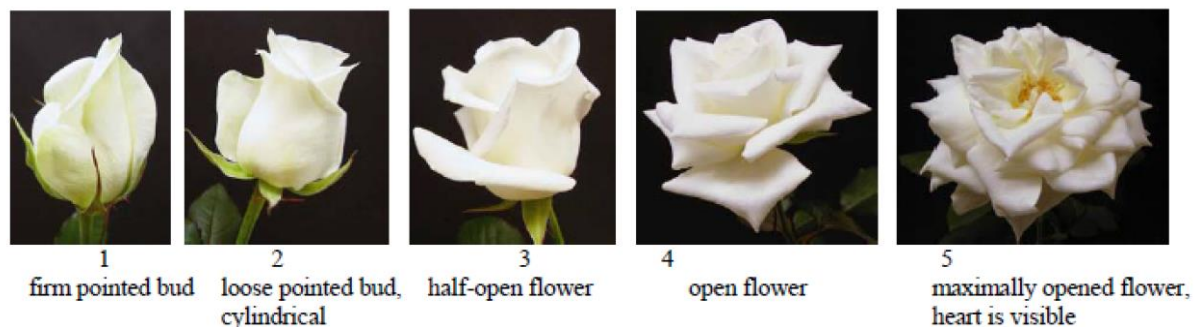


Figure 3: Different phases of a rose [13]

Usually, the rose is cut from the stem when it is in the first or at maximum in the second phase. When the conditions are good enough the rose will start to open. The next pictures show the phases of the rose. For most people, stage four (an open flower) is the most good-looking flower. However, the vase life of a rose, sold in stage four is significantly shorter than the vase life of a rose in earlier stages. Therefore most flowers are sold when they are not yet fully opened. A trade-off has to be made between beauty and length of vase life.

Another aspect that has to be taken into account is the fact that a rose can not be completely closed when it is sold. When a rose is closed, a florist can not guarantee that the rose will open after a certain time. A special case is the selling of flowers for funerals and weddings. A florist has to use roses that are fully opened (stage 4). When stage 5 is reached, the end of the vase life is nearby. After a certain time, some petals are falling and the beauty of the rose will regress.

Another quality criterion is the thickness of the stem. Consumers want to buy a rose that has a thick, firm stem. A firm stem prevents a rose from buckling. The thickness of the stem is a criterion for grading the quality of a flower but it is hardly correlated with vase life [14].

One of the selection criteria for the buying of a rose is the length of the stem. The price of a rose containing a long stem is higher than a rose containing a short stem. However, regarding the vase life, a rose containing a shorter stem has a longer vase life [8].

The next criterion of a rose is the colouring of the bud. For a good quality, the rose has to be in the original, genotypical colour. During the deterioration process, the colour of the bud can change. Some brown spots can occur on the outer petals. If that is the case, the rose is probably infected by the fungus *Botrytis Cinerea* [13]. In the next picture an example of an infected rose is visible.



Figure 4: Rose infected by *Botrytis Cinerea* [15]

The deterioration of a rose can be visible in other aspects regarding the color. When the vase life comes to an end, the outer petals can turn brown or yellow (desiccation) or can become pale. Another sign of the life-end of a rose can be the existence of black or blue edges on the bud of the rose.

According to florists, the most important criteria for determining the quality of a rose is the robustness of a rose. The robustness of a rose can be determined by squeezing the bud of a rose a little bit. The amount of resistance to squeezing determines the freshness of a rose. A very robust, solid rose is a fresh rose. The vase life of a soft rose is probably short. When the rose is infected by *Botrytis Cinerea*, the bottom of the rose, the receptacle, can be damaged. That influences the robustness of a rose.

The following quality criterion is the freshness of the bud. At the end of the vase life, the flower is visibly limp and the petals can become wrinkled. This quality criterion is one of the most subjective criteria, mostly denoted as the wilting of a rose. However, florists make use of those subjective criteria to judge the quality of a rose.

The next criterion is the angle of the neck. The neck is the stem just below the bud. When a rose is fresh, the rose will point upwards. However, when the vase life of a rose comes to an end, the neck of the rose will bend.

Another quality criterion is the appearance of the stem and the leaves. A lot of different deterioration aspects can be seen on the stem and the leaves. The stem can turn black or grey due to *Botrytis Cinerea*. The leaves can be desiccated and turn into yellow or brown. Brown or black spots can develop on the leaves. The leaves can hang loosely or even fall from the stem.

The quality criteria described above can be summarized in the following table. The quality criteria and the corresponding optimal appearance is given.

Table 4: Optimal appearance

Quality Criteria	Optimal appearance
Opening of a rose	Between stage 3 and 4 (see figure 3)
Thickness of the stem	Thick stem
Length of the stem	Long stem
Coloring of the bud	Beautiful, pure color without deterioration signs
Robustness of the bud	A robust bud
Freshness of the bud	A fresh appearance of the bud
Angle of the neck	Flower points upwards
Appearance of the stem and the leaves	Fresh appearance of stem and leaves

The above discussed quality criteria are given to give insight in the grading of the quality of a rose. At the end of the vase life, some of the above discussed criteria will show visual deterioration. Below the criteria for write-off for Royal Flora Holland are given to show more measurable characteristics of the end of the vase life [13].

- The bent neck is greater than 90°.

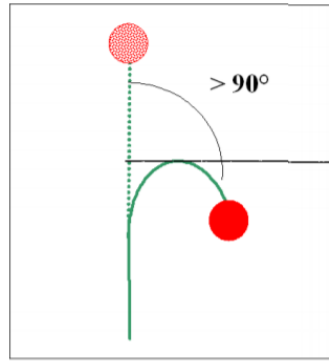


Figure 5: Bent neck determination of a rose [13]

- Five or more petals suffer from severe damage due to Botrytis.
- The receptacle is not intact anymore.
- More than five petals are turning brown, yellow or have black or blue edges.
- More than two petals are fallen off.
- More than 50% of the leaves has fallen from the stem.
- More than 50% of the leaves has deterioration signs as discussed above.

Those characteristics show the end of the vase life of a rose. However, using those characteristics is not enough to judge the end of the vase life of a rose. A combination of (objective and subjective) deterioration signs can lead to a writing-off.

In most cases the end of the vase life occurs in the home of the customers. People choose the time when the roses are thrown away. According to the definition of vase life, the vase life ends if the roses are not anymore in the vase. That is the case when they are thrown away.

2.2. Vase life influences

According to literature a lot of factors influence the vase life of a rose. Below, the factors are discussed and evaluated. The vase life of a rose will start from the point they are put in the vase at room temperature. Florists guarantee a certain vase life for their customers.

The first important aspect for a long vase life is the quality of the rose in the beginning of the vase life. Before the rose is placed in a vase in the customers' home, a logistic process is necessary. The roses are cultivated at a certain rose breeder, transported via several parties in the logistical chain and end up in the vase of the customer. In the whole logistical process the quality of the rose must be kept as good as possible.

For florists, it is necessary to sell flowers of an excellent quality. They have to guarantee a certain vase life of a rose. Two of the three interviewed florists guarantee a vase life of seven days and the third one guarantees a vase life of five days. However, the guarantee of the vase life can only be given when they are handled well during the time in the vase. That is the second important aspect for a long vase life: An appropriate care for the roses during the vase life.

These two aspects describe the deterioration from the point of cutting the rose from the plant. These aspects can be considered as postharvest factors. However, a variation in quality and vase life can be seen for roses kept under the same conditions. Apart from postharvest conditions the genotype and the growth environment influence the vase life of a rose [8]. The growth environment can be divided into the preharvest factors and harvest factors. Preharvest factors are factors like temperature, relative humidity, the light condition and potential for infection during the growing of the roses. Harvest factors can be the opening of the rose at harvest, the stem length and the conditions during harvest. [8] [12]

The phenotype can be seen as a combination of genotype and growth environment. The phenotype contributes significantly to the vase life of a rose. This report will focus on the postharvest factors. It is essential to know the limitations of the investigations in postharvest factors. It will always be combination of the phenotype and the postharvest factor determining the vase life of a rose.

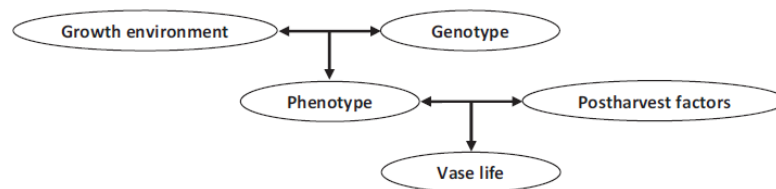


Figure 6: Factors determining vase life [8]

2.3. Influencing factors

By far, the most important factor is the **temperature**. A negative correlation between temperature and vase life is proved by several research [7] [16]. For a good storage, the temperature of a rose has to be kept as low as possible. The lower boundary of the temperature is 0°C [12]. Therefore, the roses are stored in cooling rooms when possible in several stages of the transport [12]. For this correlation, several models are developed to predict the vase life and to enhance the conditions during storage. Later in this report, these models will be shown and analysed.

The second influencing factor is the possible infection by **Botrytis Cinerea**. As discussed before, the presence of this disease will result in a decrease in quality of flowers. The vase life will end more quickly when roses are infected by Botrytis Cinerea. Botrytis Cinerea is a fungal. The rose can be infected by the fungal spores during the growth or during the storage and handling of the flowers. Botrytis Cinerea spores need water or a high relative humidity to infect the roses. [12].

Regarding the susceptibility of roses by Botrytis Cinerea, the relative humidity and temperature are important. A lower relative humidity and a higher temperature decrease the possibility for an infection by Botrytis Cinerea. Another factor for the susceptibility of roses by Botrytis Cinerea is the calcium availability in the cut flower. A calcium deficiency can result in a high susceptibility of roses by Botrytis Cinerea [8].

The roses can be infected by Botrytis Cinerea during the growing of the roses. During the growing, the temperature and relative humidity have to be controlled in a right way. The calcium concentration in the nutrient solution must be high enough to prevent a high risk on a Botrytis Cinerea infection. However, the infection can also occur during transport and storage.

Apart from the temperature effect and the risk of being infected by Botrytis Cinerea, the **relative humidity** influences the vase life of roses. Relative humidity is used to denote the ratio between the amount of water vapor in the air relative to the amount of water vapor that would be present at saturation [8]. In the preharvest phase the relative humidity influences vase life. A high relative humidity (RH>85%) can result in the malfunctioning of some stomata. These stomata are less able to adapt to the situation. That can be a reason for fast dehydration in the post-harvest phase [8] [12].

As mentioned above, a high relative humidity can be a source of infection by Botrytis Cinerea. Another factor is the possible malfunctioning of stomata for a relative humidity above 85%. However, a high relative humidity is positive for the water uptake. Especially for the dry transport after harvest, a certain relative humidity is necessary.

Another important factor during transport and storage is the **water balance** in the cut rose. The amount of water in the rose is called 'turgidity'. A rose that contains a lot of water is a turgid rose. The amount of water in the flower can be considered as a control system. The stem is responsible for the uptake of water. The leaves are responsible for the dissipation of water. The balance in the cut flower has to be neutral. A negative water balance can lead to dehydration.

Turgid roses feel stiff and does not have wilting symptoms. However, a turgid rose is very susceptible to mechanical damages. Therefore, an optimal turgidity is necessary during transport.

Often, the transport of roses is done by placing the roses in a dry environment. After a transport step in the logistical process, the roses are placed in water again. Every change between dry and wet transport, the **handling process** is important (see Appendix A). Before the roses are placed in water again, the end of the stem has to be cut of inclined. The lower leaves have to be removed and the roses have to be placed in lukewarm water in a clean environment. The process of proper handling during changes of environment is required to protect against diseases.

The factors described above are the most important quality-influencing factors during transport and storage. For most of these factors it is not possible to give any quantitative data (except for the temperature). Therefore, it is necessary to examine the relation between the different factors (turgidity and relative humidity) and the vase life of cut roses.

2.4. Temperature models

As described before, the temperature is an important influencing factor for the vase life of roses. The temperature influence is discussed in literature. Therefore, several models are developed to model the relation between temperature and vase life. The two most-used models are the Degree-days model and the First order Arrhenius model.

2.4.1. Degree-days model

The first model describing the vase life of a rose is the degree-days model (DD). This model is based on the assumption of a linear relation between the temperature and the loss in vase life. In that model, the amount of degree-days is an estimation of the loss of vase life. For a constant temperature, the amount of degree-days can be calculated by the product of the time (in days) and the temperature (in degrees Celsius) [7]. If the temperature is not constant, the amount of degree-days (DD) can be calculated using the following formula.

$$DD = \int_0^{time} T dt \quad (1)$$

To calculate the loss in vase life, the amount of degree-days can be compared to the situation in the vase. For example a storage of 10 days at 2°C will result in the loss of one day of vase life at 20°C. 20°C is the standard vase temperature. Therefore, the following formula calculates the new vase life of a rose:

$$VL_{new} = VL_{old} - \frac{DD}{20} \quad (2)$$

The symbols are explained below:

Table 5: Symbols degree-hours model

Symbol	Paramter [unit]
DD	Degree Days [°C*days]
T	Temperature [°C]
t	Time [days]
VL _{new}	Vase life after storage at temperature T for time t [days]
VL _{old}	Vase life before storage at temperature T for time t [days]

In the cut-flower industry, the method of the Degree-days model (or sometimes uses as the degree-hours model) is used for predicting the vase life reduction of roses [7] [17].

2.4.2. First order Arrhenius model(FOA)

For most other perishable products, a first order reaction kinetics equation is used for describing the quality decay over time. This model uses a temperature dependancy following Arrhenius. [7] [18] [19]. The first order reaction kinetics equation is given by the following equation:

$$\frac{dq}{dt} = -k_T q \quad (3)$$

In this formula, q can be seen as a parameter denoting the quality of a certain perishable product and k_T is the temperature dependancy following Arrhenius [7]. The Arrhenius temperature dependancy is determined by the deterioration processes. The temperature dependancy and the activation energy of the different processes determine the paramater k_T . These processes can be chemical, biochemical, microbial and physical. The Arrhenius temperature dependancy holds the best for the chemical reactions [20].

