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Barge hinterland transport of orange juice in Europe

by

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Abstract

The purpose of this thesis is to verify the feasibility of using tank container barge services for the European hinterland transport of orange juice, to reduce transport costs and to promote the opportunity to divert tanker truck traffic from the congested Port of Rotterdam area to waterborne travel as an alternative transport modal.

The world orange juice trade market, industry structure, value and transport chain are discussed in order to help the understanding of this world industry, its products and quality specification which will determine the transport quality requirements and care of the product.

The study investigated existing container barge services in established fairways along the river Rhine and the Mittellandkanal to supply customers in Germany, along the river Rhine to supply customers in France and along the Dutch province of Zeeland waterways' to supply customers in Belgium through information obtained from barge operators. The existing logistic infrastructure for inland waterway transport taking into consideration the studied corridors were also analyzed in order to determine their appropriateness to handle this new tank container service.

The findings of the investigation conducted indicate that the tank container barge service is economically feasible; therefore, for some destinations, barging tank containers would allow avoiding the road tanker truck transport along the congested area of the Port of Rotterdam.

Operation and capital costs were analyzed. The operating cost would vary according to the final destination and may result on transport cost reduction around 50% if compared to road transport mode. Capital cost, around € 11,000,000 is the bottleneck of the inland transport mode operation analyzed in the case study and it is represented by the acquisition of reefer tank containers to be deployed for the barge services to orange juice processing companies located in the Fruitport. The actual capital and operating costs would be determinate through a further detailed operations plan for the new service. A detailed operating plan should be developed to implement a start-up tank container service between the Port of Rotterdam's Fruitport and the orange juice packer located in Sarre Union, France.

The tank container barge service would replace 18,500 tanker trucks per year from the congested area of the Port of Rotterdam with a decrease in 1.0 ton of CO_2 emission per ton-mile per year only taking into consideration the orange juice transshipments done by the major companies located in Rotterdam's Fruitport.

Relationship between Thesis Objectives and Report Structure

Thesis objectives	Chapter 1	Chapter 2	Chapter 3	Chapter 4	Chapter 5	Chapter 6	Chapter 7
Objective 1	●						
Objective 2		●	o	o			
Objective 3			●	●			
Objective 4					●	●	
Objective 5							●

● strong relationship
o weaker relationship

Objective 1: Methodology

Objective 2: Describe the orange juice world and European markets

Objective 3: Get knowledge of the product to be transported and its industry value chain

Objective 4: Feasibility study of orange juice inland waterways transport

Objective 5: Conclusions

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List of Abbreviations and Definitions

°Brix: concentration of all soluble solids in juice and is determined by measurements of juice density or refractive index.

AIJN: Association of the Industry of Juice and Nectars from Fruits and Vegetables of the European Union.

Ascorbic Acid: vitamin C.

Blending: to mixture different qualities of FCOJ and NFC in order to obtain a consistent customer-specific juice quality.

Box: 40.8 kg of oranges.

Browning: darkening due to oxygen reaction with orange juice components during tank storage.

BTU: British thermal unit is the amount of heat energy needed to raise the temperature of one pound of water by one degree F.

CIF: cost, insurance and freight.

Cloud loss (Gelation): undesirable occurrence of orange juice separating into a clear upper phase and bottom sediment due to enzymatic activity.

Cloud: opaque appearance of orange juice responsible for the orange juice mouth feel.

CPO: Cold-Pressed Oil.

CPPO: Cold-Pressed Peel Oil.

Enzymes: proteins that catalyze biological reactions, necessary for the growth of all living matter.

FAO: Food and Agricultural Organization (United Nations).

FCOJ: Frozen Concentrate Orange Juice.

Free-carrier warehouse: orange juice price includes freight charges to the port of Rotterdam.

Futures: contracts agreed for the future delivery of a physical commodity.

Gelation (Cloud loss): the tendency of concentrate to become lumpy and difficult to reconstitute.

Grove: group of trees.

NFC: Not-from-Concentrate Juice.

NYCE: New York Cotton Exchange.

Pasteurization: orange juice heat-treatment to destroy microorganisms and inactivate enzymes.

Pectin: type of polysaccharide which is a natural colloidal stabilizer that gives the orange juice its body or viscosity.

Physical prices: price at which the actual commodity is selling for.

PoR: Port of Rotterdam.

Pulp: the solid parts of the orange juice.

RDT: ready-to-drink (juice made from concentrate).

Refractive index: a measure of how much light is refracted when passing from one medium to another, it depends on the solution concentration and can be translated into concentration of soluble solids of a solution such orange juice.

Relative density 20/20: density of sucrose solution at 20°C relative to the density of water at 20°C also referred as specific gravity 20/20.

Ripeness: state of fruit maturity, readiness to be processed into orange juice.

Single strength: term assigned to juice as its natural strength, either directly from the extraction process or in a reconstituted form.

Single-strength equivalent (SSE): concentrate and other products stated as their corresponding amount of single-strength juice.

Soluble solids: solid materials dissolved in the orange juice (e.g. sugars and acids).

Supply chain: movement of materials as they flow from their source to the end customer.

Ton-mile: product of the distance that freight is hauled, measured in miles, and the weight of the cargo being hauled, measured in tons.

Value chain: connected series of organizations, resources, and knowledge streams involved in the creation and delivery of value to end customers.

Vertical integration: process in which several steps in the production and/or distribution of a product or service are controlled by a single company or entity, in order to increase that company's or entity's power in the marketplace.

WESOS: Water-Extracted Soluble Orange Solids.

WPCI: World Ports Climate Initiative.

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1. Introduction

Nowadays companies have been challenged, among others, by two major problems: the financial crises and the global warming caused by the emission of gases with greenhouse effects. The so called credit crises created a severe economic downturn and the global warming is turning on society's red lights against fossil fuels emissions. Concerned and affected by these two problems, companies are working hard to minimize and even solve them and it is in this context that the orange juice industry is doing its efforts to minimize the effects of the economic downturn on its financial results focusing on restructuring its operations and on costs reduction and working on creative solutions to reduce carbon emissions from its own or related operations.

Observing the supply chain of the orange juice industry it is easy to notice that 100% of the hinterland product transport has been done by tanker trucks and due to the problems stated above the idea of using barges for the hinterland transport of orange juice came up so that the present thesis was proposed. The aim of this thesis is *to verify the feasibility to use container barge services for the European hinterland transport of orange juice* and consequently reduce costs by using intermodal transport and promote the opportunity to divert tanker truck traffic from the congested Port of Rotterdam area to inland waterborne transport as an alternative modal.

1.1. Research methodology

The methodologies utilized to carry on this thesis are:

- Literature review and on site observations: the first part of the thesis is a compilation of comprehensive literature and on site observations of the orange juice international market, orange juice processing, industry structure and transport chain. Current literatures on the subject consist on technical publications, journals, Port of Rotterdam statistics, newsletters and international organizations statistics and bulletins. This review aims at obtaining an understanding of the orange juice world market, industry structure and products quality. Factors that have a direct influence on the orange juice transport requirements.

- Interviews with experts in the field of orange juice production, inland navigation, ports and terminals logistics, vessels and tank containers manufacturers and service barge companies. The interviews aim at acquiring a better understanding of the orange juice quality and transport issues, vessel and tank container manufacturers and inland shipping industry players' insights in terms of transport logistics and determining factors to consider when undertaking food quality product transport by barges.

- Case study method used for the European hinterland transport of orange juice by barges. The objective of presenting this case study is to see in practical terms the feasibility of using inland waterway modal to transport orange juice. Major juice packer companies in Germany, France and Belgium were chosen and their type of orange juices and weekly volumes transported from the fruit port of the Port of Rotterdam to their respective hinterland addresses were taken into consideration for the feasibility study. Finally, conclusions are drawn and a recommendation of a pilot project for a detailed economic feasibility study is made in order to make the barge transport economically viable on the basis of the research and analysis made throughout the thesis.

1.2. Thesis structure

To carry on the feasibility study, information related to the orange juice world trade, orange juice types and required quality, industry players, storage and transport requirements is necessary in order to construct a thorough knowledge of the product to be transported. Information related to the European barge fleet and inland waterways are also necessary to make the orange juice hinterland transport by waterways feasible.

Therefore, the thesis is formed by seven chapters:

Chapter 1 contains the research topic and the methodology used to carry on the study. *Chapter 2* is based on literature review and it provides a brief description of the industry history, an overview of the orange juice world and European market and its major producers, exporters and importers. *Chapter 3* based on literature review and on site observation introduces the orange juice production process in order to understand the product types and quality requirements which will compose the aseptic transport requirements of food quality product. *Chapter 4* based on literature review and on site observation presents the industry value chain where it is possible to understand the importance of each industry player on the orange juice manufacturing and their correlated transport quality requirements as well as the transport and storage requirements for each stage of orange juice processing. *Chapter 5* introduces the Fruitport and the orange juice processing companies located there and a description of how the bulk product shipped from Brazil is transported to the Port of Rotterdam. Also, it reviews the logistic infrastructure for orange juice transport through a brief description of inland terminals and of the European inland vessels fleet and the bottle-necks and expected investments of the European inland waterways related to the case. In *Chapter 6*, the tank container is detailed and the concepts of inter-modality and containerization are introduced. These concepts will be applied in the logistics of orange juice transport since the tank container will substitute the tanker truck mono-modal transport. The case study is then presented, the feasibility to use container barge services for the European hinterland transport of orange juice as well as environmental issues are discussed. Finally, *Chapter 7* concludes the thesis by stating the main findings and a recommendation for further studies is suggested.

1.3. Relevance of the topic

The shipment of orange juice by barges using tank containers from the fruit terminal brings the possibility to use intermodal transport for this product creating greater possibilities of transport modal maneuvers towards transport rationalization and cost reduction. Moreover, the Port of Rotterdam will benefit from a better usage of its inland waterways improving its hinterland connectivity which might attract more cargo flows to its territories. The reduction of the tanker truck traffic in the congested area of Port of Rotterdam will contribute to less green-house gases emission, better air quality, less accidents and less environment degradation. Will decrease travel time and increase people's mobility increasing overall the productivity of the region. Furthermore, barges are more fuel efficient and produce less noise when compared with tanker trucks.

1.4. Difficulties and suggested next steps

This research involved orange juice producer's site visit and interviews with industry experts giving the author the opportunity to understand the orange juice production process, storage and transport which complement the body of knowledge to perform the feasibility study of orange juice by barges using tank containers. The research shows that this transport modal is feasible but in order to be cost competitive in some routes further research should be done. This research should be extended to analyze and solve the lack of resources of the fruit terminal container handling and the cargo bundling to attract regular barge services from the fruit terminal in the Port of Rotterdam and the various European inland terminals and the needed capital investments as well.

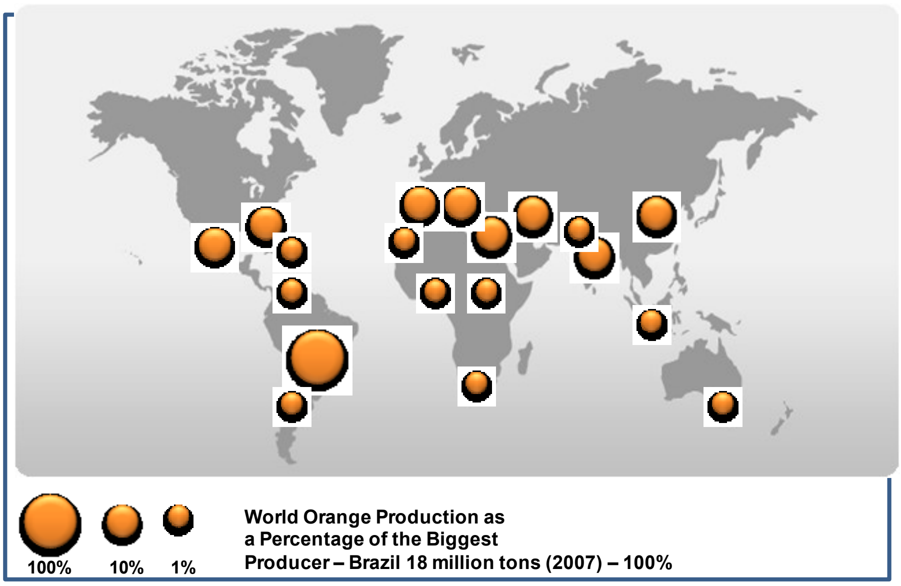
2. The orange juice world market

The orange juice world market is presented in this chapter. It starts with a brief history of the orange juice industry, as well as the definition of the two types of industrialized orange juice which will be used along the whole thesis. Some aspects of the production of the orange fruit which will intervene in the orange juice production are also discussed.

2.1. Orange fruit origins

The orange is the world's most popular fruit. Like all citrus plants, the orange tree originated in the tropical regions of Southeast Asia and spread gradually to other parts of the world. Oranges are mentioned in an old Chinese manuscript dating back to 2,200 BC. The development of the Arab trade routes, the spread of Islam and the expansion of the Roman Empire led to the fruit being cultivated in other regions. The orange spread to India, the east coast of Africa, and from there to the eastern Mediterranean region. The plant was brought to the Americas by Columbus and his followers in 1,500. Nowadays oranges are cultivated in tropical and subtropical region around the world.

Figure 1: *Major World Orange-Growing Regions*



Source: FAO (2007)

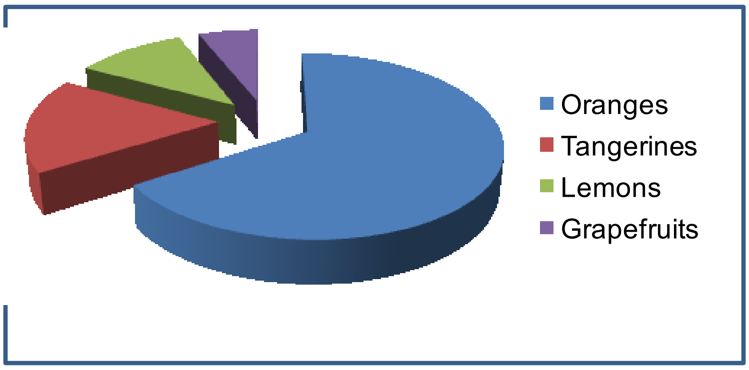
2.2. Industry history

Commercial cultivation of oranges intended for large-scale processing into fruit juice began in Florida in the 1920's. In the late 1940's frozen concentrated orange juice for home dilution was developed in the USA. This consumer trend resulted in a enormous growth in orange juice consumption and consequently the cultivation of orange and the Florida's orange juice processing capacity grew in a quick pass. Severe frosts in Florida during the 1960's, the 70's and the 80's drastically reduced fruit yields and killed many trees. This fact encouraged producers in Brazil to expand orange tree plantations and large processing plants were built for orange concentrate to attend the Brazilian and American markets. In 1983 Brazil surpassed the USA as the world's number one orange producer.

2.3. World orange fruit production

Oranges account for more than two thirds of the world production of all citrus fruits, of which other important species are lemon, grapefruit and mandarin orange or tangerine varieties.

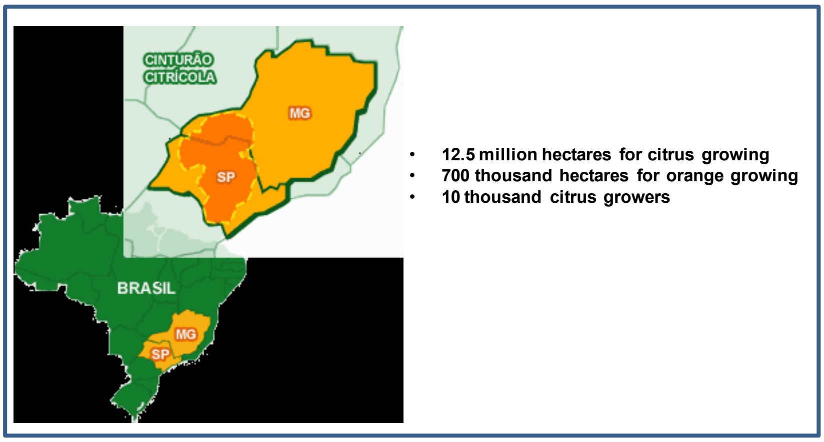
Figure 2: *World citrus fruit production by types*



Source: FAO (2005)

About 64 million tones of orange per annum are produced globally. Of this, around 40% is processed into juice and the rest is consumed as whole fresh fruit. Brazil and the USA grow about 50% of the world's oranges. During the 2007 season, the orange crop in Brazil was about 18 million tons or 440 million boxes of 40.8 kg and in the US the orange crop was about 8 million tons or 195 million boxes of 40.8 kg. The most important orange growing and processing regions are the state of Sao Paulo in Brazil due to its excellent soil and climate conditions is the lowest-cost producing region in the world (98% of Brazil production) and the state of Florida in the United States of America. Together these regions account for nearly 90% of global orange juice production of 12 billion liters per year. Brazil dominates the orange juice exports to the world (80% of the concentrated juice), the US exports are quite small as a consequence of the large domestic market for orange juice.

Figure 3: *Brazilian Orange Fruit Production Area (SP – Sao Paulo / MG – Minas Gerais)*



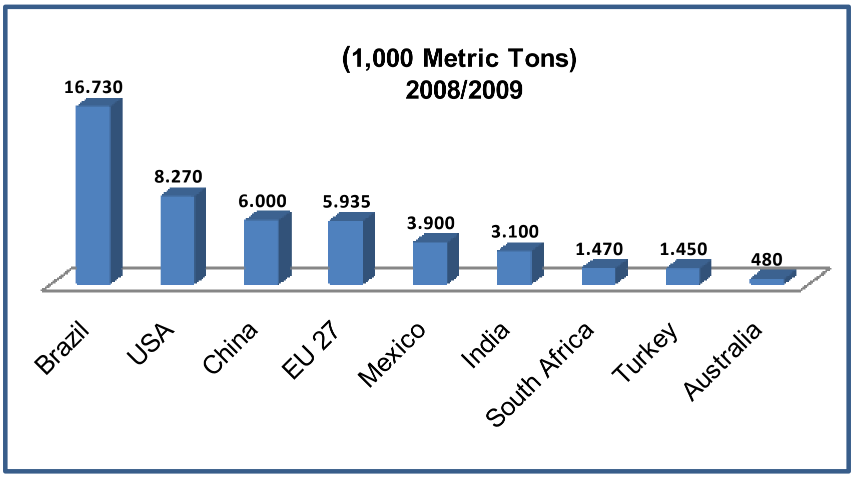
Source: www.citrosuco.com.br

In the *Appendix 1* it is shown an orange grove in the city of Avare, State of Sao Paulo, Brazil.

In the Mediterranean region oranges are primarily grown for the fresh fruit market, both for domestic and for export to European countries. About 15% of regional crops go into processing. The major orange growers are Italy which produces about 2.5 million tons per year or 60 million boxes of 40.8 kg and Spain which produces about 2.1 million tons per year or 50 million boxes of 40.8 kg. Production of orange concentrate has been reduced in Europe because production costs are not competitive with world-market concentrate prices. This is despite the fact that processors in European Union countries are entitled to a significant subsidy for purchasing fruit for juice production.

Oranges can only ripen on the tree and the quality of the fruit begins to deteriorate immediately after picking. The time between picking the fruit and processing it into juice should be as short as possible, usually less than 24 hours. Because orange is a seasonal fruit, each region strives to grow orange varieties with different ripening periods. This prolongs the total harvesting period in a region and allows greater utilization of processing equipment.

Figure 4: *World orange fruit production in tons*



Source: United States Department of Agriculture – Foreign Agricultural Service (February 2009)

2.4. Orange juice types

Before going on with the orange juice world and European markets it is important to describe the orange juice types since the terms NFC and FCOJ will occur many times along this thesis.

The orange juice is produced on a seasonal basis therefore it must be stored between seasons to ensure a year-round supply to consumer markets. Most juice is produced as frozen concentrated orange juice, FCOJ, because it can be stored for long periods of time and shipped at lower cost as it contains less water. Not-from-concentrate juice, NFC, which is at single-strength (juice as its natural strength, either directly from the extraction process or in a reconstituted form), requires much larger volumes during storage and shipping.

2.4.1. NFC (not-from-concentrate)

NFC is orange juice as it is extracted directly from the fruit, its average concentration is 12°Brix. Due to its low concentration the NFC is normally consumed by markets located near the processing plants, nonetheless, its world trade is increasing. For the same amount of ready-to-drink (RTD) juice, produced from concentrated juice by adding water, in order to store it before joining the water, if compared to the NFC juice, it will be needed 5 to 6 times less storage volume. Thus shipping costs over long distances are significantly higher for single-strength products like the NFC juice. Regulations and the production process allow for very limited adjustments to product characteristics other than blending NFC from different varieties. Therefore careful selection of the fruit is necessary for the NFC production. Most NFC products also consist of a blend of juices extracted at different times of the season. Blending of NFC may take place within the producing country or in the importing market. The difference in quality and yield between different orange varieties is reflected in the range of market prices.

