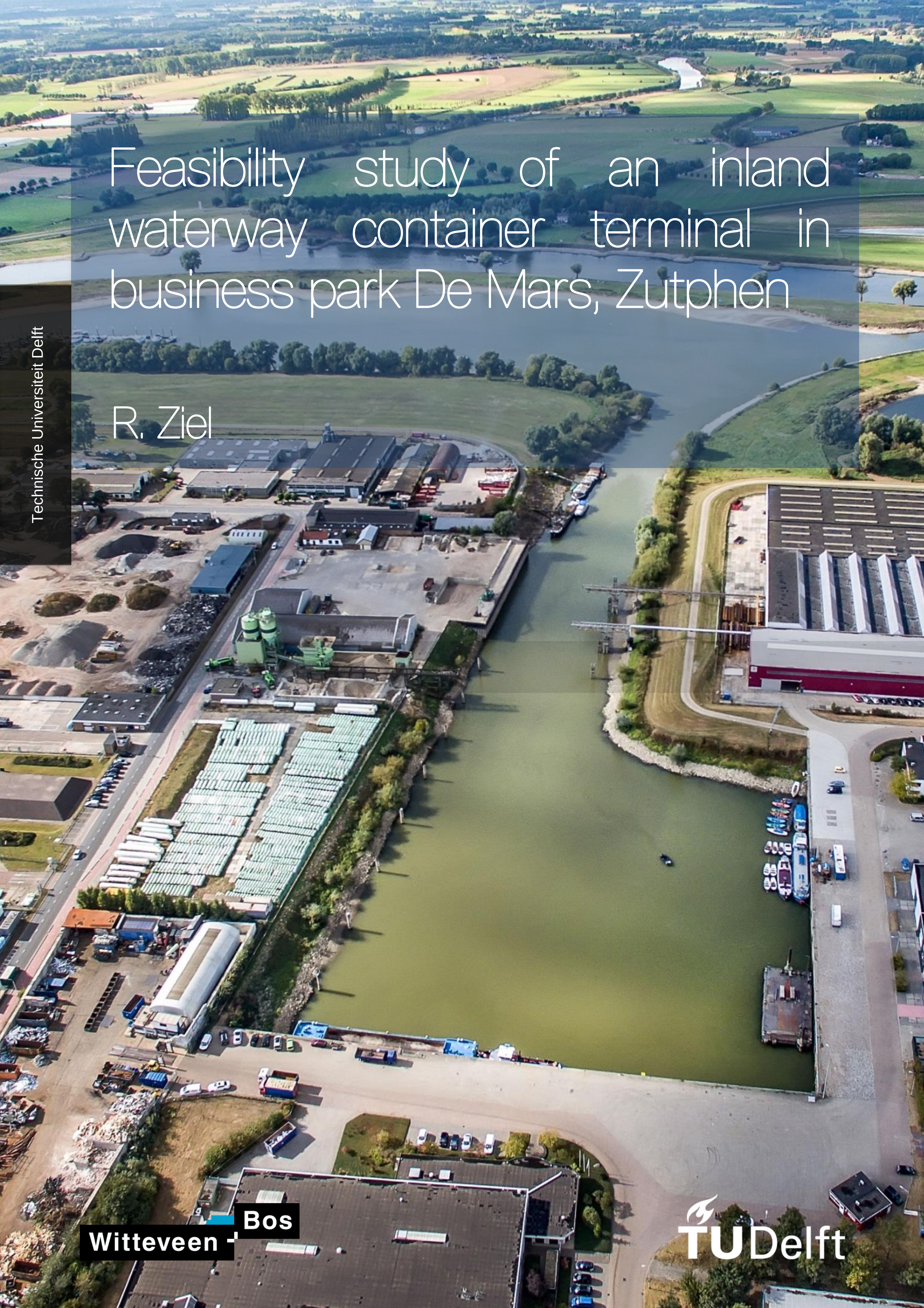

Feasibility study of an inland waterway container terminal in business park De Mars, Zutphen

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Technische Universiteit Delft

Cover image:

Aerial picture of the industrial harbour in De Mars, Zutphen

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Feasibility study of an inland waterway container terminal in business park De Mars, Zutphen

By

Rolf Ziel

in partial fulfilment of the requirements for the degree of

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Preface

This report presents the results of the feasibility study of an inland waterway container terminal in business park De Mars in Zutphen. This master thesis is carried out as part of the Master Hydraulic Engineering with specialization Ports and Waterways at the Delft University of Technology.

This graduation project is the result of an initiative from the local political party PvdA and the Cleantech Center in Zutphen. Their desire is to improve the utilization of the inland waterways with a freight connection at business park De Mars. It was found that the best opportunities to improve the use of the waterways lie at realizing a barge container terminal, which led to this challenging study with many elements.

I would like to express my gratitude to all members of my graduation committee for their guidance during this study: prof. ir. T. Vellinga, ir. P. Quist, dr. ir. J.C.M. van Dorsser and dr. B.W. Wiegmans. Furthermore I would like to thank the company Witteveen+Bos for supporting me during this thesis with their resources, in-house expertise and great working environment.

On a personal note I would like to show my appreciation to my parents, sister and friends for their support during my studies.

Rolf Ziel
Delft, August 2017

Summary

Introduction
Zutphen is a historical Hanseatic city in the Netherlands, located along the IJssel River and the nautical access of the Twentekanaal. In the north of the city, business park De Mars is located, which suffers from a high vacancy rate. This is despite the fact that in the last decade, the municipality has invested to revitalize the business park. To ensure the future of De Mars, its business climate has to be improved to attract new entrepreneurs to settle their businesses. The municipality aims to do so by improving the freight connection. By exploring the possibilities of developing a freight connection via the inland waterways, the municipality wants to utilize their favourable location along the waterways. This initiative provided the basis for this research, leading to the main research question:

"How can a viable inland waterway terminal be realized in Zutphen's business park De Mars to improve its freight connection?"

After analysing the regional and local infrastructure and transport flows around Zutphen, it was found that the best opportunities arise for the development of an intermodal inland waterway transport (IWT) connection, including an inland container terminal at De Mars. In order to initiate an intermodal barge service with constant cargo volumes, the import and export container flows towards Port of Rotterdam are considered. The main competitive transport modes were identified to be intermodal IWT via the terminals in Nijmegen and Doesburg.

For the development of such a terminal, a water-bound location has to be found at the business park. Due to the limited cargo volumes that are available, a location that requires limited initial investments is aimed for. This was found at the industrial harbour, where some infrastructure is already present. This location was used for the development of potential terminal solutions.

Intermodal inland waterway transport
A literature study was carried out to indicate all elements that determine the feasibility of a container barge terminal. In order to successfully initiate operation of an inland terminal, the terminal operator has to offer a competitive intermodal IWT service. This includes sailing, terminal handling and pre- and end-haulage. These elements combined determine the performance of the intermodal IWT chain. The performance is determined by to the distance from the seaport and the scale of operation, for which it is required to attract sufficient cargo. Cargo can only be attracted if shippers are willing to make a modal change.

The shippers' modal choice is based on a combination of costs and qualitative aspects. The critical qualitative service attributes were found to be reliability and frequency, whereas some flexibility regarding the travel time seems to exist. The shipper has a preference for qualitative aspects over costs up to a certain threshold, which has to be examined for each situation. Only when a better price can be offered than the best price of the competitors at a comparable service level, cargo can be attracted.

Wiegmans (2003) identified the critical qualitative service attribute to be reliability. A reliable intermodal transport service can only be realized if the terminal operator has access to sufficient and constant flow of cargo volumes available to be transported. According to KiM (Visser, Francke, & Gordijn, 2012), almost all existing inland terminals have one or more large customers. These launching customers transport sufficient containers to initiate an intermodal IWT service. The smaller customers then join at a later stage. The presence of a

launching customer is considered to be an absolute precondition for a terminal to start operations. A launching customer is necessary to generate sufficient cargo flow volumes to reach the required minimum scale of operation.

In a competitive transport market, terminal operators are expected to manage more services than just the transhipment of containers. Being able to manage all components of the intermodal IWT chain, including barge transport and pre- and end-haulage is considered to be a requirement. For a terminal in Zutphen, this implies that barge transport to the Port of Rotterdam has to be offered, either via initiating a new barge service or cooperating with an existing barge service.

Framework to assess terminal feasibility

A framework was prepared to assess the feasibility of a terminal in Zutphen, which consists of two parts. The first part contains several analyses to collect input for the design of possible terminal solutions. It includes an assessment of the cargo volumes, identification of the shipper's preferred service attributes and analysis of the cost competitiveness. These analyses provide input for the design of possible terminal solutions in De Mars.

The second part of the framework presents the method to assess the feasibility of the proposed terminal solutions. A terminal solution is found to be financially feasible if a business case can be defined, because a private party has to be found that is willing to run the terminal operations. The terminal operator has to offer barge transport to the seaport and facilitate terminal operations. A profitable intermodal IWT service can be found if these activities generate sufficient revenues, outweighing the required investments and operational costs for both the terminal and the barge service. The revenues rely upon the available cargo volumes, which can only be captured if the terminal operator is able to satisfy the shippers' preferred service attributes and offer competitive transport tariffs. The financial performance of the terminal is expressed by calculating the Net Present Value, for which a cash flow analysis is worked out.

Assessment of potential cargo volumes

The cargo assessment pointed out that no launching customer could be found in Zutphen. Sufficient cargo has to be found further along in the service area, comprising Apeldoorn, Deventer and Lochem. The total potential cargo volumes were found to be approximately 31,000 TEU/year. Most of these cargo volumes were identified in Apeldoorn. The analysis of the cost competitiveness showed that the competitive transport modes are able to offer very competitive prices; hence the available margins to initiate a profitable barge service and terminal operations are limited. The poor road connection towards Apeldoorn induces high costs for pre- and end-haulage by truck, which complicates Zutphen attract potential shippers from Apeldoorn. It was concluded that the expected cargo volumes to be captured are restricted to a small share of the total identified potential cargo volumes of 31,000 TEU/year.

Based on the expected cargo volumes, it becomes clear that Zutphen has to aim for a low-cost and low-profile terminal. To develop such a low-cost terminal, solutions should be considered that make use of existing facilities and infrastructure. The required investments for the development of a terminal at location Fort de Pol are considered to be too high to be viable. Therefore, as a location, only the industrial harbour will be taken into consideration for the development of terminal solutions. Three preliminary designs of proposed terminal solutions were worked out in the industrial harbour.

Results of the feasibility assessment

The three proposed terminal solutions were assessed for feasibility following the framework. The results of assessment made clear that for the current and expected market conditions no business case could be found for any of the proposed terminal solutions. Even for the least negative alternative, the resulting NPV is far more negative than the required initial investment, which shows that the operations itself are loss-making.

The minimal required cargo volumes that need to be captured for a break-even situation of terminal solution at the embankment were calculated to be approximately 16,000 TEU/year. For the optimal stated tariffs, the captured cargo volumes are insufficient to create revenues that can outweigh the costs. The lack of cargo volumes is partly due the absence of a launching customer in business park De Mars. The structural deficits of the revenues to obtain a break-even NPV were determined. For the least negative solution, it was found that a subsidy has to be granted of 17% of the total required revenues for a break-even situation. This means that for each transported TEU, 17% of the costs needs to be subsidized over the entire duration of the project.

Conclusion

In order to realize a viable terminal in business park De Mars, either significant subsidies need to be granted on a structural basis, or additional cargo volumes need to be captured. The identified destination where most of the potential cargo volumes are accumulated is Apeldoorn. Due to the poor road connection between Zutphen and Apeldoorn, the costs for pre- and end-haulage weigh in heavily on the total transport costs. The effects of an improved road connection to Apeldoorn were analysed, but it was found that an improved road connection does not enhance the competitiveness such, that it enhances decisive improvements. The main problem is caused by the lack of available cargo volumes. It is concluded that finding a launching customer in business park De Mars is a precondition for realizing a container terminal that is able to generate profitable terminal operations.

Recommendations

The municipality of Zutphen may have other objectives than the profitability of the terminal. From the municipality's viewpoints of employment, sustainability or congestion, investing in realization of a terminal can be desirable, despite the fact of its loss-making activities. This can be done by granting structural subsidies.

It is recommended that the municipality should focus more on attracting additional cargo volumes to business park De Mars. The lack of the presence of a launching customer is the main reason that no business case can be found. The following measures could be taken by the municipality to attract additional cargo volumes:

- Finding a launching customer that transports significant containerized cargo volumes via the inland waterways.
- Actively pursue business policies to influence the entrepreneurs to settle their business location at business park De Mars. This can be achieved by offering lower land prices than in surrounding cities.
- Initiate to bring parties together to develop a joint program. For instance, seek cooperation with the pending initiative in Deventer by bundling of cargo volumes, to share the costs for barge transport.
- Consider the possibilities of containerized bulk transport. By conducting an active policy to stimulate companies transporting bulk and general cargo to containerize their goods, induces additional cargo volumes.

List of Abbreviations

In this section a selection of the commonly used abbreviations in this report are listed followed by a brief explanation.

Term/Abbreviation	Explanation
BCTN	Binnenlandse Container Terminal Nederland (terminal operator)
BED	Break Even Distance
CAPEX	Capital Expenditures
CEMT	Conférence Européenne des Ministres de Transport (European Conference of Ministers of Transport)
CPT	Cone Penetration Test
c.t.c. distance	Centre-to-centre distance
CTT	Combi Terminal Twente (terminal operator)
FEU	Forty-foot Equivalent Unit (= 2 TEU)
IRR	Internal Rate of Return
IWT	Inland Waterway Transport
KiM	Kennisinstituut voor Mobiliteitsbeleid (Institute for Transport Policy Analysis)
NAP	Normaal Amsterdams Peil (Amsterdam Ordnance Datum)
NPV	Net Present Value
OPEX	Operational Expenditures
SLS	Serviceability Limit State
TEU	Twenty-foot Equivalent Unit
ULS	Ultimate Limit State
WACC	Weighted Average Cost of Capital

Contents

1 Introduction

This chapter gives an introduction to the subject of this thesis. The problem is introduced, followed by the selected scope that will be covered in this thesis. This leads to the research question that serves as a guideline to obtain the objective of this study. The sub questions follow the outline of the thesis that will be concluding this introductory chapter.

1.1 Background

1.1.1 The city of Zutphen

Zutphen is a historical Hanseatic city in the province of Gelderland in the Netherlands. It is located along the IJssel River and south of the nautical access of the Twentekanaal. As of 2016, the municipality of Zutphen has a population of 46,990 and has remained stable in recent years (CBS, 2016a). In the north of the city, business park De Mars is located (see Figure 1-1), which is 130 hectares large and home to approximately 200 companies, providing over 5000 jobs (Gemeente Zutphen, 2016).

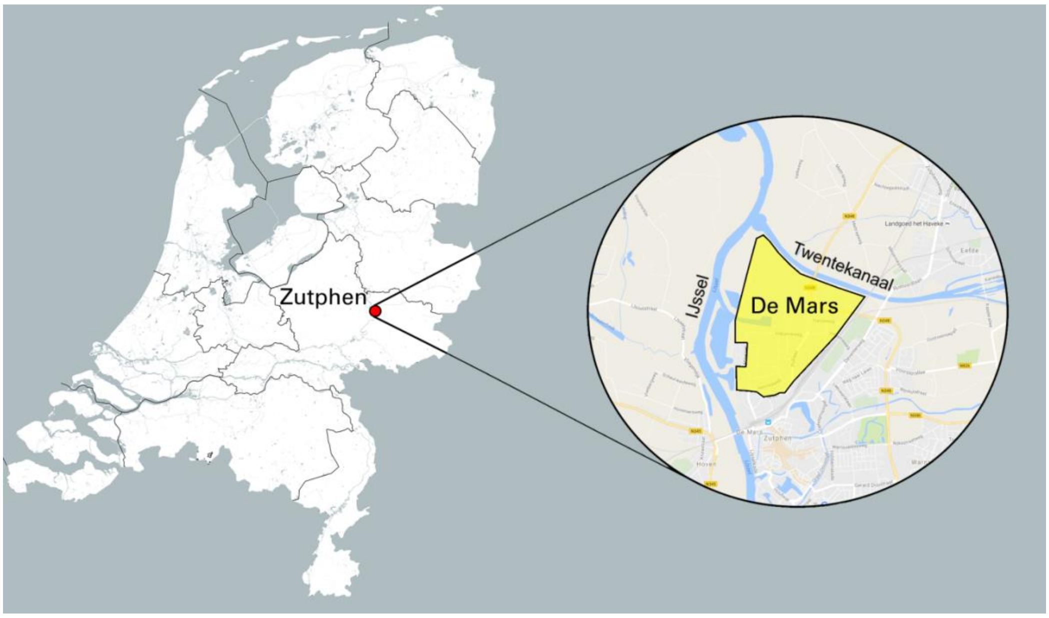


Figure 1-1. Geographical location of Zutphen and business park De Mars. Source: Google Maps and Van Aalst (n.d.)

1.1.2 Problem description

In recent years several large companies went bankrupt or decided to move their activities elsewhere, which lead to a high vacancy rate on De Mars (De Stentor, 2016). This is despite the fact that in last decade, the municipality of Zutphen has invested to revitalize the business park. Although new parties settled in Zutphen as well, the future development of De Mars is uncertain, which puts the business park under pressure. The business climate on De Mars has to be improved, to attract new entrepreneurs. The municipality thinks this might be achieved by improving the freight connection.

Zutphen is accessible by road, rail and water, but due to the absence of a rail or inland waterway terminal, most cargo is being transported by road. Neighbouring cities have a similar or better access to the motorway, however compared to neighbouring cities; Zutphen has a favourable geographic location for waterborne transport, being located at the intersection of the IJssel River and the nautical access of the Twentekanaal.

1.1.3 Initiators of this study

The local PvdA party (labour party) and the Cleantech Center are the initiators of this research to explore the possibilities of realizing a new freight connection in Zutphen. This way the city wants to distinguish themselves from other cities in the region by making use of the beneficial location of De Mars at the inland waterways. Zutphen aims to improve the use of the inland waterways. The scope of this thesis is limited to the feasibility of an inland waterway terminal in business park De Mars.

This study is carried out as a master thesis at the Delft University of Technology and is being facilitated by Witteveen+Bos, a specialist company that provides engineering and consulting services in the fields of infrastructure, water, the environment, spatial development and construction.

1.2 Objectives

The current barge activities are limited to bulk transport and are carried out on a small scale by companies located at the waterfront, using their own private quay with (un)loading equipment. According to long term and recent growth projections for inland waterway transport (IWT), the volumes of containerized goods are expected to grow faster than for bulk in next decades (Ecorys, 2010; Rabobank, 2016). A terminal that would include the handling of bulk goods is very complex, because it has to cope with different companies and types of goods. Therefore, the presumption is made that Zutphen has to aim for an inland waterway container terminal.

Starting an inland waterway container terminal on De Mars gives opportunities to operate a new freight connection that distinguishes Zutphen from the rest of the region. Intermodal barge transport has proven to be a reliable and cost-attractive mode of transport, if there is a sufficient demand for cargo to be transported.

There have been earlier attempts to realize a container terminal in De Mars. For many years efforts have made to develop an inland waterway terminal at business park De Mars, but for different reasons, a viable terminal has not yet been established. There is a demand to clarify in a comprehensive manner what is needed for a feasible terminal to be realized and if a business case can be found at De Mars.

The first objective of this thesis is to present a clear framework that assesses the feasibility of an inland waterway terminal in general. The goal is to provide insight in the components and boundary conditions that are required for realization of a viable inland terminal. This framework can be applied to evaluate the feasibility of any inland terminal in the Netherlands.

The second objective is to develop several terminal solutions that fit in De Mars and to apply the framework to assess the feasibility of these alternatives. These proposed terminal solutions will be subjected to a qualitative and quantitative assessment to determine whether a business case can be defined for a profitable inland waterway terminal in De Mars.

1.3 Research question

In line with these objectives, the following research question was defined:

Research Question
"How can a viable inland waterway terminal be realized in Zutphen's business park De Mars to improve its freight connection?"

To gain a better understanding about the current situation in Zutphen and a theoretical background of the components that influence the feasibility of an inland terminal, the following sub questions were defined to create a structured approach:

Sub Questions
1. *What options could be explored in business park De Mars to develop an inland waterway terminal?*
2. *What are the main drivers that determine the competitiveness of intermodal inland waterway transport?*
3. *What are the critical performance conditions that determine feasibility of an intermodal IWT service?*
4. *What are the critical performance conditions for an inland container terminal in the intermodal IWT chain?*
5. *How can a viable business case be found for an inland waterway container terminal?*
6. *What are the expected cargo volumes that can be captured by an inland container terminal in Zutphen?*

The first sub question provides a description of the existing situation of the transport system in Zutphen and will be treated in chapter 2. The next three sub questions are addressed to provide a literature review on the feasibility aspects of intermodal inland waterway transport in general, and the role of the inland container terminal within the intermodal IWT chain. These three sub questions will be treated in chapter 3. Sub question 5 provides insight how a business case can be defined to evaluate the terminal feasibility by presenting a feasibility framework in chapter 4. From the literature study it followed that the performance of an inland container terminal is dependent on the available cargo volumes, as will be addressed in sub question 6. This will be treated in chapter 6, where an assessment is worked out for the potential cargo volumes to be handled by a terminal in Zutphen.

1.4 Scientific contribution

This thesis was defined in compliance with the desire of the municipality of Zutphen and the Cleantech Center to obtain credible insight if a business case could be defined for the development of a viable inland waterway terminal. The scientific contribution of this practical issue is limited to the feasibility framework and the outcome of the feasibility assessment. The scope has been formed into a research that uses a scientific approach, covering a broad variety of analyses and considerations. Based on both technical design skills and economic decision-making methods, a well-informed advice can be given.

1.5 Thesis outline

The outline of this thesis can be divided into four phases. In order to indicate the system we are dealing with, in chapter 2, a description of the current freight transport system is given. The region is scanned for possible terminal solutions. The identified terminal solutions that will be assessed later on in the report will be briefly introduced as well. Chapter 3 provides a theoretical background how the feasibility of an intermodal IWT terminal in the intermodal transport chain can be assessed in general. In chapter 4, a framework is presented how the feasibility of inland container terminals can be assessed. Several analyses will be worked out in chapter 5 that are used as input for the development of potential terminal solutions. The feasibility of these terminal solutions is assessed in chapter 6, by calculating whether business case can be found. Chapter 7 gives conclusions and recommendations. A graphical representation of the thesis outline is presented in Figure 1-2.

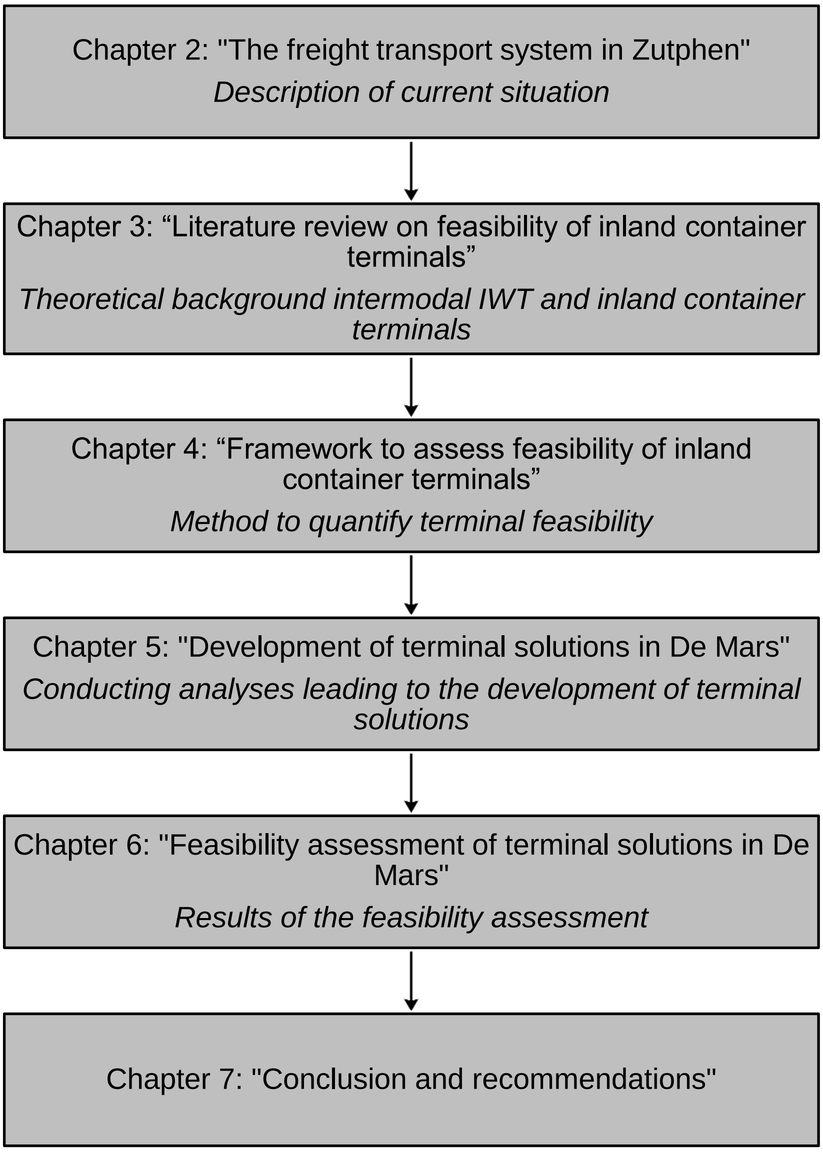


Figure 1-2. Outline of research structure

2

The freight transport system in Zutphen

In this chapter, sub question 1 is addressed: "What options could be explored in business park De Mars to develop an inland waterway terminal?" In order to indicate these options, a description of the existing freight transport system is given: the transportation of cargo in the region around Zutphen and the modal share that is transported via the inland waterways. To indicate the possibilities of improving the freight connection via the inland waterways, the existing infrastructure will be analysed both on regional and local level. It follows that for inland waterway transport (IWT) that the best opportunities arise at the development of intermodal transport. The chapter concludes with possible terminal solutions at business park De Mars that will be assessed later on in this report.

2.1 Infrastructure and transport flows on regional level

In this section, the regional infrastructure around Zutphen and the currently used freight transport modes are discussed.

2.1.1 Regional accessibility of Zutphen by existing infrastructure

In the region around Zutphen, several modes of infrastructure are present. Zutphen is accessible by road, rail and water, but due to the absence of a rail or inland waterway terminal, most freight is transported by road. This thesis focusses on the waterborne and road activities.

2.1.1.1 ***Road connection***

In Figure 2-1 the road infrastructure of the region around Zutphen is illustrated. It can be noted that Zutphen is only accessible by provincial roads, while the neighbouring cities can be accessed via the motorways. It follows that Zutphen has a less favourable freight connection compared to the large neighbouring cities.

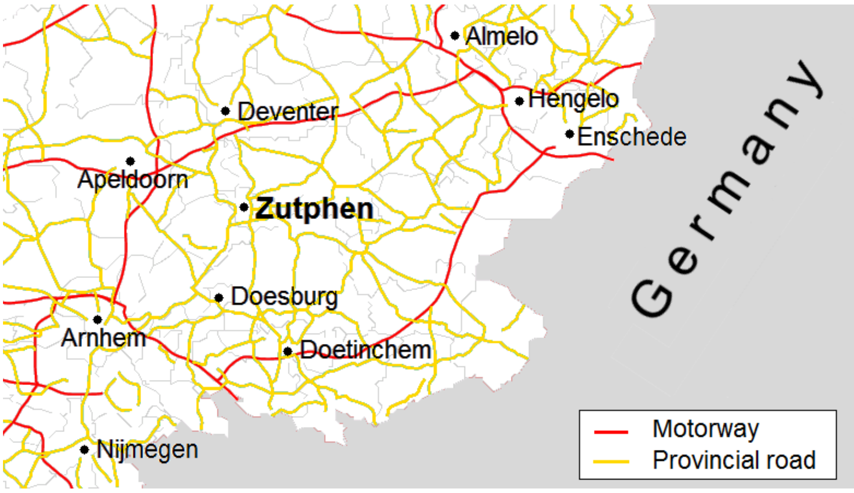


Figure 2-1. Available road infrastructure of region around Zutphen

2.1.1.2 *IJssel River and Twentekanaal*

Zutphen has a favourable geographic location for barge transport, being located at the intersection of the IJssel River and the nautical access of the Twentekanaal, as can be seen in Figure 2-2. In Europe, the vessel sizes are classified by the Conférence Européenne des Ministres de Transport (CEMT). A selection of the barge classes is shown in Table 2-1.

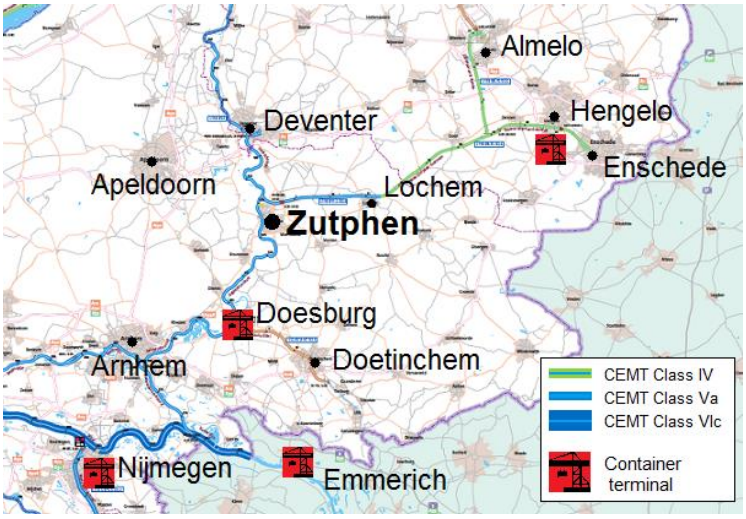


Figure 2-2. The present waterway infrastructure and locations of barge container terminals

Table 2-1. CEMT barge classes and its dimensions. Source: Richtlijn Vaarwegen (Rijkswaterstaat, 2011)

CEMT Class	Length [m]	Beam [m]	Max. draught [m]
IV	80 - 85	9.5	2.9 - 3.0
Va	110	11.4	3.5 - 4.0
VIa	110 - 135	13.5 - 17.0	4.0
VIb	185 - 195	22.8	3.5 - 4.0

The IJssel River is navigable by CEMT Class Va vessels. The discharge is unregulated, which means that the water levels are not controlled by hydraulic structures such as weirs. This causes the water level variations over the year to be quite significant as can be seen in Table 2-2. These water level variations have consequences for unloading equipment. For example, a reachstacker is not able to (un)load a vessel during average or low water levels.

Table 2-2. Water levels at measurement point Zutphen Noord for different situation.

Situation	Exceedance frequency	Water level [m + NAP]
OLR (Agreed low water level)	5% undershooting frequency	2.76
Average discharge		4.40
Exceeded once per year	1x year	7.20
Normative highwater	1x per 1,250 year	9.15

These water level variations affect the loading capacity of the barges for very low and high water levels. The bridge Oude IJsselbrug near Zutphen limits the air draft for shipping during high water levels, which limits the stacking height to a maximum of 3 layers for container barges (Arcadis, 2016). For low water levels the draught of the vessel is limited, affecting the maximum tonnages that can be transported. These water level limitations are discussed in detail in Appendix D. It was found that the least sounded water depths on the IJssel River are the governing limitation for the loading degree of container barges. The 5% undershooting criterion of the 'agreed low water level (OLR) corresponds to a water depth of 2.76m. A statistical analysis showed that the 5% non-exceedance probability was only met for a least sounded water depth of 2.30m.

The Twentekanaal is navigable for CEMT Class Va vessels towards Hengelo and the tributary towards Almelo. The air draft for container barges towards the Combi Terminal Twente (CTT) in Hengelo is currently restricted by bridges to a maximum stacking height of 2 containers. Also the water depth limits the draught of Class Va vessels at some locations along the canal. Currently the Twentekanaal is being upgraded by widening and deepening of the channel to allow Class Va vessels to manoeuvre safely at a higher capacity. Also the air draft will be upgraded to 3 layer container transport. Simultaneously the Eefde locks, located just north of Zutphen at the entrance of the Twentekanaal, will be expanded with a second lock chamber. These upgrades are scheduled to be completed in 2020 (Rijkswaterstaat, 2016). These upgrades allow a higher shipping intensity towards the terminal in Hengelo. CTT is also aiming to open a second terminal in Almelo mid-2017.

2.1.1.3 *Neighbouring inland waterway container terminals*

Within a 50 km radius around Zutphen, several terminals can be identified; Doesburg, Nijmegen, Hengelo, and Emmerich (Germany) (see Figure 2-2). Most of these terminals however, have their service area in a different direction than Zutphen. As described later on in paragraph 3.2.2.4, a competitive service area stretches further as an extension of the direction of arriving goods. In the reversed direction, the goods have to be carried back, covering the same distance twice, reducing the competitiveness. Therefore the terminals in Doesburg and Nijmegen are assumed to be the main competitors for a terminal in Zutphen. A brief description of the competitive terminals is given below.

BCTN Nijmegen

The terminal in Nijmegen was opened in 1987 and is the oldest inland terminal in the Netherlands. Located at the River Waal, very large barges can be handled here, up to a 2x2 convoy CEMT Class VIb (Length 192m, width 22.8m, draft 4m). The terminal has an annual capacity of 160,000 TEU and provides many terminal services, such as 24/7 operations, customs, warehousing, gas measuring, stuffing and stripping. The terminal it is part of BCTN BV that also exploits inland terminals in Rotterdam, Den Bosch, Nijmegen, Venray and Meerhout (Belgium). It is also shareholder of terminals in Hengelo, Almelo, Pernis trimodal and Bad Bentheim rail (Germany). BCTN BV handles 600,000-700,000 TEU per year and has contracts with many shippers. Therefore it can guarantee efficient operations, broad availability of containers and competitive prices.

Rotra Doesburg
In April 2016 a new container terminal was opened in Doesburg, a small village located just 15 km south of Zutphen in a straight line, or 25km by road. It is being exploited by Rotra, a logistic forwarder that operates this terminal as an extension of their logistic activities. Their warehouse is located at the waterfront, which enables Rotra to create a modal shift of the containers that are now being transported by truck towards the Port of Rotterdam and Antwerp to barge transport. The quay is suitable for handling CEMT Class Va vessels. Rotra exploits its own CEMT Class IV vessel, performing multiple sailings per week. The expected number of containers to be handled at the terminal is 10,000 TEU per year.

Terminal initiative in Deventer
In recent years, several studies have been carried out to realize a container terminal in the neighbouring city Deventer. Realization of a terminal in Deventer is a potential threat for viability of a terminal in Zutphen, because Deventer is located in the potential service area of Zutphen. In this thesis the realization of a terminal in Deventer is not taken into account, but it must be noted that if such a terminal will become operational, this affects the feasibility of a terminal in Zutphen.

2.1.2 Description of regional transport flows

The major city close to Zutphen is Apeldoorn. Due to its beneficial accessibility by two motorways, most of its transport flows are performed by road. Other cities that generate significant cargo flows are Deventer and Zutphen itself. Also here, most of the cargo is transported by road. For containerized cargo with low value goods destined for export to the Port of Rotterdam, intermodal IWT via the terminal in Nijmegen is used in most cases. However, in general unimodal road transport is the most used mode of transport.

In Lochem several companies with water-bound activities are present, where bulk cargo is being transported using their own quay and (un)loading equipment. The intermodal transport flows on the IJssel River are primarily directed to the terminal of CTT in Hengelo. The transhipment volumes of CTT have been consistently growing the last decades. This is likely to continue after the capacity expansion of the Twentekanaal.

Development of transport flows in Stedendriehoek region
Zutphen is part of the Stedendriehoek region, a partnership between the municipalities of Apeldoorn, Brummen, Deventer, Epe, Lochem, Voorst and Zutphen. This partnership focuses on themes such as accessibility, quality of life, innovation and social capital. One of their priorities is to develop a sustainable economy and society with a low carbon footprint. An intermodal transport point fits well within their sustainable ambitions, because IWT has a low carbon footprint compared to road transport. Furthermore the congestion on the roads is growing, while the capacity of the inland waterways is more than sufficient.

2.2 Infrastructure and transport flows in business park De Mars

This section gives an overview of the current infrastructure in De Mars is given. Similar to the previous section, waterborne and road transport are taken into account. Rail transport is not included in the scope of this thesis.

2.2.1 Existing infrastructure on business park De Mars

2.2.1.1 *Road*

Business park De Mars is accessible for trucks via the provincial roads N348 (directed to Deventer) and N346 (directed to Lochem). The Oude IJsselbrug crossing the IJssel River cannot be accessed by trucks (see Figure 2-3). Therefore, trucks have to take a detour via Deventer to get to Apeldoorn.

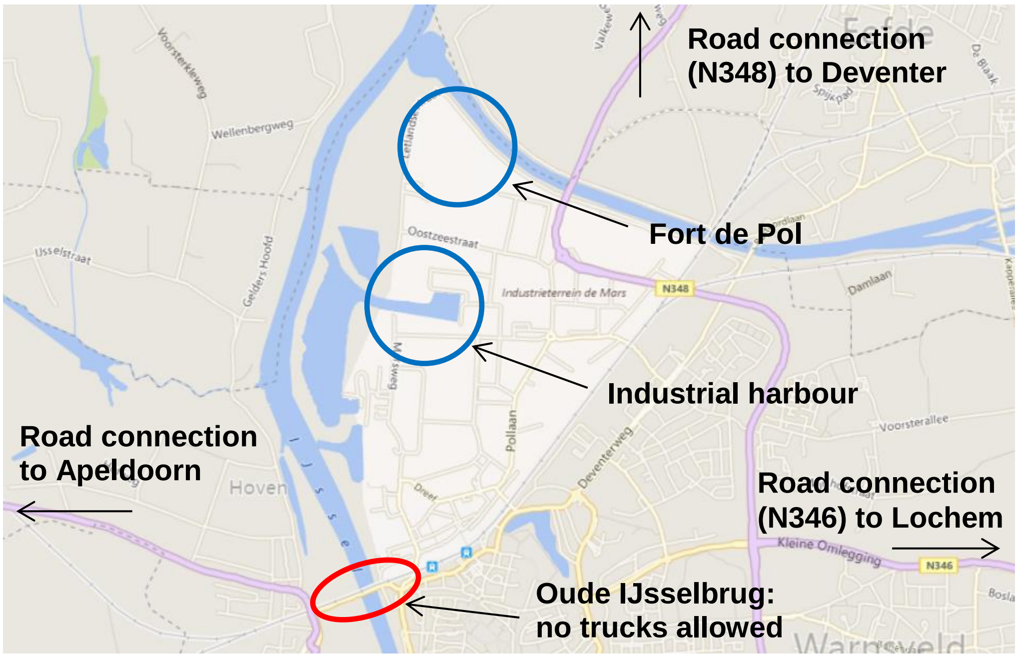


Figure 2-3. Map of business park De Mars, where the road access by truck and the potential water-bound locations are indicated

2.2.1.2 *Industrial harbour*

In De Mars, an industrial harbour is present (see cover photo), surrounded by several water-bounded companies and a public quay. The only activities for barge transport consist of bulk transport at the companies located at the waterfront, by using their own loading equipment. Nowadays the public quay is barely used for freight transport activities. The bottom level of the industrial harbour is located at NAP 0.0m, which means that for average water levels (Table 2-2) in the IJssel River, CEMT Class IV and Va vessels are able to enter the harbour without any hinder. However, for the 5% undershooting criterion, corresponding to a water depth of 2.76m or less in the industrial harbour, the maximum draught of these barges may be limited. For the draught to tonnage ratios is referred to Appendix D.

In the year 2002, a group of private parties, forming Container Terminal Zutphen B.V. was operating a container terminal by using a mobile crane at the industrial harbour in De Mars. For these terminal activities, the quay was structurally upgraded, a storage area was appointed and strengthened accordingly and the harbour basin was dredged. The terminal was intended to operate temporarily as such, before expending to a final terminal (Royal Haskoning, 2002). However, it went out of business in 2003 before it ever operated on full scale. This was reported to be due to insufficient cargo volumes, insufficient storage for transhipment and inefficient handling by the mobile crane (Gemeente Zutphen, 2012).

2.2.2 Description of local transport flows

Currently most cargo in Zutphen is being transported by road, except for the few companies that have their own (un)loading facilities for bulk transport by barge. Several companies that transport containers are using the intermodal transport mode via the terminal in Nijmegen. According to long term and recent growth projections for inland waterway transport, the volumes of containerized goods are expected to grow significantly faster than for bulk in next decades (Ecorys, 2010; Port of Rotterdam, 2016; Rabobank, 2016).

A terminal that would include the handling of bulk goods is very complex, because it has to cope with different companies and types of goods. Moreover, a quick scan in the region indicates that most companies transporting bulk goods are already located at the water front with their own quay. This study therefore focuses on the development of intermodal IWT transport, by assessing the feasibility of an inland waterway container terminal at De Mars. The main shipping route is considered to be the import/export of containers between Zutphen and the Port of Rotterdam.

2.3 Available water-bound locations at business park De Mars

For the development of a barge container terminal, a suitable water-bound location has to be found on De Mars. Due to Natura 2000 regulations and the municipal borders, there are only two areas available at the waterside where a terminal could be developed. These areas are indicated in Figure 2-3: the industrial harbour and Fort de Pol.

2.3.1 Industrial harbour

The industrial harbour was already introduced in the previous subsection. Several companies are located around the industrial harbour. Some of these companies do not use their terrain for water-bound activities and might be available for terminal operations. The length of the existing quay is approximately 120 m long and therefore suitable for CEMT Class IV vessels. In addition to the quay, there are mooring posts located along the embankment side of the industrial harbour, providing sufficient space for a Class Va barge to moor.

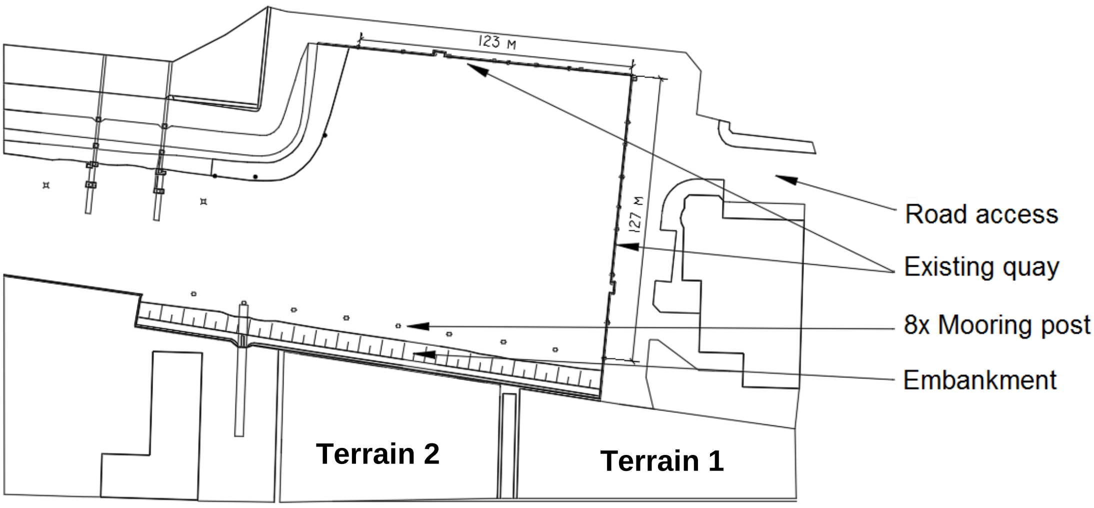


Figure 2-4. Current situation in the industrial harbour where two water-bound locations are indicated

The harbour basin is provides sufficient space for turning a CEMT Class IV vessel, but is too small for manoeuvring of longer vessels. If a CEMT Class Va vessel would moor along the mooring posts at the embankment, it would have to sail out backwards onto the IJssel.