The temperature dependancy is given by the following equation [7]:

$$k_T = k_{ref} e^{B \left(\left(\frac{1}{T_{ref}} \right) - \left(\frac{1}{T} \right) \right)} \quad (4)$$

The solution of equation 3 is [7]:

$$q(t) = q_0 e^{-k_T t} \quad (5)$$

The vase life will decrease when the quality of a rose decreases. Therefore the vase life can be expressed by the following equation for varying temperature T [7]:

$$VL_{new} = VL_{old} - \int_0^{time} \frac{k_T}{k_{ref}} dt = VL_{old} - \int_0^{time} e^{B\left(\left(\frac{1}{T_{ref}}\right) - \left(\frac{1}{T}\right)\right)} dt \quad (6)$$

In those equations the following symbols are used:

Table 6: Symbols degree-hours model

Symbol	Parameter [unit]
Q	Quality of a perishable good [-]
k_T	Quality decay rate (Arrhenius Temperature dependency) [-]
k_{ref}	Quality decay rate at T_{ref} [-]
T	Temperature [K]
T_{ref}	Reference temperature [K] (293.15K)
B	Product dependent parameter [K]
t	Time [days]
VL_{new}	Vase life after storage at temperature T for time t [days]
VL_{old}	Vase life before storage at temperature T for time t [days]

2.4.3. Comparison

Those two models can be used to predict the vase life depending of the temperature and storage time. The Degree-days model is a more practice-based model. The First order Arrhenius model is a more theory-based model. In literature, a comparison is made between the two different models.

In the figure below the normalised reaction rate $\frac{k_T}{k_{ref}}$ is shown as a function of the storage temperature. The dotted lines show the result for different values of Q_{10} . Q_{10} is defined as the normalised reaction rate ($\frac{k_{T_2}}{k_{T_1}}$), for $T_2 - T_1$ is 10K (T_2 is assumed as 283K and T_1 is assumed as 273K). The factor Q_{10} is product dependent and is for roses 3 [7] [21]. The linear line is the line for the degree-hours model.

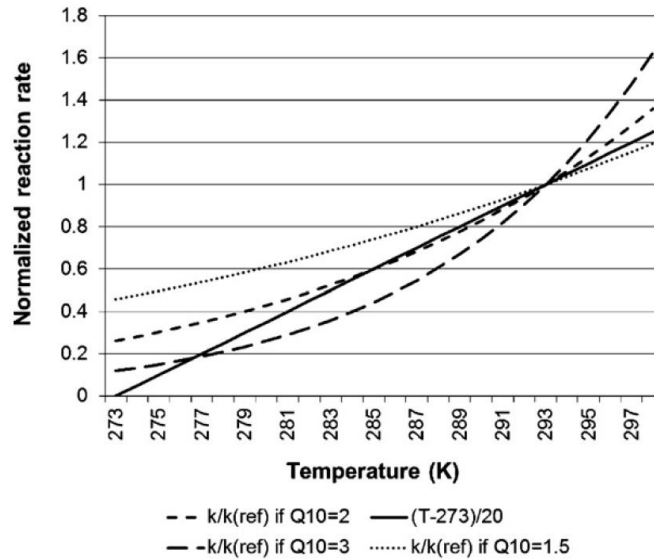


Figure 7: Temperature versus normalized reaction rate [7]

The predicted behaviour of both models is totally different. However, around 4°C and 20°C the predicted reaction rate is comparable. The predicted reaction rate is correlated with the reduced vase life: A higher reaction rate results in more reduced vase life. Below 4°C and above 20°C, the First order Arrhenius model predicts more vase life reduction and between 4°C and 20°C, the degree-hours model predicts more vase life reduction.

In literature, those models are compared with actual test data. From this research, the following results can be given [7]

- For temperatures between 2°C and 6°C, the degree-hours model gives a good approximation of the vase life.
- The FOA model shows the trend of underestimating the vase life at lower temperatures (0 - 6°C) and overestimating the temperatures at higher temperatures (10 - 16°C) The temperature dependency of the normalized reaction rate is underestimated for the range of 0 - 16°C.
- For low storage temperatures (0°C - 2°C) both models are wrong. The Degree-days model overestimates the vase life and the FOA model underestimates the vase life.

- At higher temperatures (above 10°C), both models overestimate the vase life of roses.

The conclusions above hold only for ending of the vase life by natural senescence. When the vase life is ended by Botrytis Cinerea or other diseases, these conclusions will not hold.

The use of the Degree-days model is far more simple than the use of the FOA-model. Therefore, degree-hours model has a preference for the use in practice. However, as concluded above, the degree-hours model can only predict the vase life good enough in the range of 2°C to 6°C. Below those values, the vase life is overestimated. Above this range the vase life is underestimated. This suggest a different approach for the determination of the vase life. Below the new approach is visible.

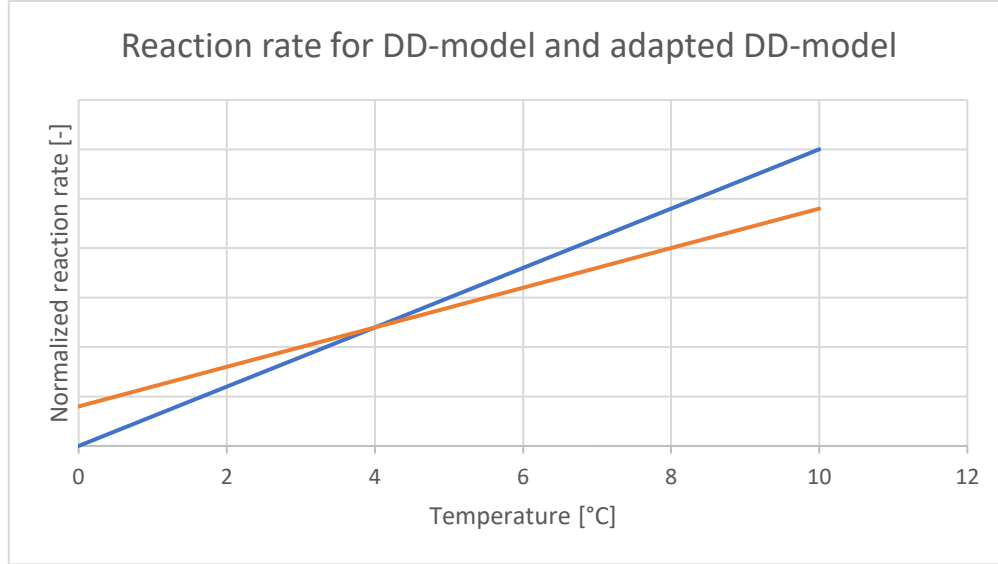


Figure 8: Reaction rate for DD-model and adapted DD-model

The blue line denotes the normal Degree-days model. The orange line is the proposed change of the Degree-days model. This model can possibly handle better the part of underestimation and overestimation. In literature, this model is already used [17]. The model proposes to determine the vase life according to a linear equation using partly the temperature-time dependency (Degree-days model) and a pure time dependency. This leads to the behaviour, visible in the graph above.

The following equation describes the proposed behaviour.

$$VL_{new} = VL_{old} - \int_0^{time} (AT + B)dt \quad (7)$$

The First order Arrhenius model uses knowledge from deterioration behaviour of the roses to determine the model. However, the FOA model does not result in an appropriate prediction of the vase lifes. The linear, Degree-days model results in even good predictions of the vase lifes. In the region between 2°C and 6°C, the predictions are good enough to be used in prediction models. However, the addition of a factor, that is not dependent of the temperature will probably result in better predictions.

2.4.4. Temperature changes

Florists state that temperature changes are negative for the vase life of a rose. One of the disadvantages of a cooling room is the increase in the number of temperature changes. According to one of the florists, the roses will open and become limp very quick when they are brought to a higher temperature. Florists prevent sudden temperature changes and they control the shop temperature as good as possible. Every transport step it is important to adapt the temperature slowly (acclimatisation). (See appendix A).

In literature, some investigations are done to research the effect of the temperature changes. A difference is present between a constant temperature and a stepwise changing temperature (keeping the same time-temperature sum). However, the results are not significant enough to show a clear relation between the number of temperature changes and the predicted vase life [7].

When the temperature is changed, the processes in the flower have to adapt to the new situation. Probably, those adaptations influence the vase life of the rose. Therefore, it is necessary to investigate in the effect of those changes.

2.4.5. Conclusions and further research

The proposed model in equation 7 and the Degree-days model are not based on knowledge of the deterioration processes of the roses. The Degree-days model can be used because it is proven for the predicting the vase life of roses. Especially in the range of 2°C to 6°C, the Degree-days model approximates reality. For values above 6°C it is not good enough to use. When it is used for determining the vase life, the vase life will be probably longer in reality. So it can be used for a conservative estimation.

For the temperature range between 0°C and 2°C, more research has to be done. Can the deterioration behaviour be seen as linear, temperature dependent behaviour? New initiatives [22] are present for storing the roses on low temperatures. For these initiatives, a good insight in the behaviour in that range is required. However, the First order Arrhenius model can be used for a conservative estimation of the vase life for these low temperatures.

The model proposed in equation 7 seems promising. However, this model has to be tested in reality to make it useful for predicting the vase life. The temperature and the time have to be the dependent variables. The other variables have to be set as independent variables in the experiment. Important independent variables are relative humidity, applied water and nutrient, cultivar and the grow history (conditions during growing) and harvest conditions (Equal opening during harvest, equal length and equal amount of leaves). Fixed vase life ending criteria should be handled, like the vase life ending criteria used by Royal Flora Holland [13].

For different values for temperature and time, the test can be executed. When the data is available, it can be compared to the proposed model. A value for A and B can be found and the deviation from the real data should be determined. Those data can be compared to the fitting data from the Degree-days model and the FOA-model [7]. Another important verification is the comparison between the measured data and the data used in literature. Does the data in literature result in the same behaviour?

Apart from investigating in this model, investigations in the effect of temperature changes (constant time-temperature sum) has to be done to result in a good approximation of vase life and knowledge about the influence of temperature.

2.5. Discussion

In this chapter, the different causes for quality deterioration of flowers are investigated. For this research, the deterioration in roses is examined. The most important parameter for reflection is the vase life of a rose. The vase life ends when the rose is visibly deteriorated according to certain quality criteria.

Parameters influencing the quality criteria are temperature, relative humidity, change of infection by Botrytis Cinerea, water balance and the handling of the roses. For all parameters except the temperature, the executed research is really limited. Therefore more research has to be done to know the influence of these parameters and to model the relation between vase life and these parameters. By investigating these parameters, the transport process can probably be optimized.

For the temperature two models exist to express the relation between vase life and temperature. The Degree-days model assumes a linear relationship between temperature and deterioration over time. The First order Arrhenius model assumes an exponential relationship. As discussed in the main part of this chapter, the suggestion is to work out the adapted degree-days model. That model will probably fit the data.

Another suggestion is to do a study to the effects of temperature alterations. Practical experts think the number of alterations and the temperature gradients are important regarding quality decay. However, limited literature is available. A study has to be done to the effect of the alterations.

In this chapter, the effect of the different parameters is discussed. The knowledge of these parameters has to result in optimal handling of the flowers. Therefore the current handling process and eventual improvements have to be discussed. That is done in the next chapter.

3. Flower handling

The roses, examined in this research, are transported from Kenya to the Netherlands. From the Netherlands, they are transported to wholesalers and ultimately to florist and other shops. A part of the flowers is exported again to certain countries in Europe. To fulfil this logistic process, a lot of handling steps are required. During the logistic process, the different parameters discussed in the previous chapter should be as optimal as possible. Sometimes it is difficult due to the absence of good knowledge about some parameters as turgidity and relative humidity. For evaluating the current handling process of cut roses grown in Kenya, this process is given [23]. The information is extended by information of the florists (see Appendix A). In figure 9, the handling steps are summarized for the logistics between a Kenyan farm and the end of the aircraft flight.

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

When the roses arrive at the importer (in the Netherlands), the roses are cutted and placed in water again. Dependent of the supply chain of the roses, different steps are taken. The different steps can be summarized by storage steps and transport steps. In most cases, the roses are stored dry in a cooling room. The transport is done wet or dry (dependent of length, mode and temperature) and can be intracontinental. All actors try to keep the temperature as low as possible.

At the end of one of more steps, the cut roses are stored at the wholesaler. At the wholesaler, the roses are stored in water and the temperature is kept low (for example 5°C). For the transport to the florist, two options are possible. Florist can collect the flowers at the wholesaler and can do the transport by themselves. In those cases, the roses are kept dry at room temperature during transport. The two florists that choose for this option have to travel for half an hour. They can transport the roses by themselves due to the relatively short distance to the wholesaler. The other option is to outsource the transport of the roses. A wholesaler can deliver the roses to the shop. The third interviewed florists makes use of that option. In that case, the flowers are cooled and stored in water during transport.

When the flowers arrive in the florist shop, the flowers are cutted and the lower leaves are removed. The flowers are placed in a bucket containing lukewarm water and in some cases flower food. One of the florists puts a lot of effort in the temperature regulation. The flowers have to adapt slowly to the temperature in the shop. One florist could make use of a cooling room. In that case, a part of the flowers



Figure 9: Overview transportation steps import roses [28]

are placed in the cooling room. When necessary, the roses are brought to the shop itself. The temperature in the shop is somewhat below room temperature. The florists try to keep the temperature low to prevent quality decay.

In most cases, cut roses are sold dry. The florists have given information about the treatment of flowers to the customers. For a good treatment of flowers, the following steps have to be followed:

- Transportation time as short as possible.
- The end of the stems has to be cutted curved and the lower leaves have to be removed.
- The roses have to be placed in a clean vase containing lukewarm water and flowerfood.