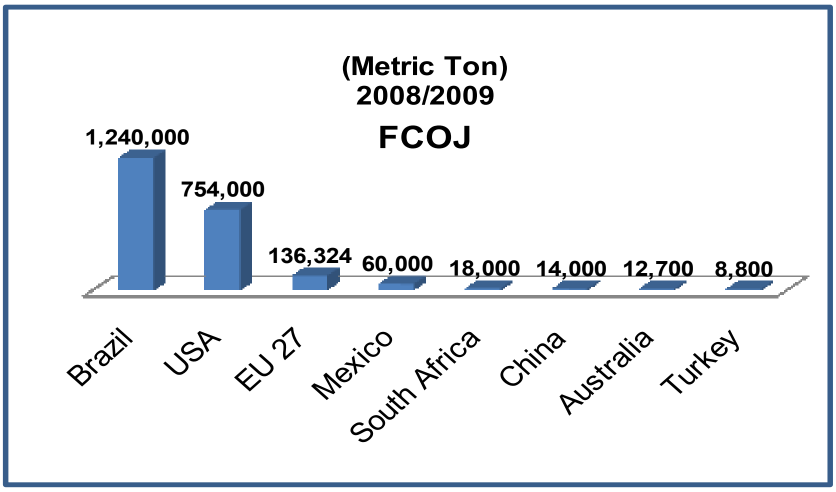
2.4.2. FCOJ (frozen concentrated orange juice)

FCOJ is orange juice concentrated to 66 °Brix. It is allowed during the FCOJ processing, blending concentrated juice from different orange fruit varieties in order to have throughout the year the same quality expected by the consumers. As concentrated juice quality is created during the evaporation process and essence recovery *(Section 3.4)*, producers can adjust quality requirements and different product specifications during this phase of the production process. Therefore, for the concentrated juice when compared to NFC production, variations in the orange fruit quality are less important. For this reason, in all plants where NFC is produced, concentrate juice is also produced to use the orange fruits not suitable for the NFC processing. Some orange fruit growers which produce orange to be eaten fresh also have juice processing facilities to, in the same way, for those oranges which do not have the quality, go to the market went to be processed into concentrated orange juice.

2.5. Orange juice world and European markets

Brazil is the largest orange juice producer. In the harvest of 2008/2009, it produced 1,240,000 metric tons of FCOJ which corresponds to 50% of the world production, followed by the USA with a FCOJ production of 754,000 tons, 34% of the world's production. Together, both countries account for 84% of the world's FCOJ production. Below, in the *Figure 5*, it is given the world production of FCOJ classified per major world producers.

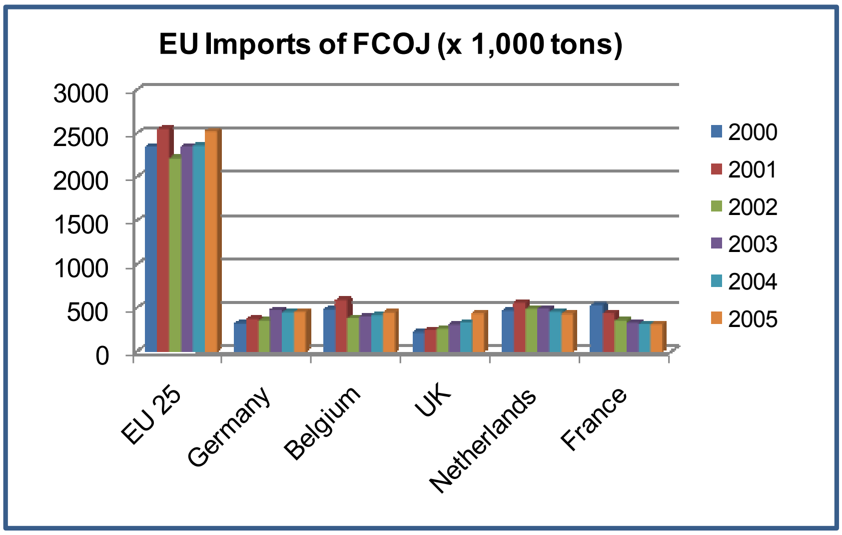
Figure 5: *Major FCOJ world producers*



Source: United States Department of Agriculture – Foreign Agricultural Service (February 2009)

North America and the European markets are the largest consumers of orange juice. The USA and Canada account for some 50% of global consumption of packaged orange juice, whereas Western Europe accounts for 30% of the total volume. In Europe, nearly all retail orange juice is ready-to-drink (RDT) – juice made from concentrate, there is very little consumption of concentrate juice for home dilution. The European Union is the largest FCOJ importer from Brazil, in 2006 837,000 tons were imported and in 2007 the total amount imported was 874,489 tons. Almost 70% of Brazil's production is exported into the European Union.

Figure 6: *European Union Imports of FCOJ*

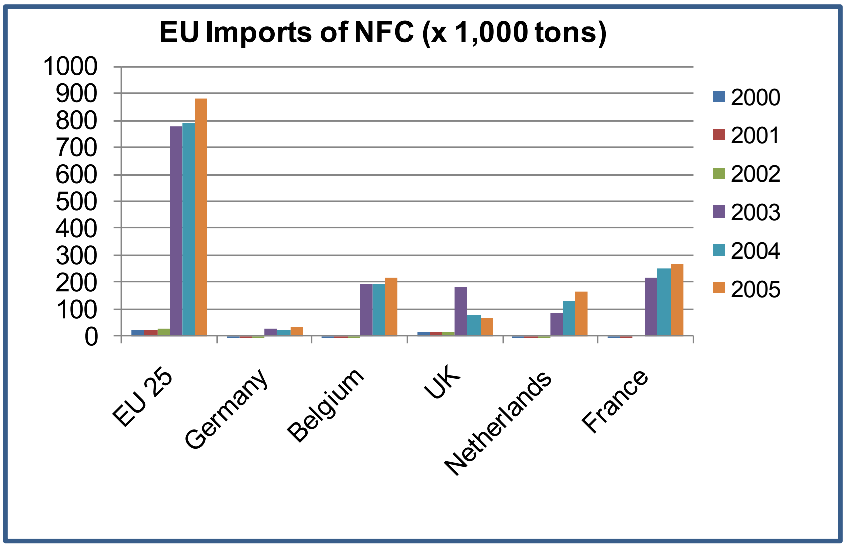


Source: United States Department of Agriculture – Foreign Agricultural Service (2006)

Almost 45% of the total juice volume consumed in Western Europe is orange juice. Although juice made from concentrate packed for distribution at ambient temperature remains the most popular orange juice product in Western Europe, chilled NFC is showing significant growth in many markets as it can be seen on *Figure 7*. Consumers sense that NFC juice is very close to the original fruit on a convenient form and very healthy.

The consumption of NFC has increased over the last five years and in 2005 accounted for about 5% of the total orange juice EU imports *(Figures 6 and 7*). The growth in per capita income and the perception of NFC quality as being similar to that of fresh fruit have driven the increase in NFC sales even with its higher price. NFC is marketed at up to double the price of orange juice made from concentrate. Compared with FCOJ, the 5 to 6 times larger storage and shipping volumes for NFC combined with the stricter quality demand on raw fruit for NFC result in a significantly higher cost for bulk NFC imported into Europe.

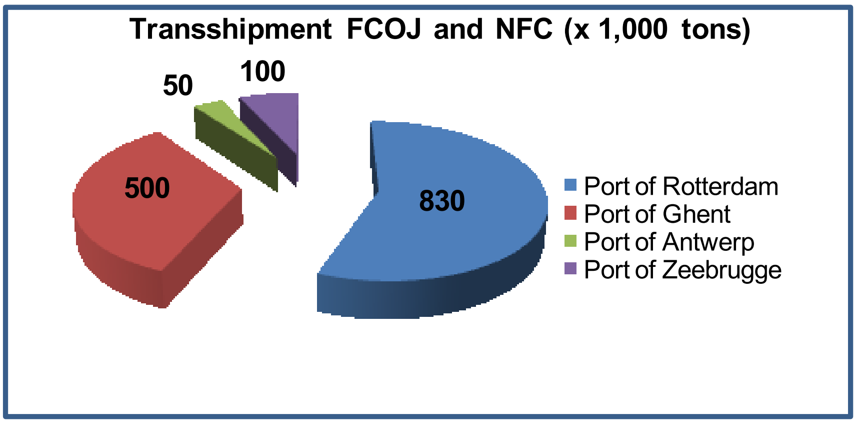
Figure 7: *European Union Imports of NFC*



Source: United States Department of Agriculture – Foreign Agricultural Service (2006)

The companies active in the orange juice market in the Western Europe are mainly concentrated in the Ports of Rotterdam, Ghent, Antwerp and Zeebrugge. The companies located in the Port of Rotterdam are the Brazilian Cutrale (Continental Juice and its European Juice Terminal – EJT), the Dutch Kloosterboer, the Japanese HIWA (Nicherei Group) and the German Wild Juice (Wild Flavors Group) together these companies generated the turnover about 830,000 tons of FCOJ and NFC in 2007. The Port of Ghent is represented by the Citrus Coolstore Terminal owned by the Brazilian company Citrosuco Paulista (Fisher Group) responsible for the turnover of 500,000 tons of FCOJ in 2007. In the Port of Antwerp the Brazilian company Citrovita (Votorantim Group) imported 50,000 tons of FCOJ and NFC into Western Europe in 2007. The Port of Zeebrugge hosts Sea-Invest, which operates the Belgian New Fruit Company, Belfruco and Flanders Cold Storage. Sea-Invest handled 100,000 tons of Tropicana NFC juice imported from Florida, USA.

Figure 8: *Major European Orange Juice Transshipment Port*



Source: Port of Rotterdam (2007)

2.6. The orange juice world market pricing

Orange juice prices have shown wide fluctuations over the years. They are strongly related to weather conditions since the price of the orange fruit are largely dependent of supply and demand. Freezes in Florida and drought in Sao Paulo, leads to sharp increases fruit prices. Brazil is the world dominant exporter of concentrate and Europe the largest market, with import harbors in Belgium and the Netherlands. Rotterdam is a commonly used reference for the FCOJ world market prices. Free-carrier warehouse means that the price includes freight charges to the port of Rotterdam, and loading product, e.g. on road tankers (US$/ton CIF Rotterdam). Import duty and transport costs from the tank farm to the user need to be added.

The buying and selling of FCOJ have evolved into commodity trading. Two multinational commodity trading companies which also trade orange juice, Cargill and Luis Dreyfus influenced the trading of concentrate juice on the commodity trade market (futures market). The futures market provides a tool to manage risks for the orange juice industry, mechanisms of hedging can be applied by the industry players in order to be protected against financial losses caused by fluctuations in physical prices for products. Trading of FCOJ futures takes place through the Citrus Associates of the New York Cotton Exchange, NYCE. The futures market is not only important to the citrus industry as a tool for risk management but also as a price basis for purchasing fruit and for sales contracts for bulk concentrate.

3. Orange juice processing

In this chapter the orange juice production processes are briefly described due to the fact that the thorough understand of the product, its types and quality requirements will compose the minimum knowledge necessary to promote the safe and correct aseptic transport of a food quality product by inland navigation deploying tank containers.

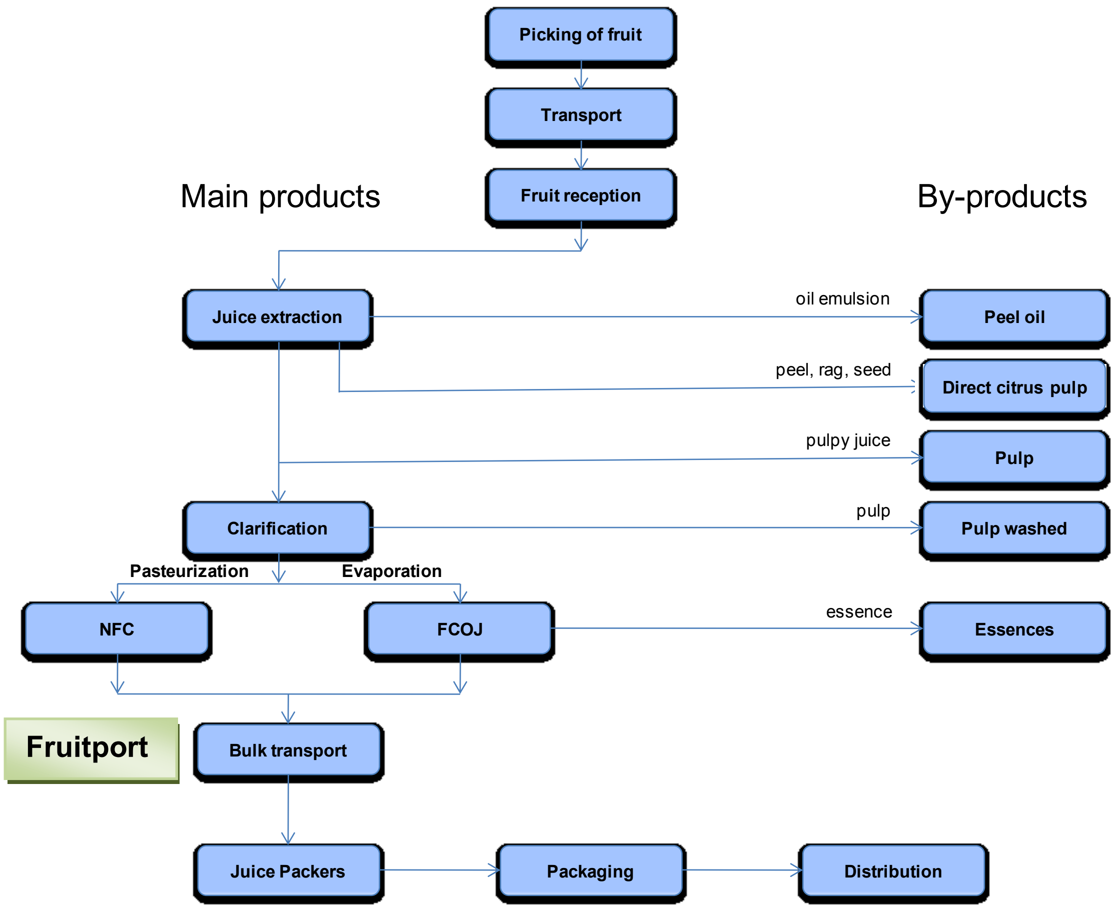
The orange juice contains sugars, acids, vitamins, minerals, pectin and colored components along with many other components. Orange colored substances called carotenoid in the fruit peel give its characteristic color. Juices from early and late fruit varieties differ in quality as regards color, sugar content, etc. The maximum juice yield from an orange is 40 to 60% by weight depending on the fruit variety and local climate.

In the state of Sao Paulo, Brazil, the harvest and processing season is from mid June to mid October, whereas in the state of Florida, USA, the harvest and processing season is from mid October until mid June which allows processing companies located in both countries, which is the case of the major Brazilian producers, to bridge the seasons and produce orange juice the whole year.

Orange processing plants are located near the fruit groves due to the fact that the fruit should be processed as soon as possible after harvesting because it deteriorates quickly at the high temperatures found in the citrus-growing areas *(Figure 1)*. Orange juice, on the other hand, are produced in a form that allows it to be stored for extended periods (about one year) and shipped over long distances. In the orange juice industry, the basic count of reporting crop and plant intake is the fruit box which is defined as containing 40.8 kg of fruit. Just as an example, the world’s largest orange juice plant is located in the city of Matao, state of Sao Paulo, Brazil owned by Citrosuco which has a processing capacity of 60 million boxes (2.4 million tons) per season.

Following it is described the processing steps of orange juice production:

Figure 9: *Production processes of orange juice*



Source: The Orange Book page 66

All production processing stages are done in Brazil, until the bulk transport to the Fruitport, from there, juice packers, blending houses and soft drink producers in the European Union make the final product according to their customer's specifications.

3.1. Fruit reception

After harvesting, fruit picked in the groves are loaded onto trucks of 20 tons which is unloaded onto a specially designed tipping ramp which allows the fruits roll off the truck going directly onto a conveyor belt to the prewash station where dust, dirt and pesticide residues are removed. The fruits then move onto de-stemming and pre-grading in order to remove stems and leaves and to have rotten and visibly damaged fruits removed which will be sent to the feed mill to animal feed processing. A sample of fruit is taken for analysis from each truck. The main parameters analyzed are juice yield, °Brix, acidity and color, this gives the processor an indication of fruit ripeness and each batch of fruit goes to a bin storage (for less than 24 h) and is tagged and identified. Then it will be possible to select suitable fruit from various sources for blending during the extraction process to achieve the desired final product quality.

3.2. Juice extraction

Juice extraction involves squeezing juice out of the fruit by means of mechanical pressure. After the washing process, the raw fruit is selected by its size since the extractor yield is greater the more uniform the fruit size is. The extractor determines the quality and the juice yield therefore it is the most important process in orange juice production. Its operational pressure must be regulated in order to produce as much as possible juice without the presence of peel, oil and other components of the fruit from entering the juice. Over squeezed juice leads to bitterness in taste and during its storage other defects will occur. Extractors operate at a fixed number of oranges processed per minute therefore the plant's throughput is very sensitive and dependent of fruit size and quality. The standard operating speed of a five-headed extractor is 100 rpm or 500 oranges per minute, as the fruit not always flow to each cup of the extractor 90% utilization is a high figure. A typical capacity for a medium-sized fruit is 5 tons/h of fruit per extractor, which is about 2,500 l/h of juice. Three streams result from the extraction process: oil emulsion; peel, rag and seeds and, pulpy juice briefly described in the *Section 3.6.*

3.3. Clarification

The juice produced by the extractors is called pulpy juice and it is full of pulp and other substances which accounts for 20 or 25% in weight that must be removed before processing the juice into FCOJ or NFC. Therefore it goes to a process called clarification before going on in the production process. It is not possible to use this juice in the evaporation process to produce FCOJ and it is not possible to transform this juice into NFC. The clarification process involves equipment called finisher which is a cylindrical sieving screen. Applying mechanical or centrifugal forces (depends on the equipment used) the pulp is separated from the juice. The juice flows through the screen holes and the pulp remains concentrated inside the screen. FCOJ for use in the production of orange nectars and drinks requires the lowest pulp content which ranges is from 1 to 3% in weight of pulp.

Now, if it is necessary, the juice is ready for blending with juice from other batches in order to balance its flavor, color, acidity and °Brix levels before going on in the production process. If this clarified juice is for NFC production, it is ready and in order to avoid microbiological activity it is necessary to cool it to 4°C before storage in buffer or blending tanks.

3.4. FCOJ production

The FCOJ production involves its concentration, in other words, it involves the reduction of water content of the clarified juice. This is often done in order to reduce transport costs since from one liter of FCOJ it is possible to make five liters of RDT orange juice. The clarified juice then goes to the evaporators. During the evaporation process the clarified juice is pre-heated and held at 95 to 98°C under vacuum. This is so in order to avoid microbiological and enzymatic activities. The evaporation stages bring the clarified juice to a concentration up to 66°Brix. The total evaporation process lasts around 7 minutes. The evaporators are designed for enormous juice volumes and their capacities can exceed 100,000 kg/h of water evaporated.

Volatile flavor components go out of the clarified juice during the evaporation process together with water and in order to be recovered the evaporators have an essence recovery system. The volatile flavor components are separated from the water by distillation under vacuum and then cooled to condensate. By cooling them they are they are separated into oil and aqueous phases which will be separated through decantation or centrifugation processes. Aroma and essence oil are sold to concentrate blending houses, juice packers and flavor manufacturing companies.

According to the client specifications the FCOJ concentrated up to The 66°Brix will be blended with concentrates of other produced batches and then cooled to long bulk storage (about one year) at -10°C. The average density for FCOJ is 1.30t/m³.

3.5. NFC production

The clarified juice is ready to be transformed into NFC which is also known to be a single-strength product. After the clarification process the juice is found mixed with a great amount of oxygen which reduced the juice quality in terms of loss of vitamin C, browning and changes in flavor, therefore the clarified juice must be submitted to a de-aeration process carried under vacuum chambers, then it is cooled to avoid microbiological growth or enzymatic reactions during its storage period. Before storage for long periods of time, the single-strength juice must undergo a process called pasteurization, better described in the *Section 3.7.* The NFC must go to the pasteurization process before storage to have its enzymes deactivated and to avoid microbiological activation the juice must be microbiologically stable. Due to its low osmotic pressure, low sugar content which is up to 12°Brix and higher water content, the NFC is more prone to microbiological growth. In the same way, its chilled and not frozen storage requires a better hygienic storage if compared to FCOJ frozen storage.