2.3.2 Fort de Pol

The former garbage dump area at Port de Pol, located in the north of De Mars along the Twentekanaal, is an elevated area that is suited for redevelopment. In the last decade, several studies have been worked out for this location. These studies included a container terminal as part of the design (DHV B.V., 2009; Royal Haskoning, 2002; Veenenbos en Bosch landschapsarchitecten, 2010). At the time, the so-called *quick-wins* subsidies were available to cover half of the estimated investment costs of €8.1 million (Ecorys, 2010).

This project reached the tender phase, where it became clear that a business case could not be found to continue the project, since only one party was interested and their offer was too low for a concession agreement to realize the terminal. For the design at Fort de Pol, it was assumed that for the launch of the terminal, transhipment of 15,000-20,000 TEU per year was possible and that 35,000 TEU would be handled in 2021 (Gemeente Zutphen, 2012).

Since the tender failed, even with the significant amount of granted subsidies, the projections and other expectations for the design appear to have been vastly overstated.

2.3.3 Selected location for terminal development: industrial harbour

As will be shown later on in subsection 5.1.2, the available cargo volumes in the area are in the range of 4,000-12,500 TEU per year. These expected volumes are considered to be too small to cover the investments that are required for redevelopment of Fort de Pol. It was found that there is a demand for a small scale, low cost terminal. In the industrial harbour, already mooring facilities and a connection to existing infrastructure is present, which allows reducing the required investments. Therefore only this terminal location is selected for the development of alternative terminal solutions and Fort de Pol will not be taken into consideration.

2.3.4 Conclusion: options to be explored in business park De Mars

In this subsection, an answer is given to sub question 1: *"What options could be explored in business park De Mars to develop an inland waterway terminal?"*

After analysing the regional and local infrastructure and transport flows around Zutphen, it was found that the best opportunities arise for the development of an intermodal IWT connection, including an inland container terminal at De Mars. For the development of such a terminal, two water-bound locations are available at the business park. Due to the limited cargo volumes that are available, only the location at the industrial harbour will be taken into consideration for the exploration of potential terminal solutions. Three terminal solutions were proposed and are briefly introduced in the following section.

2.4 Proposed terminal solutions at industrial harbour

At the industrial harbour, two options are present where terminal operations could be executed: one using the existing quay and another one using the mooring posts along the embankment. Another option is the use of a crane vessel. These three terminal solutions are the alternatives that will be assessed for feasibility in this report.

2.4.1 Mobile crane on existing quay

The first terminal solution that will be assessed is similar to the terminal initiative from 2002 initiative that went out of business. The advantage is that it requires very low investment costs, because the quay and stack area are already present. The quay allows CEMT Class IV vessel to be unloaded on the public quay, from where a reachstacker or forklift truck moves the container to the stack area as indicated in Figure 2-5.

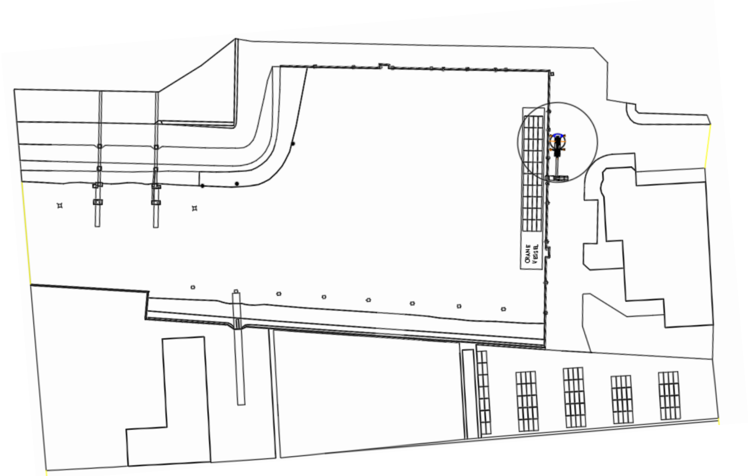


Figure 2-5. Terminal solution at the existing quay

Here the assumption is made that terrain 1 becomes available for the development of the stacking area of the terminal. This terrain is of private property by Daly Plastics BV and is currently leased to Schrijver BV. Its feasibility has to be assessed for 2017 conditions. The circumstances of the inland container transport market have changed since 2002; therefore the feasibility has to be reassessed for 2017 conditions.

2.4.2 Crane vessel moored at existing quay

The Mercurius Shipping Group owns a crane vessel that is able to unload the containers onto the quay, directly on the trainer of a truck. The dimensions of this vessel are 86 x 11.55m and are therefore able to moor at the existing quay. Advantage of this solution is that no container terminal has to be realized; hence no initial terminal investment is required.

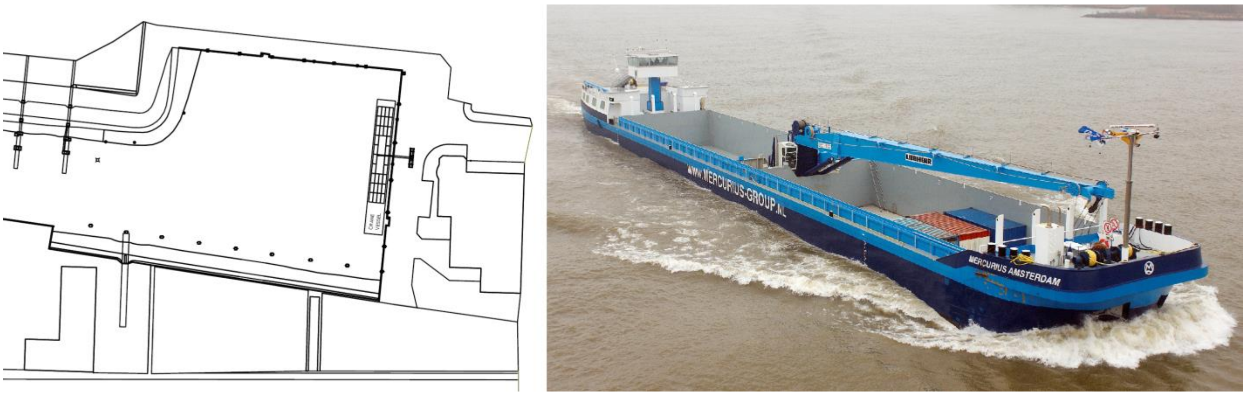


Figure 2-6. Left: Impression of the crane vessel moored at the existing quay. Right: Crane vessel Mercurius. (Mercurius Shipping Group, n.d.)

2.4.3 Cofferdam at embankment

At the current embankment at the industrial harbour, mooring posts are already present. Terrain 2 is currently used by the company Primagaz as a long-term ground lease with the municipality. The assumption is that this terrain could become available to be exploited as a private area for terminal operations. This terminal solution requires the construction of a cofferdam, where a crane is placed for the handling of containers. The stack area has to be reinforced such that it is able to withstand all the loads, of which the wheel loads of a reachstacker are governing. A barge of CEMT class Va is able to moor at this location. For an impression, see Figure 2-7.

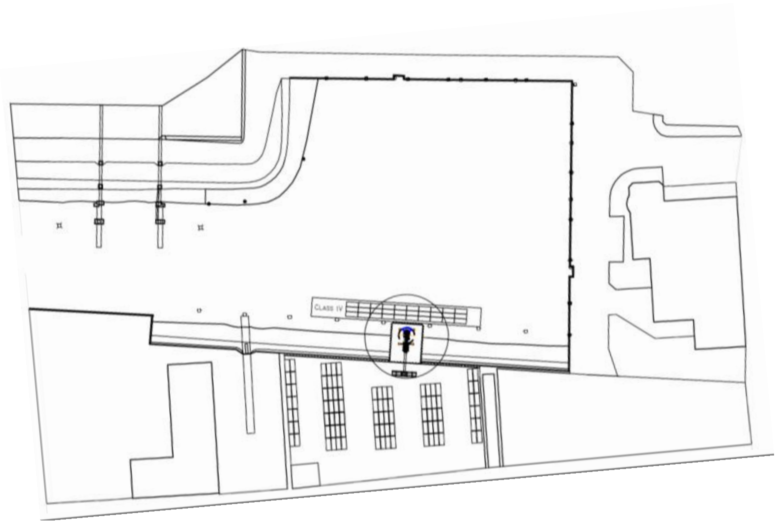


Figure 2-7. Impression of the terminal solution at the embankment

3

Literature review on feasibility of inland container terminals

This chapter provides a literature review for assessing the feasibility of an inland waterway container terminal, where the sub questions 2 to 4 will be treated. The terminal is part of the intermodal IWT chain. In order to initiate operation of an inland barge terminal, an intermodal IWT service has to be set up. Therefore, an introduction is given into the intermodal transport chain in the first section. Section 3.2 gives an overview of the performance indicators that determine the feasibility of the intermodal IWT chain. A distinction is made between the qualitative and quantitative aspects, since the shippers' modal choice to choose a certain freight transport mode is always made on a combination of qualitative aspects and costs. In section 3.3 the role of the terminal in the intermodal IWT chain is discussed. Again a distinction is made between the qualitative and quantitative performance indicators that determine the terminal feasibility.

3.1 Introduction to intermodal inland waterway transport chain

This section addresses sub question 2: "*What are the main drivers that determine the competitiveness of intermodal inland waterway transport?"* It provides a general introduction to the development of inland waterway transport into intermodal IWT is given, followed by a brief description of all components that determine the competitiveness of the intermodal transport chain with respect to other transport modes.

3.1.1 Development of barge transport into intermodal IWT chain

Waterborne transport has historically been the most important transport mode in the Netherlands, since it was the primary infrastructure that was available. After development of rail- and road transport networks, these modes took over the majority of high valued goods and left IWT with the lower valued bulk goods and a decreased market share.

After the development of the standardized shipping container, IWT has gained market share again by means of intermodal container barge transport. The first IWT container terminal at shorter distance to the seaport was opened in 1987 in the Netherlands, after which more inland container terminals followed. The number of inland container terminals had increased to 16 by 2002. In 2012, 31 inland terminals and 29 intermodal terminals in seaports could be identified (Visser et al., 2012). For a comprehensive description of the development of the IWT market, chapter 2 of the dissertation of Van Dorsser (2015) is mentioned.

The increased use of intermodal barge transport is likely to be continued in the future as it is supported by many policies (e.g. European Commission, 2011; Port of Rotterdam, 2011) that aim for a modal shift from unimodal road transport towards more sustainable intermodal transport solutions.

3.1.2 Components of the intermodal IWT chain

When referring to intermodal transport, cargo remains in a single loading unit, which uses successively two or more modes of transport without handling the goods themselves in changing mode (United Nations, 2001), as is the case for containerized transport. When discussing the intermodal transport chain for inland waterway transport, three components can be distinguished and will briefly be introduced below.

3.1.2.1 *Barge transport*

The main haulage in the intermodal IWT transport chain is carried out by barge between the seaport and the inland terminal. The relatively low cost of container barge transport and the reliability of its services are the main reasons intermodal barge transport has increased in popularity during the last few decades. According to Konings (2003), the major factors that influence the cost level are the vessel size and circulation time of the vessel. The vessel size affects the scale of operation for which a sufficient loading degree is required to cover the costs of a service.

3.1.2.2 *Terminal handling*

For the transhipment from one mode of transport to another, a terminal is required for the handling of the containers. Dependent on various factors, such as terminal location, handling equipment, cargo type and transhipment volume, several terminal characteristics can be distinguished.

3.1.2.3 *Pre- and end-haulage*

Pre- or end-haulage consists of the transportation over a relatively short distance for the first or last part of the route from the shipper or to the consignee. This part is carried out by truck. The distance of the pre- or end-haulage depends on the costs for which the intermodal transport chain is still competitive. In general, this distance is no more than 30 km from the inland terminal (Hofstra, 2010; Policy Research Corporation, 2007).

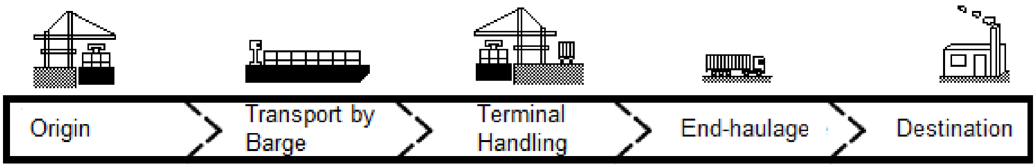


Figure 3-1. Schematization of the intermodal IWT chain. Source: Van Dorsser (2015), modified

3.1.3 Conclusion: Main drivers that determine competitiveness of intermodal IWT

In order to determine the competitiveness of the intermodal inland waterway transport chain, its components combined have to be competitive with respect to other modes of transport, such as unimodal transport (a door-to-door transportation service with one mode of transport from shipper to consignee), or a competitive intermodal transport mode, e.g. intermodal rail transport or intermodal IWT via a competitive inland terminal.

Each of the transport modes has its strengths and weaknesses, leading to its overall performance. In general, unimodal road transport can be characterized as being fast and reliable, but more expensive and less sustainable. IWT is characterized by low costs, reliability, low speeds and sustainability. In the Netherlands, rail transport is not always regarded as being very competitive, with low speed, relatively high costs and low reliability (Wiegmans & Konings, 2016). Rail transport is particularly interesting for transportation over longer distances and in areas where waterways are absent. Because of the low presence of rail terminals in the Netherlands destined for the domestic market, this transport mode will not be taken into account.

An answer can now be given to sub question 2: "*What are the main drivers that determine the competitiveness of intermodal inland waterway transport?"*

Intermodal IWT consist of three components: sailing, handling at the terminal and pre- and end-haulage by truck. The competitiveness of intermodal barge transport is determined by these components combined, and has to be compared with other transport modes. The main drivers that make intermodal IWT competitive with other transport modes are the low costs, reliability and sustainability. The low costs are related to the distance from the seaport and scale of operation. The further the distance from the seaport, the more intermodal transport chain can benefit from the low barge costs of the main haul. The scale of operation depends on the available cargo volumes, that influences the vessel size that can be deployed while maintaining a sufficient utilization rate and shipping frequency.

3.2 Performance indicators for feasibility of the intermodal IWT chain

This section addresses sub question 3: "*What are the critical performance conditions that determine feasibility of an intermodal IWT service?"* Setting up an intermodal IWT connection can only be realized if it satisfies the preferences of the main actors that decide to use a certain transport mode. The major actors that influence the modal choice of transport are the shippers (freight owners). Therefore it is crucial to identify the shippers' preferences that influence their modal choice of freight transport.

This section will elaborate on performance indicators that are required for feasibility of an intermodal IWT service. A distinction will be made between qualitative and quantitative aspects, since the shippers' decision for a certain transport mode is always made on a combination of costs and qualitative aspects. The qualitative characteristics of the shippers' modal choice will be treated in subsection 3.2.1. The quantitative characteristics for the determination of the costs will be elaborated in subsection 3.2.2.

3.2.1 Qualitative determinants of intermodal IWT chain: service attributes

As mentioned in this section's introduction, the decision for a certain transport mode is always made based on a combination of costs and qualitative aspects. The qualitative performance indicators will be discussed in this subsection.

3.2.1.1 *Shippers' preferred transport service attributes*

Danielis et al. (2005) studied the logistics managers' preferences for the following freight service attributes: freight costs, travel time, risk of delay and risk of loss and damage. The study indicates that shippers have up to a certain threshold a strong preference for quality attributes over costs, especially for reliability and safety. The observation that in first instance shippers focus more on the overall service quality than on costs is in line with the studies conducted by McGinnis (1990), Murphy & Hall (1995) and Muilerman (2001).

Danielis & Marcucci (2007) investigated whether intermodal truck-rail freight transport could be a valid substitute for unimodal road transport by means of studying attribute cut-offs and their acceptable variation levels. The following seven attributes were considered: cost, transit time, late arrivals, loss and damage, flexibility, frequency and transport mode. It appeared that the minimum requirements regarding the attributes cost, late arrivals and damage and loss are quite strict for logistics managers, whereas they appear to be less concerned regarding transit time increases, as long as the shipment arrival is within the scheduled date. Shippers have little acceptance in risk of damage and loss of their freight (Danielis et al., 2005), but in general, intermodal IWT performs well in this area. Due to the growing social awareness on sustainability, shippers are increasingly focused on sustainability as qualitative aspect, especially the large shippers (NEA, 2010). Intermodal IWT transport has a low CO_2 footprint compared to road transport, which makes it an attractive alternative if other service attributes remain largely unaltered.

3.2.1.2 *Influence of barge service on qualitative determinants*

Konings (2003) mentioned 'vessel size' and 'circulation time' to be the main factors influencing both the qualitative and quantitative determinants. For the qualitative determinants, the vessel size influences the scale of operation and the circulation time the number of possible transports within a period of time. Konings (2003) states that the scale of operation and vessel circulation time are not independent decision variables, but are related to quality features such as frequency, transit time and reliability. The service attribute that depends directly on the barge service is frequency. To attract shippers, their preferred sailing frequency needs to be offered; hence in order to satisfy the required sailing frequency at a sufficient scale of operation, a certain minimum amount of cargo volumes has to be available.

3.2.1.3 *Decisive service attributes*

It can be concluded that numerous qualitative factors influence the modal choice of shippers. In order for intermodal IWT to be taken into consideration by the shipper, the offered service has to satisfy a certain threshold of qualitative aspects, before the costs can be decisive for shippers to consider a modal change. In the case of setting up an intermodal IWT connection, a barge service has to be initiated between the seaport and the inland terminal as well as pre- and end-haulage. The service attributes that apply to this case and are considered to be decisive are:

- *Reliability*: the reliability has to be ensured with respect to competitive transport modes. This can be accomplished by proper planning of the logistic schedule.
- *Frequency*: the shipper desires a certain frequency of services per week. The minimum required service frequency that should be offered varies per case. Generally a shipping frequency of 3-5 times per week is preferred. In some cases, 2 shipments per week meet the demand of the shippers.

3.2.2 Quantitative determinants of intermodal IWT chain: costs

In general, the transport cost remains one of the most important criteria in modal choice (Danielis & Marcucci, 2007). If the qualitative service attributes sufficiently satisfy the shippers' preferences, the costs are usually the decisive factor in the modal choice of the shipper. Therefore the offered transport costs have to be competitive with existing transport modes. The quantitative aspects that influence the determination of these transport costs will be discussed in this subsection.

3.2.2.1 *Break-even-distance for intermodal transport chain*

In order for intermodal transport to be competitive with unimodal road transport, the cumulative costs of all individual transport components should be less than the cost for unimodal transport. The distance at which the costs of intermodal transport equals the costs of unimodal road transport is defined as the Break-Even Distance (BED) (Rutten, 1995), as illustrated in Figure 3-2. Here segment $\overline{CE}$ represents unimodal transport, and the segments $\overline{CD}$ and $\overline{DE}$ correspond to the intermodal transport chain. It can be noted from the steep slope $\boldsymbol{a}$ of section $\overline{DE}$, that the rate for end-haulage by truck (€ per km) is higher than the rate for long-distance truck costs, indicated by the gentler slope $\boldsymbol{b}$ of section $\overline{CE}$, as is the case for unimodal road transport (Kim & Van Wee, 2011). This is due to the waiting and loading times for the truck that has to be spread over a relatively short distance.

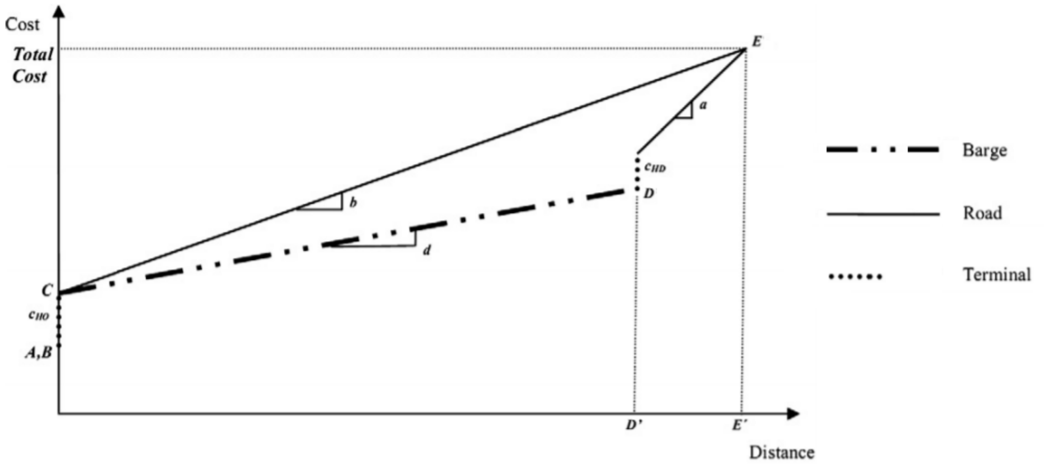


Figure 3-2. Break-Even Distance for intermodal transport chain versus unimodal road transport. Source: Kim & Van Wee (2011), modified

The costs for terminal handling at the seaport are indicated in segments $\overline{AB}$ and $\overline{BC}$ on the vertical axis. These handling costs at the seaport onto the transport mode destined for the hinterland are usually already included in the maritime transport costs and therefore have no influence on the cost competitiveness. For convenience it is assumed that the initial costs for intermodal and unimodal road transport are equal at point A.

In general, the competitiveness of intermodal transport with respect to unimodal road transport improves when the distance between origin and destination increases. This is due to the strong influence of the pre- and end-haulage costs (e.g. Holtgen 1996; Niérat 1997) and the handling costs at the terminal (e.g. Konings & Priemus (2008); Smid et al. (2016); Wiegmans & Konings (2015)) on the total intermodal transport costs. The more the intermodal transport chain can benefit from lower costs of the main trip by barge, the more competitive the intermodal transport chain.

The attractiveness of intermodal IWT for a certain destination can be determined by comparing the costs for all relevant transport chains. This implies that it has to be competitive with both unimodal transport and intermodal transport via other inland terminals. To calculate the cumulative costs for intermodal transport, the cost components have to be determined.

3.2.2.2 *Cost components of intermodal IWT chain*

This subsection discusses how each of the cost components for the intermodal IWT chain can be determined and what determines their competitiveness.

Sailing costs

The sailing cost of barge transport consists of fixed and variable costs. The fixed costs comprise amongst others insurance costs, repair- and maintenance costs, interest costs, depreciation, port dues, wages and other costs. The variable costs consist mainly of fuel costs. These costs can be determined using the key figures issued by Rijkswaterstaat (Panteia, 2015) and the cost model of Van Dorsser (2015). For an explanation of the cost calculation reference is made to Appendix A.

The fixed costs can be considered as time-related and the variable costs as distance-related. As mentioned before, Konings (2003) stated that vessel size and circulation time determine the performance of container barge transport. The relatively low cost for barge transport is dependent on the scale of operation. A larger vessel is potentially able to offer lower transport rates per unit load, but only for a sufficient loading degree. Since most of the costs are fixed, a low utilization rate will have a significant effect on the missing revenues, while the fixed costs remain more or less the same. If the circulation time of the vessel is reduced, the number of possible trips increases within the same period of time. The fixed costs can be spread out over more transport services, which decreases the transport costs per unit load.

The vessel size is determined by a combination of factors. First of all, the maximum vessel size is dependent on the terminal characteristics and the waterway dimensions (discussed in subsection 3.2.2.3). Next, the available cargo volumes have to be spread over the desired shipping frequency to obtain the optimal vessel size. The following vessel sizes with their corresponding maximum loading capacity in TEU can be distinguished in The Netherlands:

Table 3-1. Dimensions and capacities of container barges in The Netherlands. Source: Richtlijn Vaarwegen (Rijkswaterstaat, 2011)

CEMT Class	Length [m]	Beam [m]	Max. draught [m]	Max. capacity [TEU]
Neokemp	63	7.0	2.1	8 x 2 x 2 = 32
IV	85	9.5	2.9	10 x 3 x 3 = 90
Va	110	11.4	3.5	13 x 4 x 4 = 208
VIa	135	14.2	4.0	17 x 5 x 5 = 425

The maximum capacity of the vessels in Table 3-1 is the potential maximum loading degree that still has to be checked for stability of the barge. The stability of the loaded containers has to be calculated following art. 22 of the ROSR regulations (Ministerie van Infrastructuur en Milieu, 1995). The stability depends amongst others on the tonnages per TEU, stacking height, dimensions of the hold and the centre of mass. For instance, a CEMT Class Va vessel can in practice sail with only 3 layers of loaded containers for stability reasons.

Handling costs

The terminal handling costs can have a significant share in the total intermodal transport chain costs, dependent on the transport distance by both barge and truck. Macharis and Verbeke (2004) calculated the cost structure of the intermodal transport chain for the Port of Antwerp, with the barge transport distance of only 55 km. In this calculation, the share of the handling costs amounted up to 30%. The costs of handling are dependent on amongst others the type of equipment and size of the terminal.

To operate a profitable terminal, transhipment volumes of a certain scale are required. In literature various break-even volumes of a profitable terminal can be found. The break-even volumes are expressed in number of moves, because 20ft and 40ft containers both require one handling. In most cases, a container requires two moves at the terminal. Van Klink (2004) assumed 30,000 moves to be required for a break-even situation. Decisio (2002) shows an annual break-even volume of 14,000 moves for a low-profile terminal and a minimum transhipment volume of 20,000 moves for a full-service terminal. The terminal size, utilization rate and supportive activities at the terminal determine the cost performance of the terminal. Subsection 3.3.2 will elaborate on the handling costs.

Pre and end-haulage costs

The pre- and end-haulage costs can also have a substantial share in the total intermodal transport chain costs (e.g. Holtgen, 1996; Niérat, 1997). The trucking costs per kilometre in pre- and end-haulage trips are higher than for unimodal road transport, because the fixed costs weigh in more heavily over a short distance than over a longer distance. Bontekoning et al. (2004) found that costs for pre- and end haulage accounts between 25% and 40% of the total transport costs. This share is dependent on the covered distance by the main haul by barge. Macharis & Verbeke (2004) determined that for a barge haul of 55 km with 20 km end-haulage by truck no less than 45% of the total transport costs. These high cost for pre- and end-haulage over a short distance puts pressure on the profitability of intermodal transport services.

Also the cost structure of pre- and end-haulage cost consists of time-related fixed costs and distance-related variable costs. Dependent on the characteristics of the haulage, there are several strategies to reduce costs (Konings, 2008). To reduce the variable costs, the empty-load kilometers have to be minimized, for instance by combining trips. To reduce the fixed costs per trip, the productivity has to be maximized, e.g. by using 'stay-with' or 'drop & pick' strategies. At a stay-with trip, the truck waits at the location for the truck to be (un)loaded, whereas for drop & pick operations, the trailer is dropped off at the location to be picked up later. Wiegmans & Konings (2015) concluded that drop & pick operations for short distances in pre- and end-haulage lead to the largest cost savings.

When 20ft containers are used instead of 40ft containers, the competitiveness of intermodal IWT with respect to unimodal road transport is considerably improved. Here it is assumed that a truck with container chassis can carry one container, either a 20ft or a 40ft one, leading to the same trucking costs for 20 and 40ft containers. However, the barge costs for transporting a 20ft container is half of a 40ft one, improving the overall competitiveness the intermodal IWT (Wiegmans & Konings, 2015).

Cost optimization

Now that a general overview of the cost components of intermodal IWT is given, the cost competitiveness of the intermodal IWT service has to be determined. To evaluate the cost performance, it has to be compared to the costs of existing transport modes, such as unimodal transport or intermodal transport via competing terminals. The total transport costs depend on the sailing frequency and scale of operation that is possible. These are on its turn dependent on the characteristics of the waterways, affecting the maximum possible vessel size and the available cargo volumes in the service area.

3.2.2.3 *Waterway characteristics*

The characteristics of the waterways play an important role in the performance of container barge service, since it influences the maximum vessel size. This is affected by amongst others locks, bridges and other hydraulic structures. These factors influence the transit time, reliability and utilization rate, e.g. a limited draft caused by low bridges height affects the number of layers of containers that can be transported on vessels. Therefore the waterway infrastructure has to be explored to identify the possibilities and possible threats for operating a barge service.

Jonkeren et al. (2014) studied the effects of future climate conditions on inland waterway transport in for the river Rhine and stated that longer periods with low water are likely to occur more often, which leads to a restriction of the loading degree of the barges. Smit et al. (2016) calculated that extreme high or low water level lasting two weeks; occurring four times a year causes a cost increase of 2.3–3.4%.

The estimations of climate change go along with great uncertainties. Therefore it is advised to perform a statistical analysis of the measured water levels over a longer period of time to possibly identify trends. Rijkswaterstaat (Ministerie van Infrastructuur en Milieu, 2016) measures the water levels at multiple measuring points along the main waterways in the Netherlands. Also the least sounded water depths for several river sections are monitored and reports when the water depth is 3.0m or less.

3.2.2.4 ***Service area of inland terminal***

The service area is the region in reach of the terminal for which intermodal IWT can offer a competitive service. To determine this region for a terminal, the region has to be scanned for potential shippers and customers. Also the service areas of competitive terminals have to be taken into account, because ideally, the service area does not intersect with the service area of other inland terminals.

Policy Research Corporation (2007) states that as the terminal is located further inland, the service area for end-haulage will increase, with a radius of 20-30 km for barge transport over 100 km with respect to unimodal road transport. According to Hofstra (2010) the size of the service area for maritime container transport has a radius of about 25 km or 30 minutes travel time. Notteboom & Rodrigue (2009) presented a framework that analyses the relationship between the profitability of an inland terminal and the size of the service area. With the terminal located in vicinity of the seaport, the service area covers a range of 10km or less, while far away from the seaports (>300 km), it can reach up to 60 km.

Several shapes of the service area are described in literature. Policy Research Corporation (2007) assumes the shape of the service area to be circular. Macharis & Verbeke (2004) stated the service area shape to be trapezoidal, where the small side is located towards the seaport, indicated in Figure 3-3. Hofstra (2010) considers the trapezoidal shape for maritime container transport and a circular service area for continental transportation.

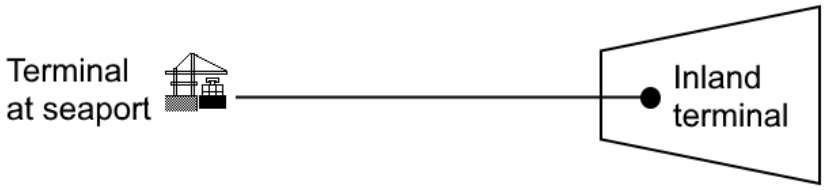


Figure 3-3. Trapezoidal shape of the service area according to Macharis & Verbeke (2004)

Niérat (1997) put the pre- and end-haulage into spatial perspective by examining the shape of the terminal service area and its size relative to freight characteristics, as shown in Figure 3-4. The intermodal points form an oval that leans slightly in the opposite direction of the long-haulage. Niérat concluded that for all shippers within the oval market area (depicted in grey), the intermodal transport chain is the competitive mode of transport. Outside the oval, the unimodal road transport mode is the competitive mode of transport. The theories of Niérat (1997) and Macharis & Verbeke (2004) have in common that the service area is more competitive to be located as an extension of the direction of the arriving goods, to prevent covering the same distance twice with two modes of transport.

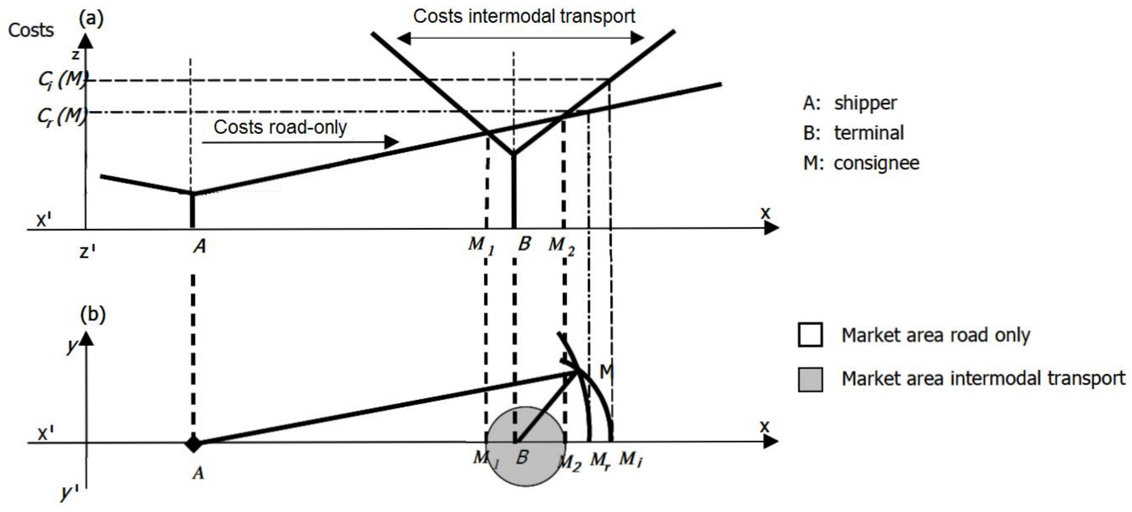


Figure 3-4. Construction of the intermodal market area according to Niérat (1997)

The above mentioned ranges can be used as a starting point to estimate the service area. A more precise way is to carry out a cost comparison for the considered terminal location and compare it with cost calculations for unimodal road transport and intermodal transport via competing terminals. An inland terminal can only be competitive if it can cope with the minimal tariffs of unimodal road transport and intermodal transport via competing terminals. This is an iterative process where several vessel sizes and shipping frequencies have to be considered.

3.2.3 Conclusion: Feasibility requirements for intermodal IWT service

In the preceding subsections, several qualitative and quantitative aspects that influence the shippers' modal choice were identified, which are used to answer sub question 3: "*What are the critical performance conditions that determine feasibility of an intermodal IWT service?"*

It can be concluded that the competitiveness and hence the feasibility of intermodal barge transport depends on a combination of qualitative and quantitative aspects. For setting up an intermodal IWT connection, a barge service has to be initiated between the seaport and the inland terminal as well as pre- and end-haulage. Some flexibility regarding the travel time seems to exist, whereas the critical qualitative performance conditions were found to be reliability and frequency. The shipper has a preference for qualitative aspects over costs up to a certain threshold, which has to be examined for each situation.

If a shipper is satisfied with their current transport service, switching to another transport mode is unlikely, unless a substantial cost advantage can be realized. The cost performance for intermodal IWT is strongly related to the available cargo volumes, distance from the seaport and infrastructure.

3.3 Performance indicators for feasibility of the inland terminal

Now that the performance indicators for the intermodal IWT service are identified, the role of the terminal within the intermodal IWT chain has to be addressed. Several requirements for feasibility of the intermodal IWT chain should be fulfilled by the operator of the inland terminal. This is defined in sub question 4 as follows: "*What are the critical performance conditions for an inland container terminal in the intermodal IWT chain? "*

The core business of the terminal operator is providing facilities for the loading and unloading of containerized cargo. Besides the transhipment of containers, the terminal operator is also able to offer supportive activities to extend the quality of service. Several sizes of inland container terminals can be distinguished in the Netherlands, with different qualitative and quantitative characteristics. These terminal characteristics influence the overall performance of the intermodal IWT chain.

3.3.1 Qualitative performance indicators of the inland terminal: service attributes

The performance conditions for container terminals can according to Wiegmans (2003) be distinguished between the external relations of the terminal and the internal structure. The external relations depend on all actors in the market the terminal operator deals with, whereas the internal structure is related to operations of the terminal itself.

3.3.1.1 *External performance indicators for inland container terminals*

The performance of the external relations of inland container terminals depends on the transport market, network structure and logistics. The organizational structure of the current intermodal IWT service networks in the Netherlands is analysed to identify the service attributes required for terminal feasibility.

An interesting development is the ownership structure of inland terminals in the Netherlands, that is following a horizontal integration strategy taking shares in other terminals (Staalduinen, 2014). Examples are Brabant Intermodal, BCTN, CTU and MCS. Together these companies control approximately 50% of the total handled volumes in the Netherlands. Interesting is that all these actors have their own geographical scope. This allows the terminal operators to bundle containers from multiple terminals that are located along the same waterway on the barges for optimization of the logistics. It enables to transport more cargo to maintain a sufficient loading degree, which provides the opportunity to increase the sailing frequency. The choice of calling at one or more inland terminals depends on a number of factors: the available transport volumes at the different terminals, the desired service frequency and vessel size.

When a competitive market is present, terminal operators are expected to offer more services than just the transhipment of containers. Currently, most intermodal IWT service networks are linked to a single terminal operator, including the organization of the barge services and pre- and end-haulage by truck. For feasibility of an inland terminal, offering a full-service is considered to be a requirement in competitive markets. If such a full-service cannot be initiated, involvement in the organisation of transport networks is vital. For a terminal in Zutphen, this implies that barge transport to the Port of Rotterdam has to be offered, either via initiating a new barge service or cooperating with an existing barge service.

Wiegmans (2003) identified the critical performance condition to be reliability. A reliable intermodal transport service can only be realized if the terminal operator has access to sufficient and constant flow of cargo volumes available to be transported. Therefore the external performance indicator for the terminal operator ensuring reliability of the intermodal transport service is the commitment of sufficient cargo volumes by the main shippers. Noteworthy is that according to KiM (Visser et al., 2012), almost all existing inland terminals have one or more large customers. These launching customers transport sufficient containers to initiate an intermodal IWT service. The smaller customers then join later on. The presence of a launching customer is considered to be an absolute precondition for a terminal to start operations and to generate sufficient cargo flow volumes to reach the required minimum scale of operation.

3.3.1.2 *Internal performance indicators for inland container terminals*

The internal structure of an inland container terminal focusses on the performance of the quality of the services and the required investments to produce these container terminal services. The performance of the terminal is related to the handling efficiency of the terminal, the quality of the supportive activities and economies of scale (Konings & Priemus, 2008). The latter will be discussed in subsection 3.3.2 as a quantitative performance indicator, since the overall terminal performance has to outweigh the investment costs. The qualitative aspects and their influence on the shippers' preferred qualitative service attributes will be discussed here.

Handling efficiency

The handling efficiency depends on the following aspects (e.g. Konings & Priemus, 2008; Wiegmans & Konings, 2015):

- Terminal equipment: type of crane, number of cranes, number of reachstackers, experienced personnel;
- Terminal capacity: quay length (number of berths), storage area, stack capacity;
- Opening hours: terminal size, regulations.

The terminal equipment affects the handling speed. In general, a gantry crane will be able to handle more containers per hour than a mobile harbour crane, dependent on the skills of the crane operator. For terminals with little water level differences at the quay, direct loading of the barge with a reachstacker might be possible. Together with the terminal capacity and opening hours, this influences the waiting time at the terminal and hence the vessel circulation time. Handling efficiency has a major effect on the reliability of the intermodal IWT chain. These aspects also weigh heavily on the total investments and operational costs of the terminal.

Supportive terminal services
Alongside the main activity of the transhipment of containers, Decisio (2002) suggests that additional activities can be offered by the terminal operator to respond to the desires of the shippers. The following supportive activities are frequently offered at inland terminals:

- Pre- and end-haulage
- Freight forwarding
- Supply of empty containers
- Stuffing and stripping of containers
- Warehouse activities
- Reefer connections
- Gas measurement of the container
- Customs

These supportive activities affect several qualitative determinants. The demand for these additional activities strongly depends on shipper's preferred service attributes. For each case an assessment has to be conducted to identify the shipper's preferences.

3.3.2 Quantitative performance indicators of the inland terminal: costs

The cost estimation for the entire intermodal transport chain determines what margins are available for the handling costs, in order to offer competitive tariffs. Dependent on several terminal characteristics that will be discussed in this subsection, the handling costs can be determined.

3.3.2.1 ***Economies of scale***

As mentioned in subsection 3.2.2.2, the scale of operation of the terminal influences the costs per handling, since a minimum throughput is required to cover the investment costs of the terminal. Furthermore, the supportive activities weigh in heavily on the terminal costs.

Decisio (2002) analysed the small terminals in the Netherlands and made a distinction between 'low-profile' and 'full-service' terminals. The low-profile terminals save considerably on qualitative services of the terminal, thereby lowering the investment costs, which affects the performance of the qualitative aspects negatively. These terminals only have mobile handling equipment, limited storage facilities and no regular service to the seaport (less than three times a week). In contrast, full-service terminals have a fixed crane, a regular shipping service and a more substantial transhipment volume. The break-even transhipment volumes for a low-profile and full-service terminals are assumed to be 14,000 and 20,000 moves per year respectively.

Van Staalduinen (2014) analysed all terminals in the Netherlands and identified only 8 terminals that handle less than 20,000 containers on an annual basis. In line with classification of Decisio (2002), 6 of these terminals in the Netherlands have little terminal capacity and facilities and could therefore be regarded as low-profile terminals. An important observation is that 4 of these low-profile terminals are situated in Noord-Nederland, where the density of intermodal transfer points is very low and hence have less competition and a larger service area. These low-profile terminals lack the ability to offer all qualitative supportive activities. As a result it can be assumed that low-profile terminals can only succeed in areas with little competition.

Wiegmans & Konings (2015) calculated for different terminal sizes varying between 20,000 and 200,000 TEU/year the cost performance for intermodal IWT. They concluded that for small terminals, the relative high handling cost reduces the competitiveness of intermodal IWT. This is confirmed by Smid et al. (2016), who modelled the cost sensitivity for different inland waterway terminals sizes, illustrated in Figure 3-5. They concluded that terminals with a higher container throughput encounter less costs per container and can charge a lower price for a sufficiently high utilization rate of the terminal capacity and questioned whether small (20,000 TEU volume/year) and medium (50,000 TEU volume/year) sized terminals will be able to offer handling costs following the market price.

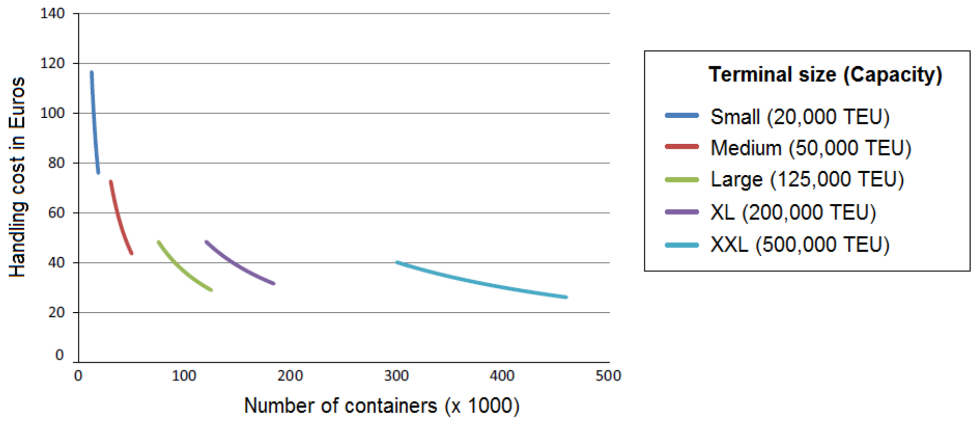


Figure 3-5. Handling costs for five terminal sizes, according to Smid et al. (2016)

In areas where there is strong competition, Smid et al. (2016) argued that it is important for small and medium terminals to grow in size quickly to be able to lower the handling costs. A common strategy is to start operation of small terminal with a few large shippers, the so-called launching customers, after which smaller shippers join, allowing the terminal to expand their operations (Visser et al., 2012). This can only be realized if sufficient growth potential of the cargo volumes can be identified in the area.