When a certain number roses are sold together, the florists will sell the roses in a wet environment, when possible. That can be done, when a customer buys a vase or by placing a 'bag' of water around the ends of the stems. (See appendix A for the interviews with the florists)

Above, the current handling of cut roses is described. In chapter two a number of parameters affecting quality is discussed. In the section below, these factors are evaluated and some improvements are suggested.

3.1. Temperature

The most important factor affecting the quality is the temperature. Therefore, temperature control is important during the transport and storage. In chapter two, the influence of temperature is discussed. The following conclusions can be drawn:

- The temperature has to be as low as possible but can not be lower than 0°C.
- Temperature changes has to be limited.

These two conclusions can be used to evaluate the transport and storage process.

3.1.1. Evaluation

During the grading process the temperature of the environment is 20-25°C for a period of several hours. The temperature of the roses will increase. Due to both conclusions drawn above, this has to be prevented if possible. Although the effect of the amount of Degree-days is limited, the effect on vase life is not neglectible. It has to be examined, if it is possible to do the grading process in different conditions.

A pallet of roses will increase in temperature due to internal heat generation. In the midst of the pallet, the temperature will increase faster than on the sides of the pallet. Therefore, the roses stored in the midst of the pallet, can lose more vase life than roses stored on the sides of the pallet. For keeping the temperature in the right order, the pallet is cooled in some stages. Therefore vacuum cooling is used. The full pallet is placed in the vacuum cooler and the temperature will drop.

A pallet is stacked efficiently. No air can enter between the different boxes. For a more equal temperature throughout the pallet, more space for air has to be reserved. Then, the heat generated by the roses can be transported to the outside. Another advantage is the increased possibility for the cooling of the pallet. For economic reasons, this is not done yet. For the travelling by reefer containers, this is already advised due to the long travelling times and available cooling in the reefer [12].

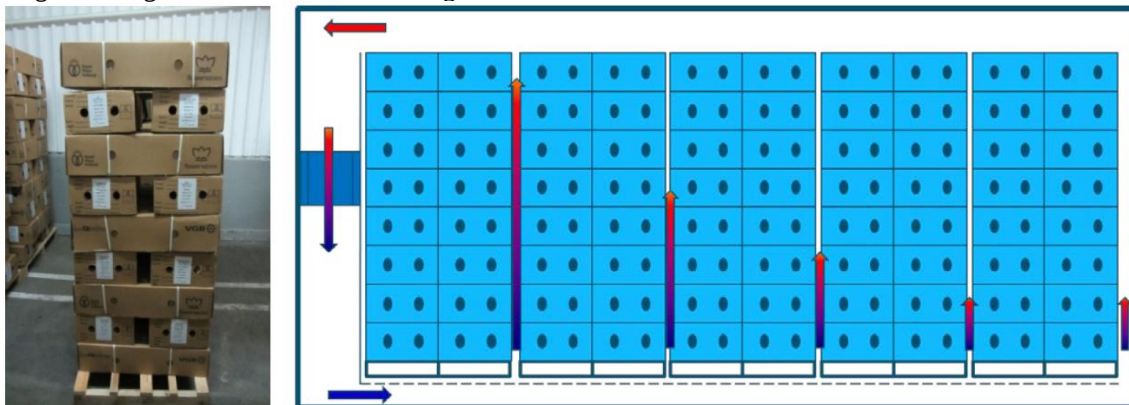


Figure 10: Stacking to promote airflow (on a pallet (left) and in a reefer container(right)) [12]

Apart from the stacking of the boxes on the pallets, more parameters influence the cooling capacity of the pallet. The number of roses in a box is inversely proportional to the cooling possibilities. More roses results in reduced space for heat transportation by the air. In the boxes, holes are present for ventilation. When the box is too full, the box cannot completely be closed and the ventilation holes are blocked. Blocking of the holes and a wrong position of the holes at the pallet can result in bad cooling possibilities. The last thing is the covering of the

pallet. The material of the cover influences the amount of air that can pass the cover. The use of linen instead of plastic is positive regarding the cooling capacity. Another option is the use of covers containing holes. [12]

3.1.2. Temperature sensors

In all cases, a low temperature during the logistic process is important for a long vase life. A low temperature is the set point for a controller. The controller is part of the control framework of Figure 2. The temperature controller has to receive information from the system. The system can be considered as a certain number of roses, present at a certain time and place, having a certain temperature. The information is received by measurements executed by sensors. Therefore, temperature sensors need to be discussed.

Below an example is given for the temperature measurements during the transport of roses via air. In this research [12], the full supply chain is considered, including vase life simulation.

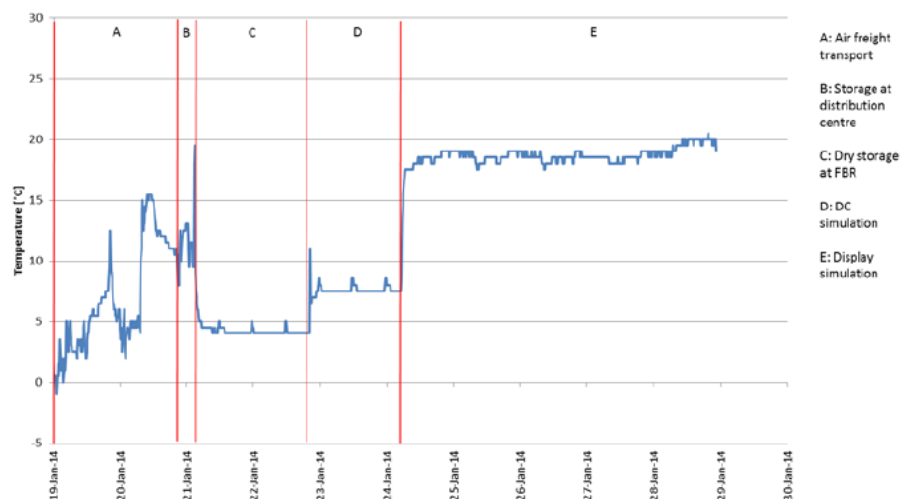


Figure 11: Temperature measurements from transport from Kenya to Antwerp (Air transport) [12]

During the international transport, roses are stapled on pallets. The temperature of the roses is dependent of the place on the pallet. Due to internal heat generation, the roses in the midst of the pallet can be warmer than roses stored on the side of the pallet. Therefore, the temperature must be measured on different places on the pallet.



3.1.3. Temperature actuators

Temperature sensors are available to obtain information regarding temperature development over time. Depending of the control input, the temperature has to be changed according to a desired set point. Due to internal heat generation, the temperature will rise while no action is executed. Therefore, actuators have to cool the roses to a certain desired temperature.

For the cooling of roses several options are available. When the roses are stored in warehouses, the roses are placed in **cooling rooms**. The temperature of the roses will slowly converge to the desired temperature. The cooling speed is dependent of the heat balance. The heat balance is the balance between the internal heat generation and the supplied cold air.

The flow of the cold air is important for the removing of the heat around the boxes. As stated earlier, the space between the boxes of roses is important for the flowing of cold air. Dependent of the possibilities the air flow can

be forced to flow around the roses. In a reefer container, the air flow is directed in a certain direction for the removing of the hot air around the boxes. In the figure below the cooling scheme for a reefer container is shown. Dependent of the placement of evaporator and condenser, the flow of cold air will flow through the boxes of roses.

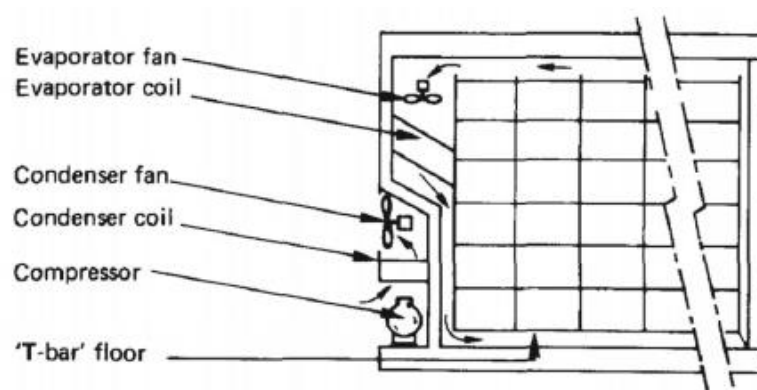


Figure 12: Temperature regulation reefer container [24]

In the case of air transport the temperature of the roses before entering the aircraft cargo compartment has to be as low as possible. When the roses are transported via places having high temperatures, **blankets** can be used. Blankets can be placed upon the pallet of roses. When a blanket is available, the temperature of the outside cannot flow into the pallet of roses. A blanket is only beneficial in the cases when the temperature outside is higher than the temperature of the roses.

Pre-cooling of the pallets of roses can be done in two ways: Forced air cooling and Vacuum cooling. **Forced air cooling** forces the air to flow. The cooling rate is dependent of the speed of the air flow. [25]. Therefore, forced air cooling performs better than cooling by simply placing the roses in a cold environment. The cooling method of a reefer container can be considered as forced air cooling.

A **vacuum cooler** uses a different technology. The pressure in the vacuum cooler is lowered to a certain level. At that level water starts boiling at 2°C. The boiling process at this temperature takes away the heat of the product. [26]. The cooling speed of vacuum cooling is higher than the cooling speed of forced air cooling [12].

3.2. Handling process

The cut roses have to be handled in a proper way. Damage to the roses will result in a reduced vase life. The first aspect of the handling of the roses is the process of cutting the end of the stem bias and the lower leaves of the roses have to be removed. This has to be done, when the roses are placed in a new wet environment. According to the florists this is important to prevent against diseases.

Another aspect is the packing of the roses during transport. Normally, the roses are stapled in two layers (see picture). By using this method, a high number of roses fits in the box. However, a high packing rate results in a lot of heat generation and limited cooling possibilities. Another disadvantage of a high packing rate is a more chance on damage. To limit the damage possibilities, Single Folded Kraft (SKF) can be used. This SKF prevents damage and can absorb water. The disadvantage of SKF is the reduced packing efficiency.

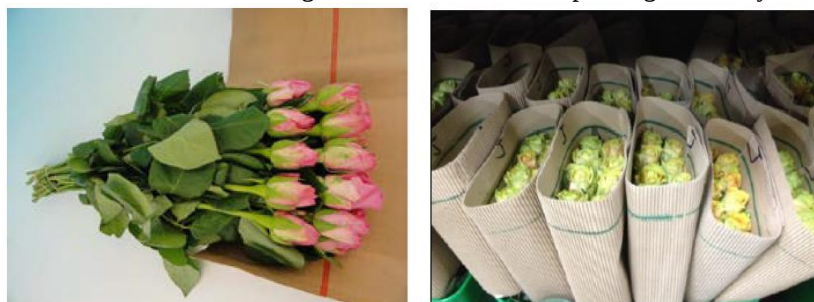


Figure 13: Two-layer stapling of roses (left) and roses in Single Folded Kraft (right) [12]

3.3. Water availability

A high relative humidity results in a higher risk for a Botrytis Cinerea infection. However, a low relative humidity can result in fast dehydration. A good trade-off between these two risks has to be made. Dehydration is the case when the water balance in the flower is too negative. Flower wilting, a reduced flower opening and bent-neck can be symptoms of a negative water balance.

Dry transport of roses performs better than wet transport of roses. For transport around 10°C a significant difference is measured. For other temperatures, dry storage of roses performs at least as good as wet storage of roses [27]. The transport of roses is an alteration between wet storage and dry transport due to the necessity of water for the roses. However, the effectivity of this alteration is discussed [12]. Too many alterations lead to higher risk of infections. Research must be done to the optimal number of alterations. It can be better in some cases to keep the roses in their dry environment instead of placing them in buckets of water. This is only possible when the dehydration is limited.

One of the most important factors affecting quality is the presence of *Botrytis Cinerea*. It is important to limit the chance of an infection. A factor that is important for the infection by *Botrytis Cinerea* is the presence of condensation water on the roses. The condensation water has to be removed fast to prevent infections. Good ventilation is important to prevent *Botrytis Cinerea*. As discussed in a previous part, Single Folded Craft can prevent damage. Another advantage of SFK is the possibility to absorb water. SFK helps to prevent *Botrytis Cinerea*.

When roses are put into a wet environment flower food or anti-bacterial can be added. Anti-bacterial is used to prevent bacterial infections. This can be added at a point in the logistic process, for example at the reception of the imported roses in Holland [28]. Flower food stimulates the optimal development of the buds and will contribute to a beauty appearance of the flower, according to merchandiser. He states that the vase life can increase up to 60% by using flower food. [29] The opinion of florists about flower food is different. Two florists advice to use flower food. One of them thinks flower food does not contribute to a longer vase life. (See appendix A)

3.4. Discussion

In this chapter, the different handling conditions are discussed. First the current handling steps are discussed and after that different improvements are suggested. These improvements are mostly regarding temperature during the transport process. However, a lot more improvements regarding handling conditions are possible. Therefore, more research is required to search for the influence of some parameters like the contribution of flower food and the effect of the relative humidity on the vase life. Practical tests have to be executed to conclude about these effects. Nowadays, the handling of roses is dependent on the common knowledge of the persons working with the roses. However, due to different opinions, research has to be done to end in optimal handling conditions.

In this chapter the optimal handling conditions of the roses are determined. These handling conditions can be used to design the logistic chain. Therefore, the logistic chain has to be investigated in more depth. This is done in the next chapter.

4. Logistic process

The logistic process of flowers is a complicated process. Several parties are involved in the process. First the current logistic process is explained. For this logistic process different transport modalities can be used. The four possible modalities are discussed in this chapter. Furthermore, all internal transport modes are discussed.

4.1. Current logistic process

The logistic process of roses is a complex process. Several companies and persons can be involved in the logistic process. Below a list of relevant stakeholders are given.