The NFC can be bulk stored in the long run (about one year) under either frozen or aseptic conditions. NFC production involves large product volumes; for the same amount of final juice, NFC volumes are 5 to 6 times larger than FCOJ, therefore NFC transport costs are also higher if compared to FCOJ. Energy and warehouse costs of freezing and storing frozen NFC are high. Moreover freezing NFC leads to handling problems because it freezes solid, whereas frozen orange concentrate is very viscous but it is still possible to be pumped. Frozen storage of NFC at -18°C is more appropriate to low NFC volumes, stored in mild steel drums of 200 l lined with a polyethylene plastic bag. Large volumes producers store NFC aseptically in very large stainless-steel tanks up to 4 million liters capacity for the aseptic storage of juice at -1°C. The average density for NFC juice is 1.045t/m³ and has on average a concentration of 12°Brix.

3.6. By-products

The scope of this study is based on the main products of orange juice processing, FCOJ and NFC. Therefore, it will be given just few information related to the by-products of the orange juice production:

- **Peel oil:** the extraction process produces an emulsion of oil and water and to remove this oil is removed by means of oil concentration this concentrated oil is called peel oil. It is normally packed in 200 l drums and is stored at -10°C and is traded as Cold-Pressed Oil (CPO) or Cold-Pressed Peel Oil (CPPO) and is used as a raw material in the flavor manufacturing industry, and by the concentrated blending houses and drink-base manufacturers.

- **Direct citrus pulp:** after the juice extraction about 50% of the fruit remains in the form of peel, rag, seeds and pulp not used for commercial purposes
  In the large processing plants this waste is sent to a feed mill to be processed. The feed mill broke down this material to small pieces by hammer mills, by pressing and drying processes the moisture is removed and it pelletized to be sold as livestock feed.

- **Pulp:** the solid particles in the orange juice form are called pulp. Pulp is also the commercial name of the orange juice processing by-product which consists of broken pieces of cell sacs and segment wall which are added back o the final juice. The dry pulp is packed in 20kg corrugated cardboard boxes lined with polyethylene bag or in 200 l drums and then frozen for storage.

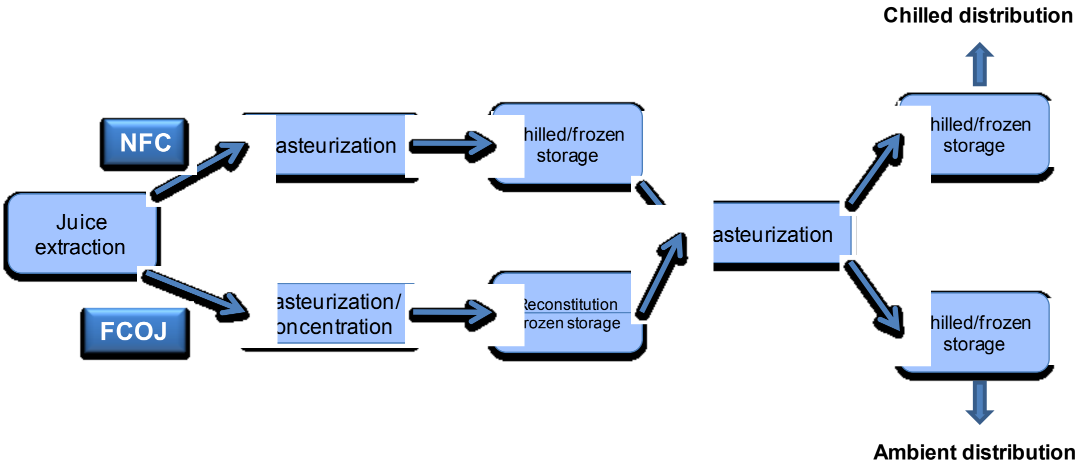
- **Pulp washed concentrates:** it is the waste pulp produced by all juice processes steps which are washed and recovered. It is then concentrated and may be added back to concentrated orange juice. It can also be packed in 200 l drums and frozen to be sold as base for juice drinks. Pulp wash is also referred as water-extracted soluble orange solids (WESOS).

- **Essences and essence oils**: the essence recovery is an integral part of the evaporation process and was described in the section of concentrate production.

3.7. Pasteurization

Pasteurization is a food production process which involves heat treatment. In orange juice it is frequently done after the extraction process and before its bulk long run storage. It is necessary for destroying the microorganisms capable of growing during storage, in other words to make the orange juice microbiologically stable and for inactivating enzymes (proteins that catalyze biological reactions, necessary for the growth of all living matter) to prevent a orange juice defect called cloud loss. Cloud gives rise to the opaque appearance of orange juice and it is important since it contributes to orange juice mouth feel. Cloud loss or gelation is the undesirable occurrence of orange juice separating into a clear upper phase and bottom sediment insoluble compounds can no longer be maintained in suspension. In order to avoid gelation orange juice should be pasteurized to inactivate enzymatic reactions and destroy microorganisms as soon as possible after extraction. The required time-temperature combination for the pasteurization of extracted juice 95 to 98°C for 10 to 30 seconds and then cooled at storage temperature. Pasteurization must be done as many times as the juice is processed after extraction.

Figure 10: *Orange juice pasteurization steps*



Source: Quality Control Manual for Citrus Processing Plants

3.8. Orange juice quality

From the fruit juices market the orange juice is the most consumed one (*Section 2.3).* Orange juice processors must be very careful on its manufacturing processes since anyone can buy and squeeze fresh orange juice from the fruit and compare its taste with the manufactured one. It is known that food quality is subjective and it is defined by the costumers. Therefore the quality of orange juice as perceived by the consumer is made up of taste, mouth feel and color. As orange juice is traded and consumed worldwide, its quality cannot be determined solely by subjective assessment, therefore several quality parameters have been defined. All parameters listed in *Figure 11*, except flavor can be determined by standard methods of analysis, orange juice flavor can only be evaluated by sensory means, usually by groups of panelists.

Figure 11*: AIJN Quality Requirements for Orange Juice*

Properties	Direct Juice	Reconstituted Juice
Relative density 20/20 Correponding °Brix	min. 1.040 min. 10	min. 1.045 min. 11.2
Properties		**Direct Juice / Reconstituted Juice**
L-ascorbic acid (vit. C) at the end of shelf live, mg/l Volatile oils, ml/l Hydroxymethylfurfural (HMF), mg/l Volatile acid as acetic acid, g/l* Ethanol, g/l D/L Lactic acid, g/l Arsenic and heavy metals, mg/l		 min. 200 max. 0.3 max. 10 max. 0.4 max.3.0 max. 0.2 range 0.01 - 05.0
* indication of hygiene, not juice acidity		

Source: AIJN Code of Practice, EU reference guideline for orange juice, 2003

Orange juice's most important properties are its sugar content and ratio of sugar to acid content. This ratio indicates the balance between sweetness and acidity in the juice. When the fruit matures, this ratio increases as sugars are formed and the acid content decreases. The sugars are mainly sucrose, glucose and fructose in a ratio approximating to 2:1:1. This sugar content is normally expressed as degree Brix scale (°Brix) which was developed by the sugar industry and relates to sugar-cane sucrose concentration, for orange juice, it relates not only to the concentration of dissolved sugars but also to all soluble solids. In concentrate juice where the acid content is high, the level of acid is often measured and a correction is made (Brix corrected), this not so for single strength juice where the Brix scale is used without correction.

The fruit juice industry in the European Union countries is guided by compulsory directives found at the European Union Council Directive 2001/112/EC, by national fruit juice regulations that are in force in the respective EU country and it is also guided by recommendations which are given by the Association of the Industry of Juices and Nectars (AIJN) from Fruit and vegetables of the European Union which was revised in 2003.

The quality of fruit and the juice extraction process determines the quality of the orange juice no other further production process can do it. Only in cases of allowed posterior blending (FCOJ) the orange juice quality can be improved. Water is another element very important in the orange juice quality made from concentrated juice since it is added around 85% of water in the FCOJ for the production of a RTD juice. Orange juice exposition to oxygen can decrease its quality through browning, loss of vitamin C and changes in flavor. Therefore care must be taken to store and transport orange juice. Juice packers will always check the above quality requirements before accepting the delivery of a cargo.

3.9. Vitamin C

Ascorbic acid (vitamin C) is the most important nutrient of orange juice. Typical values for vitamin C in freshly extracted juice range from 450 to 600 mg/l. Provided that the production procedures are correct, only a small loss of vitamin C will occur. More significant loses will occur during the packaging process and storage. Typical values for orange juice when consumed range from 200 to 400 mg/l. Vitamin C is essential for the synthesis of collagen, the most abundant protein in mammals, it is the major fibrous element of skin, bone, blood vessels and teeth. It is suggested that it has anticancer effects by its reaction with and inactivation of free radicals, it has never shown that vitamin C has a preventive effect on the common cold. In the *Appendix 2* it *is* given the average vitamin C content of some fruits compared with the vitamin C content of the orange juice and in *Appendix 3* it is shown the nutrient composition of orange juice.

3.10. Orange juice processing and the supply chain

Orange juice is a commodity and has as supply chain characteristic to be efficient rather than responsive. The focus is on the cost reduction along the supply chain. The orange juice processing industry needs to focus on supply chain efficiency as the market uncertainties are low and consequently the responsiveness in the supply chain is less required. As we have seen in this chapter the harvesting is always somehow known before the orange juice processing and the market is a mature one. This chapter and the following one describes what the industry does in order to achieve efficiency in the supply chain as concentration of orange juice and overseas transport of bulk orange juice by big refrigerated vessels aiming low transport costs by volume unit. The goals of the orange juice supply chain, being characterized as efficient is to supply the demand at the lowest cost. To achieve this objective, the orange juice processing companies carry low profit margins since FCOJ is a commodity and their customers are price driven with high inelastic demand characteristic. As it was seen in this chapter the orange juice processors must have high manufacturing volumes to benefit from economies of scale to reduce manufacturing costs. It is necessary to maintain inventory costs low and to reduce lead times without increasing costs. The supply strategy must be based on low costs and high quality. Orange juice quality requirements are presented in this chapter on *Sections 3.8 and 3.9*.

The aim of a supply chain is to add value to the customers and at the same time reduce the costs along the supply chain raised to satisfy the customer needs. Profitability of a supply chain is the difference between products value and what is spent along all operations within the supply chain. Thus, to be successful a supply chain must be profitable not only on its individual stages but along the whole chain *(Chopra and Meindl)*.

The orange juice industry is not vertically integrated *(Section 4.1)* and it deals with food products, therefore, a thorough knowledge of the product is necessary along the whole supply chain in order to avoid unwanted costs due to product damage from inadequate handling or processing. In order to be competitive, the orange juice processors must fit their supply strategies with their corporate competitive strategies and this can be achieved by understanding the customer needs and fixing the supply chain strategies to the customer needs covered by the umbrella of the corporate competitive strategies. Also, as the orange juice industry is not vertically integrated companies along the supply chain must work on a coordinated way avoiding optimization of individual performance but working to promote optimization along the entire supply chain to achieve the expected high supply chain profitability.

Transport cost is an important component in the price of the bulk orange juice *(Section 4.2), Chapter 6* describes how orange juice transport by inland vessels deploying tank containers can increase supply chain efficiency by reducing transport costs not increasing inventory costs and reducing inbound transport costs for the orange juice packers therefore reducing their order costs.

4. Industry value and transport chain

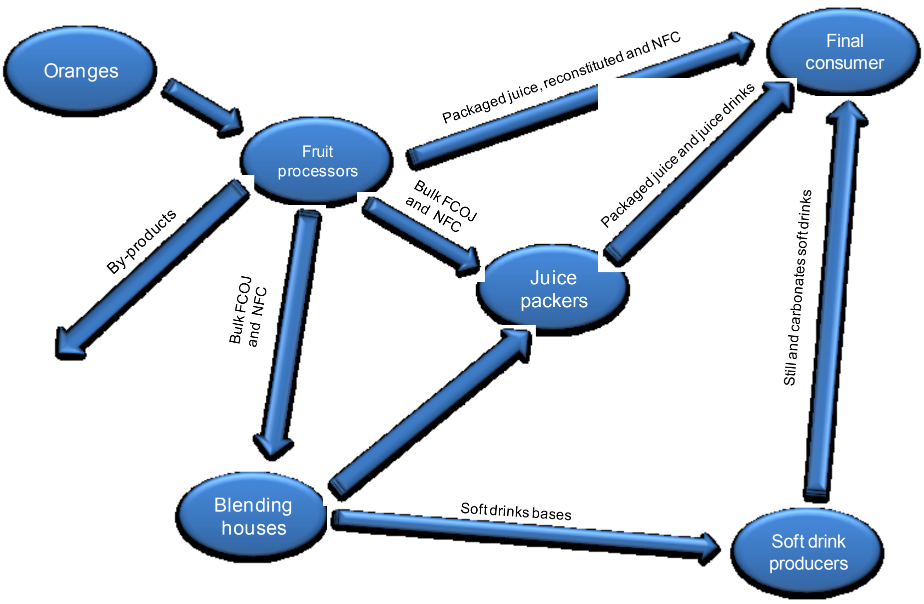
In order to know the industry players and understand their importance on the orange juice manufacturing and transport chain and their correlated quality issues as well as the transport and storage requirements for each stage of orange juice processing, this chapter brings information related to the orange juice industry structure.

4.1. Industry value chain

The orange industry is formed by the orange fruit growers, by the bulk processors which sell their product in bulk form, by the marketing processors which produce and sell their own juice brands, by the blending houses which provide concentrate juice and supply it on a consistent base according to customer specifications, by the juice packers which treat bulk product as required and then pack it into customer packages and finally by the soft drink producers which use orange juice concentrate and prepared bases from blending houses as raw material.

Vertical integration in the orange industry is not common. Rare are the companies that participate in all phases of the orange juice value chain: from the fruit groves to the juice packers. It has been observed that as the industry matures, the needs of specialization in each phase of the value chain are growing, each link in the production chain is becoming more and more independent as the demands of the market for specialized services grows and long term contracts have been agreed among the value chain players as well as the use of the future markets both practices aiming the reduction of international price fluctuation risks.

Figure 12: *Orange* juice industry value chain



Source: The author

4.1.1. Orange growers

The first link of the orange juice value chain are the orange juice growers, they own, manage and harvest the grove. Normally they are small enterprises which sell the orange fruit to a handler or sell it to the large processing companies through a cooperative. The relationship between the orange growers and the large processing companies are through long term supply contracts. Some large processors in Brazil still get part of their fruit (around 20%) from their own groves and the remaining fruit is obtained from independent growers.

Growers are paid not on quantity of boxes or weight of delivered fruit but on the amount soluble solids obtained from the fruit. A sample of fruit is taken for analysis from each truck and the quantity of fruit's soluble solids is calculated from the volume of juice extracted from the fruit multiplied by the °Brix of the juice. This gives the processor an indication of fruit ripeness.

4.1.2. Fruit processors

Orange juice processors buy the fruit and process it to produce FCOJ and NFC. They are divided in two groups: marketing processors and bulk processors.

Marketing processors sell packaged juice under their own brand name, which requires retail and consumer marketing skills. The largest marketing processors are Tropicana and Citrus World which are based in Florida, USA. They are the NFC leading producers. They process fruit into juice and fill it into retail packages at their own facilities. They also purchase additional juice in bulk from other bulk processors. The control, of product availability is regarded more important than ownership of manufacturing assets. As an example, Coca-Cola focuses on marketing and distributing Minute-Maid brands, while the production facilities are owned by the Brazilian bulk processors.

Bulk processors mainly sell their products in bulk form, which requires skills in the efficient distribution and marketing of a commodity. The majority of orange juice worldwide is produced by bulk processors. Bulk delivery is most important to the large Brazilian processors; they do not have their own consumer brands in order to avoid competing with their bulk juice customers. Bulk processors make money from the difference in bulk concentrate prices and fruit prices (the bulk processing margin). In order to more efficiently operate in the world market, Brazilian processors own about half of Florida's juice production. Operating in both markets offers benefits such as higher trading efficiency and balancing concentrate quality through juice blending.

4.1.3. Blending houses

The orange juice customers demand a juice with consistent quality. As it was described in *Section 2.4.2* due to variations in the fruit quality along the season which by consequence create variations in operation conditions it is impossible to maintain the same juice quality along the year, it will be experienced variations in flavor profile, °Brix, acidity, pulp levels etc, therefore, consistent quality between batches of FCOJ are not maintained. This need of quality consistence created the blending houses. In order to provide juice packers with a concentrate and even NFC juice that consistently meets defined quality specifications, these companies blend juice of different origin and add flavor fractions, often according to customer specification. The large Brazilian processors who have their own terminal facilities also offer blending house operations. The preparation of soft drinks bases is another important business activity for the blending houses. Purchasing juice from a blending house is more expensive than buying it from the spot market but the buyer can be assured that the product quality meets his demands.

4.1.4. Juice packers

This industry segment is responsible for buying orange and other type of juices in bulk, put them according to the customers' specifications and then pack the juices in consumer packages. They may also control the distribution of the packaged juice. There are two main categories of juice packers: those who market their own brands and those who co-packing for private label brands. Fluctuations in world market prices not always are reflected in the retail prices, thus, for a successful operation, juice packers need to have special skills in areas such as:

Sourcing: raw material costs constitute a major share of the total costs, right juice quality and favorable contracts are vital to overall profitability.

Processing and packaging: focus is maintaining product quality and keeping running costs and product losses down.

Distribution: as distribution plays also an important role in juice packers' profitability, an efficient distribution system must be in place.

Marketing: important to those who market its own brand.

4.1.5. Soft drink producers

Companies in this link of the value chain are manufacturers of retail packaged carbonated beverages and fruit-flavored still drinks. They may use orange concentrate as raw material, but often purchase a prepared base from a blending house. For drinks of fruit content, the flavor of FCOJ is not strong enough and has to be enhanced with additional flavors. Other ingredients are emulsifiers, preservatives, sugar, acids, water and carbonation when required. Blending houses play an important role for soft drink producers since they are a source of experience and product knowledge which can help in the development of new soft drinks in response to new consumer trends and demands.

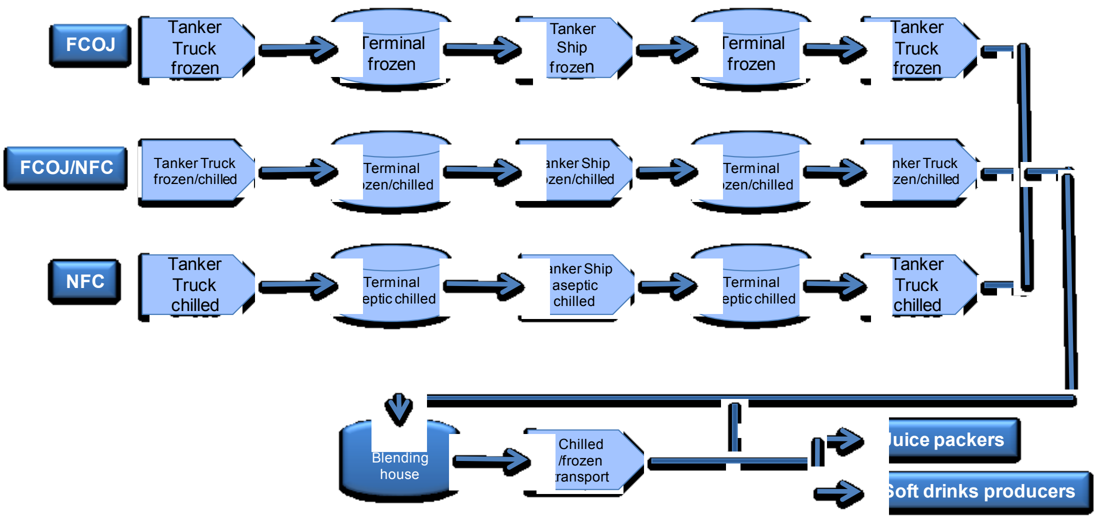
4.2. Industry transport chain

Shipping of orange juice products is dominated by bulk shipments, mainly frozen concentrate. Shipping costs depend on the modes and current rates of shipment.

The sales price for the bulk product usually includes the cost of the bulk package, and often the transport cost to the import harbor. Orange juice consumption in Europe with regard to imported Brazilian juice requires shipping large quantities of juice products over long distances. Transport cots constitute a significant part of the bulk product price, typically 15 to 20%. Thus, efficient control of the transport chain is very important *(Section 3.10)*. Long distance overseas shipping of juice products in retail packages is not common for reasons of cost and logistics.