For the starting phase of new terminals, a supportive government may be a critical force through financial backing and favourable laws and regulations (Wiegmans, 2003). The government could provide subsidies or act as landlord to reduce the investment costs, but in general stays out of the business processes of the container terminal operation.

3.3.2.2 ***Factor costs of transhipment at terminal***

Efficiency and scale of operation are important for the handling costs at container terminals. The high initial investment cost that are required for launch of a new terminal initiative causes the performance of the terminal to be volume-driven as shown by Wiegmans & Konings (2015) and Smid et al. (2016). The most important factor costs that influence the costs per handling are discussed below. For a detailed overview of all cost drivers refer to Appendix A.

Fixed costs:

- Terminal (e.g. land, quay)
- Terminal equipment (e.g. cranes, reachstackers)
- Labour costs
- Overhead costs
- Insurance

Variable costs:

- Fuel costs
- Repair and maintenance

The costs per handling depend on the fixed and variable costs. For an increasing terminal size, the relative increase in the fixed costs weighs in less heavily than for smaller terminal sizes. For instance, small and medium terminals both require one reachstacker. Hence, the investment costs in the reachstacker for the medium terminal can be divided over more terminal handlings, decreasing the costs per handling.

Relation of costs with qualitative service attributes
The qualitative service attributes that are desired by the shipper have a strong influence on the fixed costs. If a warehouse function is desired, this will affect the terminal area that is required. The same holds for the opening hours of the terminal. In order to optimize the logistics, a continuous barge service is often used. If the opening hours of the terminal are limited, this hinders the optimization of the sailing schedules. However, if a small size terminal is operating 24/7, the cost burdens for additional labour costs of the opening hours are not outweighed by the benefits. A balance has to be found between the qualitative and quantitative performance to optimize the performance of the terminal. Therefore, when the preferred qualitative aspects are indicated, an estimate for the required terminal investments should be prepared to determine whether a financially feasible business case can be found.

3.3.2.3 *Examination of quantitative feasibility by cash flow analysis*
The quantitative performance of the inland container terminal can be evaluated by estimating the fixed and variable costs and the expected revenues of the terminal. The financial feasibility can be determined by conducting a cash flow analysis (van Dorsser, 2016). A cash flow analysis determines the overall profitability of a new investment by taking into account the expected revenues and expenditures of the terminal and by calculating the corresponding financial performance indicators. During the design stage, a simplified financial model can be used, such as a real pre-finance - pre-tax financial evaluation.

The total expected expenditures consist of the capital expenditures (CAPEX) and the operational expenditures (OPEX). The CAPEX comprise the investment costs for construction of the terminal that are usual non-recurring, whereas the OPEX are recurring costs to operate the terminal. These expenditures can be determined using key numbers for terminal design and operations. Based on the expected throughput volumes, an assessment of the expected tariffs can be made in order to determine the expected revenues.

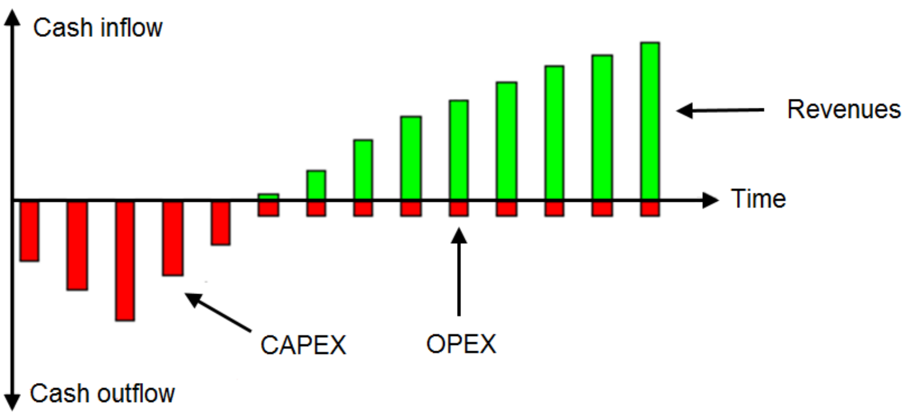


Figure 3-6. Cash flow for a port project. Source: Lecture slides CIE4330 (van Dorsser, 2016)

One of the principles of economics is that one money-unit today is worth more than the same money-unit tomorrow, also known as the time value of money. By applying discounting techniques, the future values of the expected cash flows can be expressed into the present value.

In economics, the nominal value refers to current prices expressed in a money-unit that has not been adjusted for inflation, while the real value refers to the value that has been adjusted for changes to the general price level over time expressed in a money-unit at constant price level of a certain base year. A discount is applied to the compare the value at different periods of time. The discount rate is often determined by the minimum return requirement. This return requirement is based on the extent of the risks of the investment.

The Weighted Average Cost of Capital (WACC) is commonly used to determine the discount rate. It is defined as the rate at which the present value of the discounted free cash flow is similar to the present value of equity cash flows plus the present value of the debt cash flows:

$$WACC = r_D \cdot \frac{D}{D+E}(1-t) + r_E \cdot \frac{E}{D+E} \tag{1}$$

In which:

D	=	value of debt
E	=	value of equity
r_D	=	required return on debt
r_E	=	required return on equity
t	=	tax rate

The financial feasibility can be evaluated using several performance indicators. A commonly used indicator is the Net Present Value (NPV). The NPV can be calculated as the sum of the present values of incoming and outgoing cash flows over a period of time. If NPV > 0 it indicates that value is added, meaning that the required rate of return exceeds the discount rate. When the discount rate is kept constant over time, the NPV can be expressed as follows:

$$NPV(CF) = \sum_{t=0}^{T} \frac{CF_t}{(1+r)^t} \tag{2}$$

In which:

$NPV(CF)$	=	net present value of a cash flow
CF_t	=	cash flow at time t
t	=	number of time periods ahead
T	=	duration of project
r	=	the applied discount rate

The simplified financial model can be used to analyse the overall profitability of the investment that is required for terminal operations. It is expressed in real terms and does not take the effects of inflation and taxes into account. If a positive NPV can be found for the simplified pre-finance - pre-tax financial model, next step is to let economists apply a full financial model: the nominal post-finance - post-tax financial evaluation. Now the effects of inflation, depreciation, finance and taxes are taken into account.

3.3.3 Conclusion: Critical conditions for inland waterway container terminals

The modal choice of shippers was found to be based on a combination of qualitative and quantitative aspects. The inland container terminal plays an important role in the intermodal IWT chain for both the costs and service attributes. The performance of the terminal depends on the external relations and the internal structure. The external relations relate to all actors in the transport market the terminal operator deals with, whereas the internal structure is related to operations of the terminal itself. The critical performance conditions are identified by providing an answer to sub question 4: "*What are the critical performance conditions for an inland container terminal in the intermodal IWT chain?"*

Wiegmans (2003) identified the critical qualitative service attribute to be reliability. A reliable intermodal transport service can only be realized if the terminal operator has access to sufficient and constant flow of cargo volumes available to be transported. According to KiM (Visser et al., 2012), almost all existing inland terminals have one or more large customers. These launching customers transport sufficient containers to initiate an intermodal IWT service. The smaller customers join at a later stage. The presence of a launching customer is considered to be an absolute precondition for a terminal to start operations and to generate sufficient cargo flow volumes to reach the required minimum scale of operation.

In a competitive transport market, terminal operators are expected to manage more services than just the transhipment of containers. Being able to manage all components of the intermodal IWT chain, including barge transport and pre- and end-haulage is considered to be a requirement. For a terminal in Zutphen, this implies that barge transport to the Port of Rotterdam has to be offered, either via initiating a new barge service or cooperating with an existing barge service.

Regarding the internal terminal structure, terminal operators have to differentiate themselves in a competitive market to attract potential shippers. This can be realized by offering competitive prices or exploiting a full-service terminal, where besides the transhipment of containers, supportive terminal services are offered. These supportive activities cause an increase of the required investments and operational costs, but also increase the expected revenues if more cargo volumes can be captured. On the contrary, a low-profile terminal saves considerably on qualitative services, among other things by offering no regular service to the seaport (less than three times per week). The optimal profile of the terminal services is a trade-off between the offered supportive services and the investment costs.

The handling costs are strongly related by the terminal capacity and its utilization rate. Terminals with a higher container throughput encounter fewer costs per container and can therefore charge lower tariffs. In areas with strong competition, Smid et al. (2016) argued that it is important for small (20,000 TEU volume/year) and medium (50,000 TEU volume/year) terminals to grow in size quickly to be able to lower the handling costs. This can only be realized if sufficient growth potential of the cargo volumes can be identified in the area.

4

Framework to assess feasibility of inland container terminals

This chapter addresses sub question 5: "How can a viable business case be found for an inland waterway container terminal?" A framework is presented based on the in chapter 3 identified elements that influence the feasibility of a barge container terminal. The framework consists of two parts. The first part is discussed in section 4.1 and consists of several analyses leading to input for the design of the intermodal IWT service, to which the possible terminal solutions will be developed. Section 4.2 presents a framework to assess the financial feasibility of the terminal solutions. A viable business case is considered to be found for a positive NPV, for which a financial analysis is worked out.

4.1 Framework to collect input for the intermodal IWT service design

In order to successfully initiate operation of an inland terminal, the terminal operator has to offer a competitive intermodal IWT service, which includes sailing, terminal handling and pre- and end-haulage. The performance of the intermodal IWT connection is related to the distance from the seaport and the scale of operation, for which it is required to attract sufficient cargo. This can only be realized when sufficient potential cargo volumes are available in the region and shippers that are willing to make a modal change. The shippers' modal choice is based a combination of qualitative and quantitative aspects, which have to be identified and satisfied in order to attract cargo.

Several analyses need to be carried out to identify the potential cargo volumes that can be captured by a terminal, as is described in the framework below. The framework was prepared for the situation in Zutphen, but its steps are generally applicable and can be used with minor adjustments for any inland terminal as a guideline:

Area exploration

The area has to be scanned for accessibility on national, regional and local level by exploring the existing infrastructure and transport flows, similar to chapter 2. On national and regional level, the distance to the seaport, quality of existing infrastructure and location of competitive terminals are relevant to indicate the service area. The service area can be estimated taking into account the literature described in paragraph 3.2.2.4 (i.e. range of 20-30km, orientation as extension of the direction of arriving goods). On local level, a suitable water-bound location has to be found for the development of a terminal.

Assessment of potential cargo volumes
The cost performance of both the barges and terminals depend on the scale of operation, since a certain capacity and utilization rate is required in order to be able to offer competitive prices. To determine the potential scale of operation, a cargo assessment has to be worked out to identify the potential cargo volumes in the service area. A distinction has to be made between 20ft and 40ft containers, since the costs are different per container size. Also the expected potential growth of the cargo volumes has to be assessed. This can be done by analysing the regional and national trends and developments in the inland barge container market.

Shippers' preferred service attributes
In addition, the shippers' preferred service attributes have to be identified, in order to determine which qualitative requirements have to be fulfilled to attract potential shippers. The desired sailing frequency is the most relevant qualitative aspect for the logistics of the intermodal IWT service. It influences the required vessel size and its loading degree and therefore the sailing costs. Also the tonnages per container should be taken into account, since this affects the required handling equipment at the terminal and the draught of the barges and hence the maximum loading degree.

Analysis of cost competitiveness
In order to attract potential customers, the cost for intermodal IWT transport via Zutphen has to be competitive with the costs of existing transport modes. The cost for intermodal IWT transport via Zutphen towards all relevant industrial areas within the estimated service area has to be calculated. These have to be compared with the transport costs via the existing transport modes; unimodal road transport and intermodal IWT via competitive terminals. Only when a better price can be offered than the best price of the competitors at a comparable service level, cargo can be attracted.

Development of possible terminal solutions
The above steps provide input for setting up the intermodal transport service: a barge service between Rotterdam and Zutphen, including terminal handling and pre- or end-haulage. The potential cargo volumes and cost competitiveness were analysed, after which an indication of the potential scale of operation can be given. Next step is to develop several terminal solutions. Once these terminal solutions are worked out, the feasibility of these alternatives can be assessed with the framework presented in section 4.2.

4.2 Feasibility framework of the terminal in the intermodal IWT chain

After the development of the terminal solutions, the feasibility of these alternatives has to be assessed. A terminal solution is found to be feasible if business case can be defined, because a private party has to be found that is willing to run the terminal operations. For the business case, the terminal operator has to offer barge transport to the seaport and facilitate terminal operations. A profitable intermodal IWT service can be found if these activities generate sufficient revenues, outweighing the required investments and operational costs for both the terminal and the barge service. The revenues rely upon the available cargo volumes, which can only be captured if the terminal operator is able to satisfy the shippers' preferred service attributes and offer competitive transport tariffs. The following framework can be followed to evaluate whether a business case can be found:

Step 1. Setting tariffs and selection of service level
Set the transport tariff for sailing plus terminal handling and select the sailing frequency. The preferred service frequency influences the cost competitiveness, since a service level with a higher shipping frequency requires either smaller barges or more cargo volumes. The fixed tariffs lead to a transport price for shipping and terminal handling that generate revenues for the terminal operator.

Step 2. Framework conditions for captured share of potential cargo volumes

Dependent on the best price of the competitors, the selected tariffs lead to a price difference with the existing transport modes. Together with the offered service level, shippers will face a trade-off between transport modes whether they are willing to make a modal change or not. For higher costs or a lower service level than competitive transport modes, it is unlikely the shipper will change. Based on interviews with potential customers and expert consultation of supervisor J.C.M. van Dorsser[1], the following relation between the cost savings and service level to the share of potential cargo volumes to be captured was proposed by the author. Note: This relation was specifically prepared for the situation in Zutphen.

Table 4-1. Share of captured potential cargo volumes in relation with costs and service attributes

Market share		Service level			
		Very low	Low	Medium	High
Charact-eristics	Sailings per week Operating hours/week Supportive services*	1 20 None	2 40 Low services	3 60 Medium services	5 80 Full-service
Costs	Higher costs	0%	0%	0%	0%
	Equal costs	0%	10%	15%	20%
	10% cost saving	5%	20%	30%	50%
	20% cost saving	10%	30%	50%	80%
	30% cost saving	15%	50%	80%	95%

*) The supportive terminal services are described in paragraph 3.3.1.2. A full-service terminal is able to offer most of these services and a very low-profile terminal little or none. A higher service level entails higher operational expenditures.

The captured cargo volumes and shipping frequency lead to a required barge capacity for each roundtrip. The scale of operation influences the vessel size and loading degree that can be used, which affects the costs for sailing. The assumed barge capacities are presented in Table 4-2. It is assumed that for stability reasons and air draft restrictions by bridges, the capacity of a Class Va vessel is limited to three layers. Note: Although omitted here, a stability calculation should be carried out for all barge classes to obtain more precise results. This may lead for other barge classes to be limited in capacity as well.

Table 4-2. Barge classes with their corresponding assumed capacities

TEU/roundtrip	CEMT Class	Capacity
1-32	Neokemp	32 TEU (on 2 layers)
33-90	IV	90 TEU (on 3 layers)
91-156	Va	156 TEU (on 3 layers)

Speed of modal change in start-up phase

The expected share of the potential cargo volumes to be captured is not obtained in the first year. It takes some time before the total share of expected volumes can be realized. It is assumed by the author that in the start-up year 50% of the total captured share can be realized and expands with 50% of the remaining share every following year. This leads to the following stakes of the total captured cargo volumes in the start-up phase:

Table 4-3. Percentage of the total share of potential captured cargo volumes in the start-up phase.

1st year	2nd year	3rd year	4th year	5th year
50%	75%	88%	94%	97%

[1] Dr. ir. J.C.M. van Dorsser is transport economist specialized in the field of inland waterway transport

In the start-up phase also the operational expenditures are limited, but not at such an extent as for the revenues. In the start-up phase the costs for fuel, maintenance and labour are lower due to limited handlings. The following stakes of the total OPEX are assumed in the start-up phase:

Table 4-4. Percentage of total OPEX in the start-up phase as a result of limited handlings

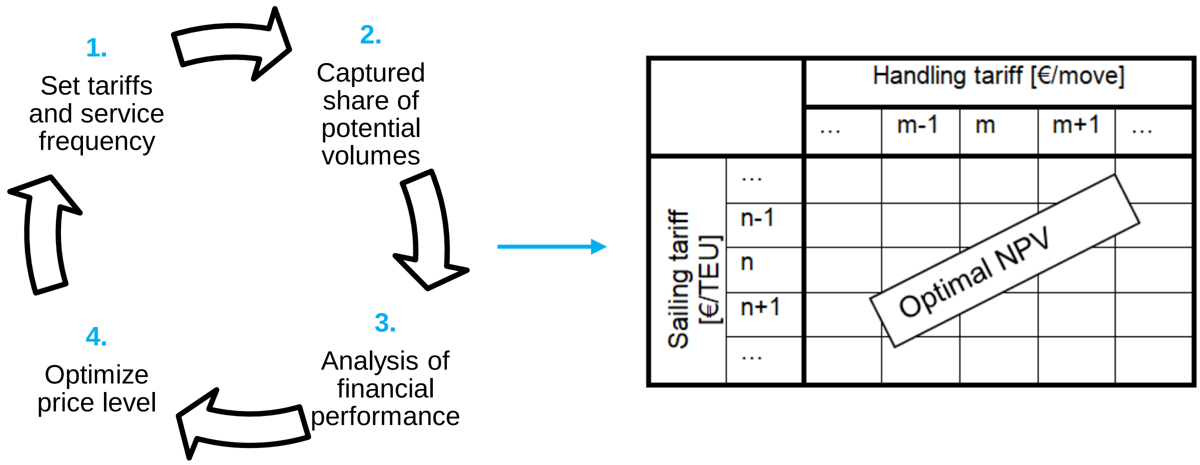
1st year	2nd year	3rd year	4th year	5th year
75%	85%	90%	95%	100%

Step 3. Analysis of financial feasibility

Now that the available cargo volumes are determined, the financial performance of the terminal solution has to be calculated. A real pre-finance - pre-tax financial evaluation was used to indicate the potential success of each alternative. A cash flow analysis will be used to evaluate the financial performance. The costs and revenues for sailing and terminal handling have to be considered separately, because for sailing these are expressed in $€/\mathrm{TEU}$ and for terminal handling in $€/\mathrm{move}$. The OPEX for the terminal and the fleet together form the total OPEX. In case of an initial terminal investment, also the CAPEX have to be determined, after which a cash flow analysis can be worked out. The NPV can be used as performance indicator to evaluate the financial feasibility over the duration of the concession.

Step 4. Optimization of price setting

The optimal financial performance of each terminal solution can be determined iteratively by altering the selected tariffs and service level. After repeating these steps numerous times for each terminal solution, the resulting NPV for each tariff and service level can be calculated and subsequently the optimal price setting for a chosen service level can be found. For each of the terminal solutions, the NPV (or other financial performance indicators) can be used to evaluate whether a business case can be defined.



4.3 Conclusion

For initiating a viable terminal, a terminal operator has to be found that is able to offer barge transport and handling of the containers, plus the pre- and end-haulage by truck. To attract a private party, a financial feasible business plan is required, as is addressed in sub question 5*: "How can a viable business case be found for an inland waterway container terminal?"*

The presented framework shows a method to assess the financial feasibility. It includes several analyses that are required to identify the cargo volumes that are likely to be captured. The resulting input is used for the development of terminal solutions, which can be assessed for financial feasibility by means of working out a cash-flow analysis.

5

Development of terminal solutions in De Mars

The analyses described in the first part of feasibility framework are worked out in this chapter. The potential cargo flow volumes in the region are identified and the cost competitiveness with other transport modes is determined. It was found that the potential cargo flow volumes in Zutphen itself are limited and have to be captured in the region around. Also the available margins to be cost competitive with other transport modes are limited. As a result, Zutphen has to aim for a low profile, low-cost terminal. Three proposed terminal solutions are worked out on preliminary design level, all integrated in the industrial harbour.

5.1 Analysis of cargo flow volumes in service area

The literature review in chapter 3 showed that the realization of an intermodal IWT service depends strongly on the available cargo volumes. This is addressed in sub question 6: "*What are the expected cargo volumes that can be captured by an inland container terminal in Zutphen?*"

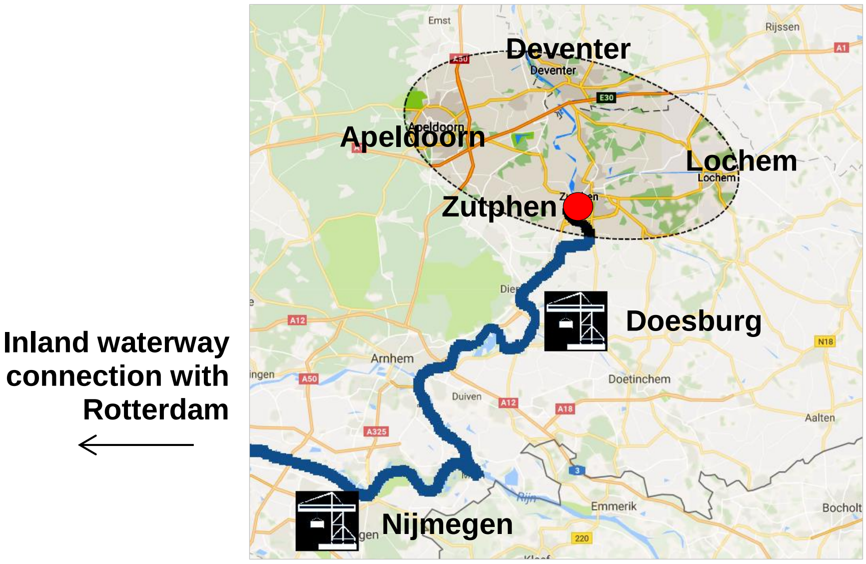
To assess the available cargo volumes, the first part of the framework (section 4.1) will be applied. First the area will be explored for potential customers, in order to make an estimate of the service area. Next, the potential cargo volumes in the service area will be assessed together with the shippers' preferred service attributes. An intermodal cost calculation is worked out to determine the cost competitiveness of intermodal transport via Zutphen. As a result, the available margins to initiate a competitive transport mode can be determined.

5.1.1 Exploration of the area

First step of the framework is to explore the area around Zutphen to estimate the extent of the service area where potential destinations with customers can be found. A system description of the region around Zutphen was presented in chapter 2. Based on literature (paragraph 3.2.2.4), an estimate of the potential service area can now be given. The barge service is connected to a seaport, which is considered to be the Port of Rotterdam.

Kennisinstituut voor Mobiliteitsbeleid (KiM) (Visser et al., 2012) indicated the Deventer-Apeldoorn-Zutphen region to be located in a ‘white spot’. This is defined as a region with economic potential and container volumes that are situated at too great distance from existing terminals (>30km). Apeldoorn was pointed out as hotspot location, with the highest concentration of logistic activities. This indicates that Zutphen could potentially serve this area with a terminal. However, this report was published in 2012, before the new container terminal in Doesburg was put into operation.

The major cities with industrial areas within a 20km range of Zutphen are Apeldoorn, Deventer and Lochem. These cities are located further away from Doesburg, and therefore possibly not intersecting with the service area of Doesburg. Following the service area oval in extended direction of the arriving goods as concluded by Niérat (1997), and assuming a shuttle service to Rotterdam, the freight is delivered from the south-westerly direction. This means that the potential service area may be found north-east of Zutphen. As a result, the oval area north-east of Zutphen, comprising Apeldoorn, Deventer and Lochem, will be included in the subsequent analyses as potential service area.



5.1.2 Assessment of cargo volumes

For the initiation of an inland terminal, it was noted that all three elements of the intermodal IWT chain have to be offered: a barge service, terminal handling and pre- or end-haulage by truck. For the terminal operator this means that it has to facilitate the handling of containers and arrange barge transport to the Port of Rotterdam. The latter can be obtained by initiating their own barge service or find an independent logistic barge service provider. In order to initiate a profitable barge service and handling operations at the terminal, a sufficient and constant supply of cargo volumes is required. For pre- and end-haulage by truck it is assumed that a logistic trucking company will be used, since it does not require significant cargo volumes.

The potential cargo volumes that are available in the service area will be assessed in this section. These are determined by using existing data, interviews with customers and prognoses following the trends and developments for the transport market. As a result, the total potential cargo volumes to be captured by a terminal in Zutphen are identified. These volumes will be used to evaluate the terminal feasibility later on in chapter 6.

5.1.2.1 *Identification of current potential cargo volumes*

To initiate a modal shift towards intermodal transport, a certain scale of operation is required to be competitive with existing transport modes. Following the strategy described by KiM (Visser et al., 2012), a launching customer has to be found that transports sufficient cargo volumes to create a constant transportation demand after which the smaller shippers join. Business park De Mars was scanned to identify a launching customer.

There was limited data available regarding the regional cargo volumes. The report of KiM (Visser et al., 2012) indicated for the white spot Deventer-Apeldoorn-Zutphen a total cargo volume of 89,000 TEU in 2008 of which 89% was being transported by road. Though, this number is based on the entire COROP region Veluwe, which extends a broader region than Deventer-Apeldoorn-Zutphen. In Appendix C the assessment of the potential cargo volumes is worked out. The service area was scanned for the containerized cargo that is suitable for intermodal IWT. To initiate an intermodal transport service, the cargo needs to be transported on the same route. Hence, the import and export flows via the Port of Rotterdam were considered.

In the assessment, most companies at business park De Mars were contacted in order to identify the potential cargo volumes in Zutphen. The conducted interviews focussed on companies that transport containers with a regular frequency on the same shipping route (Rotterdam - Zutphen) or are interested in doing so. It was concluded that no launching customer could be found in Zutphen that is able to deliver the required cargo volumes to initiate terminal operations. Just three companies at the business park transport containers on a weekly basis towards Rotterdam with a combined volume of 100 TEU per week, of which the ratio 20ft/40ft containers is 1:2, corresponding to a TEU-factor of 1.67.

Further along in the service area, the expected cargo volumes were estimated by the author based on literature, the best available data and expert consultation. For Deventer, Lochem and Apeldoorn it is assumed a similar TEU-factor as for Zutphen can be used. The following total potential cargo volumes were identified for each city in the service area:

Table 5-1. Potential cargo volumes identified in the possible service area

Potential volumes	Zutphen			Deventer			Lochem			Apeldoorn			Total in region		
	20ft	40ft	TEU	20ft	40ft	TEU	20ft	40ft	TEU	20ft	40ft	TEU	20ft	40ft	TEU
Verified by companies[1)]	20	40	100												
Expected based on literature [2)]				20	40	100	10	20	50	70	140	350			
Total weekly volumes	20	40	100	20	40	100	10	20	50	70	140	350	120	240	600
Total annual volumes	1040	2080	5200	1040	2080	5200	520	1040	2600	3640	7280	18,200	6240	12,480	31,200

[1)] Based on interviews with companies, refer to Appendix E
[2)] All based on literature and best available data (CBS, 2016b; TLN, 2014)

Table 5-1 shows the total potential cargo volumes in the service area. The share of these potential volumes that is likely to be captured can be determined following Step 2 of the framework in section 4.2. The shippers that are willing to make a modal change to transport their containers via a terminal in Zutphen have to be attracted by offering competitive prices, while satisfying their preferred qualitative service attributes.

A remark must be made that from the interviews it became clear that not all shippers are willing to commit beforehand due to various reasons. In Zutphen there is scepticism towards a successful realization of a terminal, due to the failure of previous attempts and the recent opening of the terminal in Doesburg. Also the shippers in Deventer are not likely to commit beforehand, due to the pending terminal initiative in Deventer. Therefore, the cargo assessment should be interpreted with caution.

5.1.2.2 *Expected growth rate of cargo volumes*

National cargo flow prognoses

In the last decades, several cargo flow prognoses in the Netherlands have been conducted, that almost all accounted considerable growth. A commonly used study that predicts the long term effects up to year 2040 is the CPB report 'Welvaart en Leefomgeving', (Janssen et al., 2006). This report presented the so-called WLO-scenarios, where 3 of the 4 scenarios expect considerable growth in The Netherlands as a result of globalisation. The Port of Rotterdam (PoR) based their old cargo flow prognoses on these WLO-scenarios, but the realization of growth rate lagged behind the expectations (see Figure 5-1: right), as is confirmed by the latest port vision update of the Rotterdam port authorities (Port of Rotterdam, 2016).

The Port of Rotterdam presented four new scenarios showing a much lower growth expectation. These PoR-prognoses show that growth of the cargo volumes is no longer evident. A stable and fairly flat development of the cargo flows may be expected and even a decline of the cargo volumes is taken into account for 2 scenarios after the year 2020. The realized cargo flows are illustrated with respect to the new and old prognoses in Figure 5-1.

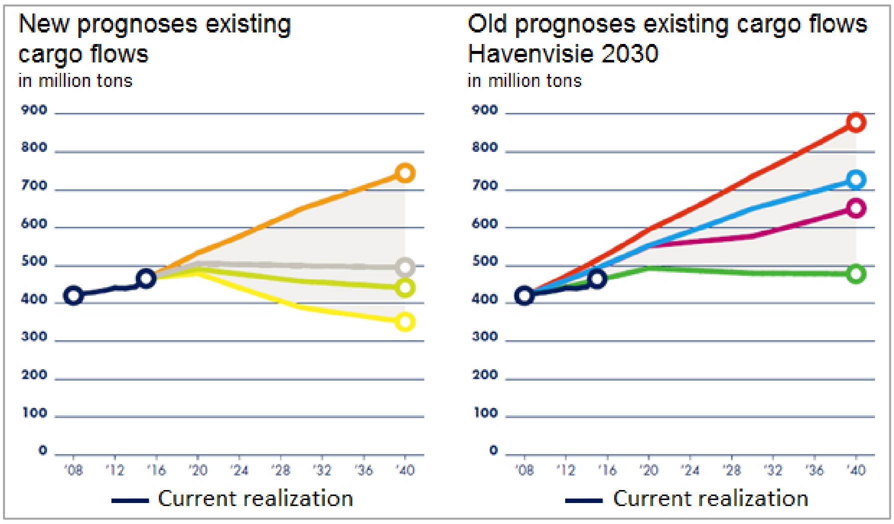


Figure 5-1. Development of cargo volumes with respect to: 1) left: the new prognoses by Port of Rotterdam and 2) right: the old prognoses from Havenvisie 2030. Source: (Port of Rotterdam, 2016)

Local trends at De Mars

In the last decade, business park De Mars has been under pressure, due to the high vacancy rate caused by the disappearance of several large firms that went bankrupt or moved their business elsewhere (De Stentor, 2016). The municipality is aiming to attract new companies, amongst others by improving the business climate towards the cleantech sector. Realization of a terminal might attract new businesses accompanied with new cargo flows, but this has a lot of uncertainties.

Expected growth of cargo volumes for Zutphen region

The PoR-prognoses show the trends and developments on national level and do not necessarily correspond to regional trends and developments in Zutphen. Since the PoR-prognoses are the best available ones, a safe assumption is that these conservative trends can be followed for the regional market. The author has introduced three growth rates for the Zutphen region: A baseline scenario (0%), a decline scenario (-1%) and a growth scenario (+2%). The baseline scenario is considered to be the most probable one. The decline and growth scenarios for the Zutphen region take the average growth rates of respectively the two lowest and highest PoR-prognoses into account. This development is of importance, because so far most policymakers always naturally assumed growth of the cargo volumes. The new prognoses show that this cannot be guaranteed anymore.

For simplicity, these three growth scenarios will be coupled to an existing parameter. It was chosen by the author to couple these growth rates to the share of the potential cargo volumes to be captured, as presented in the framework in Table 4-1. The baseline scenario corresponds to these values of the captured share, whereas for the decline and growth scenarios, it is assumed that respectively a smaller or larger share of the potential cargo volumes will be captured. The corresponding share of the potential volumes to be captured for the three growth scenario is shown in Table 5-2.

Table 5-2. Growth scenarios for the Zutphen region

	Cargo flow prognoses for Zutphen region		
	Decline	**Baseline**	**Growth**
Growth rate	- 1%	0%	+ 2%
Share of potential volumes captured	90% of assumed volumes	As per Table 4-1	120% of assumed volumes*

* No more than 100% of total potential cargo volumes

5.1.3 Shippers' preferred service attributes

The shippers' preferred service attributes have to be identified, to determine which qualitative requirements have to be fulfilled to attract potential shippers. Interviews with several company managers in De Mars (refer to Appendix E) indicated that most shippers value the convenience of the offered service. Most shippers prefer to manage as little of the transport process as possible. This includes dealing with one actor for the entire transport chain and the delivery empty containers. The large customers at De Mars demand a minimum sailing frequency of two roundtrips per week. Also the required cost savings were questioned in order to consider a modal shift. In hindsight, the input from these interviews together with the in literature stated performance indicators were transformed into the framework conditions for captured share of potential cargo volumes, as presented in Table 4-1.

The type of industry has a strong influence on the average tonnages per container. The main industries located at De Mars transport raw materials such as paper, plastics and metals. Based on the interviews with the companies, the expected tonnage per container is found to be 20 ton for a 20ft and 25 ton for a 40ft container. With the identified TEU-factor of 1.67 this leads to an average of 14 ton/TEU. In case of draught limitations on the waterways, these average tonnages have to be taken into account

5.1.4 Analysis of cost competitiveness

The framework shows that competitive transport tariffs have to be offered in order to attract potential shippers. The cost competitiveness is determined by working out an intermodal cost calculation to all potential destinations in the service area. The best prices the competitive transport modes are able to offer to these destinations are taken as point of reference. Subsequently, the costs for intermodal IWT via Zutphen is worked out for different barge classes and utilization degrees, to determine the costs competitiveness.

5.1.4.1 *Used parameters in cost calculation*

The calculations are based on the cost components described in subsection 3.2.2. The used parameters for the calculations are briefly presented in this subsection. Refer to Appendix A for an elaboration on these numbers.

Sailing parameters

The sailing cost of barge transport consists of fixed and variable costs. The key figures issued by Rijkswaterstaat (Panteia, 2015) and the cost model of Van Dorsser (2015) are used for the calculations. The following properties and input parameters were used:

Table 5-3. Properties for fixed and variable costs for different barge classes. Source: Adapted from Panteia (2015) and Van Dorsser (2015)

CEMT Class	Capacity $[TEU\ in\ l \times b \times h]$	Fixed costs $[€/day]$	Fuel consumption $[l/km]$	Average sailing speed $[km/h]$
Neokemp	8 x 2 x 2 = 32	1,096	4	13
IV	10 x 3 x 3 = 90	1,607	6	14
Va	13 x 4 x 3 = 156	2,263	9	14
VIa	17 x 5 x 4 = 340	2,937	13	15

The cost for duty and tax free gasoline was obtained by contacting bunker stations. The average fuel cost over 2016 was $€0.33/l$. The 2016 fuel prices are at a historically low level. Based on forecasts in the energy market (EIA, 2017), the fuel costs are expected to increase in the near future. To anticipate a fuel price increase, $\mathbf{€0.40/l}$ will be used for barges.

For the import and export flows of containers, the Port of Rotterdam is considered to the one seaport for the barge service. The ECT Delta Terminal on the Maasvlakte is assumed to be the starting point of the sailing route and is used for all comparative calculations, with the following corresponding distances:

Table 5-4. Sailing distance for barge service between Rotterdam and inland terminal. Source: The Blue Road Map (Bureau Voorlichting Binnenvaart, n.d.)

Route	Sailing distance
Rotterdam – Zutphen	200 km
Rotterdam – Doesburg	175 km
Rotterdam – Nijmegen	135 km

Truck parameters

The fixed and variable costs for truck transport are determined using the cost model of Van Dorsser (2015). The main input parameter in this model is the oil price, for which the average oil price of January 2017 ($45 per barrel Brent oil, €/$-exchange rate: 1.061) was applied. In the cost model this led to the following costs for a truck with container chassis:

Fixed costs: *€46.58/hour*
Variable costs: *€0.30/km*

The distance and travel time for each trip by truck was determined using Mappy.com, a route planner that is able to calculate routes with loaded trucks, which is of importance since some roads may not be accessed by trucks (e.g. the Oude IJsselbrug crossing the IJssel River westward of Zutphen). The distance and travel time for each of the considered destinations are depicted in Table 5-5.

Table 5-5. Distance and travel time for trucking between originating terminal and destination. Source: Mappy.com, vehicle: Truck 3 axles, MTM>12T, with trailer.

		Destination							
		Zutphen		Deventer		Lochem		Apeldoorn	
		Distance	Time	Distance	Time	Distance	Time	Distance	Time
Origin	Rotterdam	194 km	160 min	186 km	153 min	210 km	174 min	170 km	140 min
	Zutphen	3 km	6 min	13 km	21 min	20 km	28 min	28 km	35 min
	Doesburg	23 km	35 min	36 km	49 min	37 km	46 min	26 km	41 min
	Nijmegen	51 km	62 min	65 km	62 min	68 km	75 min	47 km	54 min

Note: The presented travel times are exclusive of congestion

The corresponding costs per roundtrip per container are shown in Table 5-6. Here congestion was included by applying a congestion factor of 1.1 to the travel time.

Table 5-6. Costs per container per roundtrip for pre- and end-haulage by truck. Source: own calculations

		Destination			
		Zutphen	**Deventer**	**Lochem**	**Apeldoorn**
Origin	Rotterdam	€ 460	€ 445	€ 496	€ 413
	Zutphen	€ 48	€ 77	€ 91	€ 100
	Doesburg	€ 104	€ 131	€ 127	€ 108
	Nijmegen	€ 158	€ 163	€ 186	€ 135

5.1.4.2 *Best price of competitive transport modes*

For each potential destination in the service area, the best price the competitive transport modes are able to offer was calculated. The considered competitive transport modes are unimodal road transport and intermodal IWT via the terminals in Doesburg and Nijmegen. The calculation was worked out in Appendix B using the above assumptions and input parameters from the preceding subsection. The results are presented in Table 5-7.

The following prior assumptions were made for the best price calculation of the competitors:

- Doesburg exploits its own barge service with a Class IV vessel. The sailing costs are calculated for a Class IV barges with a utilization rate of 90%.
- The terminal in Nijmegen is able to handle much larger vessels. For the sailing costs it is assumed that a Class VIa barge with a utilization rate of 80% can be used.
- The handling costs are assumed to be 40 $€/\text{move}$ for the terminal in Nijmegen and 50 $€/\text{move}$ in Doesburg. The terminal in Nijmegen d operates on a larger scale. The terminal has more efficient handling equipment available at a higher occupancy rate. Hence, the handling costs are considered to be lower at the terminal in Nijmegen.
- It is assumed that a truck with container chassis carries just one container per trip, either a 20ft or a 40ft unit.

Table 5-7. Best prices by competitive transport modes for a roundtrip between Rotterdam and considered destinations. Source: own calculations

Competitive transport mode	Cost item	Destination							
		Zutphen		**Deventer**		**Lochem**		**Apeldoorn**	
		20ft	40ft	20ft	40ft	20ft	40ft	20ft	40ft
Intermodal IWT via BCTN Nijmegen	Sailing	45	90	45	90	45	90	45	90
	Handling	80	80	80	80	80	80	80	80
	Pre- and end-haulage	158	158	163	163	186	186	135	135
	Total	**283**	**328**	**288**	**333**	311	**356**	**260**	**305**
Intermodal IWT Via Rotra Doesburg	Sailing	83	166	83	166	83	166	83	166
	Handling	100	100	100	100	100	100	100	100
	Pre- and end-haulage	104	104	131	131	127	127	108	108
	Total	287	370	314	397	**310**	393	291	374
Unimodal road transport	Truck	460	460	445	445	496	496	413	413
Best price competitors		**283**	**328**	**288**	**333**	**310**	**356**	**260**	**305**

All units in € per container. The most competitive prices are shown in bold text.
Note: All costs are based on a roundtrip between Rotterdam and the considered destination.

From the results it can be seen that based on transport costs, intermodal IWT via Nijmegen is the most competitive transport mode. Despite the high costs for pre- and end-haulage, the large scale of operations result in such low sailing and handling costs that it enables Nijmegen to offer the most competitive integral transport price. In addition, it can be seen that unimodal road transport involves the highest costs. As a consequence, unimodal road transport is not considered as a main competitor when looking at the transport costs.

5.1.4.3 *Available margins for sailing and handling tariffs*

The terminal operator in Zutphen has to challenge the most competitive prices that were shown in Table 5-7, otherwise no shippers can be attracted. The cost for pre- and end-haulage is assumed to be fixed and therefore does not provide room to set competitive rates. As a consequence, the cost competitiveness of the intermodal IWT chain has to be created by setting competitive tariffs for sailing and terminal handling. The maximum available margins to set these tariffs can be determined by subtracting the fixed costs reserved for pre- and end-haulage from the best price of the competitors, as is shown in Table 5-8.

Table 5-8. Available margins for sailing + handling tariffs per roundtrip between Rotterdam and Zutphen. Source: own calculations

	Destination							
	Zutphen		Deventer		Lochem		Apeldoorn	
	20ft	40ft	20ft	40ft	20ft	40ft	20ft	40ft
Best price competitors	*283*	*328*	*288*	*333*	*310*	*356*	*260*	*305*
Reserved for pre- and end-haulage	48	48	77	77	91	91	100	100
Maximum available margin for sailing + handling tariffs	**235**	**280**	**211**	**256**	**219**	**265**	**160**	**205**

All units in € per container.

The above presented available margins for the tariffs are expressed in € per container. These have to be divided in separate tariffs for sailing and handling, expressed in $€/\mathrm{TEU}$ and $€/\mathrm{move}$ respectively. With these selected tariffs, the total price for intermodal IWT transport via Zutphen for 20ft (1 TEU) and 40ft (2 TEU) containers can be set. In order to attract cargo, the tariffs have to be set even lower than these maximum available tariffs, because the framework conditions from Table 4-1 reveal that most shippers are only willing to make a modal change if cost savings can be realized. From the resulting share of the potential cargo volumes are likely to be captured, the revenues can now be determined.

Table 5-8 shows that the available margins for destination Apeldoorn are limited, because the competitors' lowest rate for transport towards Apeldoorn is very sharp and the pre- and end-haulage costs from Zutphen to Apeldoorn are relatively high. The latter is due to the inefficient road connection, since the Oude IJsselbrug crossing the IJssel River cannot be accessed by trucks requiring to make a detour via Deventer.