Table 7: Stakeholders and responsibility

Stakeholder	Main responsibility
Grower	Cultivation of roses
Trader	Responsible for specific part of the logistic process
Auction	Connect incoming flows to outgoing flows
Retailer	Find customers for the roses
Customer	To enjoy the roses
Transport company	Fast and good quality transport
Government	Sets rules for flower logistics

All different stakeholders (except customer and government) have the goal to make profit. The total earnings have to be higher than the total costs. The earnings are received from the selling of the product. The costs are due to the buying of the products and the expenditure of external costs. External costs can be for example personnel costs, climate control costs and housing costs.

The business model for external companies can be different. For example, transport companies deliver services for a certain price. They are not involved in the trading of the product itself. Customers and the government play a different role in the logistic chain. A customer buys the products according to the determined price. The government determines the boundaries for the behaviour of the different stakeholders by setting rules.

The transport companies and the government are external stakeholders. The other stakeholders are part of the logistic chain. Below a general outline for the logistic process is given. The actual logistic chains can be summarized by this overview.



Figure 14: Overview rose logistics

The grower is the farm where roses are grown. The grower is the first step in the logistic process. The grower wants to get a fair price for his roses. Dependent of his location, size and possibilities, the grower can choose to bring his roses to the auction or sell the roses to a certain trader.

The second block is the block of the auction and/or traders. In most logistic processes, several traders and the auction are involved in the logistic process. The last two parts of the logistic process are the retailer and the customer itself

The exact realization of the logistic process, especially the second block is different due to several reasons. Roses grown in the Netherlands and sold in the Netherlands experience a different logistic chain than roses grown in Kenya, auctioned in the Netherlands and exported to Germany.

Therefore, an example of the logistic chain is shown in figure 15. In this example, the roses are cultivated at a certain farm in Kenya. The roses are transported by aircraft to The Netherlands. In the Netherlands, the flowers are brought to the auction. The roses are bought at the auction and exported to Germany. In Germany, the roses are sold to a retailer that can sell the roses to its customers.

In the following paragraphs, this option is worked out in more detail. Furthermore, the differences between the several possible logistic chains are discussed.

4.1.1.Import supply chain

As discussed before, a lot of roses are grown in Kenya. The grower of the roses is the first part of the logistic chain. The grower of the roses sends the roses to a warehouse in the neighbourhood of the airport. The transport between grower and forwarder is done by truck. The truck is owned by the grower or can be owned by the forwarder. A third option is a third company, that is responsible for the transport of roses by truck.

The forwarder makes the roses ready for transport. The roses are packed in boxes and placed on pallets. The roses are transported by aircraft. In that part of the chain, the airline is responsible for the transport.

In the Netherlands, a forwarder is responsible for the reception of the roses. The forwarder can sell the roses to a certain trader. In most cases, the auction is involved in the selling process. In the example of figure 15, the roses are determined for the auction in The Netherlands, Royal Flora Holland.

When the roses arrive on the airport, the forwarder accepts the roses. This forwarder is in Aalsmeer, the location of the auction. The auction area is located next to Schiphol Airport, the arrival location of the flowers. The transport can be done by in-house transport modes like transport by fork-truck. [28]

The forwarder unpacks the roses and checks the number, quality and temperature of the roses. Roses not meeting the quality standard are thrown away. The stems are cut and the roses are placed in water and anti-bacterial. The roses are packed according to the demands of the customers. The packing can be the normal packing suitable for the Royal Flora Holland auction or can be customer specific. The selling of the roses can be done by the clock system of Royal Flora Holland or can be done directly to (large) customers [30].

4.1.2.Auction logistics

Royal Flora Holland is the greatest flower auction in the world. In 2015, 3.6 billion roses are sold in the auction. [4] The auction handles two different flows: The clock flow and the connect flow. The auction clock is the most important selling instrument for Royal Flora Holland. Growers and importers can deliver their products for selling via the auction clock. Before, the auction starts, customers (wholesalers, exporters, etc.) can see and judge the different supplied roses.

Customers can choose to be present in the auction room or can buy via an internet connection (Kopen Op Afstand (KOA)) [31]. The roses are sold in badges from the same grower, quality and type. The starting price is a price higher than the expected price. The price on the clock will decrease over time. At a certain moment, a buyer can decide to buy the badge. The first buyer gets the badge of flowers and has to pay the price on the clock [28].

It is also possible to buy flowers without using the clock. Therefore, Royal Flora Holland uses an online trade platform named Floramondo. At this platform two options are available: Clock forward sale and direct trade. The first option is the clock forward sale. A limited part of the products destined for clock sale can be bought for a price determined by the grower. The second option is the direct trade option. These flowers are not destined for clock sale. These flowers can be bought only on the platform Floramondo. It is possible to sell or buy these in large quantities. [32]

In 2015, 47,7% of the turnover is the result of sale by the clock. In 2014, 48,9% of the turnover is due to sale per clock [4]. The other part of the turnover is mainly earned due to direct trade. That is the visible trend in the selling of flowers. More customers of Royal Flora Holland use direct ways to buy their products. The benefit of buying at the auction clock is the possibility to influence your price. The benefit of buying without the auction clock is the limited effort that is required for buying roses in the auction and the increased flexibility.

4.1.3.Export logistics

A large group of different exporters and wholesalers buy their products at the auction. The exporters transport the flowers to different countries. The export countries of flowers are mainly European countries. 27,9% of the flowers is exported to Germany, 16,6% to the United Kingdom and 13,5% is exported to France. All countries in the top 10 of export countries of Royal Flora Holland are European countries [4]. An example of the export logistic chain is shown in figure 15 (from auction to retailer).



Figure 15: Logistic process to the customer [28] [32]

For the export of the flowers, exporters are responsible for the transport. In most cases, a truck is used for the transport (see chapter 1). A truck is the most flexible option to bring flowers to any specific location that can be reached via land. Flowers can be stored into containers. Therefore, different transport modalities could be used: Train, short-sea transport and inland waterway transport. The possibility of the use of these options is dependent of the availability of infrastructural and geological constraints.

The exporter of the goods can transport the roses to the destination country. In the destination country, the exporter visits different retailers. Retailers judge the quality of flowers. According to quality and price, the retailers decide which flowers he will buy. Large export companies can use photos to show the quality of their roses to foreign customers. Another option is to sell the flowers to a wholesaler in the destination country. Then the wholesaler can sell the flowers to the retailers. This is the case for the example in figure 15. Retailers (or wholesalers) in the destination country choose the right quantity of the flowers having the right quality and a good price. In that case, the right quantity is transported to retailer or wholesaler [28].

4.1.4. Customer logistics

The customer is the last part of the logistic process. The customer buys his/her roses at a certain retailer. The retailer can be the local florist, a certain shop that sells flowers apart from their other products or can be an online web store. These retailers buy their flowers at the wholesaler.

The wholesaler can be active in the Dutch market or can be active in a foreign market. The wholesaler can buy his flowers from the auction, from another wholesaler or from an exporter. For the logistic process between wholesalers and retailers, different logistic processes are possible. The three interviewed florists are part of three different logistic processes (See appendix A).

A lot of Dutch wholesalers are around Aalsmeer, near the auction Royal Flora Holland. Florists can buy their roses at the location of the wholesaler. The florists can take care for the transport. In certain time intervals (for example two days), the florists went to the wholesaler and buy according to a prediction of the selling. The number of flowers that has to be bought is also dependent of the possibility to store the flowers in a cold environment.

The transport of roses by smaller florists is done mostly by just a normal car, a delivery van or a small truck owned by the florist. During the transport the roses are stored dry and the temperature can increase (dependent of the cooling possibilities).

Some florists prefer to outsource the transport of flowers. In that case either the wholesaler or a third company can take care of the transport. The wholesaler can offer the service to deliver flowers to florist shops. Outsourcing of the transport is dependent of the business model of the florist. In the case of delivering of the flowers by the wholesaler or a third transport company, the transporter will bring the flowers to several retailers. Therefore, the flowers can be transported in a truck with temperature control.

The last stage of the logistic process is the process between retailer and customer. In the most common case, the customer buys a rose in a flower shop. It can be a single rose as a present to show love or friendship to anyone. Another option is the presence of a rose in a bouquet. The customer is responsible for the transport of roses. The customer itself is the endpoint of the logistic process. From the moment, the rose is put in the vase, the vase life starts.

Another option is the ordering of roses online. Although roses cannot be judged, it becomes increasingly popular. In that case, the retailer is responsible for the transport to the customer.

4.2. Transport modalities

The logistic chain of a rose is a complicated logistic process. The logistic chain can consist of intercontinental transport and short-distance transport. These transport tasks can be executed by different transport modalities. In this part of the report the different transport modalities are discussed. These transport modalities are compared according to five evaluation criteria.

4.2.1. Evaluation Criteria

For the choice of a transport mode, several different aspects must be considered. Below a list of important aspects for the choice of a transport mode are given:

- **Costs.** In the full supply chain of the roses, a lot of commercial companies are involved. All these companies want to limit the costs and improve the revenue. In the choice of a transport mode, the cost of a transport mode is important.

- **Quality during transport.** In the transport of roses, it is important to keep the quality of the roses as high as possible. A transport mode that has cooling facilities is beneficial compared to modes without these possibilities. All transport modes have to limit the temperature inside the vehicle. Other aspects regarding the quality can be the possibility to transport in a wet environment and the humidity control in the vehicle.
- **Transport time.** The transport time has to be as fast as possible. The main reason for fast transport is the quality decay during the transport. When the travel time is longer, the quality will decay more. Another benefit of fast transport is the fact that the various parties in the supply chain receive their product in time.
- **Flexibility.** The flexibility of the different transport modes can be defined as the possibility to deliver the right service in the right time on the right place. For transport over land, transport by truck is very flexible; a truck can pick up the roses at most places and can deliver the roses at most places. Other modes are bound to certain places like ports, train stations and airports. For less flexible modes, multimodal transport is necessary. When multimodal transport is necessary, the roses have to be shifted to another mode. During the overloading process, the roses can be damaged and experience higher temperatures for a short time.
- **Sustainability.** The transport sector is responsible for 14% of the Greenhouse Gas Emissions [33]. Due to that huge contribution, it is important to consider the emission of the chosen transport mode. For the comparison between the different modes, the emission of CO₂ is compared in literature [12]. The emission of CO₂ does not take all sustainability aspects into account. However, CO₂ emission can be used for a fair comparison between the modes. It is important to express the emissions per unit of product (flowers) due to the different sizes of the transport modes.

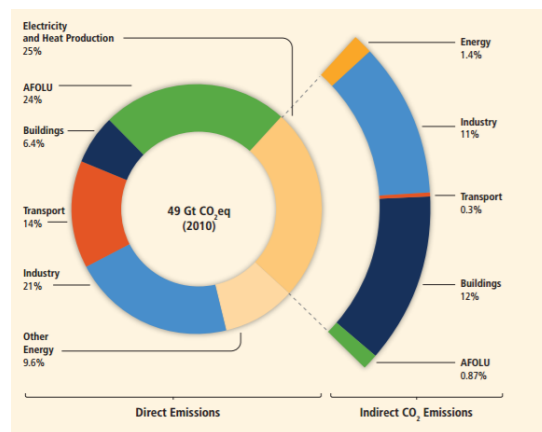


Figure 16: Greenhouse Gas Emissions by Economic Sector [33]

4.2.2. Transport by truck

A truck is the most flexible transport mode for travelling between two places that can be reached via land. Trucks can use the road infrastructure. Due to the highly developed (dense) road network, the truck can choose a short path to its destination. The average speed of a truck is high compared to other modes like sea and rail. However, the truck cannot meet the average speed of an airplane.

Another advantage is the departure time flexibility of a truck. A truck is not bounded to a certain schedule, due to the transport of a single container at one time. When more containers are transported, several trucks are used, departing on their own desired departure times. For a limited number of containers, the transport of roses via road is competitive to other modes regarding the price [34].

The trucks use the existing road network. Therefore, trucks can experience congestion, especially during peak hours. Although, the following statement must be made: 'Everyone who experience congestion, contributes to the congestion'. Due to the congestion, the arrival time can become more unpredictable.

A truck can also contribute to multi-modal transport. Other transport modes rely on the existence of (air)ports or stations. The transport from the transfer point (pre-haulage) and the transport from another transfer point (end-haulage) is often done by a truck.

Transport of flowers by trucks can be done in two options. The first option is to store the roses in a (reefer) container. The reefer container can be loaded upon a truck. This option is especially used for multimodal transport. The container of roses can be brought to a specific transfer point. The container can be transferred to ship or train. Another option is the storage of roses into the cargo compartment. That option is often used for unimodal transport.

4.2.3. Transport by air

Transport of roses by air is the fastest option. In 18 hours, an airplane can bring roses from Kenya to the Netherlands. Currently, air transport is the most widely used transport modality for long-distance transport of roses (see chapter 1). Other modalities cannot guarantee the quality of roses for intercontinental transport. Although new research is done to the replacement of air transport by sea transport [22], this research must be extended to show limited quality depreciation for many samples.

According to GreenChainge, sea transport will result in 87% less CO₂ emission compared to air transport [35]. The costs can be reduced by 30 – 40% when shifting from air transport to sea transport for long-distance transport [36]. However, till now, air transport is the most chosen option for long-distance transport due to its high speed.

Transport by air is dependent of the availability of airports in the neighbourhood of the desired locations. Pre-haulage and end-haulage should be used to bring the roses from or towards an airport. Often truck transport is used to provide pre- and end-haulage. In the situation of the location in Aalsmeer for the auction Royal Flora Holland the location is next to the airport Schiphol. In that case, internal transport can provide the transport between the airport and the auction location.