The bulk juice is transported in tanker ships, tanker trucks or in individual containers using 200 l drums and one tone bag-in-box. Efficient transport is vital for these commodity products. The larger Brazilian processors own terminals in Brazil for exporting bulk products from Brazil, and in Europe, the USA and Japan for importing FCOJ into these markets. They also own large tanker ships designed and dedicated to transporting FCOJ. With the increase in NFC consumption, bulk ships and terminals dedicated to handling chilled aseptic NFC from Brazil are also in operation. Frozen Concentrate Orange Juice (FCOJ) and Not-from-concentrate Juice (NFC) due to their season characteristics may be stored for more than a year and during this bulk storage the product must be kept under conditions that minimize changes in quality. The demands on the storage conditions depend on the orange juice product.

Figure 13: *Bulk transport and storage of orange juice*



Source: The author

4.2.1. FCOJ storage and transport

FCOJ shipping is normally done in ships, tanker trucks and drums. For shipping in tanker trucks the product is typically kept at - 8 to -10°C. For drums the FCOJ is normally packed in 200 l steel drums with double polyethylene liners and stored frozen at -18 to -25°C. It is also packed in aseptic bags using drums or wooden bins for outer support as under these conditions they do not require frozen storage conditions they allow more flexibility in the transport chain. FCOJ is bulk stored frozen at temperatures from - 6 to - 25°C to avoid degradation of product quality, the longer the storage time the lower the storage. The transport of FCOJ in bulk tanker ships is made easier by special port terminals and the major Brazilian processors have built their own terminal facilities in Brazil, Europe USA and Japan. Tanker ship capacities are in the range of 6,000 to 15,000 tons of product. Some of the major Brazilian processors run their own ships for transporting the bulk orange juice to their foreign terminals. The handling of FCOJ in bulk tanker ships requires heavy investment in infrastructure such as the ships themselves and special terminals but when this infrastructure is in place it turns to be an effective way of transporting large orange juice volumes.

4.2.2. NFC storage and transport

NFC is bulk stored frozen in 200 l drums at -18°C or lower, or chilled in large aseptic tanks or aseptic bag-in-box containers at -1 to 1°C. Both forms of storage give a shelf life of one year. This long shelf life is necessary since juice from fruit harvested at different times of the season is blended to obtain consistent quality year round. Low temperature storage is important. A temperature of 0°C is low enough to avoid deterioration of the juice while keeping the juice as a liquid; single-strength juice starts to freeze at around - 2°C. An advantage of aseptic NFC storage over frozen NFC is that the juice does not have to be thawed before final packaging. This avoids the use of crushing equipment and high energy input for quick thawing. At ambient temperature thawing takes several days and therefore product quality may deteriorate during this period due to microbial growth and flavor degradation. Freezing NFC leads to handling problems because it freezes solid, whereas frozen orange concentrate is very viscous but it is still possible to pump it. Frozen storage of NFC at -18°C is more appropriate to low NFC volumes, stored in mild steel drums of 200 l lined with a polyethylene plastic bag. Large volumes producers store NFC aseptically in very large stainless-steel tanks up to 4 million liters capacity for the aseptic storage of juice at -1°C, just above the freezing temperature of the juice. While in Florida carbon steel tanks with the internal surfaces coated with an epoxy lining, Brazilian producers use mainly stainless-steel tanks for NFC storage. The tanks are sterilized fluid (iodoform) and are installed within a large refrigerated building. The juice must be agitated periodically to avoid separation of sinking pulp and to maintain °Brix uniformity. Pressurized nitrogen above the juice surface is often maintained to minimize the risk of quality and vitamin C loss through oxidation.

4.3. Storage and transport - effects of oxygen on quality

Oxygen plays a major role in the loss of quality in orange juice during storage due to color changes (browning), flavor and vitamin C degradation. It is a very reactive element which can induce several changes in the chemical composition of orange juice and the most dominant of which is the loss of vitamin C and consequent loss of nutritional value of the product. The vitamin C degradation can occur through both aerobic (depending on oxygen) and anaerobic (not depending on oxygen) which one predominates depends on the temperature and availability of oxygen. During processing the aerobic degradation of vitamin C predominates, whereas during orange juice storage both systems help with vitamin C degradation. In the aerobic degradation, 1 mg of oxygen corresponds theoretically to a loss of 11 mg of vitamin C. Also, the desirable taste of freshly squeezed orange juice is easily affected by bulk storage. When the right processing conditions are followed by the fruit processor, the loss of vitamin C from orange fruit to frozen orange juice concentrate is in general negligible. Therefore, the bulk storage of orange juice in the FCOJ or NFC forms must be done not only under the recommended temperature but also as stated before in positive pressurized warehouses and in stainless steel tanks with inert gas (normally nitrogen).

4.4. Comparison with the chemical industry transport chain

The chemical industry has various similarities in regard to the orange juice transport chain. The products are processed in large batches and are transported as liquid bulk from the processing plants to the final customers. This is normally done using tanker barges, tanker trucks and trains. This particular industry have been using tank containers *(Section 6.2)* since long time ago, practice which permits the application of intermodal transport *(Section 6.1)*, goods can be transported in different modalities without the necessity of handle the cargo at each modal change. This is only possible using the tank container. The chemical industry mastered the concept of containerization *(Section 6.6.1)* applying the usage of standardized containers in order to unitize cargo and transfer it from one transport modal to other transport modal by means of standardized handling equipment, and provides cheap door to door products delivery handling it only at the point of origin and destination. The possibility to choose the transport mode more convenient for each cargo to be transported creates a competitive advantage on a very competitive market where this industry is allocated. Therefore, the same concepts should be applied for the orange juice industry, respecting all of its particularities and technicalities seen in this chapter.

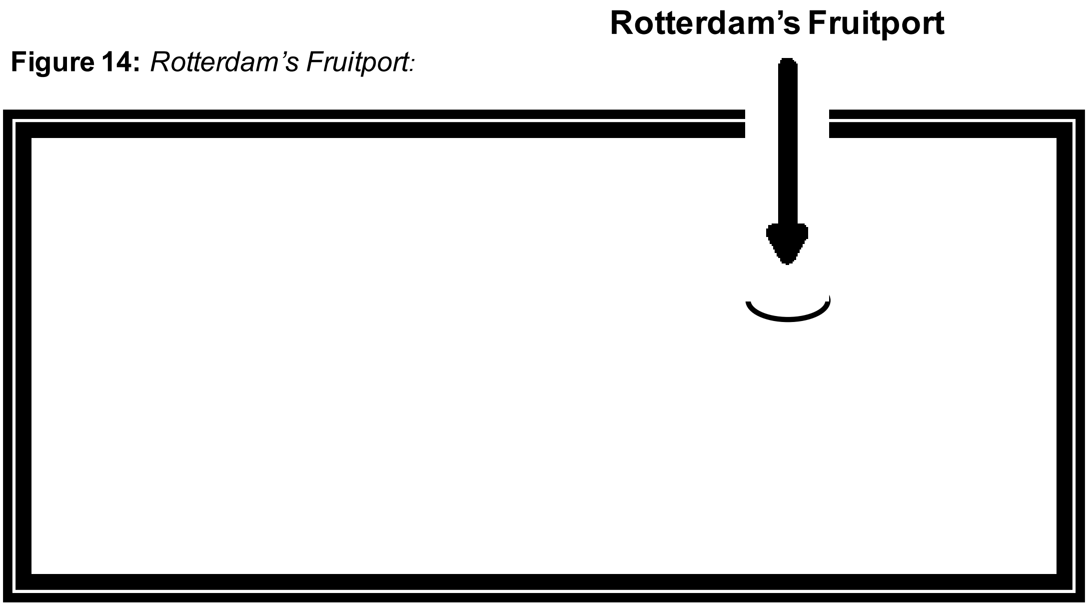
5. Logistic infrastructure for orange juice hinterland transport

This chapter introduces the Fruitport and the orange juice processing companies located there and a description of how the bulk product shipped from Brazil is transported to the Port of Rotterdam. Also, it reviews the logistic infrastructure for orange juice transport through a brief description of inland terminals and of the European inland vessels fleet and the bottle-necks and expected investments of the European inland waterways related to the case study.

It is known that the strength of a transportation system is based on its diversity with each modal carrying its own advantage: trucks with its ability to door-to-door services, water carriers with the ability to carry goods safely at low costs and trains able to carry all sorts of goods at long distances. In the Port of Rotterdam it is possible to find all this modalities for the hinterland transport of goods. This thesis, due to the characteristics of the product and available water transport infrastructure in Europe benefiting from its river systems, will explore the feasibility of European inland water transport of orange juice by barges.

5.1. Rotterdam's Fruitport and its orange juice processing players

Figure 14: *Rotterdam's Fruitport:*



Source: Port of Rotterdam

The companies located in the Port of Rotterdam active in the juice market are historically grouped in the Vierhavensgebied and the Merwehaven and due to this geographic clustering this port area is called the Fruitport. Due to their proximities to the city center, these areas are to be transformed in residential areas. By 2020 the Merwehaven and by 2030 the Vierhavens are to be re-developed into residential areas. The Merwehaven has been active in the transshipment and storage of fruit and vegetables since 1971 and currently has a capacity of 43,000 m² of cold storage facilities. In the Vierhavens especially in the Lekhaven and in the IJsselhaven, fruit juices are transshipped and modified. The Fruitport currently has a capacity of almost 3 million m³ of cold storage facilities.

The major juice processors/traders in the Fruitport of Rotterdam are:

Continental Juice (Cutrale Group): Brazilian company which is the biggest producer of orange juice in the world, located in the IJsselhaven since 1985. The company operates the European juice terminal (EJT).

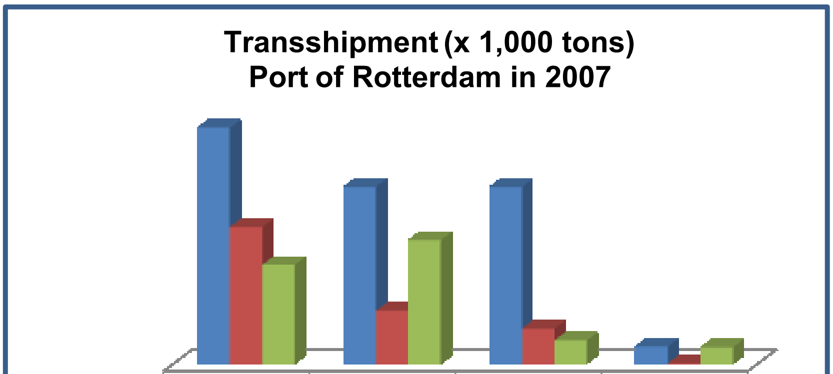
HIWA (Nicherei Group): Japanese company located in the Fruitport operating also the company Eurofrigo. It handles and stores more than 60% of FCOJ packed in drums destined to Europe.

Kloosterboer: Dutch company which has a storage capacity of 40,000 tons of FCOJ in Rotterdam and 175,000 tons in The Netherlands; 40% of their loads is FCOJ and 60% is NFC.

Wild Juice (Wild Flavors Group): German company which in 2005 acquired the multi-fruit business of Louis Dreyfus, on an early basis, transships 1.5 tons of NFC and 28.5 tons of FCOJ.

In the figure below it is shown these companies transshipments from the Fruitport Rotterdam into Western Europe in the year of 2007.

Figure 15: *Major companies' orange juice transshipments - PoR (2007)*



	Continental Juice	HIWA	Kloosterboer	Wild Juice
Total	400	300	300	30
NFC	232	90	60	1,5
FCOJ	168	210	40	28,5

Source: Port of Rotterdam

5.2. Shipping FCOJ from Brazil to Europe

About 80% of the Brazilian orange juice production is controlled by four companies: The Brazilians Cutrale, Citrosuco, Citrovita and the French Group Louis Dreyfus-Coinbra. Worldwide they control the prices and the rules of the FCOJ market, and the whole value chain as well: production, processing, export, transport and storage. The majority of the orange juice processors are located in the state of Sao Paulo with distance from the export harbor in the Port of Santos within the range of 400 and 800 km. A dedicated fleet of 25 tons tanker trucks carry the FCOJ from the production sites to the terminals in the port of Santos where it is stored in dockside tanks at -10°C under nitrogen atmosphere. At a tightly controlled schedule bulk tanker ships after arriving in Santos receive the FCOJ pumped on board within 24 to 36 hours depending on the size of the ship. The bulk tanker ships are filled completely to allow no headspace. The orange concentrate is loaded and transported at -10 °C. The journey from the Port of Santos in the state of Sao Paulo, Brazil to the Port of Rotterdam in The Netherlands, Europe takes 13 days. During the whole voyage the storage conditions of the product is continuously monitored. After arriving in the Rotterdam terminal with dedicated dockside facilities to receive FCOJ, large pumps (8 inch piping) on board the ship pump out the FCOJ directly into storage tanks on land. This operation takes also 24 to 36 hours, depending on the size of the ship. Operation of a terminal requires unlimited choice of product specifications, thus it needs to be controlled by modern automation system which allows the operators to get a rapid overview of pumping operations at all times. After have been unloaded, the bulk tanker ship returns to Santos ballasted and may also take freight containers on deck. The ship's empty tanks are not cleaned but are kept under nitrogen. Apart from the road transport the FCOJ is kept all the time under nitrogen protective atmosphere.

5.3. Shipping NFC from Brazil to Europe

Unlike in Florida where NFC is mainly stored and utilized on a processor's site, NFC produced in Brazil is primarily intended for export. The aseptic tank farms are therefore installed at the dockside export terminal instead at the juice factory. Clarified juice is then pre-pasteurized and cooled down to 0°C at the processing site and transported by insulated road tanker of 25 tons to the dockside storage facilities at the export harbor located in Port of Santos, situated within the range of 400 and 800 km from the processing plants. Full pasteurization of juice takes place at the terminal before it is transferred to the large aseptic storage tanks of nearly 4 million liters volume for long-term bulk storage to bridge the season or to be aseptic transferred to sea vessels fitted with bulk aseptic tanks. The aseptic tanks are located in insulated refrigerated storage areas where the temperature is maintained at 0°C. Juice is then transported to Europe under chilled aseptic conditions, normally at 0°C, on board of specially designed ships which can take up to 35,000 tons of NFC each. They are more than 200m long and 30m wide. Each ship contains four insulated refrigerated holds with several freestanding cylindrical tanks in each hold. Sloping bottoms ensure that the tanks can be completed drained. Each ship is equipped with own sterilization system for the bulk tanks and the piping system is sterilized before juice transfer. Aseptic seals are maintained on tank valves throughout the journey. Individual bulk tanks are maintained under continuous nitrogen pressure, even during loading/unlading when nitrogen is exchanged with dockside tanks. On arrival at Rotterdam, samples from onboard tanks are checked to confirm that the juice is microbiologically acceptable. The piping system is sterilized before aseptic juice transfer from onboard tanks to dockside storage using similar facilities to that at the export terminal in Brazil. A nitrogen system ensures that the entire system of tanks and piping is under nitrogen pressure during the NFC transfer. Voyage time and load/unload operations time are similar of the FCOJ case. For the ballasted return trip to Brazil the empty tanks are filled with nitrogen. In order to reduce the costs of the returning trip, they can also take on deck dry or refrigerated freight containers. Juice in the dockside tanks is sampled regularly to verify that their contents are microbiologically acceptable. The juice from the tank storage is dispatched chilled by road tanker, hygienic but not aseptic, to the customer.

5.4. Transport of bulk FCOJ and NFC versus transport of packaged products

As for concentrate shipping volumes are 5 to 6 times smaller in order to obtain constituted juice it is simple to conclude that bulk shipping in this case is more economic (*Appendix 4* calculates the quantity of concentrate needed to make 1 liter of juice). However, for the NFC the volumes are the same whether it is shipped in bulk or in retail packages. In the USA for instance, NFC produced in Florida is retail packed and shipped within the USA.

In the case of Brazil where almost all production is dedicated for export, bulk shipping is more cost efficient; bulk package can maintain a long shelf life whereas after the retail packaging in non-aseptic packages the shelf live is relatively short and this is a problem when almost a month of shelf live is eliminated by the transport chain. Another import point to be considered is the fact that it is not possible to respond quickly to market demands due to the long time required to get retail packages to the consumer.

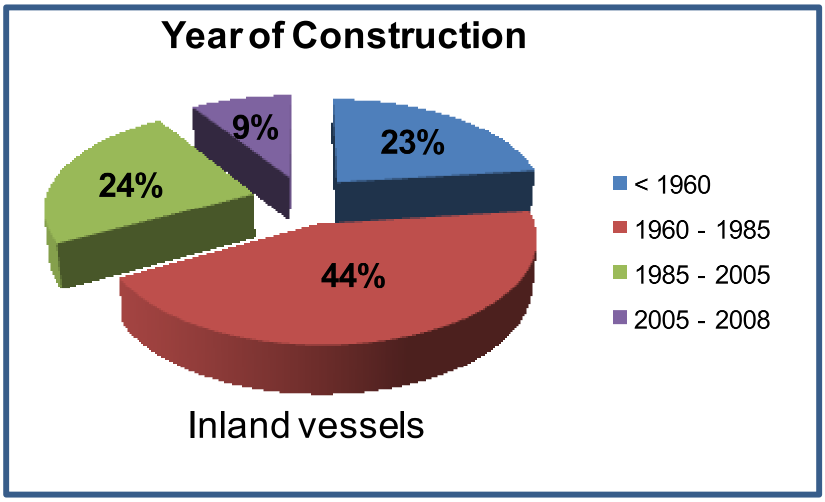
5.5. Inland terminals

Inland terminals are inland ports located in inland waterway such as a river, lake or canal. They are linked with a sea port and between themselves and have as a function being a specialized facility where containers are transferred and shipped in different mode of transport without the cargo being loaded and unloaded before its final destination. The inland shipping sector operates regular scheduled services to all terminals (liner services). In northwest Europe there are more than 50 inland terminals which create a network of scheduled liner services for container transport, 20 in The Netherlands, 20 in Germany and 10 in Flanders (Belgium). In order to be more efficient transshipers try to bundle cargo as much as possible to benefit from scale economies creating therefore, thicker cargo flows in major routes. Door to door transport for almost any destination can be done only by trucks therefore the last leg of the goods delivery is almost always done by trucks. Some statistics show that 60% of the total road transport covered distances of less than 50 km thus, road transport could be done only for the very first and the very late leg of transport and the long haulage could be covered by inland shipping with transshipments done in the network of inland terminals. The *Appendix 5* shows a picture of CONTARGO GmbH & Co. KG tri-modal container barge inland terminal locate in Dortmund, Germany.

5.6. Western European inland navigation fleet

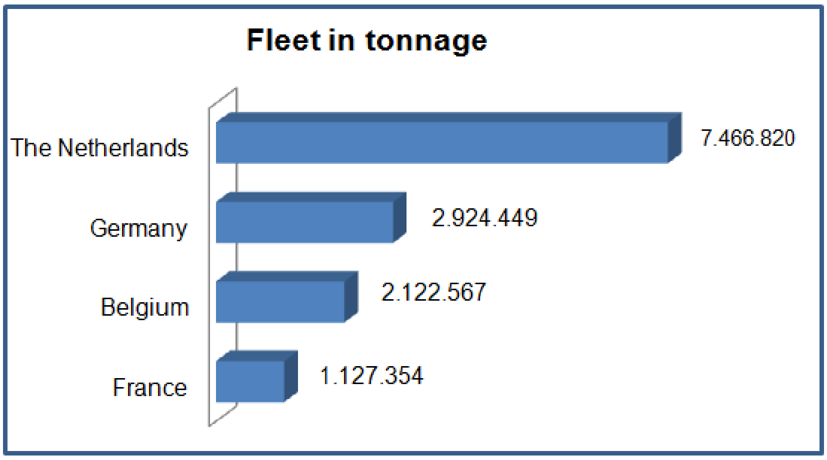
Due to continuous investments the western European inland navigation fleet is the largest and the most modern in the world. The fleet tonnage is in excess of 14 million tons and together with the reserve capacity of the western European waterways for the inland shipping mode take over some of the road cargo will not require great investments (*Internationale Vereniging Rijnschepenregister*).