Sailing costs for different available cargo volumes

The sailing costs depend on the used barge class and loading degree. Lower unit costs can be obtained for a larger barge class with high loading degree, but this can only be realized under the condition that these higher cargo volumes are available to load the vessels. Table 5-9 presents the sailing costs for a roundtrip between Rotterdam and Zutphen for various barge classes at different loading degrees. Also the corresponding required cargo volumes per roundtrip and the draught are denoted. It can be seen that for high available cargo volumes, the sailing costs can go down significantly. The draught is of importance, because the water depths on the waterway towards Zutphen can be very shallow. A draught limitation of 2.30m was found with a probability of non-exceedance of 10% for an average year (see

Appendix D). Although not included in the sailing costs below, it is assumed that for barges with a greater draught than 2.30m additional sailing costs have to be taken into account.

Table 5-9. Sailing costs per container for different barge sizes at different loading degrees with corresponding draught. Source: own calculations

CEMT Class	**Capacity**		**Utilization rate**									
			100%		90%		80%		70%		60%	
			20ft	40ft	20ft	40ft	20ft	40ft	20ft	40ft	20ft	40ft
Neokemp	32 TEU	Sailing costs	€145	€290	€161	€322	€181	€362	€207	€414	€241	€482
		TEU required per roundtrip	32 TEU		29 TEU		26 TEU		22 TEU		19 TEU	
		Draught*	2.11 m		N/A		N/A		N/A		N/A	
Class IV	90 TEU	Sailing costs	€76	€152	€84	€168	€95	€190	€108	€215	€126	€252
		TEU required per roundtrip	90 TEU		81 TEU		72 TEU		63 TEU		54 TEU	
		Draught*	2.52 m		2.37 m		2.20 m		2.04 m		1.88 m	
Class Va	156 TEU (on 3 layers)	Sailing costs	€62	€124	€69	€138	€78	€156	€89	€178	€104	€208
		TEU required per roundtrip	156 TEU		140 TEU		125 TEU		109 TEU		94 TEU	
		Draught*	2.80 m		2.61 m		2.43 m		2.23 m		2.05 m	

*) Draught of the barges corresponds to an average load of 14 ton/TEU

When comparing the maximum available margins (Table 5-8) and the sailing costs it appears that for 20ft containers a competitive intermodal IWT service can be realized for most barge classes. Unfortunately, the 20ft containers only represent a minor part of the total cargo volumes. The competition for 40ft containers is fierce, and requires considerable cargo volumes in order to drive down the sailing costs.

The sailing costs form together with the handling costs the total operational costs. A viable barge service can only be initiated if the tariffs are set at such a rate that the total transport price is lower than the competitors' best price, triggering shippers to make a modal change. The resulting revenues have to outweigh the total operational costs and initial investments over the duration of the project. The available cargo volumes that are attracted need to be at a satisfactory scale, such that an adequate large barge size and utilization rate is obtained, to reduce the sailing costs. This will be examined in in the feasibility assessment in chapter 6.

5.1.5 Conclusion: Expected cargo volumes for the terminal design

After conducting several analyses, an answer can be given to sub question 6: "*What are the expected cargo volumes that can be captured by an inland container terminal in Zutphen?*

The above analyses demonstrate that determining the expected cargo volumes is complex and depends on several factors. First the area was explored to identify potential customers and competitive transport modes. The major cities with industrial areas within a 20km range of Zutphen are Apeldoorn, Deventer and Lochem, and are considered to comprise the service area. The competitive transport modes were found to be intermodal IWT via the terminals in Nijmegen and Doesburg.

The cargo assessment pointed out that no launching customer being able to deliver the cargo volumes that are required to initiate terminal operations could be found in Zutphen, The total available cargo volumes in Zutphen are limited and from interviews it became clear that no commitment could be given beforehand by the shippers. Further along in the service area, the total potential cargo volumes were found to be approximately 31,000 TEU/year, of which most cargo volumes were identified in Apeldoorn. The share of these potential cargo volumes that can be captured depends on the offered transport tariffs and service level. Only if this satisfies the shipper's preferred service attributes, cargo can be attracted.

The analysis of the cost competitiveness showed that other transport modes are able to offer very competitive prices; hence the available margins to initiate a profitable barge service and terminal operations are limited. The poor road connection towards Apeldoorn induces high costs for pre- and end-haulage by truck, which complicates Zutphen to offer competitive transport tariffs to attract potential shippers from Apeldoorn. As a result, it can be concluded that the expected cargo volumes to be captured are restricted to a small share of the total identified potential cargo volumes of 31,000 TEU/year.

Design criteria for the terminal
Based on the expected cargo volumes, it becomes clear that Zutphen has to aim for a low-cost and low-profile terminal. To develop such a low-cost terminal, solutions should be considered that make use of existing facilities and infrastructure. The required investments for the development of a terminal at location Fort de Pol are considered to be too high to be viable. Therefore, as a location, only the industrial harbour will be taken into consideration for the development of terminal solutions.

To limit the investment costs, the existing facilities in the industrial harbour should be used where possible for the development of the terminal solutions. Other measures to reduce the initial investments can be taken by using second hand equipment or offer little supportive services at the terminal. The latter may affect the shippers' modal choice, dependent on their preferred service attributes.

5.2 Technical design and cost estimates of proposed terminal solutions

Based on the design criteria mentioned above, three technical designs were worked out for the industrial harbour. These alternatives were already introduced briefly in chapter 2. Here the technical specifications will be given that are necessary to estimate the required investment cost and operational expenditures for each terminal solution. First a brief introduction will be given into the used norms, guidelines and general boundary conditions that apply to all three alternatives.

Norms and guidelines
The following norms and guidelines were followed for the design of the three proposed terminal solutions:

- CUR 166: Dutch design guideline for sheet pile structures (CUR, 2005)
- NEN 9997-1: Dutch design standard for geotechnical design of structures (NEN, 2012)
- RVW 2011: Dutch waterway guidelines (Rijkswaterstaat, 2011)
- EAU 2012: German guidelines for ports and waterways (EAU, 2012)

Design water levels

- The bottom level in the industrial harbour was found to be equal to the bottom level in the IJssel River (both at NAP 0.0m), given the assumption that the industrial harbour is dredged for maintenance. In the analysis of the water levels (refer to Appendix D) it was concluded that based on experiences of the local harbour master and reports of the recently constructed Noorderhaven marina in Zutphen (Witteveen+Bos, 2012), the water level in the IJssel River at measurement point Zutphen Noord (close to the mouth of the industrial harbour) is considered to be equal to the water level in the industrial harbour.
- The same analysis shows that the water levels exceed the OLR value of 2.76m for 95% of the time. This does not limit the maximum draught (2.5m) of a fully loaded Class IV vessel for the average tonnages per container that were identified (14ton/TEU). As a result, besides maintenance dredging, the industrial harbour does not require capital dredging in order to facilitate the mooring of a fully loaded container barge.

- The industrial harbour is part of dike-ring 50, a primary flood defence system, where the norm prescribes an exceedance probability of 1/1250 per year. The corresponding design of the quay is prescribed to a retaining height of NAP +9.15m.
- The lowest recorded water level in the industrial harbour since 1990 is NAP +2.06m. This is considered the governing low water level for the design of the quay.
- The highest recorded water levels in the IJssel River for which no obstruction for inland navigation occurs is considered to be equal to the water level corresponding to the yearly exceedance probability of NAP +7.20m. This water level is considered the governing high water level during terminal operations.
- The water levels variations during governing situations require a terminal crane with a reach of at least 15m, which excludes (un)loading of the barges with a reachstacker.

Loads

The following loads were taken into account for the terminal design. For a specification of these values is referred to Appendix F.

- For container movements in the stack, a reachstacker is preferred over the use of a forklift truck, because a reachstacker is more efficient in use of space. A reachstacker with a lift capacity of 42 ton is taken into account. The governing load was found to be a wheel load of 790 kN/m^2.
- For the mobile crane, two governing load situations can be distinguished: during lifting operations and during repositioning of the crane. A mobile crane with a lifting capacity of 42 ton was considered in the design. During terminal operations, the dynamic load on the outrigger pads induces a force of 1080kN. Dependent on the size of the outrigger pads, this load is transferred onto the quay. A governing wheel load of 129kN was calculated as a result of repositioning of the mobile crane, which corresponds with a contact area of 0.09m^2 and after applying a reduction factor to a wheel pressure of 142 kN/m^2.
- The stacking area has to be able to withstand a uniform load of 40kN/m^2 for the stacking of 3 layers of containers.
- Following the waterway guidelines of Rijkswaterstaat “Richtlijn Vaarwegen” (RVW 2011), the bollard forces for barges are considered to be 200kN for CEMT Class IV barges and 250 kN for CEMT Class Va barges.

Soil parameters

At several locations at the dike-ring around Zutphen, cone penetration tests (CPTs) were performed (Grontmij, 2003). Based on these CPTs, a representation of the soil profiles can be determined. 4 CPTs were performed at the industrial harbour (see Appendix F), where the soil appeared to be fairly consistent. By interpreting the CPTs using the representative values according to table 7.1 of CUR166 and following the Grontmij-report, the following soil material properties are determined:

Table 5-10. Representative soil material properties at the industrial harbour

Soil type	Upper level [m +NAP]	Volume weight γ/γ_{sat} [kN/m^3]	Angle of repose φ [º]	Cohesion c′ [kPa]
Sandy clay	9.15	17.7/19	25.2	0.9
Sand	8.5	18/19	30	0
Clay	7.0	18.1/18.7	25.6	3.2
Sand	6.3	18/19	30	0
Silty sand	4.3	17.7/19	25.2	0.9
Sand	3.5	18/19	30	0

Second-hand equipment

To limit the initial investments for the terminal solutions, it will be considered to use second-hand instead of new terminal equipment, such as a mobile crane for lifting operations and reachstacker to work in stack.

5.2.1 Alternative 1: Mobile crane at existing quay

5.2.1.1 *Description of terminal solution*

This terminal solution was developed to limit the initial investments as much as possible by reusing the existing facilities in the industrial harbour. The existing quay in the industrial harbour is used for loading and unloading of barges and the terrain indicated Figure 5-2 as stacking area. The assumption is made that this terrain, private property of Daly Plastics BV and leased to Schrijver BV becomes available for development of terminal activities.

The design largely corresponds to the terminal initiative of 2002 that went out of business. The main advantage is that now a much lower level of investments is required. Disadvantage is that as a maximum size Class IV barges can be handled. Furthermore the quay is accessible to the public, which requires security measures to guarantee safe operations. A reassessment for 2017 conditions will make clear if a viable business case can be found.

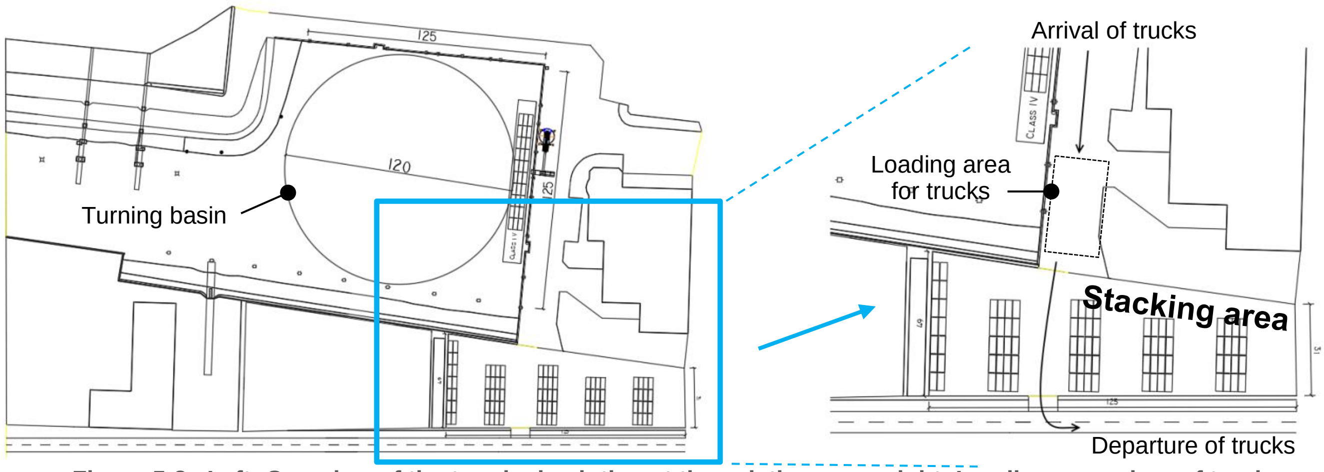


Figure 5-2. Left: Overview of the terminal solution at the existing quay, right: Loading procedure of trucks

5.2.1.2 *Description of logistics*

The length of the quay measures 125m and the diameter of the turning basin is 120m. RVW2011 prescribes a turning basin of 1.2 times the vessel length, which allows safe manoeuvring of a vessel with a maximum length of 100m, hence it is assumed that a Class IV is maximum vessel size that can be handled at the quay.

A mobile crane is placed on the quay for the handling of containers, from where a reachstacker move the containers to the stack. The stacking area can be accessed from the road south of the terminal and via the public quay at the industrial harbour. The width of the industrial harbour is on average 15 m. A road tractor with container chassis with a combined length of 15m requires a turning radius of 9.70m (see Appendix F), hence the width is insufficient for turning. Although not ideal, it is assumed that the arrival and loading of the trucks takes place at the public quay of the industrial harbour, after which the truck crosses the stacking area to leave the terminal via the southern road.

5.2.1.3 *Stability check of structure*

At the time of the previous container terminal, the quay and stack were strengthened to withstand the load of a mobile crane and reachstacker. The structural properties of the quay were calculated by Fugro (1998) for several load combinations, including terminal activities with a mobile crane and reachstacker. In 2013 a recalculation was carried out by Van Roekel & Van Roekel (2013) for similar load combinations with a mobile crane and reachstacker. These calculations were checked by the author and conclude that minor structural adjustments to the anchors are required to satisfy the norms according to CUR166. This will be discussed below. The existing quay consists of the following structural properties:

Hoesch 175 Sheet pile	
- Steel quality	S240
- Top level	NAP +9.15 m
- Bottom level	NAP -4.5 m
Ø45 Anchor rods	
- Steel quality	S355
- Anchor level	NAP +6.5 m (2.65 m below ground level)
- Angle	0 degrees
- c.t.c. distance	1.05m
Hoesch 95 Anchor wall	
- Top level	NAP +8.2 m
- Bottom level	NAP +4.2 m

Fugro calculation report

The Fugro-report calculated for several load combinations the effects on the quay wall. The wheel load of the reachstacker was found to be governing as is presented in Table 5-11. The bottom level of the industrial harbour was considered to be located at NAP 0.0m in these calculations.

Table 5-11. Load combinations at industrial harbour with corresponding maximum Moment, Anchor force and displacement. Source: Fugro (1998)

Situation	Description load situation	Moment [kNm]	Displacement [mm]	Anchor force [kN]
1	Mobile crane situation A	260	-31	161
2	Mobile crane situation B	260	-33	162
3	Repositioning of mobile crane	263	-34	192
4	Reachstacker at 1.0m from quay	165	-26	**302**
5	Reachstacker at 2.5m from quay	**266**	**-34**	204

Water level NAP +3.5m for all load situations

Unity check of sheet pile and anchor

The maximum moment in the UGT of the governing loading combination is 266kNm/m'. The moment capacity of the used Hoesch 175 sheet pile with steel quality S240 has a moment capacity of 611 kNm/m'. A reduction factor of 0.90 is applied for corrosion, leading to a corrected moment capacity of 549.9 kNm/m'. The resulting unity check is 0.48.

Following CUR166, the maximum allowable displacement is 1/100 of the retaining height (=91.5mm) or 50mm, of which the latter is governing. The maximum displacement in the SLS is 34 mm. This leads to a unity check of 0.68. As a result, it can be concluded that the Hoesch 175 sheet pile meets the requirement.

The governing anchor force $F_{a,max}$ = 302 kN/m'. The anchorage is placed at a c.t.c. distance of 1.05m, leading to an anchor force $F_{a,max}$ = 317.1 kN per anchor. The allowable anchor force was determined by Fugro to be 375 kN per anchor, hence the anchors suffice.

Van Roekel & Van Roekel recalculation report

A recalculation was performed by Van Roekel & Van Roekel. Similar load situations as in the Fugro-report were considered, but this time three different water levels were considered as can be seen in Table 5-12. For each load situation also a horizontal bollard force of 100kN was taken into account. Different from the Fugro calculations, this report assumes the bottom level of the industrial harbour to be located at NAP -0.5m. As can be noted in the table, this has a considerable effect on the maximum moments, displacements and anchor forces.

Table 5-12. Calculated load combinations with corresponding maximum moment, displacement and anchor force. Source: Van Roekel & Van Roekel (2013)

Situation	Description load situation	Moment [kNm]	Displacement [mm]	Anchor force [kN]
1	A: Outrigger pads crane load [1]	302.8	-20.4	304.2
2	B: Reachstacker wheel load [1]	314.5	-21.5	336.4
3	High water level: load situation A [2]	322.3	-22.1	332.3
4	High water level: load situation B [2]	326.6	-22.6	349.6
5	Low water level: load situation A [3]	338.4	-24.6	344.0
6	Low water level: load situation B [3]	**340.3**	**-24.8**	**358.1**

[1]) Water level NAP +4.5m; [2]) Water level NAP +6.5m; [3]) Water level NAP +3.5m

The occurring maximum moment in the UGT of 340.3 kNm/m' leads to a unity check of 340.3 kNm/m' / 549.9 kNm/m' = 0.62. The maximum displacement of 24.8mm leads to a unity check of 24.8mm / 50mm = 0.50. As a result, the sheet pile is verified.

The governing anchor force $F_{a,max}$ = 358.1 kN/m' corresponds to $F_{a,max}$ = 376.0 kN per anchor. The allowable anchor force was determined to be 375 kN per anchor, hence the anchors do **not satisfy** the CUR166 criterion. Following the calculations by Van Roekel & Van Roekel, the anchors need to be reinforced to meet the norm.

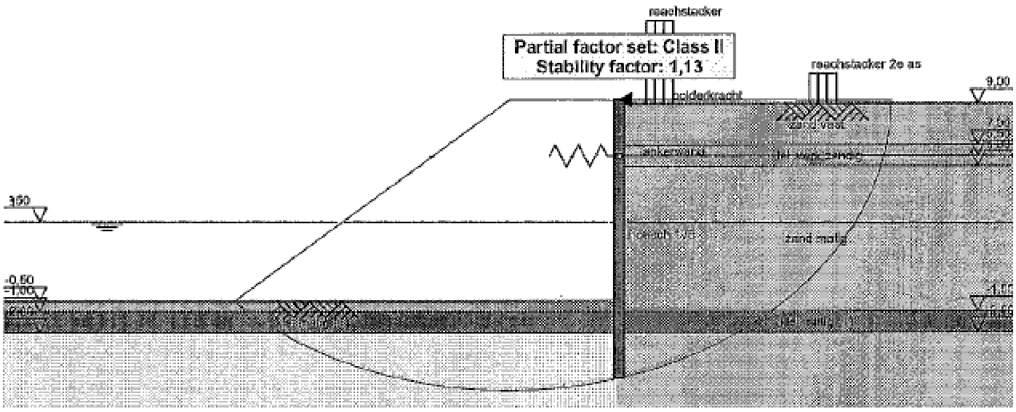


Figure 5-3. Governing load situation in recalculation: reachstacker wheel load during low water level (NAP +3.5m). Source: Van Roekel & Van Roekel (2013)

Remarks

The governing low water level was assumed to be NAP +3.5m in both the Fugro- and Van Roekel & Van Roekel-reports. However, in the analysis of water level variations (Appendix D) it was shown that the OLR water level of NAP +2.76m has an undershooting frequency 5%, which is expected to negatively affect the forces to the quay. It is advised to consider a more conservative governing low water level, by using the lowest recorded water level since 1990 of NAP +2.06m. It is expected that the maximum anchor force will increase as a result of the lowering of the water level, which requires strengthening of the anchor rods.

Conclusion

Several load combinations were calculated in the reports of Fugro and Van Roekel & Van Roekel to determine the maximum moments, deformations and anchor forces occurring at the existing quay. The assumptions in both reports were largely in line with each other, but some differences between assumptions were found as well. Most noteworthy are differences in the assumed bottom level of the industrial harbour. Whether the bottom level is located at NAP 0.0m following the Fugro-report or at NAP -0.5m following the Van Roekel & Van Roekel-report, makes a significant difference resulting forces and deformations. The author follows the latter as most conservative assumption for the preliminary design phase. This has to be verified by an accurate survey of the bottom profile for further design stages.

For the governing load situation; the wheel load of a reach stacker during a low water situation, the sheet pile suffices, but the anchors do not. This implies that the anchor rods require a strengthening to withstand a higher anchor force. The bollards at the quay must be able to transfer a horizontal load of 200kN. In the Fugro-report, no calculations were found regarding these forces. The Van Roekel & Van Roekel-report included a horizontal force of 100kN in their calculation. The additional 100kN is expected to be fully transferred to the anchors. Therefore it is advised to strengthen the anchors rods. Dywidag Ø40 anchor rods, steel grade 950/1050 N/mm^2 are assumed as a first estimate to do the job. The design capacity of these anchor rods is 940kN, which should be sufficient to withstand the additional anchor force occurring at lower water levels and the additional bollard force of 100kN.

5.2.1.4 *Cost estimate: mobile crane at existing quay*

From the existing calculations it can be concluded that the sheet pile of the existing quay is verified to withstand the loads of the mobile crane and the reachstacker. The anchors however, should be reinforced to withstand the wheel load of the reachstacker during a governing low water situation, as well as horizontal bollard forces. In the cost calculation, a reservation for an upgrade of the anchors is included. With a reservation for the proposed Dywidag Ø40 anchor rods and new bollards, the investment costs for structure are limited. The largest share of investment costs concerns the purchase of a mobile crane and reachstacker. In the cost calculation it is assumed that second-hand mobile crane can be found, leading to the cost estimate presented in Table 5-13.

The construction costs were calculated and verified by Witteveen+Bos experts, who advised to apply a multiplication factor of 2.5 to the construction costs to obtain a cost estimate for the total required investment costs in the preliminary design stage. This multiplication factor includes engineering costs, property costs and other associated costs such as risk, tax and implementation. The multiplication factor leads to an approximation of the total investment costs within a bandwidth of 30%.

Table 5-13. Cost estimate for the terminal solution 1: mobile crane at existing quay

Description cost item	quantity	unit	unit costs	total costs
Structural upgrade				
Reservation for upgrade anchors [Dywidag Ø40 1.05m c.t.c. Length 17m]	1,700	m	€ 75	€ 127,500
Mooring facilities				
Bollards of 200 kN capacity	8	st	€ 1.250	€ 10,000
Total construction costs				€ 137,500
Multiplication factor defined by cost engineer [incl. cost for execution, engineering, risk, tax]			× 2.5	**€ 343,750**
Handling equipment				
Second-hand mobile crane [i.e. Gottwald HMK 90]	1	st	€ 1,200,000*	€ 1,200,000
Second-hand reachstacker	1	st	€ 300,000	€ 300,000
Total Capital Expenditures				**€ 1,843,750**

*) Source: Estimate based on consultation Witteveen+Bos expert

5.2.2 Alternative 2: Crane vessel

5.2.2.1 *Description of terminal solution*

For this alternative no terminal is realized, but instead a crane vessel, such as the MCKS Mercurius of the Mercurius Shipping Group will be used for the handling of containers at the existing quay in the industrial harbour. The crane vessel is able to load directly onto the truck as shown in Figure 5-4: Right. According to Mercurius Shipping Group, no reachstacker or mobile crane is required for the movement of containers on the condition of tightly scheduled loading and unloading times. This is different from regular terminal operations, where the container is handled onto the quay where it is picked up by a reachstacker to load the truck.

Due to the absence of heavy loading equipment on the quay, the anchor rods do not require an upgrade as is the case for alternative 1. The bollards have to be checked to withstand the horizontal forces. This is considered to be a limited investment and is therefore ignored in the preliminary design. The advantage of this alternative is that no initial investment is required. The costs are therefore restricted to the rent of the crane barge. Operation of this vessel induces higher operational costs than a regular barge, as will be discussed later on.

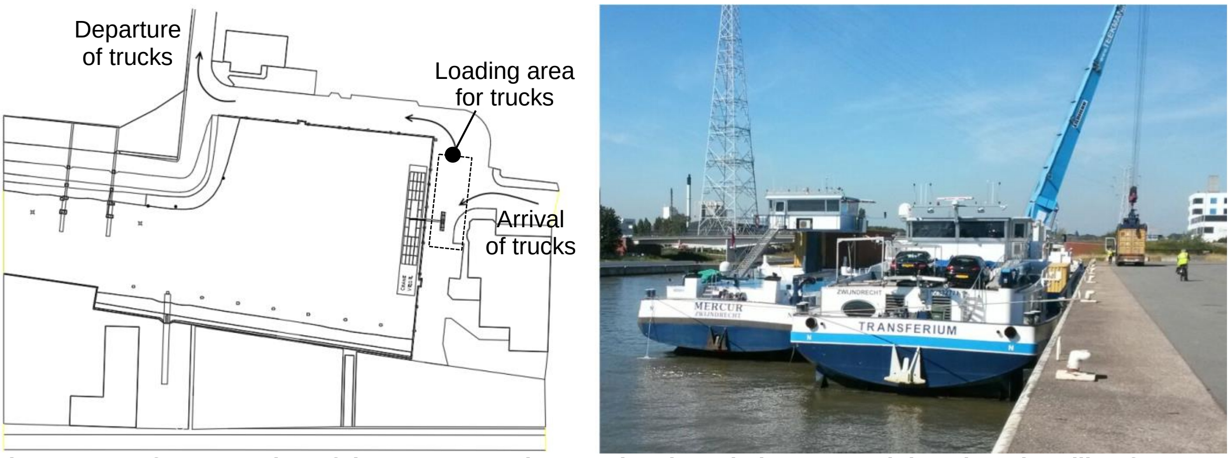


Figure 5-4. Left: Impression of the crane vessel moored at the existing quay. Right: Direct handling from crane vessel onto the truck. Source: Mercurius Shipping Group (n.d).

5.2.2.2 *Description of loading procedure and logistics*

The turning basin allows vessels up to a length of 100m to manoeuvre safely; hence the crane vessel is with its length of 86 m able to access the industrial harbour. The lifting capacity of the crane is sufficient at the required reach for container handling onto the quay, also during a governing low water situation.

Table 5-14. Properties of the Mercurius crane vessel. Source: Mercurius Shipping Group (n.d.)

Dimensions	Max. capacity	Sailing speed	Crane capacity	Handling speed
86*11.55 m	96 TEU on 3 layers	15 $\mathrm{km/h}$	35 ton at 23m reach	20 $\mathrm{moves/hour}$

In order to successfully realize transhipment of containers from the crane vessel onto the truck without using terminal equipment on the quay for an additional move, it is essential that a tight logistic schedule is followed. Dependent on the skills of the crane operator, the handling speed can go up to approximately 20 moves per hour. A handling speed of 15 $\mathrm{moves/hour}$ is taken into account by the author. It is assumed that each truck requires 2 moves per container: one for loading and one for unloading. In order to load and unload a fully loaded crane barge of 96 TEU with TEU-factor of 1.67, 115 moves are required. This corresponds to approximately 8 hours of handling operations. To prevent a long queue of trucks, a schedule with reserved pick-up times for each truck has to be made, that allows 7 trucks per hour at maximum.

The sailing schedule has to be organized such that it complies with the planning of the transhipment from the crane vessel to the truck. The crane vessel has to be moored at the existing quay for at least 8 hours, but several hours of margin is preferred. The sailing speed of the crane vessel is specified to be 15 $\mathrm{km/h}$. When taking into account 2 hours of waiting time for locks and bridges, the time for a single trip between Rotterdam and Zutphen results in 15.5 hours. For loading and unloading at several terminals in the Port of Rotterdam, 24 hours is considered. With the required sailing time and handling time at the terminal, a maximum of 2 roundtrips per week can be carried out between Rotterdam and Zutphen. Table 5-15 depicts the sailing schedule as proposed by the author, where 12 hours were taken into account for transhipment at the industrial harbour.

Table 5-15. Proposed sailing schedule for the crane vessel on route Rotterdam - Zutphen

Departure Rotterdam	**Time**	**Arrival Zutphen**	**Time**	**Departure Zutphen**	**Time**	**Arrival Rotterdam**	**Time**
Monday	15.30	Tuesday	7.00	Tuesday	19.00	Wednesday	10.30
Thursday	15.30	Friday	7.00	Friday	19.00	Saturday	10.30

5.2.2.3 *Cost estimate: crane vessel*

In case of the crane barge, all container handlings are carried out with the on-board crane. Since no terminal equipment on the quay is required, the handling costs are included in the barge costs and no initial investment has to be made. On the downside, the operational costs of the crane vessel are higher than regular barges. The on-board crane takes up space and its weight causes additional draught, hence more drag resistance. As a result the fixed costs and fuel costs are higher than for regular container barges, which induce higher unit costs.

The costs are determined based the above presented sailing schedule with 2 roundtrips per week, where a continuous barge service is used. For a given utilization rate, the costs for sailing + handling are calculated per roundtrip as shown in Table 5-16. These costs can be considered as the operational expenditures. The corresponding cargo volumes that are required per roundtrip and draught are denoted as well to obtain thee considered loading degree. As mentioned earlier on, a draught limitation of 2.30m was found with a probability of non-exceedance of 10% for an average year (Appendix D). For the crane barge it can be seen that considering the identified average container weight of 14 $\mathrm{ton/TEU}$, the draught will be limited for a utilization rate higher than 70%. This will induce additional sailing costs during limited water depth events.

Table 5-16. Costs per roundtrip for sailing + handling with crane vessel on route Rotterdam - Zutphen for different loading degrees.

	Utilization rate									
	100%		90%		80%		70%		60%	
	20ft	40ft	20ft	40ft	20ft	40ft	20ft	40ft	20ft	40ft
Costs for sailing + handling	€180	€356	€199	€395	€224	€444	€255	€506	€297	€590
TEU required per roundtrip	96 TEU		86 TEU		76 TEU		66 TEU		57 TEU	
Draught*	2.66 m		2.52 m		2.36		2.21		2.09 m	

*) Draught of the barges corresponds to an average load of 14 ton/TEU

5.2.3 Alternative 3: Cofferdam at embankment

5.2.3.1 *Description of terminal solution*

The third alternative comprises a terminal solution that is located along the existing embankment in the industrial harbour, where 8 mooring posts are already present. For this alternative, a new terminal has to be constructed at the embankment as indicated in Figure 5-5. The design exists of two parts: a cofferdam and a stacking area.

At the embankment a sheet pile cofferdam will be constructed, reaching up to the existing mooring posts, where the vessels are able to moor. On top of the cofferdam, a crane is placed in fixed position for the transhipment of containers from the barge to the quay. Due to the existing mooring function along the mooring posts, scour protection is already present and the existing bottom level provides sufficient draught for the barges. As a consequence, besides regular maintenance dredging, no structural adjustments are required in the industrial harbour. The terrain behind the cofferdam is designated as stacking area. The embankment needs to be strengthened over the full length of 100 m with anchored sheet pile walls to withstand the wheel load of a reachstacker and uniform load of containers. An overview is presented in Figure 5-5 and an impression of the cross section in Figure 5-6.

The advantages of this terminal solution are that larger Class Va vessels can be handled and that the terrain is private, hence not accessible by the public. Disadvantage is the higher initial investment costs that are required.

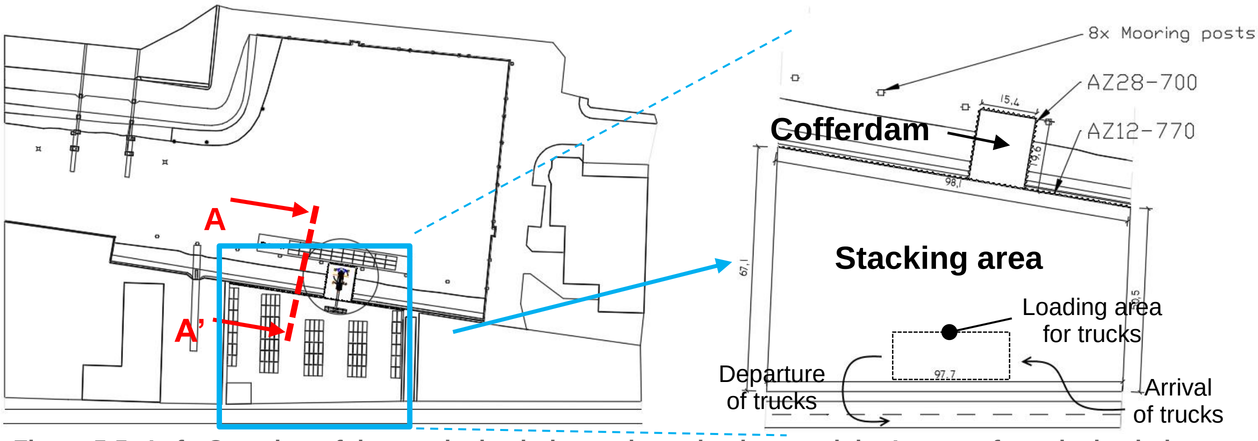


Figure 5-5. Left: Overview of the terminal solution at the embankment, right: Layout of terminal solution at embankment

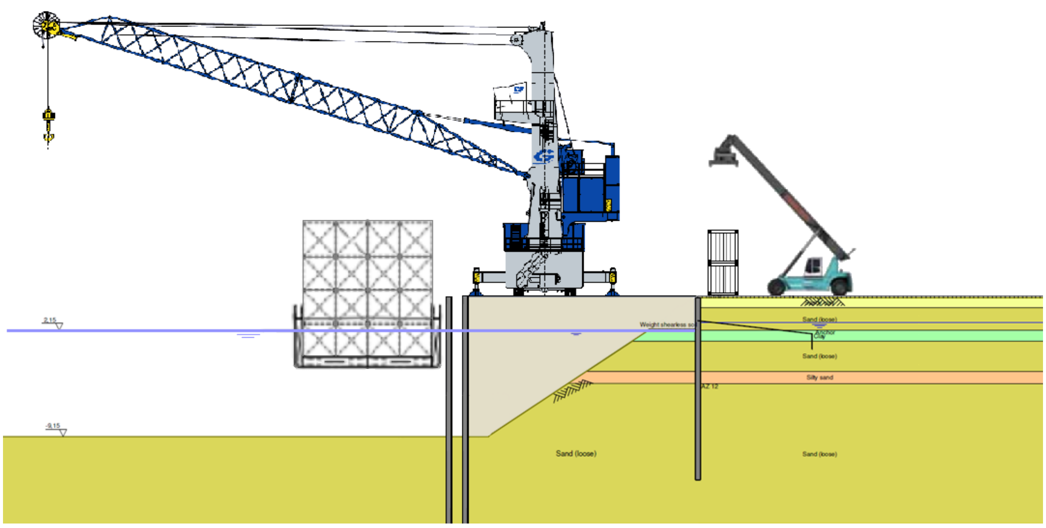


Figure 5-6. Impression of the cofferdam at the embankment. Cross section A-A' in Figure 5-5.

5.2.3.2 *Description of logistics*

The accessibility by larger vessels is checked by the RVW2011 guidelines. The embankment is located parallel to the entrance from the IJssel River to the industrial harbour. RVW2011 prescribes that for harbour basins located at a waterway with less than 30,000 passing cargo vessel per year, the main waterway may be used for turning of the vessels. The NIS database from Rijkswaterstaat showed for the past 5 years a maximum of 12,000 annual passing vessels at the Eefde Locks in the Twentekanaal. It is assumed that this number corresponds to the order of magnitude of passing vessels at the IJssel River along Zutphen, hence it is concluded that the larger Class Va vessels can safely access the terminal. For departure, the barges sail out backwards onto the IJssel River where the turning manoeuvre takes place, to return their journey to Rotterdam.

The stacking area can be accessed by trucks from the road south of the terminal. The length of the terminal provides sufficient space for a road tractor with container chassis to access the stacking area in longitudinal direction. The truck is (un)loaded by the reachstacker at the stacking area, after which it departs onto the same road as indicated in Figure 5-5: Right.

5.2.3.3 *Preliminary design*

Anchored sheet pile structure

The design of both the cofferdam and the stacking area consists of an anchored sheet pile structure. A tie rod anchor with anchor wall is applied, as illustrated in Figure 5-7. The main components of the design are calculated and verified following the design norms in order to make an estimate of the required investments for this terminal solution. The calculations were performed using software package D-Sheet Piling version 15.1 (Deltares, 2016). The stability was calculated following the Ultimate Limit State (ULS) and the displacements for the Serviceability Limit State (SLS). The calculation results are presented in Appendix F.

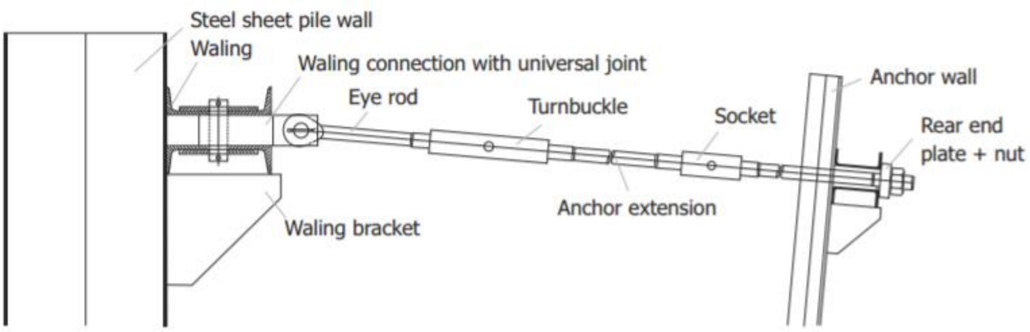


Figure 5-7. Elements of an anchored sheet pile structure

5.2.3.3.1 Cofferdam

The cofferdam covers a total length of 55 m, as illustrated in Figure 5-5. A sand fill needs to be applied on top of the existing embankment up to NAP +9.15m, comprising 1500m^3. The design is checked for several load combinations. The governing load combination was found when the maximum load at the outrigger pads of the mobile crane occurred during the normative low water level, as illustrated in Figure 5-8.

The following structural elements are used in the design:

AZ28-700 Sheet pile

- Steel quality	S240
- Top level	NAP +9.15 m
- Bottom level	NAP -5.85 m

Ø40 Dywidag Anchor rods	
- Steel grade	950/1050 N/mm2 (yield/ultimate)
- Anchor level	NAP +6.35 m [2.80 m below ground level]
- Angle	0 degrees
- c.t.c. distance	1.40 m
AZ12-700 Anchor wall	
- Top level	NAP +6.35 m
- Bottom level	NAP +4.35 m
Waling 2x UNP 220 profile	
- Steel quality	S235

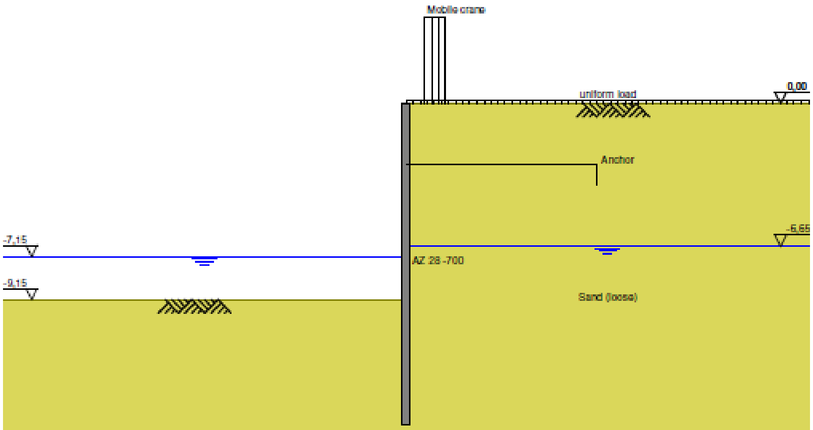


Figure 5-8. The governing load combination at the cofferdam: Maximum load at outrigger pads of mobile crane during governing low water situation.

Verification sheet pile

The maximum occurred moment in the UGT is found to be 232.1kNm/m'. The used sheet pile AZ28-700 with steel quality S240 has a moment capacity of 662kNm/m', leading to a unity check 662kNm/m' / 232.1kNm/m'=0.35.

Following CUR166, the maximum allowable displacement is 1/100 of the retaining height (=91.5mm) or 50mm, of which the latter is governing. The maximum displacement in the SLS is 30.9 mm. This leads to a unity check of 30.9mm / 50mm = 0.62. The selected sheet pile profile satisfies the requirements.

Verification anchors

The calculation shows a governing anchor force $F_{a,max}$ = 477.2 kN/m'. For the applied AZ28-700 sheet pile, the anchorage is placed at a c.t.c. distance of 1.4m, leading to a force $F_{a,max}$ = 668.1 kN per anchor. Following CUR 166, the anchor rod has to be designed to withstand a force $F_{a,max;d}$ = 1.25 * $F_{a,max}$ = 835.1 kN. The ultimate strength of the used Ø40 Dywidag rods (1050 N/mm^2) is able to withstand an anchor force of 1320kN, which corresponds according to CUR 166 to a design capacity of 940 kN. This leads to a unity check of 0.89.

According to CUR 166, the allowable force of the anchor wall needs to exceed 1.5 * $F_{a,max}$ = 715.8kN. The calculation shows an allowable anchor force of 904.2kN, leading to a unity check of 715.8kN / 904.2kN = 0.79. The applied anchor suffices.

The waling has to withstand the maximum design anchor force following CUR 166: $F_{a,max;d}$ = 1.1 * $F_{a,max}$ = 1.1 * 668.1 kN = 734.9 kN, and the corresponding bending moment for steel walings (EAU, 2012): $M_{w;d}$ = 1/10 * $F_{a,max;d}$ * 1.4 m = 102.9 kNm. For steel quality S235, a $W_{el,y}$ of 437.8*10^3 mm^3 is required, for which 2 UNP 220 profiles suffice.

5.2.3.3.2 Stacking area

The existing terrain in front of the embankment has to be reinforced with sheet piles over a length of 98.1m to withstand the governing load combination. The governing load combination includes a uniform load of 40 kN/m^2 for the static load of 3 layers of loaded containers and the wheel load of a reachstacker of 790 kN/m^2 during the governing high water level. The embankment will remain unaltered, due the beneficial passive soil pressure for the stability. The following structural elements are applied:

AZ12-770 Sheet pile	
- Steel quality	S240
- Top level	NAP +9.15 m
- Bottom level	NAP -2.85 m
Ø40 Dywidag Anchor rods	
- Steel grade	950/1050 N/mm2
- Anchor level	NAP +7.65 m [1.50 m below ground level]
- Angle	5 degrees
- c.t.c. distance	1.44 m
AZ12-770 Anchor wall	
- Top level	NAP +7.52 m
- Bottom level	NAP +5.52 m
Waling 2x UNP220 profile	
- Steel quality	S235

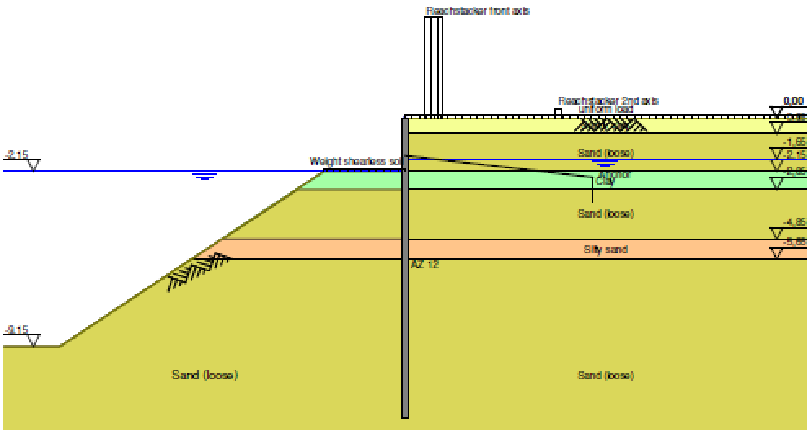


Figure 5-9. Governing load combination for the design of the stacking area

Verification sheet pile

The maximum bending moment in the UGT is found to be 113.0kNm/m'. With the moment capacity of 299kNm/m' of the used sheet pile AZ12-770 with steel quality S240 this leads to a unity check 113kNm/m' / 299kNm/m' = 0.38.