4.2.4. Transport by sea

The benefit of a ship is the enormous amount of storage area. Reefer containers can be placed upon the ship. In chapter 3, the possibility of the transport of roses from Kenya to the Netherlands is discussed. The average speed of a ship is slow compared to other modalities. However, due to good cooling options in reefer containers, some studies suggest the possibility to replace the air transport by sea transport [22] [12].

For long-distance transport, more research must be done to the feasibility of sea transport. However, for shorter-distance transport, sea transport is a feasible option. Sea transport is environmentally friendly and cheap (both due to the great capacity). The disadvantages are the lack of flexibility (the ship has to collect all the different containers in a port before it can leave) and unreliable vessel schedules. [34]

Another limitation for sea transport is the accessibility of several destinations. The ship can use the sea itself and the inland water ways to reach its destination. The ships are dependent of the availability of ports that can handle containers. In the figure below, all inland waterways in Europa are visible. In this figure, the blue spots show the ports that can handle containers. Using pre- and end-haulage, the flowers can reach destinations near these ports.



Figure 17: Inland Waterways Europe [37]

4.2.5. Rail transport

Apart from truck transport, rail transport is another modality capable of transporting roses via land. The difference between truck and rail is the infrastructure demands. Trucks have to drive via road; trains have to drive via rail. The road network is far more extended than the rail network. Another difference is the flexibility within the network. A train is bounded to predefined time-slots (train schedule) and predefined stopping locations (stations). These factors limit the flexibility of a train.

The transport time for rail transport is higher compared to truck transport. However, congestion problems can result in even higher transport times for truck transport. Due to the prevention of the congestion, the use of rail transport is positive regarding the sustainability. Another advantage regarding sustainable transport is the use of electrical energy and the transport of more volume at the same time. Rail transport can be evaluated more positive than truck transport regarding sustainability. Regarding CO₂ emission, a reduction 65% can be achieved compared to road transport [38].

However, due to the lack of flexibility, train transport is rarely used for transport of flower via land. The only known rail transport of flowers is the transport from The Netherlands to Italy (Milan). Due to the sustainable benefits, GreenChainge [22] is researching the possibility of delivering roses by train to destinations in Europe. They show the possibility to transport the roses over rail [38]. However, due to the flexibility limitations, rail transport is not widely used. However, train transport can be used more in the future. In that case, more cooperation (also with other sectors) is required. In cooperation, a long train can be composed for the transport from a certain location to another.

4.2.6. Evaluation transport modes

Above discussed transport modes can be evaluated according to the proposed evaluation criteria. -- is the most negative evaluation and ++ is the most positive evaluation.

Table 8: Evaluation transport modes

Evaluation Criteria	Road	Air	Sea	Rail
Costs	+ (Small amount) - (Large amount)	--	++	++
Quality during transport	+	-	+	+
Transport time	+	++	-	-
Flexibility	++	-	--	--
Sustainability	-	--	++	++

The evaluation shows the fact that sea transport and rail transport are evaluated in the same way. Both transport modalities are slow and are not flexible. However, the costs are low compared to road and air (especially for large quantities). Two other positive evaluations are the quality during transport and the sustainability. For air transport only the transport time can be evaluated positive. However, this is currently decisive in the modality choice for long distance transport. Road transport performs well, except the sustainability evaluation criteria. For large quantities, the costs for road transport can be high due to the high number of required trucks.

In the next chapter a model is proposed to use for the decision for a certain transport modality. This model can choose according to different parameters which modality is the best for a certain transport task.

4.2.7. Modality shift

Sea transport performs better regarding costs and sustainability compared to air transport. That is the reason for the study on the possibility of the transport of roses by ship [39]. In that case, the roses are stored in a reefer container and cooled to 0,5 - 1°C. These temperatures are not reached in aircraft cargo compartments.. However, a big difference can be seen between the travel times. Travelling by ship can take upto 4 weeks. Due to the length of travelling, the amount of Degree-days can be up to 28 Degree-days. For travelling by air the average amount of degree hours is 7,2 Degree-days. Another point is the underestimation of the Degree-days model for lower temperatures. The decrease in vase life for lower temperatures should be more than calculated in the Degree-days model. So, the vase life reduction of transport by sea should be more than the vase life reduction for transport by air.

However, a fysical test executed by greenchainge shows different results. In that test, roses are transported in a reefer container from Kenya to the Netherlands. In the Netherlands a simulation is done for the transportation to several destinations (also export destinations). Results show an average vase life of 10 days at the customer. That is more than the required 7 days [40].

This test is not enough to conclude about the possibility of the transportation of roses. New tests show that a 7 day vase life can not be guaranteed for roses stored 4 weeks under 0,5 - 1°C [39]. That is logic due to the higher amount of Degree-days and the underestimation for low temperatures. However, the positive result show the possibility to transport roses by reefer containers that have a good quality. More research has to be done to this option to show if reefer transport is a possible way of transporting the roses.

4.3. Internal transport modes

Above discussed transport modes can be used for transport between two different locations in the total supply chain. However, transport of roses is also necessary at a certain location in the chain. Therefore, several possible transport modalities for internal transport are listed below.

The first option for the transport of flowers is the use of a **pallets** for the temporarily storage of flowers. This is the case in the warehouse at the airport in Kenya. These pallets are prepared for transport by aircraft. The transport of these pallets can be done by a fork-lift truck. A fork-lift truck is flexible within the (surfaced) environment of a warehouse or another storage location.

When the roses arrive in The Netherlands the roses are manually relocated to certain **transport carriers**. These transport carriers can function in more parts of the logistic chain. Two important carriers are available: Auction Trolleys and Danish Containers. Roses can be stored on these carriers and can be transported in a certain (surfaced) area. These carriers circulate throughout the whole logistic chain in the Netherlands. Growers deliver their flowers placed on these carriers to wholesalers and to the auction [41]. For the transport to another location, the carriers are placed in the cargo compartment of a truck. Due to the use of these transport carriers, an empty flow, back to the growers is necessary to balance the number of carriers throughout the logistic chain.



Figure 18: Auction Trolley [42] (left) and Danish Container [43] (right)

When more carriers have to be transported over a certain distance, the carriers can be coupled. A fork-lift or tractor can deliver the traction, required for the transport. In Royal Flora Holland, for the transport between the central area and location south, a different concept is used: The Aalsmeer Shuttle. This is a system that transports carriers automatically. The system consists of several frame elements that hang on the rail of the Aalsmeer shuttle. These frame elements move along the rail. Carriers can be placed in these frame elements. [44]

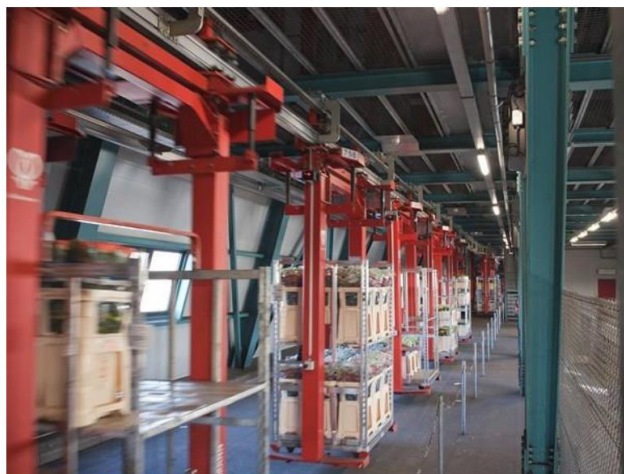


Figure 19: Aalsmeer shuttle [44]

This solution is responsible for the transport of full and empty carriers over this route. On this route, several wholesalers are located. These wholesalers own an entry point to the Aalsmeer Shuttle system. At these points carriers can be placed in or retrieved from the system. The system is responsible for transport of full and empty trolleys. [45]

Sometimes an exchange between transport methods is necessary. That is especially the case for the import of flowers. Imported flowers are efficiently stored in boxes. When the flowers arrive, the flowers must be placed

upon auction trolleys or Danish containers. For a change in transport modality, the flowers must be replaced **manually**.

For internal transport, manual transport is required often. In the auction of Royal Flora Holland flowers arrive from different companies. These companies can deliver different types of flowers having various quality standards. These flowers can be auctioned or can be sold by the Floramondo platform. Each batch of flowers is sold to a certain customer. The redistribution of all flowers according to the correct buyer is a time-intensive task. If all the flowers on a certain carrier are destined for one specific customer, the carrier can be transported to that specific customer. However, in some cases, the flowers on the carriers have to be divided over a certain number of customers. In that case, the flowers have to be redistributed manually to transport carriers destined for that customer.

4.4. Discussion

In this chapter, the logistic process of the roses is described. The logistic process starts at a certain farm where roses are grown. Via several steps of importers, traders, the auction and/or exporters, the roses are sold to a certain retailer. This retailer is responsible for the selling of the roses to the customers.

In these steps, several logistic choices have to be made. For the transport between two locations, four modalities can be used. The four modalities are air transport, road transport, sea transport and rail transport. Nowadays air transport is used for long distance transport and road transport is used for short to medium distance transport. However due to sustainability and cost reasons a modality shift to sea and rail transport has to be considered.

More investigation has to be done in the development of the logistic chain for the use of rail and sea as possible transport options. A study has investigated in the use of sea transport for long distance transport. However, this study cannot guarantee a vase life of seven days after sea transport.

Now the current logistic chain and the current handling methods are known. Apart from that some suggestions are given to result in optimal behaviour. The system has to be steered in the good direction. That is the task of the controllers. In the next chapter, control is suggested to steer the system in the good direction.

5. Control

In the first chapters of the literature research several issues are described regarding the transport of flowers. Flowers are perishable products. Due to that fact, the conditions during transport have to be optimal. These optimal conditions are examined and optimal handling conditions are proposed. For the roses, an extended logistic process is necessary for the transport from grower to customer. In all these logistic process the conditions have to be kept optimal within the boundaries set by the possibilities to influence these conditions. The total of all biological and logistical aspects in the transport process can be considered as the system.

For these optimal conditions and the knowledge about the different transport methods optimal behaviour can be proposed. To reach the optimal behaviour, the optimal behaviour has to be compared with the current behaviour. If necessary, control actions have to be executed. Control actions are part of the framework of figure 2. The control is meant to steer the system in the desired direction. In this case, the system is the logistic chain of the perishable flowers. Measurements and actions determine the arrows between the system and its control.

In this research, the system of perishable roses is examined. The system has both logistical and biological aspects. To control such a system is really complicated. The control methods must deal with both aspects. Therefore, Rong [46] did research to a general control approach for perishable products. In the research a mixed-integer linear programming model is proposed. The model involves temperature control during the full supply chain and supply chain configuration. For the temperature, an Arrhenius temperature dependency is assumed. [46] This general model can be useful to build a complete model of the logistic chain of roses. However, any case must be evaluated if the general model is applicable to the situation.

In this report control examples are given for specific situations. These situations will be described by a model describing the necessary part of the system. The system can be considered in three different levels: Strategic, tactical and operational. In the figure below these three layers are visible.



Figure 20: Different control levels

The strategic level is determined for long-term decisions. On this level, strategic decisions are made regarding the network design. Regarding the logistic process of roses, the strategic level includes the framework of the supply chain. Which parties are involved in the process and how are the links between these parties functioning? In the strategic level, the auction system and the overall control architecture are discussed.

The tactical level is determined for a more detailed working out of the strategical level. On a time-line the tactical level can be seen as medium term. For the logistic process of roses the tactical level is visible in the choice of the transport modality between two stages in the logistic chain. It can be changed without adapting the full supply chain. However, contracts with transporters and loading and unloading demands require preparation of the modality choice.

The operational level is determined for daily decisions. These decisions are based on the direction determined on the upper levels (strategic and tactical). An example of the operational level in the field of roses logistics is the departure time choice for trucks. Trucks can choose their departure time based on the expected congestion on the road. These decisions are short-term. [47]

For all these three levels control is necessary to steer the system in the desired direction. For each of the levels, an example is worked out of possible control to influence the system.

5.1. Strategic level

The strategic level is used for control on the long-term. In this phase, adaptations in the supply chain can be advised. Therefore, the current control architecture is discussed.

5.1.1. Control architecture

Regarding the supply chain of the roses, different actors are present. The first actor is the grower of the roses. Via different traders and (in most cases) the auction the roses are sold to the retailer. The retailer can sell the roses to the customers. Each actor in the supply chain determines the required number of roses. These roses are bought at the previous party. The seller, the buyer or a third party is responsible for the transport.

This situation can be described by a distributed control approach. The order flow and the product flow are determined by the connected parties in the supply chain. In the figure below this is shown schematically. For distributed control, no top layer is available to determine the actions of the individual links.

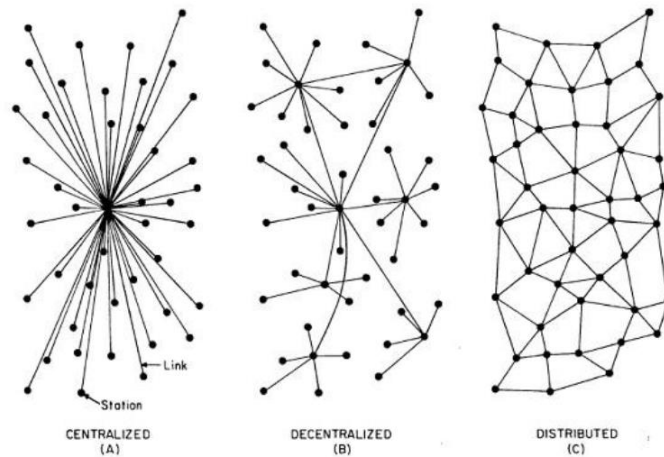


Figure 21: Three types of control explained [48]

The length of the supply chain is dependent from the individual actions of the actors. Choices are dependent on the possibility to make profit on the roses. Each next actor demands a good quality of roses. That is an incentive for the different actors to deliver roses of a good quality (Keep track of good storage).

However, each actor will focus on their own part of the supply chain. That's different compared to a centralized control architecture. In a centralized control architecture one agent controls the full chain. In the case of perishability control, the central agent receives information from important parameters regarding the perishability and manages those important parameters during transport.