Figure 16: *Western European inland navigation fleet year of construction*



Source: *Internationale Vereniging Rijnschepenregister (2009)*

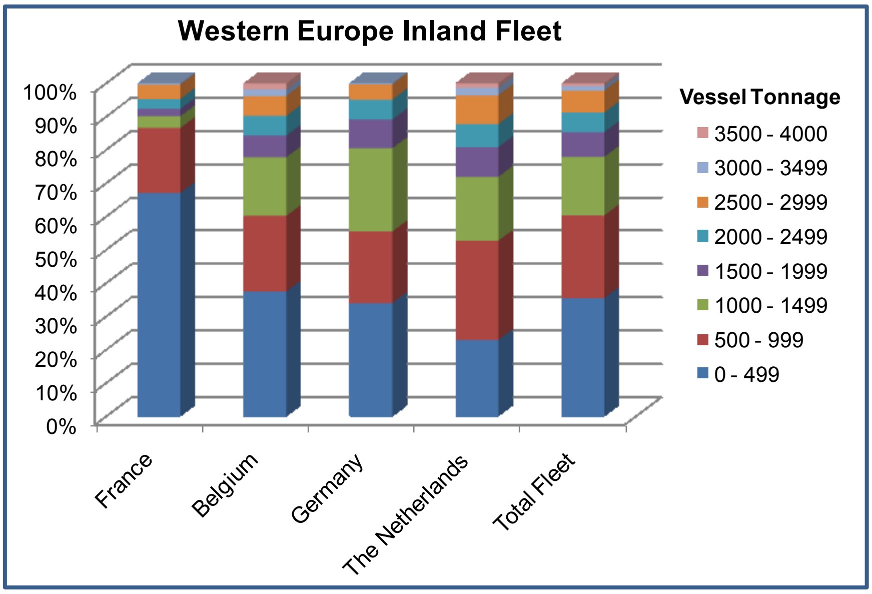
Figure 17: *Dutch, German, French and Belgium inland navigation fleet (tonnage)*



Source: Internationale Vereniging Rijnschepenregister (2009)

Following the overall shipping industry trends, the inland shipping industry is also producing new vessels taking into consideration economies of scale factors. Some years ago the maximum capacity available was vessels of 3,500 tons with maximum dimensions of 110 m length, 11.40 m width and 3.5 m draught whereas nowadays it has been built vessels with capacities of 4,000 to 5,000 tons, 135 m length, 14 /17 m width and 4 m draught. As the regional smaller waterways like in northern Germany and France are maintaining their importance in the inland shipping, vessels of less than 1,000 tons have also being built as well as smaller ships of 300 and 400 tons have being planned for service in France.

Figure 18: *Western European inland navigation fleet by class tonnage*



Source: Internationale Vereniging Rijnschepenregister (2009)

The *Appendix 6* brings the inland vessels classification according to the CEMT-Conférence Européenne des Ministres de Transport.

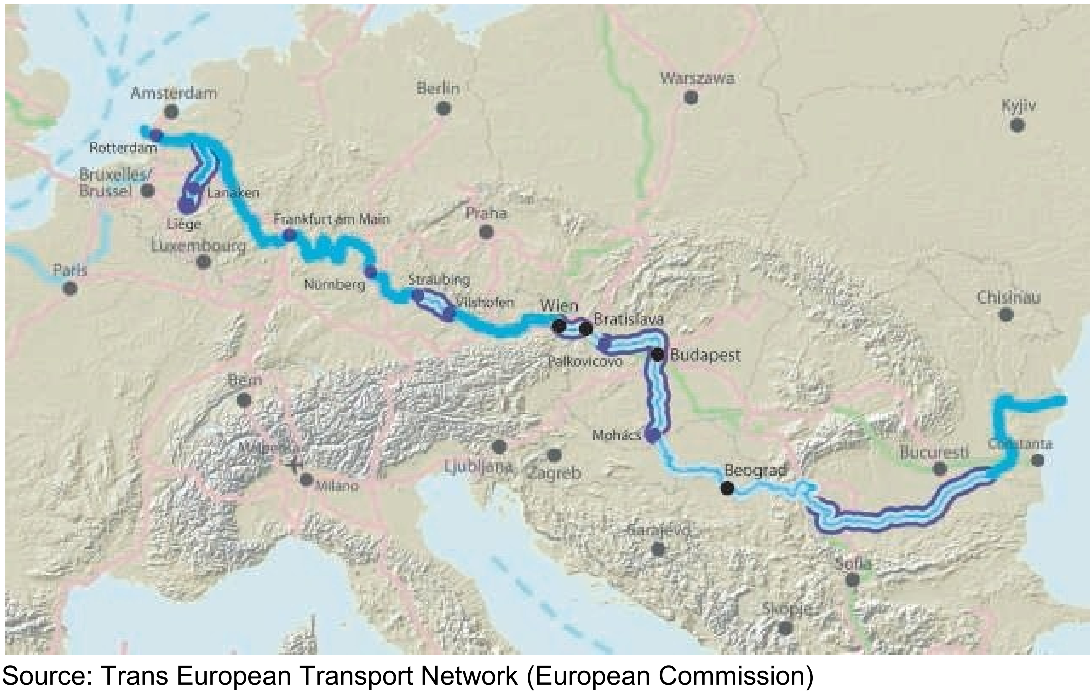
5.7. Inland waterways

The European inland waterways are a valuable natural resource which brings to its countries savings in goods movement through the waterborne transport. The European Union at a cost of 600 million Euro lunched in 2006 the trans-European transport network (TEN-T) which aims the creation of a multimodal network to ensure that the most appropriate transport mode may be chosen for each stage of a journey. By 2020, the inland waterway system will amount to 11,250 km, including 210 inland ports and more than 1,740 km of inland waterways will be upgraded. Two TEN-T Projects are worth mentioning which are related to the case study:

5.7.1. TEN-T 18: Rhine/Meuse - Main - Danube Inland Waterway Axis

The Rhine-Main-Danube waterway is a major freight route which links the North Sea (Port of Rotterdam) to the Black Sea (Port of Constanta). Several sections of this route during certain periods of the year present drafts less than 2.8 m and in order to receive vessels of 3,000 tons, 2.5 m should be the minimum draft of this waterway during the whole year. This is particularly the case of the Straubing-Vilshofen section in Germany. The upgrading of the whole route (1,542 km) is due in 2019. (European Commission. Pages 46-47 *Trans European Transport Network*, 2005).

Figure 19: *TEN-T 18: Rhine/Meuse - Main - Danube Inland Waterway Axis*

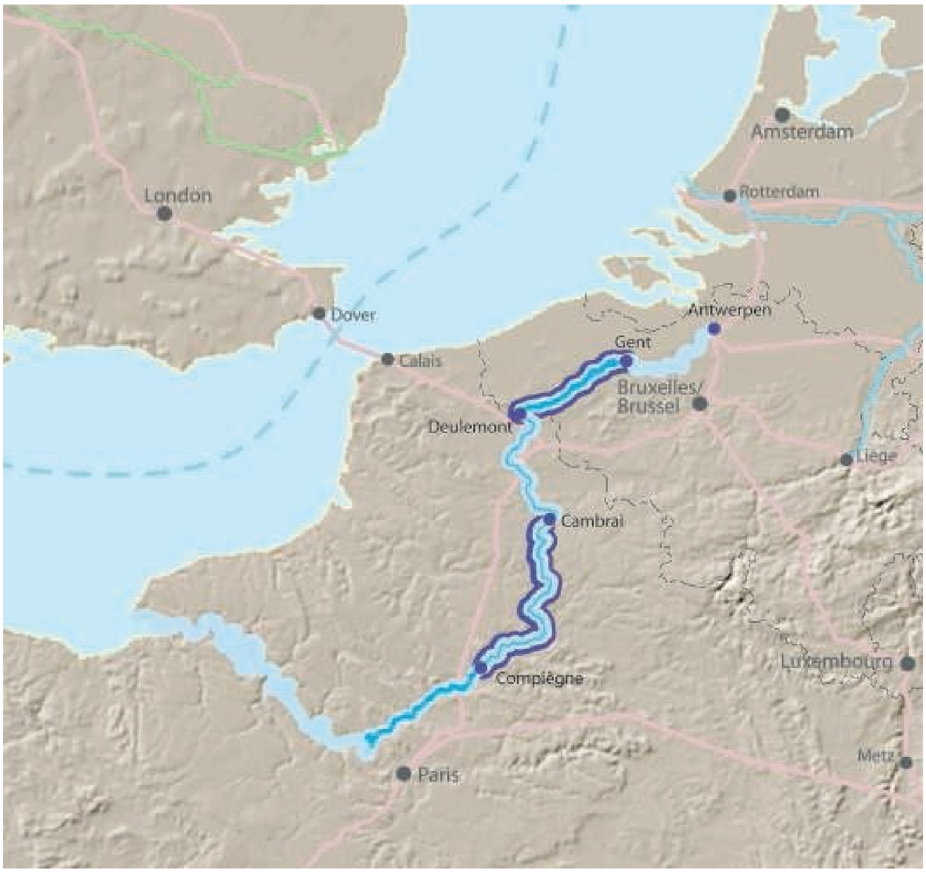


Source: Trans European Transport Network (European Commission)

5.7.2. TEN-T 30: Inland Waterway Seine-Scheldt

The aim of this project is to improve the link between the Seine and Scheldt rivers which connect the Paris region and the Seine basin with the entire Benelux inland waterway network. The bottle-neck to promote inland waterway transport between the Benelux and Paris is located between Compiègne and the Dunkirk–Scheldt canal. Navigability on that section is restricted to vessels of 400 up to 750 tons. The objective is to enlarge the canal (105 km) to receive barges up to 4,400 tons. The project will due in 2016 and entails 185 km. (European Commission. Pages 70-71. *Trans European Transport Network*, 2005).

Figure 20: *TEN-T 30: Inland Waterway Seine-Scheldt*

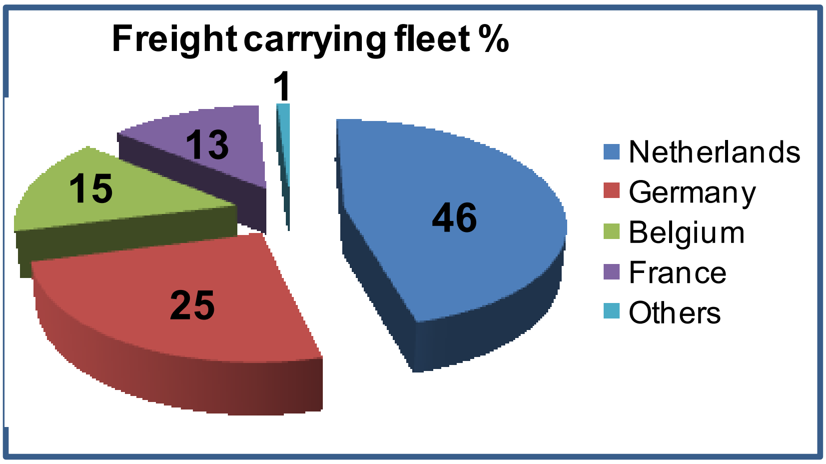


Source: Trans European Transport Network (European Commission)

The Dutch waterways accounts for 5,046 km, of which 47% is usable by inland vessels of 1,000 metric ton capacity or larger. The extensive national and international European waterways network with good navigation conditions enables to operate vessels from 90 up to 400 TEUs capacity whereas trains, due to their length constraints of 700 m and impossibilities of double stacking, offer capacity up to 90 TEUs. The average speed of both modes is 15 to 20 km/h respectively (Visser, J. et al, 2006).

More than half of the transport of all goods and 40% of container transport within the Netherlands is carried out using inland shipping vessels and the figure below confirms this Dutch preference by this mode of transport since 46% of the Western Europe inland shipping freight carrying fleet is under the Dutch flag. Even though, almost all European hinterland transport of orange juice from the Fruitport is done solely by tanker trucks.

Figure 21: *Western European inland shipping freight carrying fleet (%)*



Source: Internationale Vereniging Rijnschepenregister (2009)

6. Barge hinterland transport of orange juice in Europe: case study

This chapter introduces the tank container and the concepts of inter-modality and containerization. These concepts will be applied in the logistics of orange juice transport since the tank container will substitute the tanker truck mono-modal transport. The case study is then presented, the feasibility to use container barge services for the European hinterland transport of orange juice as well as investment and environmental issues are discussed.

6.1. Intermodal transport

According to the *Europe Forum on Intermodal Transport*, *intermodal transport is defined as a service involving transference between different modes of transport through the use of different modes of transport while transporting a cargo in the same load unit without handling the cargo when the modes are changed. Intramodal transport is defined as the transport using different elements of a modal subsystem requiring cooperation among them.* In order to be competitive in the international market a country needs to have an efficient and diversified transport mode. This diversified transport mode creates interdependency among them and makes the transportation designers think on a coordinated way when deciding for transport modes to be used in specific cases. It is this concept that will be used in this case study.

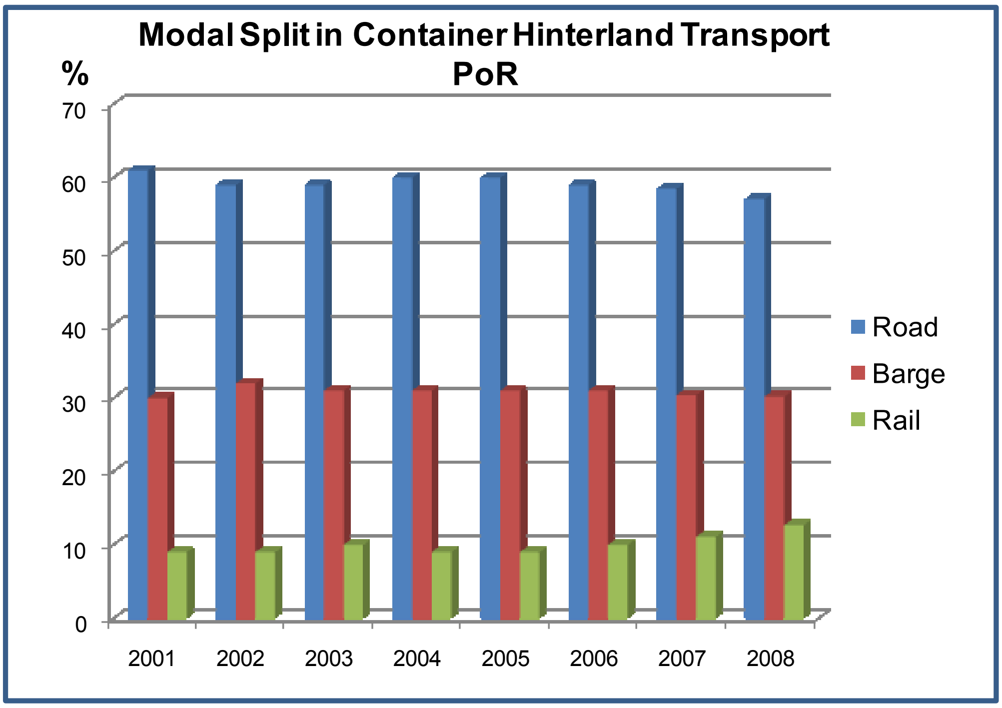
Inland shipping involves pre and post transport operations in order for goods reach their final destination. Intermodality, the combination of different modes of transport, relays on transshipment to other modes as trains and trucks and this operation can be easily done by using standardized containers sizes.

6.1.1. Containerization

Containerization is to use standardized containers in order to unitize cargo for supply, storage and transport. Rather than being loaded and unloaded, cargo can be transferred from one transport mode to another by means of standardized handling equipment without being re-handled. The goods will be loaded or unloaded only at the port of origin or destination, on a door to door base.

Using tank containers it will be promoted the containerization of the orange juice transport and thus, the concepts of intermodal and intramodal transport can be applied since it will be possible to use different hinterland transport modals as barges, trains and trucks on a coordinated way. In Europe, intermodal hinterland transport (trains and barges) is gaining importance since using it will promote the modal shift from congested road transport by trucks to trains and barges. This is the particular case of the ports of Rotterdam and Antwerp where inland waterways and railways promote a cost effective hinterland connection. In the figure below it is possible to see that the modal split among road, rail and barge remained constant over the years of 2001 and 2006 but this is about to change with the deployment in 2007 of the rail system called the Betuweline connecting the port of Rotterdam and the German hinterland and the increasing importance of barge inland transport offering cheap and reliable services. From the port of Rotterdam, 40% of the river Rhine volume transported by barges corresponds to German inland waterways transport within distances around 900 km and 35% within distances around 180 km. The remaining volume corresponds to Dutch national traffic within the range of 50 km and 250 km.

Figure 22: *Port of Rotterdam's Modal Split 2001 to 2008*



Source: Port of Rotterdam

6.2. The tank container

Large quantities of orange juice can be transported by 20 foot tank containers which are mobile aseptic tanks up to 24,000 liters or 31 tons of varying designs. Some are built inside a freight container and transported as such and others are designed to take the form of a self-contained tank sized to fit into tracks, ships and trains. Aseptic tank containers can also be used for in-site storage of juice product before it is shipped. They provide better economy of scale for handling aseptic NFC if compared with drums but sterilization costs are incurred and care must be taken with the sterilization process to avoid product damage. The loss of temperature on an insulated tank container is within the range of 0.2 to 0.5ºC per day. In the *Appendix 7* it is presented the technical specifications of the IMO type T11 frame tank container and the *Appendix 8* shows pictures of a frame tank container. There are no differences in loading and unloading tank containers if compared to tanker trucks in terms of time, pumping equipment, valves and hoses. While loading and unloading the tank container does not need the truck and the truck driver waiting during the operation while it is not the same in the loading and unloading operation of a tanker truck. The total time to load a tanker truck of 25 tons and a tank container is 40 minutes for the FCOJ and 15 minutes for the NFC. For our study purposes and taking into consideration the average densities of FCOJ as being 1.30t/m³ *(Section 3.4)* and for the NFC 1.045t/m³ *(Section 3.5)* respectively, the full tank container weight for FCOJ will be 30 tons (24 m³ X 1.30t/m³) and for NFC 25 tons (24 m³ X 1.045t/m³). However, due to road weight restrictions regulations it is assumed that the weight transported for FCOJ and NFC by tank containers is always 25 tons, the same weight carried by the tanker trucks.

6.3. Feasibility of orange juice hinterland transport by barges

For our particular feasibility study it was chosen major juice packer companies which receive the orange juice in bulk located in cities in Germany, France and Belgium shipped by an orange juice processing company located in the Fruitport in the Port of Rotterdam, as follows:

Figure 23: *Major juice packer companies locations included in the case study*

GERMANY	Weekly Number of Tank Containers
FCOJ	
Rinteln (Hannover)	15
Hennef (Bonn)	25
Paderborn	30
NFC	
Calvorde (Berlin)	40
Monchengladback (Dusseldorf)	30

FRANCE	Weekly Number of Tank Containers
FCOJ	
Signes (Marseille)	12
NFC	
Macon (Lyon)	40
Saint Denis L'hotel (Paris)	40
Sarre Union (Stasbourg)	20

BELGIUM	Weekly Number of Tank Containers
FCOJ	
Gent	5

Source: orange juice processor - Fruitport

Due to the lack of inland waterway services for Paderborn, the nearest big city is Dortmund 140 km away, barge transport for this German juice packer company was deemed not feasible. In the same way, the lack of good waterways in the north of France due to the bottle-neck located between Compiègne and the Dunkirk–Scheldt canal, discussed in *Section 5.7*, which restricts navigability to vessels of 400 up to 750 tons making the barge transport costs too high per tank container unit, barge transport to the city of Saint Denis de L'hotel nearby Paris was also deemed not feasible, tanker truck mode is more suitable. Still in France, the juice packer company located in the city of Macon, nearby Lion is better reached by train but as NFC will be transported refrigeration is needed thus tanker trucks with reefer must be used as trains do not have reefer systems. The juice packer company located in Signes, also in France, nearby Marseille is better reached by train or short-sea shipping, as FCOJ will be transported, train without reefer system could be a transport mode possibility but as this modal is not that reliable and the distance is big, around 1,200 km, short-sea shipping transport mode is the best possibility. Thus orange juice transport by barge was also deemed not feasible for these two French juice packers located in the cities of Macon and Signes.

Concerning barge transport to the German juice packer companies located in the cities of Rinteln, Hennef, Calvorde and Monchengladback, the juice packer company located in Sarre Union, France and the juice packer company located in Gent, Belgium, the inland waterway transport mode by barges using container tanks was deemed feasible. Taking into consideration the route to the city of Rinteln, due to a lock restriction, only class IV of inland vessels can be used whereas for the remaining destination routes, up to class VI of inland vessels can be used.

The inland waterway routes front the Fruitport in the Port of Rotterdam to the cities where the above mentioned juice packer companies are located are described below:

Juice packer companies located in Germany in the cities of:

Rinteln: river Rheine and Mittellandkanal *(Appendix 9)*

Hennef: river Rheine *(Appendix 10)*

Calvorde: river Rheine and Mittellandkanal *(Appendix 11)*

Monchengladback: river Rheine *(Appendix 12)*

Juice packer company located in France in the city of:

Sarre Union: river Rheine *(Appendix 13)*

Juice packer company located in Belgium in the city of:

Gent: Dutch Province of Zeeland inland waterway routes *(Appendix 14)*

Putting together the six juice packer companies, 135 tank containers per week will be transported on inland waterways by barges, NFC will account for 90 tank containers per week (67%) and FCOJ will account for 45 tank containers per week (33%). According to the information given by the Port of Rotterdam *(Figure 15, Section 5.1)* the Fruitport transshipment of orange juice promoted by Continental Juice accounted for 400,000 tons in the year 2007. Considering 52 weeks on a year and each container tank filled with 25 tons of orange juice it will result that almost 45% (180,000 tons) of all Continental Juice's hinterland transshipments can be done by barges using the extensive European inland waterways or 45% less road transport which add up a reduction around 7,200 tanker trucks per year in the congested European highways. Of the 180,000 tons per year, NFC transshipments will account for 67% or 120,600 tons and FCOJ will account for 33% or 59,400 per year *(figure 23).*

6.4. Transport costs

Two barge companies were quoted to find out the market cost to transport FCOJ and NFC from the Fruitport in Rotterdam to their European hinterland destinations:

The lowest cost between the two companies for each route was taken into consideration to perform the case study. Each total barge freight cost includes the straight-line depreciation cost of € 28.00 per week and per tank container considering a tank container economic live of 15 years.