The maximum displacement in the SLS is 25.8mm. The same criterion as for the cofferdam is valid. This leads to a unity check of 25.8mm / 50mm = 0.52. The design of the selected sheet pile profile is verified for stability.

Verification anchor

The maximum anchor force was found in the calculation to be $F_{a,max}$=462.4kN/m', which corresponds to $F_{a,max}$ = 665.9 kN per anchor. Following the CUR 166 criterion, the anchor rod has to withstand $F_{a,max;d}$ = 1.25 * $F_{a,max}$ = 832.3 kN. The used Ø40 Dywidag rod has a design capacity of 940 kN, leading to a unity check of 832.3kN / 940kN = 0.89

The allowable Kranz anchor force was calculated to be 805.8kN. According to CUR166, the anchor wall needs to exceed 1.5 * $F_{a,max}$ = 693.6kN. The resulting unity check is 0.86.

The maximum design anchor force that the waling has to withstand following CUR 166 is: $F_{a,max;d}$ = 1.1 * $F_{a,max}$ = 1.1 * 665.9 kN = 732.5 kN, and the corresponding bending moment: $M_{w;d}$ = 1/10 * $F_{a,max;d}$ * 1.44 m = 105.5 kNm. For steel quality S235, a $W_{el,y}$ of 448.8*10^3 mm^3 is required, for which 2 UNP220 profiles have to be installed.

Remarks

Other types of anchorage have been considered as well. For a larger c.t.c. distance, significantly heavier anchor rods are required, but instead of a continuous anchor wall, separate anchor plates can be applied. At the corners of the cofferdam, it is common that struts are applied instead of anchors. It is assumed that the above dimensioned elements provide an adequate cost estimate for the preliminary design.

5.2.3.4 *Cost estimate: cofferdam at embankment*

The construction costs were calculated for the above mentioned structural elements. The same assumptions for the handling equipment were applied as for alternative 1. This means a second-hand mobile crane was used in the cost estimate. Also these construction costs were calculated and verified by Witteveen+Bos experts. The multiplication factor of 2.5 applied to the construction costs include engineering costs, property costs and other associated costs such as risk, tax and implementation.

Description cost item	**quantity**	**unit**	**unit costs**	**total costs**
Cofferdam				
Sheet pile AZ28-700 [15m deep]	825	m^2	€ 160	€ 132,000
Capping beam (500*800mm)	55	m	€ 350	€ 19,250
Anchor rods Dywidag Ø40 [c.t.c. 1,40m, length 15m]	400	m	€ 75	€ 30,000
Anchor wall AZ12-700 [2m height]	100	m^2	€ 150	€ 15,000
Waling, 2x UNP220	55	m	€ 150	€ 8,250
Soil fill	1,500	m^3	€ 15	€ 22,500
Protection Embankment				
Sheet pile AZ12-770 [12m deep]	1,200	m^2	€ 120	€ 144,000
Capping beam [500*800mm]	100	m	€ 350	€ 35,000
Anchor rods Dywidag Ø40 [c.t.c. 1,44m, length 10m]	700	m	€ 75	€ 52,500
Anchor wall AZ12-770 [2m height]	200	m^2	€ 150	€ 30,000
Waling, 2x UNP220	100	m	€ 150	€ 15,000
Pavement	6,000	m^2	€ 40	€ 240,000
Mooring facilities				
Bollards of 250 kN capacity	4	st	€ 1.500	€ 6,000
Reservation mooring posts			€ 100.000	€ 100,000
Total construction costs				€ 849,500
Multiplication factor defined by cost engineer [incl. cost for execution, engineering, risk, tax]			× 2.5	**€ 2,123,750**
Handling equipment				
Second-hand mobile crane [i.e. Gottwald HMK 90]	1	st	€ 1,200,000	€ 1,200,000
Second-hand reachstacker	1	st	€ 300,000	€ 300,000
Total Capital Expenditures				**€ 3,623,750**

5.3 Overview of three proposed terminal solutions

For convenience, the main characteristics of the three proposed terminal solutions are presented in the table below:

	Alternative 1: Mobile crane at existing quay	**Alternative 2: Crane vessel**	**Alternative 3: Cofferdam at embankment**
Short description	Transhipment of containers at the existing public quay in the industrial harbour. A private terrain is leased as stacking area. Requires purchase of a second-hand mobile crane and reachstacker and a structural upgrade of the anchor rods.	Concession with a crane vessel. The crane barge can moor at the existing quay at the industrial harbour, where the on-board crane is able to (un)load directly on a truck.	Construction of a new terminal along the embankment in the industrial harbour that consists of a cofferdam and a stacking area. Requires purchase of a second-hand crane and reachstacker.
Required investment	€ 1,843,750	€ 0	€ 3,623,750
Maximum barge capacity [TEU/roundtrip]	CEMT Class IV [90 TEU]	Crane vessel [96 TEU]	CEMT Class Va [156 TEU]
Advantages	- Low investment costs	- No investment costs	- Accessible by larger Class Va barges - Private terrain
Disadvantages	- Publicly accessible - Limited accessibility to Class IV barges	- Publicly accessible - High operational expenditures - Loading and unloading only possible 2 days per week following a tight schedule	- High investment costs
Terrain requirements	Requires the availability of the stacking area that is aimed for. The terrain is property of a private party and is currently being leased.	Public quay is available. No terrain required.	Requires the availability of terrain along the embankment for construction of the cofferdam and stack. The terrain belongs to the municipality and is currently being leased.

6

Feasibility assessment of terminal solutions in De Mars

The financial feasibility of the proposed terminal solutions will be assessed in this chapter, following the framework presented in section 4.2. An illustration of the calculation procedure is presented in the first section. The general parameters are introduced, followed by a step-by-step illustration of the calculation of the financial performance for different price settings and chosen service levels. The results of the feasibility assessment are presented in section 6.2, where it was pointed out that for none of the proposed terminal solutions a business case could be found. It emerged that for the available cargo volumes, no cost competitive intermodal IWT service could be initiated. For the three alternatives, the shortcomings in the revenues were calculated in order to obtain a break-even NPV. The final section discusses which circumstances need to change in order to define a business case for a private investor.

6.1 Calculation procedure of the financial performance

The financial performance of the three proposed terminal solutions in business park De Mars will be assessed in this chapter. The feasibility framework from section 4.2 is applied for the in chapter 5 defined input parameters. The financial performance is evaluated by conducting a cash flow analysis. The financial performance indicator that is used is the NPV. If a negative result is found for the NPV, it is important to indicate what circumstances need to change to obtain a positive NPV. This will be done by assessing the missing revenues that are required to find a business case, which can be translated in additional required cargo volumes or required subsidies.

Before the steps from the feasibility framework can be assessed, several general parameters have to be defined. This section starts with the introduction of these parameters, followed by an illustration of the calculation procedure.

6.1.1 Introduction to the used parameters

The feasibility of the proposed terminal solutions is determined by calculating the financial performance to which a cash flow analysis is worked out. The financial performance indicator that will be used is the NPV, which is a summation of the incoming and outgoing cash flows over a period of time. For a positive NPV over the considered period, value is added to the project. It is assumed that for a positive NPV, a business case or a private investor can be found. A simplified pre-finance - pre-tax financial evaluation is used for the assessment (explained in subsection 3.3.2.3). Several parameters are assumed to be constant as is discussed below.

Discount rate

By applying discounting techniques, the future values of the expected cash flows can be expressed into the present value. A discount rate has to be determined to calculate the future value of the expected cash flows into the NPV. Use is made of a real discount rate that does not include inflation. This was done since inflation is hard to forecast more than a few years ahead (van Dorsser, 2015). The real discount rate is determined by following the calculation of the WACC, where the following parameters were considered:

$$WACC = r_D \cdot \frac{D}{D+E}(1-t) + r_E \cdot \frac{E}{D+E}$$

Value of debt	D	=	60% over lifetime
Value of equity	E	=	40%
Required return on debt	r_D	=	6% (nominal)
Required return on equity	r_E	=	7.5% (nominal)
Tax rate	t	=	25% (marginal rate)

This leads to a real discount rate $\boldsymbol{r = 5.5\%}$ that will be used as a constant over time for the calculation of financial performance. This corresponds to the discount rate prescribed by the Dutch government for most projects (Werkgroep Discontovoet, 2015).

Years of capital expenditures

In case of an initial investment that takes over several years, the capital expenditures have to be delayed where possible. This is because 1 money unit one year ahead is worth $1/(1+R)$ units today. However, the considered terminal solutions that require an initial terminal investment are considered to be realized within one year, hence to capital expenditures can be delayed. The terminal solution with the crane vessel does not require an initial investment, which means that the revenues are generated at the start of the first year, whereas for the other terminal solutions the revenues start at the second year, with a present value of $1/(1+R)$.

Operational years

The terminal will not be able to operate on full-scale in the start-up phase; hence the maximum revenues will be reached after some years. The number of operational years that will be considered to evaluate the NPV therefore is of importance for the investor. In case the revenues exceed the operational costs, the payback period is defined at the period it takes before the cumulative revenues are larger than the cumulative expenditures. Based on expert consultation, the author assumed that a potential investor is interested in a period of time of 25 years. As a consequence, if no positive NPV can be found after a period of 25 years, the assessment concludes that no business case for a private investor can be found.

Costs for sailing and pre- or end-haulage

The parameters that are used to calculate the costs for sailing and pre- or end-haulage are the same parameters as used in analysis of the cost competitiveness in subsection 5.1.4. Refer to Appendix A and B for an elaboration these numbers.

6.1.1.1 *Operational costs for terminal*

Table 6-1 presents the cost items for terminal operations are used for different service levels. The numbers are based on own interpretation and the cost model of Van Dorsser (2015). These operational costs do not apply for the terminal solution with the crane vessel.

Table 6-1. Cost items for terminal operations for different service levels

Service level	Sailing frequency	Labour costs	Repair and maintenance	Fuel + Energy	Insurance	Overhead costs
Very Low	1	€ 75,000	€ 75,000	€ 50,000	€ 20,000	€ 100,000
Low	2	€ 100,000	€ 100,000	€ 75,000	€ 25,000	€ 120,000
Medium	3	€ 200,000	€ 200,000	€ 100,000	€ 50,000	€ 180,000
High	5	€ 300,000	€ 300,000	€ 150,000	€ 100,000	€ 240,000

These cost items are used for the considered service levels. Besides these variable costs, the costs for the rent of the land are fixed. These costs were obtained via the municipality of Zutphen and are assumed to be $€30{,}000/\text{year}$. An illustration of the resulting operational expenditures for terminal operations with service level 'Low' is shown in Table 6-2.

Table 6-2. Illustration of the operational expenditures for service level 'Low'

OPERATIONAL COSTS	SERVICE LEVEL		LOW	
Description cost item	**Quantity**	**Unit**	**Unit costs**	**Total**
Labour	1	€/year	€100,000	€ 100,000
Land [5%/year *100€]	6,000	m2	€ 5	€ 30,000
Repair and maintenance	1		€100,000	€ 100,000
Electricity and diesel	1		€ 75,000	€ 75,000
Insurance	1		€ 25,000	€ 25,000
Overhead costs	1		€ 120,000	€ 120,000
Total Operational Expenditures				**€ 450,000**

6.1.2 Illustration of the calculation procedure

This subsection provides a step-by-step illustration of the calculation of the NPV following the framework presented in section 4.2. A spreadsheet was drawn up to calculate the framework conditions and the corresponding NPV for the selected tariffs and service level. To illustrate the use of this spreadsheet, the calculation procedure is presented for the terminal solution 1 'Mobile crane at existing quay', where the medium growth scenario was selected, assuming an average annual growth of 0%.

Step 1. Setting tariffs and selection of service level

A handling tariff of $€40/\text{move}$ and sailing tariff of $€60/\text{TEU}$ per roundtrip was selected and service level 'Low', with a sailing frequency of 2 sailings per week was chosen.

Step 2. Captured share of potential cargo volumes

To determine the captured share of the potential cargo volumes, the in Figure 6-1used tab in of the calculation sheet was used. With the selected tariffs for sailing and terminal handling, the total transport tariff is calculated for all potential destinations in the service area. This leads to a certain cost savings compared to the best price of the competitors. The cost savings together with the selected service level, lead to the share of the potential cargo volumes that are likely to be captured as defined by Table 4-1.

From the calculation sheet it can be noted that for the chosen service level and selected sailing tariff of $€60/\text{TEU}$ and handling tariff of $€40/\text{move}$, a total of $6{,}656\ \text{TEU/year}$ can be captured from the potential cargo volumes. With the calculated average TEU-factor of 1.56, this leads to maximum revenues for terminal handing + sailing of $€740{,}480/\ \text{year}$.

Now that the revenues are determined, also the operational costs for the barge service can be calculated. To transport the annual transport volumes of 7,566 TEU with a frequency of 2 sailings per week, a barge capacity of 64 TEU per roundtrip is required, which corresponds to a Class IV barge with a utilization rate of 71%. The resulting sailing costs for such a barge are $€106.6/\text{TEU}$. It can be noted that the sailing costs are considerably higher than the set tariff. Also the operational costs of the terminal are too high to yield a positive result.

ADJUSTABLE INPUT VARIABLES		OUTPUT					
Inland terminal	Zutphen	**Handling tariff**	40,00	€/move	**Growth scenario**	0%	
Sailing frequency	2	**Sailing tariff**	60,00	€/TEU	**Fuel costs**	0,4	€/liter

Destination	Zutphen	Lochem	Deventer	Apeldoorn
Pre-and end-haulage				
Distance [km]	5,0	20,0	13,0	28,0
Hauling time [hour]	0,1	0,5	0,4	0,6
Loading time [hour]	0,3	0,3	0,3	0,3
Waiting [hour]	0,5	0,5	0,5	0,5
Total transport time [hour]	1,0	1,8	1,6	2,0
Costs pre- and end-haulage	**€ 48,1**	€ 91,1	€ 77,0	€ 100,3

Transport tariffs	Zutphen 20ft	Zutphen 40ft	Lochem 20ft	Lochem 40ft	Deventer 20ft	Deventer 40ft	Apeldoorn 20ft	Apeldoorn 40ft
Sailing tariff [€/TEU]	€ 60,0	€ 120,0	€ 60,0	€ 120,0	€ 60,0	€ 120,0	€ 60,0	€ 120,0
Handling tariff [€/move]	€ 80,0	€ 80,0	€ 80,0	€ 80,0	€ 80,0	€ 80,0	€ 80,0	€ 80,0
Pre- and end-haulage [€/container]	€ 48,1	€ 48,1	€ 91,1	€ 91,1	€ 77,0	€ 77,0	€ 100,3	€ 100,3
Total transport tariff	**€ 188,1**	**€ 248,1**	**€ 231,1**	**€ 291,1**	**€ 217,0**	**€ 277,0**	**€ 240,3**	**€ 300,3**
Best price competitors	€ 283,0	€ 328,0	€ 310,0	€ 356,0	€ 288,0	€ 333,0	€ 260,0	€ 305,0
Price difference via Zutphen	-34%	-24%	-25%	-18%	-25%	-17%	-8%	-2%
Cost saving (Round by 5%)	35%	25%	25%	20%	25%	15%	10%	0%
Share of potential volumes captured	50%	40%	40%	30%	40%	25%	20%	10%

	Zutphen 20ft	Zutphen 40ft	Zutphen TEU	Lochem 20ft	Lochem 40ft	Lochem TEU	Deventer 20ft	Deventer 40ft	Deventer TEU	Apeldoorn 20ft	Apeldoorn 40ft	Apeldoorn TEU
Potential cargo volumes identified	1040	2080	5200	520	1040	2600	1040	2080	5200	3640	7280	18200
Potential volumes that are captured	520	832	2184	208	312	832	416	520	1456	728	728	2184

	20ft	40ft	TEU	TEU-factor
Total potential cargo volumes	6240	12480	31200	1,67
Total cargo volumes captured	1872	2392	**6656**	1,56

SAILING COSTS		
Required fleet capacity per roundtrip	**64**	**TEU**
Corresponding CEMT Class	IV	
and utilization rate	71%	
Sailing time [hour]	16,29	hr
Handling time [hour]	5,4	hr
Loading time [hour]	24	hr
Weekly fixed costs	€ 11.250	€/week
Weekly fuel costs	€ 2.400	€/week
Roundtrips per week	2	
Total sailing costs	**106,6**	**€/TEU**

Figure 6-1. Calculation sheet for the captured shares of the potential cargo volumes and sailing costs

Step 3. Analysis of the financial feasibility

The NPV is calculated to determine the financial performance for the selected tariffs, service level and annual growth scenario. In the above step, it was already noticed that the operational costs exceeded the maximum revenues. As a result, the NPV will never become positive and therefore no business case can be found for the selected variable parameters. The resulting NPV yields € - 7,606,584, which indicates a heavily loss-making project. See Figure 6-2 for the calculation of the NPV:

NET PRESENT VALUE	Variable input	Fixed input	Output		
TERMINAL SOLUTION	Existing quay	**Service level frequency**	2	Annual growth	0%
First year	2018	Operational years	25	Handling price [€/move]	€ 40,0
Years of cap. expenditure	1	Discount rate	5,5%	Sailing price [€/TEU]	€ 60,0
CAPEX	€ 1.843.750				
OPEX terminal	*€ 450.000*	*Max. Handling revenues*	*€ 341.120*	Moves/year	8528
OPEX sailing	*€ 709.795*	*Max. Sailing revenues*	*€ 399.360*	TEU/year	6656
OPEX total	€ 1.159.795	Max. Annual revenues	€ 740.480	Average TEU-factor	1,56

	Year	Speed of modal change	Annual Revenues (Sailing + terminal)	CAPEX (terminal)	OPEX (Sailing + terminal)	Total (Revenues - CAPEX - OPEX)	NPV
0	2018	0%	€ -	€ 1.843.750	€ -	€-1.843.750	€-1.843.750
1	2019	50%	€ 370.240	€ -	€ 867.122	€-496.882	€-470.978
2	2020	75%	€ 555.360	€ -	€ 1.013.458	€-458.098	€-411.579
3	2021	88%	€ 647.920	€ -	€ 1.086.626	€-438.706	€-373.608
4	2022	94%	€ 694.200	€ -	€ 1.123.210	€-429.010	€-346.304
5	2023	97%	€ 717.340	€ -	€ 1.141.503	€-424.163	€-324.541
6	2024	98%	€ 728.910	€ -	€ 1.150.649	€-421.739	€-305.864
7	2025	100%	€ 740.480	€ -	€ 1.159.795	€-419.315	€-288.252
8	2026	100%	€ 740.480	€ -	€ 1.159.795	€-419.315	€-273.225
9	2027	100%	€ 740.480	€ -	€ 1.159.795	€-419.315	€-258.981
10	2028	100%	€ 740.480	€ -	€ 1.159.795	€-419.315	€-245.480
11	2029	100%	€ 740.480	€ -	€ 1.159.795	€-419.315	€-232.682
12	2030	100%	€ 740.480	€ -	€ 1.159.795	€-419.315	€-220.552
13	2031	100%	€ 740.480	€ -	€ 1.159.795	€-419.315	€-209.054
14	2032	100%	€ 740.480	€ -	€ 1.159.795	€-419.315	€-198.155
15	2033	100%	€ 740.480	€ -	€ 1.159.795	€-419.315	€-187.825
16	2034	100%	€ 740.480	€ -	€ 1.159.795	€-419.315	€-178.033
17	2035	100%	€ 740.480	€ -	€ 1.159.795	€-419.315	€-168.752
18	2036	100%	€ 740.480	€ -	€ 1.159.795	€-419.315	€-159.954
19	2037	100%	€ 740.480	€ -	€ 1.159.795	€-419.315	€-151.615
20	2038	100%	€ 740.480	€ -	€ 1.159.795	€-419.315	€-143.711
21	2039	100%	€ 740.480	€ -	€ 1.159.795	€-419.315	€-136.219
22	2040	100%	€ 740.480	€ -	€ 1.159.795	€-419.315	€-129.118
23	2041	100%	€ 740.480	€ -	€ 1.159.795	€-419.315	€-122.386
24	2042	100%	€ 740.480	€ -	€ 1.159.795	€-419.315	€-116.006
25	2043	100%	€ 740.480	€ -	€ 1.159.795	€-419.315	€-109.958
26	-	100%	€ -	€ -	€ -	€0	€0
27	-	100%	€ -	€ -	€ -	€0	€0
28	-	100%	€ -	€ -	€ -	€0	€0
29	-	100%	€ -	€ -	€ -	€0	€0
30	-	100%	€ -	€ -	€ -	€0	€0
Totals			€ 17.783.090	€ 1.843.750	€ 28.418.665	€ -12.479.325	€ -7.606.584

Figure 6-2. NPV for the selected tariffs and service level of alternative 1: 'Mobile crane at existing quay'

Step 4. Optimization of price setting

The same procedure is repeated many times for different combinations of the handling and sailing tariffs. For a higher sailing tariff, the revenues per transported container increase. At the same time, the cost savings for the potential shippers with respect to competitive transport modes becomes smaller; hence a smaller share of the shipper can be captured. The same relation holds vice versa. The optimal resulting NPV can be obtained either by having large revenues multiplied by limited cargo volumes captured, or having limited revenues multiplied by a large number of cargo volumes.

In the calculation spreadsheet, for all combinations of handling and sailing tariffs the NPV was calculated to find the optimal tariffs for the selected service level. The resulting NPV is plotted in large tables, for which a simplified version (i.e. smaller step size) is illustrated in

Figure 6-3. The red colour illustrates that for all combinations of tariffs at the selected service level 'Low' with 2 sailings per week, not a single positive NPV can be found. The optimum for the NPV was found at a handling tariff of €50/move and sailing tariff €40/TEU, resulting in a NPV of € -5,158,040.

It can be seen that for all tariffs the NPV is far negative. The resulting NPV is even far more negative than the CAPEX of € 1,843,750, which shows that the operations itself are loss-making. Therefore it can be concluded no business case can be found for a private investor. Additional revenues are required to obtain a positive NPV, which can be obtained by looking into a public-private partnership by granting subsidies, or finding additional cargo volumes by attracting a launching customer. This will be discussed later on.

		Handling tariff [€/move]							
	NPV	35	40	45	50	55	60	65	70
Sailing tariff [€/TEU]	35	-9.250.963	-8.643.403	-8.498.796	-5.744.128	-5.397.453	-7.450.294	-9.180.607	-11.832.635
	40	-8.502.073	-8.637.177	-9.440.218	-5.158.040	-7.160.202	-9.033.733	-11.405.778	-6.831.610
	45	-8.775.559	-9.388.760	-5.275.258	-7.038.246	-8.264.305	-11.456.247	-6.872.311	-7.104.072
	50	-9.527.142	-8.971.347	-6.792.574	-7.969.364	-11.288.348	-11.512.500	-7.121.743	-7.950.643
	55	-8.919.890	-6.909.791	-7.856.960	-10.563.071	-11.562.968	-7.162.443	-7.742.257	-8.132.982
	60	-6.711.690	-7.606.584	-10.251.070	-11.391.535	-6.799.094	-7.768.015	-8.165.542	-9.470.117
	65	-7.723.802	-10.172.122	-10.673.777	-6.849.563	-7.808.716	-7.957.155	-9.220.500	-9.684.501
	70	-9.905.350	-10.359.036	-6.711.256	-7.430.334	-7.987.228	-9.253.060	-9.787.036	-10.558.771
	75	-10.285.437	-10.960.308	-7.480.802	-8.027.928	-9.044.674	-9.520.056	-10.583.191	-11.284.831
	80	-10.640.905	-7.336.515	-7.641.609	-9.099.550	-9.552.616	-10.998.262	-10.558.771	-10.373.288
	85	-6.563.569	-7.692.077	-9.140.251	-9.344.229	-10.575.014	-10.583.191	-11.284.831	-10.363.520
	90	-7.544.736	-8.709.310	-9.411.509	-10.607.574	-10.998.262	-10.558.771	-10.373.288	-11.545.314
	95	-8.759.779	-9.452.209	-10.399.187	-10.575.014	-10.583.191	-11.284.831	-10.363.520	-7.677.731
	100	-8.999.565	-10.553.282	-10.607.574	-10.998.262	-10.558.771	-10.373.288	-11.545.314	-7.677.731
	105	-10.593.982	-10.399.187	-10.575.014	-10.583.191	-11.284.831	-10.363.520	-7.677.731	-7.677.731
	110	-10.553.282	-10.607.574	-10.998.262	-10.558.771	-10.373.288	-11.545.314	-7.677.731	-7.677.731
	115	-10.399.187	-10.575.014	-10.583.191	-11.284.831	-10.363.520	-7.677.731	-7.677.731	-7.677.731

Figure 6-3. Table with resulting NPV for all combinations of handling and sailing tariffs for terminal solution 'Mobile crane at existing quay' at service level 'Low'

6.2 Feasibility assessment of the proposed terminal solutions

This section presents the results of the feasibility assessment for the three proposed terminal solutions. A terminal solution is found to be feasible if a private business case can be found, which is considered to be the case for a NPV > 0. Since all terminal solutions are low-cost and low profile, service level 'High' is not taken into account in the assessment. The calculation procedure in the previous section already showed that the available margins for the tariffs are limited and that for all tariff combinations in the considered example not positive NPV could be found. For convenience, the available margins as calculated in the intermodal cost comparison are shown once again below.

Table 6-3. Available margins for sailing + handling tariffs per roundtrip between Rotterdam and Zutphen (similar to Table 5-8). Source: own calculations

	Destination							
	Zutphen		Deventer		Lochem		Apeldoorn	
	20ft	40ft	20ft	40ft	20ft	40ft	20ft	40ft
Best price competitors	*283*	*328*	*288*	*333*	*310*	*356*	*260*	*305*
Reserved for pre- and end-haulage	48	48	77	77	91	91	100	100
Maximum available margin for sailing + handling tariffs	**235**	**280**	**211**	**256**	**219**	**265**	**160**	**205**

All units in € per container

First the resulting NPVs will be discussed for each the three proposed alternatives. It can be seen that for none of the terminal solutions, a private business case can be found. This section concludes in subsection 6.2.4 with a discussion of the results. The financial performance of the three alternatives will be compared to each other, to identify the solution with the least negative results. The required subsidies to close the gap for a break-even situation are presented for all three alternatives, to illustrate the magnitude of the deficiencies.

6.2.1 Feasibility assessment of alternative 1: Mobile crane at existing quay

The initial investments for terminal solution 1: 'mobile crane at existing quay' were calculated to be € 1,843,750 as shown in subsection 5.2.1.4. A CEMT Class IV barge, with a capacity of 90 TEU is the maximum vessel size that can be handled at this terminal. This means that the lowest sailing costs can be found when operating a fully loaded Class IV barge at a 100% loading degree. The corresponding sailing costs are €76 / TEU, which can only be realized when 90 TEU is available for every roundtrip (see Table 5-9).

If the sailing tariff would be set at €76 / TEU, this corresponds to a sailing tariff of €152 for a 40ft container. In order to attract cargo from destination Apeldoorn, a margin of just €53 is available for carrying out 2 handling moves at the terminal. Following Table 4-1 from the feasibility framework, cargo can only be attracted when the offered tariffs are lower than the competitors' best price. This illustrates that it is impossible to set a combination of the sailing and handling tariffs to obtain a positive NPV for a private business case, considering the identified cargo volumes in the service area

The cash flow analysis was worked out in the spreadsheet, and the resulting optimal NPV for al considered service levels and growth scenarios is depicted in Table 6-4. As already mentioned it is impossible to find a private business case, which is can be seen from the resulting NPVs in Table 6-4 showing a strong negative NPV for all combinations.

Table 6-4. Results of the optimal NPV for terminal solution 1: 'Mobile crane at existing quay'. Source: own calculations

NPV for optimal tariffs		**Sailing frequency**	**Growth scenario**		
			Low (-1%)	**Medium (0%)**	**High (2%)**
Service level	Very low	1	€ -6.603.481	€ -6.621.230	€ -6.404.401
	Low	2	€ -6.050.947	**€ -5.158.040 ***	€ -4.475.424
	Medium	3	€ -10.048.684	€ -10.707.961	€ -8.488.797

*****) Corresponds to the optimal NPV calculated in the illustrated procedure in subsection 6.1.2

6.2.2 Feasibility assessment of alternative 2: Crane vessel

The sailing costs for the crane vessel were introduced in section 5.2.2.3 and were based on a continuous sailing schedule with 2 roundtrips per week. In contrast to the other alternatives, the feasibility assessment will only take the situation with a sailing frequency of 2 roundtrips per week into account.

For a 100% utilization rate of the crane vessel, the resulting costs per roundtrip for sailing + handling are €180 for a 20ft container and 356 for a 40ft container. With the available margins for sailing and handling tariff depicted in Table 6-3, it is clear that the costs are much higher than the available margins. As a result, the operational costs of the crane vessel are always higher than the tariffs that have to be offered in order to attract customers.

For the presented financial performance of the crane barge, the optimum was found when the crane barge was fully utilized. However, this could only be realized when the stated tariffs are well below the cost level of the service. The resulting NPV is strongly negative for all combinations as is clearly illustrated in the table below.

Table 6-5. Results of the optimal NPV for terminal solution 2: 'Crane vessel'. Source: own calculations

	Sailing frequency	**Growth scenario**		
		Low (-1%)	**Medium (0%)**	**High (2%)**
NPV for optimal tariffs	2	€ -12.532.955	**€ -12.567.625**	€ -10.604.651

6.2.3 Feasibility assessment of alternative 3: Cofferdam at embankment

For the terminal solution with the Cofferdam at the embankment, the required initial investment of €3,623,750 is higher than for the terminal solution at the existing quay. The advantage is that larger Class Va barges with a capacity of 156 TEU are able to moor at this alternative. If sufficient cargo volumes can be captured, the sailing costs can be decreased, which might provide sufficient margins for profitable terminal operations.

The optimal financial performance was calculated in the spreadsheet and it was found that for no profitable combination of sailing and handling tariffs, the required cargo volumes could be captured to initiate a barge service with a Class Va vessel. The optimal setting of the tariffs led to a fully loaded Class IV barge, hence the advantage of the larger mooring capacity is irrelevant for the identified cargo volumes. Due to the higher CAPEX, the resulting NPV is even worse than for the alternative 1 at the existing quay, as is shown in Table 6-6.

Table 6-6. Results of the optimal NPV for terminal solution 3: 'Cofferdam at embankment'. Source: own calculations

NPV for optimal tariffs		Sailing frequency	Growth scenario		
			Low (-1%)	Medium (0%)	High (2%)
Service level	Very low	1	€ -8.170.137	€ -8.168.482	€ -7.972.974
	Low	2	€ -7.025.337	**€ -6.938.040**	€ -5.860.227
	Medium	3	€ -11.522.901	€ -10.320.101	€ -7.851.692

6.2.4 Discussion: Comparison of the results of the three alternatives

The results of the feasibility assessment clearly show that for all terminal solutions it is not possible to define a private business case. Two main reasons for this problem are indicated: the limited margins for setting the transport tariffs and insufficient cargo volumes. The limited margins are the result the highly competitive prices that the terminals in Nijmegen and Doesburg are able to offer. The limited margins cause that low tariffs need to be offered in order to attract cargo. In the cargo assessment in subsection 5.1.2 was concluded that no launching customers are present in Zutphen, while it was stated to be an absolute precondition for terminal feasibility. For the cargo volumes that could be identified in Zutphen, no commitment could be given by the shippers beforehand. As a result of the absence of a launching customer, the required cargo volumes need to be attracted further along in the service area. The destination where most of the potential cargo volumes were identified is Apeldoorn. Due to the poor road connection that Zutphen has towards Apeldoorn and the limited available margins, it became clear that it is hard for Zutphen to attract cargo from there.

For all combinations of the tariffs within the available margins, there are insufficient cargo volumes available in order to operate a cost efficient barge service. The scale of operation that can be realized for the captured cargo volumes result in a loss-making barge service and terminal. From the feasibility assessment, it can be seen that even for the most optimistic growth scenario 'High', where 2% growth of the cargo volumes is considered and a larger share of the cargo volumes is captured, the resulting optimal NPV is still far negative. The gap towards a positive NPV is considerable, which indicates that the available cargo volumes do not come close to the required volumes.

To compare the financial performance of the three alternatives, the cash flows are depicted in Figure 6-4, which shows the cumulative course of the NPV over duration of the project. Service level 'Medium' with 2 sailings per week was considered together with the most probable growth scenario 'Medium' where 0% growth of the cargo volumes occurs. It is clear that for the identified cargo volumes in the service area, alternative 2 with the crane vessel involves the highest level of loss-making operations. The loss-making operations for alternatives 1 and 3 are of a comparable level, since the optimal tariff settings lead to a fully loaded Class IV barge in both situations. Hence, the difference in optimal NPV between alternatives 1 and 3 is almost completely due to the difference in CAPEX.

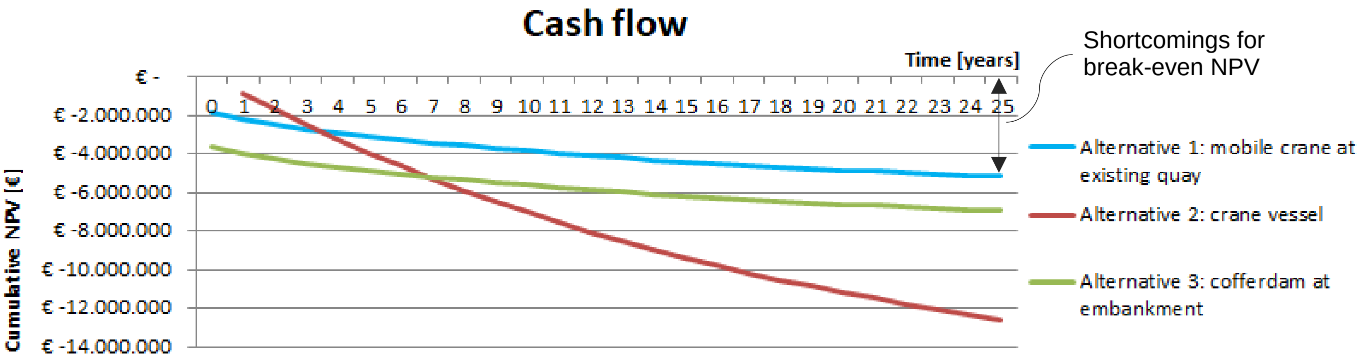
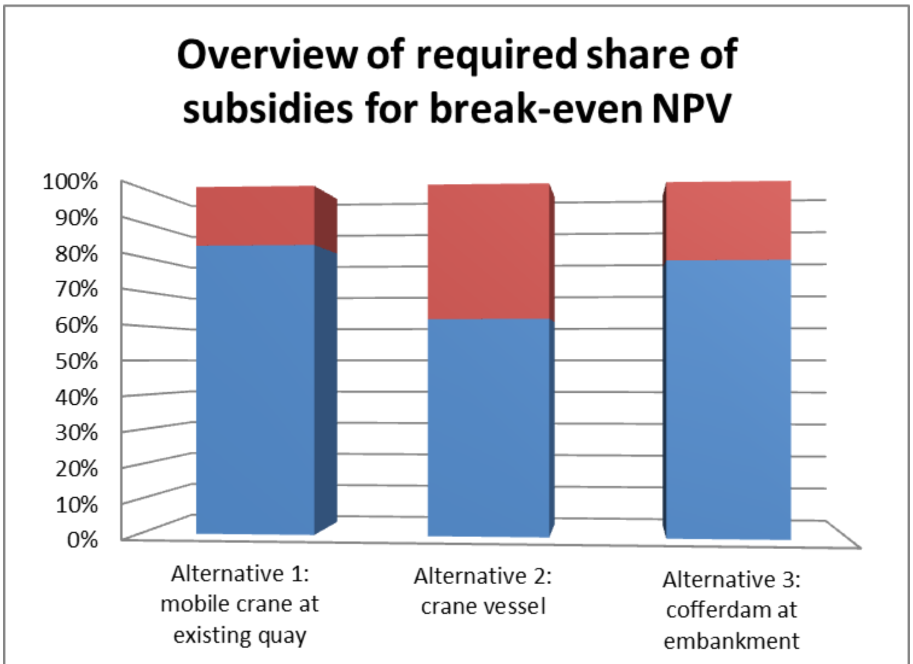


Figure 6-4. Comparison of the cash flow for the three proposed terminal solutions, considering service level 'Low' with 2 sailings per week and growth scenario 'Medium' with 0% growth of cargo volumes

To provide insight in the deficits, the revenues were supplemented with subsidies up to point where a break-even NPV was obtained. Because the optimal tariff settings led to different captured volumes, the required subsidies are presented in percentages. This gives an impression of the shortcomings of the realized revenues for profitable operations for each alternative, which is illustrated in Figure 6-5. For the identified market conditions, the least negative solution was found to be terminal solution 1: 'mobile crane at existing quay', which requires a subsidy for 17% of the total required revenues for a break-even situation. This means that for each transported TEU, 17% of the costs needs to be subsidized over the entire duration of the project.



	Alternative 1: mobile crane at existing quay	Alternative 2: crane vessel	Alternative 3: cofferdam at embankment
Required subsidies	17%	38%	22%
Revenues	83%	62%	78%

Figure 6-5. Comparison between the required subsidies for a break-eve NPV for three proposed terminal solution. Source: own calculations

Remarks
The used parameters are sensitive for small changes. For instance, the assumed handling price for the terminal in Nijmegen is set at €40/move. If this handling price would be considered to be higher, also the competitors' best price would increase. As a result also the available margins for setting the tariffs increase accordingly. However, for a large terminal as in Nijmegen this is highly unlikely. The handling costs for such a large capacity terminal are deemed to be lower than the assumed €40/move. All assumptions were based on the best available information, but for an improvement of the reliability of the results it is advised to conduct a sensibility analyses for all parameters that were assumed to be constants.

6.3 Required circumstances for terminal feasibility

As mentioned above, the inability to find a business case is caused by the limited margins for the transport tariffs and insufficient cargo volumes. This section will point out what circumstances need to change to obtain a positive NPV without granted subsidies.

In subsection 6.3.1 a calculation was performed to determine the cargo volumes that are required for the proposed terminal solutions in order to obtain a positive NPV. This gives a rough indication of the circumstances that need to change. Subsection 6.3.2 discusses the effect of an improved road connection towards Apeldoorn and evaluates whether a business case could be found for the changed situation.

6.3.1 Calculation of minimum required cargo volumes to obtain positive NPV

The feasibility assessment showed for the three proposed terminal solutions no private business case could be found for the existing market situation. In this section it was investigated what cargo volumes need to become available in order to obtain a positive NPV for any of the alternatives.

The alternative with crane vessel will not be included here, since it was calculated in subsection 5.2.2.3 that the costs for sailing + handling are much higher than the available margins. As a result, it concluded that no private business case can be found for any circumstances without subsidies. For the other two terminal solutions, the cargo volumes that are required to find a business case were calculated using an iterative procedure. It was found that from all considered barge classes[2], a Class IV barge it is not possible to achieve a positive NPV. Even for a fully loaded Class IV barge, the sailing costs are too high to be able to initiate a profitable business. As a result, for the terminal solution 'Mobile crane at existing quay' no business case can be found for any circumstances with a Class IV barge.

A vessel with a larger capacity, such as a Class Va barge with a high utilization rate is required to obtain low sailing costs. This vessel size is too large to be handled at the existing quay in the industrial harbour. Consequently, the required cargo volumes for the alternative 'Cofferdam at embankment' have to be assessed, since this is the only considered terminal solution where Class Va barges can be handled. An iterative calculation was worked out for growth scenarios 'Medium' and service level 'Low' with two sailings per week. The calculation pointed out that a break-even NPV is found for terminal solution 'Cofferdam at embankment' for the following cargo volumes:

Table 6-7. Minimum required cargo volumes for a positive NPV. Source: own calculations

TEU/year	16,000 - 16,250
Moves/year	19,500 - 20,000
TEU-factor	1.60 - 1.65

[2]) A remark has to be made that intermediate vessel sizes, such as a shortened Class Va barge (86m x 11.4m) were not included in the assessment, which might provide room for improved results.

The required cargo volumes that need to be captured for a break-even situation of terminal solution at the embankment was calculated to be approximately $16{,}000\ \mathrm{TEU/year}$. Ideally, a launching customer has to be found in Zutphen, that is committed to account for the main share of these required cargo volumes. If such a launching customer is not present, the cargo volumes need to be attracted further along in the service area. It was calculated by the author that this would require for the three considered growth scenarios an overall increase of the potential cargo volumes for the entire service area as shown in Table 6-8. It can be seen that the cargo volumes for the most probable growth scenario 'Medium' have to increase by a factor 2.5, which is more than considerable.

Table 6-8. Required increase of potential cargo volumes in the service area to obtain a break-even NPV. Source: own calculations

	Growth scenario		
	Low (-1%)	Medium (0%)	High (+2%)
Required increase of potential cargo volumes	295%	250%	173%

From the above depicted required increase of cargo volumes to find a private business case, it can undoubtedly be concluded that without the presence of a launching customer, such a considerable volume increase cannot be realized in the service area.

6.3.2 Influence of improved road connection to Apeldoorn

The road connection between Zutphen and Apeldoorn was denoted to be one of the bottlenecks for attracting sufficient cargo volumes. Since the bridge crossing the IJssel River towards Apeldoorn may not be accessed by trucks, a detour has to be taken via Deventer, which induces additional costs for pre- and end-haulage. A hypothetical situation is considered, where a direct road connection between Zutphen and Apeldoorn is present. The lower costs for pre- and end-haulage will enable a greater margin for transport tariffs and therefore a better competitive position with respect to the terminals in Nijmegen and Doesburg.

When a detour via Deventer is taken, the travel distance is 28km and the travel time 32 minutes. The corresponding costs for pre- or end-haulage between Zutphen and Apeldoorn was calculated to be $€100/\mathrm{container}$. When a hypothetical direct road connection between Zutphen and Apeldoorn would be present, the travel distance is assumed to become 20km and the travel time decreases to 25 minutes, which results in pre- or end-haulage costs of $€85/\mathrm{container}$. This means that a larger share is likely to be captured for the same tariffs.

A feasibility assessment similar to one performed in section 6.2 was conducted and showed an improved NPV for the three considered alternatives, but the results were still far negative, as can be seen in Table 6-9 to 6-11.