In some cases, the central agent is not directly connected to the different actors. Some control agents are responsible for a group of actors. These control agents are connected to the central agent. In that case, the information and action flow requires two steps. This is the case for decentralized control.

As discussed earlier, the supply chain of roses is controlled by distributed control. The disadvantage of distributed control is the limited amount of information available. A study shows that information sharing via centralized control can result in a fresher product. This study is focussed on perishable products in general. The remaining lifetime at the retailer is increased by 18.3% and the number of products not available for selling (at the retailer decreases with 39.0% [49]

However, in the case of centralized control, the central control agent has to handle a lot of information. Especially new sensors and communications systems will contribute to an increased amount of information. High information availability requires (too) much computational capacity. In the case of distributed or decentralized control the amount of information for a single agent is limited. [24]

5.1.2. Auction as control agent

The auction is a central point in the logistic chain. The auction can be considered as a part of a distributed control approach. The auction cannot influence directly the parties, selling roses to the auction. The same holds

for the parties that buy roses at the auction. Everyone can bring roses to the auction and everyone can buy roses at the auction.

However, the central position of the auction is important for the supply chain of roses. The auction can set up a set of standards for the products. These standards can be for example package, length and/or quality level. Apart from that, the auction determines the way how the incoming flow is connected to the outgoing flow. These aspects influence a bigger part of the supply chain. Therefore, the auction has some characteristics of a control agent on a higher level ((de)centralized control).

The determination of the way how the incoming flow is connected to the outgoing flow is a typical strategic decision. As discussed earlier, the auction has two different ways to connect these flows: Via the clock system and via direct trade using Floramondo (in the case of Royal Flora Holland).

In the current situation, all products are transported to the auction location. At the auction location, the flowers can be bought. After the auction process a transporter can bring the roses to the destination. Nowadays it is already possible to stay at your own location as a buyer. This is possible via KOA (Kopen of Afstand, Buy from a distance).

For KOA, it is not anymore possible to judge the roses on the location of the auction. Therefore, appropriate photos are necessary to show the roses and their quality. Apart from the photos, accurate and sufficient information is required to result in proper information transfer. The trend in the future is the replacement of the physical auction clocks by virtual clocks. The price-determination process is equal for both clocks. The main difference is, that the bid-process is online using product photos. [50]

In that case, the buyer is not obligated to be present at the auction anymore. However, the physical product still has to pass the auction system for connecting seller and buyer. Now, Royal Flora Holland develops a new way of connecting the different parties. This project is named: 'Vandaag voor Morgen'. This can be translated by 'Today for Tomorrow'. Today stands for the day of the buying process. Wholesalers and exporters can buy their products according to photos of the product. At that moment, the products are still transported (for foreign products) or present at the grower (for Dutch growers). Tomorrow stands for the day of delivery. [51]

The 'Vandaag voor Morgen' process can enhance the logistic process. Flowers does not necessarily have to pass the auction physically. The auction will develop more into an external intermediation company. The price determination process and the logistic process will be decoupled [52].

These enhancements will simplify and shorten the logistic process. The development of this process will take a lot of time. Advanced logistic operation is required for the distribution of the roses (without a central distribution system). Nowadays a lot of roses travel via the Netherlands to European destinations. If the roses can travel directly to their destination is beneficial regarding to costs, sustainability and quality depreciation. The development of this logistic process will require a lot of research and a different way of thinking (decoupling price determination and logistics). However, the first move is made.

5.2. Tactical level

For the transport between two different locations in the network, a certain transport modality has to be chosen. This choice is made on the tactical level. In most cases, the choice of a transport modality does not influence the design of the network (strategic level). Furthermore, the transport modality choice will not change daily (operational level). Therefore, the choice for a transport modality is a good example of operation on the tactical level.

5.2.1. Model

For the choice of a transport modality Chen develops a time-dependent route choice model [34]. The objective of the model is to maximize the profit of the buyers. The profit is dependent of the auction price and the several costs made. The costs spend during transport are considered as varying in the model. Therefore, the model can be used to evaluate the different transport modes regarding the different costs.

For a fair comparison between the different modes, a cost function is constructed. This cost function, constructed by the different aspects discussed in chapter 4, has to be minimized to come to an optimal transport modality choice. For the transport of roses from Aalsmeer to Duisburg and Hamburg the following cost function is constructed [34]:

$$B_x(y, i) = TC_x(y, i) + DeC_x(y, i) + DaC_x(y, i) \quad (8)$$

In this cost function, the following parameters are used.

Table 9: Cost function parameters

Symbol	Parameter [unit]
x	Destination [-]
B	Route Cost [euro/TEU]
TC	Transport Cost [euro/TEU]
DeC	Depreciation Cost [euro/TEU]
DaC	Damage Cost [euro/TEU]

The cost function uses three different types of costs. These three types of cost will be discussed and evaluated [34].

The first costs are the **transport costs** itself. In this part of the cost function, transport cost of time, transport cost of distance and scheduled delay costs are considered. For the transport cost of time, the travel time has to be calculated. The travel time is the nominal travel time and the extra travel time due to congestion. The costs for travel time are based on the use of personnel and other time-dependent costs. All these costs are linear related to the travel time. Transport costs of distance are based on the total distance of the route. These costs can be for example electricity or fuel costs and vehicle rent.

The less flexible modes are bound to scheduled departure times. In some cases, the roses must wait before the specific modality is leaving. Often, the roses have to wait at the preceding location or in the preceding modality (often a truck). This waiting time can be regarded as the delay time. More delay time requires more cooling costs, personnel costs, etc. The frequency of the chosen modality influences the delay time. Another influencing factor is the arriving pattern of the roses. When the arrival pattern is equally distributed over time, the average waiting time will be higher compared to the situation when all roses will arrive just before the departure of the modality. In that case, the logistic chain has to be adapted according to the departing schedule of the modality.

Another part of the schedule delay costs is the influence of the delay time on the arrival time. When the flowers arrive later than the preferred arrival time, more costs are calculated. It can be seen as a kind of punishment for being too late.

For the transport time, the following equation is given, based on information from the master thesis of Chen [34].

$$TC = \sum_{i=1}^n ((t_i - t_{i-1})VOT_{i-1,i} + P_{i-1,i} * L_{i-1,i}) + \sum_{k=1}^{n+1} SCD_k \quad (9)$$

In the table below, the different parameters are explained.

Table 10: Parameters transport time

Symbol	Parameter [unit]
TC	Transportation Costs [€]
n	Number of different transport steps
t_{i-1}	Time at the start of a certain transportation step [hr]
t_i	Time at the end of a certain transportation step [hr]
$VOT_{i-1,i}$	Value of Time [€/hr]
$P_{i-1,i}$	Price per distance [€/km]
$L_{i-1,i}$	Distance of a specific transport step [km]
SCD_k	Scheduled delay cost for a change-over of transport mode and punishment for being too late.

The transportation of a certain number of flowers can consist of different transport steps. For example, the transport of roses from Kenya to Royal Flora Holland contains one or more steps that require a truck and one step that requires an airplane. The transport costs of the different transport steps will be added together in the equation. The scheduled delay costs are added (together with the punishment costs) for all change-overs in the logistic process and the first loading and the last unloading step,

In the formula above, the Value of Time, denotes the costs that are dependent of time. The VOT is dependent of the different transport modes. Below the relation between the transport tariff (VOT) and the specific transport time is given. Different modes show different characteristics as shown below.

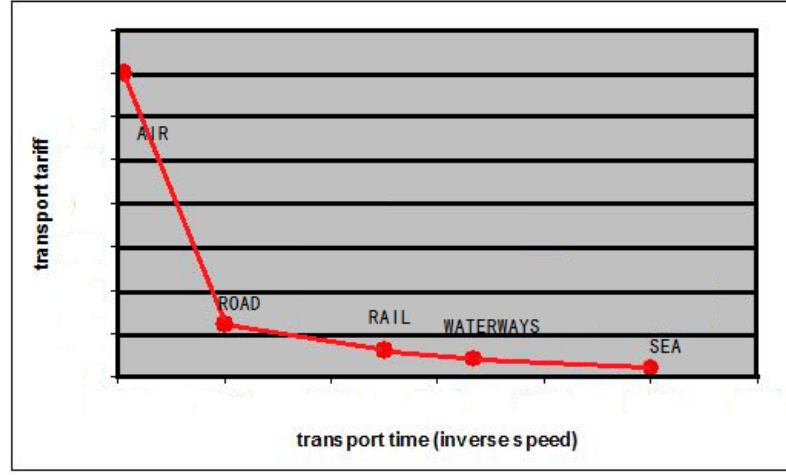


Figure 22: VOT versus transport time [34]

The second part of the cost function constructed by Chen [34], are the costs due to **depreciation**. Depreciation costs consider the quality decay of the roses during transport. The depreciation costs are calculated using the following formula [34]:

$$DeC_x = re(t_{end} - t_{begin}) \quad (10)$$

In the formula above, re is a certain depreciation ratio, $t_{end} - t_{begin}$ shows the time of the trip. According to Chen, the value of the depreciation ratio re is 5 euro/TEU/hour. The function shows a linear relation between costs and depreciation of the roses. However, questions could be asked about the correctness of this relation. In reality, during quality depreciation, a quality level reduction or eventually a disapproval can take place. This will occur, only in cases when the quality depreciation is to a certain visible level. The relation between quality depreciation and the actual loss of value can be regarded as a stepwise function.

Although, the assumption is not fully right, a linear function can approach the real situation. Different retailers, traders and goods inspectors can come to a different judgement for the same quality of roses. This point reduces the stepwise behavior of the relation and renders the plausibility of a linear relation.

The third aspect of the cost function proposed by Chen [34] are the **damage** costs. The damage costs are the costs due to a reduction in quality due to external damage. External damage can occur when during transport or loading, a certain force is exerted on the flowers. A relation between the number of transshipments and the damage costs is assumed. The following relation is given for the damage costs:

$$DaC_x = ra * ttrans_x \quad (11)$$

In this formula ra is the damage ratio and $ttrans_x$ is the number of transshipments. The value of ra is assumed to be 27 Euro/TEU/hour.

These different costs result in the cost function shown in equation 8. For different transport modalities, the total costs are build up in a different way. Below the transport from Aalsmeer to Duisburg is visible. The main transport mode is the ship. A truck is used for pre-haulage and end-haulage. The flowers are transported from Aalsmeer to the port of Rotterdam by truck (pre-haulage). From Rotterdam to Duisburg, inland waterways (IWW) are used. From the port in Duisburg the flowers are transported to the retailer by truck (end-haulage). Pre-haulage is 73 km and end-haulage is 2.6 km.

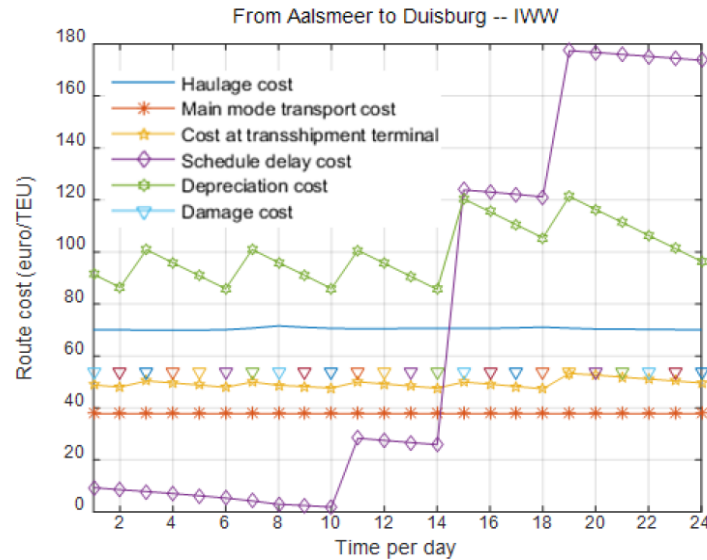


Figure 23: Composition of costs for Aalsmeer-Duisburg [34]

On the X-axis of the figure above, the departure time of the day is shown. Most costs are independent of the chosen departure time. Haulage, damage and transshipment costs are dependent of the chosen transshipments between modalities but independent of chosen departure time. The main mode transport costs are dependent of the length of the waterway connecting the port of Rotterdam and Duisburg and the nominal transport time of the ship.

Two types of costs are dependent of the departure time of the day: depreciation costs and schedule delay costs. For the depreciation, the departure time of the ship is important. The time between the arrival of the (pre-haulage) truck and the departure of the ship, the container is stored on the container yard. There, the depreciation process will continue. Therefore, the depreciation costs will increase for increasing waiting time. The zigzag behaviour is coupled to the departure of the ship. The frequency of the ship departure is five times per day.

When the departure time is later than 14:00, the schedule delay costs will increase suddenly. This is the result from the penalty because the flowers arrive too late. Due to the high costs in the model for this penalty, the schedule delay costs are increasing very fast.

5.2.2. Evaluation of the cost function

In the beginning of the paragraph, five points are mentioned for the evaluation of a cost functions. The proposed cost function is evaluated according to these five points:

- **Costs.** The basis of the proposed cost function is a function based on actual costs. Therefore, the costs are considered in the function.
- **Quality during transport.** The damage costs and the depreciation costs are both part of the cost function. The damage costs are more focused on quality decay due to handling errors. The depreciation costs are focused on quality decay due to normal deterioration as a function of temperature and other factors.
- **Transport time.** The first element of the cost function is based on the costs due to transport time.
- **Flexibility.** The flexibility of a transport mode is not directly considered. However, indirect effects can be seen in the cost function. Less flexible modes cannot reach their destination directly. Therefore, multimodal transport is required. For multimodal transport, more scheduled delay costs (SCD) are taken into account. For less flexible modes, higher costs are considered.
- **Sustainability.** Sustainability is partly considered. Due to several measures from the government like the oil tax, a transport company has to pay for sustainability. However, the transport company does not pay (enough) for compensating all negative effects of greenhouse gas emissions. Research has to be done to establish a function that involves the compensation for these negative environmental aspects. However, the difficulty of this part of the function is the expression of sustainability in costs. Sustainable costs do not have to be paid by the transport company itself. However, research has to be done to the calculation compensation costs. For CO₂ emission, a value of €135/ton CO₂ has been used [53].