The tanker truck 25 tons freight costs reflect the average market truck road rates for the chosen destinations. These rates include the gasoil surcharge of 1.8% and the LKW-Maut tax for the German highways.

The value added tax (VAT) is excluded in all given costs.

Three scenarios were then created to evaluate the cost of inland waterway transport of orange juice by barges using the tank containers versus the cost of transport it by tanker trucks of 25 tons.

The first scenario, the more realistic one for the actual situation of no inland waterway transport mode of orange juice, takes into consideration the costs of a barge round trip. It is understood as a round trip to take the tank container from the inland hub terminal in the Port of Rotterdam, deliver it to juice packer and bring it back empty to the inland hub terminal in the Port of Rotterdam. This happens because of the trade unbalance between the Fruitport and the juice packers. Once the tank container is emptied it finds no more application in the nearby market and has to be brought back to the hub terminal in the Port of Rotterdam.

The second scenario simulates a future situation where the market of orange juice transport by tank containers via inland waterways is consolidated, the barge service is charged only for the single trip and as in the case of road transport the empty tank container is used for further transport from its last destination, the trade imbalance is eliminated.

The third scenario, is the expected future situation, where the transport market of orange juice in tank containers by barges from the Fruitport is already consolidated and the volume handled is large enough to justify a container terminal in the Fruitport sheared by all companies located there or stimulates the barge companies to create a regular service to inland waterway transport mode of orange juice from the Fruitport to the European hinterland deploying crane barges *(Appendix 15).*

The table below shows for comparison the barge transport times (given by the barge companies), the truck transport times (average speed of 70 km/h) and the road distances for the chosen destinations:

Figure 24: *Transport times and road distances for the chosen destinations*

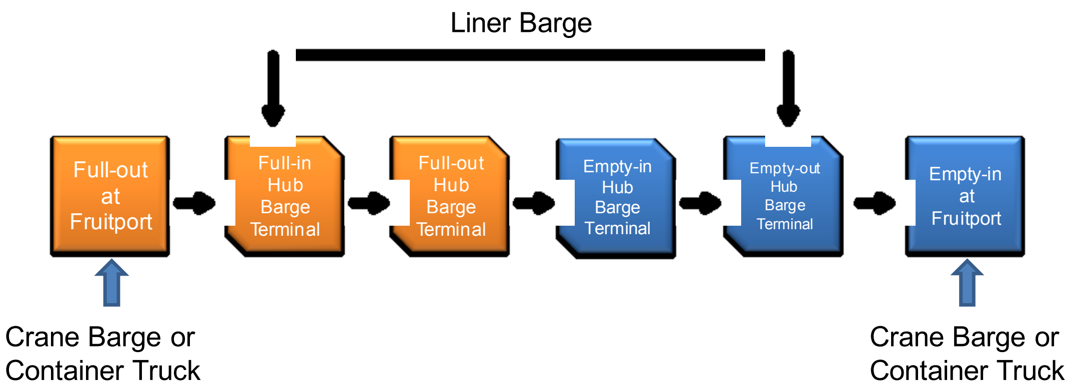
Destination	Transport Time barges (days)	Transport Time trucks (hours)	Road Distance (km)
Rinteln	4	5:10	358
Calvorde	5	7:40	534
Hennef	2	4;20	305
Monchengladback	2	3:00	211
Sarre Union	5	7:10	501
Gent	1	2:20	162

Source: The author

The barge transport times include slack times at the inland terminals. It is worth noting that for some destinations the total time given by barge operating companies varies a little from the ones given by the software PC Navigo *(Appendices 9 to 14).*

As all hinterland transport of orange juice is done by tanker trucks, the Fruitport does not have container handling facilities. Therefore, the first two scenarios described above carry on the € 195.00 per tank container of additional cost due to the transport from the Fruitport by crane barge or container truck to the barge inland hub terminal (€110.00 per tank container) and handling at the barge hub terminal (€85.00 per 2 moves), as described in the figure below:

Figure 25: *Tank container transport and handling at the Fruitport*



Source: The author

In this cost it is included a tank container duel time of 10 days.

Therefore the total amount to be added to the barge freight cost will be:

- € 195.00 (handling) + € 28.00 (tank container depreciation) = € 223.00

In all three scenarios described above, handling costs at the foreign inland terminal and the road transport costs to the final destination are included in the given barge freights on the tables of *Figures 26 and 27*.

6.4.1. First scenario

The table below details the costs comparison for the first scenario:

Figure 26: *First scenario transport costs per container tank*

Destination	Barge Freight round trip (€)		Total Barge Freight (€)	Truck Freight single trip (€)
	Reefer	**No Reefer**	**€ 223.00**	
Rinteln		803.00	1,026.00	795.00
Calvorde	1,078.00		1,301.00	993.00
Hennef		485.00	708.00	910.00
Monchengladback	360.00		583.00	728.00
Sarre Union	735.00		958.00	1,323.00
Gent		340.00	563.00	380.00

Source: The author

Barge freight round trip: the tank container is transported from the inland hub terminal in the Port of Rotterdam, unloaded in the customer and brought back empty to the inland hub terminal in the Port of Rotterdam.

Total barge freight cost: tank container handling costs and transport cost from the fruit terminal to the hub inland terminal in the Port of Rotterdam.

6.4.2. Second scenario

The table below details the costs comparison for the second scenario:

Figure 27: *Second scenario transport costs per container tank*

Destination	Barge Freight single trip (€)		Total Barge Freight (€)	Truck Freight single trip (€)
	Reefer	**No Reefer**	**€ 223.00**	
Rinteln		490.00	713.00	795.00
Calvorde	705.00		928.00	993.00
Hennef		320.00	543.00	910.00
Monchengladback	260.00		483.00	728.00
Sarre Union	573.00		796.00	1,323.00
Gent		270.00	493.00	380.00

Source: The author

In the second scenario it is considered just the barges single trip, the tank container trade imbalance is eliminated and it finds other applications in the market nearby.

Total barge freight cost: tank container handling costs and transport cost from the fruit terminal to the hub inland terminal in the Port of Rotterdam.

6.4.3. Third scenario

The table below details the costs comparison for the third scenario:

Figure 28: *Third scenario transport costs per container tank*

Destination	Barge Freight single trip (€)		Truck Freight single trip (€)	Cost Savings %
	Reefer	**No Reefer**		
Rinteln		518.00	795.00	35
Calvorde	733.00		993.00	26
Hennef		348.00	910.00	62
Monchengladback	288.00		728.00	60
Sarre Union	601.00		1,323.00	55
Gent		298.00	380.00	22

Source: The author

The third scenario is the future expected situation where the transport market of orange juice in tank containers by barges from the Fruitport is already consolidated and the volume handled is large enough to justify a container terminal in the Fruitport sheared by all companies located there or stimulates the barge companies to create a regular service to inland waterway transport mode of orange juice from the Fruitport to the European hinterland deploying crane barges.

It is worth noting that using inland waterway transport mode results in cost savings for all destinations and as Hennef, Monchengladback and Sarre Union are covered by barge regular service with local delivery, they are actual freight rates and represent cost savings above 50% on average even for reefer transport. For the destinations of Rinteln and Calvorde as there is no regular barge service, the transport freight is not an actual rate but a calculated one taking into consideration the total barge voyage costs divided by 60 TEUs in 2 layers due to several bridges on the track added to the handling costs in the inland terminal in Germany and local tank container transport to the juice packer. Thus, it is important to bundle cargo to create a regular barge service for Rinteln and Calvorde in the German Mittellandkanal to reduce even more the barge freight rate. For the destination Gent, the tanker truck transport is competitive but even so it is achieved a reduction in transport costs of 29% using inland shipping by barges.

The deep-sea transport of orange juice from Brazil to Europe is out of the scope of the thesis but it is worth mentioning that the use of tank containers, as it was seen in *Section 6.1*., brings the possibility to work with intramodal concepts. According to *Sections 5.2 and 5.3*, the transport of NFC and FCOJ from Brazil to the port of Rotterdam is done by dedicated bulk tanker ships but, using tank containers the possibility to transport part of the orange juice cargo by liner deep-sea shipping with reefers is open. Therefore, considering the two destinations in the northern part of Germany, Rinteln and Calvorde, calling the port of Hamburg as port of entrance to Europe, the inland barge freight costs will decrease considerably as the table below shows:

Figure 29: *Rinteln and Calvorde calling the port of Hamburg (no reefer available)*

Destination	Barge Freight single trip (€)		Truck Freight single trip (€)	Cost Savings %
	Reefer	No Reefer		
Rinteln		438.00	795.00	45
Calvorde		423.00	993.00	57

Source: The author

For the three scenarios, a cost of € 55.00 per container is also charged one time which includes the transport cost to bring the empty 20 foot tank container from the depot to the orange juice processing facility in the Fruitport. As in the long run this onetime cost will not influence our conclusions it is not considered in the calculation. The cost of aseptic cleaning the tank container is not considered as well since the cost of cleaning the tank of a tanker truck is similar to that of a tank container, thus it will not affect the case study conclusions.

6.5. Floating stocks

By definition, floating stocks is the use of intermodal transport in order to deliver goods to the supply chain before customers demand (Dekker et al, 2006). The orange juice total transport time deploying barges is higher if compared to the total transport time of tanker trucks for the same destination *(Figure 24).* This higher transport time can be transformed in advantage for the inland waterway transport mode if the concept of floating stocks is used in practice. On each harvest season, after the signature of the supplying contracts, orange juice processing companies store in batches the orange juice to be delivered to their clients in huge aseptic tanks located in their terminals in the Fruitport *(Section 4.2).* Applying the floating stocks concept, the orange juice processing companies can deliver by barges the contracted weekly product volumes to the nearest customers' inland terminals. Doing so inventory's occupancy cost, space costs of having orange juice stored in big stainless steel tanks will be reduced, more space to tank storage will be available to supply new customers without the need to invest in new storage capacity. On the other hand, the juice packers will also benefit since the product will be located in the nearby inland terminals for immediately deliver upon demand avoiding the long hours of tanker truck transport from the terminals in the Fruitport. More storage from the Fruitport to inland terminals will promote a reduction in the order reaction times. Also, possibilities of pooling orange juice distribution arise if near the inland terminal exists a cluster of juice packers. The implementation of floating stocks will act on decreasing static inventories in favor of transit inventories (pipeline inventories) decreasing storage costs since it benefits from the free of charge storage conditions in the inland terminals (three days – no reefer) it will be seen increasing holding costs but they are lower than the storage costs.

- Tank container NFC holding cost:

  Retail price: € 2.98 / l
  VAT 6% = € 0.18
  Assumption: total profit margin = 50%
  Production cost: (€ 2.98 - € 0.18) X 0.5 = € 1.40 / l
  NFC volume:
  25,000 kg / 1.045 (t/m^3) = 23,923 l
  23,923 l X € 1.40 = € 33,492.00
  Assumption: holding cost = 20% per year
  Holding cost:
  € 33,492 X 0.05% = € 16.75 / tank container / day

- Tank container FCOJ holding cost:

  Retail price (RTD): € 0.59 / l
  VAT 6%: € 0.04
  Assumption: total profit margin = 50%
  Production cost: (€ 0.59 - € 0.04) X 0.5 = € 0.28 / l
  Appendix 4: 1 liter RDT = 180g FCOJ
  0.180 kg / 1.30 kg/l = 0.14 l
  0.14 l FCOJ = € 0.28 1 liter FCOJ = € 2.00
  FCOJ volume:
  25,000 kg / 1.30 (t/m³) = 19,231 l
  19,231 l X € 2.00 = € 38,462.00
  Assumption: holding cost = 20% per year
  Holding cost:
  € 39,462 X 0.05% = € 19.75 / tank container / day

To check the feasibility of the concept a detailed operational cost study should be done.

6.6. Investments

As all European hinterland transport of orange juice has been done by tanker trucks, one major issue in the whole process is the acquisition of tank containers which has to be done by the orange juice processing companies and/or by the juice packers who are the ones who actually contract the road transport. Normally, the big liner shipping companies own their containers but in the case of the barge companies this is not so. According to our case study (*Section 6.3),* about 45% of Continental Juice orange juice transshipments can be done by barges For Continental Juice *(Section 6.3),* 33% of all transshipments are composed by FCOJ without rigid needs of temperature control due to its low initial transport temperature - 8°C which allows temperature variations without product damage - the gain of temperature in a tanker container insulated is from 0.2 to 0.5°C per day *(Sections 4.2.1 and 6.2)*. NFC composes 67% of the total volume to be transshipped with rigid temperature control requirements since its transport temperature must be between - 1°C and 1°C *(Section 4.2.2)*.

The table below shows the average number of tank containers to hold Continental Juice weekly transshipments:

Figure 30: *Weekly average number of tank containers*

Destination	Transit Time (days) Import	Transit Time (days) Return	Total Travel (days)	Full Tank Containers (weekly)	Total Tank Containers (weekly)
Rinteln	4	4	8	15	40
Calvorde	5	5	10	40	100
Hennef	2	1	3	25	50
Monchengladback	2	1	3	30	60
Sarre Union	5	3	8	20	50
Gent	1	1	2	5	10

Source: The author

For the calculation of the total tank containers shown in the table above, it was considered 5 weekly working days, and a buffer in the processing companies and juice packers of one day for transit times greater than three days.

6.6.1. Tank Container

As the other three major orange juice processing companies located in the Fruitport play in the same market with the same products let's use the same percentages for the total amount of the orange juice transshipped by barges in the Fruitport as a matter of total investment costs. From the *Figure 15, Section 5.1* the Fruitport total orange juice transshipment in the year 2007 accounted for 1,030,000 tons whereas Continental Juice transshipped 400,000 tons, thus the total volume transshipped by the companies located in the Fruitport accounts for 1.58 times more than Continental Juice. Just as a matter of investment calculation as stated above, the number of weekly total tank containers from the table above will be multiplied by 1.58. Therefore, the total amount of investment required for tank containers will be:

Tank container manufacturing company quotation for tank container with reefer system:

- Tank container with reefer system: € 22,000

According to the table in the *Figure 30* above:

- Weekly number required of tank containers = 310 X 1.58 = 489.80 = 500
- 500 X € 22,000 = € 11,000,000

Tank Container Investment Fruitport ➡ **€ 11,000,000**

It is important to mention that the tank container can be transported by trucks which also transport standard 20 foot container, thus, the same chassis can be used for both types of container whereas in the case of the tanker truck, the tank must be coupled to a dedicated chassis. According to a tank for trucks and tank container manufacturer the acquisition of a tank for a truck plus chassis is twice more expensive than the acquisition of a tank container.

6.6.2. Tank Container Leasing

Leasing, an option to be considered for the short term and initial phase of the project, will bring the following costs according to quotation done by a tank container manufacturing company:

- Leasing short term (up to 3 years) – daily rental € 11.00
- Leasing long term (3 years plus) – daily rental € 9.00

Considering short term leasing and according the numbers given in the text above:

- 500 tank containers X € 11.00 X 360 days X 3 years = € 5,940,000

The following onetime cost also incurs:

- Accreditation Body Surveys - € 50.00 per tank container
- 500 X € 50.00 X 2 (initial and final surveys) = € 50,000
- Payment for damages (end of contract leasing) - € 1,000 per container
- 500 X € 1,000 = € 500,000

Total short term leasing cost = € 5,940,000 + € 50,000 + € 500,000 = € 6,490,000

Short Term Leasing Cost (3 years) ➡ € 6,500,000 / year

6.6.3. Crane Barge

In the third scenario where the transport market of orange juice in tank containers by barges from the Fruitport is already consolidated and the volume handled is large enough to justify and to stimulate the barge companies to create a regular service to transport orange juice from the Fruitport to the European hinterland, investment in crane barges *(Appendix 15)* will be necessary if the decision is not to construct a container terminal to be shared by all companies located in the Fruitport. Estimated investment:

Crane Barge: ➡ € 4,000,000

6.6.4. Mobile Quay Crane

According to information from a terminal operator company, one mobile quay crane for the Fruitport to be shared by all companies located there would be enough at investment a cost of:

Mobile Quay Crane: 40 tons ➡ € 2,000,000

Handling equipments are not considered in this case study since container terminal design is out of the scope of this thesis.

6.7. Investment appraisal

In this section the net present value (NPV) and the internal rate of return (IRR) are calculated to the related investments in the orange juice inland transport destinations deemed feasible in this case study and their proposed three scenarios discussed in the *Section 6.4*. In this appraisal it is considered the investment that needs to be done in the acquisition of tank containers for each destination. Investments in crane barges and/or in mobile quay cranes are not considered due to the fact that further studies must be done concerning issues like the relocation of the Fruitport and possibilities of cargo bundling among juice processor and fruit traders.

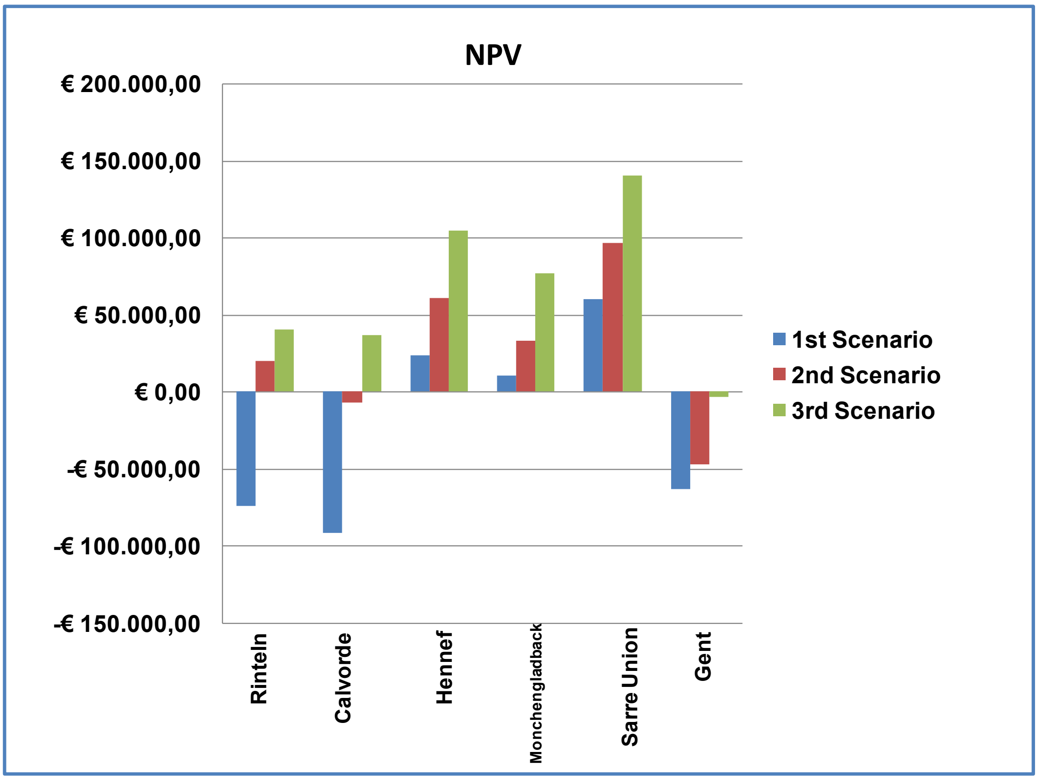
Parameters for the NPV and IRR calculation:

- Discount rate: 5% (industry market average)
- Period: 5 years
- Cash flow: difference between the tanker truck freight cost and the barge freight cost per year along the period of 5 years
- Container tank investment: € 22,000 per container

The *Figures 31 and 32* show the NPV and IRR related to investments in tank container for each feasible destination and scenario:

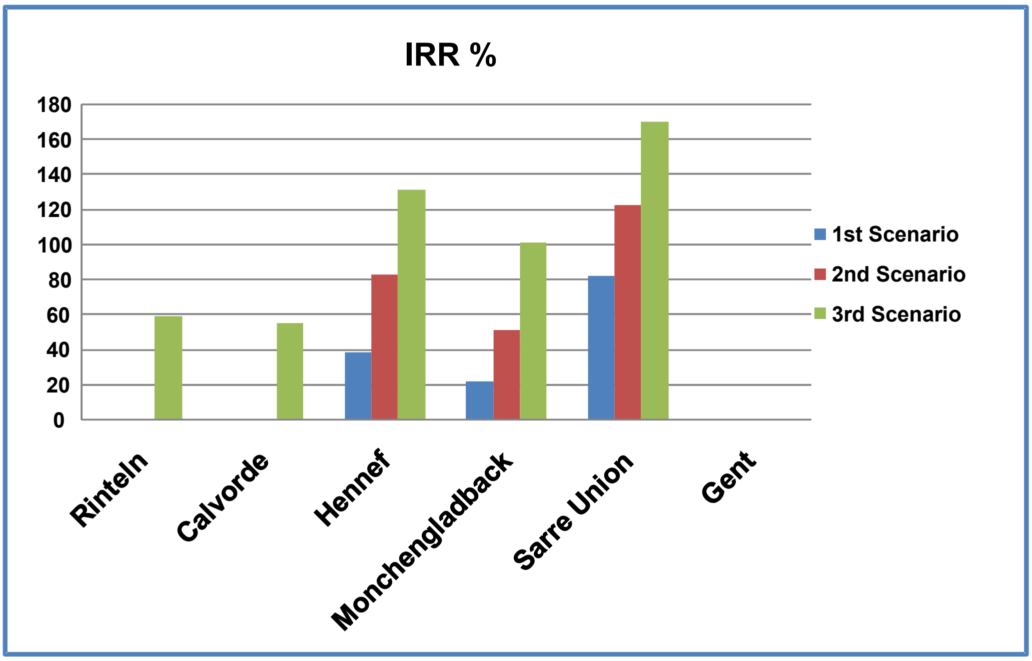
Investments in tank containers to the destinations Hennef, Monchengladback and Sarre Union presented positive NPV in the three scenarios while Gent presented negative NPV in all of them even in the third scenario where the barge freight cost is lower than the tanker truck freight cost showing that investment in tank containers with only 22% reduction in freight costs is not economically feasible. The calculation of NPV and IRR is important because from the investment appraisal became clear that the most cost effective destination is Sarre Union in France. Therefore, a pilot project to deliver orange juice by barges to the juice packer located on this destination is suggested.

