The possibilities for drop and swap logistics at Odfjell Terminals Rotterdam

By Lars van Rhede van der Kloot

"A research to the possibilities of realizing a drop and swap concept for the chemical transshipment of Odfjell parcel tankers at Odfjell Terminals Rotterdam."

ODFJELL

TU Delft

Delft University of Technology

The possibilities for drop and swap logistics at Odfjell Terminals Rotterdam

"A research to the possibilities of realizing a drop and swap concept for the chemical transshipment of Odfjell parcel tankers at Odfjell Terminals Rotterdam."

Master Thesis
Rhede van der Kloot, van L.E.H
Student number: 1152130
Transport, Infrastructure, and Logistics
Delft, June 2009

Graduation Commission
Professor: Prof.ir. J.C.Rijsenbrij (Transport Engineering & Logistics)
Supervisor: Dr.ir. D.L.Schott (Transport Engineering & Logistics)
Supervisor: Prof.dr.ir. A.Verbraeck (Systems Engineering)
External supervisor: Mrs. Vos (Manager Marketing & Sales Odfjell Terminals Rotterdam)

Preface

Last months I have been occupied with my master thesis, investigating the possibilities for drop and swap logistics at Odfjell Terminals Rotterdam. In this period, my knowledge of port processes has increased enormous. I have always seen ports as the most exciting and interesting logistical networks in the world. A lot of money is involved in transportation of chemicals with parcel tankers. Costs of having parcel tankers in port are very high. The environment of handling these parcel tankers is very complex and dynamic. It was a big challenge to investigate possibilities and consequences of implementing drop and swap alternatives for Odfjell parcel tankers at Odfjell Terminals Rotterdam.

I would like to thank my supervisors for their assistance. Dingena Schott for her advises during the research and her endless patience with the structuring of the report, Alexander Verbraeck for his advices during the research, and Professor Rijsenbrij for his time spent on checking the my deliverables for our meetings.

Furthermore, I would like to thank Laura Vos for her support and friendliness during, and after, my time at Odfjell Terminals Rotterdam. At last, but definitely not least, I would like to thank my family and friends for their patience and support.

Lars van Rhede van der Kloot
Delft, June 2009

Executive summary

Odfjell is a leading company in the global market for transportation and storage of chemicals and bulk liquids. Odfjell consists of two separated profit centers of which Odfjell Shipping (OS) is responsible for the transportation of chemicals with Odfjell parcel tankers, and Odfjell Terminals BV is responsible for the storage of chemicals. The terminal in the port of Rotterdam is called Odfjell Terminals Rotterdam (OTR). Odfjell parcel tankers also transship chemicals at terminals of other companies in the port of Rotterdam. OTR handles, besides Odfjell parcel tankers, also tankers of other companies.
In 2008, each tanker spent an average of 8 days in the port of Rotterdam to transship its chemicals at an average of 4 different terminals. Average costs for a single tanker in the port amounts to circa 1.250 euro per hour, depending on the size of the tanker. A unique way of cooperation between the different profit centers could exist in the realization of a drop and swap concept for Odfjell parcel tankers at OTR. Odfjell wants to explore the possibilities of implementing such a concept.
With a drop and swap concept, Odfjell parcel tankers can discharge and load all chemicals at OTR and leave the port without visiting other terminals. Barges, which are much cheaper, will be used for transportation of the chemicals from OTR to other terminals and vice versa. However, extra transshipment costs and loss in revenues, due to the use of deep-sea berth capacity and storage capacity, are realized too. Using the database (port tracker 2008) of Odfjell and a model, build in Microsoft Excel, a case study, analyzing the implementation of several drop and swap alternatives, has been executed. Odfjell wants to explore possible drop and swap alternatives and analyze if, and in which way, extra profit can be realized for Odfjell with these alternatives.

To compare the different alternatives with the current situation, logistical and financial criteria are formulated. With the financial criteria extra profit for Odfjell due to the implementation of a drop and swap alternative is determined.

Logistical criteria are:

- The deep-sea berth occupancy at OTR.
- The barge berth occupancy at OTR.
- The average waiting time for tankers to moor at OTR.

Financial criteria are:

- The reduction in costs for Odfjell.
- The extra transportation costs for Odfjell.
- The extra transshipment costs for Odfjell.
- The loss in revenues for Odfjell due to the use of extra deep-sea berth capacity at OTR.
- The loss in revenues for Odfjell due to the use of extra storage capacity at OTR.

Deep-sea berth and barge berth occupancy at OTR must be lower than 85% and 75% respectively, and extra profit for Odfjell must be realized. If one of these boundaries is not fulfilled, the drop and swap alternative is not implemented. In determining the financial criteria, an associated profit center for OS and OTR is assumed.

A possible concept is to drop and swap all chemicals transported by specific Odfjell parcel tankers that visit the port of Rotterdam. In total, four different alternatives are analyzed:

1. Drop and swap all chemicals transported by Odfjell parcel tankers of a specific trade lane.
2. Drop and swap all chemicals transported by Odfjell parcel tankers with a specific chemical quantity to transship in the port of Rotterdam.

3. Drop and swap all chemicals transported by Odfjell parcel tankers with a specific number of chemical parties to transship in the port of Rotterdam.
4. Drop and swap all chemicals transported by Odfjell parcel tankers with a specific number of calls to make in the port of Rotterdam.

For each alternative, sub-alternatives are formulated concerning the specific trade lanes, chemical quantities, number of chemical parties, and number of calls. Each sub-alternative is analyzed towards the logistical and financial criteria for Odfjell.

Loss in revenues depends on the occupation of the deep-sea berths and storage, needed with the extra transshipment of the dropped and swapped chemicals at OTR. During this occupation, used deep-sea berth and storage capacity do not generate revenues for Odfjell. To determine the total loss in revenues for Odfjell per sub-alternative, three future scenarios, dependent on the demand for deep-sea berth and storage capacity at OTR, are formulated:

A. Demand for deep-sea berth and storage capacity decreases in the near future. With a reduction in demand for deep-sea berth and storage capacity no loss in revenues is realized with the implementation of a drop and swap alternative. Deep-sea berth and storage capacity are not fully used, which results in free capacity for chemicals that are dropped and swapped.
B. Demand for deep-sea berth and storage capacity is equal to the current demand. Loss in storage revenues is realized with the implementation of a drop and swap alternative due to temporary storage of dropped and swapped chemicals. No loss in deep-sea berth revenues is realized because deep-sea berth occupancy is not fully used in this scenario.
C. Demand for deep-sea berth and storage capacity increases in the near future. Loss in deep-sea berth and storage revenues is realized for Odfjell with the implementation of a drop and swap alternative. Because of increasing demand, Odfjell has to refuse customers to use deep-sea berth and storage capacity.

Storage capacity, for dropped and swapped chemicals, can be organized in two ways:

- Use dedicated storage capacity for dropped and swapped chemicals. This storage capacity is used only for dropped and swapped chemicals.
- Use non-dedicated storage capacity for dropped and swapped chemicals. Storage capacity for dropped and swapped chemicals is created last-minute. If no chemicals are dropped and swapped, storage capacity is used for other chemicals and no loss in revenues is realized.

From the case study, it can be concluded that due to the construction of an extra deep-sea berth at OTR, boundaries concerning the deep-sea berth and barge berth occupancy are fulfilled in each alternative. Also waiting time to moor at OTR in the alternatives is shorter than in the current situation.
When the demand for deep-sea berth and storage capacity decreases (scenario A), a drop and swap alternative, which realizes extra profit for Odfjell can be implemented. In this scenario, the alternative that realizes the highest extra profit for Odfjell is, to implement a drop and swap concept for all chemicals transported by Odfjell parcel tanker that need to transship more than 40.000 cbm of chemicals in the port of Rotterdam. Extra profit for Odfjell is circa 2.4 million euro per year, or circa 106 thousand euro per tanker in this scenario.
When demand remains as in the current situation or increases (Scenario B and C), implementing a drop and swap alternative does not realize extra profit for Odfjell.
Recommended is to investigate possibilities to avoid the loss in revenues due to the use of storage capacity. Interesting could be to store chemicals, which need to be stored at OTR for a longer period (months or even years), at a different, for example more land inward, storage

location. This storage location must be less valuable than storage capacity at OTR. Extra profit by implementing drop and swap alternatives have to be compared to extra costs for storing these chemicals on a different, less valuable, location.

Table of contents

List of Figures

List of Tables

List of notions

Notion	Meaning
Agent	Person who is responsible for the organization of the transport in the port of Rotterdam. The agent makes the planning (rotation plan) for the tankers.
Barge	Inland tanker that can be used for the transportation of chemicals between terminals inside the port of Rotterdam.
Board-board transshipment	Transshipment in which the chemical is transshipped directly from one ship into another.
Bunkering	Stocking of fuel, water, food, etc into the tanker at a terminal.
Ceteris paribus	'Considering everything else stays the same'.
Chemical party	One batch of a chemical quantity.
Coaster	A small sea ship, used for regional transport.
Loading master	Employee of terminal, responsible for transshipment from a ship to the shore and vice versa.
Manifold	Central point in a parcel tanker where all lines come together and connections to other storage locations are made.
Operator	Person that connects and disconnects hoses for transshipment at a berth.
Parallel transshipment	Transshipment of more than 1 chemical party at the same time.
Parcel tanker	A large tanker with several chemical parties on board.
Port tracker 2008	Database of Odfjell Shipping with information of all Odfjell parcel tankers that visited the port of Rotterdam.
Rotation plan	Route that parcel tankers make in a port (designed by an agent) to transship chemicals.
Rower	Person who is responsible for safe and correct mooring and unmooring of tankers.
Standard deviation	The standard deviation is a measure of the differences between an average and the individual values included in the average. A low standard deviation indicates that individual values do not differ much from the average, while high standard deviation indicates that individual values differ much from the average.
Surveyor	Person who is hired by the customer to check whether the chemical is transshipped correctly concerning the quality and quantity of the chemical.
Tank pit	Area at a terminal, which consists of a number of tanks in the same category.
Tug boat	Little ship that navigates a parcel tanker in the port.

1 Introduction

The position of Odfjell in the transportation and storage of chemicals is described in paragraph 1.1 followed by the problem definition of the research in paragraph 1.2. Research questions, the research method, and the report outline are given in paragraph 1.3, 1.4, and 1.5 respectively.

1.1 Odfjell in the port of Rotterdam

Every year, more than one hundred million tones of oil and oil products are transshipped in the port of Rotterdam. The port of Rotterdam offers excellent facilities for the transshipment of raw chemical materials and European distribution of these raw materials, semi- manufactured, and end products. Rotterdam has a large concentration of suppliers, buyers and service providers. As a result of these favorable business-locating conditions, the port has one of the biggest chemical complexes in the world. Odfjell is one of these providers.

Odfjell is a leading company in the global market for transportation and storage of chemicals and other bulk liquids. Odfjell Shipping is in charge of the transportation and Odfjell Terminals BV is in charge of the storage of chemicals. Originally set up in 1916, the company pioneered the development of the parcel tanker (chemical tanker) trades in the middle of the 1950's and the tank storage business in the late 1960's. Odfjell Shipping owns and operates circa 100 parcel tankers in global and regional trade as well as a network of tank terminals. Each parcel tanker is capable of transporting 1 to 50 chemical parties[1] at once. Their strategy is to continue developing their position as a leading logistics service pioneer with customers worldwide. The aim is to maintain this position through efficient and safe operation of deep-sea and regional parcel tankers and tank terminals.
Odfjell Terminals BV forms part of the Odfjell Group. As per January 2008, Odfjell Terminals relocated its head office to Rotterdam in order to strengthen the focus on their expanding tank terminal network. Odfjell's existing tank terminals are located in Rotterdam, Houston, Singapore, Onsan (Korea), Dalian, and Ningbo (China).

In total, the Odfjell Terminals network employs more than 1.000 people and currently offers more than 3.0 million cbm of storage space in about 980 tanks in 16 ports around the world. The combination of a global shipping network and tank terminals at strategic locations makes Odfjell a world leader in combined shipping and storage services. The strategy of Odfjell Terminals is to grow along Odfjell's major shipping lanes and at important petrochemical logistics junctions around the world. Odfjell Rotterdam is considered as a strategic location along Odfjell Shipping's main trade lanes. Odfjell Terminals Rotterdam is projected to serve as an international hub between the international trades of Odfjell.

1.2 Problem definition

At this moment, Odfjell Terminals Rotterdam (OTR) and Odfjell Shipping the Netherlands (OS) try to optimize the use of their international hub connection by building mutual contracts[2] with clients. Mutual contracts are needed because currently OTR and OS operate as two separate profit centers with associating objectives. These different objectives create a synergy challenge between both parties in the port of Rotterdam. One of the synergy-challenges lies within the policy of OTR. The terminal currently operates as a public terminal, allowing vessels at berth on a 'first-come, first-serve' basis. For OS this implies that despite their connection with the terminal, they still have to wait for free berths just like other parcel tankers. For OTR this means

[1] One batch of a chemical type

[2] Contract of a customer with OTR and OS together.

that OS also transships chemicals at terminals of other companies. A unique way of cooperation between both parties could exist with the realization of a drop and swap concept. Nowadays, Odfjell parcel tankers spend 8 days on average to transship (load and discharge) their chemicals in the port of Rotterdam, while calling[3] at an average of 4 different terminals. Sometimes an Odfjell parcel tanker spends 1 day to transship all chemicals, and in extreme cases, it needs 20 days to transship all chemicals in the port of Rotterdam (Odfjell, 2008b).
Total average costs of a parcel tanker in port add up to circa 1.250 euro per hour (30.000 euro per day), depending on the size of the tanker. In 2008, 147 Odfjell parcel tankers called at a total of 556 different berths in the port of Rotterdam. Of these calls, 75 were done at OTR. Each Odfjell parcel tanker needed to transship an average of 13 different chemical parties per visit.

OTR wants to explore the possibility of offering a drop and swap for the load and discharge of chemicals transported by Odfjell parcel tankers. Benefits are expected in avoiding the rotations that Odfjell parcel tankers have to make in the port. However, costs for collection and distribution of the dropped and swapped chemicals between terminals in the port of Rotterdam are realized.
With a drop and swap concept, it is possible for an Odfjell parcel tanker to visit OTR and transship all chemicals it needs to transship in the port of Rotterdam at OTR. Figure 1 shows a possible rotation of an Odfjell parcel tanker in the current situation (left) and a basic drop and swap rotation (right).

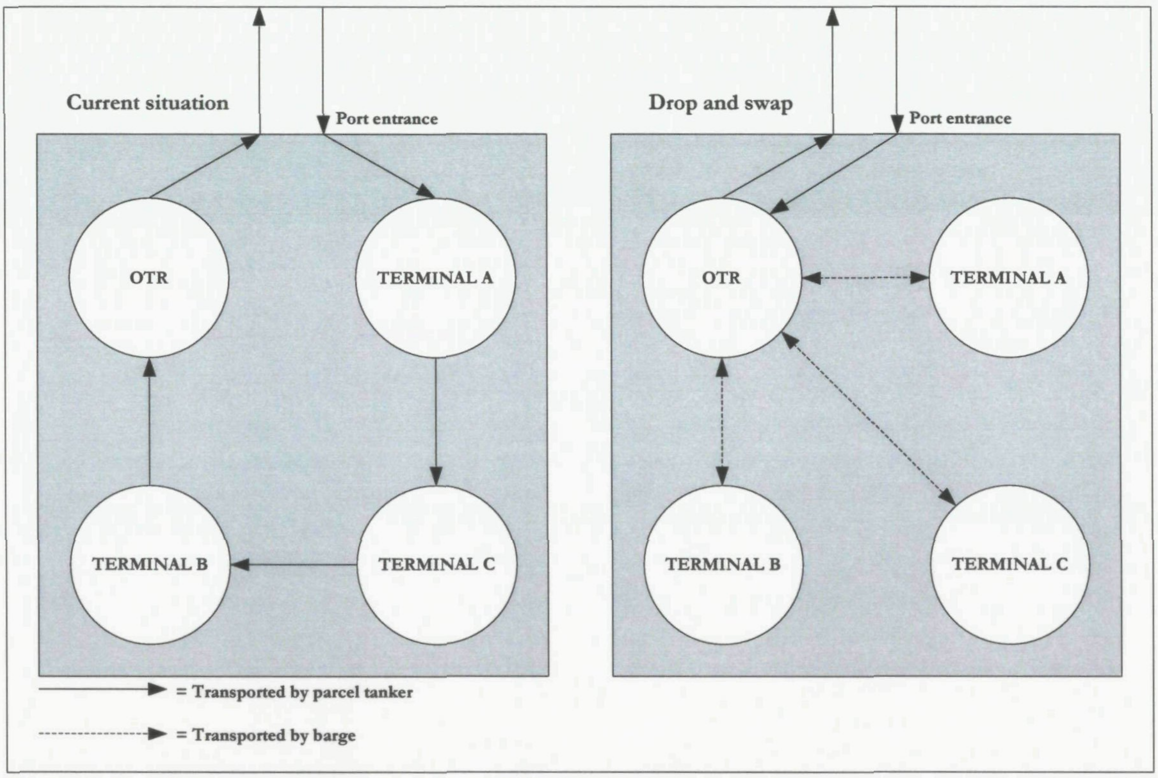


Figure 1: Possible current situation and possible drop and swap concept

The figure shows the current situation (left), in which the tanker enters the port of Rotterdam and needs to transship chemicals at four different terminals in the port of Rotterdam. Every call causes extra delays due to occupied berths and navigation times for example. In this research, different drop and swap alternatives, of which an example is graphically presented in figure 1 (right), are analyzed. The figure shows an Odfjell parcel tanker entering the port, discharging and

[3] Visiting a berth to transship chemicals.

loading all chemicals at OTR, and leaving the port again. Advanced collection of the chemicals that need to be loaded, from other terminals to OTR is necessary. Chemicals, discharged at OTR but destined for other terminals, need to be distributed. Barges are used for collection and distribution of these chemicals.
A drop and swap concept looks profitable because of the avoidance of having an Odfjell parcel tanker in the port for 8 days. However, other costs increase because of the drop and swap concept. Implementing a drop and swap concept will not only have financial, but also logistical consequences for Odfjell. Also customer's perspective (the owners of the chemicals) has to be taken into account. All together, it is not sure if, or in which way, a logistical and financial attractive drop and swap concept, in comparison with the current situation, can be implemented for Odfjell. Within this research, only tankers of Odfjell that visit Rotterdam are taken into account. The research includes transportation of chemicals to terminals in the port of Rotterdam. Further transportation (e.g. to the hinterland) is not taken into account. Also different types of chemicals are not taken into account. In the research, one and the same chemical type is used.

1.3 Research Questions

With the implementation of a drop and swap concept for the loading and discharging of Odfjell parcel tankers, a unique competitive position could be created for Odfjell. The port time of Odfjell parcel tankers can be reduced, resulting in a more efficient and profitable usage of these tankers. To realize this competitive position, the advantages of implementing a drop and swap concept at OTR must be bigger that the disadvantages. Drop and swap alternatives are evaluated on the logistical and financial consequences for OTR and OS together (an associated profit center is assumed). This means that for example, when the alternative is not profitable for OS, it can still be profitable for the whole Odfjell Company. Therefore, the main research question of the research is:

"What are possible drop and swap alternatives for loading and discharging chemicals of Odfjell parcel tankers at Odfjell Terminals Rotterdam, and which alternative is the most attractive one?"

To answer the main research question, 5 sub-questions are formulated. With the first sub-question, current transportation and storage of chemicals by Odfjell is analyzed (chapter 2):

SQ1: How does Odfjell currently organize the transportation and storage of chemicals?

Using the results of the current organization and a literature study (chapter 3.1), the second sub-question, concerning the consequences for Odfjell due to the implementation of a drop and swap concept, is answered (chapter 3):

SQ2: What are consequences for Odfjell when a drop and swap concept is implemented at OTR for the Odfjell parcel tankers?

When consequences of implementing a drop and swap are known, criteria, to score different drop and swap alternatives for Odfjell, can be formulated. This results in the third sub-question (chapter 4):

SQ3: On which criteria can different drop and swap alternatives be scored?

There are several possibilities to implement a drop and swap concept at OTR. The answer to the fourth sub-question gives an overview of alternatives, analyzed in this research (chapter 5):

SQ4: What are potential drop and swap alternatives for Odfjell?

These alternatives are analyzed and scored on the formulated criteria. Finally, the most attractive alternative for Odfjell needs to be chosen (chapter 6 and 7):

SQ5: Which drop and swap alternative is the most attractive one for Odfjell?

After answering these 5 sub-questions, conclusions towards the main research question are formulated together with recommendation for future research (chapter 8).

1.4 Research method

Goal of the research is to formulate and analyze different alternatives for implementing a drop and swap concept for the transshipment of chemicals, transported by Odfjell parcel tankers, in the port of Rotterdam. To investigate these alternatives, a case study of all Odfjell parcel tankers that visited the port of Rotterdam in 2008 is done. The methodology used in this research is shown in figure 2.

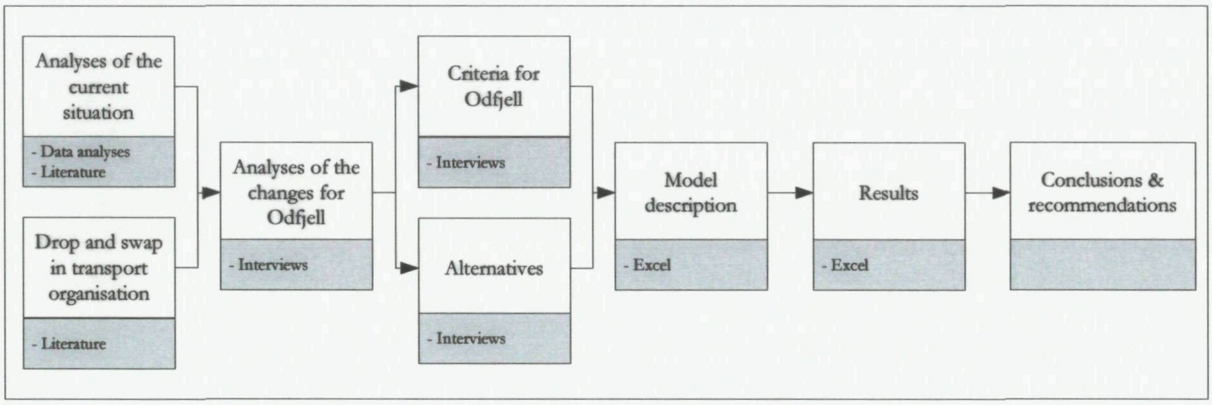


Figure 2: Methodology (Verbraeck, Heijnen and Blockstael-Blok, 2005)

First, current transportation and storage of chemicals by Odfjell is analyzed. The port tracker 2008 (database of OS including all processes done by Odfjell parcel tankers in the port of Rotterdam in 2008), and a literature study of OTR are used to describe the current situation. Together with this description of the current situation, a literature study concerning existing drop and swap concepts in other transport organization is done. With results of the current situation, literature study, and several interviews, consequences for Odfjell with the implementation of a drop and swap concept are described. When consequences for Odfjell are known, criteria and system boundaries to score and compare different drop and swap alternatives are formulated together with different alternatives that are analyzed in the research.
Using the performances of OS and OTR in 2008, a Microsoft Excel model, to investigate changes due to implementing a drop and swap alternative, is described. Using this model, results of formulated alternatives are scored and compared on the criteria. Finally, conclusions and recommendation on the research are given.

1.5 Report outline

Steps to come to the Microsoft Excel model are taken in chapter 2 to 5. Chapter 2 describes the current transportation and storage of chemicals by Odfjell. Using results of this chapter, and literature study of drop and swap concepts in other transport organizations (chapter 3.1), consequences for Odfjell with the implementation of a drop and swap concept are given in chapter 3. Chapter 4 formulates criteria to score and compare different drop and swap alternatives for Odfjell. Different drop and swap alternatives are determined in chapter 5. The Microsoft Excel model is described in chapter 6, followed by results of the different drop and swap alternatives in chapter 7. Conclusions and recommendations for Odfjell are given in chapter 8.

2 Transportation and storage of chemicals by Odfjell

To investigate the possibilities of implementing a drop and swap concept at Odfjell, current transportation and storage of chemicals by Odfjell needs to be analyzed. Odfjell Shipping (2.1) is responsible for the transportation of chemicals, and Odfjell Terminals BV is responsible for the storage of chemicals. The terminal in the port of Rotterdam is called Odfjell Terminals Rotterdam (2.2). At the end of the chapter, a summary and conclusions concerning current transportation and storage of chemicals by Odfjell is given (2.3).

2.1 Transportation by Odfjell Shipping

Odfjell Shipping the Netherlands (OS) is responsible for handling of Odfjell parcel tankers in the port of Rotterdam, Amsterdam, Terneuzen and Antwerp. This research only takes the tankers that visit Rotterdam into account. Using literature of Odfjell, a description of OS is given (2.1.1). To get an overview of the processes of the Odfjell parcel tankers, the database of OS (port tracker 2008) is analyzed (2.1.2). This analysis shows some possible quick wins for OS (2.1.3).

2.1.1 Odfjell Shipping

The Odfjell fleet consists of close to 100 tankers, trading in a global network. Headquarter for the commercial and operational management is in Bergen, Norway. The fleet consists of a variety of tanker types, both in terms of size, sophistication, number of tanks, tank configuration, and other criteria of importance. Three kind of ships are used for the transportation of chemicals; parcel tankers, coasters and barges. Table 1 gives a description of the three different ships.

Table 1: Characteristics of ships that transport chemicals (Odfjell, 2008a)

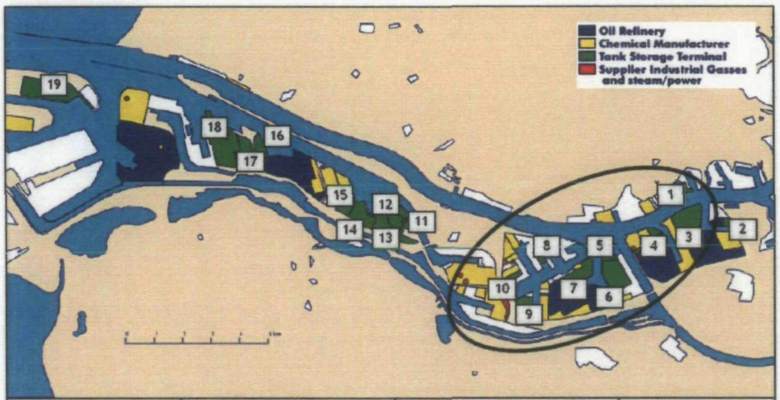
Ship type	Number of tanks	DWT (ton)	Length (m)	Width (m)
Parcel tanker	Up to 52	Up to 50.000	200	32
Coaster	Up to 20	Up to 10.000	120	19
Barge	Up to 12	Up to 3.000	110	11

Parcel tankers are mainly used for transportation across the oceans. Coasters and barges are used for transportation over smaller distances. Barges are used for transportation from one terminal to another in the port of Rotterdam. To transport chemicals in the port of Rotterdam, OS rents barges of another company because OS does not have its own barges in Europe. Shipping agents of OS are responsible for an efficient transportation inside the port of Rotterdam.

Shipping agent

Odfjell parcel tankers usually visit more than one terminal in the port of Rotterdam. Most important task of a shipping agent of OS is to design a rotation plan for each Odfjell parcel tanker that visits the port of Rotterdam. Goal of a rotation plan is to design a route for the tanker in which the port time is as short as possible, with a minimum number of berths to visit, and at minimal costs. This rotation plan is designed before the tanker enters the port of Rotterdam but is changed most of the times while the tanker is in the port (for example due to delays). With the design of the rotation plan, the agents also take possible board-board transshipments into account. When for example a small chemical quantity (< 3.000 cbm) needs to be transported to terminal B, agents will try to transship these chemicals board-board at terminal A, where bigger transshipment of chemicals needs to take place. Chemicals are being transshipped from the tanker to a barge and transported further by barge to the destined terminals (Odfjell, 2008a). With the board-board transshipment at terminal A, the parcel tanker does not need to visit terminal B anymore, which reduces the port time and minimize the costs for the tanker. An example of a rotation plan, together with the explanation how it is designed, is shown in Appendix A.

Visited terminals in the port of Rotterdam
OS transports chemicals to several terminals in the port of Rotterdam. An overview of the most visited terminals by Odfjell parcel tanker in 2008 is given in figure 3.



1. Vopak Terminal Vlaardingen	6. Odfjell Terminal	11. Vopak Terminal Europoort	16. TEAM Terminal
2. Mobil Oil	7. Vopak Terminal Botlek	12. Maatschap Europoort Terminal	17. TEAM Terminal
3. Nerefco Pernis Terminal	8. Vopak Terminal TTR	13. Vopak Terminal Europak	18. Shell Europoort Terminal
4. Koole Tank Storage	9. Vopak Terminal Chemiehaven	14. Maatschap Europoort Terminal	19. Maasvlakte Olie Terminal
5. LBC	10. Vopak Terminal Laurenshaven	15. Lyondell Europoort Terminal	

Figure 3: Most visited terminals by Odfjell parcel tankers in the port of Rotterdam

As can be seen in the figure, most visited terminals by OS are Vopak Terminal Vlaardingen, Nerefco Pernis Terminal, Koole Tank Storage, LBC, Odfjell Terminal, Vopak Terminal Botlek, Vopak Terminal TTR, Vopak Terminal Chemiehaven and Vopak Terminal Laurenshaven (Odfjell 2008a).

Tankers handled by OS in 2008
In 2008, a total of 184 Odfjell parcel tankers were handled by OS, of which 147 visited the port of Rotterdam. These 147 tankers spent a total of 1.156 days in the port of Rotterdam to discharge and load chemicals at different terminals. An overview of the port times per tanker is shown in figure 4.

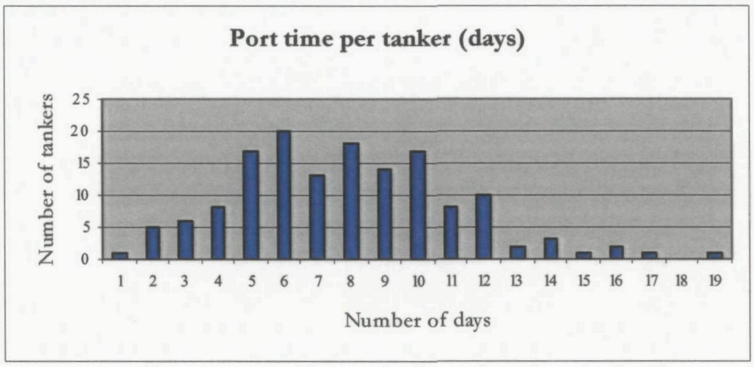


Figure 4: Port time of Odfjell parcel tankers in 2008 (Odfjell, 2008b)

The figure shows that most tankers needed 2 to 12 days to tranship chemicals in the port of Rotterdam; one tanker even needed 19 days to transship (mainly due to waiting for an occupied berth). Average port time of the tankers was 7,86 days with a standard deviation of 3,33 days

(42%)[4]. The standard deviation is a measure of the variability in the different port times of the parcel tankers. A low standard deviation indicates that port time per tanker tends to be very close to the average, while a high standard deviation indicates that port time per tanker are spread out over a large range.
Port time of tankers depend on many factors. Port time of the tankers are higher when it needs to transship a bigger quantity of chemicals, a higher number of chemical parties, or needs to visit more different terminals[5]. Exact predictions of the port time per tanker are difficult because of the many different other influences on the port time.

Each Odfjell parcel tanker needs to transship (discharge and load) a certain quantity of chemicals in the port of Rotterdam. An overview of the chemical quantity transshipped per tanker in 2008 is shown in figure 5.

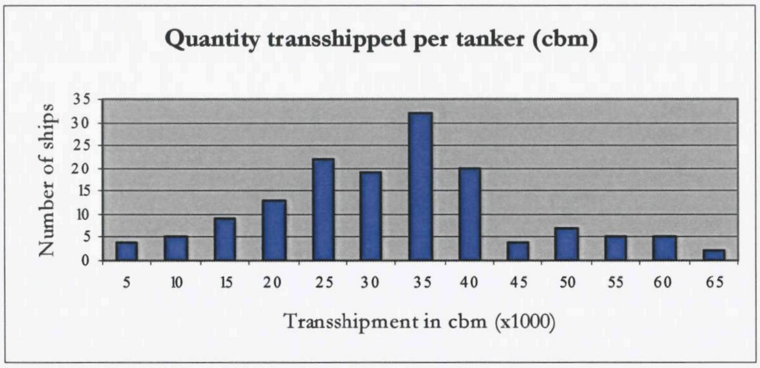


Figure 5: Quantity per Odfjell parcel tanker in 2008 (Odfjell, 2008b)

The figure shows that most tankers needed to transship between 10.000 and 60.000 cbm of chemicals in the port of Rotterdam. This can be discharging chemicals, loading chemicals or both. On average, the tankers transshipped 29.693 cbm of chemicals per visit with a standard deviation of 12.927 cbm (44%) per tanker[6].

The chemical quantity, transshipped by each tanker, consists of one or more chemical parties. Each tanker discharges and/or loads a number of chemical parties in the port of Rotterdam. An overview of the number of chemical parties transshipped per tanker in 2008 is shown in figure 6.

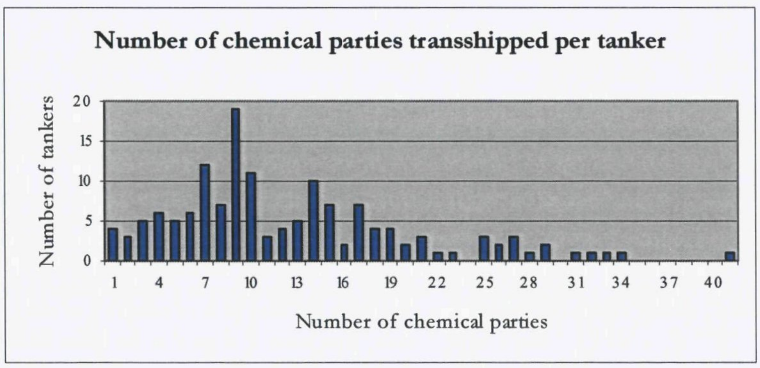


Figure 6: Chemical parties per Odfjell parcel tanker in 2008 (Odfjell, 2008b)

4 Appendix B1
5 Appendix B1
6 Appendix B2

The figure shows most tankers needed to transship between 1 and 30 chemical parties. This can be discharging, loading, or both. On average, the tankers transshipped 12,48 chemical parties with a standard deviation of 7,77 chemical parties (62%) per tanker[7].

Odfjell parcel tankers transship chemicals at different terminals in the port of Rotterdam. An overview of the number of terminals (number of calls) that were visited per tanker in 2008 is shown in figure 7.

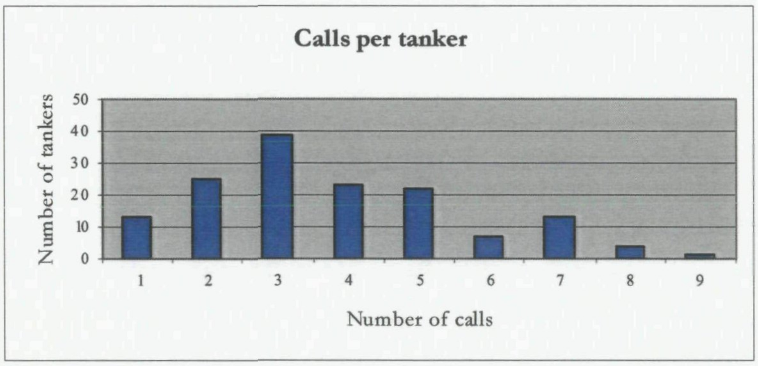


Figure 7: Number of calls per Odfjell parcel tanker in 2008 (Odfjell, 2008b)

The figure shows that most tankers needed to make 1 to 7 calls, while 9 calls was the maximum number of calls that a tanker made. On average, the tankers made 3,78 calls with a standard deviation of 1,86 calls (49%)[8] per tanker.

Trade lanes

Flexibility and inter-changeability of tankers between routes and trades have always been an important factor for Odfjell. Some of Odfjell's tankers are involved in an 'around the world' trade, servicing ports in Europe, the US, Asia, Pacific and Africa. Odfjell's major trade lanes are from the US and Europe to Asia, India, the Middle East and South America. In addition, there is a considerable bilateral trade between the US and Europe (Odfjell, 2008b). In general, Odfjell parcel tankers are involved in eight different trade lanes, which are formulated in table 2

Table 2: Trade lanes of Odfjell parcel tankers in 2008

Trade lane	Number of parcel tankers in 2008
Africa - Rotterdam	3
Europe - Rotterdam	52
Far East - Rotterdam (via Africa)	8
Far East - Rotterdam (via the Suez Canal)	12
Mid East - Rotterdam (via Africa)	2
Mid East - Rotterdam (via the Suez Canal)	5
South America - Rotterdam	44
North America - Rotterdam	21

The table shows most common trade lanes for Odfjell, to the port of Rotterdam, are from Europe, South America and North America.

2.1.2 Port time of Odfjell parcel tankers

The port time of the Odfjell parcel tankers can be split up into four different actions: shifting of the tanker, port delays, operational delays, and transshipping. Port delays are delays while the

[7] Appendix B3
[8] Appendix B4

tanker is shifting, and operational delays are delays while the tanker is at a berth. Table 3 shows the contribution per action to the total port time of the tankers that visited the port of Rotterdam in 2008.