Table 6-9. Optimal NPV for terminal solution 1: 'Mobile crane at existing quay', with improved road connection towards Apeldoorn. Source: own calculations

NPV for optimal tariffs		Sailing frequency	Growth scenario		
			Low (-1%)	**Medium (0%)**	**High (2%)**
Service level	Very low	1	€ -6.390.137	€ -6.388.482	€ -6.192.974
	Low	2	€ -5.245.337	**€ -4.935.327 ***	€ -4.080.227
	Medium	3	€ -9.742.901	€ -8.540.101	€ -6.071.692

Table 6-10. Optimal NPV for terminal solution 2: 'Crane vessel', with improved road connection towards Apeldoorn. Source: own calculations

	Sailing frequency	Growth scenario		
		Low (-1%)	Medium (0%)	High (2%)
NPV for optimal tariffs	2	€ -11.481.675	**€ -11.369.401**	€ -10.164.104

Table 6-11. Optimal NPV for terminal solution 3: 'Cofferdam at embankment', with improved road connection towards Apeldoorn. Source: own calculations

NPV for optimal tariffs		Sailing frequency	Growth scenario		
			Low (-1%)	Medium (0%)	High (2%)
Service level	Very low	1	€ -8.170.137	€ -8.168.482	€ -7.972.974
	Low	2	€ -7.025.337	**€ -6.715.327**	€ -5.860.227
	Medium	3	€ -11.522.901	€ -10.320.101	€ -7.851.692

It is concluded that an improved road connection to Apeldoorn only marginally improves the overall financial performance. It does not enhance decisive improvements such that a business case can be found. Even with an improved road connection it is difficult to attract cargo volumes from Apeldoorn.

6.3.3 Conclusion

The results of assessment made clear that for none of the proposed terminal solutions a private business could be found. Even for the least negative alternative, the resulting NPV is far more negative than the required initial investment, which shows that the operations itself are loss-making.

The captured cargo volumes are insufficient to create revenues that can outweigh the costs. The lack of cargo volumes is partly due the absence of a launching customer in business park De Mars. As a consequence, the cargo volumes need to be attracted elsewhere from the service area. The margins that are available to set the transport tariffs are limited. This is the result of the highly competitive prices that the terminals in Nijmegen and Doesburg are able to offer, which makes it hard for Zutphen to attract cargo and make sufficient profits.

In order to realize a viable terminal in business park De Mars, either significant subsidies need to be granted on a structural basis, or additional cargo volumes need to be captured. The identified destination where most of the potential cargo volumes are accumulated is Apeldoorn. Due to the poor road connection between Zutphen and Apeldoorn, the costs for pre- and end-haulage weigh in heavily on the total transport costs. The effects of an improved road connection to Apeldoorn were analysed, but it was found that an improved road connection does not enhance the competitiveness such, that it enhances decisive improvements.

Therefore, it is concluded that finding a launching customer that generates sufficient cargo volumes in De Mars is a precondition for the feasibility of an inland container terminal for a private business case.

7

Conclusion and recommendations

This chapter discusses the conclusions that can be drawn from this research. First a brief summation of the answers on the research sub questions will be given. Subsequently, an answer is provided to the main research question and the results of the feasibility assessment will be discussed. A conclusion is presented regarding the feasibility of an inland container terminal in business park De Mars in Zutphen. Recommendations are given to improve the results of feasibility assessment, followed by recommendations for the municipality of Zutphen.

7.1 Conclusion

7.1.1 Answers to the research sub questions

In section 1.3 the main research question and sub questions were defined to address these objectives. The sub questions were answered in detail in chapters 2 to 5. These sub questions will briefly be answered to present the most important findings that were done throughout the report.

SQ 1. *(chapter 2)* *What options could be explored in business park De Mars to develop an inland waterway terminal?*

The best opportunities arise for the development of an intermodal IWT connection, including an inland container terminal at De Mars. For the development of a container terminal, a water-bound location has to be found at the business park. Two water-bound locations were found to be available, for which only the location at the industrial harbour will be taken into consideration, due to the limited cargo volumes that are available.

SQ 2. *(chapter 3)* *What are the main drivers that determine the competitiveness of intermodal inland waterway transport?*

Intermodal IWT consist of three components: sailing, terminal handling and pre- and end-haulage by truck. The competitiveness of the intermodal barge transport is determined by these components combined. The main drivers that make intermodal IWT competitive with other transport modes are the low costs, reliability and sustainability. The low costs are related to the distance from the seaport and scale of operation. The further the distance from the seaport, the more intermodal transport chain can benefit from the low barge costs of the main haul. The scale of operation depends on the available cargo volumes. This affects the maximum vessel size that can be deployed while maintaining a sufficient utilization rate and shipping frequency.

SQ 3. *(chapter 3)* *What are the critical performance conditions that determine feasibility of an intermodal IWT service?*

For setting up an intermodal IWT service, a barge service has to be initiated between the seaport and the inland terminal as well as pre- and end-haulage, which can only be realized if sufficient cargo volumes are available. In order to attract cargo, shippers have to be triggered to make a modal change to the new transport mode. The shippers' modal choice is based on a combination of costs and qualitative aspects.

The shipper has a preference for qualitative aspects over costs up to a certain threshold, after which the costs are decisive. Some flexibility regarding the travel time seems to exist, whereas the critical qualitative performance conditions were found to be reliability and frequency. If a shipper is satisfied with their current transport service, switching to another transport mode is unlikely, unless a substantial cost advantage can be realized. The cost performance for intermodal IWT is strongly related to the available cargo volumes, distance from the seaport and infrastructure.

SQ 4. *(chapter 3)* *What are the critical performance conditions for an inland container terminal in the intermodal IWT chain?*

A reliable intermodal transport service can only be realized if the terminal operator has access to sufficient and constant flow of cargo volumes available to be transported. According to KiM (Visser et al., 2012), almost all existing inland terminals have a launching customer that transports sufficient containers to initiate an intermodal IWT service. The smaller customers join at a later stage. The presence of a launching customer is considered to be an absolute precondition for feasibility of a terminal.

In a competitive transport market, terminal operators are expected to manage more services than just the transhipment of containers. Being able to manage all components of the intermodal IWT chain, including barge transport and pre- and end-haulage is considered to be a requirement. For a terminal in Zutphen, this implies that barge transport to the Port of Rotterdam has to be offered, either via initiating a new barge service or cooperating with an existing barge service.

SQ 5. *(chapter 4)* *How can a viable business case be found for an inland waterway container terminal?*

A business case is considered to be found if the project is financially feasible for a private investor, for which the revenues have to outweigh the costs. A framework was prepared to identify the cargo volumes that are likely to be captured. The analyses that have to be worked out include a cargo assessment and analysis of the cost competitiveness. The financial performance of the terminal is expressed by calculating the Net Present Value, for which a cash flow analysis is worked out. A viable business case is assumed to be defined for a positive NPV.

SQ 6. *(chapter 5)* *What are the expected cargo volumes that can be captured by an inland container terminal in Zutphen?*

The major cities with industrial areas within a 20km range of Zutphen are Apeldoorn, Deventer and Lochem, and are considered to comprise the service area. The competitive transport modes were found to be intermodal IWT via the terminals in Nijmegen and Doesburg.

No launching customer could be found in Zutphen being able to deliver the cargo volumes that are required to initiate terminal operations. Further along in the service area, the total potential cargo volumes were found to be approximately 31,000 TEU/year, of which most cargo volumes were identified in Apeldoorn. The share of these potential cargo volumes that can be captured depends on the offered transport tariffs and service level. Only if this satisfies the shipper's preferred service attributes, cargo can be attracted.

The analysis of the cost competitiveness showed that the competitive transport modes are able to offer very competitive prices; hence the available margins to initiate a profitable barge service and terminal operations are limited. The poor road connection towards Apeldoorn induces high costs for pre- and end-haulage by truck, which complicates Zutphen attract potential shippers from Apeldoorn. It was concluded that the expected cargo volumes to be captured are restricted to a small share of the total identified 31,000 TEU/year.

7.1.2 Answering the main research question

The knowledge that was gained by addressing the sub questions are used to answer the main research question:

> *"How can a viable inland waterway terminal be realized in Zutphen's business park De Mars to improve its freight connection?"*

Identifying feasibility aspects

By addressing the sub questions it was identified that for realizing a feasible terminal in Zutphen's business park De Mars, the best opportunities arise for the development of an intermodal IWT service, including a container terminal in Zutphen. To initiate an intermodal IWT service with a terminal Zutphen, three components of the intermodal transport chain have to be offered: barge transport between Zutphen and the Port of Rotterdam, transhipment of containers at the terminal and pre- and end-haulage by truck.

The literature review pointed out that for the feasibility of the intermodal IWT chain sufficient cargo volumes have to be available. In order to attract sufficient cargo volumes, shippers have to be triggered to make a modal change. The presence of a launching customer is an absolute precondition for a terminal to start operations and to generate sufficient cargo flow volumes to reach the required minimum scale of operation. Involvement of a party prepared to exploit the terminal operations is required, for which a private party can only be found if a business case can be defined.

Method to assess feasibility

A framework was presented in chapter 4 that consists of two parts. The first part presents several analyses, including the cargo volumes that are likely to be captured by a terminal Zutphen. This was used as input for the technical design of possible terminal solutions in De Mars. In the second part, the method to assess the financial feasibility of the proposed terminal solutions is presented. A private business case is considered to be found for a positive NPV, for which a financial analysis is worked out.

Analysis of cargo volumes in the service area

No launching customer could be found in Zutphen. The cargo assessment pointed out that the potential cargo flow volumes at business park De Mars are limited. There is scepticism towards the terminal initiative, due to the failure of previous attempts and the recent opening of the terminal in Doesburg. Further along in the service area, comprising Apeldoorn, Deventer and Lochem, most cargo volumes were identified in Apeldoorn. The analysis of the cost competitiveness showed that the competitive transport modes via the terminals in Nijmegen and Doesburg are able to offer very competitive prices, especially for destination Apeldoorn. This complicates Zutphen to attract potential shippers from Apeldoorn. The shippers in Deventer are not likely to commit beforehand, due to a pending terminal initiative in Deventer. As a result of the low expected cargo volumes, it was concluded that Zutphen has to aim for a low-profile, low-cost terminal.

Results of feasibility assessment

Three preliminary designs of proposed terminal solutions were worked out that use the existing infrastructure in the industrial harbour to limit the initial investments. The required investments for the development of a terminal at location Fort de Pol are assumed to be too high to be viable. A feasibility assessment was worked out for the three alternatives for many combinations of selected tariffs and service levels. The results of the assessment showed for all alternatives a far negative NPV. The resulting NPV is even more negative than the CAPEX which shows that the operations itself are loss-making. Therefore it was concluded that for the identified market conditions no business case can be found for a private investor.

Several causes for the inability to find a private business case were identified. First of all, the cargo assessment pointed out that no launching customer is present in Zutphen, while it was stated to be a precondition. As a consequence, the cargo volumes that are required to initiate a barge service and terminal operations need to be attracted elsewhere from the service area. The available margins to set the transport tariffs are very limited, which is caused by the highly competitive prices that the terminals in Nijmegen and Doesburg are able to offer.

In order to realize a viable terminal in business park De Mars, either significant subsidies need to be granted on a structural basis, or additional cargo volumes need to be captured. The identified destination where most of the potential cargo volumes are accumulated is Apeldoorn. Due to the poor road connection between Zutphen and Apeldoorn, the costs for pre- and end-haulage weigh in heavily on the total transport costs. As a result, it is hard for Zutphen to attract cargo from there. Several options are discussed below.

Required subsidies to close structural deficits

To identify the structural deficits of the revenues to obtain a break-even NPV, the required subsidies were determined. Because the optimal tariff settings led to different captured volumes, the required subsidies are presented in percentages of total required revenues. The least negative solution was found to be alternative 1: ‘mobile crane at existing quay’, which requires a subsidy for 17% of the total required revenues for a break-even situation. This means that for each transported TEU, 17% of the costs needs to be subsidized over the entire duration of the project.

Required circumstances for terminal feasibility
The minimal required cargo volumes that need to be captured for a break-even situation of terminal solution at the embankment were calculated to be approximately 16,000 TEU/year. Ideally, a launching customer has to be found in Zutphen that is committed to account for the main share of these required cargo volumes. If such a launching customer is not present, the cargo volumes need to be attracted further along in the service area. With the assumed share of the cargo volumes to be capture, the total potential cargo volumes in the service area would have to increase by 250%, which is unlikely given the current market conditions. It was concluded that without the presence of a launching customer, the required cargo volumes cannot be realized for a break-even NPV.

Effects of improved road connection with Apeldoorn
Another situation that was considered were the effects of an improved road connection to Apeldoorn. The lower costs for pre- and end-haulage will enable a greater margin for transport tariffs and therefore a better competitive position with respect to the terminals in Nijmegen and Doesburg. This means that a larger share can be captured for the same tariffs. An assessment was worked out for these conditions, where it was concluded that an improved road connection to Apeldoorn only marginally improves the overall financial performance. Even with an improved road connection it is difficult to attract cargo volumes from Apeldoorn. It is difficult to compete with the cost competitiveness intermodal transport modes via the terminals in Nijmegen and Doesburg.

7.2 Recommendations

7.2.1 Recommendations for the municipality of Zutphen

The scope of this thesis was defined as a result of an initiative from the local political party PvdA and the Cleantech Center in Zutphen, who expressed the desire to improve the utilization of the inland waterways with a freight connection at business park De Mars.

The feasibility assessment showed that for the current and expected market conditions, no private business case can be found to successfully initiate operations of an inland waterway container terminal. The resulting NPV is even more negative than the required initial investments, which shows that the operations itself are loss-making. The circumstances that need to be changed in order to achieve a positive NPV require significant additional cargo volumes to become available. For a private investor it is therefore recommended that for the current conditions no pursue should be given to the development of a container terminal.

The municipality of Zutphen may have other objectives than the profitability of the terminal. From the municipality's view on employment, sustainability or congestion, investing in realization of a terminal can be desirable, despite the fact of its loss-making activities. This can be done by granting subsidies. It was identified that the least negative NPV was far more negative than the initial required investments of the terminal, indicating the operations itself are loss-making. The main problem is caused by the lack of available cargo volumes. For each transported TEU, 17% of the required revenues are missing on a structural basis. During the period of the project, the subsidies would have to cover a total NPV of € -5,158,040.

It is recommended that the municipality should focus more on attracting additional cargo volumes to business park De Mars. The lack of the presence of a launching customer is the main reason that no business case can be found. The following measures could be taken by the municipality to attract additional cargo volumes:

- Finding a launching customer that transports significant containerized cargo volumes via the inland waterways.
- Actively pursue business policies to influence the entrepreneurs to settle their business location at business park De Mars. This can be achieved by offering lower land prices than in surrounding cities.
- Initiate to bring parties together to develop a joint program. For instance, seek cooperation with the pending initiative in Deventer by bundling of cargo volumes, to share the costs for barge transport.
- Consider the possibilities of containerized bulk transport. By conducting an active policy to stimulate companies transporting bulk and general cargo to containerize their goods, induces additional cargo volumes.

This main focus of this study was specifically concerned with the feasibility of an inland container terminal. The possibilities of developing a multi-purpose terminal were rejected at an early stage during this thesis. Pending initiatives, such as realization of a biomass plant running on pruning waste, might provide opportunities for bundling quay activities for both containerized and bulk activities.

7.2.2 Recommendations for further research

The following recommendations are given for future research:

- Sensitivity analysis
  Although the used assumptions throughout report were done with the best available data, there is room for improvement of the results. Several parameters were considered to be constants in the feasibility assessment. By conducting a sensitivity analysis, the effects and uncertainties for these parameters are included, which improves the reliability of the results.

- Include barges with intermediate sizes
  Several barge sizes were considered in this thesis following the CEMT specifications. In the cost calculations, it was assumed that a Class IV barge with a capacity of 90 TEU is the maximum vessel size that can be handled at the existing quay in the industrial harbour. A shortened Class Va barge with a capacity of 120 TEU was not included in the assessment. Such an intermediate vessel size could be examined in future research to improve the results.

- Variation of the transport tariffs for different destinations
  The transport tariffs were assumed to be equal for all destinations in the feasibility assessment. This gives a broad indication of the cargo volumes that are likely to be captured. In order to optimize the cargo volumes to be captured, the tariffs may be varied between the considered destinations. For instance, the tariffs could be lowered somewhat for cargo with Apeldoorn as destination to increase the cargo volumes that can be captured from there. This has to be compensated for the other tariffs. It is expected that this will only marginally improve the financial performance and does not affect the conclusions that were drawn in the feasibility assessment

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Appendix A Cost calculation of intermodal IWT chain

This appendix discusses the general parameters that are used in the cost calculation for the intermodal IWT chain. The three elements of the intermodal IWT transport mode; sailing, terminal handling and pre- and end-haulage, will be discussed separately.

A.1 Sailing costs

The sailing costs are calculated based on a roundtrip between the seaport and the inland terminal. It consists of fixed costs and variable costs. Distinction will be made between the following vessel sizes:

Table 0-1. Dimensions and capacities of considered barge classes. Source: Richtlijn Vaarwegen (Rijkswaterstaat, 2011)

CEMT Class	RWS Class	Length [m]	Beam [m]	Max. draught [m]	Max. capacity [TEU]
Neokemp		63	7.0	2.1	8 x 2 x 2 = 32
IV	M6	85	9.5	2.9	10 x 3 x 3 = 90
Va	M8	110	11.4	3.5	13 x 4 x 4 = 208
VIa	M11	135	14.2	4.0	17 x 5 x 5 = 425

Fixed costs

The fixed costs are determined using the key figures issued by Rijkswaterstaat (Panteia, 2015) and the cost model of Van Dorsser (2015). A 24/7 operation (8400 effective hours per year) is assumed. The Panteia key figures are based on the principles of the factor costs prepared by NEA (2004) and include insurance costs, repair- and maintenance costs, interest costs, depreciation, port dues, wages and other costs. The Panteia parameters for the Rhine River and tributaries were considered in the calculation. The cost model of Van Dorsser is based on his own experiences and data obtained from Hekkenberg (2013) and Beelen (2011). It includes the same cost items as the Panteia key figures, except the port dues.

The fixed costs show similarities for both methods, but due to some discrepancies in the Panteia key numbers for smaller vessel sizes, the Van Dorsser cost model was used and corrected for the 2015 values. The port dues following the Panteia key figures were added again. The fixed costs per vessel size are shown in Table 0-2. Due to the sailing schedule that is expressed per week, the total fixed costs have to be expressed in weeks too:

$$TFC_{sailing} = FC \; * 7 \; [days/week] \quad (3)$$

In which:

$TFC_{sailing}$ = Total Fixed Costs [€$/week$]

FC = Fixed Costs [€$/day$]

Variable costs

The variable costs consist of the fuel costs of the barge and the circulation time per roundtrip. These depend on the vessel size and the fuel price of diesel. The properties that determine the circulation time for the different vessel sizes were obtained from the cost model of Van Dorsser (2015) and are depicted in Table 0-2.

Table 0-2. Properties for fixed and variable costs for different barge classes

CEMT Class	**Fixed costs** $[€/day]$	**Fuel consumption** $[l/km]$	**Average sailing speed** $[km/h]$
Neokemp	1096	4	13
IV	1607	6	14
Va	2263	9	14
VIa	2937	13	15

The average fuel costs of duty and tax free gasoline over the year 2016 for inland vessels were obtained from bunker stations in The Netherlands. These bunker stations requested to remain anonymous.

Table 0-3. Average prices for 1000 litre duty and tax free gasoline for barges in 2016

Average price per 1000 litre per month in 2016			
January	€ 255.00	July	€ 335.00
February	€ 255.00	August	€ 330.00
March	€ 295.00	September	€ 340.00
April	€ 300.00	October	€ 370.00
May	€ 345.00	November	€ 370.00
June	€ 365.00	December	€ 420.00

The average fuel costs over 2016 are $€0.33/l$. Historically, the fuel prices are at a very low level in 2016. Based on forecasts in the energy market (EIA, 2017), it is assumed that the fuel costs may increase in the near future. To anticipate a higher fuel price increase, a fuel price of $\mathbf{€0.40/l}$ will be used for barges. The Total Variable Costs (TVC) can be determined using the following relation:

$$TVC_{sailing} = fp \cdot fc \cdot x_{roundtrip} \cdot n_{roundtrips} \quad (4)$$

In which:

$TVC_{sailing}$ = Total Variable Costs $[€/week]$
fp = Fuel Price $[€/l]$
fc = Fuel Consumption $[l/km]$
$x_{roundtrip}$ = Distance covered per roundtrip $[km]$
$n_{roundtrips}$ = Number of roundtrips per week $[-]$

Roundtrips per week

Dependent on the sailing distance and properties of the vessel, the number of roundtrips per week can be determined. If more roundtrips are possible with the same fixed costs, the costs per transported container decrease. The properties of the vessel such as sailing speed and number of transported containers determine the total time required for sailing.

$$n_{roundtrips} = \frac{24 * 7}{\left(2 * \left(t_{sailing} + t_{handling}\right) + t_{loading}\right)} \quad (5)$$

$$t_{sailing} = \frac{x_{sailing}}{v_{barge}} + t_{additional} \quad (6)$$

$$t_{handling} = \frac{N_{containers}}{v_{handling}} \quad (7)$$

In which:

$t_{sailing}$	=	Sailing time for one-way trip $[hour]$
$t_{handling}$	=	Handling time for loading or unloading at inland terminal $[hour]$
$t_{loading}$	=	Loading time at several terminals at seaport $[hour]$
$x_{sailing}$	=	Sailing distance for one-way trip $[km]$
v_{barge}	=	Navigation speed of the vessel $[km/hour]$
$t_{additional}$	=	Additional sailing time, e.g. waiting for locks, bridges $[hour]$
$N_{containers}$	=	Number of containers on the barge $[TEU]$
$v_{handling}$	=	Handling speed at the inland terminal $[moves/hour]$

The total time required for a roundtrip is denoted in the denominator of formula (5). The time required for sailing and handling is taken into account twice, since it is given for a one-way trip.

When the Total Costs and number of possible roundtrips are known, the sailing costs can be determined per TEU as follows:

$$TC_{sailing} = \frac{TFC_{sailing} + TVC_{sailing}}{n_{roundtrips} * N_{containers}} \quad (8)$$

A.2 Handling costs

For intermodal transport with a shuttle service to a seaport (e.g. Port of Rotterdam), two moves per roundtrip are required. One to unload from the vessel to the terminal, and one to load from the terminal to the truck for end-haulage. Following Smid et al (2016) and Wiegmans & Konings (2015), the handling costs are related to the terminal size and utilization rate of the terminal. The terminal costs consist of fixed and variable costs. For an increasing terminal size, the relative increase in the fixed costs weighs in less heavily than for smaller terminal sizes. For instance, small and medium terminals both require one reachstacker. Therefore, the investment costs in the reachstacker for the medium terminal can be divided over more terminal handlings, decreasing the costs per handling. The factor costs for terminal handling defined by Wiegmans & Konings (2015) is presented in Table 0-4.

Table 0-4. Factor costs of terminal handling at inland barge container terminals (reference date: 2011). Source: Wiegmans & Konings (2015)

	measure	**Small**	**Small (low profile)**	**Medium**	**Large**	**Very large**
Terminal profile						
Handling capacity	Container throughput /year	20.000	20.000	50.000	125.000	200.000
Terminal equipment	units	1 MS 1 RS	1 MS* 1 FL	1 MS 1 RS	1 PC 1 MC 2 RS	2 PC 3 RC
Surface	ha	1,5	0,75	3	3	7
Quay length	meters	200	100	200	240	300
Fixed costs:						
Land	€ / year	88.000	66.000	200.000	264.000	616.000
Quay	€ / year	75.000	37.500	75.000	90.000	113.000
Equipment (cranes + transport)		163.000	29.700	163.000	373.000	445.000
Labor costs	€ / year	200.000	200.000	400.000	600.000	1.200.000
Interest		272.000	272.000	368.000	598.000	957.000
Variable costs:						
Fuel costs (diesel + electricity)		100.000	100.000	150.000	300.000	600.000
Repair and maintenance costs		22.000	12.000	28.000	42.000	65.000
Office	€ / year	10.000	10.000	10.000	10.000	10.000
ICT	€ / year	100.000	100.000	100.000	100.000	100.000
Other costs	€ / year	83.000	83.000	110.000	111.000	118.000
Other	€ / year	22.000	12.000	28.000	42.000	65.000
Management fee		100.000	50.000	150.000	300.000	500.000
Transhipment costs:						
Cost at 60% terminal utilization	€/ handling	103	81	60	38	40
Cost at 80% terminal utilization	€ / handling	77	61	45	28	30
Cost at 100% terminal utilization	€ / handling	62	49	36	23	24

MS: mobile crane, MS*: second hand mobile crane, PC: portal crane
RS: reachstacker, FL: forklift truck

A.3 Pre- and end-haulage costs by truck

The cost of road transport by truck consists of fixed and variable costs. The fixed costs comprise the costs for interest, insurance, road taxes, overhead and depreciation. The variable costs can be divided in costs related to time and distance. The time-related costs comprise wages, whereas the distance-related costs consist of fuel cost and maintenance.

The costs for road transport can be determined based on several calculation methods (Van Dorsser, 2004, 2005). In literature, the costs calculations are usually based on time and distance of the transport. In practise, the daily yield of a truck is being used to calculate the transport costs. The calculation based on daily yield is applicable when a truck can offer a full day of work by shuttle service. In this report, the costs for road transport will be calculated based on time and distance as presented in equation (9), since for pre- and end-haulage the costs of individual trips are of importance.

$$TC_{truck} = \tau \cdot t + \xi \cdot x \quad (9)$$

In which:

TC_{truck}	=	Total costs for road transport [€]
τ	=	Time-related costs [€/hour]
t	=	Number of hours [hour]
ξ	=	Distance-related costs [€/km]
x	=	Covered distance [km]

The resulting total costs for the intermodal transport chain is the sum of the three cost components as indicated in equation (10):

$$TC_{intermodal} = TC_{sailing} + TC_{handling} + TC_{truck} \quad (10)$$

Appendix B Cost calculation for transport modes in Zutphen region

This appendix shows the cost competitiveness of transport modes in the region around Zutphen. In order to determine the potential success of the new intermodal transport mode with a terminal in Zutphen, the most competitive prices from the existing transport modes have to be determined. The main competitors were identified to be unimodal road transport and intermodal IWT transport via the existing terminals in Nijmegen and Doesburg.

B.1 Cost calculation for unimodal road transport

The first mode of transport that has to be competed with is unimodal road transport. The total costs for unimodal transport will be determined based on time and distance, as described in paragraph 0. The distances and travel time between Maasvlakte and the destinations are presented in Table 0-5. These numbers were determined using Mappy.com, a route planner that allows calculating with different types of vehicles. This is of importance, because the Oude IJsselbrug (the bridge crossing the IJssel River westward of Zutphen) only allows passenger cars. For this calculation, the heaviest truck class "*3 axles, MTM > 12T, with trailer*" was selected.

Table 0-5. Distance and travel time between Maasvlakte and destination. Source: Mappy.com, vehicle: Truck 3 axles, MTM > 12T, with trailer.

Route	Distance by road	Travel time
Maasvlakte – Zutphen	194 km	2 hours, 40 min
Maasvlakte – Lochem	210 km	2 hours, 54 min
Maasvlakte – Deventer	186 km	2 hours, 33 min

Calculation example unimodal road transport

A calculation example for the unimodal costs with destination Zutphen illustrated to show the procedure and assumptions that were made.

The fixed costs and fuel costs are determined according to the cost model of Van Dorsser (2015). The main input parameter to determine these costs is dependent on the oil price. The average oil price of January 2017 was applied:

Brent oil: $45 per barrel
€/$ exchange rate: 1.0607

In the cost model this lead to following costs for a truck with container chassis:
Fixed costs: *€46.58/hour*
Variable costs: *€0.30/km*

The travel time determined with Mappy.com does not include congestion. A congestion factor of 1.1 is taken into account. This factor will be multiplied with the travel time.

Travel time for Zutphen – Maasvlakte is t_{trip} = *2.67hr*
Multiplying congestion factor of 1.1: t_{trip} = *2.933 hr*

The service is a two-way trip, so travel time has to be multiplied by 2. Additional time for waiting and loading at the origin and destination is added to obtain the total time.

t_{origin} = *0.5hr*
$t_{destination}$ = *1.0 hr*

Total time: *2 ** t_{trip}+ $t_{factory}$+ t_{retail}= *7.37 hours*

Now the total costs for unimodal road transport can be calculated:
Total truck costs: $46.58\,{}^{€}/_{hr} * 7.37\,hr + 2 * 0.30\,{}^{€}/_{km} * 194km = €\mathbf{460}$ **per container**

The costs for unimodal road transport between Rotterdam and the three destinations in the service area are presented in Table 0-6.

Table 0-6. Transport costs for unimodal road transport [€ per container]

	Unimodal road transport (container chassis)	
	20ft	40ft
Rotterdam – Zutphen	€ 460	€ 460
Rotterdam – Lochem	€ 496	€ 496
Rotterdam – Deventer	€ 445	€ 445

B.2 Cost calculation for intermodal inland waterway transport chain

To determine the competitiveness, the tariffs of intermodal transport to the destinations Zutphen, Lochem and Deventer are calculated for different vessel sizes. Zutphen has to compete with the tariffs of the terminals in Nijmegen and Doesburg. It is assumed that these terminals have an efficient system with high utilization rates and regular shipping frequency. Zutphen has to able to offer lower transport costs than is currently offered via the existing intermodal transport routes in order to be competitive.

The intermodal transport costs will be calculated following the method described in section 3.2.2. For the three cost components several assumptions were done that introduced in this paragraph. The paragraph ends with a calculation example.

I. Sailing costs

Shipping routes

The distance of the shipping routes to the Maasvlakte in Rotterdam has to be determined. These distances for the waterborne transport route are measured using the measuring tool in Google Maps as depicted in Figure 0-1. The route towards Zutphen and Doesburg can be sailed via the Nederrijn or the Waal to the River IJssel. In this route, the Waal River was chosen Nijmegen can be reached via the River Waal. The corresponding distances are presented in Table 0-7. The additional obstructions by hydraulic structures such as locks or bridges also have to be taken into account. Based on the distances and obstructions, the sailing time per barge can be determined.

Table 0-7. Distance between Maasvlakte and terminal by barge

Route	**Distance by waterway**
Rotterdam – Zutphen	200 km
Rotterdam – Doesburg	175 km
Rotterdam – Nijmegen	135 km

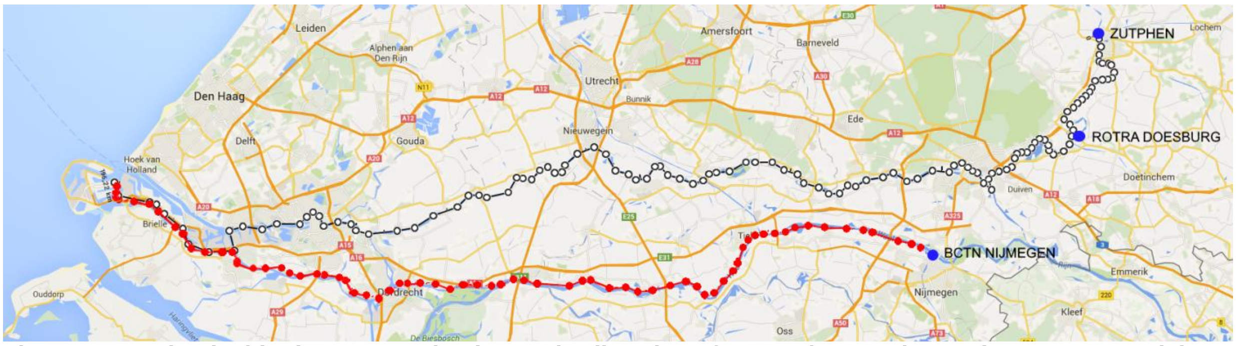


Figure 0-1. Inland shipping route via the Nederrijn River for Zutphen and Doesburg to Maasvlakte depicted in black. Inland shipping route towards Nijmegen via the Waal River indicated in red.

Vessel size

To calculate the tariffs, the vessel sizes and utilization rates have to be determined. Zutphen and Doesburg are located along the same waterway and can both be reached by barges up to CEMT Class Va. The terminal in Doesburg exploits is own barge service with a Class IV vessel. The terminal in Nijmegen is located on the Waal River and can be reached by larger vessels of CEMT Class VIb.

In the intermodal cost comparisons, several combinations of vessel capacities transporting cargo via Zutphen will be compared to the tariffs that can be offered by efficient services offered by terminals in Doesburg and Nijmegen. It is assumed that smaller vessels have a higher utilization rate than larger vessels, as depicted in Table 0-8.

Table 0-8. Utilization rate of barge classes

CEMT Class	Utilization
IV	90%
Va	85%
VIb	80%

II. Handling costs

The handling costs are assumed to be €40/move for the terminal in Nijmegen and 50€/move for Doesburg and Zutphen. Nijmegen operates on a larger scale and therefore will have more efficient handling equipment available at a higher occupancy rate. Hence, the handling costs are lower at the terminal in Nijmegen.

This is a very rough assumption, because the handling costs are very sensitive for small changes on the total price of the intermodal transport chain. Especially in the start-up phase of a terminal, operations are not expected to be as efficient as for the terminal in Nijmegen. Governmental subsidies in the start-up phase could allow to close this gap until the terminals is expended to a sufficiently large terminal size and utilization rate.

II. Pre- and end-Haulage

Next step is to determine end-haulage distances by truck to the final destinations. The same procedure as used for unimodal transport using Mappy.com is used. The end-haulage to destinations Zutphen, Deventer and Lochem are considered from the three terminals. The loading and unloading time is assumed to be $t_{loading}$= 0.8 hr and also here the congestion factor is assumed to be 1.1.

Table 0-9. Distance and travel time of end-haulage between terminal and destination. Source: Mappy.com, vehicle: Truck 3 axles, MTM>12T, with trailer.

Route	Distance by road	Travel time
Zutphen – Zutphen	3 km	6 min
Zutphen – Lochem	20 km	28 min
Zutphen – Deventer	13 km	21 min

Route	Distance by road	Travel time
Doesburg – Zutphen	23 km	35 min
Doesburg – Lochem	37 km	46 min
Doesburg – Deventer	36 km	49 min
Route	**Distance by road**	**Travel time**
Nijmegen – Zutphen	51 km	1 hour, 2 min
Nijmegen – Lochem	68 km	1 hour, 15 min
Nijmegen – Deventer	65 km	1 hour, 2 min

Calculation example intermodal transport

Similar to the unimodal transport example, a calculation example will be carried out for intermodal transport via Zutphen, with end-haulage towards Deventer with a distance of 13km. The used numbers can be found in the presented

Barge CEMT Class Va transport on route Maasvlakte – Zutphen, with end-haulage to Deventer

I. Sailing costs

Fixed costs ship

A barge of CEMT class Va is considered, which corresponds according to Appendix A to fixed costs of €2269 per day, a fuel consumption of 9 l/km and average navigation speed of 14 km/h.

The weekly fixed costs can be calculated by:

$$TFC_{sailing} = 2269 \frac{€}{day} * 7 \frac{days}{week} \quad = \quad €15883 \text{ / week}$$

The distance Maasvlakte - Zutphen by waterway is 200km. When adding the extra distance that has to be made in the Maasvlakte area to pick up cargo of 100km, the total distance for one roundtrip is 500km. With a fuel price of 0.40 €/l and fuel consumption 9.0l/km is, the total variable costs per roundtrip are:

$$TVC_{sailing} = 0.40 \frac{€}{l} * \ 500 \text{ km} * 9.0 \frac{\text{km}}{l} \quad = \quad €1800 \text{ / roundtrip}$$

Now the number of roundtrips that are possible per week have to be determined. Assume a CEMT class Va barge loaded with 3 layers that has a capacity of 13*4*3 = 156 TEU, that is on average loaded for 85%, resulting in 133 TEU. There will be two separate calculations for a barge fully loaded with 20ft and 40ft containers. In reality this would be a mixture of both types of containers, so the price per TEU will range between these two values.

Total time required for a roundtrip:

- With a handling speed of 15 moves/hr, 8.9 hours are required to unload the barge loaded with 20ft containers and 4.4 hours for a barge with 40ft containers. Therefore it takes 2 * 8.9 = 17.7 hours to completely load and unload a barge loaded with 20ft containers and 8.9 hours for a barge with 40ft containers.
- Sailing speed on the Nederrijn and IJssel River is on average 15km/h for a Class Va barge. Therefore the sailing time is:

  $200km \,/\, 15km/h \,=\, 13.3hr$ for a one-way trip

  There are three locks in the Nederrijn and Lek, for which an additional 2 hours is taken into account, which brings the total sailing time for a roundtrip to 30.6 hours.
- It is assumed that the barge has to be loaded at several terminals in Rotterdam, which will take an additional 24 hours.

When added up, approximately 3.0 days are required for one roundtrip with solely 20ft containers and 2.6 days for a roundtrip with solely 40ft containers, so *2 roundtrips per week* are possible for barge transport between Maasvlakte and Zutphen.

The total sailing costs for a barge solely loaded with **20ft containers**

Total costs per week, carrying out 2 roundtrips:

Fixed costs ship:	7 * €2269 / day	=	€15880 / week
Fuel costs:	2 * variable costs	=	€ 3600 / week
			€19480 / week

Total for 2 roundtrips carrying 133 TEU: €19480

Total fixed costs per container: €19480 / 266 TEU = **€73 / TEU**

II. Handling costs

Total handling costs per container is 2 * *€50 / move* = **€100 / container**

III. Costs for pre- and end-haulage

It is assumed that a truck with container chassis carries just one 20ft container per trip. The distance to final destination Deventer is 13 km. This corresponds to a trip time (including congestion factor of 1.1) of:

t_{trip} = 0.385 hr

Next assume the loading time:

$t_{loading+\ unloading}$ = 0.8 hr

Leading to a total time: $t_{total} = 2^* t_{trip} + t_{loading+\ unloading}$ = 1.57 hr

Total end-hauling costs:

1.57hr * 46.58 €/h + 0.30 €/l * 13km = **€77 / container +**

Total costs per 20ft container = €250 / container

Similarly for a **40ft container** (2 TEU), where is assumed that a truck with a container chassis can move one 40ft container per trip:

I.	Sailing costs for 2 roundtrips carrying 133 TEU	=	€146 / container
II.	Handling costs per container 2 * 50€/move	=	€100 / container
III.	End-haulage costs	=	€ 77 / container +
Total costs per 40ft container		**=**	**€323 / container**

B.3 Results of the intermodal cost comparison

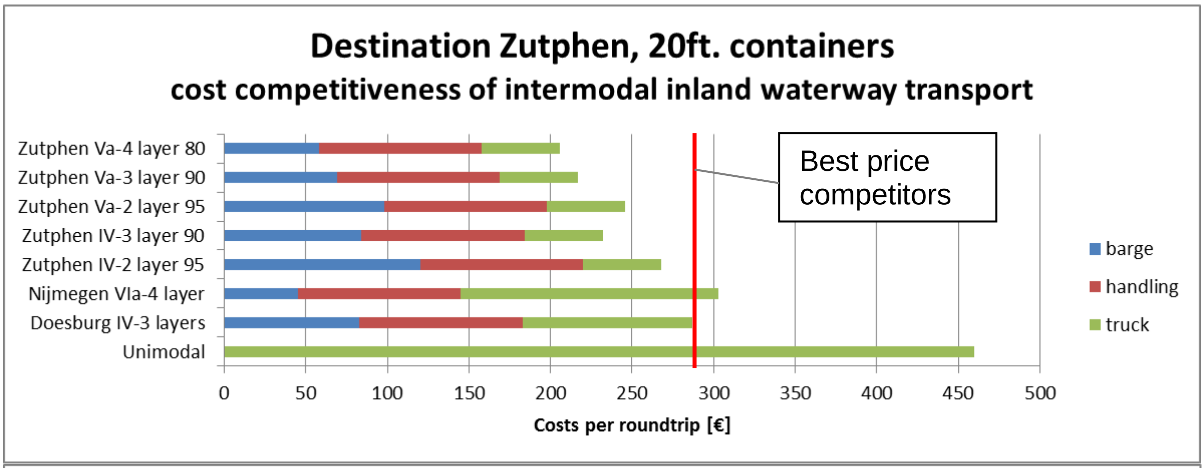
Calculations for both unimodal transport by truck and intermodal transport by barge and truck were performed for several routes and barge classes. It could immediately be seen that intermodal transport towards Zutphen, Lochem and Deventer is much cheaper via all three container terminals than unimodal road transport. Therefore, unimodal transport is not considered as the main competitor in this comparison.

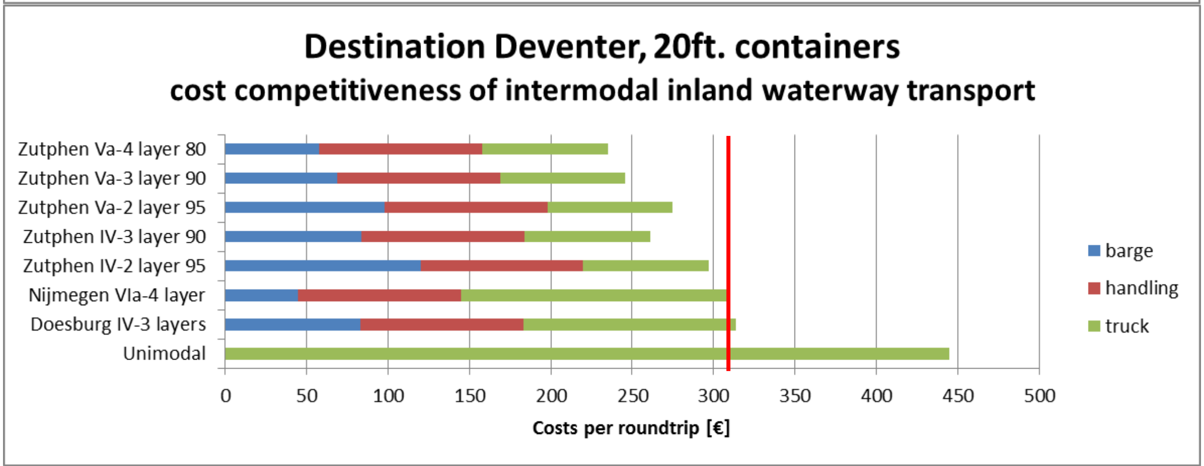
The shipping route Maasvlakte Rotterdam – Zutphen with end-haulage towards the cities Apeldoorn, Deventer, Lochem and Zutphen itself, were compared to the most efficient intermodal transport routes via the existing container terminals in Nijmegen and Doesburg. The tariff that Zutphen has to offer in order to be competitive is then related to the minimum required vessel size. Barge classes IV and Va were considered for different loading degrees in the cost comparison. Smaller vessels, the so-called Neokemp size were also considered in an initial calculation, but were found not to be cost competitive to any destination within the service area and therefore cannot be used to realize a cost competitive intermodal transport service.