Figure 31: *NPV – tank container investment*



Source: The author

Figure 32: *IRR – tank container investment*



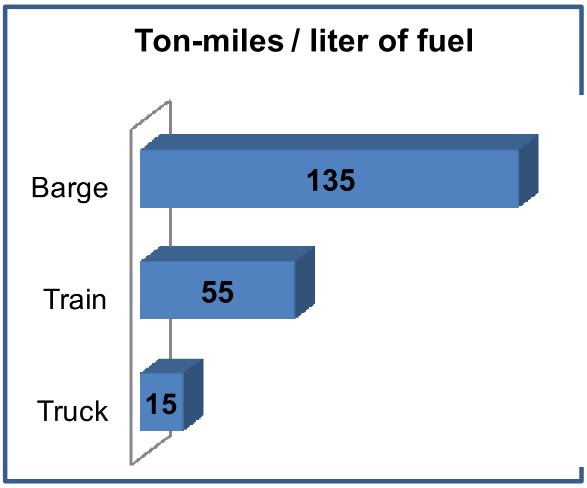
Source: The author

6.8. Environmental issues

Due to its scale, waterborne transport consumes relatively little propelling energy by ton-kilometer which results in lower exhaust emissions, when compared to trucks and trains. Furthermore, inland shipping is safer if compared to truck transport and according to the *Dutch Agency of Inland Shipping (BVB)* the number of ships must more than double in order to create some sort of water congestion. Roads and railways are expensive to be built and maintain whereas most of the waterways were created by nature and requires less investments and lower maintenance costs. Inland shipping therefore creates less external costs for the society, environmental pollution; noise and congestion are minimal with this transport mode.

According to the *U.S Department of Transportation Report on Environmental Advantages of Inland Barge Transportation (August 1994)*, inland shipping transportation is the most fuel efficient mode of transport for moving cargo and the least energy intensive method of freight transportation when moving equivalent amounts of cargo. On average, water carriers consume 500 BTUs of energy per ton-mile whereas trains consume 750 BTUs and trucks 2,400 BTUs. In terms of capacity, a 1,500 ton barge carries as much as sixty 25 ton trucks. A standard barge is 90 m long and the sixty trucks one after the other would be about 900 m long.

Figure 33: *Ton-miles carried per liter of fuel by transport modal*



Source: U.S Department of Transportation Report on Environmental Advantages of Inland Barge Transportation

The barge transport will also bring environmental benefits for the Port of Rotterdam area, following the objectives of the Rotterdam Climate Initiative since using barges will decrease in 45% the number of tanker trucks transporting orange juice. These benefits can be enumerated as less fossil fuel burning per unit of cargo and consequently less exhaust emissions of green-house gases, less road accidents and congestion and reduced noise levels. The table below shows that an average Class IV barge produces 77% less CO_2 per ton-mile than an average 25 tones tanker truck.

Figure 34: *Total CO_2 emission per transport mode (ton-mile)*

TRANSPORT MODE	Tanker Truck	Inland Barge
Type	25 tons	Class IV
Number of TEUs transported	1	90
Tonnage transported (25 tons/TEU)	25	2250
Unit of distance (km)	100	100
Avarage modal speed (km/hour)	70	10
Operational hours per 100 km (hour)	1,43	10,00
Installed power (kw)	250	750
Averaged used power	50%	50%
Averaged delivered power (kw)	125	375
Averaged delivered power during the operational hours (kwh)	178,57	3750,00
Specific fuel consumption (g/kwh)	200	200
Fuel consumption for the delivered power (kg)	35,71	750,00
Fuel consumption for the delivered power in litters = kg X 1.2	42,86	900,00
CO_2 production per litter of fuel = 2.6 kg		
Total CO_2 production (kg)	111,43	2340,00
Total CO_2 production per km (kg/km)	1,11	23,40
Total CO_2 production per ton-km (g)	44,57	10,40
Total CO_2 production per ton-mile (g)	71,73	16,74

Source: The author and Marin

Continental Juice, HIWA, Kloosterboer and Wild Juice, the four major players in the orange juice market in the Port of Rotterdam, accounts for 1,030,000 tons of orange juice transshipments per year *(Figure 15, Section 5.1)*. As the four companies play in the same market with the same products let's assume that all three companies have the same shipping pattern so also 45% of the total volume (1,030,000 tons) or 463,500 tons of orange juice, were to be transported by barges thus, 18,540 tanker trucks of 25 tons would be off the roads per year. According to the calculation below almost 1.0 ton of CO_2 emission per ton-mile per year would not be produced.

18,540 tanker trucks per year X (71.73g - 16.74g) CO_2 emission per ton-mile =

= 1.02 tons of CO_2 emission per ton-mile per year

Almost 1,000 trucks leave the fruit port daily to distribute fruit juices, fruits and vegetables throughout Europe if all of these trucks were substituted by barge transport almost 20 tones of CO_2 emission per ton-mile transported per year would be avoided.

The World Ports Climate Initiative (WPCI) formalized in 2008 through the World Ports Climate Declaration has active projects which includes the Carbon Footprint Project of which the Port of Rotterdam is a participating Port. Carbon footprint has as objective to establish the total set of greenhouse gas emissions (CO_2, CH_4 and N_2O) caused directly or indirectly by an organization over a period of time and it is divided in three scopes:

Scope 1 (emissions direct from the Port): port-owned fleet vehicles, port employees and buildings.

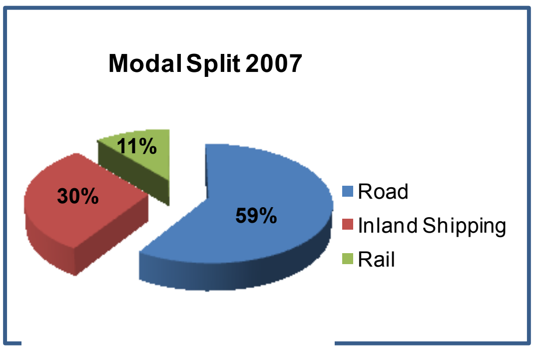
Scope 2 (emissions indirect from the Port): purchased electricity for port-owned buildings and port operations.

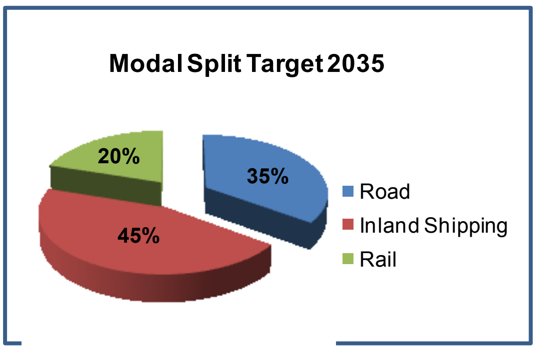
Scope 3 (emissions from the Port tenants): ships, trucks, cargo handling equipment, rail, harbor craft, buildings and purchased electricity.

Therefore, the use of barges instead of trucks will help the Port of Rotterdam carbon management related to the scope 3. The Port of Rotterdam has a goal to be an organization climate-neutral in 2012, and at the end of 2011 it aims to reduce the CO_2 footprint by 35% compared to the footprint for activities in 2007.

Part of the Port of Rotterdam sustainability (the balance between people, planet and profit) strategy is based on the increment of the modal split deploying more rail and inland shipping in spite of road transport so that for the year 2035 it is expected that the volume of inland shipping goods would be increased in percentage 1.5 times if compared to the volumes in percentage of 2007.

Figure 35: *Port of Rotterdam's Modal Split in 2007 and Target for 2035*





Source: Port of Rotterdam

Finally, innovations in engine technology have already achieved remarkable results both in road transport and inland shipping. Both modes of transport use the same types of engines from the same factories. At some point between 2010 and 2020, emissions per cargo ton-mile will be the same for vessels' engines and trucks. In other words, inland shipping also benefits from all the research and innovations that take place in this field in the road transport sector. The difference is that the replacement of vessels' engines takes longer, because the lifetime of vessels is longer than that of trucks. Regarding pollutant emissions as NOx, SO_2 and PM (particulate materials) the modalities do not differs very much (den Boer et al, 2008).

To summarize the discussion in this section it is presented the table below where it is found for the feasible destinations their respective total transport times, total freight costs (three scenarios) and CO_2 emission:

Figure 36: *Sections' summary table*

Destination	Total Times		Transport Costs (€)				CO_2 Emission		Savings
	Truck (h)	Barge (days)	Truck	Barge			Truck	Barge	CO_2
				1st Scenario	2nd Scenario	3rd Scenario	(tons/year)	(tons/year)	(tons/year)
Rinteln	5:10	4	795.00	1,026.00	713.00	518.00	5,009	16,179	11,170
Calvorde	7:40	5	993.00	1,301.00	928.00	733.00	17,182	64,356	47,173
Hennef	4:20	2	910.00	708.00	543.00	348.00	6,028	22,973	16,945
Monchengladback	3:00	2	728.00	583.00	483.00	288.00	2,298	19,071	16,772
Sarre Union	7:10	5	1,323.00	958.00	796.00	601.00	9,870	30,189	20,318
Gent	2:20	1	380.00	563.00	493.00	298.00	523	2,440	1,916
									114,297

7. Conclusions

Rotterdam is the main entry Port in Europe for orange juice, particularly shipped from Brazil, the major export country. Primarily, the orange juice is shipped in bulk, refrigerated and under protective atmosphere, by dedicated special tanker seagoing vessels from the port of Santos, Brazil to the Port of Rotterdam's Fruitport, The Netherlands, where the major orange juice processors terminals are located. The European hinterland transport is done by tanker trucks and under this context the Rotterdam's Port Authority and industry participants all agree that the sole use of road transport will be unfeasible in the near future, the extensive Rotterdam's intermodal network must be better explored by this industry segment and the use of reefer tank containers will create greater possibilities of intermodal exploitation.

The extensive national and international European waterways network with good navigation conditions enables to operate inland vessels from 90 up to 400 TEUs capacity and it was not observed any lack of capacity regarding the western European fleet of inland vessels. Due to continuous investments the western European inland navigation fleet is considered the largest and the most modern in the world. The fleet tonnage is in excess of 14 million tons and together with the reserve capacity of the western European waterways for the inland shipping there is no fleet or inland waterways constraints, there is capacity available for a fleet enlargement and increase of goods flow. The western European inland shipping sector operates regular scheduled services to all inland terminals able to handle reefer containers which create a network of scheduled liner services for reefer tank container transport.

European hinterland transport of NFC and FCOJ by inland waterways using barges is feasible. There is no quality restriction on using reefer tank container, no fleet and waterways capacity constraints and the inland container terminals have no restrictions to handle reefer tank containers. Inland waterway transport mode shows to be cost competitive mostly in routes to Germany and France along the river Rheine and in routes to Belgium along the waterways of the Dutch province of Zeeland. Some barge companies have regular and local delivery services along the river Rheine which turns the inland waterway transport mode very cost competitive if compared to the long haulage road mode. Using tank container makes it possible to use barges for the long leg of the transport and container trucks for the short leg or delivery to the juice packers as are the cases of companies located in Monchengladback, distant 30 km from the inland port of Dusseldorf, Hennef, distant 20 km from the inland port of Bonn, in Germany and the juice packer located in Sarre Union, France, distant 90 km from the inland port of Kehl (Strasbourg area). Orange juice transport by barges to juice packers located in these destinations will perceive a reduction on their orders reaction time through the use of floating stocks. The northern part of France near Paris presents severe inland navigation problems, inland vessels are restricted from 400 up to 750 tons which turns barge transport more expensive than tanker truck transport to juice packer companies located in this area. The European Union TEN-T 30 - Inland Waterway Seine-Scheldt - project aims to improve the link between the rivers Seine and Scheldt which connects the Paris region and the Seine basin with the entire Benelux inland waterways network, the objective is to enlarge the canal to receive barges up to 4,400 tons, the project will due in 2016.

Demand for NFC and FCOJ is correlated with respective welfare levels, for the incoming years it is expected a stable growth in Western Europe and higher growth in Eastern Europe. The economic expansion in East Europe as new member states join the European Union, will shift the centre of economic growth in the coming years towards the east and south with the expected economic growth of east and south Germany, and of the new EU countries as Poland, Estonia, Latvia, Czech Republic and Slovakia. This entails in the expansion of the Port of Rotterdam hinterland capabilities and a better utilization of the European Union waterways. As far as the south-eastern Europe is concerned, the European Union TEN-T 18 – Rhine/Meuse – Main – Danube Inland Waterway – project aims to upgrade the whole route of this major freight route which links the North Sea (Port of Rotterdam – The Netherlands) to the Black Sea (Port of Constanta - Romania) maintaining the minimum draft during the whole year at a minimum of 2.5 m to receive inland vessels of 3,000 tons. This project is due in 2019.

It is important to mention the “Fresh Corridor”, project chaired by Mr. Jo van Nunen, Professor in Logistics and Information Systems at the Erasmus University, Rotterdam, supported by Dutch fruit trading companies, which aims to develop an effective network of terminal and intermodal connections for the European transport of fresh products in reefer containers from Rotterdam. In terms of intermodal transport it primarily looks inland shipping, trains and short-sea shipping will be addressed in a later phase. Barges with reefer connections are aimed to transport reefer containers within the port and beyond. Deep-sea reefer containers at the Maasvlakte terminals are shuttled from there to consolidation points for fruits and vegetables further down the port, alleviating the congested A15 highway *(Fast Forward, Summer 2009, issue 45)*. By using tank containers, it will be promoted the containerization of orange juice transport; it then could be transferred from one transport mode to another without being re-handled and the benefits of intermodal transport can be accrued. It will be possible to create a cost effective European hinterland transport of orange juice using on a coordinated way different transport modals to different final destinations.

In order to minimize the handling costs of the tank containers of the orange juice processors located in the Fruitport, their products should be bundled with those of the participants in the Fresh Corridor project. As far as it will be possible to bundle as more cargo as possible, liner barges will come to the Fruitport and so increase even further the reliability and frequency of the barge services which will reduce costs and the amount of tank containers needed. As soon as the tank container is on the barge, the juice packers will gain cargo visibility, their cargo can be traced, therefore they can control the transport process again which means that the amount of quality information decision makers have at their disposal will increase.

Tank containers handling at the Fruitport can be solved deploying a mobile quay crane at a cost estimated of € 2,000,000 (land side handling equipment not considered) or through the Rotterdam's Port Authorities planned relocation of the Fruitport from the north bank of the port to the Waalhaven/Eenhaven area on the south bank which has a strong concentration of container-related activities.

This research shows that the bottlenecks of the European hinterland transport of orange juice by inland waterways using barges is the lack of regular barge services in the Mittellandkanal in northern Germany, the Paris region due to its restrict navigability conditions and the unavoidable capital expenditure regarding the acquisition of tank containers which for the case in point for the total volume transshipped by the orange juice processing companies located in the Fruitport accounts for € 11,000,000 with the option of a three years leasing contract of € 6,500,000.

The hinterland transport by barges also brings environmental benefits. Almost 1,000 trucks leave the fruit port daily to distribute fruit juices, fruits and vegetables throughout Europe if all of these trucks were substituted by barge transport almost 20 tones of CO_2 emission per ton-mile transported per year would be avoided and road congestion would be diminished. The European Union offers through its Marco Polo project financial incentives for initiatives related to the reduction of road congestion and these financial incentives could be applied to solve part of bottleneck. Also, the Kyoto Protocol allows carbon credits for the reduction of greenhouse gases emission which would bring financial benefits to be used to solve part of the bottleneck costs.

This thesis shows that the hinterland transport of orange juice by barges is just the start of a completely new market for inland shipping. The use of inland shipping can only be done if transport costs, including storage and transshipment, are at the very least on a par with those incurred using road transport. Transshipers will not make the switch to inland shipping if this means of transport is more expensive than road transport. As recommendation, a pilot project involving the transshipment of NFC from the Rotterdam's Fruitport to the juice packer in Sarre Union, France, destination which presented the best return on investment (NPV and IRR), should be performed in order to find out hidden issues and hidden costs not revealed in this case study, in order to have a feeling of the juice packers' acceptance of this new transport mode and as next step produce a detailed economic feasibility study about the subject.