Table 3: Overview of actions in port time (Odfjell, 2008b)

Action	Average percentage of total port time	Standard deviation	Contribution in port time for an average tanker (8 days)
Shifting	9,9%	1,6%	18 hours
Port delay	10,4%	14,6%	21 hours
Operational delay	20,4%	23,2%	37 hours
Transshipping	59,3%	15,3%	113 hours

Total average port time per tanker was almost 8 days (189 hours). Most of the port time (circa 60%) was caused by the transshipment of chemicals. On average, tankers spent circa 80% of the port time at a berth due to operational delays or transshipping. The other 20% of the port time was spent on shifting and port delays. Port delays and operational delays together, were responsible for 30% of the port time per tanker.
The standard deviations show that the contribution to the total port time of shifting and transshipping, per individual parcel tanker, do not differ much from the average contribution of these actions to the total port time. Standard deviations of the port delay and operational delay show that average contributions to the total port time differ much from individual parcel tankers. As an example, an overview of all actions performed by one of the Odfjell parcel tanker that visited the port of Rotterdam (Bow Fortune) is shown in appendix C.

Shifting

Shifting of an Odfjell parcel tanker in the port of Rotterdam consists of three different actions. These actions are sailing, mooring and unmooring. Sailing takes place from and to the port entrance and between terminals, and is done with the help of tugs[9]. To moor a tanker, a master pilot conference is carried out and rowers do the actual maneuvering to get alongside the berth. When the tanker is alongside, the tugs are being unfastened, the shore's gangway is rigged and the tanker is called 'all fast'. Unmooring is again done with the help of tugs and rowers. Figure 8 shows the contribution to the port time per action.

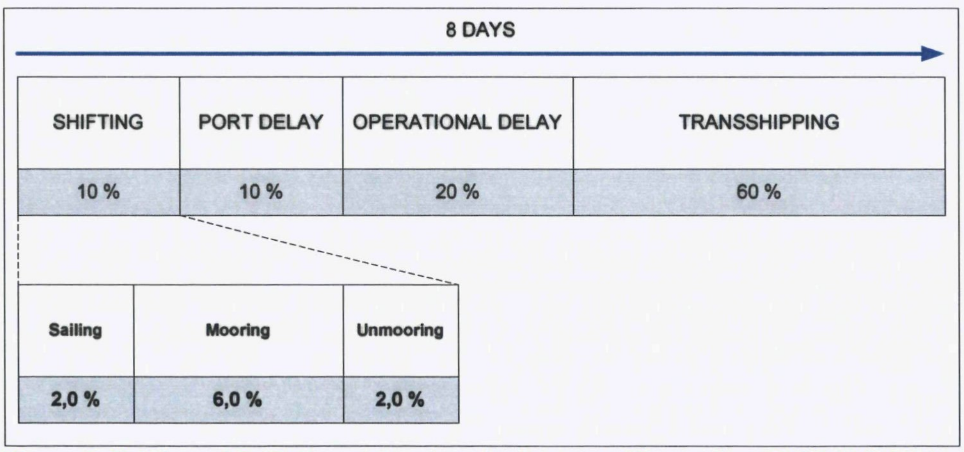


Figure 8: Shifting of Odfjell parcel tankers in the port of Rotterdam (Odfjell, 2008b)

Shifting during the port time takes place a couple of times. Each call that a tanker has to make, results in an extra shift. Total average shifting time of an Odfjell parcel tanker was circa 18 hours.

[9] Little ships that navigate parcel tankers in the port

Within the shifting, mooring of the tanker takes most of the time. On average, the mooring took 6% (circa 11 hours) of the total port time per tanker.

Port delay

Port delays are actions that take unforeseen time, while the tanker is shifting. Delays due to tie restrictions, occupied berths or reparation of the tanker are examples of port delays. An overview of different port delays with their contribution to the port time is shown in figure 9.

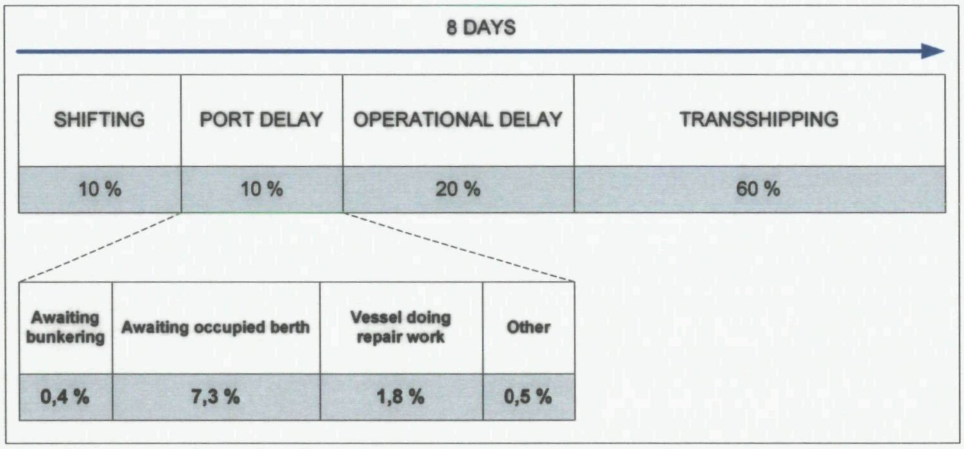


Figure 9: Port delays of Odfjell parcel tankers in the port of Rotterdam (Odfjell, 2008b)

Port delays can occur during every shift a tanker makes. Total average port delay of an Odfjell parcel tanker was 20 hour. Most frequent port delay was the delay due to occupied berths. In total, waiting for an occupied berth took 7,3% of the total port time per tanker. Port delays do not occur with every call a tanker makes. In total, 84 of the 147 (57%) tankers that visited the port of Rotterdam in 2008 had port delays. Port delays up to 80 hours were not uncommon (5 tankers had a total port delay of circa 80 hours).

In total, 50 of the 147 tankers were delayed due to the waiting for an occupied berth. This caused a total of 2.759 port delay hours, which is 73% of the total port delay hours. A more detailed analysis concerning the port delay is shown in appendix D1.

Operational delay

Operational delays are actions that take unforeseen time while the tanker is at a berth to transship chemicals. Delays due to waiting for shore readiness to transship, waiting for barges or coaster to transship, and waiting for surveyors are examples of operational delays. An overview of the different operational delays with their adding to the port time is shown in figure 10.

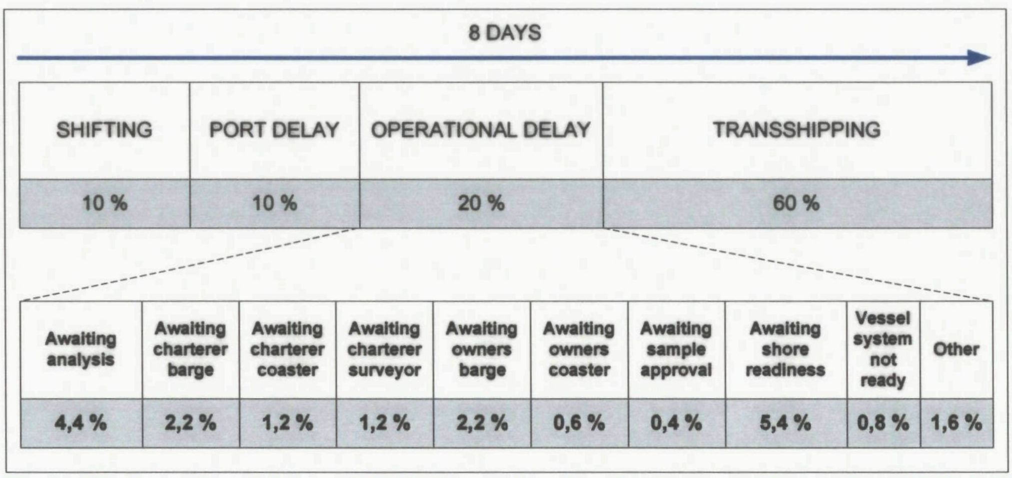


Figure 10: Operational delays of Odfjell parcel tankers in the port of Rotterdam (Odfjell, 2008b)

Total average operational delay of an Odfjell parcel tanker was 37 hours. The most common operational delays were waiting for the surveyor's analysis[10] and waiting for shore readiness to transship. These operational delays took respectively 4,4% and 5,4% of the total port time.
All 147 tankers that visited the port of Rotterdam in 2008 had operational delays. Operational delays up to 90 hours were not uncommon (5 tankers had a total port delay of circa 90 hours). In total, 185 calls of the 556 calls (33%) were operational delayed due to the waiting for shore readiness, which caused a total of 1.430 operational delay hours (27% of total operational delay hours). 180 calls of the 556 calls (32%) were operational delayed due to the waiting for the surveyor's analysis, which caused 1.203 operational delay hours (22% of total operational delay hours). A more detailed analysis concerning the operational delay is shown in appendix D2.

Transshipping

Transshipping contributes most time (circa 60%) to the total port time of the Odfjell parcel tankers. The transshipment time depends on the average transshipment rates (chemical quantity transshipped per hour) of the terminal where Odfjell parcel tankers transshipped, and the total chemical quantity that needs to be transshipped at that terminal. The average transshipment rate for Odfjell parcel tankers in the port of Rotterdam was 255 cbm per hour, while OTR reached a transshipment rate of around 350 cbm per hour (Odfjell, 2008b). The average transshipment rate depends on several factors[11].
Total transshipment throughput of OS in the port of Rotterdam in 2008 was 4.364.880 cbm of chemicals. Transshipping can be the discharge or load of chemicals. Most part (74%) of the transshipment was discharging of chemicals. A total of 140 tankers (95% of all tankers) needed to discharge at least one chemical party, while 79 tankers (54% of all tankers) needed to load at least one chemical party (Odfjell, 2008b).
The terminals that are visited the most, also causes the longest delays. OTR has relatively small operational delays but waiting times due to occupied berth are high in comparison with other terminals that were visited by Odfjell parcel tankers. A more detailed analysis concerning the transshipping is shown in appendix D3.

Financial consequences of the port time

OS strives to minimize port time of the Odfjell parcel tankers because of the high financial consequences of having a tanker in a port. Main goal of a tanker is to transport chemicals over the oceans (long distances). Odfjell has determined the total costs per hour of port time for the Odfjell parcel tankers, depending on the size of the tankers. Table 4 shows these total costs.

Table 4: Cost per hour of port time for Odfjell parcel tankers (Odfjell, 2008b)

Size of the Odfjell parcel tanker	Costs per port time hour
15.000 cbm	€ 750
20.000 cbm	€ 1.000
25.000 cbm	€ 1.300
30.000 cbm	€ 1.550
35.000 cbm	€ 1.825
40.000 cbm	€ 2.000
50.000 cbm	€ 2.700

Table 4 shows that keeping an Odfjell parcel tanker in the port is very expensive. Depending upon the size, costs of keeping the tanker in the port vary between 750 and 2.700 euro per hour. When an Odfjell parcel tanker stays in the port for one day, costs are between 18.000 and 65.000 euro per tanker. Goal of the drop and swap concept is to reduce the total port time of an Odfjell

[10] Surveyors check chemical quality and quantity after transshipments (Appendix E)
[11] Appendix F

parcel tanker. Another financial consequence is caused by reduction in the number of calls (shifts) per tanker. Depending on the tanker and the weather conditions, 1 or 2 tugs and 2 to 4 rowers are needed for the shifting of the Odfjell parcel tanker in the port of Rotterdam. According to Odfjell, costs per shift are approximately 5.000 euro (Odfjell, 2008b).

2.1.3 Quick wins in port time

After analyzing the Odfjell parcel tankers that visited the port of Rotterdam in 2008, some possible 'quick wins' for OS towards a reduction in port time can be formulated. With an average contribution of 30% to the total port time, a reduction in the delays can realize big wins in the port time for OS. Especially some quick wins in operational delays can be realized.

Most of the operational delays are caused due to waiting (waiting for surveyor's analysis, waiting for barge, etc.). Waiting times can be reduced significantly with more communication between involved actors. For example, waiting time for surveyor's analysis can be reduced most of the time by earlier communication between the loading master and surveyor. Surveyor's analysis can be done during the shifting of the tanker or during port delays (while the tanker is waiting due to an occupied berth). At the moment, frequently, the surveyor is called when a tanker is moored already. This will cause an operational delay because transshipment has to wait for the surveyor's analysis. Also other operational delays (e.g. waiting for a barge or coaster) can be reduced with improvement of the communication.

An important step to increase this communication would be a better co-operation between OTR and OS. The best solution to increase this communication would be merging the profits centers of OS and OTR to one overall profit center for Odfjell in the port of Rotterdam.

2.2 Storage by Odfjell Terminals Rotterdam

Odfjell Terminals Rotterdam (OTR) is responsible for storage of chemicals in the port of Rotterdam. Using literature of Odfjell, a description of OTR is given (2.2.1). To get an overview of the processes performed by OTR, transshipment at the berths and storage at the terminal are described (2.2.2 and 2.2.3), which show some possible quick wins for OTR (2.2.4).

2.2.1 Odfjell Terminals Rotterdam

Odfjell Terminals BV forms part of the Odfjell Group, which is a market leader in the chemical parcel tanker shipping business. Per January 2008, Odfjell Terminals relocated its Head Office to Rotterdam in order to strengthen the focus on their expanding tank terminal network.
Odfjell Terminals Rotterdam (OTR) is one of the largest single tank storage terminals in Europe and located in the heart of the port of Rotterdam. This geographical location of the installation is ideal when meeting diverse transportation demands like the North Sea, main European inland waterways, highways and rail networks. The site is also linked to local, regional and international pipeline networks. This pipeline network is not used for chemical transport though (Odfjell, 2008c). A map of OTR is shown in figure 11.

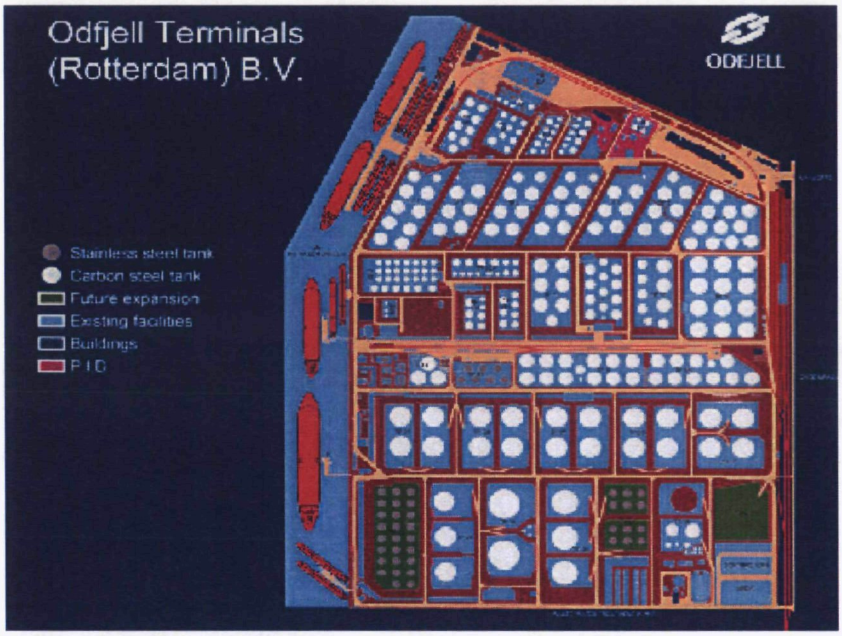


Figure 11: Map of Odfjell Terminals Rotterdam (Odfjell, 2008c)

Products

Chemical products can be subdivided among many different factors. At OTR the main line of separation is bulk chemicals (MTBE, Benzene, Toluene, and Ethanol) and commodity chemicals. All chemical products are stored upon request by the client. There is only one exception; edible oils are not stored at the terminal.

Tanks and jetties

The tank farm of OTR consists of 300 tanks, ranging in size from 735 to 40.000 cbm. The total capacity of the terminal encompasses more than 1.6 million cbm. Tanks are either stainless steel, mild steel or coated. A large percentage of the tanks are heated and insulated. All tanks have dedicated lines to a pump station. From there, the tanks feature customer dedicated, product dedicated or multipurpose shorelines. To store chemicals at OTR, 3 different tank categories are

used[12]. OTR also provides independent toll distillation services to the petrochemical industry at its Rotterdam site. Odfjell Petrochemical Industrial Distillation (PID) offers these services.
Toll distillation can provide a solution to the petrochemical industry when dealing with seasonal or peak demands. It can also be a cost effective way to quickly introduce a new product into the market without investing in additional production capacity. Odfjell PID currently operates 4 different multi-purpose distillation units with an annual throughput capacity of above 700.000 tons (Odfjell, 2008d).
The terminal has 4 deep-sea tankers, with a maximum depth of 39.6 ft (12 meters) alongside. A 5th berth for sea-going tankers is under construction and expected to be operational in the summer of 2009. Furthermore, there are 15 berths for barge activities and 19 platforms for the handling of road tank trucks, ISO-tank containers and rail tank cars.

2.2.2 Transshipment of the chemicals

At OTR, the loading masters, the operators and the planners take care of the transshipment of chemicals from parcel tankers to storage tanks and vice versa. The loading master contacts the surveyor when the tanker has arrived (sometimes before it arrives) and signs a checklist together with the captain of the tanker. The operators connect and disconnect hoses for loading and/or discharging of chemicals. Planners of OTR make sure that the right berths, pipelines, pumps, and tanks are used for the transshipment and storage of chemicals. Transshipment of chemicals can be done with more than one chemical party at the time, depending on the rotation plan, the sort of chemical and the availability of pumps and lines. When more than one chemical party is transshipped at the same time it is called parallel transshipment. Parallel transshipment can take place with the loading, the discharging, or the loading and discharging of chemicals.

Preparing for transshipment

On average, a tank is cleaned once per year. Some tanks are cleaned less, and other more frequent. This is dependent upon the contract and number of product switches of a client. Preparation of a tank varies strongly in downtime. For example, cleaning and inspecting a tank that was used for the storage of toxic chemicals and hard to clean can take eight days. Other chemicals cause a downtime of three days due to the cleaning of a tank. Dedicated lines (dedicated to a specific type of chemical) do not need to be cleaned. When cleaning of a line is required, it can take one to two days to clean, depending upon the size of the relevant line. Every parcel tanker needs to be reported to the port authorities when it is cleaned at a berth. Tankers have their own internal cleaning units in their ship tanks. Cleaning these tanks takes about four to ten hours. Many tankers clean their tanks at sea and deport their slobs via barges when they are at a berth (Odfjell, 2008c). With respect to the preparation or cleaning of tanks, there are many regulations. Polluted water and slobs have to be taken care of according to several standards. Chemical wastes can be categorized in three subcategories, each with a special treatment[13].
OTR strives for zero-emission of (toxic) vapors at the terminal. When loading a tank, pressure and vapors are released directly into the atmosphere. OTR controls and limits these emissions by means of precautionary measures like inner floats, vapor lines connected to a vapor assimilation system. Tanks that are filled with zero-emissions products (very low vapor and pressure and no emissions) do not need these extra precautions. At the moment, there are five vapor assimilation systems at the terminal. Concerning the water purification installation, OTR has its own 'Waste Water Treatment Plant'. At this plant, polluted and rainwater is collected. This water is treated here until it is cleaned sufficiently to return into the Maas. Before waste and rainwater are treated, they are stored in large tanks (Odfjell, 2008d).

12 Appendix G
13 Appendix H

Berths of OTR

Odfjell parcel tankers moor at a berth of OTR to transship chemicals. Transshipments go from tanker to shore, form shore to tanker, from tanker to barge, or form barge to tanker (board-board transshipment). At OTR, only a maximum number of 2 board-board transshipments at the same time are possible per deep-sea berth due to limited connections. Besides Odfjell parcel tankers, OTR also handles other tankers, which transship chemicals and minerals.

At the moment, OTR has 4 deep-sea berths and 15 barge berths. A 5th deep-sea berth is under construction and will be finished in the summer of 2009. Deep-sea berth occupancy was 80% in 2008. Maximum deep-sea berth occupancy at OTR is 85%, because 15% needs to be reserved for mooring, unmooring and emergencies (Odfjell, 2008d). Total barge berth occupancy was circa 35% in 2008. Maximum barge berth occupation is considered to be 75%, because the other 25% is needed for mooring, unmooring, emergencies, and extra flexibility (Odfjell, 2008d).

With the construction of the 5th berth, deep-sea berth and barge berth occupancies would be 65% and 30% respectively ceteris paribus[14]. An overview of berth occupancies per berth in 2008 is shown in appendix I. Total occupation time of the deep-sea berths by Odfjell parcel tankers in 2008 was circa 3.000 hours. Occupation time of other tankers was circa 25.500 hours. In total, the four deep-sea berths were occupied for circa 28.500 hours. Average waiting time to moor at a free deep-sea berth was 11.5 hours at OTR (Odfjell, 2008b), which is relatively long in comparison with the waiting times at other terminals.

Throughput at OTR

The total chemical throughput at OTR in 2008 was 4.488.201 cbm, of which OS transported 743.946 cbm (17% of the total throughput of OS). In total, 256 tankers visited OTR, of which 75 calls were from OS. Average throughput per Odfjell parcel tanker at OTR was almost 10 thousand cbm of chemicals. An overview of the different throughputs by OS at OTR is shown in table 5.

Table 5: Throughput of OS at OTR

Transshipment		Quantity (cbm)	Percentage	Number of parties	Percentage
Load	Board-board	35.138	5%	26	11%
	Shore-board	97.438	13%	28	12%
Discharge	Board-board	69.886	10%	33	14%
	Board-shore	541.484	72%	147	63%
Total		743.946	100%	234	100%

OTR is mainly used to discharge chemical parties. More than 80% of the total throughput was discharge of chemicals. 15% of total throughput took place with board-board transshipment.

2.2.3 Storage of the chemicals

Total storage capacity of OTR consists of 300 tanks, with a tank-capacity ranging from 735 to 40.000 cbm. At the moment total storage capacity for chemicals is circa 670.000 cbm of which during the whole 2008, more than 97% was occupied (Odfjell, 2008c).

To transport the chemicals from the tankers to the tanks, chemical lines are needed. OTR has over 700 sections of lines to transport chemicals. The majority (circa 80%) of chemical lines are dedicated to a specific type of chemical, which makes the terminal less flexible. This is caused for example due to the complexity to clean. Dedicated lines are easier to clean because the same chemical is being transported over the lines, while non-dedicated lines transport different chemicals, which makes cleaning more difficult and more important.

[14] If everything else stays the same

Planners of OTR have two important activities concerning the processes at OTR; (1) to arrange that parcel tankers will leave the berth as fast as possible and (2) to arrange the activities around the first activity like connecting lines, approvals of tanks, closing of tanks, etc.
Before arrival, the order (which chemical parties are discharged and/or loaded) needs to be determined. This order needs some puzzling because of the limitations like allocation of the cargo, which line to use to transport the cargo, heating of chemical parties, etc. Important is the planning of cleaning tanks and lines in case of a product change in the tank. Since cleaning can take three or four days (or sometimes even 8 days) it requires careful planning.

2.2.4 Quick wins in transshipment

After analyzing the processes at OTR, some possible 'quick wins' for the processes at OTR can be realized. By increasing the average transshipment rate at OTR, reduction in port time for Odfjell parcel tankers can be realized. Although the average transshipment at OTR is relatively high in comparison with other terminals, it can be increased. The transshipment distance is a factor that influences the average transshipment rate. The longer this transshipment distance, the lower the transshipment rate (Odfjell, 2008e). The distances of transshipments at OTR are not managed in the most efficient way. Investigations towards minimizing distances between tankers and tanks at OTR can decrease the transshipment time at OTR significantly (Odfjell 2008e).
By more efficient use of the storage capacity at OTR, more profit can be realized. Storage occupancy at OTR was at its maximum in 2008 (97%). Some chemical products are stored for months or even years (Odfjell, 2008d). There is a high demand for storage capacity at OTR, which makes it a valuable place to store chemicals. Interesting could be to store chemicals, which need to be stored for a longer time, at a different storage location more land inwards. This storage location more land inwards is less valuable than the storage capacity at OTR. This would create more storage capacity at OTR.

2.3 Summary and conclusion

The route that an Odfjell parcel tanker navigates in the port of Rotterdam depends on the rotation plan designed by an agent of OS. Goal of the rotation plan is to design a route for the tanker with a port time as short as possible, with a minimum number of berths to visit, and at minimal costs. Board-board transshipment of chemicals is an important way for agents to minimize these factors. Current transportation of the Odfjell parcel tankers is analyzed using the database (port tracker 2008) of OS. Results are shown in table 6.

Table 6: Results of Odfjell Shipping

Description		Result	Standard deviation
Throughput	Number of tankers visiting the port of Rotterdam	147	X
	Number of different terminals visited	26	X
	Total throughput in the port of Rotterdam (cbm)	4.364.880	X
	Average transshipment quantity per tanker (cbm)	29.693	12.927
	Average number of chemical parties per tanker	12,48	7,77
	Average number of calls per tanker	3,78	1,86
	Average transshipment rate at the terminals (cbm/hour)	255	X
Port time	Average port time per tanker (days)	7,86	3,33
	- Shifting (part of port time)	9,9%	1,6%
	- Port delay (part of port time)	10,4%	14,6%
	- Operational delay (part of port time)	20,4%	23,2%
	- Transshipping (part of port time)	59,3%	15,3%

Standard deviations of the results, concerning the characteristics of the 147 Odfjell parcel tankers that visit the port of Rotterdam, are high. Especially concerning the contribution of the port delay and operational delay to the total port time. High standard deviations indicate unreliable predictions. Reliability has to be taken into account in the further research and with the interpretation of future results, when these values are used.

Differences for Odfjell parcel tankers in trade lane, chemical quantity to transship, number of chemical parties to transship, and number of calls to make, can be used as different drop and swap alternatives.

Current storage and berth processes of OTR are analyzed using the result of 2008. These results are described in table 7.

Table 7: Results of Odfjell Terminals Rotterdam

Description		Result
Berth occupancy	Deep-sea berth occupancy with 4 berths	80%
	Deep-sea berth occupancy with 5 berth	65%
	Barge berth occupancy with 15 barge berths	35%
	Barge berth occupancy with 17 barge berths	30%
Throughput	Total throughput at OTR (cbm)	4.488.201
	Average transshipment rate at OTR (cbm/hour)	350
	Number of Odfjell parcel tankers visiting OTR	75
	Total throughput of OS at OTR (cbm)	743.946
	Average throughput per Odfjell parcel tanker at OTR (cbm)	9.919
Waiting time	Average waiting time at OTR with 4 berths (hours)	11,5
	Average waiting time at OTR with 5 berths (hours)	5
Storage occupancy	Chemical storage capacity at OTR (cbm)	670.000
	Storage occupancy at OTR	> 97%

A 5th deep-sea berth at OTR is under construction and planned to be in operation soon (summer of 2009). With this extra deep-sea berth, total deep-sea berth occupancy and barge berth occupancy will decrease to respectively 65% and 30% ceteris paribus.

Analyzing the current transportation and storage of Odfjell, some quick wins are formulated. Increasing communication between involved actors can reduce the port time for Odfjell parcel tankers. This reduction in port time can especially be realized with a reduction in the operational delays. Another quick win in port time can be realized by increasing the average transshipment rate at OTR, by minimizing the transshipment distances.
A quick win towards efficient use of storage capacity at OTR is to store chemicals, which need to be stored for a long time at OTR, at another (less valuable) location.

With the description of the current situation and a literature study of drop and swap concepts in other transport organizations (chapter 3.1), changes for Odfjell due to an implementation of a drop and swap concept can be given.

3 Consequences of a drop and swap concept

Implementing a drop and swap concept for Odfjell parcel tankers has influences on the current processes at Odfjell. To get an overview of which decisions have to be taken and what will change in the processes for Odfjell, a literature study of drop and swap concepts in other transport organizations (3.1) is done. This literature study, together with the description of the current situation, is used to analyze changes for OS (3.2) and OTR (3.3). A summary and conclusions are given at the end of the chapter (3.4).

3.1 Implementing a drop and swap concept in transport organizations

Drop and swap concepts are implemented in different transport organizations already. With a drop and swap concept, products (freight, people, chemicals, etc.) are dropped and picked up at a drop and swap location. At this location, products are collected and distributed from and to their destinations. The warehousing in the distribution of freight from supplier to customers (3.1.1) and the hub and spoke network of air transport (3.1.2) are two examples of such drop and swap concepts. These examples show some important decisions that have to be made, and chances that will arise with implementing a drop and swap concept (3.1.3). Finally, a summary and conclusion on this literature study is given (3.1.4).

3.1.1 Warehousing in the distribution of freight

The warehouse is a point in the logistics system where a firm stores or holds raw materials, semi finished goods, or finished goods for varying periods of time. Holding goods in a warehouse stops or interrupts the flow of goods, adding cost to the products. Some firms have viewed warehousing cost very negatively; in short, they sought to avoid it if at all possible. This view is changed due to the realization that warehousing can add more value than cost to a product. Other firms, particularly distributors or wholesalers, went to the opposite extreme and warehoused as many as possible. Neither end of the spectrum is usually correct. Firms should hold or store items only if possible trade-offs exist in other areas. The warehouses serve several value-adding roles in a logistics system (Coyle, Bardi & John Langley Jr., 2003).
Main area for this research is the consolidation of the financial trade-off. Warehousing can make important contributions to logistic systems and company operations. Most important often is that warehousing contribution to revenue must be greater than its cost. Warehousing favors timely distribution of freight and better synchronization with demand. It is particularly linked with the retail sector (often within large retailers), but can also be applied to manufacturing and distribution (Bontekoning and Priemus, 2004)

.

Consolidation

Companies will sometimes face less-than-truckload (LTL) shipments of raw materials and finished products. Shipping products for long distances at LTL rates is more costly than shipping at full truckload or carload rates. By moving LTL amounts relatively short distances to or from a warehouse, warehousing can allow a firm to consolidate smaller shipments into a large shipment with significant transportation savings. For the inbound logistics system, the warehouse would consolidate different suppliers' LTL shipments and ship a volume shipment (full truckload) to the firm's plant. For the outbound logistics system, the warehouse would receive a consolidated volume shipment from various plant and ships LTL shipments to different markets (Coyle, Bardi & John Langley Jr., 2003). An interesting form of warehousing is cross docking.

Cross docking
Cross docking is a form of warehousing in which warehousing of the products do not take longer than 24 hours. Its particular advantages arise at the minimization of warehousing and economies of scale in outbound flows (from distribution center to customers). With cross docking, the costly inventory function of a distribution center becomes minimal, while still maintaining the value-added functions of consolidation and shipping. Inbound flows (from suppliers) are thus directly transferred to outbound flows (to customers) with little, if any, warehousing.
Shipments typically spend less than 24 hours in the distribution center, sometimes less than an hour. In a conventional distribution system, goods are stored in a distribution center (or kept in inventory at the supplier) and wait until ordered by a customer. Under such a setting, it is difficult to have shipments that are not less than a truckload. With cross docking, goods are already assigned to a customer. The distribution center receives goods from suppliers and sorts them directly to be shipped to a consolidated batch (often including other orders from the suppliers) to the customers. Since there are fewer shipments for each supplier, most of them are full truckloads (Rodrigue, 2008). Cross docking of products is shown in figure 12.

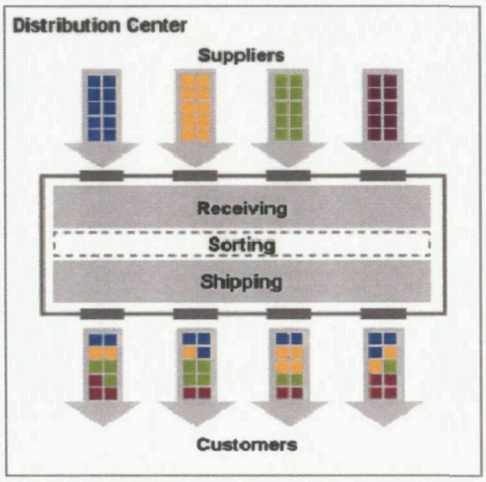


Figure 12: Cross-docking

Figure 12 shows suppliers delivering four different products, which have to be transported to customers. Each customer needs a couple of each product. By using the distribution center, products are received, sorted and transported to customers. Instead of every supplier visiting every customer, the suppliers deliver its products at the distribution center and from the distribution center exact order per customer is transported.
Cross docking can be applied to a number of circumstances. For manufacturing, cross docking can be used to consolidate inbound suppliers, which can be prepared to support just-in-time assembly. For distribution, cross docking can be used to consolidate inbound products from different suppliers, which can be delivered when the last inbound shipment is received. For transportation, cross docking involves the consolidation of shipments from several suppliers (often in LTL batches) in order to achieve economies of scale. For retail, cross docking concerns receiving products from multiple suppliers and sorting them to outbound shipments to different stores (Rodrigue, 2008).

3.1.2 Hub and spoke network in air transport
According to Bolt, there are five kind of different infrastructure networks possible to use. These different networks are shown in figure 13 on the next page and are linear networks (1), star networks (2), circle networks (3), raster networks (4) and triangle networks (5).

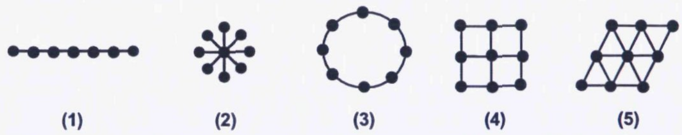


Figure 13: Infrastructure networks according to Bolt (1984)

These different types of infrastructure networks, all have their own advantages and disadvantages. They can be compared in capital costs, variable transport costs, traffic intensity, and accessibility. The hub and spoke network (drop and swap network) is an example of a star network. The hub and spoke network is a system of connections arranged like a chariot wheel, in which all traffic moves along spokes connected to the hub at the center. The hub and spoke network is commonly used in industry (particular in transport), telecommunications and freight transport (Coyle, Bardi & John Langley Jr., 2003).

In 1955, Delta Air Lines pioneered the hub and spoke system at its hub in Atlanta in an effort to compete with Eastern Air Lines. In the mid 1970s, FedEx adopted the hub and spoke model for overnight package delivery, and after the airline industry was deregulated in 1978, Delta's hub and spoke paradigm was annexed by several airlines. Airlines have extended the hub and spoke network in various ways. One method is to create additional hubs on a regional basis, and to create major routes between the hubs. This reduces the need to travel long distances between nods that are close together. Another method is to use focus cities to implement point-to-point service for high traffic routes, bypassing the hub entirely. Figure 14 shows the difference caused by the introduction of a hub and spoke network for two different air transport organizations.

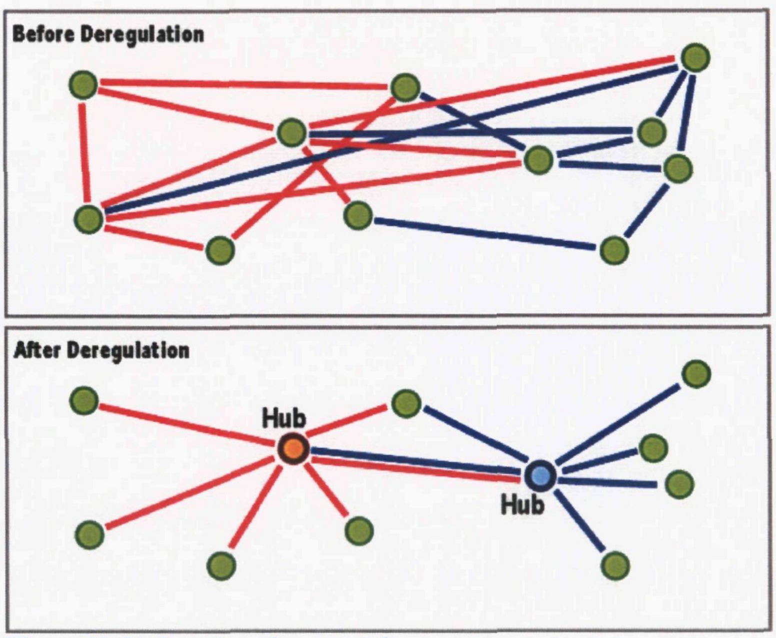


Figure 14: Hub and spoke network

In the figure above, two airline companies (red and blue) are servicing a network of major cities. A fair amount of direct connections exists, but mainly at the expense of the frequency of services and high costs (if not subsidized). Also, many cities are serviced, although differently, by the two airlines and connections are likely to be inconvenient. With deregulation, a system of hub-and-spoke networks emerges as airlines rationalize the efficiency of their services. A common consequence is that each airline assumes dominance over a hub (see figure 14, with red airline over the orange hub and blue airline over the light blue hub) and services are modified so the two hubs are connected to several spokes. Both airlines tend to compete for flights between their hubs and may do so for specific spokes, if demand warrants it. However, as this network

matures, it becomes increasingly difficult to compete at hubs as well as at spokes, mainly because of economies of agglomeration. As an airline assumes dominance of a hub, it reaches oligopolistic (if not monopolistic) control and may increase airfares for specific segments (Rodrigue, 2008).
Federal Express, UPS, Norfolk Southern and Yellow Freight are examples of organizations that all have successfully implemented hub and spoke distribution to achieve a competitive logistics advantage. They have found that this method of distribution reduces transportation costs, improves cycle times, and reduces inventory. These firms and many other companies are realizing that significant cost savings can result from improving their distribution processes (Scott Hudson, 2003).