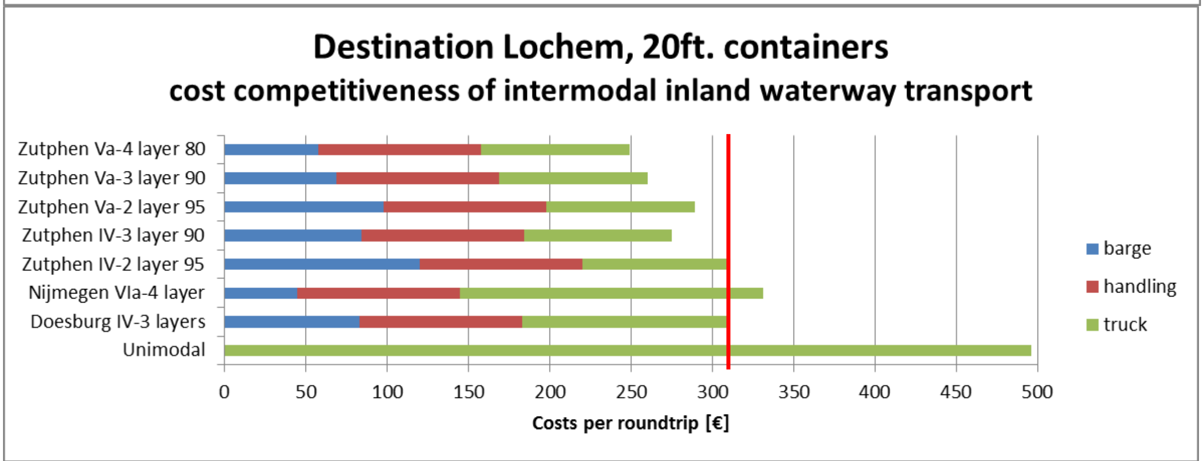
Distinction was made between 20ft (1 TEU) and 40ft (2 TEU) containers, since the costs per TEU are not the same, they are expressed as costs per container. This is due to handling costs that is expressed per container. For end-haulage it is assumed that a truck with container chassis can carry one container, either a 20ft or a 40ft one. It can be seen that for 20ft containers, intermodal transport via Zutphen is able to offer lower prices for most barge sizes. For 40ft containers, the cost competitiveness is much lower with respect to intermodal transport via Doesburg and Nijmegen.

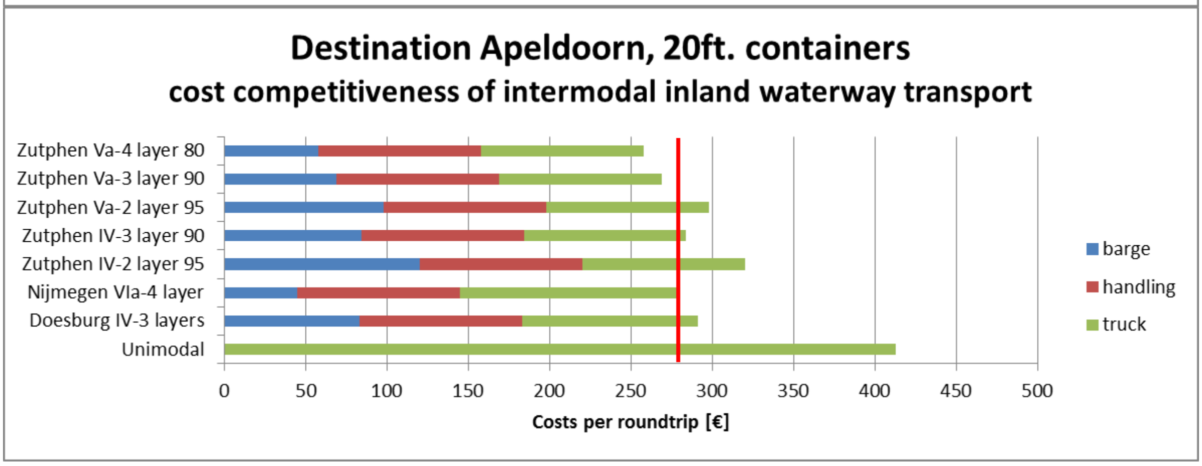
The cost for terminal handling is assumed to be equal for all three considered terminals. According to the studies of Wiegmans & Konings (2015) and Smid et al. (2016) (see subsections 3.2.2.2 and 3.3.2), the handling costs are related to the size and utilization rate of the terminal. Therefore, especially in the start-up phase of terminal operations, a terminal in Zutphen is not likely to be able to operate with the same handling costs as the terminal in Nijmegen. The tariffs for the terminal handling will be evaluated in the feasibility assessment of the inland terminal.

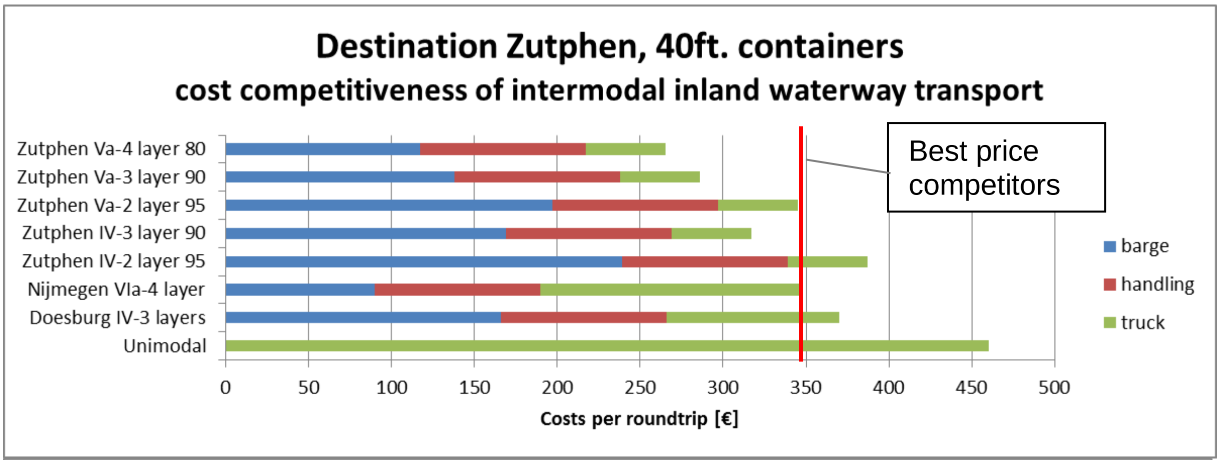
The results for the cost comparison of different barge classes and utilization rates for the potential destinations Zutphen, Deventer, Lochem and Apeldoorn are presented on the next pages. The influence of the three cost components on the total costs are indicated with different colours. The red line indicates the best price that can be offered via competitive transport modes according to the made assumptions.


Destination Zutphen, 20ft. containers
cost competitiveness of intermodal inland waterway transport
Zutphen Va-4 layer 80
Zutphen Va-3 layer 90
Zutphen Va-2 layer 95
Zutphen IV-3 layer 90
Zutphen IV-2 layer 95
Nijmegen VIa-4 layer
Doesburg IV-3 layers
Unimodal
Best price competitors
barge
handling
truck
0 50 100 150 200 250 300 350 400 450 500
Costs per roundtrip [€]


Destination Deventer, 20ft. containers
cost competitiveness of intermodal inland waterway transport
Zutphen Va-4 layer 80
Zutphen Va-3 layer 90
Zutphen Va-2 layer 95
Zutphen IV-3 layer 90
Zutphen IV-2 layer 95
Nijmegen VIa-4 layer
Doesburg IV-3 layers
Unimodal
barge
handling
truck
0 50 100 150 200 250 300 350 400 450 500
Costs per roundtrip [€]


Destination Lochem, 20ft. containers
cost competitiveness of intermodal inland waterway transport
Zutphen Va-4 layer 80
Zutphen Va-3 layer 90
Zutphen Va-2 layer 95
Zutphen IV-3 layer 90
Zutphen IV-2 layer 95
Nijmegen VIa-4 layer
Doesburg IV-3 layers
Unimodal
barge
handling
truck
0 50 100 150 200 250 300 350 400 450 500
Costs per roundtrip [€]


Destination Apeldoorn, 20ft. containers
cost competitiveness of intermodal inland waterway transport
Zutphen Va-4 layer 80
Zutphen Va-3 layer 90
Zutphen Va-2 layer 95
Zutphen IV-3 layer 90
Zutphen IV-2 layer 95
Nijmegen VIa-4 layer
Doesburg IV-3 layers
Unimodal
barge
handling
truck
0 50 100 150 200 250 300 350 400 450 500
Costs per roundtrip [€]


Destination Zutphen, 40ft. containers
cost competitiveness of intermodal inland waterway transport
Best price competitors
Zutphen Va-4 layer 80
Zutphen Va-3 layer 90
Zutphen Va-2 layer 95
Zutphen IV-3 layer 90
Zutphen IV-2 layer 95
Nijmegen VIa-4 layer
Doesburg IV-3 layers
Unimodal
barge
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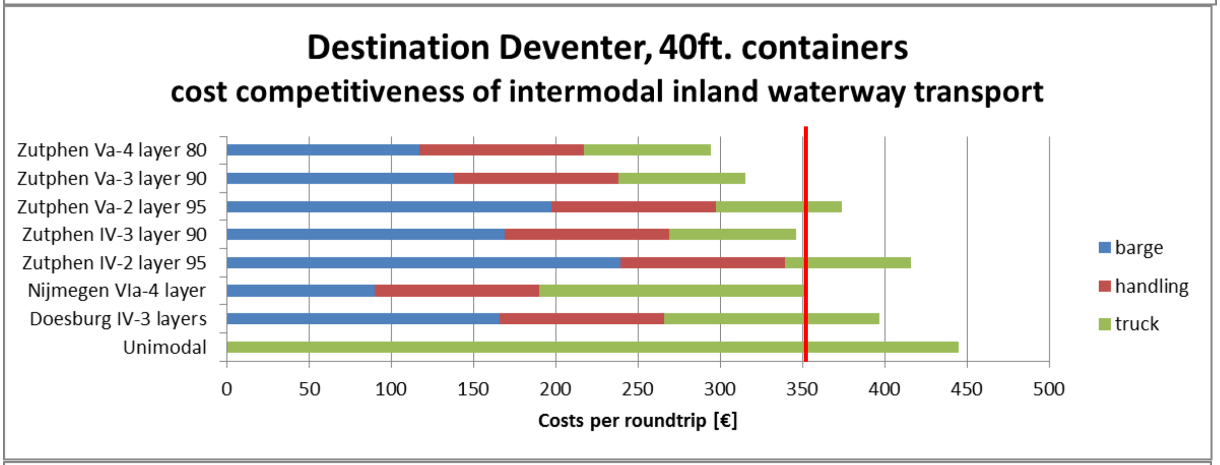
Costs per roundtrip [€]


Destination Deventer, 40ft. containers
cost competitiveness of intermodal inland waterway transport
Zutphen Va-4 layer 80
Zutphen Va-3 layer 90
Zutphen Va-2 layer 95
Zutphen IV-3 layer 90
Zutphen IV-2 layer 95
Nijmegen VIa-4 layer
Doesburg IV-3 layers
Unimodal
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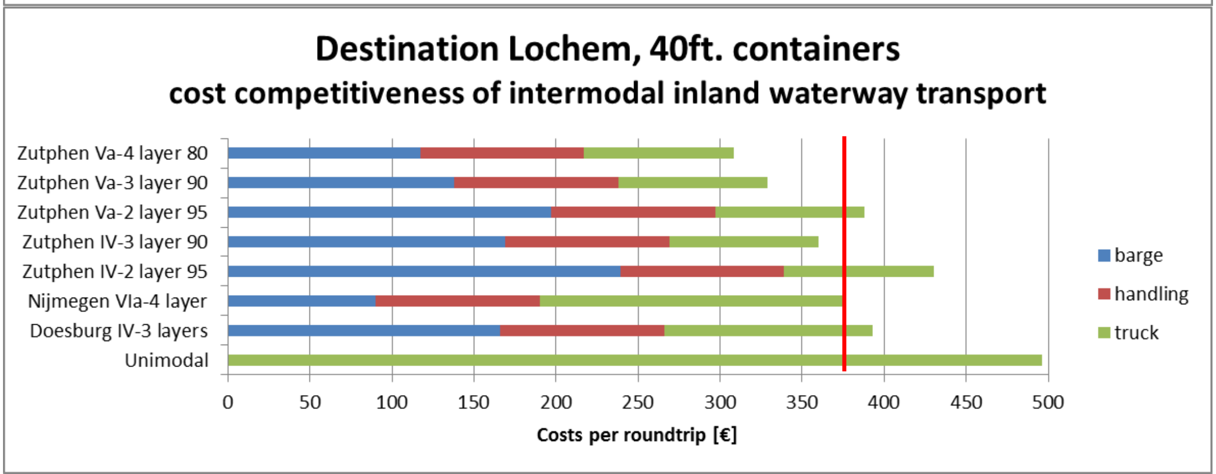
Costs per roundtrip [€]


Destination Lochem, 40ft. containers
cost competitiveness of intermodal inland waterway transport
Zutphen Va-4 layer 80
Zutphen Va-3 layer 90
Zutphen Va-2 layer 95
Zutphen IV-3 layer 90
Zutphen IV-2 layer 95
Nijmegen VIa-4 layer
Doesburg IV-3 layers
Unimodal
barge
handling
truck
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200
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350
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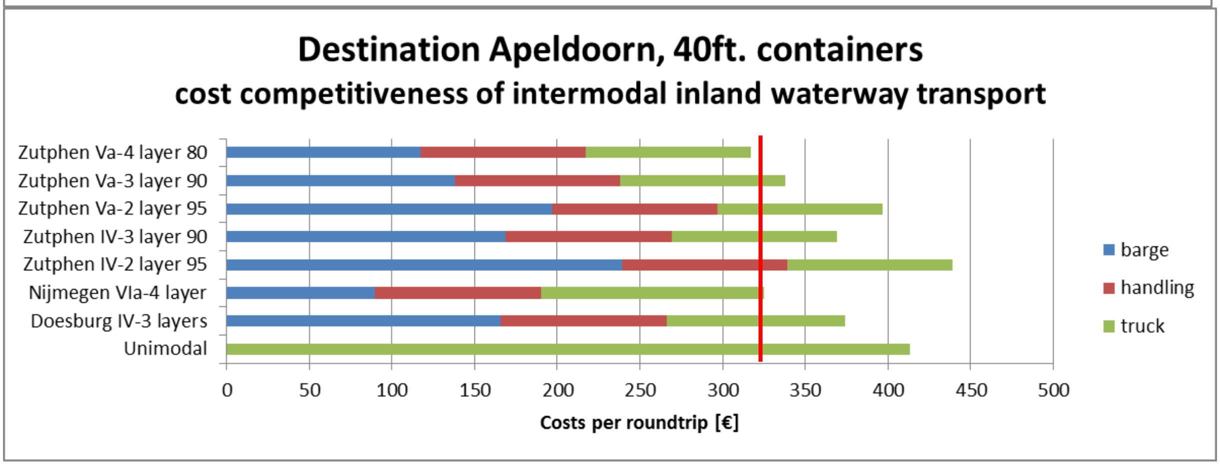
450
500
Costs per roundtrip [€]


Destination Apeldoorn, 40ft. containers
cost competitiveness of intermodal inland waterway transport
Zutphen Va-4 layer 80
Zutphen Va-3 layer 90
Zutphen Va-2 layer 95
Zutphen IV-3 layer 90
Zutphen IV-2 layer 95
Nijmegen VIa-4 layer
Doesburg IV-3 layers
Unimodal
barge
handling
truck
0
50
100
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200
250
300
350
400
450
500
Costs per roundtrip [€]

B.4 Conclusions

Several observations can be done regarding these results. The main findings are listed below:

- Apeldoorn unfeasible due to higher integral transport costs

Due to lower costs for intermodal transport via both Doesburg and Nijmegen to destination Apeldoorn, Zutphen cannot be cost competitive towards this destination. As a result Apeldoorn is found unfeasible to be included in the service area. This is due to the relatively poor road connection of Zutphen towards Apeldoorn, while Nijmegen and Doesburg have a better road connection and lower sailing costs. The Oude IJsselbrug, crossing the IJssel River cannot be accessed by trucks requiring a detour via Deventer has to be taken.

- High utilization rate of vessel required

From the cost comparison it can be noted that 2 layer transport for both CEMT class IV and Va barges are not cost competitive with the most competitive transport mode. This indicates that a sufficient loading degree for the barges is required in order to offer competitive tariffs.
It can be concluded that in order to realize a cost competitive direct shuttle service via Zutphen, it can only be cost competitive when at least a CEMT Class IV vessel with 3 layers and a utilization of 90% is used. Therefore significant cargo volumes are required to launch profitable operations. For a lower loading degree or smaller barge classes Zutphen is not able to offer a cost competitive intermodal transport service. It has to be noted that some broad assumptions were done in the calculation that are sensitive to deviations. Therefore the feasibility of a begin-and-end network must be interpreted carefully with nuance.

B.5 Discussion

According to these assumed key numbers, intermodal transport via Zutphen could be the most economically beneficial option for destination Apeldoorn, but only when a CEMT Class Va of 4 layers is used. There are however a few remarks that this class is not likely to be realisable.

First of all, it is unlikely that there will be a demand in the near future for a fully loaded Class Va barge that provides a regular shuttle service between Rotterdam and Zutphen. The identified cargo volumes in the cargo assessment will rule this argument out. Also the stability of the vessel for 4 layer transport on a Class Va vessel cannot be guaranteed according to the ROSR regulations. This depends on the average tonnages per TEU, which were due to identified industries (amongst others paper and metal) found to be too heavy for stability of a 4 layer transport. Furthermore, the dimensions of the industrial harbour are too limited for safe manoeuvring of a CEMT Class Va vessel when using the existing quay.

To design a network service with the required maximum tariff and the required vessel size is very close related. If the utilization rate cannot be fulfilled, the service will not be profitable. The terminal in Nijmegen on the other hand operates on a much larger scale and is therefore able to be much more flexible in adapting the service network.

Appendix C Assessment of potential cargo volumes

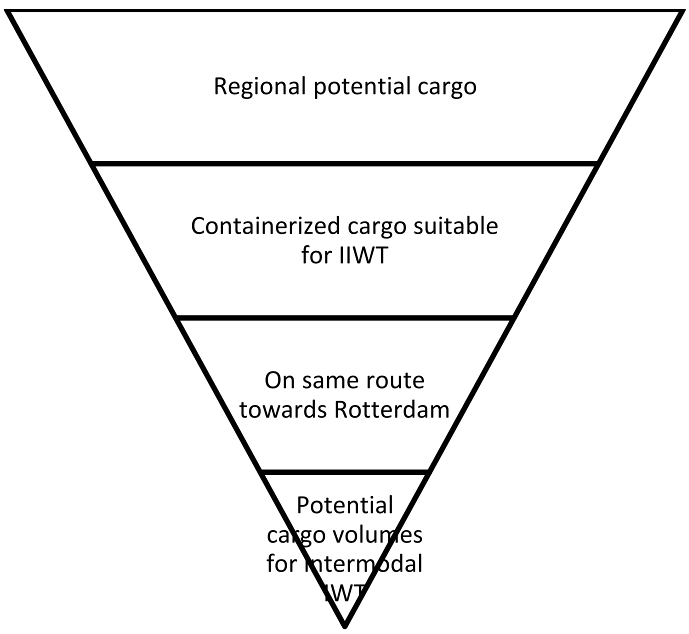
This appendix discusses the potential cargo volumes that are present in the service area. The success of initiating a new intermodal IWT service strongly depends on the available cargo volumes. An assessment was worked out taking into account the total regional cargo volumes that are transported on the same route and are suitable for intermodal transport.

C.1 Introduction

To initiate a modal shift towards intermodal transport, a certain scale is required to be competitive with unimodal road transport. Noteworthy is that according to (Visser et al., 2012) almost all existing inland terminals have large customers. Launching customers that transport a lot of containers are required for sufficient demand for an inland terminal in order to be viable. The smaller customers then join. The presence of such customers is a basic requirement for a terminal to start up and to generate sufficient cargo flow volumes.

To determine the expected scale of the cargo volumes that may be handled in Zutphen, first the potential cargo flow volumes in the service area have to be identified. The form of transportation provides whether there is demand for a bulk-, container, or multipurpose terminal. In the existing industrial harbour, there is no sufficient storage to handle bulk and as mentioned in the introduction chapter, the focus is put on containerized transport.

The current economic activities and cargo flow volumes can be determined by identifying the companies located in Zutphen and relevant industrial areas in the service area that provide potential cargo volumes. Most interesting are the import/export flows, since this is being transported on the same route to Rotterdam. In addition, the desired frequency and tonnages have to be determined. These aspects influence efficiency of the transport service, such as the ratio between the draught and loading degree and have a significant influence on the costs.



C.2 Regional cargo flows

The potential cargo flows have to be determined for the region, since launching customers are a basic requirement to initiate terminal operations. The region was explored to identify the current economic activities producing transportation flows. No reports with exact numbers of cargo flow volumes for the Zutphen region could be found. The report of KiM (Visser et al., 2012) indicated for the white spot Deventer-Apeldoorn-Zutphen a total cargo volume of 89,000 TEU in 2008 of which 89% was being transported by road. Though, this number is based on the entire COROP region Veluwe, which extends a region in a different direction than Deventer-Apeldoorn-Zutphen. These COROP regions include a much broader area than the potential service area (see Figure 0-2).Also the report of Transport en Logistiek Nederland (TLN, 2014) presented the freight volumes COROP region. These volumes are indicated in Table 0-10. The absolute numbers do not provide exact information, since it is unclear where the concentration of logistic activities per COROP region is present. It was indicated though in the KiM report (Visser et al., 2012) that the logistics hotspot of the Veluwe region is Apeldoorn. Considering the large number freight volumes for the Veluwe region, it is assumed that the majority of the potential cargo volumes can be found in Apeldoorn.

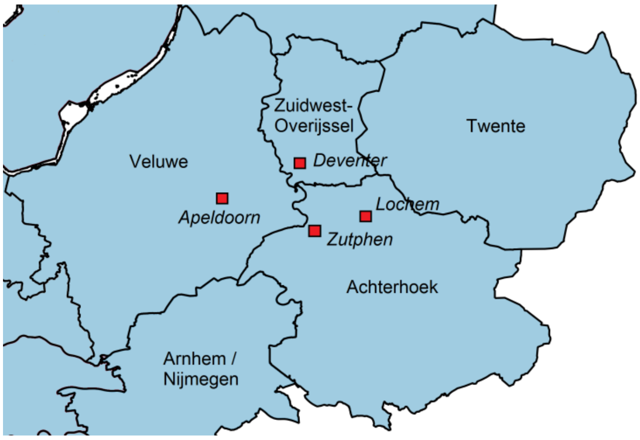


Figure 0-2. Overview of COROP regions around Zutphen

Table 0-10. Loaded and unloaded freight transport by road per COROP region. (Source: TLN, 2014)

COROP region	Loaded [x 1000 ton]	Unloaded [x 1000 ton]	Loaded and unloaded [x 1000 ton]	Share
Veluwe (Apeldoorn)	22,086	21,569	43,655	3.9%
Achterhoek (Zutphen and Lochem)	13,899	15,244	29,143	2.6%
Zuidwest-Overijssel (Deventer)	4,839	4,478	9,318	0.8%

This is somehow confirmed by the regional key figures of Centraal Bureau voor de Statistiek (CBS, 2016b) where number of business establishments per municipality are given (Table 0-11). However, these numbers represent the amount of registered businesses, without giving the company size or cargo volumes. It is illustrative and not exhaustive: it gives an indication that the relevant cities within the capture area comprise Apeldoorn, Deventer, Lochem and Zutphen itself.

Table 0-11. CBS Regional key figures: Number of business establishments per municipality (Source: CBS, 2016b)

Year	Number of businesses				
	Zutphen	Lochem	Apeldoorn	Deventer	Voorst
2013	3,105	3,060	11,165	6,425	1,970
2014	3,165	3,130	11,365	6,485	2,020
2015	3,325	3,240	11,695	6,795	2,115
2016	3,425	3,355	12,130	7,045	2,170

Other regional reports that were available were the Rabobank regional prognoses (Rabobank, 2014) and the MER-study for the extension of the Eefde locks (Grontmij, 2013). These reports expect positive trends regarding economic growth and growth of the cargo flow volumes in general; however this does not represent the service area of Zutphen, neither does it specify exact numbers of transportation demands. As a result, the major companies at business park De Mars were contacted to identify the potential cargo flows.

C.3 Launching customers on De Mars

Since the required data could not be found in the available reports, the large customers in De Mars were contacted to estimate the potential cargo flow. From these interviews it was concluded that the required cargo volumes for terminal operations could not be found by one player. Only three companies on De Mars transport containers on a weekly basis towards Rotterdam. These companies (indicated in Figure 0-3) are Van Gelder Papiergroep, Daly Plastics and Aurubis and their industries include recycling of paper, recycling of plastics and metals. Together, these companies might potentially team up as launching customers for a terminal in Zutphen, after which smaller companies can join. This can only be done if commitment is shown by all parties, since only then a minimum amount of transported containers can be realized for viability of a terminal.

After the interviews, it was found that their combined weekly transported volumes range between 25-75 containers, of which the ratio 20ft / 40ft is 1:2. A remark must be made that not all of these customers are willing to commit beforehand due to various reasons. There is scepticism regarding the policy of the municipality in the past regarding the failure of previous attempts to realize a terminal Zutphen. Also the recent start of operation of the terminal in Doesburg is seen as interfering in the service area. It can be concluded that <u>no launching customer</u> can be found in Zutphen that is able to deliver the required cargo volumes for terminal operations by one key player.

Figure 0-3. Identification of customers in De Mars that are currently transporting containers

C.4 Total identified cargo volumes in the service area

From the above consulted sources, it can be noted that the required cargo volumes should be attracted from other cities in the service area around Zutphen. The three companies on De Mars that transport containers on a weekly basis towards Rotterdam have a combined volume of 100 TEU per week, with a correspondining to a TEU-factor of 1.67. To calculate the TEU- factor the following equation is used (Ligteringen & Velsink, 2012):

$$f_{teu} = \frac{N_{20} + 2 \cdot N_{40}}{N_{20} + N_{40}}$$

In which:
N_{20} = number of TEUs
N_{40} = number of FEUs

For the remainder of the service area, the expected cargo volumes were estimated by the author based on literature, the best available data and expert consultation. For Deventer and Lochem a similar TEU-factor was assumed as Zutphen. For Apeldoorn, a higher share of 40ft containers is expected, since currently nearly all cargo is transported by road, which is economically more beneficial for 40ft containers. A TEU-factor of 1.75 is assumed. The potential cargo volumes that were identified are presented in Table 0-12.

Table 0-12. Potential cargo volumes identified in the possible service area

Potential volumes	Zutphen			Deventer			Lochem			Apeldoorn			Total in region		
	20ft	40ft	TEU	20ft	40ft	TEU	20ft	40ft	TEU	20ft	40ft	TEU	20ft	40ft	TEU
Verified by companies [1)]	20	40	100												
Expected based on literature [2)]				20	40	100	10	20	50	70	140	350			
Total weekly volumes	20	40	100	20	40	100	10	20	50	70	140	350	120	240	600
Total annual volumes	1040	2080	5200	1040	2080	5200	520	1040	2600	3640	7280	18,200	6240	12,480	31,200

[1)] Based on interviews with companies, refer to Appendix E
[2)] All based on literature and best available data (CBS, 2016b; TLN, 2014)

A remark must be made that from the interviews it became clear that not all shippers are willing to commit beforehand due to various reasons. In Zutphen there is scepticism towards a successful realization of a terminal, due to the failure of previous attempts and the recent opening of the terminal in Doesburg. Also the shippers in Deventer are not likely to commit beforehand, due to the pending terminal initiative in Deventer. Therefore, the cargo assessment should be interpreted with caution.

C.5 Trends and developments of cargo volumes

For the last decades, several prognoses for the growth expectations of the barge container market in the Netherlands have been conducted. A commonly used study for the long term predictions for the year 2040 is the CPB report ‘Welvaart en Leefomgeving’, (Janssen et al., 2006). This report presents four so-called WLO-scenarios that cover the following themes: demographics, macro-economy, regional developments, urbanization, climate and energy, mobility and agriculture.

Ecorys nationwide capacity analysis

Ecorys issued a report commissioned by the Dutch Ministry of Transport, Public Works and Water Management covering a nationwide analysis of the capacity of inland terminals (Ecorys, 2010). This study predicted a general trend of increased containerized cargo transport. These growth expectations are based on globalization and containerization of transported goods. The modal shift towards more barge transport is expected to grow accordingly, since several agreements have been committed by the government and European Union to transport more containers from Maasvlakte 2 to the hinterland by barge. However, the Ecorys rapport dates from 2010, following the two most optimistic WLO-scenarios of which the GE-scenario has officially already been rejected. Therefore these forecasts showed predictions that were too prosperous.

Port of Rotterdam port vision

That the forecasts are were too prosperous is confirmed by the latest port vision update of the authorities of the Port of Rotterdam (Port of Rotterdam, 2016). Port of Rotterdam presented four new scenarios that were drafted with consultation of the Centraal Plan Bureau, the institute Clingendael, Ecorys and the banks ING, ABN AMRO and Rabobank. These new scenarios show a much lower growth expectation than in the WLO scenarios. Where the WLO scenarios predicted a growth of 3 out of the 4 scenarios after 2020, the new sketched scenarios consider even a decline of the growth after 2020 for 2 of the 4 scenarios Figure 0-4. This will most likely also affect the growth expectations for the inland waterway transport sector.

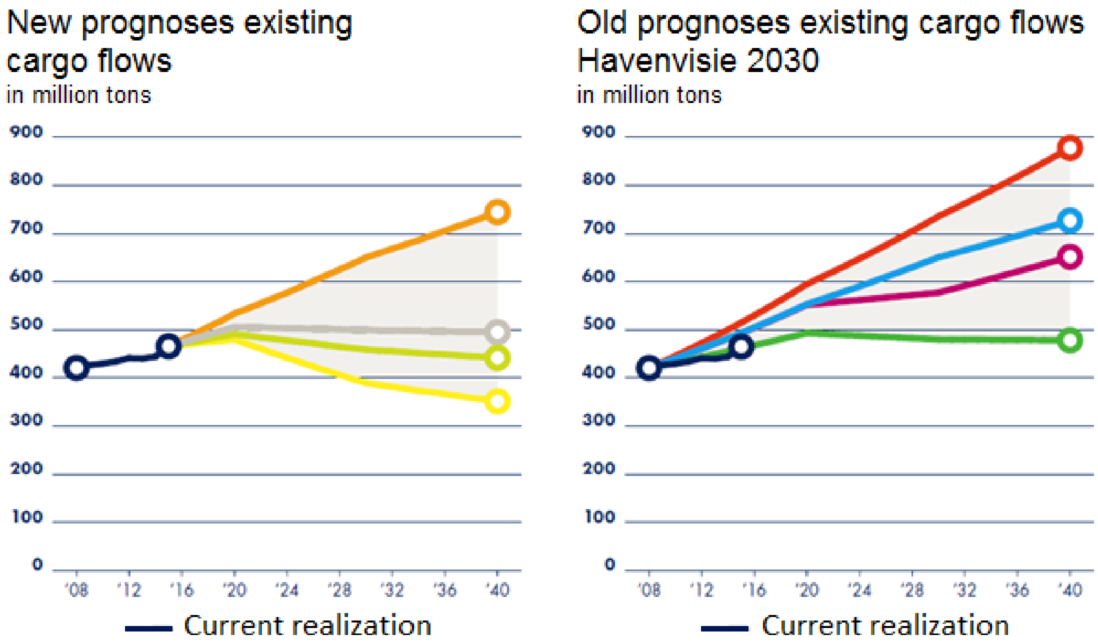


Figure 0-4. Development of cargo volumes with respect to: 1) left: the new prognoses by Port of Rotterdam and 2) right: the old prognoses from Havenvisie 2030. Source: (Port of Rotterdam, 2016)

The port vision report also shows an increase of modal split for road transport over 2016, whereas this was intended to decrease in favour of rail and barge transport. The barges in Rotterdam suffer from congestion by the handling of containers at the terminal. The Port of Rotterdam has taken measures to improve this and their expectation is that the modal split will shift towards a higher share for the inland waterway sector.

Local trends
In the last decade, the business park De Mars has been under pressure, due to the high vacancy rate. This is mainly caused by the disappearance of two large firms. Paperlinx (former Bührmann Ubbens) went bankrupt and Steffex moved their business elsewhere (De Stentor, 2016). The municipality is aiming to attract new businesses to replace the vacant places at De Mars, amongst others by improving the business climate towards the cleantech sector. Realization of a terminal might attract new businesses with intermodal transport flows towards, but comes with a lot of uncertainties.

Growth scenarios for Zutphen region
The Port of Rotterdam prognoses are based on national cargo volumes and do not necessarily apply to regional trends and developments. However, due to the uncertainties on business park De Mars and lack of regional trend reports, the trends from these prognoses will be applied for the Zutphen region as well. A baseline scenario is taken into account in case of 0% growth. The other cargo flow prognoses for the Zutphen region take the average growth rates of the two highest and lowest Port of Rotterdam prognoses into account. These regional prognoses are coupled to the share of the potential volumes to be captured as presented in Table 5-2.

Table 0-13. Growth scenarios for the Zutphen region

	Cargo flow prognoses for Zutphen region		
	Decline	Baseline	Growth
Annual growth	1% decline	0%	2% growth
Share of potential volumes captured	90% of assumed volumes	As per Table 4-1	120% of assumed volumes*

* No more than 100% of potential cargo volumes

Based on the expected cargo flow volumes, a low-cost and low-profile terminal is desired. Therefore the required investments for the development of a terminal at location Fort de Pol are assumed to be too high to be viable. The upper limit of these cargo flow scenarios is lower than the cargo volumes assumed in the preliminary design of the terminal at Fort de Pol (Royal Haskoning, 2002). Therefore, as a location, only the industrial harbour will be taken into consideration for the development of terminal solutions.

C.6 Conclusions
The above analyses demonstrate that determining the expected cargo volumes is complex and depends on several factors. First the area was explored to identify potential customers and competitive transport modes. The major cities with industrial areas within a 20km range of Zutphen are Apeldoorn, Deventer and Lochem, and are considered to comprise the service area. The competitive transport modes were found to be intermodal IWT via the terminals in Nijmegen and Doesburg.

The cargo assessment pointed out that no launching customer being able to deliver the cargo volumes that are required to initiate terminal operations could be found in Zutphen, The total available cargo volumes in Zutphen are limited and from interviews it became clear that no commitment could be given beforehand by the shippers. Further along in the service area, the total potential cargo volumes were found to be approximately 31,000 TEU/year, of which most cargo volumes were identified in Apeldoorn. The share of these potential cargo volumes that can be captured depends on the offered transport tariffs and service level. Only if this satisfies the shipper’s preferred service attributes, cargo can be attracted.

The analysis of the cost competitiveness showed that other transport modes are able to offer very competitive prices; hence the available margins to initiate a profitable barge service and terminal operations are limited. The poor road connection towards Apeldoorn induces high costs for pre- and end-haulage by truck, which complicates Zutphen to offer competitive transport tariffs to attract potential shippers from Apeldoorn. As a result, it can be concluded that the expected cargo volumes to be captured are restricted to a small share of the total identified potential cargo volumes of 31,000 TEU/year.

Appendix D Analysis of water level variations

This appendix addresses the water level variations that occur on the shipping route between Rotterdam and Zutphen. The IJssel River is an unregulated river, which causes the water levels to fluctuate quite considerably over the year. In recent years, the occurrence of low water levels led to a limited loading degree of the barges, which is of interest because it affects the scale of operation that is possible. An extensive data set was analysed to identify the water levels on the waterways towards Zutphen.

D.1 Governing water levels

Rijkswaterstaat measures the water levels on several measurement points along the main waterways in The Netherlands. When limited water levels occur, this has consequences for the loading degree of barges. A statistical analysis was performed an extensive dataset that was retrieved via Rijkswaterstaat for the period 1990-2016. The water levels near Zutphen were analysed together with the least sounded depths on the shipping route towards Zutphen.

Because the IJssel is a river unaltered by hydraulic structures such as weirs, the water level variations can be quite significant as can be seen in the table below. These water level variations have consequences for unloading equipment. For example, a reachstacker is not able to (un)load a vessel during these low water levels. Also the water depth can vary in a relatively short period, which affects the loading capacity of the barges when the depth is limited.

Situation	Water level in cm + NAP
OLR	276
Average discharge	440
Exceeded once per year	720
Normative highwater	915

D.2. Analysis of water levels at measurement point Zutphen Noord

Close to the mouth of the industrial harbour, measurement point Zutphen Noord is located. Rijkswaterstaat measures the water levels at this point, indicated in Figure 0-5. Following the data that was used in the design of Noorderhaven marina, the bottom level of the IJssel River is located at NAP 0.0 m or lower (Witteveen+Bos, 2010). If maintenance dredging is performed, the bottom level of the industrial harbour in Zutphen is equal to the bottom level of the IJssel according to Zutphen's harbour master Theo Albers and the report of Van Roekel & Van Roekel. Therefore the bottom is assumed to be located at NAP 0.0 m.

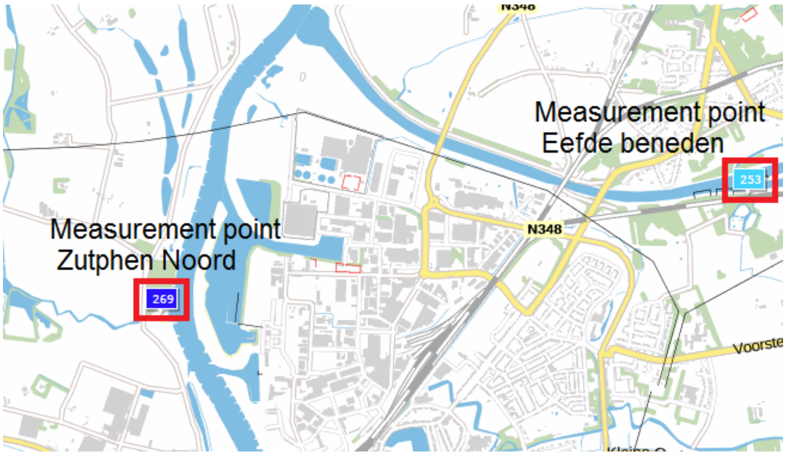


Figure 0-5. Measurement point Zutphen Noord

A dataset for the last 26 years of the water levels at Zutphen Noord was analysed. The occurrence of all water levels is evaluated by calculating the water levels into probabilities of non-exceedance. For each year, the highest and lowest water levels and the water levels corresponding to certain probabilities of non-exceedance were determined, as presented in Table 0-14. The values undershooting the OLR are indicated in bold.

Table 0-14. Probability of non-exceedance for different water levels in river Ijssel at measurement point Zutphen Noord

Year	Zutphen Noord						
	Highest	90%	70%	50%	30%	10%	Lowest
1990	724	534	417	402	385	317	**270**
1991	730	476	407	395	347	**287**	**227**
1992	678	577	445	408	386	330	**253**
1993	833	557	440	409	392	374	354
1994	760	651	533	442	405	377	321
1995	846	666	552	454	398	352	312
1996	654	497	411	388	360	325	294
1997	724	500	424	400	375	311	**267**
1998	816	611	495	434	402	350	**271**
1999	746	641	562	494	401	390	311
2000	724	624	499	450	431	414	395
2001	769	659	542	471	343	406	362
2002	754	694	574	468	424	408	374
2003	794	572	414	384	314	**248**	**205**
2004	736	518	431	411	401	361	321
2005	692	523	454	415	395	328	**267**
2006	704	595	455	414	395	337	291
2007	732	624	515	456	428	376	314
2008	667	580	462	424	411	389	337
2009	650	518	447	415	390	280	**226**
2010	707	582	473	440	422	379	345
2011	779	552	417	373	317	**257**	**218**
2012	735	596	443	423	409	360	302
2013	732	584	489	449	431	408	301
2014	566	504	453	427	400	335	287
2015	677	558	456	426	328	**269**	**234**
2016*	700	672	572	466	435	320	**227**

Most important findings of the water levels near Zutphen are that the agreed low water level (OLR) criterions are not always fulfilled. The OLR is the guaranteed water depth that can only be undermined 5% of the time. In the years 1991, 2003, 2011 and 2015 the water levels undershot the OLR criterion at more than 10% of the time. These are the ‘bad year’ scenarios with long periods with low water levels, which imposes serious consequences for the maximum draught and therefore the maximum load of the barges. Based on the 1990 – 2016 data, on average, the OLR 1990.0 (NAP +2.90 m) is being undershot at 2.7% of the time and the OLR 2006.0 (NAP +2.76m) 1.92% of the time. Assuming the bed level is located at NAP 0.0 m, the guaranteed water depth of 2.76 m is well within the 5% undershooting criterion.

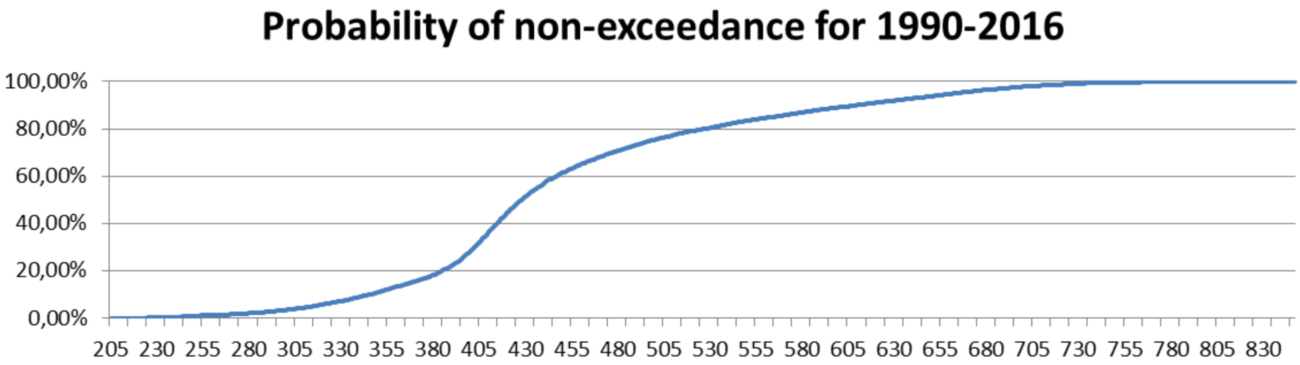


Figure 0-6. Probability of non-exceedance for entire data set for different water levels at measurement point Zutphen Noord [in cm +NAP]

D.3 Trends of the occurring water levels at measurement point Zutphen Noord.

The dataset of 27 years was subdivided in 3 datasets of 9 years, to identify more recent trends. It seems that the average water level at Zutphen Noord has decreased somewhat. The OLR criterion was adjusted by Rijkswaterstaat in 2006 from +2.90m to +2.76m, which indicates that the average water level was lowered of the course of time. This trend can slightly be recognized in Figures 0-7 to 0-10, but it has to be studied further to draw such conclusions.