5.2.3. Adaptations logistic process

Nowadays, truck and airplane are the most widely used options for the transport of flowers. Air transport is used for long-distance transport and road transport is used for short- to medium distance transport. However, rail and

sea transport perform better regarding costs and sustainability. These transport modalities are not widely used due to the low average speed and low flexibility (regarding time and place).

Chen did some research to the use of different modalities for the transport from Aalsmeer to Hamburg and Duisburg [34]. These cities are both located on the west-side of Germany at 210 km (Duisburg) and 480 km (Hamburg) from Aalsmeer. Hamburg can be reached via road transport, rail transport and via sea transport. In the case of sea transport, the North Sea itself can be used for transport by sea. This kind of transport can be seen as shortsea transport. For transport to Duisburg, road transport, rail transport and sea transport are possible again. For Duisburg, the inland waterways can be used as waterway for the ship. Transport by air is not considered because air transport is meant for long distance transport.

Below the results of the model are shown. The route costs are the total route costs containing transport costs, depreciation costs and damage costs.

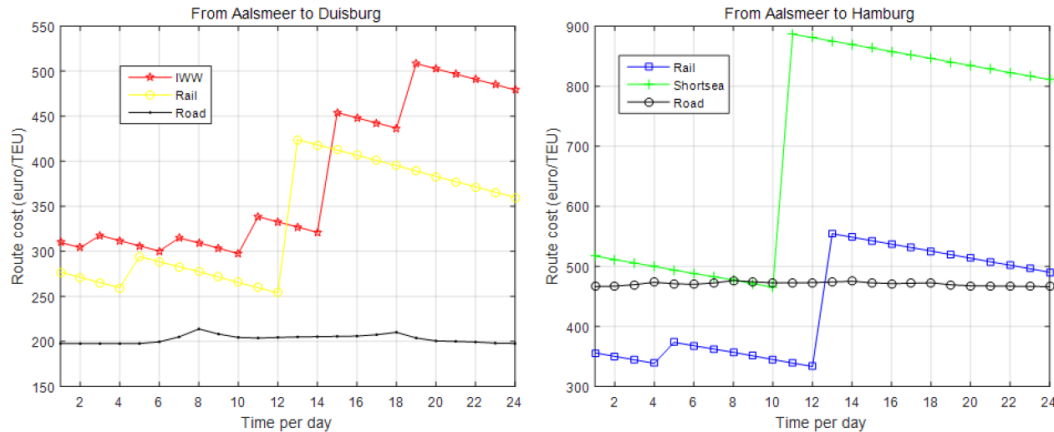


Figure 24: Transport Costs for two cities and three modes [34]

For the transport to Duisburg, road transport performs the best. For transport between Aalsmeer and Hamburg, train performs the best for departure times till 12:00. After 12:00, road transport performs the best.

For multimodal transport, pre-haulage, end-haulage and transshipment results in an increase of the costs. Especially for short distance transport these costs contribute for a significant part to the total costs (see figure 23). For the (shorter) route to Duisburg, multimodal transport cannot compete with unimodal road transport. The transport distance to Hamburg is approximately twice as long compared to the transport distance to Hamburg. For Hamburg, rail transport can compete with road transport for certain conditions.

Due to two reasons, multimodal transport can result in the optimal transport method for transport of flowers under certain conditions:

1. In the cost function, sustainability is not considered. Rail transport and sea transport perform better regarding sustainability. Adding CO₂ emission to the cost function can result in a different trade-off in the favour of rail and sea transport.
2. The trade-off is dependent of the distance between the locations. For longer distances sea and rail transport will become more attractive. Therefore, for destinations greater than 500 km (further than Hamburg) rail transport can become competitive. For sea transport this trade-off will be present for a greater distance. However, the location of this trade-off is dependent of the availability of infrastructure.

It can be concluded that transport per truck is the cheapest option for transport distances below 500 km. However, when sustainability is considered and the transport distance increases sea and rail transport become good alternatives.

Nowadays, limited control is available for the transport modality choice. Truck transport and air transport (for long distances) are the standard options for the transport of roses. Due to the presence of distributed control it is difficult to implement a new way of thinking. Every single step is responsible for the links between these steps. Centralized (or decentralized) control can result in faster transitions when the central control agent changes his mind regarding transport modality.

5.3. Operational level

The operational level is meant for the daily basis. For some parameters, the time steps between measurement is small. When the measurement time step is small, the measurement can become continuous. The controller has to

react on the received information from the measurements. It has to coordinate actions according to these measurements and the desired behaviour. These actions have to be executed for small time steps too.

An example of operation on the operational level is the temperature regulation during transport. Temperature measurements can be continuously or in small time steps. The temperature has to be adjusted as fast as possible when a difference is seen between desired and actual behaviour. The controller is the connection between the measurements and the actions. In chapter 3, the possible temperature measurements and possible actions are discussed. These sensors and actuators can be used to steer the system in the right performance.

The temperature has to be controlled during the complete logistical process. The logistic process consists of several stages. These stages can be divided in three main groups: Transport stages, storage locations and intermediate stages.

The first group consists of the different **transport stages**. An example of a transport stage is the cargo compartment of an airplane. The control possibilities are dependent of the transport modality. Truck, aircraft and reefer containers have different ways to control the temperature.

Aircrafts fly on a certain height. Due to the cold temperature in the air, the airplane has to be heated. However, no literature is found regarding the temperature control in the cargo compartment of the plane. It is known that the temperature of the roses will increase during the flight. That seems contradictable due to the heating of the airplane. Research has to be done to the temperature control in the airplane cargo compartment. Is it possible to limit the cargo compartment heating to store the roses on a lower temperature?

Reefer containers can be used for sea transport, rail transport and even for road transport. Reefer containers can contain an ingenious temperature control system. Already in 1987, the following is stated about the reefer containers control functions: "Basic control functions include supervision of compressor capacity, air, brine and refrigerant temperatures, temperature of cargo, ambient, defrosting, cooling-down programme, diagnostic information, maintenance schedule and spare parts inventory" [54]. Reefer containers can control all desired parameters in an optimal way. For the storage of roses, the challenge is to determine the optimal conditions during transport.

Road transport can make use of reefers or can use the cargo compartments of trucks. Cargo compartments of trucks can have advanced climate control possibilities like reefers [55]. Apart from the unknown control options in the cargo compartment of airplanes the control possibilities are sufficient for transport stages.

Roses are stored in different **storage locations**. In most cases the roses are stored in cold storage facilities. In those cold storage facilities, the temperature is set to a certain set point. However, this will not necessarily result in the same product temperature. The temperature in the cooling room is not equal to the set point for any place of the cooling room. Other reasons for a possible temperature difference are the heat transfer resistance and internal heat generation of the products [12].

Therefore, the air has to be measured in different places of the cooling room and in the product, itself. These values can be compared to the desired temperature [12]. These proper measurements are required to result in proper temperature control. Apart from the measurements proper temperature cooling is required. The cooling has to result in a constant temperature over the full cooling room.

The last group of stages are the **intermediate stages**. During these stages, hardly any control is available. In most cases the roses are transported via the hot environment and the roses will heat up during this stage. In some cases, temperature loggers are available during these stages. Blankets can be used for limiting heat transfer between environment and product. In most intermediate stages the actions are determined manually. It can be seen as manual control.

In all stages, the temperature has to be kept as low as possible. Dependent of the cooling capacity and the isolation of the room, the roses can reach a certain temperature. However, roses can experience damage when the temperature is beneath 0°C. Therefore, the temperature has to be higher than 0°C in any case.

5.4. Discussion

Control can be used in three different levels: The strategic, tactical and operational level. These levels differ on level of detail and time horizon. Network (re)design will take place on the strategic level. Due to changes, initiated by the auction, the network will change. The auction is still responsible for the price-determination process. However, the logistic process can be decoupled from the physical auction. This decoupling is positive

regarding costs, sustainability and quality depreciation. Due to these reasons this shift can be evaluated positively. However, more research is necessary for the forming of a new logistic network.

The transport modality choice can be part of the tactical level. According to a model, the use of a truck is beneficial for short-distance transport. For distances more than 500 km, rail and sea can become competitive. Including sustainability costs rail and sea become more attractive. That would be positive due to the mentioned aspects. More research is necessary to determine the actual costs for sustainability, for example the CO₂-emission.

Temperature regulation is part of the operational control. In several transport stages, the temperature must be controlled in an optimal way. These stages are the transport stages, the storage stages and the intermediate stages. For all these stages, the temperature has to be as low as possible. However, the temperature must be higher than 0°C in any case to prevent damaged to the roses.

Appropriate measurements and actuators are available for temperature control. Probably the improvement will be possible in other aspects. The first aspect is the modelling of temperature dependancy as stated in chapter two. The next aspect is the missing of a overall real-time temperature control strategy. Different parties can have different control strategies. This can lead to temperature changes and quality depreciation. The next suggestion is to come to an overall control approach as suggested by Rong [46]. This overall control approach have to cover all biological and logistical aspects.

6. Conclusion

This report investigates in the logistic process of flowers. For this study, relevant literature is explored and practical experts are interviewed. For this research, the following main question is leading for the research:

What is the best strategy to enhance the life of flowers during their transport?

The first step made before determining what strategy fits best is to determine what kind of flower there are to investigate. Flowers experiencing the most deterioration are most worthy to investigate. Apart from that, for flowers having a long and complex supply chain, research is worthwhile. The group of cut flowers are perishable and have (in many cases) an extended supply chain. The focus is on roses, due to their intercontinental logistics.

The clearest variable denoting the quality of flowers is the vase life. Vase life can be considered as the time the flowers can be on the vase at room temperature displaying good quality. The quality can be graded according to several visual aspects. These aspects can be the opening of the bud, the robustness of the bud, the wilting of the flower and the angle of the neck.

The most important parameter affecting quality is the temperature. For increasing temperature and increasing storage time the quality depreciation will increase. Several models describe the relation between temperature, time and vase life. The vase life reduction is (approximately) linear dependent of the product of the temperature and the time. However, for low temperatures, that model underestimates the vase life reduction.

Other influencing factors are relative humidity, infection chance by *Botrytis Cinerea*, the water balance and the execution of the handling process. The product has to be handled in a way that all parameters are set in an optimal way. Furthermore, the roses have to be handled in a way without being damaged. When the environment changes (especially for a change between a wet and dry environment) leaves have to be removed and the tip of the stem has to be cut.

The logistic processes of roses can differ a lot. However, all logistic processes start at the grower. The grower can sell the roses to a certain trader or to the auction. Via multiple traders and (eventually) the auction, the flowers will be brought to a certain retailer. The retailer is responsible for the selling of the product to the customers. Between the several links, transport solutions have to be found. The four main modalities for flower transport are air, truck, sea and air. Air and truck are the most used options. Sea and rail can become more attractive due to costs and sustainability reasons. The infrastructure availability and lack of flexibility are the most important reasons for not using those modalities.

The temperature is the most important parameter influencing the vase life of roses. Therefore, temperature measurements have to be available during the full logistic process. Temperature sensors can be placed in multiple places in the product. Several cooling mechanisms can be used to bring the temperature to a desired value. In most stages of the transport process the room can be cooled. Vacuum air cooling and forced air cooling can be used to provide faster cooling.

Operation control can be used to control the temperature in an optimal way. For an increasing time horizon, tactical control can be used for the determination of the correct modality. A time-dependent route choice model calculates the costs for the different modalities. Strategic control can be used to optimize the logistic chain of roses. New trends of the auction permit the decoupling between price determination and the logistic process. The transport of roses can become more directly from grower to retailer instead of transport via the auction.

7. Recommendations

In this report, the perishable product of a flower is examined. This report gives an overview of all information available in the literature. However, a lot of desired information is not available in the literature. Below some important 'gaps' are given between desired and available information. Research has to be done to these aspects to result in an optimal logistical process.

In this report, it is shown that the two different models describing the relation between the temperature, time and vase life reduction are not accurately representing real data. Especially for low temperatures (0-4°C) the relation has to be examined in more detail. A detailed relation is important because these temperatures are most suitable to store the roses. As discussed in the report, the adapted Degree-days model can fit the actual measurement. More research is necessary to verify and validate the model.

Apart from the temperature, several other parameters influence the vase life. Limited literature is available to show (mathematical) relations between vase life reduction and these parameters. The same holds for the effect of change in conditions. Practical experts state that changes of environment (changes in temperature and alteration between a wet and dry environment) will have negative effects on the vase life. Hardly any research is available for the confirmation of this statement. Therefore, more research is necessary to investigate in the effect of changes in environment.

A research project [22] is going on to the replacement of air transport by sea transport. This is done due to sustainability and cost reasons. The research project shows some positive results: Tested roses have a vase life of more than 7 days after sea transport from Kenya to the Netherlands. However, not all test can guarantee this required vase life of 7 days. When more results become available, more can be known about the possible change. This modality change (and the according quality depreciation) has to be examined for other routes. Especially for shorter routes, sea transport can be a promising option.

For shorter (inland) transport, truck is the most used option. For small distances and/or small orders a truck is the best option. However, for longer distances (more than 500 km) and larger amounts other modalities are possible too. Transport via rail and transport via sea (both inland waterways and short sea) are performing better regarding sustainability and costs. Therefore, more investigation has to be done in the use of these modalities. Dependent of the available infrastructure, these modalities can be responsible for flower transport.