3.1.3 Implementing a drop and swap concept

With the literature study of the warehousing in the distribution of freight and the hub and spoke network in air transport important, choices and decisions concerning the implementation of a drop and swap concept can be formulated. Most important factors that decides whether a drop and swap concept is implemented depends on the costs trade off, which is partly influenced by the logistical consequences.

Cost trade-off

The total cost, including the service impact on lost revenues, is the most important criterion used to make decisions whether to implement a drop and swap concept. For example, having many warehouses increases service provided to the consumer because the product is located closer to the customer. However, the trade-off is higher warehousing, inventory, and transportation costs. Profitability (Extra revenue – extra costs) is the determining factor.

<u>Costs of transportation</u>

Transportation, with the implementation of a drop and swap concept in a transport organization, change (Buhrmann, 2003). Scheduling of the transport is necessary in such concepts. Within the hub and spoke network for air transport, flights need to be scheduled in a way that waiting times are as small as possible. This means accurate scheduling of the transportation of products is necessary (Jacobs, Verbraeck and Mulder, 2005).
With the implementation of a drop and swap concept in the transportation of freight, products are, for example, delivered form the factory to warehouses just outside of the city centers. Transportation costs are lower for this part of transportation because travel time and travel distance are shorter (Hudson, 2003). Extra transportation costs are created because products need to be distributed from warehouses to their final destinations (Konings, 2005). Within the hub and spoke network of air transport, the hub terminal is considered to be the warehouse where products (passengers) are being collected and distributed (Pielage, Konings, Rijsenbrij and Schuylenburg, 2007).

<u>Costs of transshipment</u>

Extra transshipment in a drop and swap concept is necessary. Instead of delivering the products at their destination at once, an extra transshipment takes place. After this transshipment, quantity and quality of the products needs to be assured (Baird, 2005). Products handling is very important to any warehouse's efficient operations, both in terms of transferring goods in and out to various locations. With efficient product handling an efficient short-distance movement that usually takes place between a building and a transportation agency is meant. Product handling has four dimensions: movement, time, quantity, and space. The movement aspect of product handling involves the conveyance of goods into and out of storage facilities, as well as within such facilities. Efficient product handling, then, means efficient movement of goods, from, and within the storage facilities.

The time dimension of product handling is concerned with readying goods for production or for customer order filling. The longer it takes to get raw materials to production, the greater the chance of work stoppage, higher inventories, and increased storage space. Likewise, the longer it takes to move finished goods to the shipping area, the longer the order cycle time and the lower the customer service.

The quantity issue addresses the varying usage and delivery rate of raw materials and finished goods, respectively. Product handling systems are designed to assure that correct quantity of product is moved to meet the needs of production and customers.

Products handling equipment consumes space in the warehouse and plant. This space in a facility is fixed, and the products handling system must utilize this space efficiently (Huang and Karimi, 2006).

Costs of warehousing

Within the drop and swap concept of transport organization, storage costs are high (Blomjous and van Houten, 2003). If the company is using public warehousing, the question of what size facility is less important because the public warehousing firm can make more or less space available to meet the warehousing needs at different times. For firms using private warehousing, the size decision is more important because the private facility size, once designed and built, is fixed and cannot be modified without considerable expense.

In addition to the preceding basic warehousing decisions, a company using private warehousing is faced with the question of how to layout the warehouse's interior. The company must make decisions regarding the aisle space, shelving, material-handling equipment, and all the physical dimensions of the interior warehouse, when using a public warehouse, the public warehousing company makes the layout decisions. The layout and design of the drop and swap location will also have an important influence on the logistical, technical and financial consequences.

Inventory decisions are required as to what products in what amounts will be stored in which warehouses. These item-stocking decisions are relevant only for firms with multiple warehouses. The firms must decide if all items will be carried at all warehouses, whether each facility will carry only specific items, or whether the warehouses will combine specialization and general stocking (Coyle, Bardi & John Langley Jr., 2003).

Warehousing decisions are important and require close attention. Improving efficiency and productivity is a major management focus in warehousing operations. Properly utilizing space through carefully planned inventory management and distribution operations will be more important in the future than building additional facilities. Moreover, warehouse decisions interact very closely with other areas of the logistic system (Burke, 2004).

Logistical consequences

There are several logistical consequences of implementing a drop and swap concept. Occupancies, transportation time, flexibility, reliability, and punctuality are logistical consequences (Ovrebekk, 2007).

Occupancies

Occupancies change with implementing a drop and swap concept. With the distribution of freight, warehouse capacity is important and expensive. With the hub and spoke network in air transport occupancies on the hub terminal are much higher in comparison with the spoke terminal (Jetlund and Karimi, 2004).

Transportation time

In general, total transportation time reduces with a drop and swap network. Instead of delivering the products with one transport module, products are split up at a warehouse and loaded into different transport modules that transport the product directly to their destination. However, in a hub and spoke network, total transportation time increases because passengers are not transported directly to their destination anymore but via de hub terminal (Karimi, Sharafali, Mahalingam and Sundaramoorthy, 2005).

Flexibility

Because products can be stored at a central point, flexibility of distributing the products can be increased. However the goal is to distribute the products as fast as possible, there are possibilities to store products if necessary. When transport modules are not available at a certain moment, products can be distributed at another time. Of course this causes extra costs, but not as much as it would be in other networks (Hudson, 2003).

Reliability

With a drop and swap concept, reliability of the transportation of the chemicals can be increased. Because different connections are used to transport the products, problems like need for reparation, will not influence all transport. When one connection cannot be used anymore, other connections still are available. This also counts for delays in transport; when one transport unit (one truck that transports products from the warehouse to a customer) is delayed, other transport units will not be influenced by this delay (Hudson, 2003).

Punctuality

Because distances within a drop and swap concept are shorter per transportation, more accurate predictions concerning arriving times can be given. This creates more punctual arriving times, which will cause a more efficient use of storage and transportation (Hudson, 2003).

3.1.4 Summary and conclusions on literature

Implementing a warehouse in the distribution of freight, a hub and spoke network in air transport, or a drop and spoke concept for the transshipment of chemicals in a port, has financial and logistical consequences. These consequences are shown in table 8.

Table 8: Logistical and financial consequences

Factor	Consequence
Transportation costs	Transportation is split up into different parts. The part from the producers to the warehouse, and the distribution or collection from the warehouse to the customers. Costs for transportation changes.
Transshipment costs	Extra transshipment is necessary. During this transshipment, accurate scheduling is a must to guarantee efficiency. Extra transshipment must not influence the product quality and will increase costs.
Warehousing costs	Warehousing costs are created and are usually high.
Occupancies	Occupancies at the hub location increase, while occupancies at the spoke locations decrease.
Transportation time	Transportation time of the products is influenced. Usually, transportation time decreases, but increase of time occurs often too (for example due to waiting times in the warehouse).

Most important financial consequences are in the transportation costs, the transshipment cost, and the warehousing costs. Warehousing costs are usually high. Most important logistical consequences are in the occupancies and transportation time.

3.2 Consequences for Odfjell Shipping

When a drop and swap concept is implemented, there will be consequences for OS in transportation of chemicals in the port of Rotterdam. A higher profit for Odfjell due the reduction in port time (3.2.1) is an important goal of the drop and swap concept for Odfjell. To distribute and collect chemicals from and to OTR in the port of Rotterdam, extra transportation is necessary (3.2.2).

To investigate consequences for OS, the database (port tracker) of OS, describing the processes of the Odfjell parcel tankers, in 2008 are used. These results are used as referential situation, towards which results of drop and swap alternatives are compared. In reality, the number and characteristics of each Odfjell parcel tanker (e.g. quantity of chemicals, destination of chemicals, etc.), visiting the port of Rotterdam, is different.

3.2.1 Reduction in port time

By implementing a drop and swap concept, the number of calls an Odfjell parcel tanker has to make in the port of Rotterdam is reduced. This reduction in the number of calls results in a lower port time per tanker. Odfjell's most important goals are to realize a higher profit and increase the competitive position due to this reduction in port time (Odfjell, 2008a).

In the most extreme drop and swap alternative, each Odfjell parcel tanker that visits the port of Rotterdam transships all chemicals at OTR. Using the database of OS (port tracker 2008), changes in port time due to a reduction in the number of calls is determined. As mentioned before, port time per tanker exists of shifting time, port delays, operational delays, and the actual transshipping time of chemicals.

Shifting

In the current situation, Odfjell parcel tankers need to shift an average of 3,78 times between terminals to transship chemicals in the port of Rotterdam. Average time per shift was circa 5 hours[15].

The number of shifts is equal to the number of calls a tanker has to make. When all chemicals, transported by Odfjell parcel tankers, are dropped and swapped at OTR, the average number of calls (and shifts) per tanker reduces from 3,78 to 1 call. Considering 5 hours per shift, per tanker, a reduction of circa 14 hours in the total shifting time is realized.

Port delay

In the current situation, the total average port delay per Odfjell parcel tanker was circa 21 hours. Total port delay is not dependent on the number of calls a tanker has to make. Port delays and the number of calls of the 147 tankers, show that a reduction in the number of calls does not influence the total average port delay per tanker[16]. Therefore, total average port delay per tanker is 21 hours. Reliability of predicting the total port delay, using the number of calls, is very low because of the influence of many factors on the total port delay.

Operational delay

In the current situation, the total average operational delay per Odfjell parcel tanker was circa 37 hours. Total operational delay is partly dependent on the number of calls. Operational delays and the number of calls of the 147 tankers, show that a reduction of one call results in a reduction of 7 hours in the total operational delay[17]. A fixed operational delay of 13 hours per tanker, independent of the number of calls, is determined. Reliability of predicting the total operational

[15] Appendix J1
[16] Appendix J2
[17] Appendix J4

delay, using the number of calls, is low because of the influence of many more factors on the total operational delay.

Transshipping

Implementing a drop and swap concept, also changes the transshipping times of the tankers. The average transshipment rate and the total quantity of chemicals, that need to be transshipped, are the factors that influence the transshipping time[18]. Total average transshipment time in the current situation is circa 114 hours per Odfjell parcel tanker. Total quantity that needs to be transshipped per tanker stays the same with the implementation of a drop and swap concept. Average transshipment rate at OTR was higher than the average transshipment rate of all terminals together in 2008 (OTR had an average transshipment rate of 350 cbm per hour, while the average transshipment rate of all terminals was 255 cbm per hour).
Because of higher average transshipment rates at OTR, implementing a drop and swap concept, in which all Odfjell parcel tankers tranship all chemicals at OTR, results in a reduction in transshipping time. Average quantity transshipped per Odfjell parcel tanker in 2008 was circa 30 thousand cbm of chemicals. When these chemicals are transshipped with an average transshipment rate of 350 cbm per hour at OTR, instead of the current average transshipment rate of 255 cbm per hour, a reduction of circa 30 hours in the transshipping time is realized. In fact, when all chemicals are transshipped at OTR, more parallel transshipments are possible, which could result in an even higher average transshipment rate at OTR.

3.2.2 Transportation of chemicals in the port of Rotterdam

With a drop and swap concept, an Odfjell parcel tanker only loads and discharges chemicals at OTR. Chemicals that need to be loaded at OTR must be collected from other terminals to OTR. Chemicals discharged at OTR, but destined for another terminal, must be distributed form OTR to the other terminals. Barges do this collection and distribution of chemicals in the port of Rotterdam. Currently, OS does not have its own barges in Europe. Barges of another company are rented to transport chemicals between OTR and other terminals in the port of Rotterdam.
In total, the 147 Odfjell parcel tankers that visited the port of Rotterdam, transshipped circa 4,35 million cbm of chemicals, of which circa 17% (0,75 million cbm of chemicals) was transshipped at OTR. When all chemicals transported by Odfjell parcel tanker are dropped and swapped at OTR, circa 3.6 million cbm of chemicals need to be collected or distributed by barge. Considering a maximum capacity of 3.000 cbm of chemicals per barge, circa 1.200 barge transportations are needed for the collection and distribution. Hiring costs of barges to transport chemicals in the port of Rotterdam are approximately 4,50 euro per cbm to transport (Odfjell, 2008b).

[18] Appendix J4

3.3 Consequences for Odfjell Terminals Rotterdam

Implementing a drop and swap concept, influences the transshipment (3.3.1) and storage of chemicals (3.3.2) at OTR. To determine changes for OTR, the results of the processes at OTR in 2008 are used. These results are used as referential situation, towards which the results of drop and swap alternatives are compared. In reality, performances on these processes are different each year.

3.3.1 Transshipment of chemicals at OTR

Transshipment at OTR is influenced due to a bigger transshipment quantity of chemicals at OTR. Processes to transship chemicals, like the preparing for transshipment and safety measures, stay the same and are further neglected in the research (Odfjell, 2008c). However, Throughput, berth occupancies, and waiting time change.

Throughput

When all chemicals, transported by Odfjell parcel tankers, are dropped and swapped at OTR, the total number of Odfjell parcel tankers that visit OTR increases from 75 to 147 tankers. Average transshipment quantity at OTR increases from circa 10.000 to circa 30.000 cbm per tanker. This extra quantity of chemicals needs to be collected at, or distributed from, OTR by barge. Chemicals transshipment from tankers to barges and vice versa is needed. This transshipment can de done with board-board transshipment or with temporary storage (cross docking). A combination of both is also possible. An overview of the consequences of these different transshipments is shown in table 9.

Table 9: Collection and distribution of chemicals

Transport	Transshipment	Influences
Barge	Board-board	- Berth occupancies
	Temporary storage	- Berth occupancies - Storage occupancy

Board-board transshipment influences the berth occupancies at OTR, while cross docking also influences the storage occupancy. Board-board transshipment of all chemicals is not an option, because limited (maximum two) connections with barge berths are possible per deep-sea berth. This means that, for example, when an extra chemical quantity of 20.000 cbm needs to be transshipped at OTR, transshipping time takes very long. Board-board transshipment can only take 6.000 cbm at once (capacity of a barge is 3.000 cbm, and two connection are possible) and will decrease the average transshipment rate drastically[19].

Temporary storage influences the berth occupancies and the storage occupancy. When all chemicals, transported by Odfjell parcel tankers, are dropped and swapped at OTR, total chemical throughput increases with a minimum of circa 3.6 million cbm. Chemicals that need temporary storage need two transshipments, which result in a higher throughput at OTR. Actual extra transshipment costs are very low and can be neglected in the research (Odfjell, 2008b).

Chemicals that are dropped and swapped are transshipped one or two extra times. Owners of these chemicals (customers of Odfjell) do not agree with this extra transshipment(s) if chemical quality and quantity is not guaranteed. To guarantee the chemical quality and quantity after the extra transshipment, surveyors are needed. The surveyors check whether the quality and quantity of the chemicals is not changed due to the extra transshipment. Costs for these surveyors are circa 500 euro per checked chemical party.

[19] Appendix F

Berth occupancies

Total Berth occupation increases due to collection and distribution of chemicals. Use of this extra barge berth capacity due to the dropping and swapping of chemicals does not generate extra income for Odfjell. However, current occupancy is that low, no loss in revenue is considered either.

Total deep-sea berth occupation of Odfjell parcel tanker at OTR was circa 3 thousand hours in 2008. When all chemicals, transported by Odfjell parcel tanker, are dropped and swapped at OTR, deep-sea berth occupation increases to circa 13 thousand hours[20]. With 4 deep-sea berths at OTR this results in more than 100% occupancy. Use of this extra deep-sea berth capacity does not generate extra income for Odfjell. When demand for deep-sea berth capacity at OTR is high, the extra capacity needed, causes loss in revenue for Odfjell. Loss in revenue is circa 500 euro per hour of deep-sea berth capacity.

Waiting time

Higher berth occupancies also result in longer waiting times for tankers to moor at OTR. With four deep-sea berths operational and a total occupancy of 80%, current waiting time at OTR was circa 11,5 hours per tanker. With the construction of a 5th deep-sea berth terminals and a change in occupancy, waiting time changes too. Using the formulas in appendix K, there is determined that with the 5th deep-sea berth operation, waiting time is 5 hours ceteris paribus.

3.3.2 Storage of chemicals at OTR

Because a part of the extra throughput at OTR needs temporary storage, storage occupancy at OTR is influenced too. Use of extra storage capacity with dropped and swapped chemicals, does not generate income for Odfjell. At the moment, storage occupancy at OTR is already at its maximum (more than 97%). If demand to storage capacity stays the same or increases, storage capacity for the dropped and swapped chemicals causes loss in income for Odfjell. Building extra chemical tanks increases storage capacity, but can still cause loss in income dependent on the demand for storage. Storage capacity needs to be reserved for the dropped and swapped chemicals. This can be done in two ways:

1. Realize dedicated storage capacity that is only used for the drop and swap of chemicals that need temporary storage at OTR. Advantage is that at every moment that an Odfjell parcel tanker wants to drop and swap its chemicals, capacity is available without having to reject the storage of other chemicals. Disadvantage is that these storage tanks can be empty for big parts of the year. Another disadvantage is that storage tanks with a fixed size are used. Tanks with a capacity of 1.600 cbm are most efficient (Odfjell, 2008d). With this size, small chemical parties (<1.500 cbm) that need temporary storage do not occupy gigantic storage tanks. However, using tanks with a capacity of 1.600 cbm, big chemical parties (>5.000) need more tanks for temporary storage and will therefore have a higher loss in revenue than one big tank. Loss in revenues for these tanks is on average 130.000 euro per year per tank, tanking into account a tank of 1.600 cbm (Odfjell, 2008b).
2. Create extra storage capacity 'last-minute' when an Odfjell parcel tanker, which is going to drop and swap its chemicals, is supposed to arrive at OTR. Advantage is that no storage tanks have to be reserved for the drop and swap of chemicals and all tanks can also be used for 'normal' storage of chemicals. Another advantage is that the tank size for temporary storage is flexible, which causes a lower loss in revenues. Disadvantage is it needs accurate planning to make sure that there is free storage capacity to drop and swap the chemicals at OTR. Consequence of this planning is that orders towards storage have to be rejected to make storage capacity available for the drop and swap of chemicals. Loss in revenue is influenced by this flexible tank size and last-minute rejection of customers.

[20] An extra chemical quantity of 3.6 million cbm is transshipped at OTR with a transshipment rate of 350 cbm/hour

The time that a tank is in use for temporary storage is estimated on two weeks (Odfjell, 2008c). Loss in revenues for Odfjell in these two weeks depends on the tank size.

As can be seen, both possibilities have their advantages and disadvantages. Which of two is most efficient depends on the number of tankers that are dropped and swapped per year. The more tankers are dropped and swapped, the more efficient the use of the dedicated storage tanks become.

3.4 Summary and conclusions

Implementing a drop and swap concept for chemicals, transported by Odfjell parcel tankers, results in a lower number of calls per tanker and different throughputs at the terminals. This causes several changes in the transportation and storage of chemicals by Odfjell. A summary of changes for the transportation of chemicals by OS is shown in table 10.

Table 10: Logistical consequences of a drop and swap concept for OS

Logistical consequence	Results
Reduction in port time	
- **Shifting time**	Decreases with circa 5 hours per reduction in the number of calls.
- **Port delay**	Does not decrease with a reduction in the number of calls. The average port delay is 21 hours per tanker.
- **Operational delay**	Decreases with circa 7 hours per reduction in the number of calls. A fixed time of 13 hours of operational delay per tanker is added.
- **Transshipping time**	Decreases when average transshipment rate per tanker is increased. Average transshipment rate at OTR is high in comparison with other terminals.
Collection and distribution of chemicals	Barges take care of collection and distribution of chemicals in the port of Rotterdam. One barge can transport a maximum of 3.000 cbm of chemicals.

Due to a reduction in the number of calls, total port time per Odfjell parcel tanker reduces. The magnitude of changes in the transportation depends on the reduction in the number of calls due to the implementation of a specific drop and swap alternative. Especially, the consequences for the port delay and operational delay are difficult to forecast. Reliability of the changes in these times can be argued, and can be increased with further research. This reliability has to be taken into account with the interpretations of the results.
Transportation is also influenced due to the necessity of barge transportation. The dropped and swapped chemicals that are loaded at OTR need to be collected at OTR in advance. Chemicals discharged at OTR, but destined for another terminal, need to be distributed after discharge.

Implementing a drop and swap concept, also causes changes in the storage of chemicals at OTR. A summary of these changes is shown in table 11.

Table 11: Logistical consequences of a drop and swap concept for OTR

Logistical consequence	Results
Throughput	Total throughput at OTR increases.
Berth occupancies	Deep-sea berth occupancy and barge berth occupancy at OTR increase.
Waiting time	Waiting time for tankers to moor at OTR increases.
Storage capacity	Demand for storage capacity increases.
Product handling	Chemical quality and quantity needs to be guaranteed after the extra transshipment.

Implementing a drop and swap concept, increases the number of Odfjell parcel tankers visiting OTR and/or the transshipment time of these tankers at OTR. The magnitude of this increase depends on the specific drop and swap alternative that is implemented.
This results in an increase of the total throughput, the berth occupancies, the waiting time, and the demand for storage capacity at OTR. Because of the extra transshipment, customers (owners of the chemicals) need a guaranteed chemical quality and quantity after this extra transshipment.

These changes realize reduction in costs, extra costs, and losses in revenue for Odfjell. An overview of these costs is given in appendix L and summarized in table 12.

Table 12: Financial consequences for Odfjell

Financial consequences	Result
Port time	Depending on the size of the tanker, a reduction in port time results in a cost reduction for Odfjell of 1250 euro per port time hour.
Number of shifts	Each reduction in the number of shifts, results in a cost reduction of circa 5.000 euro.
Barge transportation	Transportation of chemicals by barge costs circa 4,50 euro per cbm.
Berth occupation	Loss in revenue due to deep-sea berth occupation is circa 500 euro per hour.
Storage occupation	Loss in revenue due to storage occupation is circa 130.000 euro per year or a variable amount of euro per two weeks.

Implementing a drop and swap concept has logistical and financial consequences for Odfjell. Storage of the 'dropped and swapped' chemicals is expensive and a reduction in port time of the Odfjell parcel tankers is very profitable for Odfjell. Loss in revenue with the use of storage capacity depends on the choice if dedicated tanks (only used for dropped and swapped chemicals) are used, or non-dedicated tanks (used for normal storage and dropped and swapped chemicals). Dedicated tanks have a capacity of 1.600 cbm and realize a loss in revenue of circa 130.000 euro per year, non-dedicated tanks differ in size and realize a variable loss in revenue per two weeks.

With this chapter, criteria for the implementation of different drop and swap alternatives can be formulated.

4 Criteria for implementing a drop and swap concept

As concluded in the previous chapter, implementing a drop and swap concept has financial and logistical consequences for Odfjell. Criteria concerning the logistical feasibility (4.1) and financial feasibility (4.2) for Odfjell of implementing a drop and swap alternative are formulated. To implement a logistical and financial feasible concept, some system boundaries have to be met in the drop and swap alternative (4.3). Finally, a summary and conclusion is given (4.4).

4.1 Logistical feasibility

Implementing a drop and swap alternative needs to be logistical feasible for Odfjell. Logistical feasibility is determined with the deep-sea berth occupancy at OTR, the barge berth occupancy at OTR, and the waiting time for tankers to moor at OTR.

Deep-sea berth occupancy at OTR

Occupancy of the deep-sea berths at OTR is influenced by implementing a drop and swap alternative. Deep-sea berth occupancy depends on the needed and available capacity of deep-sea berths at OTR and is measured with a percentage. An overview of the influences on the deep-sea berth occupancy is shown in figure 15.

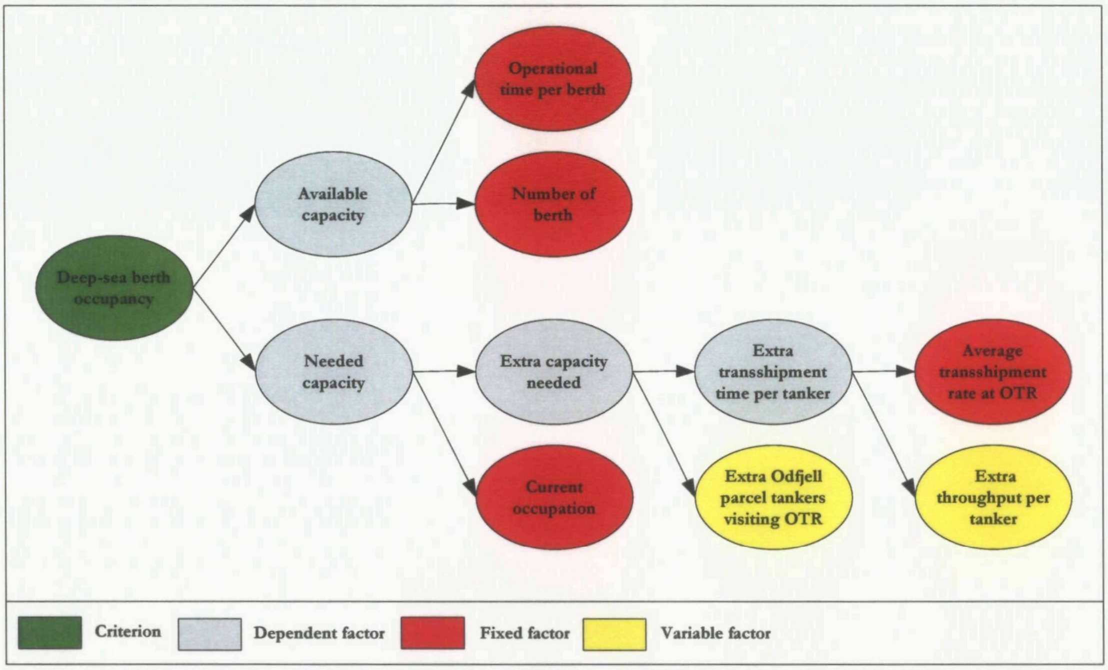


Figure 15: Influences on deep-sea berth occupancy at OTR

Available capacity depends on the number of berths and the operational time per berth. Needed capacity depends on the current occupation of deep-sea berths and extra capacity needed with the implementation of a drop and swap alternative. The extra capacity needed depends on the extra occupation due to extra Odfjell parcel tankers visiting OTR and extra transshipment time due to extra throughput per tanker at OTR. The extra throughput per tanker at OTR and the extra number of Odfjell parcel tankers that visit OTR are dependent on a specific drop and swap alternative that is implemented. The available capacity of deep-sea berths, the current occupation of deep-sea berths, and the average transshipment rate at OTR are fixed in the research. The extra Odfjell parcel tankers visiting OTR and the extra throughput per tanker at OTR depend on the alternative that is implemented.

Barge berth occupancy at OTR

Occupancy of the barge berths at OTR is influenced by implementing a drop and swap alternative. Barge berth occupancy depends on needed capacity and available capacity of barge berths at OTR and is measured with a percentage. An overview of the influences on the barge berth occupancy is shown in figure 16.

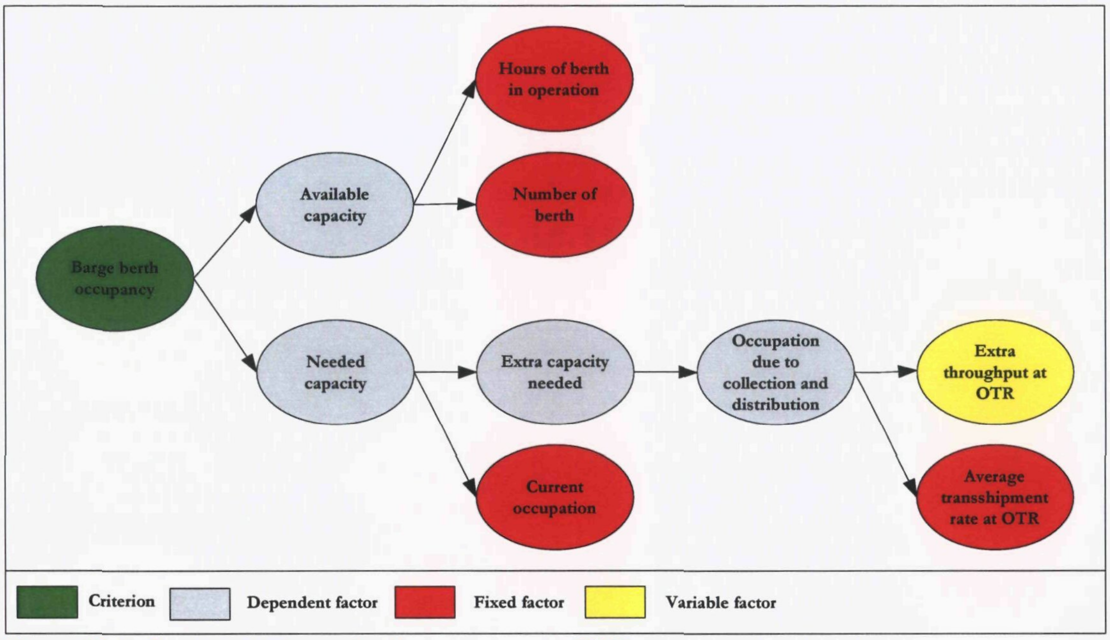


Figure 16: Influences on barge berth occupancy at OTR

Available capacity depends on the number of barge berths and the operational time per berth. Needed capacity depends on the current occupation of barge berths and extra capacity needed with the implementation of a drop and swap concept. The extra capacity needed depends on the occupation due to transshipment of the extra chemicals that are collected or need to be distributed, which depends on the extra chemical throughput at OTR and the average transshipment rate at OTR. The available capacity, the current occupation of barge berths, and the average transshipment rate at OTR are fixed in the research. The extra throughput at OTR depends on the alternative that is implemented.

Waiting time to moor at OTR

Waiting time to moor at OTR is influenced by implementing a drop and swap alternative and depends on the deep-sea berth occupancy and the number of deep-sea berths at OTR, as shown in figure 17.

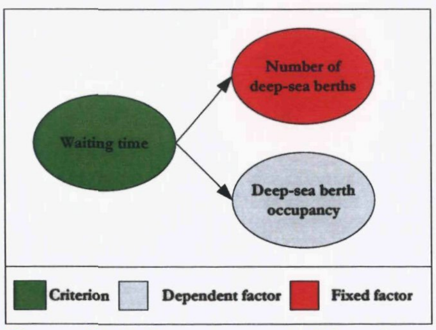


Figure 17: Influences on waiting time at OTR

Considering an M/M/c queuing system, waiting times for the different alternatives can be determined. An explanation of this queuing system, with formulas, is shown in appendix K.

4.2 Financial feasibility

Implementing a drop and swap concept also needs to be financial feasible. Goal is to increase profits for Odfjell, which means that the total reduction in costs must increase the total extra costs and loss in revenues. With this financial feasibility, an associated profit center between OS and OTR, for chemicals that are dropped and swapped at OTR by Odfjell parcel tankers, is assumed. An overview of financial consequences is given in appendix L. Financial feasibility is determined with the reduction in costs, extra costs and loss in revenue for Odfjell.

Reduction in costs for Odfjell

Reduction in costs for Odfjell, with the implementation of a drop and swap concept, are realized due to a reduction in tanker costs and shifting costs and is measured in euro per year. An overview of the influences on the reduction in costs for Odfjell is given in figure 18.

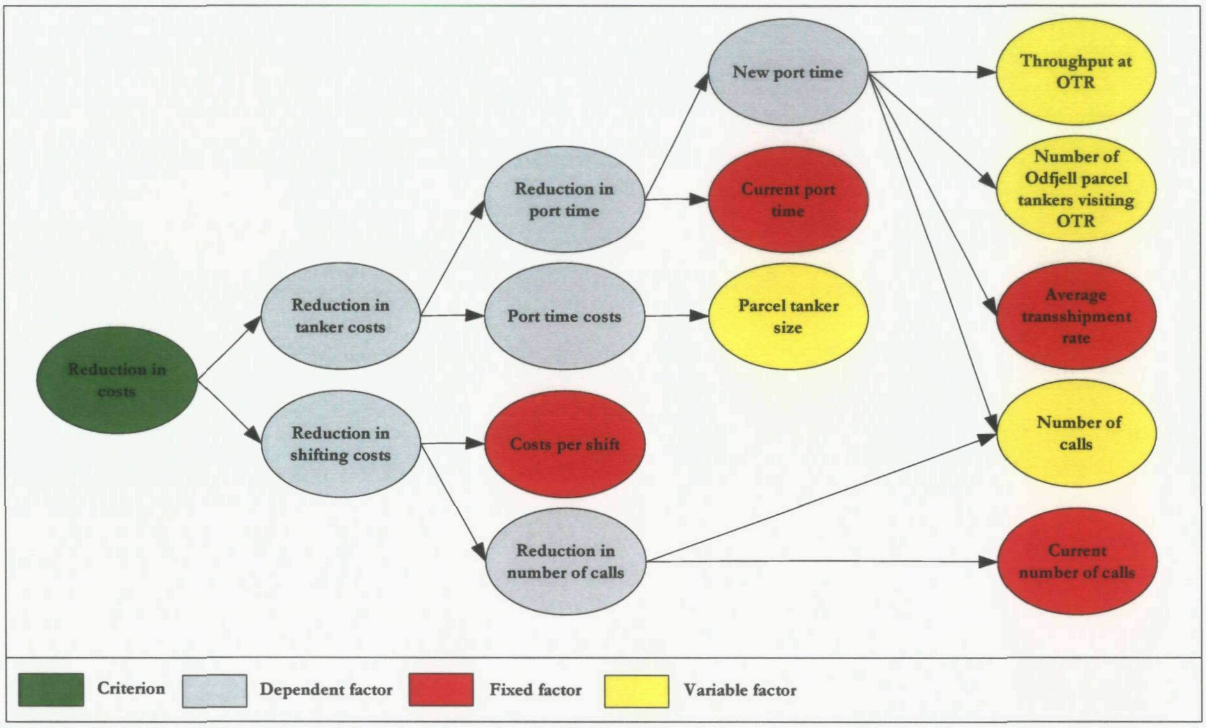


Figure 18: Influences on reduction in costs for Odfjell

The reduction in the tanker costs depends on the reduction in port time and the costs of port time per tanker. The costs of port time depend on the tanker size of the influenced tankers. Reduction in port time is the difference between the current port time and the new port time per tanker, after implementing a drop and swap concept. The new port time per tanker depends on the shifting time, port delays, operational delays and transshipping time. Duration of these actions depend on the number of calls, the throughput at OTR, the number of Odfjell parcel tankers visiting OTR, and the average transshipment rate of all visited terminals.

Reduction in shifting costs depends on the costs per shift and the reduction in the number of shifts (calls) of an Odfjell parcel tanker. The reduction in the number of shifts depends on the current number of shifts and the number of shifts that Odfjell parcel tankers have to make after implementing a drop and swap concept.

Current port time, current number of calls, costs per shift, and average transshipment rate are fixed in the research. Reduction in the number of calls, throughput at OTR, number of Odfjell parcel tankers visiting OTR, and parcel tanker size depend on the alternative that is implemented.

Extra costs for Odfjell

Extra costs for Odfjell, with the implementation of a drop and swap concept, are split up into extra transportation and extra transshipment costs and are measured in euro per year. An overview of the influences on the extra costs for Odfjell is given in figure 19.

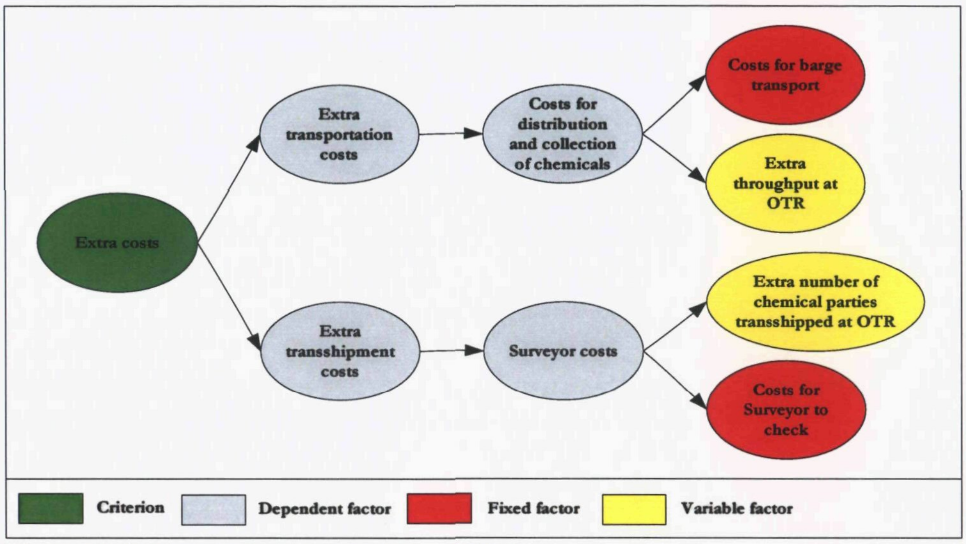


Figure 19: Influences on extra costs for Odfjell

Extra transportation costs are caused due to distribution and collection of chemicals that are dropped and swapped. These costs depend on the extra throughput at OTR and barge costs. Extra transshipment costs are realized with the necessity of surveyors to check the chemical quality and quantity after the extra transshipment. These costs depend on the number of chemical parties that are dropped and swapped and the costs for surveyor. Barge costs and surveyor costs are fixed in the research. The extra number of chemical parties transshipped and extra throughput at OTR depend on the alternative that is implemented.

Loss in revenues for Odfjell

Loss in revenues for Odfjell, with the implementation of a drop and swap concept, are split up into loss of revenue due to the use of storage capacity and loss in revenue due to the use of deep-sea berth capacity in the drop and swap alternative and is measured in euro per year. An overview of the influences on the loss in revenues for Odfjell is given in figure 20 on the next page.