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Appendices

Appendix 1: *Orange grove: City of Avare - state of Sao Paulo, Brazil*

Source: http://www.upload.wikimedia.org

Appendix 2: *Average vitamin C content of some fruits*

Fruit	Average vitamin C (mg/1000g fruit)
Peach	80
Apple	80
Blackberry	210
Kumquat	380
Grapefruit	390
Orange	530
Papaya	620
Kiwi fruit	630
Strawberry	660
Guava	1840
Blackcurrant	2100

Source: The Orange Book page 26

Appendix 3: *Nutrient composition of orange juice*

Water	Protein	Fat	Carbohydrate	Other
89.2%	0.5%	0.1%	8.8%	1.4%

Source: Food Transportation page 2

Appendix 4: *Quantity of concentrate needed to make 1 liter of juice*

Basis
Final juice: 11.2 °Brix **Concentrate**: 65 °Brix, corrected * Juice of 11.2 °Brix has a specific gravity of 1.045 kg/l Therefore: 1 l of juice at 20°C weights 1,045 g
Calculations:
1 l final juice = 1,045 X 11.2/100 = 117 g of soluble solids 1 kg concentrate = 1,000 X 65/100 = 650 g of soluble solids
Result:
To prepare 1 l of juice: Concentrate: 117/650 X 1000 = 180 g Water: 1,045 - 180 = 865 g * = value approximate because juice is not a pure sugar solution

Source: The Orange Book page 117

Appendix 5: *Tri-modal container barge inland terminal – Dortmund, Germany*

Source: CONTARGO GmbH & Co. KG

Appendix 6: *Inland Vessels Classes (CEMT- Conférence Européenne des Ministres de Transport)*

Class	Tonnage	Length (m)	Width (m)	Draft (m)
I	300	38.5	5.05	2.2
II	650	55.0	6.6	2.5
III	1000	80.0	8.2	2.5
IV	1500	85.0	9.5	2.5
V	2500	110.0	11.4	2.8
VI	6000	140.0	15.0	3.9

Source: ISSUU Digital Publishers (http://issuu.com)

Appendix 7: *IMO type T11 frame tank container specifications*

Type	:	IMO type – single compartment Insulated and steam heated tank container		
Dimmensions	:	**mm**	**ft**	**in**
Length		6,058	20	0
Width		2,438	8	0
Height		2,591	8	6
Capacity	:	24,000 Litres		6,340 US Gallons
Weights	:	**Kgs**		**Lbs**
Maximum Gross		31,000		68,342
Tare		3,620		7,984
Pressures	:	**Bar**		**Psi**
Working Pressure		4.0		58.0
Test Pressure		6.0		87.0
Steam Operating Pressure		4.0		58.0
Design Pressure @ 130 °C		6.0		87.0
Steam Test Pressure		6.0		87.0
Relief Valve		4.4		64.0
Shell Material	:	Stainless Steel, 316 A240		
Code	:	ASME VIII, division 1 where applicable		
Temperatures	:	**° C**		**° F**
Maximum Cargo Temperature		120		248
Approvals	:	Construction Certificate (Lloyd's/B.V./A.B.S.), UIC, CSC, TIR, IMO 1, ISO, UK & US (DOT), RID/ADR, TC, AAR600, FRA		
Standard Fittings				
Manlid		500mm (20") diameter, 8 closure (fore & aft) SWR (Sweet White Rubber)/PTFE (Teflon)		
Relief Valves		2 x 2.5" Safety Relief Valves with flame proof gauze		
Air Inlet Valve		1.5" Ball Valve and End Cap		
Top Discharge		3" s/s Port and Blank Flanges. Siphon Tube provision		
Spillboxes		Two off, with no covers. External Stainless steel drain Tubes		
Bottom Discharge		3" s/s Foot valve. 3" s/s Butterfly Valve. 3" s/s B.S.P. and Cap. Remote Trip		
Insulation		50mm (2") rigid polyisocyanurate foam over tank shell, compressed mineral wool over steam pan area, clad in Marine Grade White Aluminum		
Steam Heating		7 elements welded to external underside giving 8m coverage. ¾" B.S.P. with Plastic Caps		
Thermometer		Fitted. Analog in ° C and ° F		

Source: M & Shipping (PTY) Ltd. (http://www.msship.co.za/TankSpecs.htm)

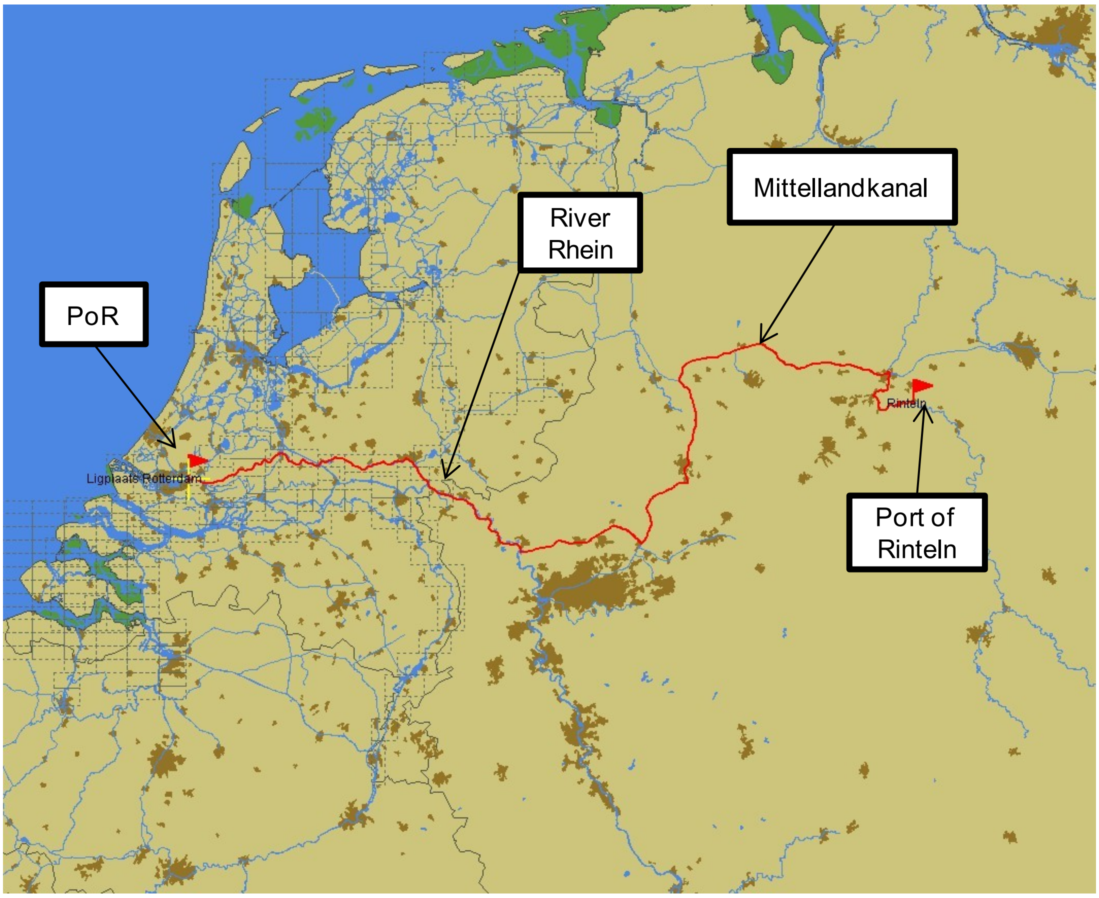
Appendix 8: *Pictures of a frame tank container*

Frame Tank Container

Frame tank container being road transported as a standard 20 foot container

Source: Holvrieka Nirota B.V. – Sneek, The Netherlands

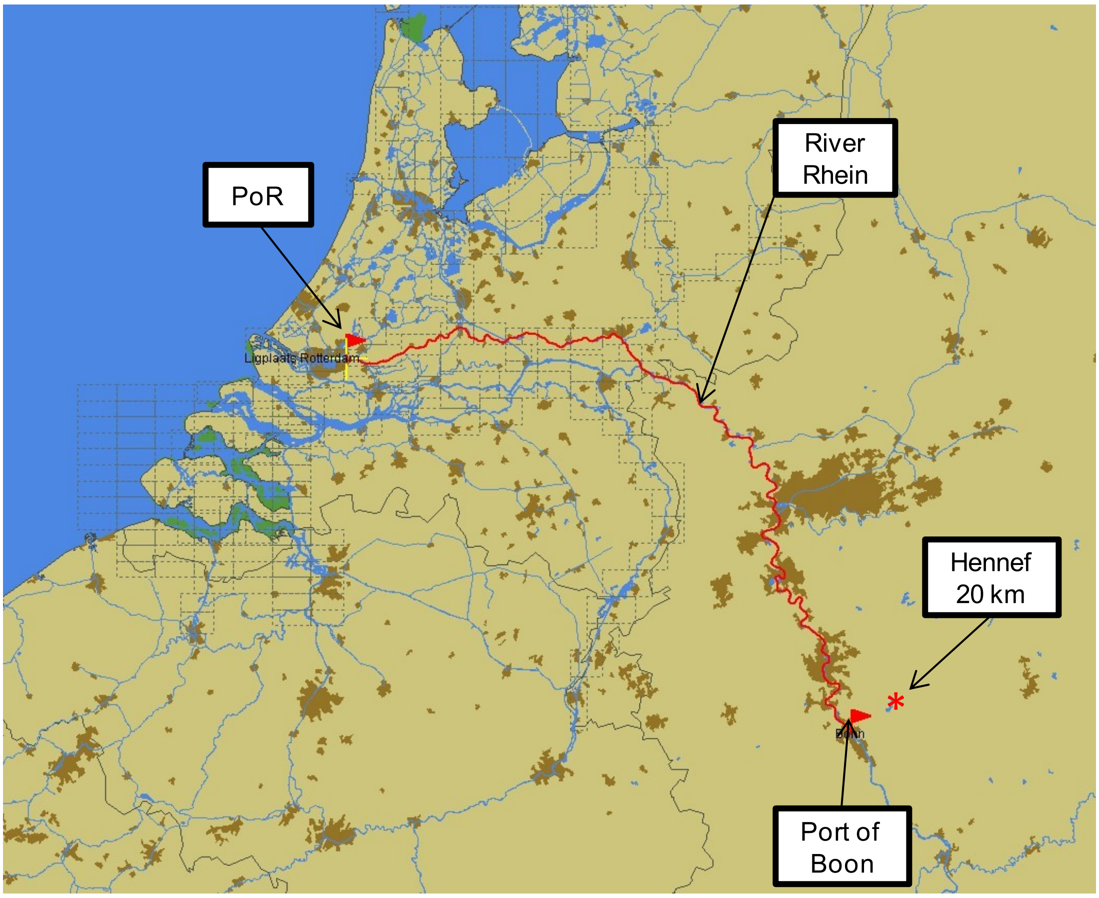
Appendix 9: *Inland waterway route Port of Rotterdam – Rinteln, Germany*



Vessel Class	**4**
Length (m)	**85**
Width (m)	**9.5**
Air draft (m)	**4.25**
Draft (m)	**2.5**
Tonnage	**1500**
Final Inland Port	**Port of Rinteln**
Distance (km)	**474.5**
Voyage time	**3 days and 12 hours**

Source: Marin - PC Navigo (software)

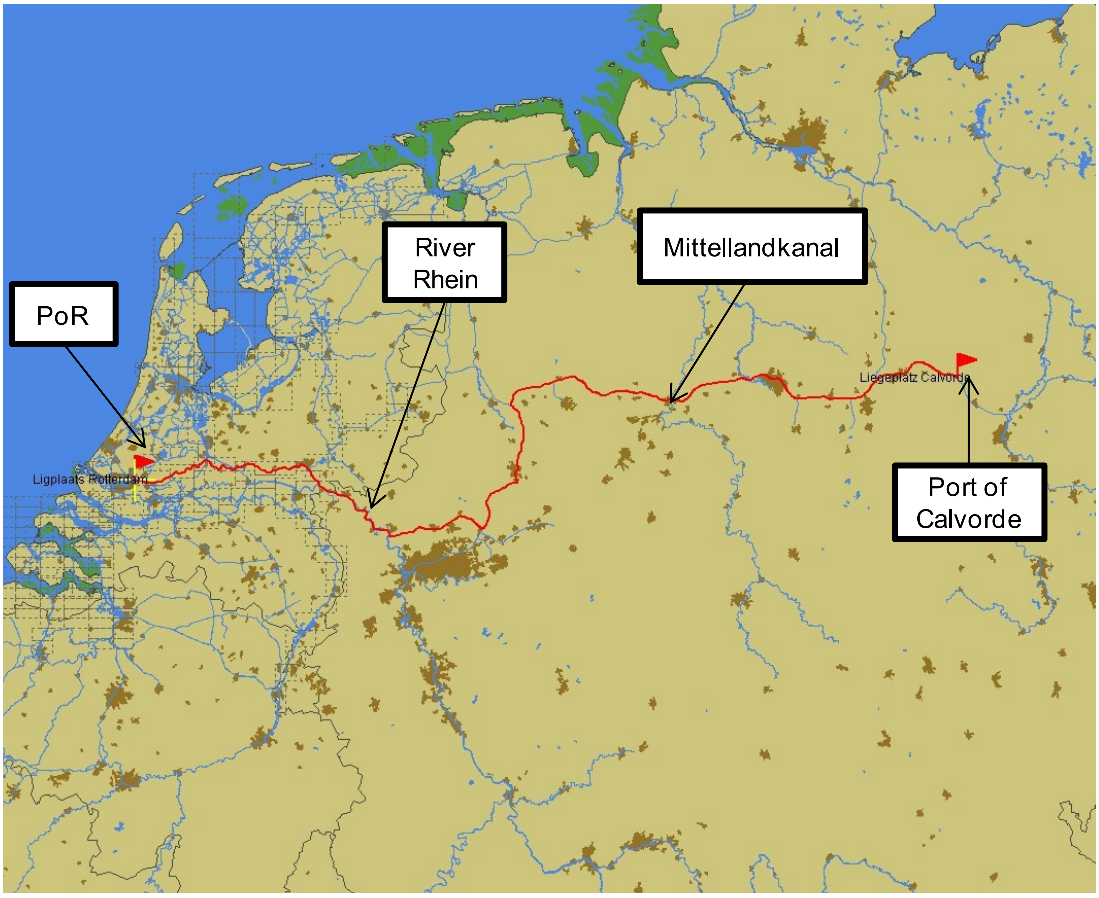
Appendix 10: *Inland waterway route Port of Rotterdam – Hennef, Germany*



Vessel Class	**6**
Length (m)	**110**
Width (m)	**17.7**
Air draft (m)	**13**
Draft (m)	**3.0**
Tonnage	**6000**
Final Inland Port	**Port of Bonn**
Distance (km)	**343**
Voyage time	**3 days and 4 hours**

Source: Marin - PC Navigo (software)

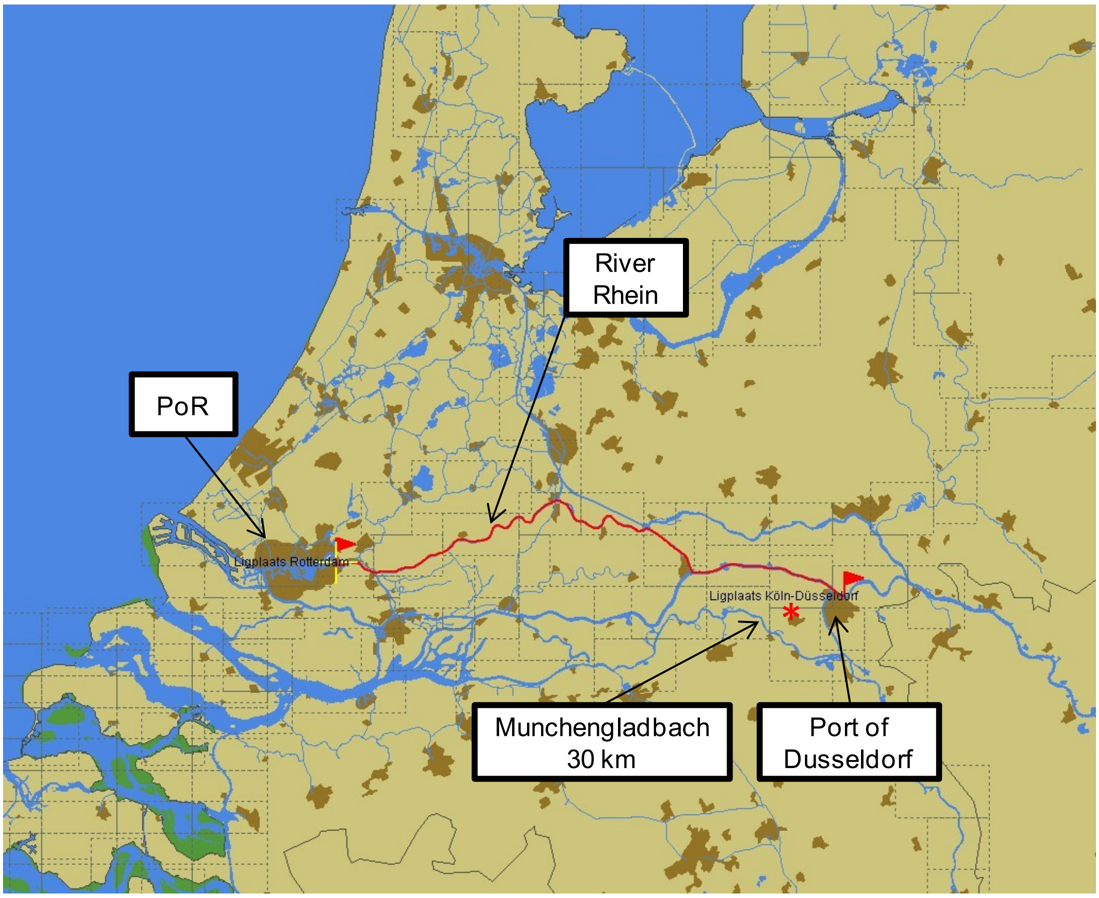
Appendix 11: *Inland waterway route Port of Rotterdam – Calvorde, Germany*



Vessel Class	**6**
Length (m)	**110**
Width (m)	**9.50**
Air draft (m)	**4.29**
Draft (m)	**2.5**
Tonnage	**6000**
Final Inland Port	**Port of Calvorde**
Distance (km)	**611**
Voyage time	**4 days and 9 hours**

Source: Marin - PC Navigo (software)

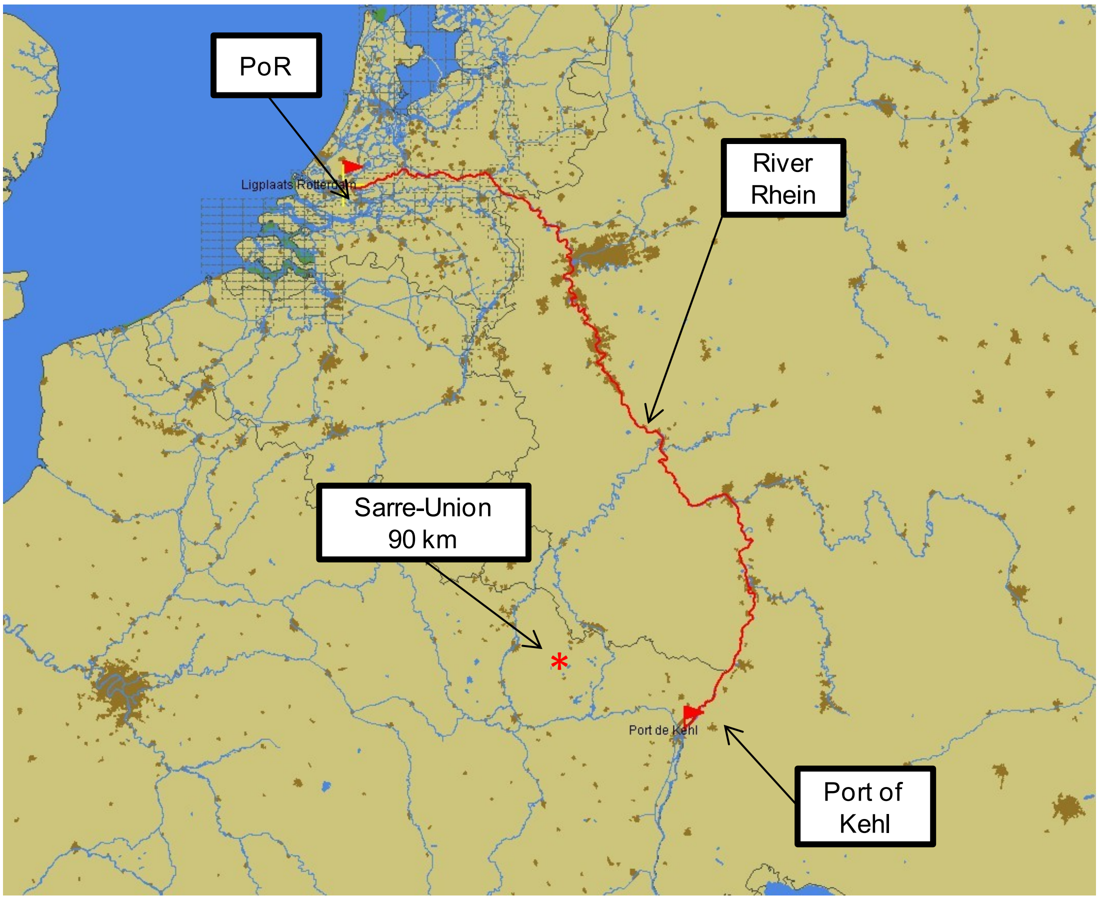
Appendix 12: *Inland waterway route Port of Rotterdam – Monchengladback, Germany*



Vessel Class	**6**
Length (m)	**110**
Width (m)	**17.7**
Air draft (m)	**13**
Draft (m)	**3.0**
Tonnage	**6000**
Final Inland Port	**Port of Dusseldorf**
Distance (km)	**109**
Voyage time	**14 hours**

Source: Marin - PC Navigo (software)

Appendix 13: *Inland waterway route Port of Rotterdam – Sarre Union, France*



Vessel Class	**6**
Length (m)	**135**
Width (m)	**22.9**
Air draft (m)	**11.4**
Draft (m)	**3.5**
Tonnage	**6000**
Final Inland Port	**Port of Kehl**
Distance (km)	**701.5**
Voyage time	**8 days and 16 hours**

Source: Marin - PC Navigo (software)

Appendix 14: *Inland waterway route Port of Rotterdam – Gent, Belgium*

Vessel Class	**6**
Length (m)	**140**
Width (m)	**16**
Air draft (m)	**4.4**
Draft (m)	**3.6**
Tonnage	**6000**
Final Inland Port	**Port of Gent**
Distance (km)	**148.5**
Voyage time	**1 day and 2 hours**

Source: Marin - PC Navigo (software)

Appendix 15: *Crane barge*

Crane barge – technical information	Mercurius Amsterdam (2006)
Loading Capacity	144 TEU
Tonnage	2,152 tonnes
Crane Capacity	± 20 moves/hour
Lift Capacity	35 tonnes at a reach of 30 metres
Automatic anti-heeling system	√
Dimensions	86 x 11.55 metres
Propulsion Power	2 x 860 hp

Source: MCT Lucassen