Currently the price-determining mechanism and the logistical process are coupled for all auction transactions. All flowers are transported to the auction. At the auction the price is determined by supply and demand. When the roses are bought, the roses can be transported to the desired destination. However, new trends show the possibilities to decouple the price-determining process and the logistical process. Then, photos and detailed product information is used for determining the price in the auction. The flowers do not necessarily have to pass the auction. Therefore, the full logistic chain has to be redesigned. New research is necessary to investigate in the optimal logistic chain.

The cooling process is important to result in high quality products at the end of the supply chain. Regarding the cooling process of the airplane cargo compartment, no information is available. Therefore, the cooling process of the airplane cargo compartment have to be examined. It has to be designed in an optimal way to result in limited loss of vase life. Another weak point during the logistic chain of the roses is the temperature control during the different stages between transport and storage. For a short time, the roses are transported via a place of higher temperature. Research have to be done to prevent these peaks in temperature.

Above mentioned recommendations show the most important subjects for new research. Research in these subjects can lead to better understanding of the perishable flower supply chain and especially for the rose supply chain. All research has to end in more sustainable and cheap operation of the logistic chain and has to guarantee a product of a good quality at the end of the chain.

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Appendix A: Interviews met bloemisten

Antwoorden interviews met bloemisten. Er zijn drie verschillende bloemisten geïnterviewd. Het gaat om de volgende drie personen:

Toke: Eigenaar van Toke Bloemen

Inge: Eigenaar van Bloemig

Pauline: Eigenaar van Pauline Bloembinders Delft

De antwoorden worden respectievelijk afgekort met T, I, en P.

Wordt er onderscheid in prijs gemaakt op basis van de kwaliteit voor een roos?

Do you sell your roses for different prices depending on their quality?

T: De prijs van een roos kan fluctueren per dag. De grootste factor die de prijs bepaald is de vraag en aanbod. Rondom hoogtijdagen als valentijn, kerst en moederdag is de prijs dan ook een stuk hoger. Daarnaast wordt er onderscheid gemaakt op basis van de kwaliteit. Een bijzondere roos heeft een hogere prijs dan een gemiddelde roos. Verder bepalen de verschillende factoren die de kwaliteit bepalen en de lengte van de steel de uiteindelijke prijs. Dit gaat zowel om de inkoopprijs als om de verkoopprijs.

I: Ik heb veel rozen die van een hoge kwaliteit zijn, namelijk van het ras Red/White Naomi. Dat is een echte kwaliteitsroos die ook veel geld kost. De prijs kan per dag wisselen en heeft vooral een hoge prijs rond dagen zoals kerst en Valentijn. Er is ook een duidelijke afhankelijkheid tussen de kwaliteit en de prijs. Soms vragen klanten om rozen met een langere steel. Die hebben ook een hogere prijs.

P: De soort roos is van invloed op de prijs. Een luxe roos is meer waard dan een doorsnee roos. Wel wordt er binnen een kwaliteitscategorie geen onderscheid gemaakt in de prijs.

Wanneer heeft een roos voor u een hoge kwaliteit? Welke factoren bepalen de kwaliteit?

When is a rose of a high quality? What factors determine the quality?

T: De volgende factoren beïnvloeden de kwaliteit:

- De dikte van de kop. Deze is vaak dikker bij een langere steel.
- De dikte van de steel.
- De roos moet iets gesprongen/geopend zijn maar niet te veel.
- De hardheid van een roos. Als de roos nog hard aanvoelt is deze nog vers. Als deze zacht aanvoelt is hij niet meer vers.

De roos is van een hoge kwaliteit als de kop voldoende dik is, de steel voldoende dik is, de roos hard aanvoelt en de opening naar wens is.

I: Mensen in Delft willen geen rozen die open zijn. In andere steden hebben mensen sneller een voorkeur voor een roos die al open is. In Delft moet de roos dus voldoende dicht zijn. Voor een begrafenis of een trouwerij zijn echter wel open rozen noodzakelijk. De stevigheid van een roos is belangrijk. Daarnaast zijn de grootte van de roos en de stamdikte van groot belang.

P: Het juiste stadium van een roos. Een roos moet net gesprongen zijn. Dat is beter dan dat een roos nog gesloten is. Bij een gesloten roos is het nog niet met zekerheid vast te stellen of deze ooit nog open gaat. Een roos mag ook weer niet helemaal open zijn. Dat betekent dat het vaasleven van een roos minder lang is. Verder is een mooie, dikke, volle knop vaak een kenmerk van een kwaliteitsroos. Dit gaat niet in alle gevallen op, maar wel in veel.

Wanneer heeft een roos een dermate lage kwaliteit dat deze niet meer verkocht wordt?

When is a rose of such a quality, that it is not sold anymore?

T: Als deze zacht aanvoelt en uitgebloeid is.

I: Dat is te bepalen met een kennersoog. Als deze niet meer stevig is.

P: Als deze helemaal open is.

Hoe lang blijven rozen gemiddeld in de winkel?

How long do you keep arrived roses in your hold?

T: Maximaal 3 dagen

I: Gemiddeld 2 tot 4 dagen en een maximum van een week.

P: Maximaal 2 dagen (Haar winkel is alleen donderdag, vrijdag en zaterdag geopend)

Welke maatregelen neemt u om de rozen zo goed mogelijk te bewaren?

What measures do you take to store the roses in the best possible way?

T: Ik heb geen koelcel. Dat komt door de kleine omvang van de winkel maar dat is ook een bewuste keuze. In de koelcel neem de groei af en dat is niet goed voor het proces van de roos. Als ze een te lange tijd in koelcel hebben gestaan en dan weer onder hoge temperatuur komen gaat het openen van de roos erg snel en zal de roos ook snel achteruitgaan (slap worden). Dat is het geval als ze meer dan twee dagen in de koelcel staan. Daarom is mijn keuze om ze gewoon in de winkel te houden. Ze worden gewoon in het water gehouden en hoeven geen voeding te krijgen. Wat wel belangrijk is, is dat de rozen bij aankomst in een schone vaas worden geplaatst. Dit in verband met eventuele bacteriën.

I: Een koelcel is een te grote investering. Wel is de temperatuur in de winkel is van groot belang. In de zomer continue en in de winter 's nachts wordt er koude lucht geblazen om de temperatuur laag te houden. De deur van de winkel wordt dan ook steeds dicht gehouden. De rozen worden bewaard in water, waar ze ook voeding krijgen. Als ze weer opnieuw worden afgesneden is het belangrijk dat ze net en schuin worden afgesneden.

P: Als ze een grote batch inkoopt wordt een deel bewaard in de koelcel. Daar worden de bloemen bewaard op 5°C. Als de voorraad bloemen in de winkel opdraakt worden de bloemen uit de koelcel gehaald en in de winkel geplaatst. In het algemeen moeten bloemen niet op de tocht staan, mogen geen bladeren in het water hangen. Moeten ze in een schone vaas met lauw water en voeding geplaatst worden en moeten ze netjes schoongemaakt worden. Dat wordt gedaan door een roos schuin af te snijden, de doornen en de bladeren te verwijderen. Daarbij mogen geen wonden ontstaan want dat geeft potentie voor infecties met bacteriën.

Wat zegt u tegen uw klanten over hoe lang de rozen op de vaas kunnen blijven staan?

What do you inform to your customers about the vase life of a rose?

T: Een week

I: 5 dagen

P: Een week

Wat gebeurt er als een klant niet tevreden is?

What happens if there is a claim from a customer?

T: Ze krijgen altijd een nieuwe

I: Klanten moeten een foto laten zien en er wordt gevraagd of ze, zich hebben gehouden aan de adviezen die gegeven zijn. Als dat het geval is wordt een nieuwe roos gegeven.

P: Er wordt gevraagd of de klanten zich aan de geadviseerde behandeling van bloemen hebben gehouden. Dat is ook zichtbaar aan het snijvlak omdat ze bewust recht afgesneden meegegeven worden. Ze moeten namelijk schuin afgesneden worden. Toch krijgen ze altijd een nieuwe bloem.

Kunt u uitleggen hoe het aankoopproces voor rozen in zijn gang gaat? Hoe wordt de kwantiteit en kwaliteit bepaald?

Can you explain the process of buying new roses? How is quality and quantity determined?

T: Ik ga zelf naar de groothandel. Daar kies ik zelf nieuwe rozen uit. Het gaat dan om rozen met een goede prijs/kwaliteit verhouding. De hoeveelheid wordt bepaald door het verkoop van de afgelopen tijd. Ik ga meestal om de twee dagen naar de groothandel.

I: Ik ga om de twee dagen naar de veiling. Daar is een soort grote gekoelde ruimte genaamd de Piramide. In de Piramide kies ik de bloemen uit met een voldoende kwaliteit. De prijs/kwaliteit verhouding is ook belangrijk, maar ik vind het belangrijk dat ik een goede kwaliteit kan leveren. De hoeveelheid is afhankelijk van hoeveel bloemen ik verkocht heb de afgelopen tijd en denk te verkopen in de komende tijd.

P: Ik koop de bloemen in bij de groothandel. Eén keer per week ga ik naar de groothandel om de bloemen te beoordelen. Ik bestel ze via de webshop en twee keer per week worden ze bezorgd. De kwaliteit en kwantiteit worden bepaald, afhankelijk van de vraag.

Wat weet u over het logistieke proces van de rozen voordat ze bij u in de winkel aankomen?

What do you know about the logistic process before the roses arrive in the store?

T: De groothandel is tegelijkertijd de importeur van de bloemen. Hij importeert de rozen uit Ecuador. Ik haal ze zelf op bij de groothandel en vervoer ze met mijn eigen auto naar de winkel. Dat is ongeveer een half uur rijden.

I: In de Piramide kunnen bloemisten hun voorraad bloemen inslaan. Deze ruimte wordt beheerd door het bedrijf Fleurametz. Zij kopen de bloemen op de veiling en bieden ze daarna aan bloemisten aan.

De bloemisten zorgen voor het transport naar hun eigen winkel.

P: De rozen komen uit Ecuador, Zuid-Africa (speciale geurende rozen) en Nederland. Ze worden door de groothandel gekocht op de veiling. Voor het kopen op de veiling moet aan het begin van het jaar €10,000 ingelegd worden. Dat krijg je alleen terug als je voor minimaal €1,000,000 aan bloemen ingekocht hebt. Kleine partijen zorgen voor hoge kosten bij de veiling en dat heeft er toe geleid dat vooral groothandels inkopen doen bij de veiling. Hierdoor is het de groothandel die bij de veiling koopt. Via de groothandel worden ze met een vrachtauto naar de bloemenwinkels vervoerd in mijn geval.

Welke maatregelen worden er tijdens het transport genomen om de kwaliteit te waarborgen?

What measures are taken to guarantee the quality during transport?

T: De rozen worden in het vliegtuig droog bewaard in verzamelingen van 25 stuks. Bij de importeur wordt een stukje van de stam afgesneden en wat bladeren verwijderd. Daarna worden ze in water gezet. Als ik ze koop worden ze tijdens het vervoer weer droog bewaard (maar dat is geen probleem voor een roos). Bij mij in de winkel snijd ik een stukje van de stam af, verwijder ik wat bladeren en worden ze weer in het water gezet.

I: In de Piramide worden de rozen op een lage temperatuur bewaard en worden de bloemen in het water gezet. De bloemen worden zo snel mogelijk naar de winkel getransporteerd. Daar worden ze direct in lauwwarm water gezet. Er wordt gezorgd dat de bloemen binnen het half uur weer in het water staan. In het hele proces van bewaren is het belangrijk dat de temperatuur niet te hoog oploopt. Verder is het belangrijk dat alles heel erg geleidelijk aan gaat. Er mogen geen snelle temperatuurstijgingen en dalingen zijn. Dat voorkomt het vervroegd opengaan van de rozen. Steeds weer acclimatiseren is een sleutel tot een lang vaasleven met een hoge kwaliteit. Als dat niet gebeurt kunnen ze snel gaan hangen.

P: Tijdens het transport uit het buitenland worden de rozen droog vervoerd in dozen. Ze worden efficiënt neergelegd in een doos. De ene roos ligt net iets verder naar achteren dan de andere roos zodat er meer inpassen. Bij de veiling worden ze schoongemaakt en in het water gezet. In de vrachtauto worden ze ook in het water getransporteerd. In de winkel worden ze weer netjes schoongemaakt en in een schone vaas met lauw water en voeding gezet.

Kunt u uitleggen op welke manieren rozen verkocht worden (boeket, los)? En welke maatregelen en bij de verkoop genomen worden (om de kwaliteit te waarborgen)?

Can you explain the different ways of selling the roses (bouquet, loose)? And what measures are taken (to guarantee the quality) when roses are sold?

T: De meeste rozen worden verkocht in boeketten. Als advies richting de klanten wordt meegegeven dat de rozen in een schone vaas gezet moeten worden, ze niet op de tocht moeten staan en dat ze niet bij vers fruit in de buurt moeten staan. Daarnaast moeten ze afgesneden worden als ze lang onderweg geweest zijn.

I: Als ze aan de klanten worden meegegeven krijgen ze een werkwijze mee over hoe om te gaan met de rozen. Binnen een half uur moeten ze in handwarm, lauw water staan. Als dat niet het geval is worden ze meegegeven in een soort vaas. Een zakje met water wat om de rozen heen wordt gebonden. Ze krijgen een zakje 'Flower Food' mee om de rozen te voeden.

P: Meestal worden ze verkocht in een gemengd boeket. Meestal worden ze droog verkocht. Dan wordt er een kaartje met behandeladvies meegegeven (Schoonmaken vaas, schuin afsnijden, bladeren verwijderen uit water, lauw water + chrysol en bloemen niet in de zon zetten). Bij de verkoop van veel rozen tegelijkertijd wordt vaak ook een vaas verkocht. De bloemen worden dan gelijk in de winkel al schoongemaakt en in de goede vaas gezet zodat kwaliteit gegarandeerd kan worden.