Loss in revenue for the use of deep-sea berth capacity depends on extra deep-sea berth capacity needed and loss in revenues for Odfjell per time unit of the use of this capacity. Extra deep-sea berth capacity used depends on the extra Odfjell parcel tankers visiting OTR and the extra transshipment time of these tankers at OTR. Extra transshipment time depends on the average transshipment rate and the extra throughput per tanker at OTR.

Loss in revenue for the use of storage capacity depends on the number of storage tanks needed and loss in revenue for Odfjell per tank used. The number of storage tanks needed depends on the extra throughput (with temporary storage) and size of the storage tanks. Extra throughput per tanker depends on the percentage of throughput that is transshipped with temporary storage and the extra throughput per tanker. The loss in revenue per tank depends on the size of the tanks and the duration of occupation of these tanks[21].

Loss in revenue per time unit of deep-sea berth capacity used and average transshipment rate at OTR are fixed in the research. Size of the storage tanks and the duration of the occupation per

[21] Appendix M

tank depend on the way temporary storage is organized at OTR (chapter 3.3.2). Extra Odfjell parcel tankers visiting OTR, extra throughput per tanker and the percentage of throughput that needs temporary storage depend on the alternative that is implemented.

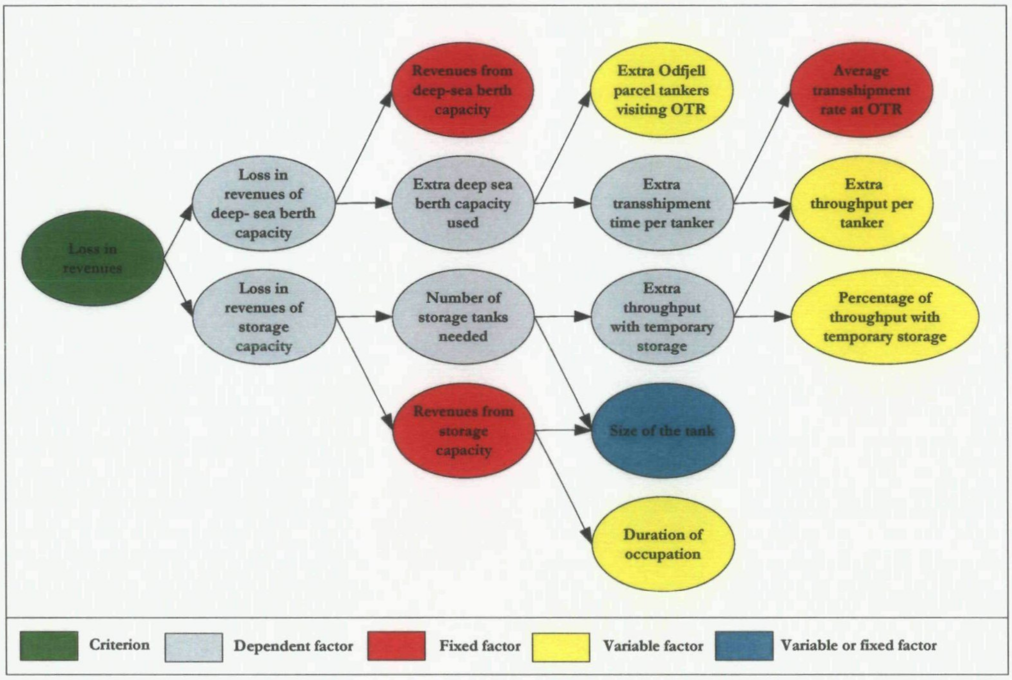


Figure 20: Influences on loss in revenues for Odfjell

4.3 System boundaries

System boundaries are values of the criteria that have to be met in the drop and swap concept. When these system boundaries are not fulfilled, the concept is not implemented. Main goal of Odfjell is to realize extra profit with the implementation of the drop and swap concept. This means that total reduction in costs of the drop and swap concept must exceed extra costs.

Implementing a drop and swap concept, increases berth occupancies at OTR. Because berth capacity for emergencies and mooring and unmooring of tankers is necessary, deep-sea berth occupancy must be lower than 85%. Barge berth occupancy must be lower than 75% to keep extra flexibility in comparison with the deep-sea berths (Odfjell, 2008c).

OTR's policy of 'first come, first serve' for tankers that visit OTR must be maintained in the drop and swap concept. Non-Odfjell parcel tankers still are an important and big customer for Odfjell and will claim a fair waiting system at OTR (Odfjell, 2008c).

Customers that transport chemicals with Odfjell parcel tankers need a guaranteed quality and quantity of their chemicals when an extra transshipment is needed.

4.4 Summary and conclusions

There are different ways to implement a drop and swap concept for transportation and transshipment of chemicals by Odfjell parcel tankers. Alternatives can be compared using different criteria. In this chapter logistical and financial criteria for Odfjell are formulated. Table 13 shows the logistical criteria.

Table 13: Criteria of logistical feasibility

Criterion	Measure
Deep-sea berth occupancy at OTR	Percentage
Barge berth occupancy at OTR	Percentage
Waiting time to moor at OTR	Hours

Results on these criteria depend on the way a drop and swap concept is implemented. Financial criteria are shown in table 14.

Table 14: Criteria of financial feasibility

Criterion	Measure
Reduction in transportation costs for Odfjell	Euro per year
Extra transportation costs for Odfjell	Euro per year
Extra transshipment costs for Odfjell	Euro per year
Loss in revenue for Odfjell due to extra deep-sea berth occupation	Euro per year
Loss in revenue for Odfjell due to extra storage occupation	Euro per year

Financial criteria are measured in euro per year. With the results of these criteria there can be determined whether the implementation of the drop and swap alternative realizes extra profit for Odfjell or not. Loss in revenues for Odfjell depends on the demand towards storage and deep-sea berth capacity at OTR. Different scenarios in which this demands differs need to be formulated.

With the results of the previous chapters system boundaries, which have to be fulfilled, are formulated. System boundaries are given in table 15.

Table 15: System boundaries

System boundaries
1. Deep-sea berth occupancy at OTR must be lower than 85%.
2. Barge berth occupancy at OTR must be lower than 85%.
3. The reduction in costs must exceed the extra costs.
4. OTR's policy of 'first come, first serve' must be maintained.
5. Chemical quality and quantity must be guaranteed after the extra transshipment.

The deep-sea berth occupancy at OTR, the barge berth occupancy at OTR and the extra profit for Odfjell are dependent on the specific drop and swap alternatives. OTR's policy of 'first come, first serve' and the guaranteed chemical quality and quantity after the extra transshipment, must be taken into account when different drop and swap alternatives are formulated and analyzed.

5 Drop and swap alternatives for Odfjell

Implementing a drop and swap concept at OTR can be done in different ways. Different drop and swap concept for Odfjell are analyzed to select one potential concept (5.1). This potential concept is split up into different alternatives and sub alternatives (5.2). Alternatives are analyzed using different scenarios (5.3). Finally, summary and conclusions are given (5.4).

5.1 Drop and swap concepts for Odfjell

Using the literature study in chapter 3.1, together with interviews at Odfjell, a total of three different ways to implement a drop and swap concept at OTR for the transshipment of chemicals by Odfjell parcel tankers are formulated:

1. Drop and swap chemicals, transported by Odfjell parcel tankers, at 2 or more different terminals in the port of Rotterdam. In this concept, Odfjell parcel tankers visit a limited number of terminals to transship all chemicals. This concept can be split up into different alternatives, depending on the number of terminals that are used and which terminals there are used.
2. Drop and swap specific chemical parties that need to be transshipped by Odfjell parcel tankers in the port of Rotterdam. This concept can be split up into different alternatives, depending on the characteristics of chemical parties that are dropped and swapped (e.g. quantity of the chemical party, type of chemical party, destination of chemical party, etc.).
3. Drop and swap all chemicals transported by specific Odfjell parcel tankers that visit the port of Rotterdam. A selection of the Odfjell parcel tanker is made, of which all chemicals are dropped and swapped at OTR. This concept can be split up into different alternatives depending on the quantity of chemicals z tanker has to transship, the number of calls it has to make in the port of Rotterdam, etc.

Using the previous research and interviews at Odfjell concerning the goals of Odfjell with the implementation of a drop and swap concept, a selection of the most potential drop and swap concept can be made based on three main goals.

<u>Reduction in calls:</u>	Odfjell want to reduce the port time of the Odfjell parcel tankers to increase profit. With the implementation of a drop and swap concept, a reduction in the number of calls per tanker is realized. The higher this reduction in call per tanker is, the more potential the concept has.
<u>Competitiveness:</u>	With the implementation of a drop and swap concept, Odfjell wants to increase the efficiency of the Odfjell parcel tankers and attract more customers to store their chemicals at OTR (Odfjell, 2008). The competitiveness with other terminals of a drop and swap concept is important.
<u>Easiness:</u>	Implementation of a drop and swap concept must be easy for Odfjell. When too many changes in the processes occur, implementation is more difficult and more expensive.

With these three goals, the different drop and swap concepts are compared. The reduction in calls is the most important criteria for Odfjell followed by the competitiveness and the easiness to implement. Table 16 on the next page, shows the results of the different concepts on these goals.

Table 16: Potential of drop and swap concepts

Concept	Reduction in the number of calls	Competitiveness	Easiness to implement
1	+	-	-
2	0	+	+
3	+	+	+

(+ = Best, 0 = Average, - = Worst)

The table shows that a concept, in which all chemicals of a specific Odfjell parcel tanker are dropped and swapped, is the most potential concept. Reduction in the number of calls per tanker is high because all chemicals of a specific Odfjell parcel tanker are transshipped at OTR. Competitiveness is high because a drop and swap concept is only implemented for Odfjell parcel tankers that visit OTR. The concept is easy to implement because only changes concerning the quantity of chemicals transshipped at OTR are necessary. This concept can be split up into different alternatives.

5.2 Drop and swap alternatives

Implementing a drop and swap concept, in which all chemicals of specific Odfjell parcel tankers are being dropped and swapped at OTR, can be done in different forms. In this research, using the results of previous analyses, four different alternatives are analyzed:

Alternative 1: Drop and swap Odfjell parcel tankers with a specific trade lane.
Alternative 2: Drop and swap Odfjell parcel tankers with a specific chemical quantity to transship in the port of Rotterdam.
Alternative 3: Drop and swap Odfjell parcel tankers with a specific number of chemical parties to transship in the port of Rotterdam.
Alternative 4: Drop and swap Odfjell parcel tanker with a specific number of calls to make after designing the rotation plan.

Alternative 1: Specific trade lanes

OS uses different trade lanes to transship chemicals from all over the world to Rotterdam. A possible drop and swap alternative is to drop and swap all chemicals of Odfjell parcel tankers of a specific trade lane. An interesting opportunity for Odfjell within this alternative is attracting more customers (that transport chemicals with Odfjell parcel tankers) to store their chemicals at OTR instead of storing at other terminals in the port of Rotterdam. With a drop and swap alternative, transshipment of these chemicals takes place at OTR anyway. Storing these chemicals at Odfjell is cheaper than transporting them to other terminals. If Odfjell recalculates this price to the customers, prices to store chemicals at OTR are cheaper for these customers. This possible advantage is not taken into account within the research. Trade lanes, used by Odfjell parcel tankers, are split up into 8 different sub-alternatives:

1a: The Africa - Rotterdam trade lane
1b: The Europe - Rotterdam trade lane
1c: The Far East - Rotterdam trade lane via Africa
1d: The Far East - Rotterdam trade lane via the Suez Canal
1e: The Mid East – Rotterdam trade lane via Africa
1f: The Mid East – Rotterdam trade lane via the Suez Canal
1g: The South America – Rotterdam trade lane
1h: The North America – Rotterdam trade lane

Alternative 2: Specific chemical quantities
Each Odfjell parcel tanker needs to transship a different chemical quantity in the port of Rotterdam. A possible drop and swap alternative is to drop and swap all chemicals of Odfjell parcel tankers with a specific chemical quantity to transship in the port of Rotterdam. Average chemical quantity transshipped per Odfjell parcel tanker in the port of Rotterdam is 30.000 cbm. Based on this average chemical quantity to transship, this alternative is split up into three different sub-alternatives:

2a: Odfjell parcel tankers with less than 20.000 cbm of chemicals to transship in the port of Rotterdam.
2b: Odfjell parcel tankers with 20.000 to 40.000 cbm of chemicals to transship in the port of Rotterdam
2c: Odfjell parcel tankers with more than 40.000 cbm of chemicals to transship in the port of Rotterdam.

Alternative 3: Specific number of chemical parties
Each Odfjell parcel tanker needs to transship a different number of chemical parties in the port of Rotterdam. A possible drop and swap alternative is to drop and swap all chemicals of Odfjell parcel tankers with a specific number of chemical parties to transship in the port of Rotterdam. Average number of chemical parties transshipped by Odfjell parcel tankers in the port of Rotterdam is 12. Based on this average number of chemical parties to transship, this alternative is split up into three different sub-alternatives:

3a: Odfjell parcel tankers with less than 8 chemical parties to transship in the port of Rotterdam.
3b: Odfjell parcel tankers with 8 to 16 chemical parties to transship in the port of Rotterdam.
3c: Odfjell parcel tankers with more than 16 chemical parties to transship in the port of Rotterdam.

Alternative 4: Specific number of calls
Each Odfjell parcel tanker needs to make a different number of calls in the port of Rotterdam after designing the rotation plan. A possible drop and swap alternative is to drop and swap all chemicals of Odfjell parcel tankers with a specific number of calls to make in the port of Rotterdam. Average number of calls to make by Odfjell parcel tankers in the port of Rotterdam is 4. Based on this average number of calls, this alternative is split up into three different sub-alternatives:

4a: Odfjell parcel tankers with less than 3 calls to make in the port of Rotterdam.
4b: Odfjell parcel tankers with 3 to 5 calls to make in the port of Rotterdam.
4c: Odfjell parcel tankers with more than 5 calls to make in the port of Rotterdam.

5.3 Scenarios

Different scenarios need to be formulated to score the different alternatives on the financial feasibility. Loss in revenue for Odfjell due to need of extra deep-sea berth capacity and storage capacity at OTR with the implementation of a drop and swap alternative, depends on the future demand for this deep-sea berth and storage capacity and the way the storage capacity needed is organized. For example, when the demand for storage capacity increases in the future, Odfjell has to refuse customers that want to store chemicals at OTR. This capacity is needed for the chemicals that are being dropped and swapped and need temporary storage. Three different future scenarios are analyzed:

A. Demand for deep-sea berth and storage capacity decreases in the near future. With a reduction in demand for deep-sea berth and storage capacity, no loss in revenues is realized with the implementation of a drop and swap alternative. Deep-sea berth and storage capacity are not fully used, which results in free capacity for chemicals that are dropped and swapped.
B. Demand for deep-sea berth and storage capacity is equal to the current demand. Loss in storage revenues is realized with the implementation of a drop and swap alternative due to temporary storage of dropped and swapped chemicals. No loss in deep-sea berth revenues is realized because deep-sea berth occupancy is not fully used in this scenario. Storage capacity, for dropped and swapped chemicals, can be organized in two ways:
    1. Use dedicated storage capacity for dropped and swapped chemicals. This storage capacity is used only for dropped and swapped chemicals.
    2. Use non-dedicated storage capacity for dropped and swapped chemicals. Storage capacity for dropped and swapped chemicals is created last minute. If no chemicals are dropped and swapped, storage capacity is for other chemicals
C. Demand for deep-sea berth and storage capacity increases in the near future. Loss in deep-sea berth and storage revenues is realized for Odfjell with the implementation of a drop and swap alternative. Because of increasing demand, Odfjell has to refuse customers to use deep-sea berth and storage capacity. Storage capacity, for dropped and swapped chemicals, can be organized in two ways:
    1. Use dedicated storage capacity for dropped and swapped chemicals. This storage capacity is used only for dropped and swapped chemicals.
    2. Use non-dedicated storage capacity for dropped and swapped chemicals. Storage capacity for dropped and swapped chemicals is created last minute. If no chemicals are dropped and swapped, storage capacity is for other chemicals

Extra profit for Odfjell per sub-alternative is determined in each scenario.

5.4 Summary and conclusions

In this chapter, the most potential drop and swap concept for Odfjell is given. Alternatives for implementing a drop and swap concept, in which all chemicals of specific Odfjell parcel tankers are transshipped at OTR, are formulated. Per alternative, sub-alternatives are formulated. An overview of all alternatives and sub-alternatives is given in table 17.

Table 17: Alternatives

Alternatives
1. Drop and swap for specific trade lanes.
1a: The Africa - Rotterdam trade lane
1b: The Europe - Rotterdam trade lane
1c: The Far East - Rotterdam trade lane via Africa
1d: The Far East - Rotterdam trade lane via the Suez Canal
1e: The Mid East – Rotterdam trade lane via Africa
1f: The Mid East – Rotterdam trade lane via the Suez Canal
1g: The South America – Rotterdam trade lane
1h: The North America – Rotterdam trade lane
2. Drop and swap for Odfjell parcel tankers with a specific quantity of chemicals to transship.
2a: Odfjell parcel tankers with less than 20.000 cbm of chemicals to transship.
2b: Odfjell parcel tankers with 20.000 to 40.000 cbm of chemicals to transship.
2c: Odfjell parcel tankers with more than 40.000 cbm of chemicals to transship.
3. Drop and swap for Odfjell parcel tankers with a specific number of chemical parties to transship.
3a: Odfjell parcel tankers with less than 8 chemical parties to transship.
3b: Odfjell parcel tankers with 8 to 16 chemical parties to transship.
3c: Odfjell parcel tankers with more than 16 chemical parties to transship.
4. Drop and swap for Odfjell parcel tankers with a specific number of calls to make.
4a: Odfjell parcel tankers with less than 3 calls to make.
4b: Odfjell parcel tankers with 3 to 5 calls to make.
4c: Odfjell parcel tankers with more than 5 calls to make.

For each sub-alternative, the loss in revenues will be analyzed using three different scenarios in which future demand for deep-sea berth capacity and storage capacity is variable. An overview of the different scenarios is given in table 18.

Table 18: Scenarios

Scenarios	Consequence for loss in revenues
A. Reduction in demand	- No loss in revenue due to use of deep-sea berth capacity. - No loss in revenue due to use of storage capacity.
B1. Current demand	- No loss in revenue due to use of deep-sea berth capacity. - Loss in revenues due to the use of dedicated storage capacity.
B2. Current demand	- No loss in revenue due to use of deep-sea berth capacity. - Loss in revenues due to the use of non-dedicated storage capacity.
C1. Increase in demand	- Loss in revenue due to use of deep-sea berth capacity. - Loss in revenues due to the use of dedicated storage capacity.
C2. Increase in demand	- Loss in revenue due to use of deep-sea berth capacity. - Loss in revenues due to the use of non-dedicated storage capacity.

When loss in revenues due to use of storage capacity is realized, this loss in revenues is determined for using dedicated storage capacity and for using non-dedicated storage capacity.

To analyze the different sub-alternatives, changes of implementing specific drop and swap alternative are determined using current results (chapter 2) and changes due to the implementation of a drop and swap concept (chapter 3). An Excel model determines the changes on the criteria per alternative (chapter 6).

6 Case study on alternatives

To analyze different drop and swap alternatives, a numerical model In Microsoft Excel is build. A description of the model is given (6.1), followed by a reflection of the model (6.2). Finally, a summary and conclusions of the chapter are given (6.3).

6.1 Model description

Using Microsoft Excel, a numerical model is build. Microsoft Excel is a spreadsheet program, which allows one to enter numerical values or data into rows or columns of a spreadsheet and to use these numerical entries for such things as calculations, graphs, and statistical analysis. The model is split up into 4 different parts (6.1.1). Each part takes care of a different alternative. With this numerical model, the alternatives can be determined on the formulated criteria. The determination of the port time (6.1.2), the berth occupancies at OTR (6.1.3), the average waiting time for tankers to moor at OTR (6.1.4), and the financial consequences for Odfjell are explained (6.1.5) respectively. Variable inputs, fixed inputs and formulas are needed in the Excel model to determine the output of the different criteria. Variable input factors are factors needed to determine the output and of which the values depend on the drop and swap alternative that is implemented. Fixed input factors are factors that have fixed values in the research and are the same for every alternative. Formulas determine the output, using the different variable input and fixed input per alternative. As an example, the alternative in which all chemicals transported by Odfjell parcel tankers of a specific trade lane are dropped and swapped at OTR is given.

6.1.1 Model per alternative

Each alternative consists of several specific Odfjell parcel tankers, of which all chemicals are dropped and swapped at OTR. The number of tankers per alternative group is different. For each alternative, with its sub-alternatives, the number of Odfjell parcel tankers that is influenced per year, is given in table 19 to 22.

Table 19: Number of tankers influenced per trade lane

Alternative	Number of tankers
The Africa - Rotterdam trade lane	3
The Europe - Rotterdam trade lane	52
The Far East - Rotterdam trade lane via Africa	8
The Far East - Rotterdam trade lane via the Suez Canal	12
The Mid East – Rotterdam trade lane via Africa	2
The Mid East – Rotterdam trade lane via the Suez Canal	5
The South America – Rotterdam trade lane	44
The North America – Rotterdam trade lane	21

Implementing a drop and swap concept for tankers of the Europe to Rotterdam or South-America to Rotterdam trade lane, influences the most tankers per year.

Table 20: Number of tankers influenced per transshipment quantity

Alternative	Number of tankers
Odfjell parcel tankers with less than 20.000 cbm of chemicals to transship.	31
Odfjell parcel tankers with 20.000 to 40.000 cbm of chemicals to transship.	93
Odfjell parcel tankers with more than 40.000 cbm of chemicals to transship.	23

Implementing a drop and swap concept for tankers that transship between 20.000 and 40.000 cbm of chemicals, influences the most tankers per year.

Table 21: Number of tankers influenced per number of chemical parties

Alternative	Number of tankers
Odfjell parcel tankers with less than 8 chemical parties to transship.	41
Odfjell parcel tankers with 8 to 16 chemical parties to transship.	68
Odfjell parcel tankers with more than 16 chemical parties to transship.	38

Implementing a drop and swap concept for tankers that transship between 8 and 16 cbm chemical parties, influences the most tankers per year.

Table 22: Number of tanker influenced per number of calls

Alternative	Number of tankers
Odfjell parcel tankers with less than 3 calls to make.	38
Odfjell parcel tankers with 3 to 5 calls to make.	84
Odfjell parcel tankers with more than 5 calls to make.	25

Implementing a drop and swap concept for tankers that need to make between 3 and 5 calls, influences the most tankers per year.

6.1.2 Port time

Port time of Odfjell parcel tankers need to be determined to determine the scores on the other criteria. For each different Odfjell parcel tanker group (e.g. the tankers of the Africa trade lane), the average port time is determined. With the port time and number of tankers per group knowing, the average port time off all Odfjell parcel tankers can be determined as shown in figure 21. Port time of the Odfjell parcel tankers in the other alternatives is determined in the same way. Odfjell parcel tankers of a specific trade lane are split up into 8 different groups.

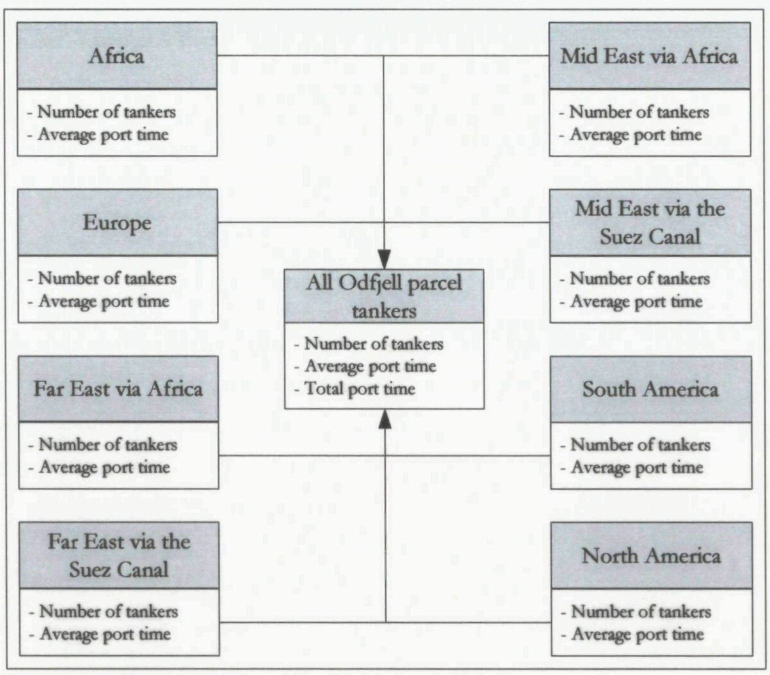


Figure 21: Determining the port time

For each Odfjell parcel tanker group, the average port time needs to be determined after implementing a drop and swap alternative. An alternative, in which chemicals of a specific Odfjell parcel tanker group are dropped and swapped, can be determined by changing the input variables of this specific group. In this way, changes due to the dropping and swapping of chemicals per specific Odfjell parcel tanker groups can be determined.

Variable input
To determine the port time per Odfjell parcel tanker group, the groups are split up into the tankers that visit OTR and tankers that do not visit OTR, as shown in figure 22.

Odfjell parcel tankers		
Visit OTR	Not visit OTR	Total
- Number of tankers - Number of calls (OTR/ other terminals) - Total throughput in cbm (OTR/ other terminals)	- Number of tankers - Number of calls - Total throughput in cbm	- Number of tankers - Number of calls - Total throughput in cbm

Figure 22: Variable input

Odfjell parcel tankers that visit OTR, also transship chemicals at terminals of other companies. Therefore the number of calls and the total throughput, of the tankers that visit OTR, are split up into OTR and other terminals as well.

Variable input factors to determine the port time are:
- The number of Odfjell parcel tankers that visit OTR.
- The number of calls Odfjell parcel tankers make in the port of Rotterdam.
- The total throughput of Odfjell parcel tankers at OTR and other terminals.

These variable input factors differ per sub-alternative that is implemented. As an example, the implementation of drop and swap alternative in which all chemicals transported by Odfjell parcel tanker of the Africa trade lane is given in figure 23.

Current situation

Africa trade lane		
Visit OTR	Not visit OTR	Total
- 1 - 3 (1/2) - 37.560 (24.511/13.049)	- 2 - 4 - 23.656	- 3 - 7 - 61.216

Drop and swap alternative

Africa trade lane		
Visit OTR	Not visit OTR	Total
- 3 - 3 (3/0) - 61.216 (61.216/0)	- 0 - 0 - 0	- 3 - 3 - 61.216

Figure 23: Changes in variable input

As can be seen in the figure, the total number of tankers and total throughput stays the same. The total number of calls is reduced because the tankers only need to visit OTR to transship chemicals. No tanker needs to visit OTR anymore.

Fixed input
Fixed input factors of the model, needed to determine the port time per Odfjell parcel tanker group, are shown in table 23.

Table 23: Fixed input factors to determine port time

Factor	Result
Average transshipment rate at OTR (cbm/hour).	350
Average transshipment rate at other terminals (cbm/hour).	255
Time per shift (hour)	5
Port delay per visit (hour)	21
Extra port delay per call (hour)	None
Operational delay per visit (hour)	13
Extra operational delay per call (hour)	7

The fixed input factors are explained and determined in the previous chapters of the report.

Formulas

Using the input factors, consequences in port time per action, due to implementing a drop and swap alternative, can be determined. As mentioned before, port time of Odfjell parcel tankers are split up into shifting time, port delay, operational delay, and transshipping time.

- Shifting time per Odfjell parcel tanker is determined multiplying the number of calls by the time per shift.
- Port delay is determined with the port delay per visit for each Odfjell parcel tanker that visits the port of Rotterdam.
- Operational delay is determined with the operational delay per visit plus multiplying the extra port delay per call by the number of calls an Odfjell parcel tanker makes in the port of Rotterdam.
- Transshipping time per Odfjell parcel tanker depends on the total throughput of the tankers at OTR divided by the average transshipment rate at OTR, and the total throughput of the tankers at other terminals divided by the average transshipment rate at the other terminals.

An overview of these formulas, with the fixed input factors included, is shown in table 24.

Table 24: Time per action per Odfjell parcel tanker

Action	Formula
Shifting time (hours)	Number of calls * 5
Port delay (hours)	21
Operational delay (hours)	13 + Number of calls * 7
Transshipping time (hours)	Throughput at OTR / 350 + Throughput at other terminals / 255
Total port time (hours)	Shifting time + port delay + operational delay + transshipping time

Output

When average port time and the number of Odfjell parcel tankers per group are known, the total port time can be determined. Multiplying the average port time per group by the number of tankers per group, the total port time of all Odfjell parcel tankers that visit the port of Rotterdam is determined by the sum of total port time per group. Dividing the total port time of all Odfjell parcel tankers by the number of Odfjell parcel tankers, gives the average port time per Odfjell parcel tanker.

6.1.3 Berth occupancies

Deep-sea berth and barge berth occupancy at OTR, after implementing a drop and swap alternative, needs to be determined.

Variable input

Variable input factors to determine the berth occupancies are the same as determining the port time:

- The number of Odfjell parcel tankers that visit OTR.
- The number of calls Odfjell parcel tankers make in the port of Rotterdam.
- The total throughput of Odfjell parcel tankers at OTR.

These variable input factors differ per alternative that is implemented.

Fixed input
Fixed input factors of the model, needed to determine the berth occupancies, are shown in table 25.

Table 25: Fixed input factors to determine berth occupancies

Factor	Result
Deep-sea berth occupation by other tankers (hours).	25.500
Available deep-sea berth capacity (hours).	43.800
Current barge berth occupation (hours).	44.676
Available barge berth capacity (hours).	148.920
Average transshipment rate at OTR (cbm/hour).	350

The fixed input factors are explained and determined in the previous chapters of the report. With the available deep-sea berth and barge berth capacities, the finished construction of the 5th deep-sea berth is taken into account.

Formulas
Using the input factors, consequences in the berth occupancies due to implementing a drop and swap alternative can be determined. With the implementation of a drop and swap alternative, needed deep-sea berth capacity and needed barge berth capacity at OTR increases.

- Needed deep-sea berth capacity is determined by adding the transshipment time and operational delay of all Odfjell parcel tankers at OTR to the occupation of the deep-sea berths by other tankers.
- Needed barge berth capacity is determined by adding the total extra throughput at OTR divided by the average transshipment rate at OTR to the current barge berth occupation.

An overview of these formulas, with the fixed input factors included, is shown in table 26.

Table 26: Needed berth capacities

Action	Formula
Needed deep-sea berth capacity (hours/year)	Total transshipping time of Odfjell parcel tankers at OTR + Total operational delay of Odfjell parcel tankers at OTR + 25.500
Needed barge berth capacity (hours / year)	(Extra throughput / 350) + 44.676

Output
Deep-sea berth occupancy at OTR can be determined dividing the needed capacity by the available capacity of the deep-sea berths. Barge berth occupancy at OTR can be determined dividing the needed capacity by the available capacity of the barge berths.

6.1.4 Average waiting times
Implementing a drop and swap alternative, increases the average waiting time to moor at OTR. Average waiting time to moor at OTR depends on the deep-sea berth occupancy and the number of deep-sea berths at OTR. After constructing the extra deep-sea berth, a total number of 5 deep-sea berths at OTR are operational.
Concerning the average waiting time, an M/M/c queuing system is assumed. Using this queuing system, waiting times per alternatives can be determined. Formulas used in this queuing system are given in appendix K.

6.1.5 Costs for Odfjell

By implementing a drop and swap alternative, extra costs and reduction in costs are realized for Odfjell. Extra profit for Odfjell, with implementing a drop and swap alternatives, needs to be determined.

Variable input

Variable input factors to determine the reduction in costs, the extra costs, and the loss in revenues for Odfjell are:

- The extra number of chemical parties transshipped at OTR.
- The parcel tanker costs per port time hour.
- The average percentage of extra throughput that needs temporary storage.
- The average size of the storage tanks with non-dedicated storage capacity.

The total number of chemical parties transshipped by the parcel tankers stays the same, but more chemical parties are transshipped at OTR. Depending on the size of the tankers that are influenced in the drop and swap alternative, the costs per tanker per port time hour are determined. The number of storage tanks needed depends on the percentage of extra throughput that needs temporary storage and the size of the storage tank, which is variable with non-dedicated storage capacity for the temporary storage of dropped and swapped chemicals. This variable input, together with the time of storage occupation per transshipment is explained in appendix M.

Fixed input

Fixed input factors of the model, needed to determine the port time per Odfjell parcel tanker group, are shown in table 27.

Table 27: Fixed input factors to determine costs for Odfjell

Factor	Result
Costs per shift	€ 5.000
Costs per transported cbm of chemicals by barge	€ 4,50
Costs per chemical party checked by surveyor	€ 500
Percentage of extra throughput that needs temporary storage	70%
Loss in revenues per tank per year due to dedicated storage use	€ 130.000
Loss in revenues per deep-sea berth per hour due to deep-sea berth use	€ 500

The fixed input factors are explained and determined in the previous chapters of the report.

Formulas

Using the input factors, the consequences in the costs for Odfjell due to the implementation of a drop and swap alternative can be determined. With the implementation of a drop and swap alternative, reduction in costs, extra costs, and loss in revenues for Odfjell are realized.

- The reduction in costs for Odfjell is determined multiplying the reduction in total port time hours by the parcel tanker costs per port time hour, plus, multiplying the reduction in total number of calls by the costs per shift.
- The extra costs for Odfjell are split up into extra transportation and extra transshipment costs. Extra transportation costs are determined multiplying the total extra cbm of chemicals transshipped at OTR by the costs to transport one cbm of chemical by barge. The extra transshipment costs are determined multiplying the number of extra chemical parties transshipped at OTR by the costs for surveyors to check one chemical party.

- The loss in revenues for Odfjell is split up into the loss in storage revenues and loss in deep-sea berth revenues. Loss in storage revenues is determined in two ways: with the use of dedicated storage capacity and with the use of non-dedicated storage capacity. With dedicated storage capacity the number of tanks needed is multiplied by the loss in revenues for using one tank a whole year. With non-dedicated storage capacity, the number of tanks is multiplied by the loss in revenues for using one tank for two weeks (This loss in revenue with non-dedicated storage capacity depends on the size of the tank).

  Loss in deep-sea berth revenue is determined multiplying the deep-sea berth capacity used to drop and swap chemicals at OTR by the loss in revenues of deep-sea berth capacity per hour.

An overview of these formulas, with the fixed input factors included, is shown in table 28.

Table 28: Changes in costs for Odfjell

Action	Formula
Total reduction in costs (€/year)	(They reduction in port time hours * tanker costs per port time hour) + (The reduction in the number of calls * 5.000)
Extra transportation costs (€/year)	The extra throughput at OTR * 4,50
Extra transshipment costs (€/year)	The extra number of chemical parties transshipped at OTR * 500
Loss in revenues due to storage use (€/year)	Extra storage tanks needed * loss in revenues per tank (Appendix M)
Loss in revenues due to deep-sea berth use (€/year)	The extra deep-sea berth capacity needed * 500

Output

Total extra profit for Odfjell can be determined with all financial consequences for Odfjell due to the implementation of a drop and swap alternative. Which costs factors need to be taken into account depends on the scenario in which the alternative is implemented (chapter 5.3).

6.2 Reflection on model

To investigate reliability of the results generated by the Excel model, verification and validation of the model is necessary. With the verification, the model is tested on quantitative correctness. During the research, assumptions have been made, which are included in the Excel model. An overview of these assumptions is given in appendix O. Validation is done to decide whether the model is an accurate representation of the real world from the perspective of the intended use of the model.

Verification

Verification is a process that is used to evaluate whether the model is quantitative correct. Verification of the model is done by checking the units after calculations, and by comparing the total values of the different alternative values, which are supposed to be equal. This verification is shown in appendix N. From this verification, there is concluded that the model is quantitative correct.

Model validation

Validation is the process of determining the degree to which the Excel model is an accurate representation of the real world from the perspective of the intended uses of the Excel model. In appendix P, a check of the Excel model towards the current situation is done. From the model validation, there is concluded that the model gives an accurate representation of the real world concerning the current situation

6.3 Summary and conclusions

With the realization of a numerical model in the computer program Microsoft Excel, results of implementing several drop and swap alternatives are determined. Variable input (which differ per alternative) and fixed input (which are the same for every alternative) are used as input for the formulas in the model. These formulas result in the output of the model. An overview is given in figure 24.

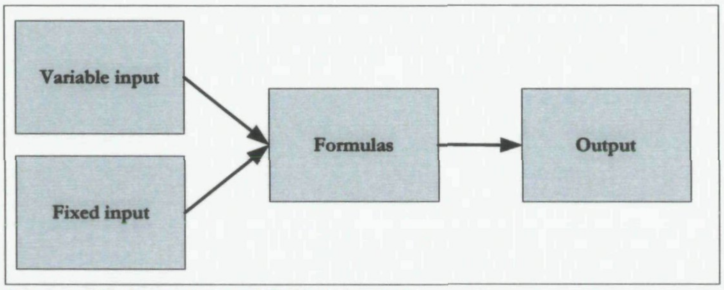


Figure 24: Overview of Excel model

By changing the variable input per alternative, results per alternative are determined. The different output factors of the model are given in table 29.

Table 29: Overview of output

Output	Measure
Total port time of the Odfjell parcel tankers that visit Rotterdam.	Hours
Average port time per Odfjell parcel tanker that visits Rotterdam.	Hours
Deep-sea berth occupancy of OTR	Percentage
Barge berth occupancy of OTR	Percentage
Average waiting time for tanker to moor at OTR	Hours
Extra profit for Odfjell	€/year

Extra profit for Odfjell depends on the scenario in which the drop and swap alternative is implemented. For each scenario, a different extra profit for Odfjell is determined. Within the model, the system boundaries concerning maintaining OTR's policy of 'first come, first serve' and guaranteeing chemical quality and quantity after the extra transshipment are taken into account and fulfilled.

Verification and validation of the model show that the Excel model is formal correct.

7 Results

Using the Excel model, results of implementing different drop and swap alternatives are determined on the logistical and financial criteria. These results are shown (7.1) followed by a validation of the results (7.2). Finally, a summary and conclusions of the results are given (7.3).

7.1 Results of alternatives

Results of implementing different drop and swap alternatives are spit up into the results for the logistical criteria and the extra profit (financial criteria) for Odfjell. Logistical criteria are the deep-sea berth occupancy at OTR, the barge berth occupancy at OTR, and the average waiting time for tankers to moor at OTR. As formulated in the system boundaries (chapter 4.4), deep-sea berth occupancy must be lower than 85% and barge berth occupancy must be lower that 75%. Current average waiting time for tankers to moor at OTR is 11,5 hours.
For each scenario, as described in chapter 5.3, the extra profit for Odfjell per sub-alternative is determined, together with the extra profit per tanker in that sub-alternative. The input variables, changes in port time, changes in detailed costs, etc. can be found in appendix Q.

7.1.1 Drop and swap alternative for specific trade lane

Odfjell parcel tankers use a total of 8 different trade lanes to transport chemicals from all over the world to the port of Rotterdam. Results on the logistical criteria, with the implementation of different sub-alternatives, are shown in table 30.

Table 30: Results of logistical criteria (specific trade lane)

	1a	1b	1c	1d	1e	1f	1g	1h
Deep-sea berth occupancy at OTR (%).	65	74	67	68	65	66	73	69
Barge berth occupancy at OTR (%).	30	32	30	31	30	30	32	31
Average waiting time to moor at OTR (hours).	5,5	6	6	6	5,5	6	6	6

1a = Africa trade lane, 1b = Europe trade lane, 1c =Far East trade lane (via Africa), 1d = Far East trade lane (via Suez Canal), 1e = Mid East trade lane (via Africa), 1f = Mid East trade lane (via Suez Canal), 1g = South America trade lane, 1h = North America trade lane

Table 30 shows that with implementing one of these sub-alternatives, deep-sea berth occupancy does not increase 85% and barge berth occupancy does not increase 75%. Average waiting times for tankers to moor at OTR are between 5,5 and 6 hours.
Results of extra profit for Odfjell, per sub alternative, are given in table 31. Extra profit is determined for all scenarios and measured in K. €/year[22].

Table 31: Extra profit for Odfjell (specific trade lane)

	1a	1b	1c	1d	1e	1f	1g	1h
Scenario A (K. €/year).	-66	-1.288	214	216	58	-22	-751	-25
Scenario B1 (K. €/year).	-1.235	-3.368	-2.516	-2.124	-2.022	-1.582	-2.831	-2.235
Scenario B2 (K. €/year).	-193	-4.156	-1.003	-1.836	-330	-512	-5.903	-3.199
Scenario C1 (K. €/year).	-1.278	-5.081	-2.828	-2.650	-2.089	-1.697	-4.463	-2.990
Scenario C2 (K. €/year).	-245	-5.869	-1.315	-2.362	-398	-627	-7.535	-3.953

1a = Africa trade lane, 1b = Europe trade lane, 1c =Far East trade lane (via Africa), 1d = Far East trade lane (via Suez Canal), 1e = Mid East trade lane (via Africa), 1f = Mid East trade lane (via Suez Canal), 1g = South America trade lane, 1h = North America trade lane

Table 31 shows that, in scenario B and C, no sub-alternative realizes extra profit for Odfjell. In scenario A, three different sub alternatives realize extra profit for Odfjell. Most extra profit for Odfjell in scenario A is to drop and swap all chemicals transported by Odfjell parcel tankers of

[22] 1 K. € = 1.000 €

the Far East trade lane (via the Suez Canal). Results of the extra profit per tanker in the sub-alternatives are shown in table 32. With these results, only scenarios in which non-dedicated storage capacity is used are taken into account.

Table 32: Extra profit for Odfjell per tanker (specific trade lane)

	1a	1b	1c	1d	1e	1f	1g	1h
Scenario A (K. €/year).	-22	-25	27	18	29	-4	-17	-1
Scenario B2 (K. €/year).	-64	-80	-125	-153	-165	-102	-134	-152
Scenario C2 (K. €/year).	-82	-113	-98	-122	-105	-125	-171	-188

1a = Africa trade lane, 1b = Europe trade lane, 1c =Far East trade lane (via Africa), 1d = Far East trade lane (via Suez Canal), 1e = Mid East trade lane (via Africa), 1f = Mid East trade lane (via Suez Canal), 1g = South America trade lane, 1h = North America trade lane

Table 32 shows the extra profit per tanker is the highest for the Mid East trade lane (via Africa) in scenario A. In scenario B and C, no drop and swap for individual tankers realizes extra profit.

7.1.2 Drop and swap alternative for specific transshipment quantity

Each Odfjell parcel tanker needs to tranship a different chemical quantity in the port of Rotterdam. These tankers are split up into three different 'quantity' groups. Results on the logistical criteria, with implementation of these different sub-alternatives, are shown in table 33.

Table 33: Logistical criteria (specific transshipment quantity)

	2a	2b	2c
Deep-sea berth occupancy at OTR (%).	68	82	71
Barge berth occupancy at OTR (%).	31	35	32
Average waiting time to moor at OTR (hours).	6	8	8

2a = less than 20.000 cbm, 2b = between 20.000 and 40.000 cbm, 2c =more than 40.000 cbm

Table 33 shows that with implementing one of these sub-alternatives, deep-sea berth occupancy does not increase 85% and barge berth occupancy does not increase 75%. Average waiting times for tankers to moor at OTR are between 6 and 8 hours.
Results of extra profit for Odfjell, per sub-alternative, are given in table 34. Extra profit is determined for all scenarios and measured in K. €/year.

Table 34: Extra profit for Odfjell (specific transshipment quantity)

	2a	2b	2c
Scenario A (K. €/year)	-520	-1.413	2.443
Scenario B1 (K. €/year)	-1.300	-3.753	-547
Scenario B2 (K. €/year)	-1.353	-12.882	-3.455
Scenario C1 (K. €/year)	-1.745	-7.185	-1.842
Scenario C2 (K. €/year)	-1.798	-16.351	-4.750

2a = less than 20.000 cbm, 2b = between 20.000 and 40.000 cbm, 2c =more than 40.000 cbm

Table 34 shows that, in scenario B and C, no sub alternative realizes extra profit for Odfjell. In scenario A, implementing a drop and swap for all chemicals transported by Odfjell parcel tankers, that need to transship a total chemical quantity of more than 40.000 cbm in the port of Rotterdam, realizes extra profit. Results of the extra profit per tanker in the sub-alternatives are shown in table 35 on the next page. With these results, only scenarios in which non-dedicated storage capacity is used are taken into account.

Table 35: Extra profit for Odfjell per tanker (specific transshipment quantity)

	2a	2b	2c
Scenario A (K. €/year).	-17	-15	106
Scenario B2 (K. €/year).	-44	-139	-150
Scenario C2 (K. €/year).	-58	-176	-207

2a = less than 20.000 cbm, 2b = between 20.000 and 40.000 cbm, 2c =more than 40.000 cbm

Table 35 shows the extra profit per tanker is the highest for the Odfjell parcel tankers that need to transship more than 40.000 cbm of chemicals in the port of Rotterdam in scenario A. In scenario B and C, no drop and swap for individual tankers realizes extra profit.

7.1.3 Drop and swap for specific number of chemical parties

Each Odfjell parcel tanker needs to transship a different number of chemical parties in the port of Rotterdam. These tankers are split up into three different 'number of chemical parties' groups. Results on the logistical criteria, with implementation of these different sub-alternatives, are shown in table 36.

Table 36: Logistical criteria (specific number of chemical parties)

	3a	3b	3c
Deep-sea berth occupancy at OTR (%).	71	77	73
Barge berth occupancy at OTR (%).	31	33	32
Average waiting time to moor at OTR (hours).	6	7	6

3a = less than 8 chemical parties, 3b = between 8 and 16 chemical parties, 3c =more than 16 chemical parties

Table 36 shows that with implementing one of these sub-alternatives, deep-sea berth occupancy does not increase 85% and barge berth occupancy does not increase 75%. Average waiting times for tankers to moor at OTR are between 6 and 7 hours.

Results of extra profit for Odfjell, per sub-alternative, are given in table 37. Extra profit is determined for all scenarios and measured in K. €/year.

Table 37: Extra profit for Odfjell (specific number of chemical parties)

	3a	3b	3c
Scenario A (K. €/year)	-1.717	-814	1.860
Scenario B1 (K. €/year)	-2.887	-3.024	-1.000
Scenario B2 (K. €/year)	-4.585	-11.995	-5.113
Scenario C1 (K. €/year)	-3.980	-5.421	-2.684
Scenario C2 (K. €/year)	-5.678	-14.391	-6.797

3a = less than 8 chemical parties, 3b = between 8 and 16 chemical parties, 3c =more than 16 chemical parties

Table 37 shows that, in scenario B and C, no sub alternative realizes extra profit for Odfjell. In scenario A, implementing a drop and swap for all chemicals transported by Odfjell parcel tankers, that need to transship a more than 16 chemical parties in the port of Rotterdam, realizes extra profit. Results of the extra profit per tanker in the sub alternatives are shown in table 38. With these results, only scenarios in which non-dedicated storage capacity is used are taken into account.

Table 38: Extra profit for Odfjell per tanker (specific number of chemical parties)

	3a	3b	3c
Scenario A (K. €/year).	-42	-12	49
Scenario B2 (K. €/year).	-112	-176	-135
Scenario C2 (K. €/year).	-138	-212	-179

3a = less than 8 chemical parties, 3b = between 8 and 16 chemical parties, 3c =more than 16 chemical parties

Table 38 shows the extra profit per tanker is the highest for the Odfjell parcel tankers that need to transship more than 16 chemical parties in the port of Rotterdam in scenario A. In scenario B and C, no drop and swap for individual tankers realizes extra profit.

7.1.4 Drop and swap for specific number of calls to make

Each Odfjell parcel tanker needs to make a different number of calls in the port of Rotterdam. These tankers are split up into three different 'number of calls' groups. Results on the logistical criteria, with the implementation of these sub-alternatives, are shown in table 39.

Table 39: Logistical criteria (specific number of calls)

	4a	4b	4c
Deep-sea berth occupancy at OTR (%).	70	80	71
Barge berth occupancy at OTR (%).	31	34	32
Average waiting time to moor at OTR (hours).	6	7	6

4a = less than 3 calls, 4b = between 3 and 5 calls, 4c =more than 5 calls

Table 39 shows that with implementing one of these sub-alternatives, deep-sea berth occupancy does not increase 85% and barge berth occupancy does not increase 75%. Average waiting times for tankers to moor at OTR are between 6 and 7 hours.

Results of extra profit for Odfjell, per sub-alternative, are given in table 40. Extra profit is determined for all scenarios and measured in K. €/year.

Table 40: Extra profit for Odfjell (specific number of calls)

	4a	4b	4c
Scenario A (K. €/year)	-2.088	-899	2.268
Scenario B1 (K. €/year)	-3.388	-3.629	-592
Scenario B2 (K. €/year)	-6.142	-11.242	-1.361
Scenario C1 (K. €/year)	-4.389	-6.648	-1.744
Scenario C2 (K. €/year)	-7.143	-14.261	-2.513

4a = less than 3 calls, 4b = between 3 and 5 calls, 4c =more than 5 calls

Table 40 shows that, in scenario B and C, no sub-alternative realizes extra profit for Odfjell. In scenario A, implementing a drop and swap for all chemicals transported by Odfjell parcel tankers, that need to make more than 5 calls in the port of Rotterdam, realizes extra profit. Results of the extra profit per tanker in the sub-alternatives are shown in table 41. With these results, only scenarios in which non-dedicated storage capacity is used are taken into account.

Table 41: Extra profit for Odfjell per tanker (specific number of calls)

	4a	4b	4c
Scenario A (K. €/year).	-55	-11	91
Scenario B2 (K. €/year).	-162	-134	-54
Scenario C2 (K. €/year).	-188	-170	-101

4a = less than 3 calls, 4b = between 3 and 5 calls, 4c =more than 5 calls

Table 41 shows extra profit per tanker is the highest for the Odfjell parcel tankers that need to make more than 5 calls in the port of Rotterdam in scenario A. In scenario B and C, no drop and swap for individual tankers realizes extra profit.

7.2 Validation of results

Validation of the results is necessary due to the assumptions that have been done during the research. An overview of all assumptions is given in appendix O. Validation of the results is done with a sensitivity analysis of the 4 less reliable assumptions. Changes in the values of these assumptions are made (of 20% more and 20% less[23]), and the impact of these changes on the results is analyzed. An overview of the assumptions that are validated with the sensitivity analysis is given in table 42

Table 42: Assumptions that are validated

Assumption	Current	Analyzed values
Average transshipment rate at OTR (cbm per hour).	350	280 & 420
Loss in storage revenues, per dedicated storage tank (euro per year).	130.000	104.000 & 156.000
Loss in storage revenues, per non-dedicated storage tank (euro per two weeks).	Variable	-20% & +20%
Percentage of extra throughput per tanker with temporary storage (percentage).	Variable	-20% & +20%

Results on the logistical and financial criteria are shown in appendix R. There is concluded that the impact on extra profit for Odfjell in the different scenario, differs per assumption. The average transshipment rate at OTR has the most impact on the extra profit for Odfjell, especially in scenario A this impact was high (maximal 80%). Other assumptions have much less impact on the extra profit for Odfjell.

7.3 Summary and conclusion

After fulfilling the system boundaries of maintaining OTR's policy of 'first come first serve' and guaranteeing chemical quality and quantity after the extra transshipment by implementing these boundaries in the Excel model, in this chapter results on the other system boundaries are determined. The system boundaries, which state that deep-sea berth occupancy must be lower than 85% and barge berth occupancy must be lower than 75%, are fulfilled in all alternatives. Average waiting time for tankers to moor at OTR (also a criterion but no system boundary) is between 5,5 and 8 hours for each alternative, which is much lower than the current average waiting time of 11,5 hours.

The system boundary, concerning the extra profit of different alternatives for Odfjell, is not fulfilled in each alternative and depends on the scenario in which it is implemented.

- Implementing a drop and swap alternative, in which all chemicals transported by Odfjell parcel tankers of a specific trade lane, can realize extra profit with several sub-alternatives in scenario A. No sub-alternative realizes extra profit in scenario B or C. Most extra profit is realized when a sub-alternative is implemented in which all chemicals, transported by the Odfjell parcel tankers of the Far East (via the Suez Canal) trade lane, are dropped and swapped. If individual tankers are dropped and swapped, tankers of the Mid Easy (via Africa) trade lane realize most extra profit.
- Implementing a drop and swap alternative, in which all chemicals transported by Odfjell parcel tankers that need to transship a specific quantity of chemicals in the port of Rotterdam, can realize extra profit in scenario A. In scenario A, this alternative only realizes extra profit when Odfjell parcel tankers that need to transship more than 40.000 cbm of chemicals in the port of Rotterdam are dropped and swapped. No sub alternative realizes extra profit in scenario B or C.
- Implementing a drop and swap alternative, in which all chemicals transported by Odfjell parcel tankers that need to transship a specific number of chemical parties in the port of

[23] From discussion after presenting the current results and current assumptions at Odfjell

Rotterdam, can realize extra profit in scenario A. In scenario A, the alternative only realizes extra profit when Odfjell parcel tankers that need to transship more than 16 chemical parties in the port of Rotterdam are dropped and swapped. No sub-alternative realizes extra profit in scenario B or C.

- Implementing a drop and swap alternative, in which all chemicals transported by Odfjell parcel tankers that need make a specific number of calls in the port of Rotterdam, can realize extra profit in scenario A. In scenario A, the alternative only realizes extra profit when Odfjell parcel tankers that need to make more than 5 calls in the port of Rotterdam are dropped and swapped. No sub alternative realizes extra profit in scenario B or C.

An overview of the most extra profit per sub-alternative per scenario is given in table 43.

Table 43: Highest extra profit per scenario for Odfjell

Scenario	Drop and swap alternative with the highest extra profit	Profit
Scenario A (K. €/year)	Odfjell parcel tankers with more than 40.000 cbm of chemicals to transship.	2.443
Scenario B1 (K. €/year)	Odfjell parcel tankers with more than 40.000 cbm of chemicals to transship.	-547
Scenario B2 (K. €/year)	Odfjell parcel tanker of the Africa trade lane.	-193
Scenario C1 (K. €/year)	Odfjell parcel tanker of the Africa trade lane.	-1.278
Scenario C2 (K. €/year)	Odfjell parcel tanker of the Africa trade lane.	-245

As can be concluded from table 43, only extra profit for Odfjell is made in scenario A. The two most interesting drop and swap alternatives are to drop and swap all chemicals of Odfjell parcel tankers that need to transship more than 40.000 cbm of chemicals (scenario A and B1), or to drop and swap all chemicals of Odfjell parcel tankers that of the Africa trade lane (scenario B2, C1, and C2).

However, extra profit per alternative depends on the number of Odfjell parcel tankers that are influenced per alternative. Extra profit per tanker is only determined with the use of non-dedicated storage capacity. Highest extra profit per alternative per tanker is given in table 44.

Table 44: Highest extra profit per tanker for Odfjell

Scenario	Drop and swap alternative with the highest extra profit per tanker	Profit
Scenario A (K. €/year)	Odfjell parcel tankers with more than 40.000 cbm of chemicals to transship.	106
Scenario B2 (K. €/year)	Odfjell parcel tankers with less than 20.000 cbm of chemicals to transship.	-44
Scenario C2 (K. €/year)	Odfjell parcel tankers with less than 20.000 cbm of chemicals to transship.	-58

As can be concluded from table 44, only extra profit for Odfjell per tanker is made in scenario A. The two most interesting drop and swap alternatives per tanker, are to drop and swap all chemicals of Odfjell parcel tankers that need to transship more than 40.000 cbm of chemicals (scenario A), or less than 20.000 cbm of chemicals (scenario B2 and C2)

A validation of the results shows that assumptions, made during the research, have a different magnitude of impact on the results. Especially the average transshipment rate at OTR has a high impact on the final results. Further research, towards these assumptions, could increase the reliability of assumptions and final results. Assumptions made during the research are shown in appendix O.

8 Final conclusions and recommendations

Conclusions towards the main research question and answer to the sub-questions are formulated in paragraph 8.1 and recommendations, concerning future research, for Odfjell are given in paragraph (8.2). Main research question of the report is: "What are possible drop and swap alternatives for loading and discharging chemicals of Odfjell parcel tankers at Odfjell Terminals Rotterdam, and which alternative is the most attractive one?"

8.1 Conclusions

A possible alternative is to drop and swap all chemicals, transported by specific Odfjell parcel tankers that visit the port of Rotterdam, at OTR. In total, four different alternatives are analyzed:

1. Drop and swap all chemicals transported by Odfjell parcel tankers of a specific trade lane.
2. Drop and swap all chemicals transported by Odfjell parcel tankers with a specific chemical quantity to transship in the port of Rotterdam.
3. Drop and swap all chemicals transported by Odfjell parcel tankers with a specific number of chemical parties to transship in the port of Rotterdam.
4. Drop and swap all chemicals transported by Odfjell parcel tankers with a specific number of calls to make in the port of Rotterdam.

For each alternative, sub-alternatives are formulated concerning the specific trade lanes, chemical quantities, number of chemical parties, and number of calls. Each sub-alternative is analyzed towards logistical and financial criteria for Odfjell.

From the case study, it can be concluded that due to the construction of an extra deep-sea berth at OTR, boundaries concerning the deep-sea berth and barge berth occupancy are fulfilled in each alternative. Also waiting time to moor at OTR in the alternatives will be shorter than in the current situation.
Extra profit for Odfjell, in comparison with the current situation, is not realized in all sub alternatives. Extra profit depends on the reduction in costs, extra transportation costs, extra transshipment costs, and loss in revenues for Odfjell with the implementation of a drop and swap alternative. Extra profit for Odfjell is determined in three different scenarios. These scenarios take into account different loss in revenues for Odfjell, dependent on the demand for deep-sea berth and storage capacity at OTR.

When the demand for deep-sea berth and storage capacity decreases (scenario A), a drop and swap alternative, which realizes extra profit for Odfjell can be implemented. In this scenario, the alternative with the highest extra profit for Odfjell is to implement a drop and swap concept for all chemicals transported by Odfjell parcel tanker that need to transship more than 40.000 cbm of chemicals in the port of Rotterdam. Extra profit for Odfjell is circa 2.4 million euro per year, or circa 106 thousand euro per tanker in this scenario. When demand remains as in the current situation or increases (Scenario B and C), implementing a drop and swap alternative does not realize extra profit for Odfjell.

During the research, assumptions have been made. Assumptions influence the reliability of the results. Further research, towards these assumptions, could increase the reliability of the assumptions and final results.

Answers of the sub questions

To answer the main research question, several sub-questions are answered during the research. Answers of the sub-questions are given.

SQ1: How does Odfjell currently organize the transportation and storage of chemicals?

Odfjell consists of two separate profit centers, of which Odfjell Shipping (OS) is responsible for transportation of chemicals, and Odfjell Terminals Rotterdam (OTR) is responsible for storage of chemicals in the port of Rotterdam.

In 2008, 147 Odfjell parcel tankers visited 26 different terminals in the port of Rotterdam to tranship almost 4,5 million cbm of chemicals. Each tanker needed to visit an average of 4 different terminals to tranship almost 30.000 cbm of chemicals divided over 13 chemical parties. Average port time per tanker was almost 8 days, of which shifting of the tanker between different terminals caused 10%, actual transshipment of chemicals caused 60%, and delays (e.g. waiting times) caused 30% of the total port time per tanker. For each Odfjell parcel tanker that visits the port of Rotterdam, a shipping agent of OS design a rotation plan. Goal of this rotation plan is to tranship all chemicals with a minimum port time for the tanker, a minimum number of berths to visit, and at minimal costs. Board-board transshipments are used frequently to achieve this goal.

OTR has 4 deep-sea berth terminals and 15 barge berths. In 2008 deep-sea berth and barge berth occupancy was 80% and 35% respectively. A 5th deep-sea berth is under construction and planned to be finished in the summer of 2009. Total throughput at OTR was almost 4,5 million cbm of chemicals, of which circa 750 thousand cbm was throughput of Odfjell parcel tankers (17%). Average waiting time for tankers to moor at OTR in 2008 was 11,5 hours. Chemical storage capacity at OTR is circa 670.000 cbm of which more than 97% was occupied in 2008.

Quick wins in the performance of Odfjell's current processes are possible. A quick win in port time is possible by improving communication between the involved actors (especially between OTR and OS). Delays per Odfjell parcel tanker can be reduced, which results in a reduction in port time. Another quick win in port time is possible by increasing the average transshipment rate at OTR. An increase of the average transshipment rate at OTR results in a lower port time for Odfjell parcel tankers and a lower deep-sea berth occupancy at OTR. Also a quick win in storage profit is possible. Extra storage capacity could be created at OTR, by storing chemicals that need to be stored at OTR for a long period (e.g. one year), at a different, less valuable, location.

SQ2: What are the consequences for Odfjell, when a drop and swap concept is implemented at OTR for the Odfjell parcel tankers?

Implementing a drop and swap concept has consequences for Odfjell (OS and OTR) in transportation, transshipment, and storage of chemicals.

Consequences for OS are in the transportation of chemicals. By implementing a drop and swap concept, average port time of the Odfjell parcel tankers is reduced due to a reduction in the number of terminals that need to be visited. Chemicals that are dropped and swapped at OTR need to be distributed from, and collected at OTR. Collection and distribution is done with barges.

Consequences for OTR are in the transshipment and storage of chemicals. By implementing a drop and swap concept, total chemical throughput at OTR increases. This increase in throughput, results in higher berth occupancies and a longer average waiting time for tankers to moor at OTR. Transshipment, of chemicals that are being dropped and swapped, can take place with board-board transshipment (directly from the tanker to the barge or vice versa) or with temporary storage at OTR (from the tanker to a shore tank and from there to a barge). Transshipping all chemicals board-board is not possible due to limited board-board connections. When temporary storage is necessary, more storage capacity at OTR is occupied. Because of the extra transshipment, customers (owners of the chemicals) need a guaranteed chemical quality and quantity after this transshipment. Surveyors are needed to check this chemical quality and quantity after the extra transshipment. Costs for Odfjell, due to consequences in transportation, transshipment, and storage of chemicals, change.

SQ3: On which criteria can different drop and swap alternatives be scored?

Criteria are formulated to score and compare different drop and swap alternatives. Criteria are split up into logistical criteria, which measure the logistical feasibility of an alternative, and financial criteria, which measure the extra profit of an alternative. Financial criteria are determined considering an associated profit center for OTR and OS.

Logistical criteria are:
1. The deep-sea berth occupancy at OTR.
2. The barge berth occupancy at OTR.
3. The average waiting time for tankers to moor at OTR.

Financial criteria are:
4. The reduction in transportation costs for Odfjell.
5. The extra transportation costs for Odfjell.
6. The extra transshipment costs for Odfjell.
7. The loss in revenue for Odfjell, due to extra deep-sea berth capacity needed at OTR.
8. The loss in revenue for Odfjell, due to extra storage capacity needed at OTR.

System boundaries, criteria that have to be fulfilled, are formulated for the drop and swap alternatives. If not all system boundaries are fulfilled in an alternative it is not implemented.

System boundaries are:
1. Deep-sea berth occupancy at OTR must be lower than 85%.
2. Barge berth occupancy at OTR must be lower than 75%.
3. The reduction in costs must exceed the extra costs for Odfjell.
4. OTR's policy of 'first come, first serve' must be maintained.
5. Chemical quality and quantity must be guaranteed after the extra transshipment.

SQ4: What are potential drop and swap alternatives for Odfjell?

After analyzing different drop and swap concepts, a total of four different drop and swap alternatives are formulated:
1. Drop and swap Odfjell parcel tankers of a specific trade lane.
2. Drop and swap Odfjell parcel tankers with a specific chemical quantity to transship in the port of Rotterdam.
3. Drop and swap Odfjell parcel tankers with a specific number of chemical parties to transship in the port of Rotterdam.
4. Drop and swap Odfjell parcel tankers with a specific number of calls to make in the port of Rotterdam.

Each of the alternatives is split up into several sub-alternatives. Each sub-alternative is analyzed on the formulated logistical and financial criteria using a Microsoft Excel model. Within this model, the system boundaries of maintaining OTR's policy of 'first come, first serve' and surveyors checking the quality and quantity of the chemicals to guarantee this quantity and quality of the chemicals after the extra transshipment are taken into account. To determine the extra profit (reduction in costs minus the extra costs) for Odfjell of the sub-alternatives, three future scenarios, dependent on the demand for deep-sea berth capacity and storage capacity at OTR are formulated:

A. Demand for deep-sea berth and storage capacity decreases in the near future. With a reduction in demand for deep-sea berth and storage capacity, no loss in revenues is realized with the implementation of a drop and swap alternative. Deep-sea berth and storage capacity are not fully used, which results in free capacity for chemicals that are dropped and swapped.
B. Demand for deep-sea berth and storage capacity is equal to the current demand. Loss in storage revenues is realized with the implementation of a drop and swap alternative due to temporary storage of dropped and swapped chemicals. No loss in deep-sea berth revenues is realized because deep-sea berth occupancy is not fully used in this scenario. Storage capacity, for dropped and swapped chemicals, can be organized in two ways:
    1. Use dedicated storage capacity for dropped and swapped chemicals. This storage capacity is used only for dropped and swapped chemicals.
    2. Use non-dedicated storage capacity for dropped and swapped chemicals. Storage capacity for dropped and swapped chemicals is created last minute. If no chemicals are dropped and swapped, storage capacity is for other chemicals
C. Demand for deep-sea berth and storage capacity increases in the near future. Loss in deep-sea berth and storage revenues is realized for Odfjell with the implementation of a drop and swap alternative. Because of increasing demand, Odfjell has to refuse customers to use deep-sea berth and storage capacity. Storage capacity, for dropped and swapped chemicals, can be organized in two ways:
    1. Use dedicated storage capacity for dropped and swapped chemicals. This storage capacity is used only for dropped and swapped chemicals.
    2. Use non-dedicated storage capacity for dropped and swapped chemicals. Storage capacity for dropped and swapped chemicals is created last minute. If no chemicals are dropped and swapped, storage capacity is for other chemicals

For each sub-alternative, the extra profit for Odfjell per scenario is determined.

SQ5: Which drop and swap alternative is the most attractive one for Odfjell?
Due to the construction of the 5th deep-sea berth at OTR, the system boundaries, which state that deep-sea berth occupancy must be lower than 85% and barge berth occupancy must be lower than 75%, are fulfilled in all alternatives. Average waiting time for tankers to moor at OTR (also a criterion but no system boundary) is between 5,5 and 8 hours dependent on the sub-alternative, which is much shorter than the current average waiting time of 11,5 hours.
The system boundary, concerning the extra profit for Odfjell, is not fulfilled in all sub-alternatives and depends on the scenario in which it is implemented. An overview of the highest extra profit per sub-alternative per scenario is given in table 45.

Table 45: Highest extra profit per scenario for Odfjell

Scenario	Drop and swap alternative with the highest extra profit	Profit
Scenario A (K. €/year)	Odfjell parcel tankers with more than 40.000 cbm of chemicals to transship.	2.443
Scenario B1 (K. €/year)	Odfjell parcel tankers with more than 40.000 cbm of chemicals to transship.	-547
Scenario B2 (K. €/year)	Odfjell parcel tanker of the Africa trade lane.	-193
Scenario C1 (K. €/year)	Odfjell parcel tanker of the Africa trade lane.	-1.278
Scenario C2 (K. €/year)	Odfjell parcel tanker of the Africa trade lane.	-245

As can be concluded from table 45, extra profit for Odfjell is only realized in scenario A. The two most interesting drop and swap sub-alternatives are to drop and swap all chemicals of Odfjell parcel tankers that need to transship more than 40.000 cbm of chemicals (scenario A and B1), or to drop and swap all chemicals of Odfjell parcel tankers of the Africa trade lane (scenario B2, C1, and C2).

However, extra profit per sub-alternative depends on the number of Odfjell parcel tankers that are influenced per sub-alternative. Extra profit per tanker is only determined with the use of non-dedicated storage capacity. The sub-alternative with the highest extra profit per tanker is given in table 46.

Table 46: Highest extra profit per tanker for Odfjell

Scenario	Drop and swap alternative with the highest extra profit per tanker	Profit
Scenario A (K. €/year)	Odfjell parcel tankers with more than 40.000 cbm of chemicals to transship.	106
Scenario B2 (K. €/year)	Odfjell parcel tankers with less than 20.000 cbm of chemicals to transship.	-44
Scenario C2 (K. €/year)	Odfjell parcel tankers with less than 20.000 cbm of chemicals to transship.	-58

As can be concluded from table 46, extra profit per tanker is only realized in scenario A. The two most interesting drop and swap alternatives per tanker, are to drop and swap all chemicals of Odfjell parcel tankers that need to transship more than 40.000 cbm of chemicals (scenario A), or less than 20.000 cbm of chemicals (scenario B2 and C2)

A validation of the results shows that assumptions, made during the research, have a different magnitude of impact on the results. Especially the average transshipment rate at OTR has a big impact on the final results. Further research, towards these assumptions, could increase the reliability of these assumptions and final results. Assumptions made during the research are shown in appendix O.

8.2 Recommendations

Results of the research show there are interesting possibilities towards implementing a drop and swap alternative which realize extra profit for Odfjell if no loss in revenues due to use of deep-sea berth capacity and storage capacity, is realized. Especially, the high demand for storage capacity results in high loss in revenues for Odfjell with the implementation of a drop and swap concept. Recommendations for further research, towards avoiding this loss in revenues are:

1. Storage capacity at OTR can be realized in two ways: by manufacturing extra storage tanks or by more efficient use of the current storage capacity. Some chemical products are stored for months or even years at OTR. Interesting could be to store chemicals, which are stored for a longer time, at a different storage location. This storage location, for example more land inwards, is less valuable than the storage capacity at OTR. Extra profit due to the implementation of a drop and swap concept have to be compared to extra costs to store these chemicals at a different, less valuable, location.
2. Barge berth occupancy is low at OTR. With the drop and swap of chemicals, board-board transshipment is the cheapest way to transship, because no temporary storage is needed. Connections between deep-sea berths and barge berths, to perform board-board transshipment are limited. Research towards increasing the number of board-board connections could make a drop and swap concept more profitable because less temporary storage is needed.

During the research, several assumptions are made to determine the results. Assumptions influence the reliability of the results. Further research, towards these assumptions, could increase the reliability of the assumptions and final results:

1. In the research, consequences of implementing drop and swap alternatives, in which specific Odfjell parcel tanker groups are influences, are determined. Exact boundaries, which show when it is profitable to drop and swap a specific individual Odfjell parcel tanker, are not determined. To determine these exact boundaries, Odfjell parcel tankers need to be analyzed per tanker individually.
2. To investigate the Odfjell parcel tankers individually, simulation of the whole process is recommended. Because of the deterministic and stochastic influences on the many processes, forecasting is difficult. With use of simulation, these deterministic and stochastic influences can be taken into account.
3. An important assumption that influences the results drastically is the average transshipment rate at OTR. Assumptions concerning this average transshipment rate have to be very reliable. On the other hand, because of the big impact of the average transshipment rate on the extra profit for Odfjell, research toward increasing this average transshipment rate at OTR is recommended.

Literature

Baird, A.J., *Optimizing the container transshipment hub location in northern Europe,* Maritime Research Group, United Kingdom, 2005.

Blomjous, P.E.J.N., Houten, S.P.A. van, *An HLA Federation for evaluating multi-drop strategies in logistics*, Faculty of Technology, Policy and Management Delft University of Technology, the Netherlands, 2003.

Bontekoning, Y., Priemus, H., *Breakthrough innovations in intermodal freight transport,* OTB Research Institute for Housing, Urban and Mobility Studies Delft University of Technology, the Netherlands, 2004.

Buhrmann, B.C. *Chemicaliëntransport in de 21ste eeuw, op weg naar een betere afhandeling van chemicaliëntankers in zeehavens en de Rotterdamse haven in het bijzonder.* TU Delft, Faculteit ontwerp, constructie en productie, 2003.

Burke, E.K., *Multi-objective approaches for robust airline scheduling,* School of Computer Science and Information Technology, United Kingdom, 2004.

Coyle, J.J., Bardi, E.J., John Langley Jr.,C.. *The Management of Business Logistics: A Supply Chain Perspective 7th Edition.* South Western, a division of Thomas Learning, 2003.

Dalhuisen, L., *Drop and swap.* Rotterdam: Odfjell Terminals Rotterdam & Odfjell Shipping the Netherlands B.V., 2006.

Huang, C., Karimi, I.A., *Scheduling trans-shipment operations in maritime chemical transportation.* Industrial and Engineering Chemistry Research 45 (6), pp. 1955-1973., 2006.

Hudson, S., *Success with hub and spoke distribution.* Supply chain management: an information digests for the SCM professional, 2003

Jacobs, P.H.M., Verbraeck, A., Mulder, J.B.P., *Flight scheduling at KLM,* Proceedings of the Winter Simulation Conference, 2005.

Jetlund, A.S., Karimi, I.A., *Improving the logistics of multi-compartment chemical tankers.* Computers and Chemical Engineering 28 (8), pp. 1267-1283., 2004.

Karimi, I.A., Sharafali, M., Mahalingam, H., Sundaramoorthy, A., *Management of supplies and movements of tank containers in chemical logistics.* AIChE Annual Meeting Conference Proceedings 2005, 2005.

Konings, J.W., *Smart collection and distribution of containers on barge in the port of Rotterdam,* Transportation Research Board Annual Meeting, pp. 1-22, Washington 2005.

Konings, R., Priemus, H., *Terminals and the competitiveness of container barge transport.* Faculty of Technology, Policy, and Management, Delft University of technology, the Netherlands, 2008.

Odfjell ASA, *Corporate quality management manual.* Odfjell, March 2008.

Odfjell Netherlands BV, *Voy 200805 preliminary stowage plan 15th ed.* Odfjell Shipping the Netherlands, August 2008a.

Odfjell Netherlands BV, *Port tracker- port summary from 01/01/2008 thru 31/12/2008.* Odfjell Shipping the Netherlands, September 2008b.

Odfjell Netherlands BV, *Outlay Rotation Bow Century.* Odfjell Shipping the Netherlands, September 2008e.

Odfjell Terminals BV, *Odfjell terminals.* Odfjell, 2008c.

Odfjell Terminals BV, *Productengids 2006.* Odfjell, 2006.

Odfjell Terminals BV, *Structure of the terminal.* Odfjell, 2008d.

Odfjell Terminals BV, *Research towards optimizing transshipment rates at OTR,* Odfjell, 2008e.

Ovrebekk, H., *Logistics & distribution: Strike blocks chemical drop.* ICIS Chemical Business 2 (60). Pp. 30., 2007.

Pielage, B.J., *Conceptual design of automated freight transport systems.* TU Delft, November 2005.

Pielage, B.A., Konings, J.W., Rijsenbrij, J.C., Schuylenburg, M. van, *Barge Hub Terminals: A perspective for more efficient hinterland container transport for the port of Rotterdam.* North Dakota State University: Upper Great Plains Transportation Institute, 2007.

Roderigue, Dr. J.P., *Cross-docking distribution center.* Department of Economics & Geography, Hofstra University, 2008.

Verbraeck, A., P.W. Heijnen, and W. Bockstael-Blok, *Reader epa 1331 Discrete Modeling.* Fifth edition. Delft: Faculty of Technology, Policy and Management, 2005.

Woltman Elpers, C.I.M., *Parcel tankers in the port of Rotterdam, Research into the process of handling parcel tankers in port and creating commitment for shortening the port time in a multi-actor environment.* Rotterdam: Initiate, 2005.

Appendix A: Rotation plan of the Bow Century designed by OS

BOW CENTURY - Rotation Voyage &

Operator Bergen:	Karianne Hove-Ødegård	Port Operator:	Robert Hoevens	Koole Pernis	Odfjell Terminals
Office Phone :	+ 47 55 27 45 28	Office Phone:	(3110) 2953646	Vopak Vlaardingen	Vopak Botlek
Cell Phone :	+ 47 476 16 436	Cell Phone:	(316) 53542521	Shell Pernis 18	
After Hours :	+ 47 55 15 11 94	After Hours:	(3110) 295 36 66	LBC Botlek	

ODFJELL
Odfjell Netherlands BV

Berth: Koole Pernis **Side alongside:** Port Side **Max Draft:** 12,50 **17/9 pm - 19/9 am**

Discharging

No.	Commodity	B/L Fig.	Charterer	Load Port	Surveyor	Vapor	Stowage	Other Info/Remarks
2	PARAFFIN WAX SX 50,LIQUID (PECTEN)	2134,090	Shell Eastern Petroleum (Pte) Ltd.	Bintulu	Intertek		5c, 6wp	b/b to owners barge tbn
3	PARAFFIN WAX SX 70,LIQUID (PECTEN)	430,021	Shell Eastern Petroleum (Pte) Ltd.	Bintulu	Intertek		5ws	b/b to owners barge tbn
6	YUBASE 4	3890,781	SK Energy Co., Ltd	Ulsan	Saybolt		1cp, 4c, 9cs, 13c	Koole Pernis shoretank
7	YUBASE 6	4859,157	SK Energy Co., Ltd	Ulsan	Saybolt		2ws, 4wps, 6ws, 7cs,	Koole Pernis shoretank
10	STEARIC ACID 1848	485,663	Peter Cremer (S) Gmbh	Pasir Gudang	Seacontrol		10cs	Koole Pernis shoretank
18	ECOROL 8/98	350,092	Ecogreen Oleochemicals (Singapore) Pte. Ltd.	Pulau Batam	Krudo / HSC		3cs, dt1p	Koole Pernis shoretank
19	ECOROL 68/30	380,332	Ecogreen Oleochemicals (Singapore) Pte. Ltd.	Pulau Batam	Krudo / HSC		7cp	Koole Pernis shoretank
20	ECOROL 26	800,161	Ecogreen Oleochemicals (Singapore) Pte. Ltd.	Pulau Batam	Krudo / HSC		1cs	Koole Pernis shoretank
21	ECORIC 68/10	1003,343	Ecogreen Oleochemicals (Singapore) Pte. Ltd.	Pulau Batam	Krudo / HSC		9wp, 13ws	Koole Pernis shoretank
22	METHYL ESTER 18 W	300,590	Ecogreen Oleochemicals (Singapore) Pte. Ltd.	Pulau Batam	Krudo / HSC		12wp	Koole Pernis shoretank
23	METHYL ESTER 18 U	400,993	Ecogreen Oleochemicals (Singapore) Pte. Ltd.	Pulau Batam	Krudo / HSC		7wp	Koole Pernis shoretank
24	DIISONONYL PHTHALATE	1424,565	The Normandy Group S.A.	Mailiao	Intertek		8wp	b/b to owners barge tbn
25	ECOROL 10/98	293,272	Ecogreen Oleochemicals (Singapore) Pte. Ltd.	Pulau Batam	Krudo / HSC		9ws	Koole Pernis shoretank
1	DIMETHYLFORMAMIDE	500,013	Samsung Fine Chemical Co. Ltd.	Ulsan	SGS		10wp	b/b to owners barge tbn

Remarks/Other Info:
Line Size:

Berth: Vopak Vlaardingen **Side alongside:** Starboard Side **Max Draft:** 11,50 -

Discharging

No.	Commodity	B/L Fig.	Charterer	Load Port	Surveyor	Vapor	Stowage	Other Info/Remarks
11	PALM KERNEL FATTY ACID	999,794	Peter Cremer (S) Gmbh	Pasir Gudang	Banjac		11c	Vopak Vlaardingen shoretank
12	Hardened coco fatty acid (C8-18)	500,107	Peter Cremer (S) Gmbh	Pasir Gudang	Banjac		12cs	Vopak Vlaardingen shoretank
13	DISTILLED TOPPED COCONUT FATTY ACID	501,141	Peter Cremer (S) Gmbh	Pasir Gudang	Banjac		12cp	Vopak Vlaardingen shoretank
14	Palm wax 1705	500,471	Peter Cremer (S) Gmbh	Pasir Gudang	Banjac		10ws	Vopak Vlaardingen shoretank
15	COCONUT FATTY ACIDS (FATTY ACID C8	499,310	Peter Cremer (S) Gmbh	Pasir Gudang	Banjac		10cp	Vopak Vlaardingen shoretank
16	DISTILLED TOPPENED HARDENED COCONUT FATTY ACID C12-18HK	501,039	Peter Cremer (S) Gmbh	Pasir Gudang	Banjac		11wp	Vopak Vlaardingen shoretank
17	PALM ACID OIL	2002,755	Peter Cremer (S) Gmbh	Bintulu	Banjac		3wp, 5wp, 9cp, 13wp	Vopak Vlaardingen shoretank
5	WAXY RAFFINATE	1535,763	Shell Eastern Petroleum (Pte) Ltd.	Bintulu	Intertek		6c	b/b to mt Stolt tbn

Remarks/Other Info:
Line Size:

Berth: Shell Pernis 18 **Side alongside:** Starboard Side **Max Draft:** 10.10 -

Discharging

No.	Commodity	B/L Fig.	Charterer	Load Port	Surveyor	Vapor	Stowage	Other Info/Remarks
8	CARADOL SC48-03	989,880	Shell Eastern Petroleum (Pte) Ltd.	Singapore	Shell		2wp, 3cp	Shell Pernis 18 shoretank

Remarks/Other Info:
Line Size:

Berth: LBC Botlek **Side alongside:** Starboard Side **Max Draft:** 10.10 -

Discharging

No.	Commodity	B/L Fig.	Charterer	Load Port	Surveyor	Vapor	Stowage	Other Info/Remarks
9	MONOPROPYLENE GLYCOL (Industrial	1980,090	Shell Eastern Petroleum (Pte) Ltd.	Singapore	Intertek		2c	LBC Botlek shoretank
24	DIISONONYL PHTHALATE	1424,565	The Normandy Group S.A.	Mailiao	Intertek		8wp	b/b to owners barge tbn

Remarks/Other Info:
Line Size:

Berth: Odfjell Terminals **Side alongside:** #N/A **Max Draft:** #N/A -

Discharging

No.	Commodity	B/L Fig.	Charterer	Load Port	Surveyor	Vapor	Stowage	Other Info/Remarks
4	SHELL GTL FUEL	2855,602	Shell Eastern Petroleum (Pte) Ltd.	Bintulu	Intertek		3ws, 7ws, 8c	Odfjell Terminals shoretank

Remarks/Other Info:
Line Size:

Berth: Vopak Botlek **Side alongside:** Port Side **Max Draft:** 12,00 -

Loading

No.	Commodity	Nom. Fig	Option	Charterer	Discharge Port	Surveyor	Vapor	WW	N2	Stowage	Other Info/Remarks
2	BUTYL ALCOHOL,N-	2000,000	Min/Max	Petro Derivatives International trade (PDIT) Inc.	Changzhou	SGS	yes	revert	no		b/b ex coaster tbn
3	EPICHLOROHYDRIN	2000,000	Min/Max	Petro Derivatives International trade (PDIT) Inc.	Changzhou	SGS	yes	revert	check		b/b ex coaster tbn
4	ISOBUTANOL	1000,000	Min/Max	Petro Derivatives International trade (PDIT) Inc.	Changzhou	SGS	yes	revert	no		b/b ex coaster tbn
5	ISO NONYL ALCOHOL	4000,000	2% MOLCO	Evonik Services GmbH	Zhuhai	LMN	no	revert	no		ex Vopak Botlek shoretank

Remarks/Other Info:
Line Size:

Figure 25: Rotation plan of the Bow Century

An Odfjell parcel tanker usually needs to discharge and load at different terminals in the port of Rotterdam. OS, as shipping agent, designs a rotation plan for each tanker that visits the port of Rotterdam. The goal of the rotation plan is to create a rotation in which the port time for the Odfjell parcel tankers is as low as possible with a minimal number of berths to visit and at minimal costs. Board-board transshipment is an important tool to reduce these factors.

The rotation plan generally consists of the following information:
- ETA (Expected Time Arrival) of the parcel tanker in the port of Rotterdam (not the ETA for the different terminals).
- Sequence in which order the different berths have to be visited.
- Chemical name to load or discharge.
- Quantity to load or discharge.
- Name charterer.
- Name load or discharge terminal.
- Stowage of the cargo in the tanker.
- Name surveying company ordered by the charterer.
- Location where the chemicals has to be loaded from/discharge in (for example to shore or to barge)

Important rules taken into account when designing a rotation plan are:
- What (load or discharge) has to be done at which terminal?
- Visit berth where the most chemicals has to be discharged first or as soon as possible; in this way parcel tankers are empty and chemicals can be loaded into these tanks.
- As less as possible double calls on berths; for example, if a tanker has to discharge and load chemicals at a certain berth. These activities have to take place at the same time the ship is at that particular berth.
- Use barges if possible; chemicals are transshipped to or from barges, which bring the chemicals to the specific terminal where the chemical needs to be stored (board-board transshipment)

Appendix B: Odfjell parcel tankers visiting the port of Rotterdam in 2008

Results in this appendix are generated using the port trackers of the 147 Odfjell parcel tankers that visited the port of Rotterdam in 2008.

Appendix B1: Port time

The mathematical distribution of the port time per Odfjell parcel tanker (figure 26), can be seen as a standard distribution with an average of 7,86 days and a standard deviation of 3.33 days (42%).

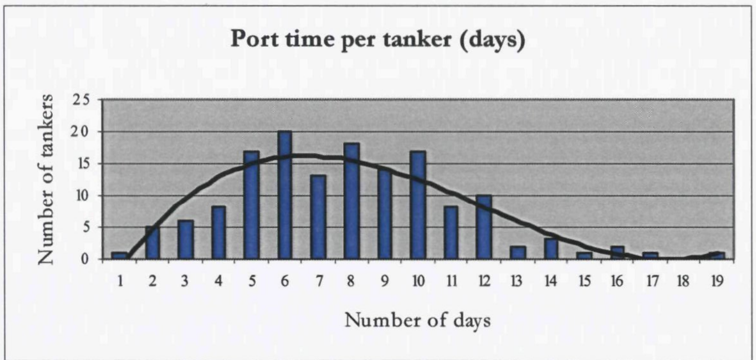


Figure 26: Standard distribution of port time per tanker

The parcel tankers have different characteristics that influence the port time of the tankers. The quantity of chemicals that a tanker needs to transship, the number of chemical parties that a tanker needs to transship, and the number of calls that a tanker has to make are important characteristics of the tankers that influence the port time.

The correlation between the chemical quantity a tanker has to transship and the port time is shown in figure 27.

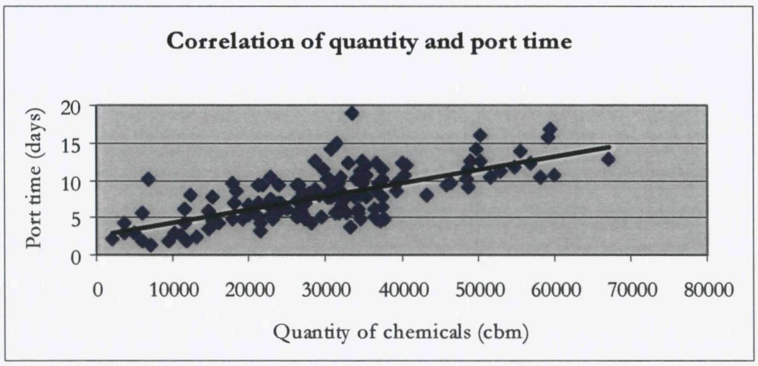


Figure 27: Correlation of quantity and port time

The figure shows that a bigger quantity of chemicals to transship results in a longer port time for the parcel tankers. R-square, which shows the predictability of the port time when the chemical quantity is known, is 0,48. This means that there can only be given a very rough prediction of the port time when the chemical quantity is known. This can be explained by the fact that port time also depends on many different influences.

The correlation between the number of chemical parties a tanker needs to transship and the port time is shown in figure 28.

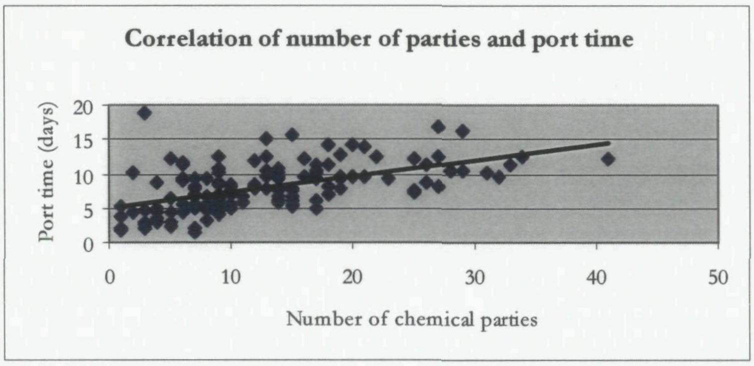


Figure 28: Correlation of number of chemical parties and port time

The figure shows that a higher number of chemical parties to transship results in a longer port time for the parcel tankers. R-square for this correlation is 0,30. This means that there can hardly be given a very rough prediction of the port time when the number of chemical parties that need to be transshipped is known. This can be explained by the fact that port time also depends on many different influences.

The correlation between the number of calls a tanker has to make and the port time is shown in figure 29.

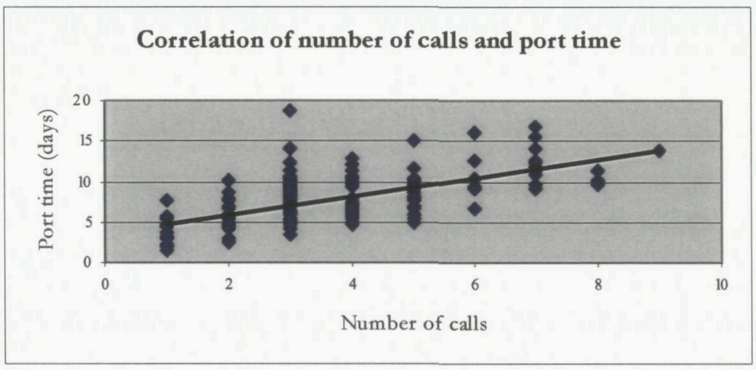


Figure 29: Correlation of number of calls and port time

The figure shows that a higher number of calls results in a longer port time for the parcel tankers. R-square for this correlation is 0,40. This means that there can be given a very rough prediction of the port time when the number of chemical parties that need to be transshipped is known. This can be explained by the fact that port time also depends on many different influences.

The different values of the R-squares show that predictability of the port time is difficult, because port time is influenced by several factors.

Appendix B2: Chemical quantity transshipped

The mathematical distribution of the quantity of chemicals transshipped per Odfjell parcel tanker (figure 30), can be seen as a standard distribution with an average of 29.693 cbm and a standard deviation of 12.927 cbm (44%).

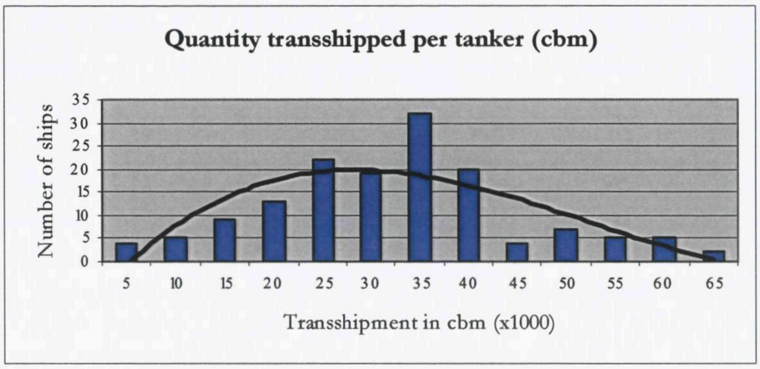


Figure 30: Standard distribution of chemical quantity per tanker

Appendix B3: Number of chemical parties transshipped

The mathematical distribution of the number of chemical parties transshipped per Odfjell parcel tanker (figure 31), can be seen as a standard distribution with an average of 12,48 parties and a standard deviation of 7,77 parties (62%)

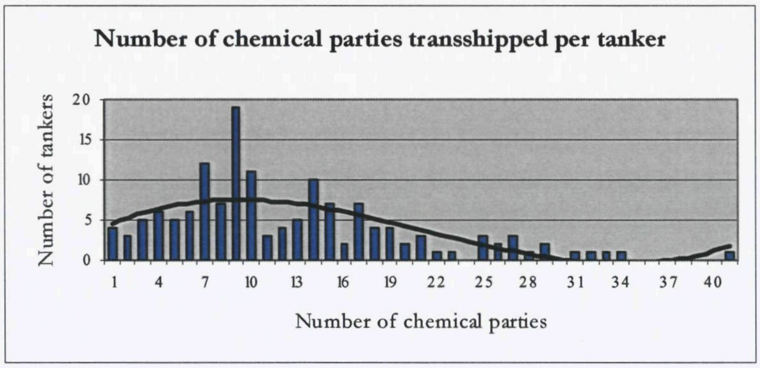


Figure 31: Standard distribution of chemical parties per tanker

Appendix B4: Number of calls

The mathematical distribution, of the number of calls per Odfjell parcel tanker (figure 32), can be seen as a standard distribution with an average of 3,78 calls and a standard deviation of 1,86 parties (49%)

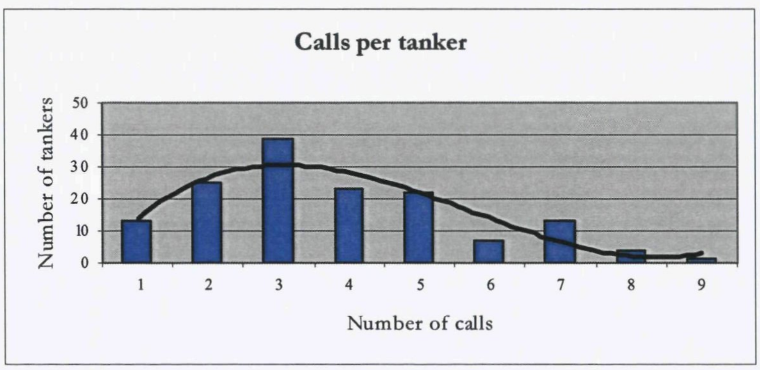


Figure 32: Standard distribution of calls per tanker

Appendix C: Outline of Bow Fortune visiting the port of Rotterdam

The Bow Fortune is one of the parcel tankers owned by Odfjell shipping. From the 30th of December 2008 until the 10th of January 2009, this tanker was in the port of Rotterdam for the transshipment of chemicals. Table 47 gives an overview of the terminals visited, and the detailed transshipment at each terminal.

Table 47: List of actions

Log Times	Hours	Berth	L. Gr[24]	L. Qty[25]	D. Gr[26]	D. Qty[27]
13:05 (12-30-08) 19:35 (01-01-09)	54,50	Koole Pernis	0	0,00	3	10916,00
20:50 (01-01-09) 19:05 (01-02-09)	22,25	OTR	1	2996,00	5	6424,00
19:40 (01-02-09) 10:05 (01-03-09)	14,42	OTR	0	0,00	1	1941,00
11:30 (01-03-09) 22:45 (01-04-09)	35,25	Vopak Chemiehaven	1	500,00	3	55,00
01:00 (01-05-09) 21:00 (01-05-09)	20,00	OTM	0	0,00	0	0,00
22:07 (01-05-09) 19:40 (01-06-09)	21,55	Shell Pernis 18	3	1237,00	0	0,00
21:00 (01-06-09) 09:00 (01-07-09)	12,00	Shell Pernis 4	1	517,00	0	0,00
10:30 (01-07-09) 17:30 (01-10-09)	79,00	OTM	8	7550,00	0	0,00

In total, the Bow Fortune stayed in the port of Rotterdam for 255 hours, making calls at 8 different terminals and transshipping a total of 26 chemical parties. The following pages show a more detailed time line of the Bow Fortune, a detailed transshipment (discharge) and detailed board-board transshipment.

24 Number of chemical parties loaded
25 Quantity of chemicals loaded (in cbm)
26 Number of chemical parties discharged
27 Quantity of chemicals discharged (in cbm)

Detailed time line of Bow Fortune

DAY	LOCATION	TIME	ACTIVITY
1	Shifting	08:15	Arrival in port of Rotterdam
	Koole Pernis	13:05	All fast at Koole Pernis
	Koole Pernis	13:35	Surveyor on board
	Koole Pernis	14:00	Loading master on board
	Koole Pernis	14:20 – 18:40	Awaiting results of surveyors analysis
	Koole Pernis	18:40 – 19:50	Awaiting shore readiness
	Koole Pernis	21:05	Commenced transshipment (discharge 3 parties)
3	Koole Pernis	18:00	Transshipment completed
	Shifting	19:20	Unmoored from berth Koole Pernis
	OTR 9	20:50	All fast at OTR 9
	*Koole Pernis	16:30 (day 1)	Surveyor on board
	OTR 9	21:45	Loading master on board
	OTR 9	23:20	Commenced transshipment (discharge 5, load 1 parties)
4	OTR 9	17:40	Transshipment completed
	Shifting	18:42	Unmoored from berth OTR 9
	OTR 7	19:40	All fast at OTR 7
	*OTR 9	17:35	Surveyor on board
	OTR 7	20:20	Loading master on board
	OTR 7	20:50	Commenced transshipment (discharge 1 party)
5	OTR 7	06:15	Transshipment completed
	Shifting	9:53	Unmoored from OTR 7
	Vopak Chemie	11:30	All fast at Vopak Chemiehaven
	*Koole Pernis	16:30 (day 1)	Surveyor on board
	Vopak Chemie	12:30	Loading master on board
	OTR 7	13:10	Commenced transshipment (discharge 3, load 1 parties)
6	OTR 7	19:25	Transshipment completed
	Shifting	22:25	Unmoored from Vopak Chemiehaven

DAY	LOCATION	TIME	ACTIVITY
7	AVR	01:00	All fast at AVR
	AVR	01:30	Loading master on board
	AVR	02:30	Surveyor on board
	AVR	04:05	Commenced transshipment (discharge 1 party)
	AVR	5:00	Transshipment completed
	Shifting	20:31	Unmoored from AVR
	Shell Pernis 18	22:07	All fast at Shell Pernis 18
	Shell Pernis 18	23:05	Surveyor on board
	Shell Pernis 18	23:05	Loading master on board
8	Shell Pernis 18	01:00 – 06:00	Awaiting results of surveyors analysis
	Shell Pernis 18	06:00 - 07:45	Awaiting shore readiness
	Shell Pernis 18	08:40	Commenced transshipment (load 3 parties)
	Shell Pernis 18	16:35	Transshipment completed
	Shifting	19:40	Unmoored from Shell Pernis 18
	Shell Pernis 4	21:00	All fast at Shell Pernis 4
	*Shell Pernis 18	23:05 (day 7)	Surveyor on board
	Shell Pernis 4	21:30	Loading master on board
	Shell Pernis 4	23:10	Commenced transshipment (load 1 party)
9	Shell Pernis 4	01:30	Transshipment completed
	Shifting	09:15	Unmoored from Shell Pernis 4
	OTM	10:40	All fast at OTM
	OTM	11:00	Surveyor on board
	OTM	11:00	Loading master on board
	OTM	16:15	Commenced transshipment (load 9 parties)
12	OTM	15:00	Transshipment completed
	Shifting	17:30	Unmoored from OTM
	Shifting	19:00	Leave port of Rotterdam

Figure 33: detailed time line of the Bow Fortune

Different actions are taken by the Odfjell parcel tanker to transship the chemical parties in the port of Rotterdam. A typical action of Odfjell parcel tankers in the port of Rotterdam is the discharge of chemicals. Figure 34 shows a detailed overview of discharging the Bow Fortune at Koole Pernis.

Ship: **Bow Fortune**
Terminal: **Koole Pernis**
Discharge: **Cargo number 2 (yubase 4 plus) from parcels 5c, 5ws and 6wp**
Cargo number 4 (yubase 4) from parcel 11c
Cargo number 5 (yubase 6)

13:35 Surveyor on board

13:40 – 14:20 Cargo sample taken by surveyor and ship crew for analysis

14:00 Loading master on board

14:20 – 18:40 Awaiting results surveyors analysis

Cargo Number 2

17:00 Analysis passed
18:40 1x6" hose connected (5ws/6wp)
18:40 – 21:05 Awaiting shore readiness
21:05 Commenced discharging
23:40 Temporary stop
23:40 – 00:05 Awaiting shore readiness
00:05 Resumed discharging
03:30 Temporary stop
04:45 Resumed discharging
05:20 1x6" cargo hose connected (5c)
05:30 Temporary stop
07:00 Resumed discharging (5c)
07:30 Resumed discharging (5ws/6wp)
10:15 Hose disconnected (5ws/6wp)
13:35 Temporary stop (5c)
13:50 Resumed discharging (5c)
15:25 Temporary stop (5c)
15:25 – 16:20 Awaiting shore readiness
16:20 Resumed discharging (5c)
17:20 Temporary stop (5c)
17:20 – 19:15 Awaiting shore readiness
19:15 Resumed discharging
18:00 Discharge completed
18:05 Tanks accepted empty by surveyor
18:30 Hose disconnected

Cargo Number 4

16:40 1x6" hose connected
18:40 Analysis passed
18:40 – 20:35 Awaiting shore readiness
19:15 Hose disconnected
19:55 1x6" hose connected
20:35 Commenced discharging
20:40 Temporary stop
20:45 Resumed discharging
04:00 Discharge completed
04:55 Tank accepted empty by surveyor
05:20 Hose disconnected

Cargo Number 5

18:40 Analysis passed
18:40 – 19:50 Awaiting shore readiness
19:50 1x6" Hose connected
19:50 – 22:00 Awaiting shore readiness
22:00 Commenced discharging
03:45 Temporary stop
04:05 Hose disconnected
04:25 1x6" hose connected
04-25 – 10:00 Awaiting shore readiness
10:00 Resumed discharging
12:20 Temporary stop
12:20 – 12:40 Awaiting shore readiness
12:40 Resumed discharging
13:55 Discharge completed
14:50 Hose disconnected

19:16 – 20:50 Pilot on board

19:20 Shore's gangway cleared

Figure 34: Time line of discharging at Koole Pernis (Bow Fortune)

As can be seen in the figure, parallel transshipment is done in this example. All three chemical parties that needed to be discharged at Koole Pernis were being discharged at the same moment.

Another common transshipment for Odfjell parcel tankers in the port of Rotterdam is board-board transshipment. Figure 35 shows a board-board transshipment of the Bow Fortune at the Vopak Chemiehaven.

Ship:	**Bow Fortune**
Terminal:	**Vopak Chemiehaven**
Board-board:	**Aceton from Bow Fortune to Consentus (barge)**

12:20 Barge "Consentus" alongside (starboard side)
12:20 – 13:40 Awaiting cargo operation to terminal to be completed
13:40 1x6" cargo hose connected to barge
13:52 1x4" vapor hose connected
13:50 – 14:10 Awaiting barge readiness
14:10 Commenced discharging to barge
14:15 Temporary stop, barge loaded first foot
14:15 – 16:10 Awaiting barges foot sample result
16:10 Informed by terminal that barges foot sample passed
16:20 Resumed discharging
19:25 Discharge completed
20:00 All tanks accepted empty by surveyor
20:00 Cargo hose disconnected
20:15 Vapor hose connected
21:40 Barge off

Figure 35: Time line of board-board transshipment at Vopak Chemiehaven

Appendix D: Port time of Odfjell parcel tankers

Results in this appendix are generated using the port trackers of the 147 Odfjell parcel tankers that visited the port of Rotterdam in 2008.

Appendix D1: Port delay

A total of 84 of the 147 tankers (57%) that visited the port of Rotterdam had port delays. An overview of the port delays per tanker is shown in figure 36.

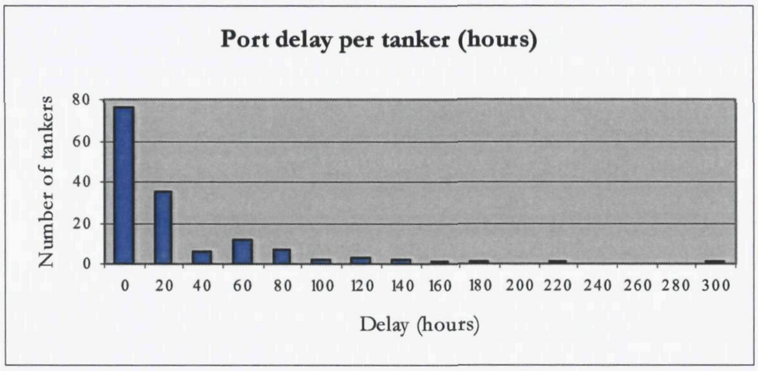


Figure 36: Port delay per tanker

As can be seen in the figure, port delays from 0 to 80 hours are not uncommon (still 5 tankers had a port delay of 80 hours). One Odfjell parcel tanker that visited the port of Rotterdam in 2008 had a port delay of even 300 hours because of an occupied berth. In total 50 of the 84 tankers (60%) were delayed due to the waiting for an occupied berth. Altogether, these 50 tankers caused a total of 2.759 port delay hours, which is 73% of the total port delay hours. Table 48 gives a more detailed overview of the actions that caused port delays for the Odfjell parcel tankers in the port of Rotterdam.

Table 48: Port delays

Port delay	Number of tankers	Percentage of all tankers
Vessel doing repair work	9	6,1 %
Awaiting occupied berth	50	34,0 %
Awaiting bunkering	5	3,4 %
Other	20	13,6 %

As can be seen, a total of 34% of all Odfjell parcel tankers that visited the port of Rotterdam had a port delay because of waiting for an occupied berth. Figure 37 shows the total port delay per action.

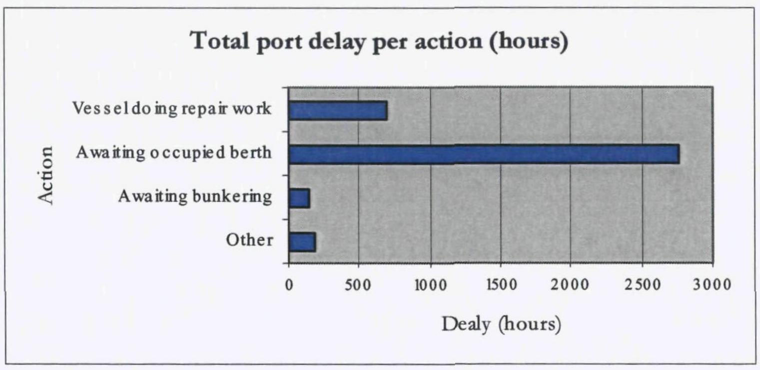


Figure 37: Total port delay per action

As mentioned, most common delay is waiting for an occupied berth. Figure 38 gives an overview of the port delay per tanker due to the waiting for an occupied berth.

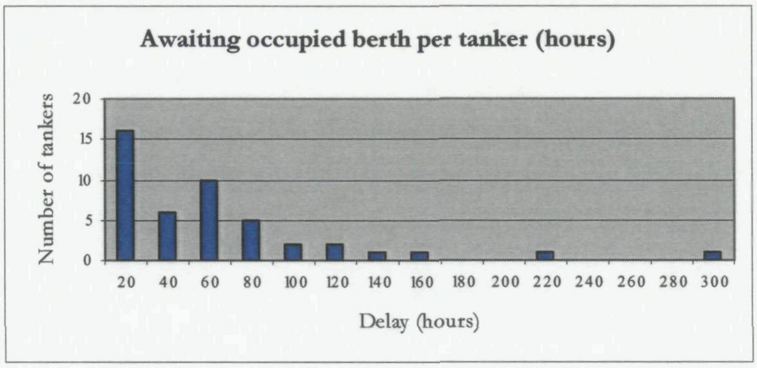


Figure 38: Delay due to awaiting occupied berth

<u>Appendix D2: Operational delay</u>

All 147 Odfjell parcel tankers that visited the port of Rotterdam in 2008 had operational delays. Operational delays can occur with every call a tanker has to make. Figure 39 gives an overview of the operational delays per tanker.

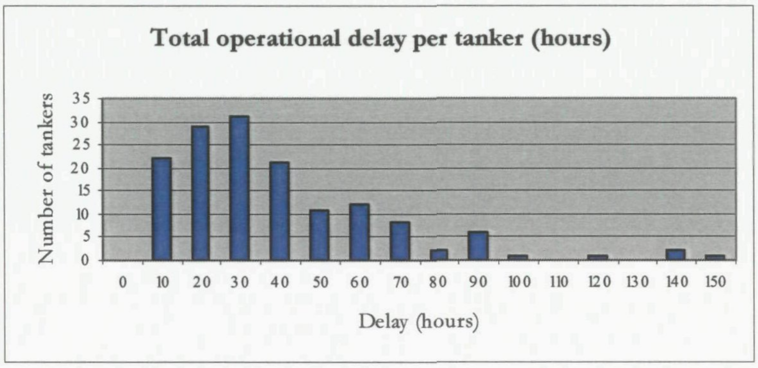


Figure 39: Operational delay per tanker

Operational delays up to 90 hours were not uncommon (still 5 of the tankers had a total operational delay of circa 90 hours). In total 185 calls of the 556 calls (33%) were operational delayed due to the waiting for shore readiness, which caused a total of 1.430 operational delay hours (27% of total operational delay hours). 180 calls of the 556 calls (32%) were operational delayed due to the waiting for the surveyor's analysis, which caused 1.203 operational delay hours (22% of total operational delay hours). Table 49 gives a more detailed overview of the actions that caused operational delays for the Odfjell parcel tankers in the port of Rotterdam

Table 49: Operational delay

Operational delay	Number of calls	Percentage of total calls (556)
Vessel system not ready	15	2,7 %
Awaiting shore readiness	185	33,3 %
Awaiting sample approval	11	2,0 %
Awaiting owners coaster	19	3,41 %
Awaiting owners barge	42	7,6 %
Awaiting charterers surveyor	106	19,1 %
Awaiting charterers coaster	47	8,5 %
Awaiting charterers barge	56	10,1 %
Awaiting analysis	180	32,4 %
Other	74	13,3 %

As can be seen, most common operational delays are waiting for shore readiness and waiting for surveyor's analysis. Figure 40 shows the total operational delay per action.

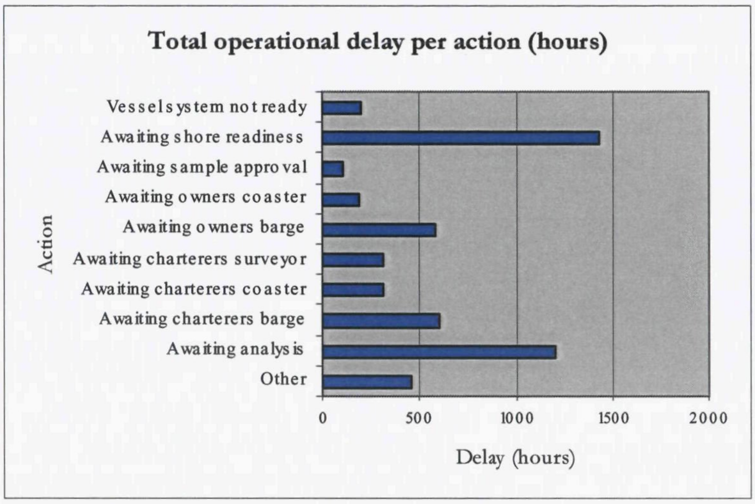


Figure 40: Total operational delay per action

As can be seen from the figure above, waiting for shore readiness and waiting for the surveyor's analysis cause the most delay hours. These two operational delay actions are shown in more detail in figure 41 and 42.

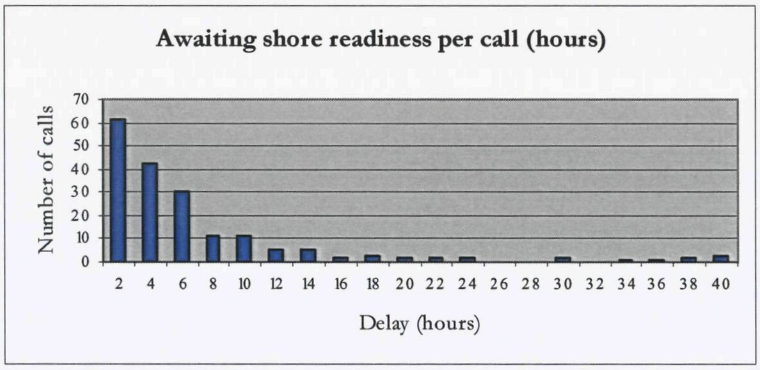


Figure 41: Waiting shore readiness per call

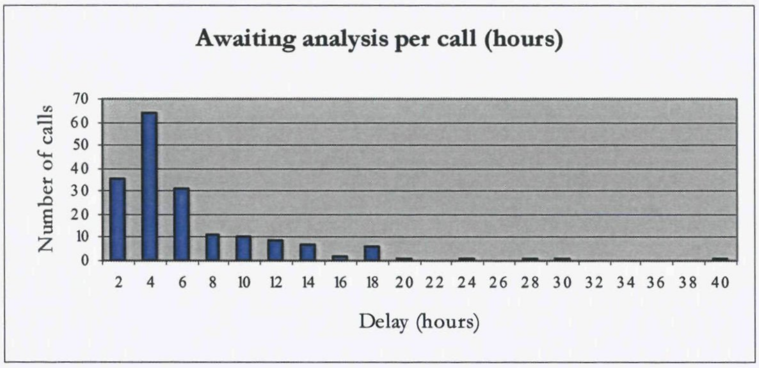


Figure 42: Waiting surveyor's analysis per call

As can be seen, both operational delays normally took between 0 and 18 hours. While, delays of 40 hours because of these actions did occur too.

Appendix D3: Transshipping

A more detailed analysis concerning the number of chemical parties transshipped is shown in figure 43 and 44. These figures show respectively the number of chemicals loaded and the number of chemicals discharged per Odfjell parcel tanker.

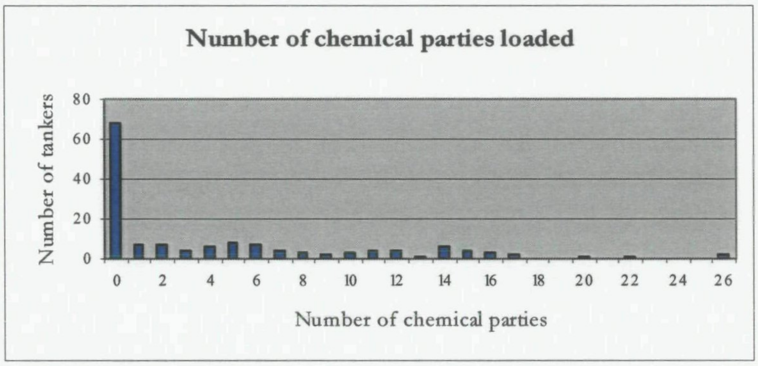


Figure 43: Number of chemical parties loaded per tanker

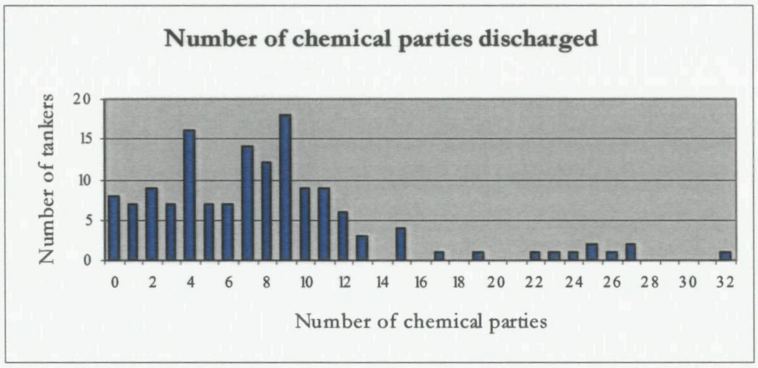


Figure 44: Number of chemical discharged per tanker

The figures show that a big part of the Odfjell parcel tankers that visit the port of Rotterdam do not load chemical parties, while almost every ship discharges chemical parties.
A more detailed overview of the quantity per transshipment is shown in figures 45 and 46. These figures show respectively the loaded quantity and the discharged quantity per tanker.

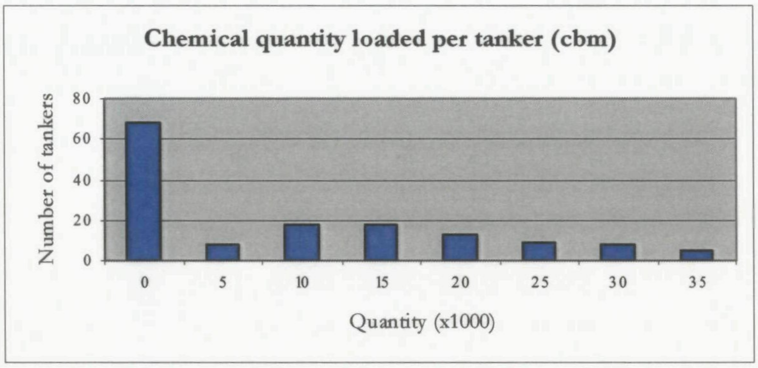


Figure 45: Loading quantity per tanker

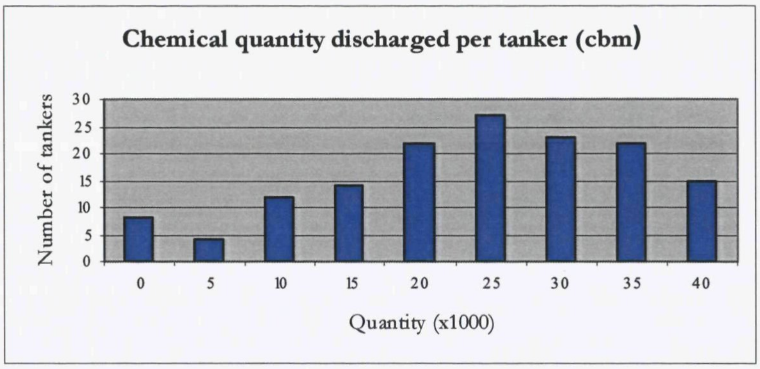


Figure 46: Discharge quantity per tanker

Average loading quantity per tanker (78 tankers) is circa 15,000 cbm and average discharge quantity per tanker (139 tankers) is circa 23,000 cbm. Table 50 gives an overview of the transshipment of the Odfjell parcel tankers and table 51 shows a short summary of the previous findings.

Table 50: Transshipment

Transshipment	Percentage per visit
Only discharge	46 %
Only load	5%
Discharge and Load	49%

Table 51: Loading and discharging

Transshipment	Average number of chemical parties per visit	Maximum number of chemical parties per visit	Average quantity per visit (cbm)
Discharge	8,0	32	23.500
Load	4,5	27	9.000

Appendix D4: Transshipment per terminal

An overview of the most visited terminals (with the number of visits) is shown in figure 47.

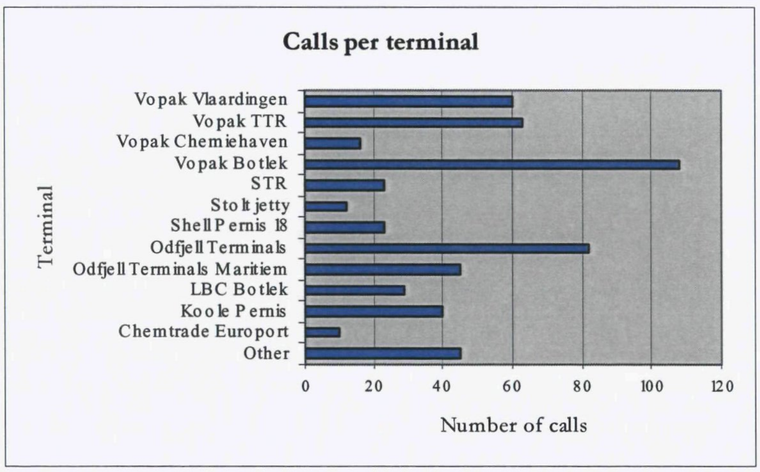


Figure 47: Calls per terminal

The figure shows that Vopak Botlek and Odfjell Terminals Rotterdam are the two most visited terminals by Odfjell parcel tankers. Also Vopak Vlaardingen, Vopak TTR, OTM and Koole Pernis are frequently visited terminals

Average transshipment rates are different per terminal. An overview of these transshipment rates of the most visited terminals by Odfjell parcel tankers is given in figure 48.

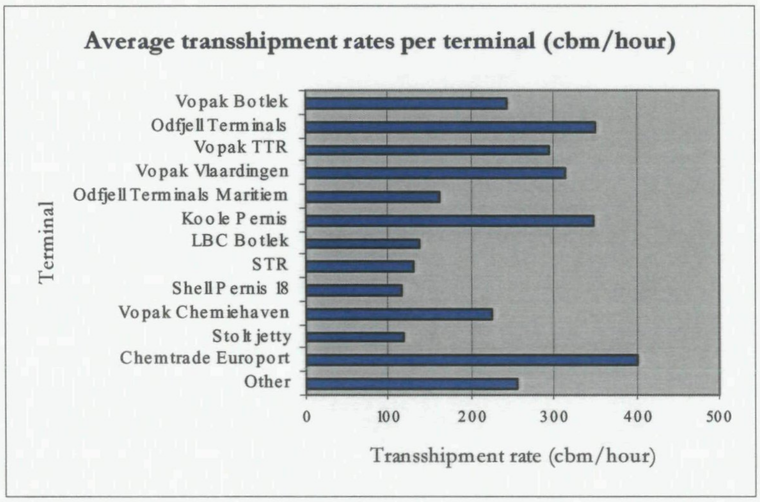


Figure 48: Transshipment rates per terminal per berth (Cbm/hour)

Average transshipment rate of terminals visited by Odfjell parcel tankers was around 255 cbm per hour. As can be seen in the figure, Odfjell Terminals Rotterdam reached an average transshipment rate of around 350 cbm per hour.

Delays per terminal for Odfjell parcel tankers were different too. Table 52 gives an overview of the delays per terminal.

Table 52: Analysis per terminal

Terminal	Number of delays due to waiting for occupied berth	Time of delays due to waiting for occupied berth (hours)	Number of operational delays	Time of operational delays (hours)
Vopak Vlaardingen	13	219	85	547
Vopak TTR	18	238	93	460
Vopak Chemiehaven	4	50	25	93
Vopak Botlek	23	311	145	1508
STR	1	55	48	422
Stolt jetty	0	0	10	79
Shell Pernis 18	3	42	22	115
OTR	34	917	95	457
OTM	4	89	65	689
LBC Botlek	5	67	29	96
Koole Pernis	9	163	62	478
Chemtrade Europort	1	6	9	47
Other	8	321	44	402

Appendix E: Actions of surveyors

The steps a surveyor takes, depend on the kind of transship done with the chemicals; discharge or load ship-shore or board-board. The samples, of the chemicals taken by the surveyor, can be analyzed thorough, on key points or visual. The thorough and key point analyses are done in the laboratory[28]. Usual, these analyses are done by external surveyor agencies. An example of such an agency is Saybolt. An overview of the parcel tanker at the berth is given in figure 51 to explain the steps taken by surveyors.

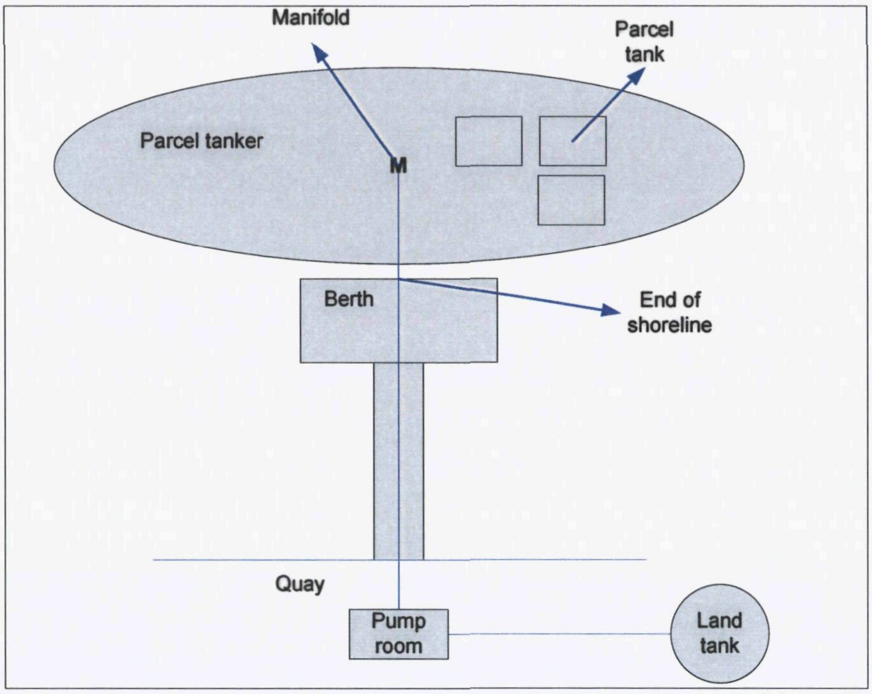


Figure 49: Overview of elements involved in the surveyor processes

As mentioned, processes performed by the surveyors to guarantee the quality and quantity of the transshipped chemicals, depends on the kind of transshipment. There is a difference between discharging, loading or board-board transshipment. Discharging is transshipment of chemicals from the parcel tanker to the land-tanks, loading is transshipment of chemicals from the land-tanks to the parcel tanker and board-board transshipment is transshipment form the parcel tanker to for example barges or vice versa.

Each step, taken by surveyors, in these different transshipment processes are described on the next page.

Discharging:

- Take sample of parcel tank; in most cases the sample is analyzed thoroughly, this depends on the instructions of the client though.
- Take sample of manifold; this is the point where the risk and responsibility shifts from the ship to the terminal and vice versa. This sample is most of the time analyzed visual.
- Take sample of land tank; if the tank is empty, a check on cleanliness is done. Otherwise, a sample is taken from the land tank.

[28] Information from K. Stelwagen, employee at Saybolt, October 2008

- Take sample of pump room; the hose is filled and a sample is taken at the pump room. If the hose is dedicated, the sample isn't analyzed. If the hose isn't dedicated, it depends on the former chemical in the hose and the instructions of the client whether the sample is analyzed visual or on key points.
- Take sample of first foot of land tank; it depends on the former chemical in the land tank and the instructions of the client if the sample is analyzed visual or on key points.

Loading:

- Inspect parcel tank on cleanliness; the way inspection is done, depends on the former chemical in the tank. A certificate of cleanliness is passed.
- Take sample of land tank and measure the level and temperature of chemical in land tank; most of the time, there is already a certificate and of analyses given for the land tank. If not, the sample is analyzed.
- Take sample of end of shoreline; this is the point where the risk and responsibility shifts from the ship to the terminal and vice versa. This sample is analyzed visual or on key points. It depends on whether the hoses are dedicated and the instructions of the client.
- Take sample of manifold; this is done by the steersman.
- Take sample of first foot of parcel tank; this sample is always analyzed on key points. Loading can't start until the sample has been approved.

Board-board transshipping:

- Inspect tank on cleanliness; the way the inspection is done, depends on the former chemical in the tank and the instructions of the client. A certificate of cleanliness is passed.
- Take sample of manifold of ship that is discharging; this is the point where the risk and responsibility shifts from one ship to the other ship. This sample is most of the time analyzed visual. Take sample of first foot of tank; it depends on the former chemical in the tank and the instructions of the client if the sample is analyzed visual or on key points.

Appendix F: Average transshipment rate

Each terminal has different average transshipment rates concerning the transshipment of the Odfjell parcel tankers. The average transshipment rates depend on several factors. An overview of the average transshipping rates per terminal per berth is shown in figure 52

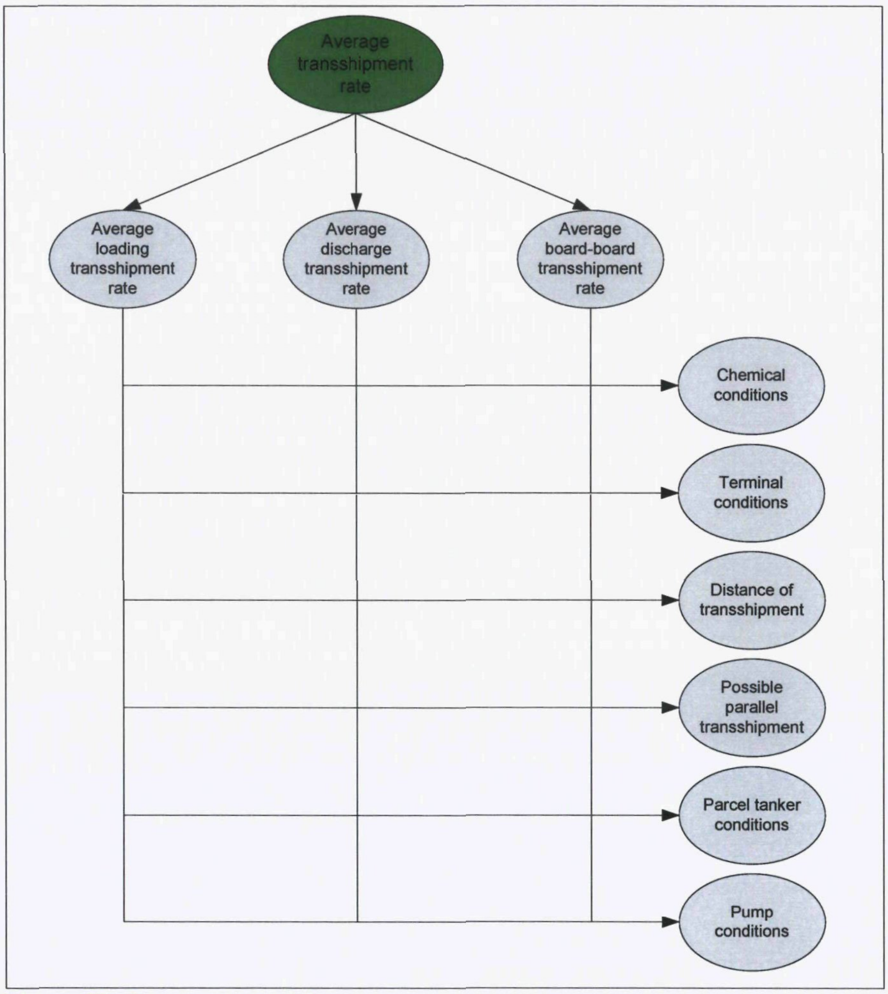


Figure 50: Average transshipment rate

Average transshipment rate of the loading, the discharging and the board-board transshipment depend on several factors. The average transshipment rate depends on the type of chemical that is transshipped, the terminal where it is transshipped, the distance of the transshipment, the number of parallel transshipments possible, the parcel tanker conditions and the pump conditions. Predicting the average transshipment quantity is therefore very difficult.

Appendix G: Tank categories at OTR

OTR has three different types of tanks to store chemicals. Characteristics of these different types are shown in table 53.

Table 53: Tank categories at OTR

Category	Characteristics
K1	- Flashpoint is lower than 21 degrees Celsius. - Capacity of the tank pit must be at least 80% of the total capacity of the tanks. - Tank pit must be located next to the road. - Tank must be painted white.
K2	- Flashpoint between 21 and 55 degrees Celsius. - Capacity of the tank pit must be at least the total capacity of the biggest tank plus 60% of the other tanks.
K3	- Flashpoint is higher than 55 degrees Celsius. - Capacity of the tank pit must be just as big as the volume of the biggest tank plus 10% of the other total tank capacity.

Most tanks at OTR are of the K1 category. Other tank categories are also available to store chemicals at OTR.

Appendix H: Cleaning of shore tanks at OTR

On average, a tank is cleaned once per year. This depends on the number of products switches per tank. Preparation for a tank varies strongly in downtime. Cleaning and inspecting a tank that was used for very toxic products and hard to clean (for example styrene) can take eight days. Considering a general process, which involves pollution in the third category it takes three days to clean. An overview of the different categories is shown in table 54.

Table 54: Cleaning of chemicals

Category	Description
1	Not/slightly polluted; preparation, absorption (via a drain) of the slops about 3 cbm of the lines
2	Limited polluted; Category 1 + rest products absorption through entering tank.
3	Normally polluted; Category 2 + cleaning bottom and first ring of the wall
4	Seriously polluted; Category 3 + erasable sludge layer which is less than 0,01 meter surface of the tank bottom.
5	Very seriously polluted; Category 3 + erasable sludge layer which is less than 0,025 meter surface of the tank bottom.

The way the wastes of chemicals are handled also depends on the type of the chemicals. Chemicals are split up into three different categories. Table 55 shows the way the different chemical categories are handled.

Table 55: Chemical wastes

Categories	Regulations
A-list chemicals (75%)	Can be added to the water purification system without limits.
B-list chemicals (20%)	Are first sifted in order to segregate the largest part of pollution from the water. This pre-wash is kept apart and deported from the terminal. The rest of the wastewater is then treated in the purification system. The bacteria in the purification system need to adapt to this chemical. Therefore, it is important to add these B-list chemicals in smaller proportions into the system.
C-list chemicals (5%)	Are prohibited to add to the purification system. These slobs are deported from the terminal

Most chemicals (75%) stored at OTR are A-list chemicals and only a small part (5%) are C-list chemicals.

Appendix I: Berth occupancies at OTR in 2008

Deep-sea berth capacity at OTR is almost maximal used. With a maximum occupancy of 85% possible, all 4 deep-sea berths almost reach this occupancy. Occupancies per berth are given in figure 51.

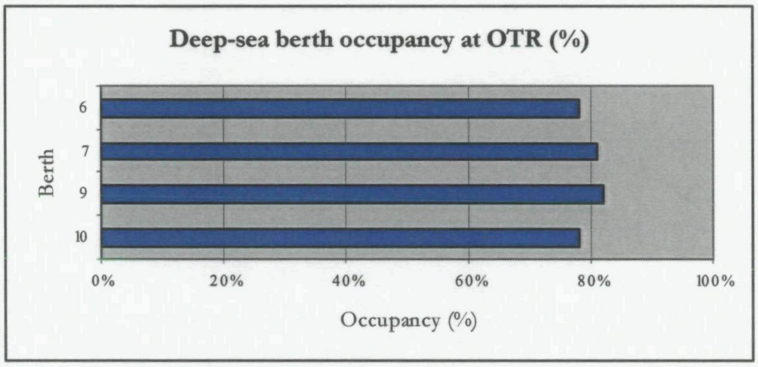


Figure 51: Occupancy deep-sea berths

A total occupancy of the four deep-sea berths together of 80% was realized in 2008. With the construction of the 5th berth, which will be in operation in the summer of 2009, total occupancy would reduce to 65% if all transshipments stay the same.

Barge berth occupancies per barge berth are shown in figure 52.

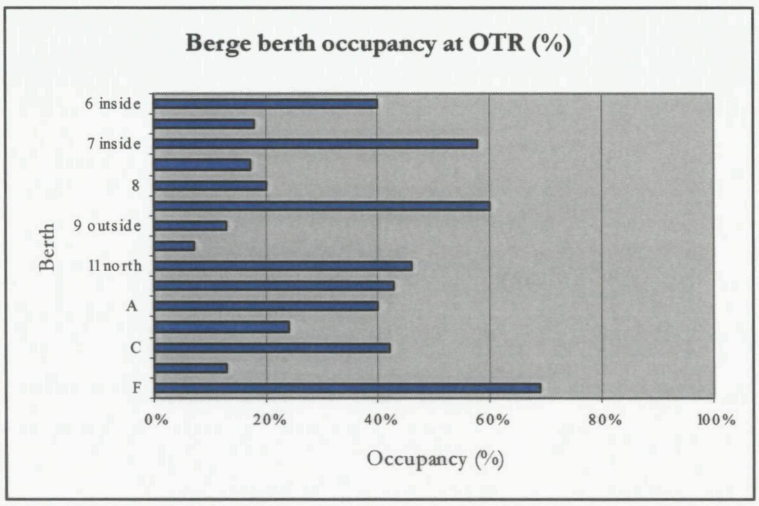


Figure 52: Occupancy barge berths

Total barge occupancy was 35% in 2008. With the construction of the extra barge berths, total barge berth occupancy is reduced to 30% if all transshipments stay the same.

Appendix J: Correlations of port time and number of calls

J1: Shifting time of Odfjell parcel tankers

The shifting time consist of the total sailing time, the total mooring time and the total unmooring time at terminals. Total sailing time depends on the number of calls the tanker has to make in the port of Rotterdam, as shown in figure 53.

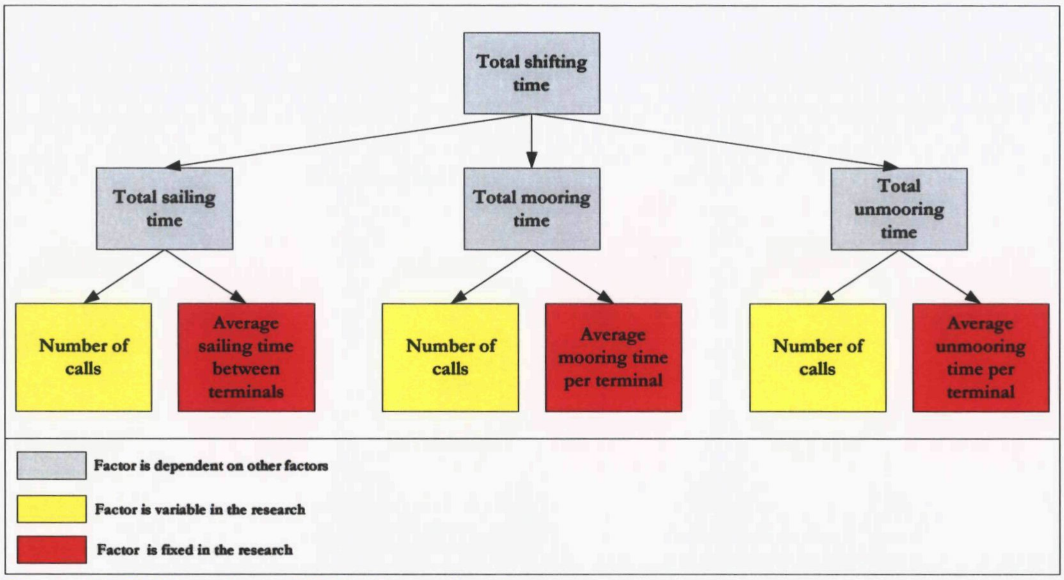


Figure 53: Shifting time of Odfjell parcel tankers

For each call, sailing from one terminal to another terminal is necessary and takes time. This sailing time also depends on the distance between the terminals and the speed of the tanker (how fast it is towed). With the implementation of the drop and swap concept, the number of calls is be reduced. In this research, a fixed distance and speed of the tanker is used, which results in a fixed average sailing time between the terminals.

The total mooring time is the time needed for Odfjell parcel tankers to moor at the different terminals where chemicals are transshipped. The total mooring time differs per terminal. In this research, a fixed mooring time will be used.

The total unmooring time is the time needed for Odfjell parcel tankers to unmoor from the terminals where it has transshipped chemicals. The total unmooring time differs per terminal. In this research, a fixed unmooring time per terminal is used.

The correlation of the total number of calls a tanker has to make and the total shifting time of that tanker, is used to determine the shifting time per call. This correlation is shown in figure 54.

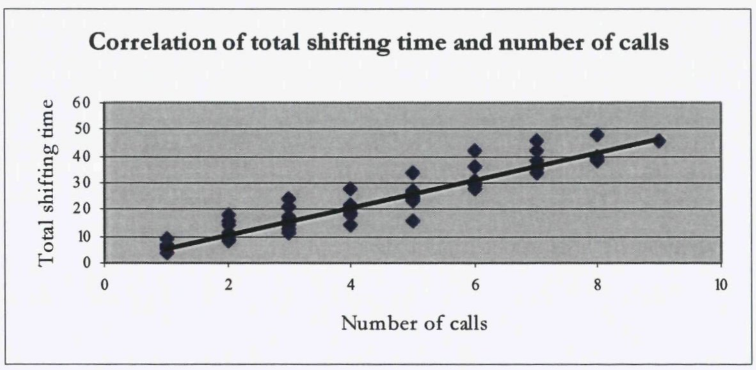


Figure 54: Correlation of total shifting time and number of calls

The total shifting time is dependent on the number of calls according to the formula: Total shifting time = 5 * number of calls. R-square for this formula is 0,93. This shows accurate predictability of the total shifting is possible with the number of calls knowing.

J2: Port delays of Odfjell parcel tankers

The total port delay consists of the total waiting time for occupied berth, the time needed for bunkering, the time needed for reparation, and the total time of other port delays. Port delays, are delays arose during the shifting of the tanker between different terminals, as shown in figure 55.

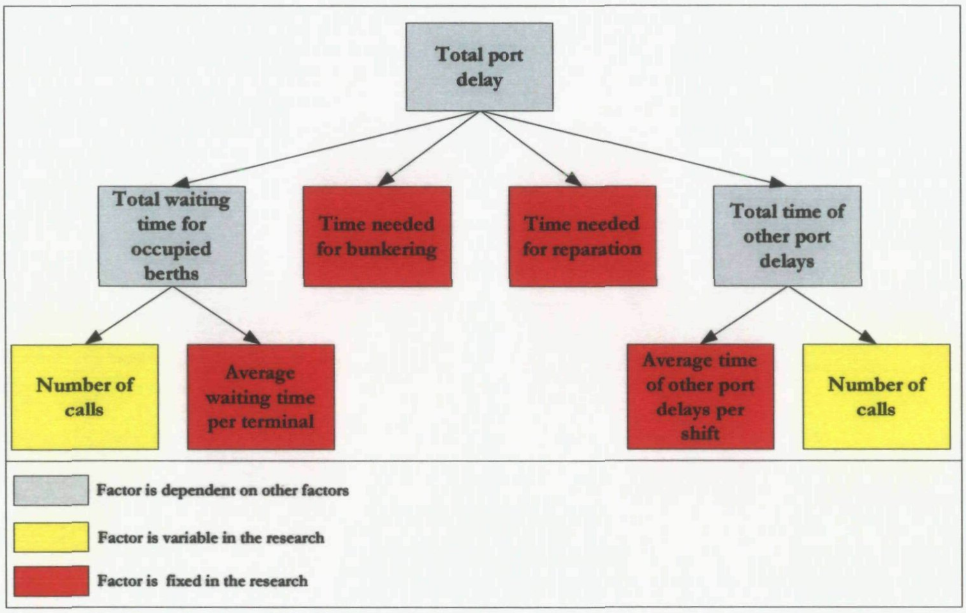


Figure 55: Port delays of Odfjell parcel tankers

The total waiting time for an occupied berth is dependent on the number of calls the tanker has to make and the average waiting time per terminal. The number of calls will change due to the implementation of a drop and swap concept, while the average waiting time per terminal fixed in the research. The time needed for bunkering and the time needed for reparation are also fixed in the research. The time due to the other port delays depend on the number of calls and the average time of these other port delays.

The correlation of the total number of calls a tanker has to make and the total port delay of that tanker, is used to determine the port delay per call. This correlation is shown in figure 56.

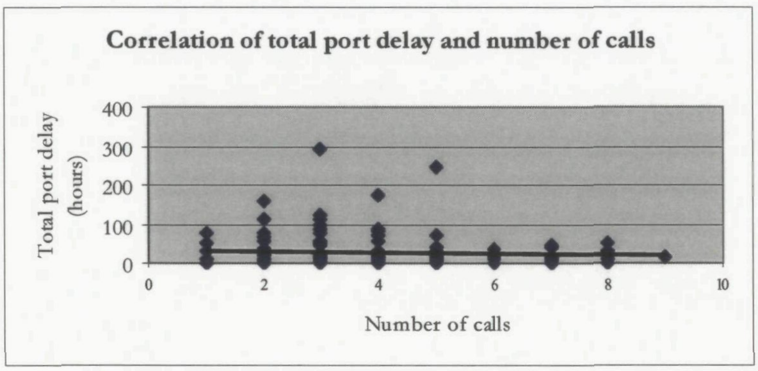


Figure 56: Correlation of port delay and number of calls

The total port delay is not dependent on the number of calls according to the formula. Total port delay is 21 hours, independent on the number of calls. R-square for this formula is 0,03. This shows accurate predictability of the total port delay is impossible with the number of calls knowing. Also with the elimination of outliers[29], R-square does not increase. To realize accurate predictability, other influences on the total port delay have to be taken into account.

J3: Operational delay of Odfjell parcel tankers

The total operational delay consists of several operational delays of an Odfjell parcel tanker. Operational delays are delays while the tanker is at a berth. An overview of the influences on the operational delays is shown in figure 57.

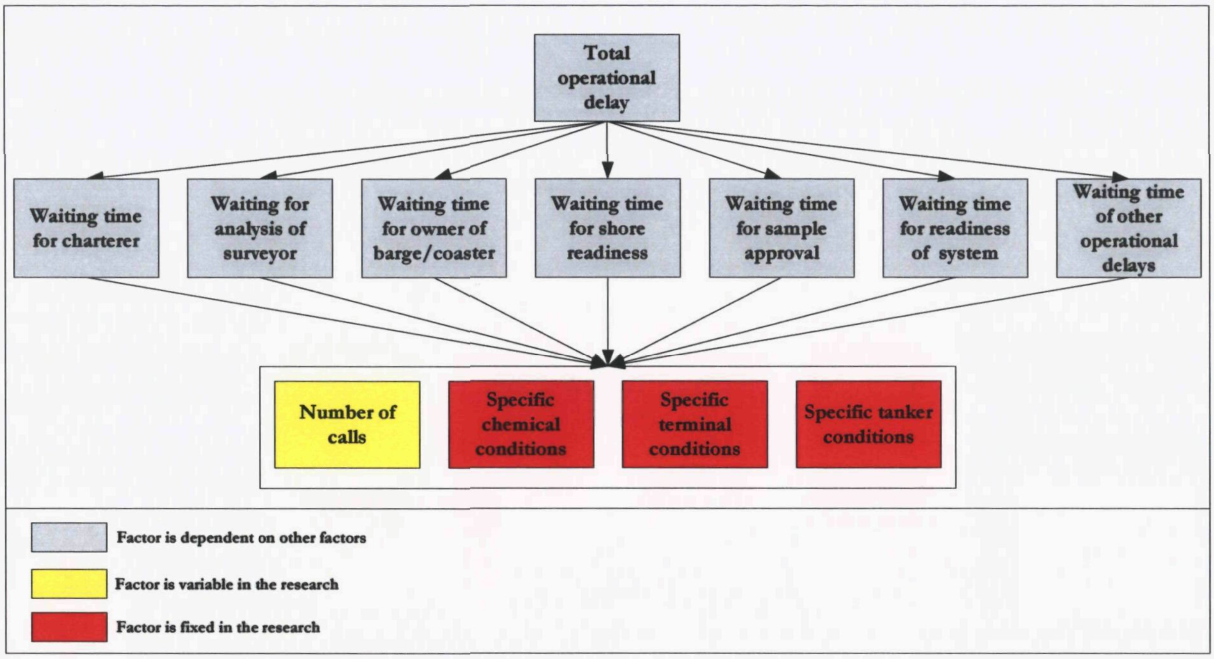


Figure 57: operational delay of Odfjell parcel tankers

Each operational delay is dependent on the number of calls, specific chemical conditions, specific terminal conditions and specific ship conditions. Some chemicals, that need to be transshipped, cause longer and more frequent operational delays than other. The same counts for terminal and tanker conditions. This chemical, terminal and tanker conditions are fixed in the research.

The correlation of the total number of calls a tanker has to make and the total operational delay of that tanker, is used to determine the operational delay per call. This correlation is shown in figure 58.

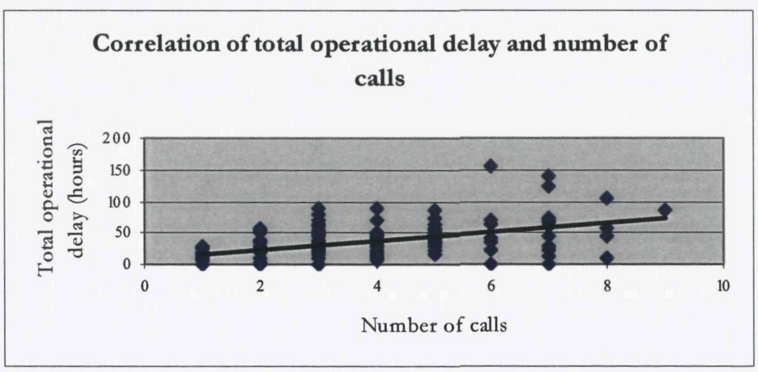


Figure 58: Correlation of operational delay and number of calls

[29] Outliers are values that are realized due to uncommon circumstances

The total operational delay is slightly dependent on the number of calls according to the formula. Total operational delay = 7 * number of calls + 13. R-square for this formula is 0,26. This shows no accurate predictability of the total operational delay is impossible with the number of calls knowing. With the elimination of outliers[30], R-square increases to 0,30, which still isn't reliable. To realize accurate predictability, other influences on the total operational delay have to be taken into account.

J4: Transshipping time of Odfjell parcel tankers

Total transshipping time is split up into total transshipping time at OTR and total transshipping time at other terminals. With the transshipping time, only the time actually used for transshipping is meant. Total transshipping depends on several factors, which is shown in figure 59.

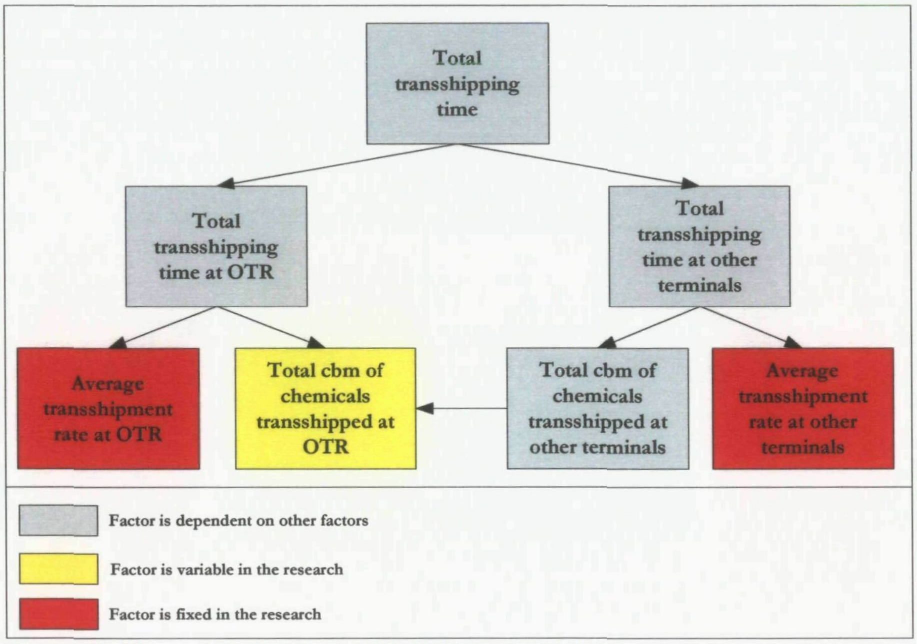


Figure 59: Transshipping time of Odfjell parcel tankers

The total transshipping time at OTR is dependent on the average transshipment rate at OTR and the total cbm of chemicals that is transshipped by Odfjell parcel tankers at OTR, which will change with the implementation of a drop and swap concept.

The total transshipping time at other terminals depends on the transshipment rate at other terminals and the total cbm of chemicals that needs to be transshipped at these other terminals. The transshipment rate at OTR and other terminals are fixed in the research.

Current average transshipment time per tanker = Total throughput of OS in the port of Rotterdam / average transshipment rate of all terminals / number of tankers → 4.3 million / 255 /147 = 114 hours

Drop and swap average transshipment time per tanker = Total throughput of OS in the port of Rotterdam / average transshipment rate at OTR / number of tankers → 4.3 million / 350 /147 = 84 hours

30 Outliers are values that are realized due to uncommon circumstances

Appendix K: Waiting times to moor at OTR

OTR has a first come, first serve principle, which means that the tanker that was in line first, can moor at OTR first. Average waiting time at OTR is determined using an M/M/c queuing system for OTR. This queuing system assumes an exponential arrival and exponential service rate for the Odfjell parcel tankers, with 'c' parallel servers (deep-sea berth). Waiting times at OTR are determined using the formulas as given in figure 60.

$$w_q = w - \frac{1}{\mu}$$

$$w = \frac{L}{\lambda}$$

$$L = c\rho + \frac{(c\rho)^{c+1} P_0}{c(c!)(1-\rho)^2}$$

$$P_0 = \left\{ \sum_{n=0}^{c-1} \frac{(c\rho)^n}{n!} + \left[(c\rho)^c \left(\frac{1}{c!} \right) \left(\frac{1}{1-\rho} \right) \right] \right\}^{-1}$$

w_q	= Average waiting time
w	= Average time in queue and at the berth
L	= Average number of tankers in queue and at the berth
λ	= Arrival intensity of the tankers
μ	= Service intensity of the tankers
c	= Number of deep-sea berths
ρ	= Deep-sea berth occupancy
P_0	=Probability of having no tankers in queue or at berth

Figure 60: Formulas to determine waiting time

With the implementation of the different drop and swap alternatives, the arrival intensity and the service intensity are changed, which influences the deep-sea berth occupancy at OTR. Determining the average waiting times, a total number of 5 deep-sea berths is taken into account.

Appendix L: Financial overview

The research considers an associated profit center for OS and OTR with the drop and swap of the chemicals at OTR transported by Odfjell parcel tankers. Currently, OS and OTR do not operate according to an associated profit center. An overview of the financial consequences per cost factor is given.

Savings in port time of Odfjell parcel tankers

Keeping an Odfjell parcel tanker in a port is very expensive. Depending upon the vessel size and tanker characteristics, costs of keeping the vessel in the port varies between 750 and 2.700 euro per hour. When an Odfjell parcel tanker stays in the port for one day, expenses will be between 18.000 and 72.000. The goal of the drop and swap concept is to reduce the total port time of an Odfjell parcel tanker. Odfjell uses different costs per Odfjell parcel tanker. Costs per Odfjell parcel tanker are shown in table 56.

Table 56: Cost per hour of port time for Odfjell parcel tankers

Size of the Odfjell parcel tanker	Costs per hour in port
15.000 cbm	€ 750
20.000 cbm	€ 1000
25.000 cbm	€ 1300
30.000 cbm	€ 1550
35.000 cbm	€ 1825
40.000 cbm	€ 2000
50.000 cbm	€ 2700

Savings in number of tugs and rowers needed

When fewer calls per Odfjell parcel tanker are needed, less rowers and tugs are needed for the shifting of the Odfjell parcel tankers between the terminals. Depending on the ship and the weather conditions, 1 or 2 tugs and 2 to 4 rowers are needed for the shifting of the Odfjell parcel tanker. According to Odfjell, costs per shift are approximately 5.000 euro. Formula for savings in number of tugs and rowers needed:

$$A = 5.000 * B$$

A = Savings in euro
B = Reduction in number of shifts per Odfjell parcel tanker that visits the port.

Extra transportation cost for collection and distribution with barges

For the collection and distribution of the chemical parties to and from OTR to other terminals only barges are used. Hiring costs of barges to tranship chemicals in the port of Rotterdam are approximately 4,50 euro per cbm (within a 24 hour rental range). Formula for collection and distribution:

$$A = 4{,}50 * B$$

A = Costs for hiring barges to collect chemicals at OTR.
B = Cbm of chemicals collected and distributed at OTR form other terminals.

Surveyor cost

Total surveyor costs depend on the number of chemical parties that need to be checked. Surveyors ask on average € 500 for each chemical party that needs to be checked. Formula for surveyor costs.

$A = 500 * B$

A = Total cost for surveyors.
B = Number of extra chemical parties transshipped at OTR.

Loss in revenue due to temporary storage

Chemical parties that are transshipped board-board do not demand extra costs for Odfjell shipping. Extra costs for temporary storage at OTR will arise though. From earlier research toward drop and swap possibilities, the following standard storage rates, shown in table 57 and 58 are used at OTR.

Table 57: Storage revenue for Odfjell

	0 – 1000 cbm	1000 – 2000 cbm	2000 – 3000 cbm	3000 – 6000 cbm	> 6000 cbm
2 weeks	€ 5.600	€ 13.000	€ 16.150	€ 28.750	€ 56.500
1 month	€ 7.650	€ 14.750	€ 18.750	€ 32.125	€ 62.500
2 months	€ 11.200	€ 19.500	€ 24.000	€ 39.060	€ 74.500

Table 58: Storage revenue for Odfjell

Additional premium	Additional costs per cbm
Stainless steel tank	€ 5
Group 2 chemicals	€ 2
Group 3 chemicals	€ 2,75
Group 4 chemicals	€ 7

Within the financial feasibility calculations, it is assumed that the temporary storage with dedicated storage is done in stainless steel tanks of 1.600 cbm, which have average storage revenues of circa 130.000 euro per year.

$A = 130.000 * B$

A = Total loss in revenue due to temporary storage.
130.000 = Costs to store 1.600 cbm for one year.
B = Total storage tanks used for drop and swap per year.

Or:

$A = B * C$

A = Total loss in revenue due to temporary storage.
B = Costs for one storage tank of a variable size for 2 weeks.
C = Total storage tanks used for drop and swap per year.

Loss in revenue due to extra deep-sea berth use

With the implementation of a drop and swap concept, OS will use extra berth capacity for their tankers. Due to this extra use of berth capacity, OTR has less capacity available for other tankers.

The loss in revenue due to this 'capacity loss' is considered to be €500 per hour[31]. The formula for the extra berth costs is:

*A = 500 * B*

A = Total extra berth costs
B = Hours of extra occupation of deep-sea berths due to the drop and swap concept.

Cost for extra storage capacity
Due to the limited capacity, investments may be required in additional tank capacity. Tanks with different capacities can be realized at OTR to cope with the extra capacity required with the drop and swap concept. An overview of the investment costs is given in table 59.

Table 59: Costs for extra storage capacity

	750 cbm	1.100 cbm	1.600 cbm	6.600 cbm	More than 20.000 cbm
K1	€ 500.000	€ 625.000	€ 750.000	€ 2.250.000	€5.000.000

In this research it is assumed that only category K1 tanks are build. K1 tanks are stainless steel tanks and fundaments with inner float (0% emissions), pump, tank line, and no insulation. In this research, it is assumed that for the temporary storage, tanks with a capacity of 1.600 cbm will be build at OTR. The formula for extra storage capacity is:

*A = 750.000 * B*

A = Total costs for extra storage capacity.
B = Number of shore tanks

[31] This value is based on the total revenue of OTR divided over its berth occupancy rate. Value of restitution of insurance companies in case of utility of a berth due to accidents is estimated on €1.400 per hour.

Appendix M: Variable input of loss in revenues due to storage capacity

The loss in revenues is determined in two different scenarios:

1. Realize dedicated storage capacity that is only used for the drop and swap of chemicals that need temporary storage at OTR.
2. Create extra storage capacity 'last-minute' when an Odfjell parcel tanker that is going to drop and swap its chemicals, is supposed to arrive at OTR.

Loss in revenues of the two different scenarios is determined using the percentage of throughput than needs temporary storage, the duration of occupation of the storage capacity, and the size and costs of the tanks that are used.

<u>Percentage of throughput that needs temporary storage</u>
The percentage of throughput that needs temporary storage depends on the total extra throughput per tanker and the percentage of the extra throughput that can be done by board-board transshipment. It is assumed that a connection with two barges is possible during the transshipment of an Odfjell parcel tanker. This means that 6.000 cbm (2 times the capacity of a barge) of the extra chemical throughput can be transshipped board-board. The other extra throughput needs to be transshipped with temporary storage.

<u>Duration of storage capacity occupation</u>
With dedicated storage, tanks are occupied for the whole year. With non-dedicated storage, an occupation time of two weeks is assumed. This occupation time is based on advanced planning, actual transshipment, preparing of the tank, and cleaning of the tank.

<u>The size and costs of the tanks used</u>
With dedicated storage, a tank size of 1.600 cbm is assumed. Loss in revenue per year for this tank is on average 130.000 euro.
With non-dedicated storage, tank size depends on the average quantity per chemical party that needs to be transshipped. Costs of these tanks can be found in appendix L.

Appendix N: Verification

The Excel model is checked using a verification of the model. Verification is a process that is used to evaluate whether the model is quantitative correct. Verification of the Excel model will be done by checking the units after the calculation and by comparing the total values of the different alternative values, which are supposed to be equal.

Verification of units

The Excel model calculates with a lot of different units. To the verification of the model, these calculations must be checked on correct use of units. The tables 60 to 66 below show this check on units of the values used.

Table 60: Deep-sea berth occupancy

Description	Calculation	Check on units
Available capacity (Hours/year)	Number of berths * Hours in operation	Constant * Hours/year = Hours/year
Needed capacity (Hours / year)	Number of tankers per year * Time per tanker	Constant/year * Hours/year = Hours/year
Deep-sea berth occupation (Percentage)	Needed capacity / Available capacity	(Hours/year) / (Hours/year) = Percentage

Table 61: Barge berth occupancy

Description	Calculation	Check on units
Available capacity (Hours/year)	Number of berths * Hours in operation	Constant * Hours/year = Hours/year
Needed capacity (Hours / year)	Number of tankers per year * Time per tanker	Constant/year * Hours/year = Hours/year
Barge berth occupation (Percentage)	Needed capacity / Available capacity	(Hours/year) / (Hours/year) = Percentage

Table 62: Reduction in costs for Odfjell

Description	Calculation	Check on units
Reduction in costs due to reduction in the number of calls (Euro/year)	Reduction in number of calls per year * Costs per call	Constant/year * Euro = Euro/year
Reduction in costs due to the reduction in port time (Euro/year)	Reduction in number of hours per year * Costs per hour of port time	Hours/year * Euro/hour = Euro/year

Table 63: Extra transportation costs for Odfjell

Description	Calculation	Check on units
Extra costs for transportation by barge (Euro/year)	Quantity that needs to be transported * Costs for transport by barge	Cbm/year * Euro/cbm = Euro/year

Table 64: Extra transshipment costs for Odfjell

Description	Calculation	Check on units
Extra costs for surveyors (Euro/year)	Number of chemical parties that need to be checked * Costs for surveyor	Chemical parties/year * Euro/chemical party = Euro/year

Table 65: Loss in revenue for Odfjell

Description	Calculation	Check on units
Loss in revenues due to use of storage (Euro/year)	Number of storage tanks reserved * Loss in revenues per storage tank	Number * Euro/year = Euro/year
Loss in revenues due to use of deep sea berth occupancy (Euro/year)	Deep sea berth occupancy used * Loss in revenues per hour	Hours/year * Euro/hour = Euro/year

From the verification of units, there is concluded that the model is quantitative correct.

Verification with check on total values

The Excel model determines the values after implementing 4 different drop and swap alternatives. For each of these alternatives, the current situation is determined using the port tracker in different ways: with the Odfjell parcel tankers split up in different trade lanes, different quantities, different number of chemical parties, and different number of calls. Current situation for all alternatives should be the same, which is checked in the tables 66 to 69 below.

Table 66: Current situation with trade lane alternative

	Tankers that visit OTR		Tankers that do not visit OTR	All tankers
Number of Odfjell parcel tankers	75		72	**147**
Number of calls	341		215	**556**
	At OTR	At other terminals		
Average throughput per Odfjell parcel tanker	9.919	23.216	26.108	**29.693**
Total throughput by OS	743.946	1.741.183	1.879.746	**4.364.875**
Total number of chemical parties	508	712	614	**1.834**

Table 67: Current situation with quantity alternative

	Tankers that visit OTR		Tankers that do not visit OTR	All tankers
Number of Odfjell parcel tankers	75		72	**147**
Number of calls	341		215	**556**
	At OTR	At other terminals		
Average throughput per Odfjell parcel tanker	9.919	23.216	26.108	**29.693**
Total throughput by OS	743.944	1.741.183	1.879.755	**4.364.882**
Total number of chemical parties	508	712	614	**1.834**

Table 68: Current situation with number of chemical parties alternative

	Tankers that visit OTR		Tankers that do not visit OTR	All tankers
Number of Odfjell parcel tankers	75		72	**147**
Number of calls	341		215	**556**
	At OTR	At other terminals		
Average throughput per Odfjell parcel tanker	9.919	23.216	26.108	**29.693**
Total throughput by OS	743.946	1.741.185	1.879.744	**4.364.875**
Total number of chemical parties	508	712	614	**1.834**

Table 69: Current situation with number of calls alternative

	Tankers that visit OTR		Tankers that do not visit OTR	All tankers
Number of Odfjell parcel tankers	75		72	**147**
Number of calls	341		215	**556**
	At OTR	**At other terminals**		
Average throughput per Odfjell parcel tanker	9.919	23.216	26.108	**29.693**
Total throughput by OS	743.948	1.741.245	1.879.744	**4.364.937**
Total number of chemical parties	508	712	614	**1.834**

The tables show, that values concerning the current situation are almost the same for the different alternatives. The only differences are in the different total throughputs by OS. These differences are very small though, and can be explained with the rounding off in the Excel model.

Also from this verification, there is concluded that the model is quantitative correct.

Appendix O: Assumptions in the research

Table 70: Assumptions in the research

Assumptions
To determine the results of implementing different drop and swap alternatives, the 147 Odfjell parcel tankers that visited the port of Rotterdam in 2008 are used. In reality, each year is different, concerning the number and characteristics (e.g. quantity of chemicals, destination of chemicals, etc.) of Odfjell parcel tankers that visit the port of Rotterdam.
A fixed correlation of the number of calls and total shifting time, total port delay, and total operational delay per Odfjell parcel tanker is determined using the 147 Odfjell parcel tankers that visited the port of Rotterdam. These correlations are used to determine the consequences of the drop and swap alternatives. Correlations of the total port delay, and total operational delay were difficult to forecast.
Average transshipment rates for the Odfjell parcel tankers in the port of Rotterdam are fixed in the research. In reality, transshipment rates fluctuate.
Results per Odfjell parcel tanker group are determined. Results of individual Odfjell parcel tankers are generated by the results of these groups, divided by the number of tankers in this group. In reality, results of individual tankers in specific groups are different.
Port time costs are determined per Odfjell parcel tanker group that is influenced by a drop and swap alternative. In reality, port time costs differ per individual Odfjell parcel tanker.
A fixed occupation of deep-sea berth capacity by other tankers is taken into account. Also with the construction of the 5th deep-sea berth, this occupation is the same. In reality, this occupation fluctuates.
A fixed current occupation of the barge berths is taken into account. In reality, this occupation fluctuates.
Waiting times are determined using an M/M/c queuing system. In reality, this queuing system is not equal to the real situation.
Barge costs, surveyor costs, savings per shift, and loss in revenue due to use of deep-sea berth capacity are based on the average costs in 2008.

The loss in revenue due to use of storage capacity is determined in two different scenarios. In each scenario, assumptions have been made.
- Use dedicated storage capacity for the temporary storage:
    o Storage tanks with a chemical capacity of 1.600 cbm are used.
    o A fixed board-board transshipment of 6.000 cbm per tanker is used.
    o The percentage of the extra throughput per tanker that needs temporary storage is determined with the average extra chemical quantity that is transshipped at OTR, minus the percentage of board-board transshipment of this quantity.
    o Maximum dedicated storage available is 70% of the maximum temporary storage that is needed at a certain moment. Extra need of temporary storage is solved with other storage capacity.
    o Loss in revenues for a storage tank with a chemical capacity of 1.600 cbm is 130.000 euro per year.
- Use non dedicated storage capacity for the temporary storage:
    o Size of the storage tanks depends on the average quantity per chemical party that is transshipped at OTR due to the implementation of a drop and swap concept.
    o A fixed board-board transshipment of 6.000 cbm per tanker is used.
    o The percentage of the extra throughput per tanker that needs temporary storage is determined with the average extra chemical quantity that is transshipped at OTR, minus the percentage of board-board transshipment of this quantity.
    o Loss in revenues per tank depends on the size of the storage tanks and a fixed occupation time of two weeks.
    o Number of storage tanks needed depends on the extra number of chemical parties that are transshipped.

An associated profit centre is assumed for OTR and OS with the Odfjell parcel tankers that are dropped and swapped at OTR. At the moment, OTR and OS have separated profit centers.

Appendix P: Validation

Validation is the process of determining the degree to which the Excel model is an accurate representation of the real world from the perspective of the intended uses of the Excel model. A check of the Excel model towards the current situation is done, together with a sensitivity analysis of the model.

Validation of the current situation

Results of the Excel model towards the results of the current situation are compared to check the validation of the Excel model. Results are shown in table 71.

Table 71: Validation of the current situation

Description	Excel model	Real world	Accuracy
Average port time per Odfjell parcel tanker (hours)	190,44	188,64	99,1%
Average shifting time per Odfjell parcel tanker (hours)	18,91	18,11	95,8%
Average port delay per Odfjell parcel tanker (hours)	21,00	19,62	93.4%
Average operational delay per Odfjell parcel tanker (hours)	39,48	37,16	94,1%
Average transshipping time per Odfjell parcel tanker (hours)	111,06	113,75	97.6%
Average number of calls per Odfjell parcel tanker	3,78	3,78	100%
Average throughput per Odfjell parcel tanker (cbm)	29.693	29.693	100%
Total throughput of OS (cbm)	4.364.875	4.364.875	100%
Total port time of Odfjell parcel tankers (hours)	27.995	27.730	99,1%

Accuracy of the model values compared to the values of the real world is high, which shows that, concerning the current situation, the model is reliable.

Appendix Q: Results

Results, concerning the logistical and financial criteria, of implementing the drop and swap alternatives are determined by changing the variable input factors per alternative.

Drop and swap for specific trade lanes

Tables 72 to 75 show the results of the variable input, logistical feasibility, and financial feasibility of implementing a drop and swap concept for chemicals transported by Odfjell parcel tankers of a specific trade lane.

Table 72: Current situation for specific trade lanes

	1a	1b	1c	1d	1e	1f	1g	1h
Number of Odfjell parcel tankers visiting OTR.	1	29	5	6	1	3	20	10
Total number of calls that the Odfjell parcel tankers make.	7	180	39	58	13	27	159	73
Throughput of the Odfjell parcel tankers at OTR (cbm)	24.511	304.074	79.294	60.306	4.889	17.191	117.576	136.105
Number of chemical parties transshipped at OTR	3	222	45	49	9	27	102	51

1a = Africa trade lane, 1b = Europe trade lane, 1c =Far East via Africa trade lane, 1d = Far East via Suez Canal trade lane, 1e = Mid East via Africa trade lane, 1f = Mid East via Suez Canal trade lane, 1g = South America trade lane, 1h = North America trade lane

Table 73: Variable input of drop and swap for specific trade lanes

	1a	1b	1c	1d	1e	1f	1g	1h
Extra number of Odfjell parcel tankers visiting OTR.	2	23	3	6	1	2	24	11
Reduction in total number of calls of the Odfjell parcel tankers.	4	128	31	46	11	22	115	52
Extra throughput of the Odfjell parcel tankers at OTR (cbm)	36.705	1.199.199	218.478	367.985	47.388	80.807	1.142.467	527.890
Extra number of chemical parties transshipped at OTR.	13	375	120	158	40	60	415	145
Parcel tanker costs per port time hour of the influenced Odfjell parcel tankers (euro).	1.000	1.300	1.825	1.825	1.300	750	1.550	1.825
Number of storage tanks needed for drop and swap.	10	19	19	16	15	14	14	16
Average percentage of throughput with temporary storage	51%	74%	78%	80%	75%	63%	77%	76%
Average tank size with non-dedicated storage	3.000	4.000	2.000	2.500	1.500	1.500	2.500	3.500

1a = Africa trade lane, 1b = Europe trade lane, 1c =Far East via Africa trade lane, 1d = Far East via Suez Canal trade lane, 1e = Mid East via Africa trade lane, 1f = Mid East via Suez Canal trade lane, 1g = South America trade lane, 1h = North America trade lane

Table 74: Logistical criteria of drop and swap for specific trade lanes

	1a	1b	1c	1d	1e	1f	1g	1h
Total port time of Odfjell parcel tankers (hours).	27.908	25.183	27.391	27.052	27.813	27.645	25.399	26.809
Average port time per Odfjell parcel tanker (hours).	189,85	171,31	186,33	184,02	189,20	188,06	172,78	182,38
Deep-sea berth occupancy at OTR (percentage).	65	74	67	68	65	66	73	69
Barge berth occupancy at OTR (percentage).	30	32	30	31	30	30	32	31
Average waiting time to moor at OTR (hours).	5,5	6	6	6	5,5	6	6	6

1a = Africa trade lane, 1b = Europe trade lane, 1c =Far East via Africa trade lane, 1d = Far East via Suez Canal trade lane, 1e = Mid East via Africa trade lane, 1f = Mid East via Suez Canal trade lane, 1g = South America trade lane, 1h = North America trade lane

Table 75: Financial feasibility of drop and swap for specific trade lanes

	1a	1b	1c	1d	1e	1f	1g	1h
Total reduction in costs (K.€/year)	106	4.295	1.257	1.950	292	372	4.597	2.423
Extra transportation costs (K.€/year)	165	5.396	983	1.656	213	364	5.141	2.375
Extra transshipment costs (K.€/year)	7	188	60	79	20	30	208	73
Loss in revenue due to dedicated storage use (K.€/year)	1.040	2.600	2.730	2.340	2.080	1.560	2.080	2.210
Loss in revenue due to non-dedicated storage use (K.€/year)	210	6.056	1.560	2.552	520	780	6.702	4.169
Loss in revenue due to deep-sea berth use (K.€/year)	52	1.713	312	526	68	115	1.632	754

1a = Africa trade lane, 1b = Europe trade lane, 1c =Far East via Africa trade lane, 1d = Far East via Suez Canal trade lane, 1e = Mid East via Africa trade lane, 1f = Mid East via Suez Canal trade lane, 1g = South America trade lane, 1h = North America trade lane

Drop and swap for specific quantity

Tables 76 to 79 show the results of the variable input, logistical feasibility, and financial feasibility of implementing a drop and swap concept for chemicals transported by Odfjell parcel tankers that need to transship a specific chemical quantity in the port of Rotterdam.

Table 76: Current situation for specific quantities

	2a	2b	2c
Number of Odfjell parcel tankers visiting OTR.	12	47	16
Total number of calls that the Odfjell parcel tankers make.	82	343	131
Throughput of the Odfjell parcel tankers at OTR (cbm)	77.584	393.478	272.877
Number of chemical parties transshipped at OTR	47	249	212

2a = less than 20.000 cbm, 2b = between 20.000 and 40.000 cbm, 2c =more than 40.000 cbm

Table 77: Variable input of drop and swap for specific quantities

	2a	2b	2c
Extra number of Odfjell parcel tankers visiting OTR.	19	46	7
Reduction in total number of calls of the Odfjell parcel tankers.	51	250	108
Extra throughput of the Odfjell parcel tankers at OTR (cbm)	311.636	2.402.986	906.316
Extra number of chemical parties transshipped at OTR.	159	925	142
Parcel tanker costs per port time hour of the influenced Odfjell parcel tankers (euro).	750	1.550	2.700
Number of storage tanks needed for drop and swap.	9	16	19
Average percentage of throughput with temporary storage	40%	77%	85%
Average tank size with non-dedicated storage (cbm)	2.000	2.500	4.000

2a = less than 20.000 cbm, 2b = between 20.000 and 40.000 cbm, 2c =more than 40.000 cbm

Table 78: Logistical criteria of drop and swap for specific quantities

	2a	2b	2c
Total port time of Odfjell parcel tankers (hours).	27.052	22.438	25.735
Average port time per Odfjell parcel tanker (hours).	184,02	152,64	175,07
Deep-sea berth occupancy at OTR (percentage).	68	82	71
Barge berth occupancy at OTR (percentage).	31	35	32
Average waiting time to moor at OTR (hours).	6	8	6

2a = less than 20.000 cbm, 2b = between 20.000 and 40.000 cbm, 2c =more than 40.000 cbm

Table 79: Financial criteria of drop and swap for specific quantities

	2a	2b	2c
Total reduction in costs (K .€/year)	962	9.863	6.642
Extra transportation costs (K .€/year)	1.402	10.813	4.078
Extra transshipment costs (K .€/year)	80	463	121
Loss in revenue due to dedicated storage use (K .€/year)	780	2.340	2.990
Loss in revenue due to non-dedicated storage use (K .€/year)	2.067	14.939	6.958
Loss in revenue due to deep-sea berth use (K .€/year)	445	3.433	1.295

2a = less than 20.000 cbm, 2b = between 20.000 and 40.000 cbm, 2c =more than 40.000 cbm

Drop and swap for specific number of chemical parties

Tables 80 to 83 show the results of the variable input, logistical feasibility, and financial feasibility of implementing a drop and swap concept for chemicals transported by Odfjell parcel tankers that need to transship a specific number of chemical parties in the port of Rotterdam.

Table 80: Current situation for specific number of chemical parties

	3a	3b	3c
Number of Odfjell parcel tankers visiting OTR.	15	34	26
Total number of calls that the Odfjell parcel tankers make.	99	247	210
Throughput of the Odfjell parcel tankers at OTR (cbm)	102.914	354.217	286.815
Number of chemical parties transshipped at OTR	47	246	215

3a = less than 8 chemical parties, 3b = between 8 and 16 chemical parties, 3c =more than 16 chemical parties

Table 81: Variable input of drop and swap for specific number of chemical parties

	3a	3b	3c
Extra number of Odfjell parcel tankers visiting OTR.	26	34	12
Reduction in total number of calls of the Odfjell parcel tankers.	58	179	172
Extra throughput of the Odfjell parcel tankers at OTR (cbm)	765.218	1.092.406	1.178.597
Extra number of chemical parties transshipped at OTR.	1.300	2.080	2.470
Parcel tanker costs per port time hour of the influenced Odfjell parcel tankers (euro).	2.395	5.245	3.685
Number of storage tanks needed for drop and swap.	10	16	19
Average percentage of throughput with temporary storage	68%	76%	81%
Average tank size with non-dedicated storage (cbm)	5.000	3.000	1.500

3a = less than 8 chemical parties, 3b = between 8 and 16 chemical parties, 3c =more than 16 chemical parties

Table 82: Logistical criteria of drop and swap for specific number of chemical parties

	3a	3b	3c
Total port time of Odfjell parcel tankers (hours).	26.485	24.062	24.677
Average port time per Odfjell parcel tanker (hours).	180,17	163,69	167,87
Deep-sea berth occupancy at OTR (percentage).	71	77	73
Barge berth occupancy at OTR (percentage).	31	33	32
Average waiting time to moor at OTR (hours).	6	7	6

3a = less than 8 chemical parties, 3b = between 8 and 16 chemical parties, 3c =more than 16 chemical parties

Table 83: Financial criteria of drop and swap for specific number of chemical parties

	3a	3b	3c
Total reduction in costs (K .€/year)	1.800	6.990	7.496
Extra transportation costs (K .€/year)	3.443	7.547	5.304
Extra transshipment costs (K .€/year)	74	257	333
Loss in revenue due to dedicated storage use (K .€/year)	1.170	2.210	2.860
Loss in revenue due to non-dedicated storage use (K .€/year)	4.226	14.778	8.645
Loss in revenue due to deep-sea berth use (K .€/year)	1.093	2.396	1.684

3a = less than 8 chemical parties, 3b = between 8 and 16 chemical parties, 3c =more than 16 chemical parties

Drop and swap for specific number of calls

Tables 84 to 87 show the results of the variable input, logistical feasibility, and financial feasibility of implementing a drop and swap concept for chemicals transported by Odfjell parcel tankers that need to make a specific number of calls in the port of Rotterdam.

Table 84: Current situation of drop and swap concept for specific number of calls

	4a	4b	4c
Number of Odfjell parcel tankers visiting OTR.	9	47	19
Total number of calls that the Odfjell parcel tankers make.	63	319	174
Throughput of the Odfjell parcel tankers at OTR (cbm)	76.156	452.393	215.399
Number of chemical parties transshipped at OTR	26	225	257

4a = less than 3 calls, 4b = between 3 and 5 calls, 4c =more than 5 calls

Table 85: Variable input of drop and swap concept for specific number of calls

	4a	4b	4c
Extra number of Odfjell parcel tankers visiting OTR.	29	37	6
Reduction in total number of calls of the Odfjell parcel tankers.	25	235	149
Extra throughput of the Odfjell parcel tankers at OTR (cbm)	700.752	2.113.395	806.842
Extra number of chemical parties transshipped at OTR.	1.300	2.470	2.470
Parcel tanker costs per port time hour of the influenced Odfjell parcel tankers.	2.190	6.605	2.525
Number of storage tanks needed for drop and swap.	10	19	19
Average percentage of throughput with temporary storage	67%	76%	81%
Average tank size with non-dedicated storage (cbm)	3.500	2.500	2.500

4a = less than 3 calls, 4b = between 3 and 5 calls, 4c =more than 5 calls

Table 86: Logistical feasibility of drop and swap concept for specific number of calls

	4a	4b	4c
Total port time of Odfjell parcel tankers (hours).	26.950	22.926	25.349
Average port time per Odfjell parcel tanker (hours).	183,33	155,96	172,44
Deep-sea berth occupancy at OTR (percentage).	70	80	71
Barge berth occupancy at OTR (percentage).	31	34	32
Average waiting time to moor at OTR (hours).	6	7	6

4a = less than 3 calls, 4b = between 3 and 5 calls, 4c =more than 5 calls

Table 87: Financial criteria of drop and swap concept for specific number of calls

	4a	4b	4c
Total reduction in costs (K .€/year)	1.170	9.032	6.037
Extra transportation costs (K .€/year)	3.153	9.510	3.631
Extra transshipment costs (K .€/year)	105	421	138
Loss in revenue due to dedicated storage use (K .€/year)	1.300	2.730	2.860
Loss in revenue due to non-dedicated storage use (K .€/year)	6.009	13.582	4.457
Loss in revenue due to deep-sea berth use (k.€/year)	1.001	3.019	1.153

4a = less than 3 calls, 4b = between 3 and 5 calls, 4c =more than 5 calls

Appendix R: Validation of the results

With the validation of the results, several assumptions, made during the research, are tested on their sensitivity. For each alternative is determined what the changes in the profit for Odfjell are if the assumed value is increased with 20% and decreased with 20%.

Average transshipment rate of 280 cbm/hour at OTR

Table 88: Average transshipment rate of 280 cbm/hour at OTR

	Influence on profit
Scenario A (K. €/year).	- 41% / - 92%
Scenario B1 (K. €/year).	- 0% / - 39%
Scenario B2 (K. €/year).	- 10% / -42%
Scenario C1 (K. €/year).	- 0% / -31%
Scenario C2 (K. €/year).	- 9% / -31%

Average transshipment rate of 420 cbm/hour at OTR

Table 89: Average transshipment rate of 420 cbm/hour at OTR

	Influence on profit
Scenario A (K. €/year).	+ 24% / + 78%
Scenario B1 (K. €/year).	+ 0% / + 29%
Scenario B2 (K. €/year).	+ 5% / + 31%
Scenario C1 (K. €/year).	+ 0% / + 22%
Scenario C2 (K. €/year).	+ 5% / +27%

The fluctuations in percentage per scenario depend on the chemical transshipment per tanker. The profit is especially influenced in scenario A is by a change in average transshipment rate at OTR. However, also profits in the other scenarios are influenced a lot.

Loss in storage revenues of 104.000 euro per year per dedicated storage tank

Table 90: Loss in storage revenues of 104.000 euro per year per dedicated storage tank

	Influence on profit
Scenario A (K. €/year).	0%
Scenario B1 (K. €/year).	+ 11% / + 20%
Scenario B2 (K. €/year).	0%
Scenario C1 (K. €/year).	+ 7% / + 19%
Scenario C2 (K. €/year).	0%

Loss in storage revenues of 156.000 euro per year per dedicated storage tank

Table 91: Loss in storage revenues of 156.000 euro per year per non-dedicated storage tank

	Influence on profit
Scenario A (K. €/year).	0%
Scenario B1 (K. €/year).	- 11% / - 22%
Scenario B2 (K. €/year).	0%
Scenario C1 (K. €/year).	- 11% / - 20%
Scenario C2 (K. €/year).	0%

The fluctuations in percentage per scenario depend on the number of dedicated storage tanks needed. The profit is only influenced in scenario B1 and C1.

Loss in storage revenues decrease with 20% per non-dedicated storage tank

Table 92: Loss in storage revenues decrease with 20% per non-dedicated storage tank

	Influence on profit
Scenario A (K. €/year).	0%
Scenario B1 (K. €/year).	0%
Scenario B2 (K. €/year).	+ 11% / + 16%
Scenario C1 (K. €/year).	0%
Scenario C2 (K. €/year).	+ 9% / + 11%

Loss in storage revenues increase with 20% per non-dedicated storage tank

Table 93: Loss in storage revenues increase with 20% per non-dedicated storage tank

	Influence on profit
Scenario A (K. €/year).	0%
Scenario B1 (K. €/year).	0%
Scenario B2 (K. €/year).	- 11% / - 16%
Scenario C1 (K. €/year).	0%
Scenario C2 (K. €/year).	- 9% / - 11%

The fluctuations in percentage per scenario depend on the price and number of non-dedicated storage tanks needed. The profit is only influenced in scenario B2 and C2.

Percentage of extra throughput with temporary storage decreases with 20%

Table 94: Percentage of extra throughput with temporary storage decreases with 20%

	Influence on profit
Scenario A (K. €/year).	0%
Scenario B1 (K. €/year).	- 11% / - 24%
Scenario B2 (K. €/year).	- 12% / - 16%
Scenario C1 (K. €/year).	- 8% / - 21%
Scenario C2 (K. €/year).	- 9% / - 12%

Percentage of extra throughput with temporary storage increases with 20%

Table 95: Percentage of extra throughput with temporary storage increases with 20%

	Influence on profit
Scenario A (K. €/year).	0%
Scenario B1 (K. €/year).	+ 11% / + 24%
Scenario B2 (K. €/year).	+ 12% / + 16%
Scenario C1 (K. €/year).	+ 8% / + 21%
Scenario C2 (K. €/year).	+ 9% / + 12%

The fluctuations in percentage per scenario depend on the number of dedicated or non-dedicated storage tanks needed. The profit is influenced in scenario B1, B2, C1, and C2.