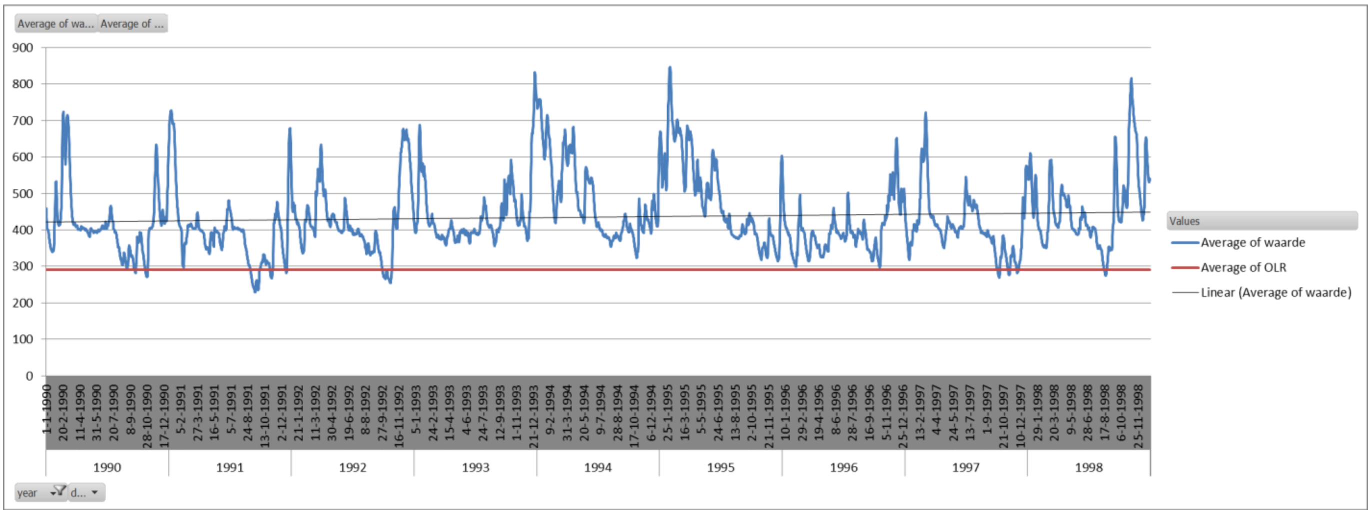


Figure 0-7. Trend line 1990-1998 slightly increasing for average water levels

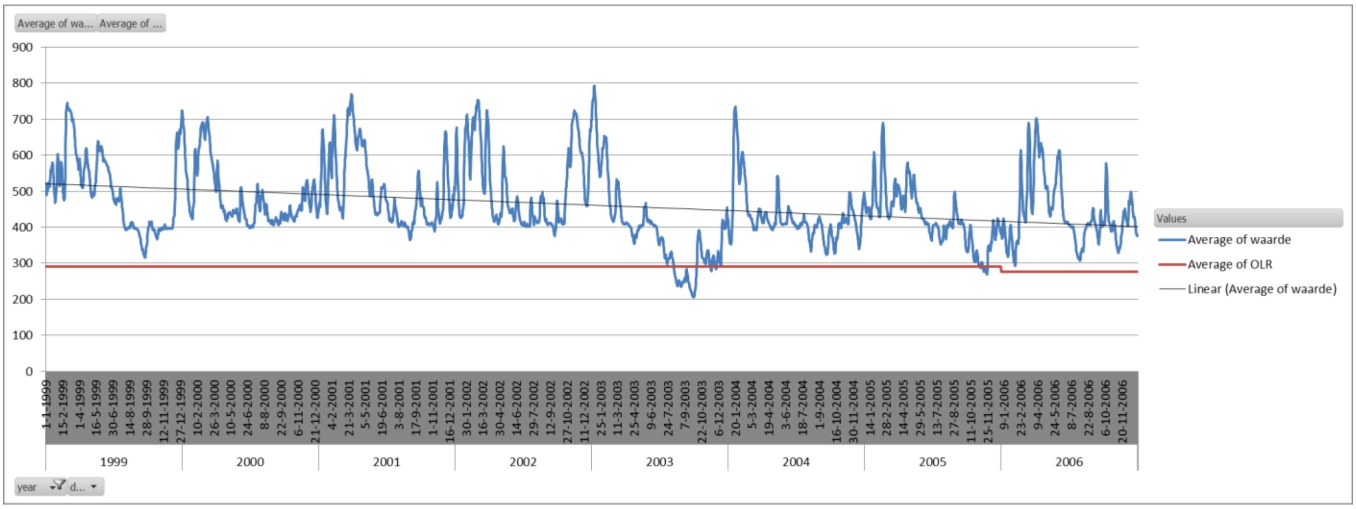


Figure 0-8. 1999-2006: Trend line sharply decreasing for average water level. Also: 2006 the OLR level was adjusted to NAP +2.76m instead of NAP +2.90m

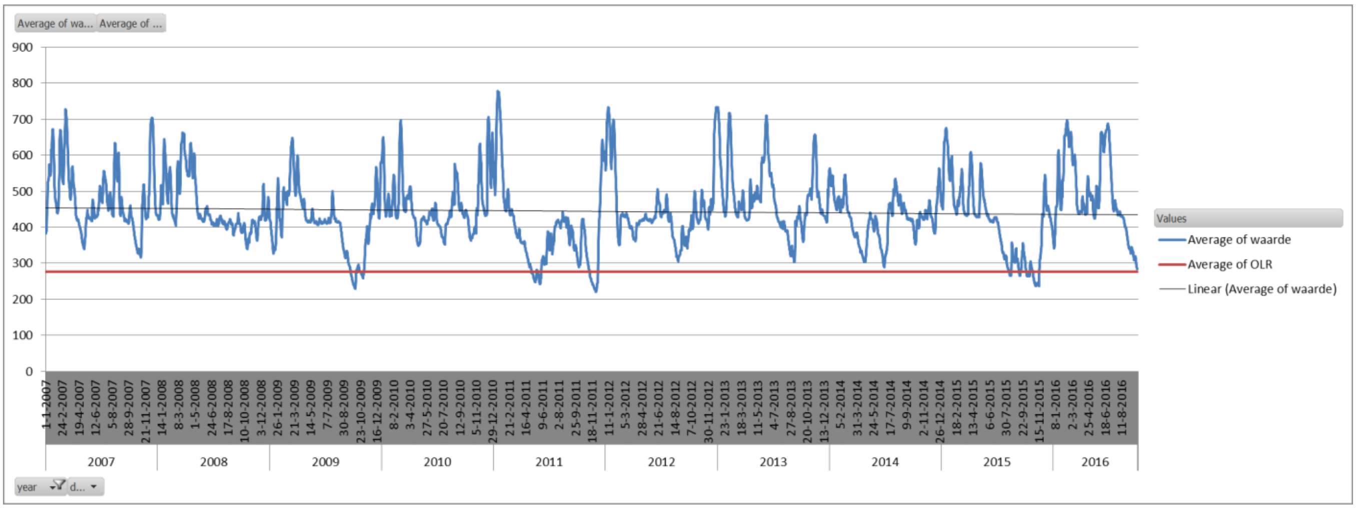


Figure 0-9. 2007-2016:Trendline slightly decreasing for average water levels

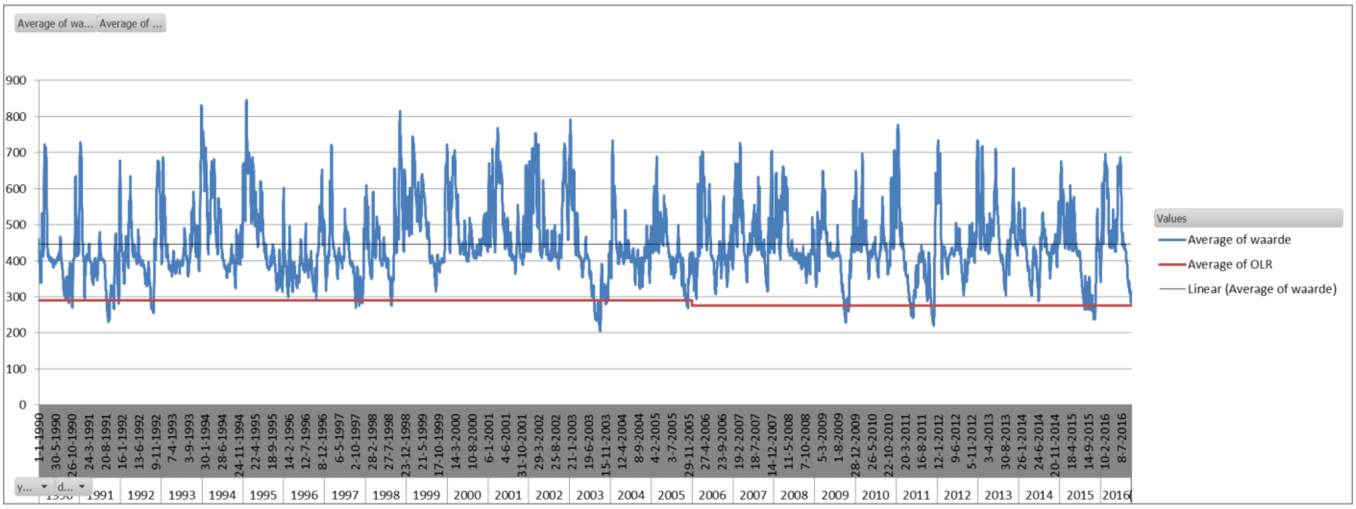


Figure 0-10. However for entire dataset 1990-2016, trend line is more or less stabile:

D.4 Least sounded water depths river section IJsselkop - Mouth Twentekanaal
Rijkswaterstaat also measures the least sounded depths at several river sections and reports when the water depth is 3.0m or less. For barge transport on the route Rotterdam – Zutphen, the normative river section is IJsselkop – M. Twentekanaal. A dataset for the same period 1990-2016 was retrieved from Rijkswaterstaat and transformed into different section with probabilities of non-exceedance. These were determined per 10cm of water depth difference. The probability of non-occurrence is presented in Table 0-15.

Least sounded water depth [cm]	**Average for period 1990 - 2016**	**Average of 5 worst years for period 1990 - 2016**
	Probability of non-exceedance	Probability of non-exceedance
180	0.8%	2.4%
190	1.3%	4.4%
200	1.7%	**7.6%**
210	2.5%	10.9%
220	3.3%	13.7%
230	4.5%	17.1%
240	6.0%	21.4%
250	7.9%	24.6%
260	**9.8%**	28.6%
270	12.2%	31.6%

Table 0-15. Probability of non-exceedance for least sounded water depth at river section IJsselkop – M. Twentekanaal for period 1990 - 2016

It can be noted that the 5% undershooting criterion is only met at a least sounded water depth of 2.30 m (!), which is significantly less than the OLR water levels that were measured at Zutphen Noord. Therefore the least sounded depths on the shipping route are the governing limitations of the waterway.

To make an assumption at what occurrence the loading degree of the barges is limited, a distinction between two scenarios will be considered; the scenario of low water depths for an average year and during a ‘bad year’. A bad year occurs approximately every five years. These ‘worst’ five years in the period 1990-2016 were analysed and their probability of non-exceedance is shown in the right column of Table 0-15. It is assumed that above a probability of non-occurrence of 1/10 of the time, the loading degree of the barges is such limited that additional sailing costs have to be taken into account. The corresponding water level limitations that will be used in the design for the 2 scenarios are:

Scenario “average year” 260 cm
Scenario “bad year” 200 cm

This means that these water levels occur on average for 1/10th of the time in an “average year” and “bad year” respectively.

D.5 Tonnage-draught relation
These water level limitations can be related to the average tonnages of the containers and therefore the limitations of the utilization. The tonnage certificate for CEMT Class IV and Va were used to determine the tonnage-draught relation. This is a nearly linear relation between the draught of the vessel and the loading capacity in tons. The expected tonnage per container is assumed to be 20ton for a 20’ and 25ton for a 40’ container. This is based on the average container weight of the current industries located at De Mars. For the given ratio this gives an average of 14 ton/TEU.

As a result the tonnage certificates are transformed into a relation between the vessel draught and the loading capacity in TEU, as presented in Figure 0-11. The corresponding loading limits for an ‘average year’ and ‘bad year’ are also indicated in the figure. For the draught of the vessel, an under keel clearance of 30cm was used. Therefore the effective limited draught of the vessels was 2.30m for an “average year” and 1.70m for a “bad year”.

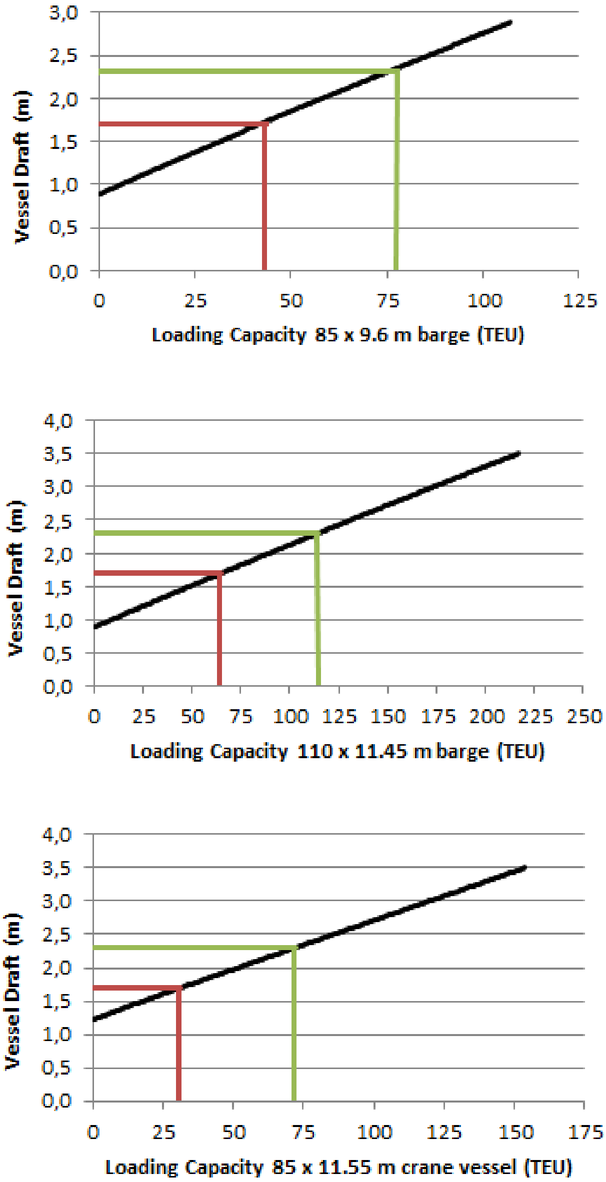


Figure 0-11. Draught - loading capacity relation for CEMT Class IV and Va barges and crane vessel, taken into account an average of 14 ton/TEU.

The water level limitations lead to limitations of the loading capacity for the barges as depicted below. Additional costs for the transport of containers have to be taken into account.

Barge size	Capacity	Limited capacity for “Average year”	Limited capacity for “Bad year”
CEMT Class IV	90 TEU	78 TEU	45 TEU
CEMT Class Va	156 TEU	115 TEU	65 TEU
Crane vessel	96 TEU	72 TEU	31 TEU

Appendix E List of interviewees

Several interviews were conducted with local policy makers and entrepreneurs to gain understanding of the interests of all parties. The interviews provided information regarding the previous terminal initiatives and served to make an estimate of the available cargo volumes in Zutphen.

Name	Function and company	Contribution
Theo Albers	Harbour master, Gemeente Zutphen	Provided information about the manoeuvrability of barges in industrial harbour
Edwin Nordkamp	Project Engineer, Gemeente Zutphen	Structural information about the strength of the existing quay in the industrial harbour
Vincent Thunnissen	Strategic consultant economics, Gemeente Zutphen	Provided general information about the companies surrounding the industrial harbour and area development
Christian Lorist	Regional manager Stedendriehoek, VNO-NCW	General information about the area policy regarding development of water bound activities
Frans Manders	Forum member, PvdA Zutphen-Warnsveld	One of the initiators of this study. Provided general information about the history of previous terminal attempts.
Frans Heitling	Council member, PvdA Zutphen-Warnsveld	One of the initiators of this study.
Henk Janssen	Director, Cleantech Center	One of the initiators of this study. Provided contact information of several parties
Jos Addink	Director, Addink Distributie Parkmanager, business park De Mars	One of the initiators of the previous terminal. Provided background information of this attempt and why it did not succeed.
Gerard van 't Hul	Managing director, Van Gelder Papier Groep Zutphen	Interview about the volumes of transported cargo volumes and frequencies. Also provided background information about the previous terminal initiative when working for Van Gansewinkel.
Rob Slager	Supply Chain Manager, Aurubis BV	Interview about the volumes of transported cargo volumes and frequencies
Hans Grootjans	Supply Chain Coordinator, Amcor BV	Interview about the volumes of transported cargo volumes and frequencies
Roy Schrijver	Entrepreneur, Schrijver BV	Interview about the volumes of transported cargo volumes and frequencies
Peter Daalder	Director, Daly Plastics	Provided background information about previous terminal initiative. Interview about the volumes of transported cargo volumes and frequencies

Appendix F Calculations for terminal solutions

This appendix presents the calculations of the technical designs of the three proposed terminal solutions, which includes a background on the made assumptions and the calculations of the anchored sheet pile walls.

F.1 Physical boundary conditions

Design water levels

- In the analysis of the water levels (refer to Appendix D), it was found that the bottom level in the industrial harbour is equal to the bottom level in the IJssel River, given the assumption that the industrial harbour is dredged for maintenance. As a result, the water level measured at measurement point Zutphen Noord (close to the mouth of the industrial harbour) is assumed to be equal to the water level in the industrial harbour.
- The same analysis shows that the water levels exceed the OLR value of 2.76m for 95% of the time. This does not limit the maximum draught (2.5m) of a fully loaded Class IV vessel for the average tonnages per container that were identified (14ton/TEU). As a result, besides maintenance dredging, the industrial harbour does not require deepening in order to facilitate the mooring of a fully loaded container barge.
- The industrial harbour is part of dike-ring 50, a primary flood defence system, where the norm prescribes an exceedance probability of 1/1250 per year. The corresponding design height of the quay is prescribed to retain a water level of NAP +9.15m.
- The lowest recorded water level in the industrial harbour since 1990 is NAP +2,06m. This is considered the governing low water level for the design of the quay.
- The highest recorded water levels in the IJssel River for which no obstruction for inland navigation occurs is considered to be equal to the water level corresponding to the yearly exceedance probability of NAP +7.20m. This water level is considered the governing high water level during terminal operations.
- The water levels variations are too big for (un)loading of the barges with a reachstacker, hence the handling of the containers has to be carried out by a harbour crane.

Soil parameters

At several locations at the dike-ring around Zutphen, cone penetration tests (CPTs) were performed (Grontmij, 2003). Based on these CPTs, a representation of the soil profiles can be determined. 4 CPTs were performed at the industrial harbour, as indicated in Figure 0-12, where the soil appeared to be fairly consistent. The CPT at the location along the embankment, illustrated in Figure 0-13 was considered to be representative for the industrial harbour. By interpreting the CPTs using the representative values according to table 7.1 of the CUR166 guideline and following the Grontmij-report, the following soil material properties are determined:

Table 0-16. Representative soil material properties at the industrial harbour

Soil type	Upper level [m +NAP]	Volume weight γ/γ_{sat} [kN/m^3]	Angle of repose φ [º]	Cohesion c' [kPa]
Sandy clay	9.15	17.7/19	25.2	0.9
Sand	8.5	18/19	30	0
Clay	7.0	18.1/18.7	25.6	3.2
Sand	6.3	18/19	30	0
Silty sand	4.3	17.7/19	25.2	0.9
Sand	3.5	18/19	30	0

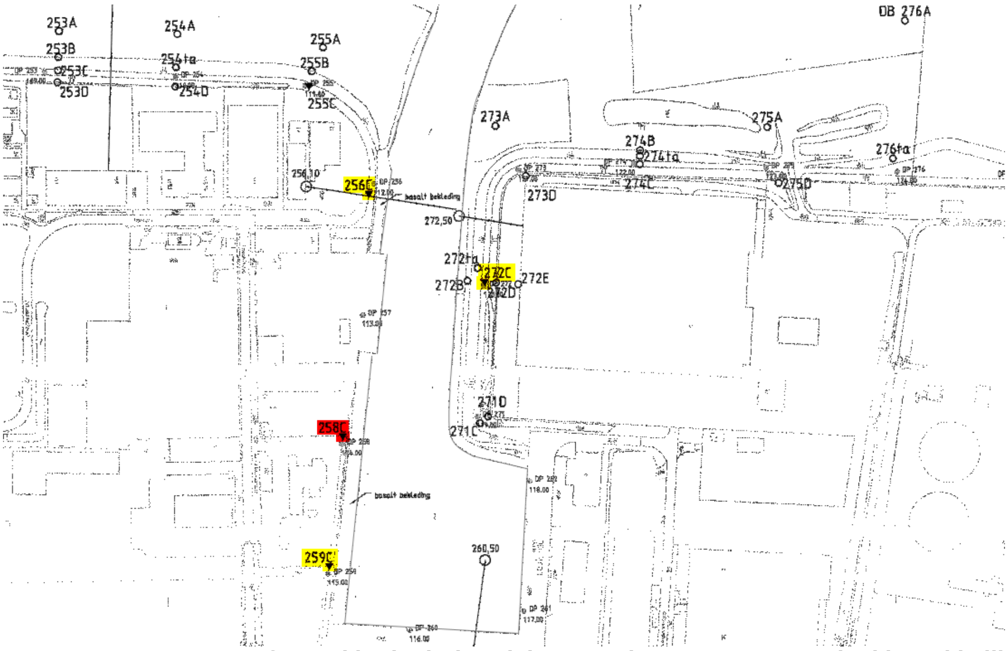


Figure 0-12. Four CPTs were performed in the industrial quay, where nr. 258C, marked in red is illustrated in Figure 0-13. Source: Grontmij (2003)

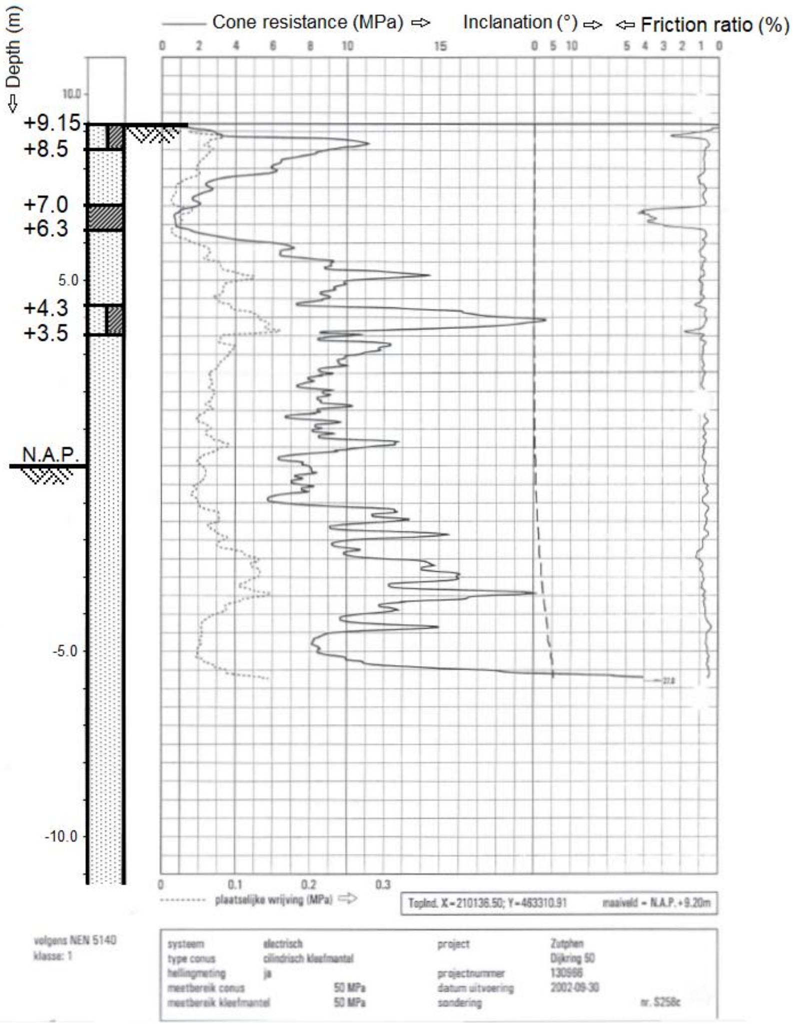


Figure 0-13. Representative CPT for the industrial harbour, marked in red in Figure 0-12.

F.2 Loads

The following loads were taken into account for the terminal design. For a specification of these values is referred to Appendix F.

- The governing loads for the handling equipment are the result of the wheel load of a reachstacker. Following the Fugro report (Fugro, 1998), where a calculation of the existing quay was conducted, a reachstacker with a lift capacity of 42ton is assumed. A corresponding wheel load of 790kN/m^2 was found to be governing.

- For the mobile crane, two governing load situations can be distinguished: during terminal handling and during allocation of the crane. A mobile crane with a lifting capacity of 42t is assumed in the design(Van Roekel & Van Roekel, 2013). During terminal operations, the dynamic load on the outrigger pads induces a force of 1080kN. Dependent on the size of the outrigger pads, a resulting load is transferred onto the quay. A governing wheel load of 129kN is calculated as a result of allocation of the mobile crane. A contact area of 0.09m^2 leads to a corresponding wheel pressure of 142 kN/m^2.

- Following “Advies Richtlijn Afmeervoorzieningen” (Rijkswaterstaat, 2004), the bollard forces for barges are considered to be 200kN for CEMT Class IV barges and 250 kN for CEMT Class Va barges.

Storage area/ stack:

Size feet / inches	Length [mm]	Width [mm]	Height [mm]	Max. mass [kg]
20 standard 20’ x 8’ x 8’6”	6,058	2,438	2,591	30,480
40 standard 40’ x 8’ x 8’6”	12,192	2,438	2,591	32,500

Source: Brochure Container Specification of Hapag-Lloyd (2012)

Stacks usually go up to 4 high
Considering 40ft containers, all with maximum loading, there will be a static load of 32,500kg * 9.8kN/kg * 4 = 1274 kN on the supporting infrastructure. The resulting average load is then: 1280 kN / (2.438*12.192 m2) = 43 kN/m2

Considering 20ft containers: static load of 300 kN * 4 = 1200 kN. The resulting average load is: 1200 / (2.438 * 6.058 m2) = 81 kN/m2

For the manoeuvrability of handling equipment 15 meter wide isles are prescribed. It is assumed that for the design of the quay wall, a uniform load of 40kN/m^2 is present. This corresponds to an average stacking height of 3 layers of containers over the entire area.

Choice of container handler

For the handling of containers at the terminal, a choice can be made between a reachstacker and a dedicated forklift truck. The choice can be made based on four main attributes: Storage, Selectivity, Capacity and Load Centre, and Manoeuvrability. A forklift container handler can stack one row only, whereas a reachstacker can stack multiple rows in ‘pyramid’ shape: e.g. 4 high in second row, 3 high on first. Because the size of the available areas is limited, a **reachstacker** is preferred, since it is much more efficient in the use of space.

Corresponding load of reachstacker
A reachstacker with a service weight of 64.1 ton and lifting capacity of 41 ton is used in the calculation. The following axle pressures were found to be governing:

Axle	Axle load [kN]	Position w.r.t. sheet pile [m]
1	947	1.0 or 2.5
2	114	7.0 or 8.5

Woth a contact area of the wheels of $0.09m^2$, this leads to **790 kN/m^2** as governing load (1 m from quay)

Mobile crane
For the mobile crane, two governing load situations can be distinguished: during terminal operations and during allocation of the crane. During terminal operations, the dynamic load on the outrigger pads induces the governing load. The wheel load induces the governing load onto the quay during allocation of the mobile crane.

With an outrigger pad size of $0.71m^2$, the resulting outrigger load yields $1503kN/m^2$

Axle loads mobile crane dwt 90ton

Axle	Axle load [kN]	Position w.r.t. sheet pile [m]
1	258	1.55
2	258	3.20
3	128	5.65
4	128	7.0
5	128	10.25

Other loads
Top load on ground level : 40 kN/m2

Mooring forces for inland vessels about 10 to 30 tonnes. These forces may act both in a longitudinal and a lateral direction. Spacing between bollards should be about 10 to 30 %of the design ship length

Bollard forces for barges:
Class III + IV: 200 kN
Class V + VI: 250 kN

Crane load
EAU (2012), Empfehlungen des Arbeitsausschusses "Ufereinfassungen", Häfen und Wasserstraßen, 11. Auflage, Ernst & Sohn, Berlin 2012
Masse und charackteristische lasten von mobilkranen

	Mobile Crane				
Max. Capacity [t]	**42**	64	84	104	140
Dead weight [t]	**130**	170	250	420	460
Related reach [m]	**12**	12	15	22	20
Static outrigger load [kN]	**920**	1250	1660	2600	3250
Dynamic outrigger load [kN]	**1080**	1450	1950	3050	3650
Outrigger pad size [m]	**5.5*0.8**	5.5*0.8	5.5*1.3	5.5*1.8	5.5*1.5

The 130t mobile crane from the EAU (2012) specifications are considered to be representative for the design loads. Following the mobile crane used in the Fugro report (1998), a mobile crane with a 30 ton ballast is considered. The outrigger pads have a c.t.c. distance of 8.6m, which leads to the following governing load situations:

Sit A	Capping beam:	499 kN per outrigger
	Quay:	52 per outrigger
Sit B	Capping beam:	541 en 254 kN
	Quay;	307 en 0 kN

F.3 Design criteria
CUR 166

Safety class II (quay for inland waterway transport) is applied, which means that failure leads to considerable damage, but low risks to personal safety. The allowable deformations are based on experience to be 1/100 of the retaining height or a maximum of 50mm.

Stack area/storage yard
The required area for the stacking of container is determined using the following relation: (Ligteringen & Velsink, 2012):

$$A = \frac{N_c \cdot \overline{t_d} \cdot A_{TEU}}{r_{st} \cdot 365 \cdot m_c}$$

In which

A	=	area required [m^2]
N_c	=	number of container visits per year per type of stack [TEU]
$\overline{t_d}$	=	average dwell time [days]
A_{TEU}	=	required area per TEU inclusive of equipment travelling lanes [m^2]
r_{st}	=	ratio average stacking height over nominal stacking height (0.6 to 0.9)
m_c	=	acceptable occupancy rate (0.65 to 0.70)

For an inland terminal with a capacity of 10,000 TEU/year, it is calculated that an area of approximately 800m2 has to become available.

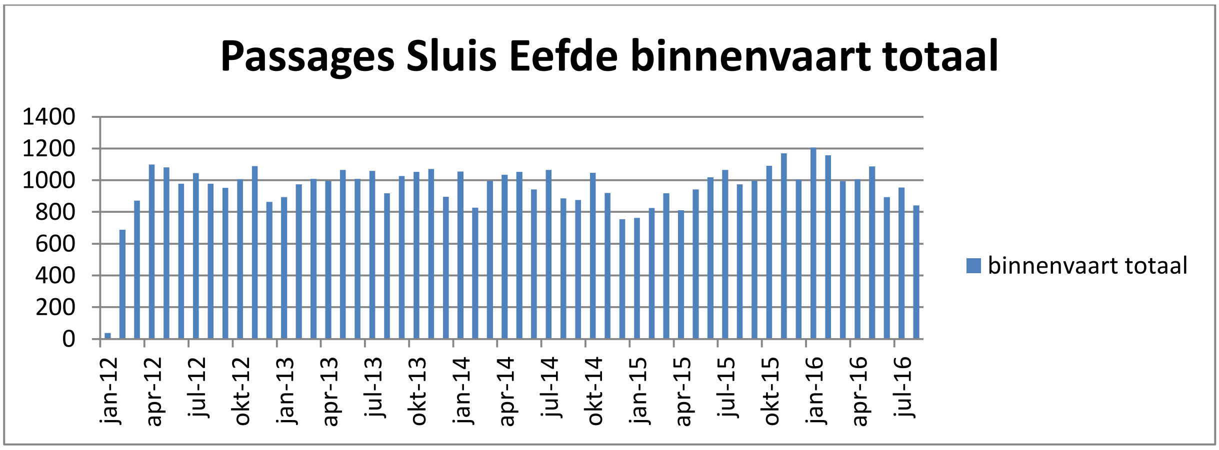
Quay length

The following guidelines from the Richtlijn Vaarwegen (RVW, 2011) need to be followed for the design in the industrial harbour:

- The turning basin requires a minimum diameter of 1.2*L_s
- The quay length needs to be 1.1*L_s (Ls is length of design ship) when the vessels moor one wide exclusively. Otherwise the design mooring length is 1.2 * $L_{s.}$
- Harbour basin along waterway:
- Width of harbour basin has to be minimum 4*Bs, if there are berths on both sides
- Harbour entrance preferably orientated in an upstream direction (vessel can enter against the current, safer manoeuvring)
- Harbour entrance sufficiently wide for ships to pass. Minimum value of 60m for Class Va vessels

The length of the existing quay is 125 m and the diameter of the turning basin is 120. As a result, a CEMT Class IV barge is the maximum vessel size that can safely moor and manoeuvre at the existing quay in the industrial harbour. For the mooring posts along the embankment, a Class Va vessel is able to access the industrial harbour, since it can sail backwards to the Ijssel River for turning. RVW2011 prescribes that for harbour basins located at a waterway with less than 30,000 passing cargo vessel per year, the main waterway may be used for turning of the vessels.

The NIS database from Rijkswaterstaat showed for the past 5 years a maximum of 12,000 annual passing vessels at the Eefde Locks in the Twentekanaal as can be seen in the graph below. As a result, the backwards sailing onto the Ijssel River for manoeuvring is considered to be allowed.



F.4 Technical designs

Alternative 1: Crane on existing quay

→ Fugro (1998) calculated the stability of the quay for the loads of a mobile crane and reachstacker. The water level in the industrial harbour was set to NAP +3.5m and is used for all calculations. The bottom level was assumed to be located at NAP 0.0m

→ Van Roekel & Roekel did recalculation in 2013. Conducted similar calculations, but considered the bottom level to be located at NAP -0.5m and included a horizontal bollard force of 100kN. The following resulting load combinations were considered and checked as in chapter 5, where it was advised to upgrade the anchor rods.

Table 0-17. Load combinations at industrial harbour with corresponding maximum Moment, Anchor force and displacement. Source: Fugro (1998)

Situation	Description load situation	Moment [kNm]	Displacement [mm]	Anchor force [kN]
1	Mobile crane situation A	260	-31	161
2	Mobile crane situation B	260	-33	162
3	Allocate mobile crane	263	-34	192
4	Reachstacker situation A	165	-26	**302**
5	Reachstacker situation B	**266**	**-34**	204

Water level NAP +3.5m for all load situations

Table 0-18. Calculated load combinations with corresponding maximum moment, displacement and anchor force. Source: Van Roekel & Van Roekel (2013)

Situation	Description load situation	Moment [kNm]	Displacement [mm]	Anchor force [kN]
1	A: Uniform load near quay[1]	284.6	-18.5	259.2
2	B: Uniform load near anchor plate [1]	285.3	-18.6	246.1
3	C: outrigger pads crane load [1]	302.8	-20.4	304.2
4	D: reachstacker load [1]	314.5	-21.5	336.4
5	High water level: load situation A [2]	308.8	-22.9	318.3
6	High water level: load situation C [2]	322.3	-22.1	332.3
7	High water level: load situation D [2]	326.6	-22.6	349.6
8	Low water level: load situation A [3]	334.9	-22.5	330.9
9	Low water level: load situation C [3]	338.4	-24.6	344.0
10	Low water level: load situation D [3]	**340.3**	**-24.8**	**358.1**

[1]) Water level NAP +4.5m, [2]) Water level NAP +6.5m, [3]) Water level NAP +3.5m

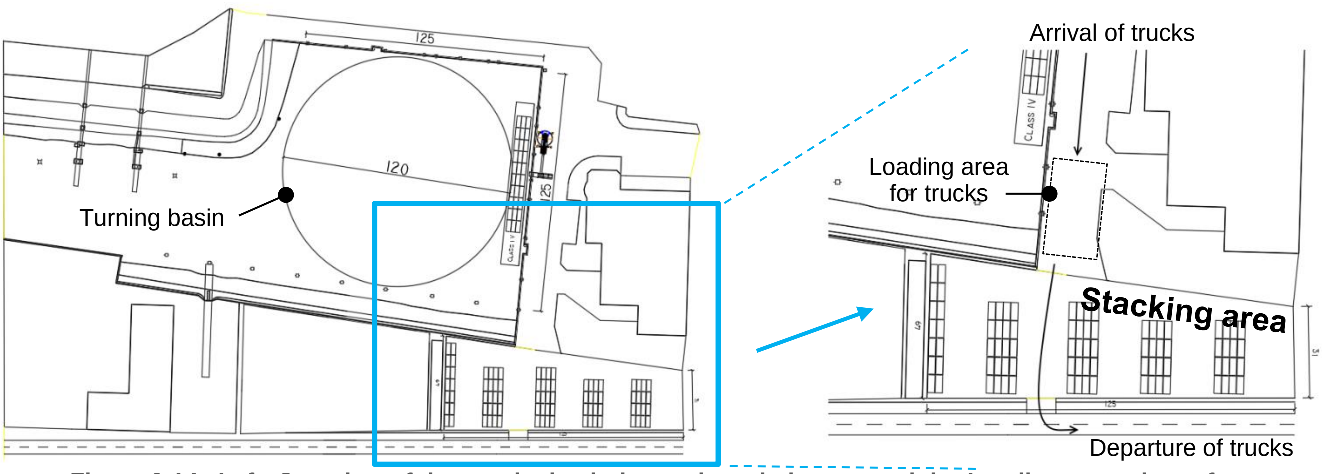


Figure 0-14. Left: Overview of the terminal solution at the existing quay, right: Loading procedure of trucks

The width of the industrial harbour is on average 15 m. A road tractor with container chassis with a combined length of 15m requires a turning radius of 9.70m, as indicated in Figure 0-15. Although not ideal, it is assumed that the arrival and loading of the trucks takes place at the public quay of the industrial harbour, after which the truck crosses the stacking area to leave the terminal via the southern road.

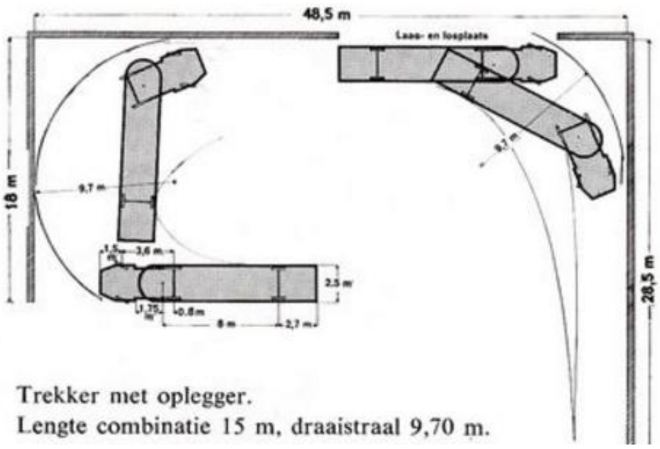


Figure 0-15. Required turning radius for a road tractor with container chassis. Source: EVO (n.d.) Retrieved from https://berkela.home.xs4all.nl/cad%20vervoer/cad%20vervoer%20draaicirkels.html#draaicirkels.

Alternative 2: Crane barge

In case of the crane barge, the handling of the containers is carried out with the on-board crane. Since no terminal is required, the handling costs are included in the sailing costs and no initial investment is required. Due to the presence of the on-board crane, the fixed costs and fuel costs for the crane vessel are higher than for regular container barges.

The crane vessel is with its dimensions able to access and manoeuvre in the industrial harbour. The crane capacity is sufficient at the required reach for container handling onto the quay. The properties of the crane vessel are presented below:

Table 0-19. Properties of the Mercurius crane vessel. Source: Mercurius Shipping Group (n.d.)

Dimensions	Max. capacity	Crane capacity
86*11.55m	96 TEU on 3 layers	35 ton at 23m

These costs can be considered as the operational costs. The corresponding cargo volumes that are required per roundtrip and draught are denoted as well to obtain thee considered loading degree. As mentioned in Appendix D, a draught limitation of 2.30m was found with a probability of non-exceedance of 10% for an average year. For the crane barge it can be seen that the draught will be limited for a utilization rate higher than 70%. This will induce additional sailing costs during limited water depth events.

Table 0-20. Costs for sailing + handling with crane vessel on route Rotterdam - Zutphen for different loading degrees

Crane vessel Capacity 96 TEU (on 3 layers)	**Utilization rate**				
	100%	90%	80%	70%	60%
Costs for sailing + handling	€176 / TEU	€195 / TEU	€220 / TEU	€251 / TEU	€293 / TEU
TEU required per roundtrip	96 TEU	86 TEU	76 TEU	66 TEU	57 TEU
Draught*	2.66 m	2.52 m	2.36	2.21	2.09 m

*) Draught of the barges corresponds to an average load of 14 ton/TEU

Alternative 3: Cofferdam at embankment

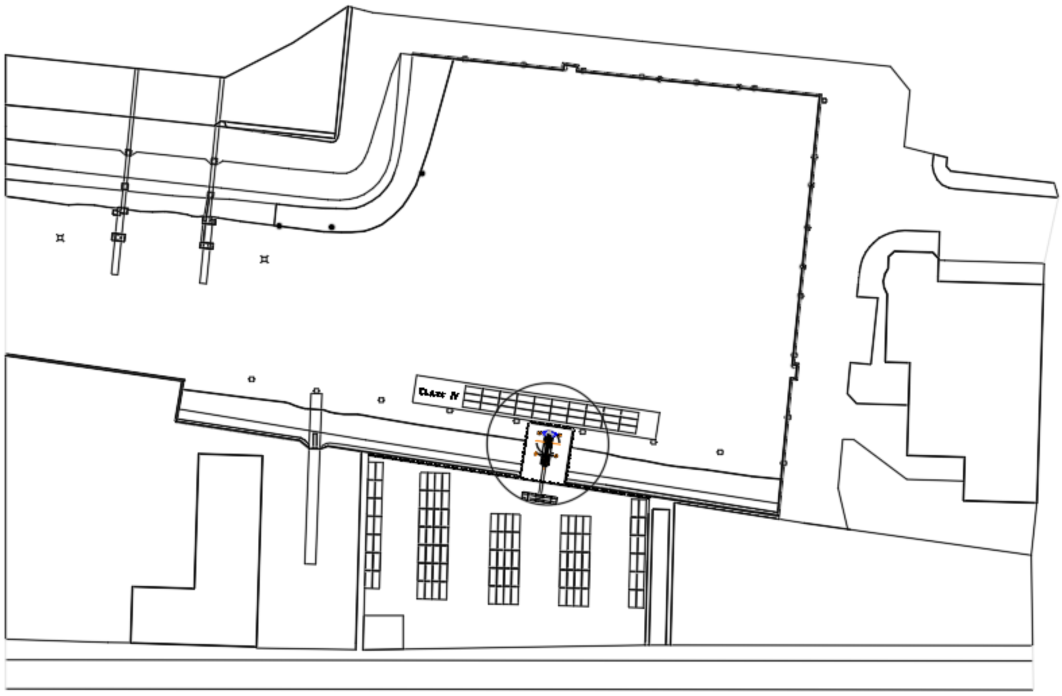


Figure 0-16. Overview of the terminal solution 'Cofferdam at embankment'

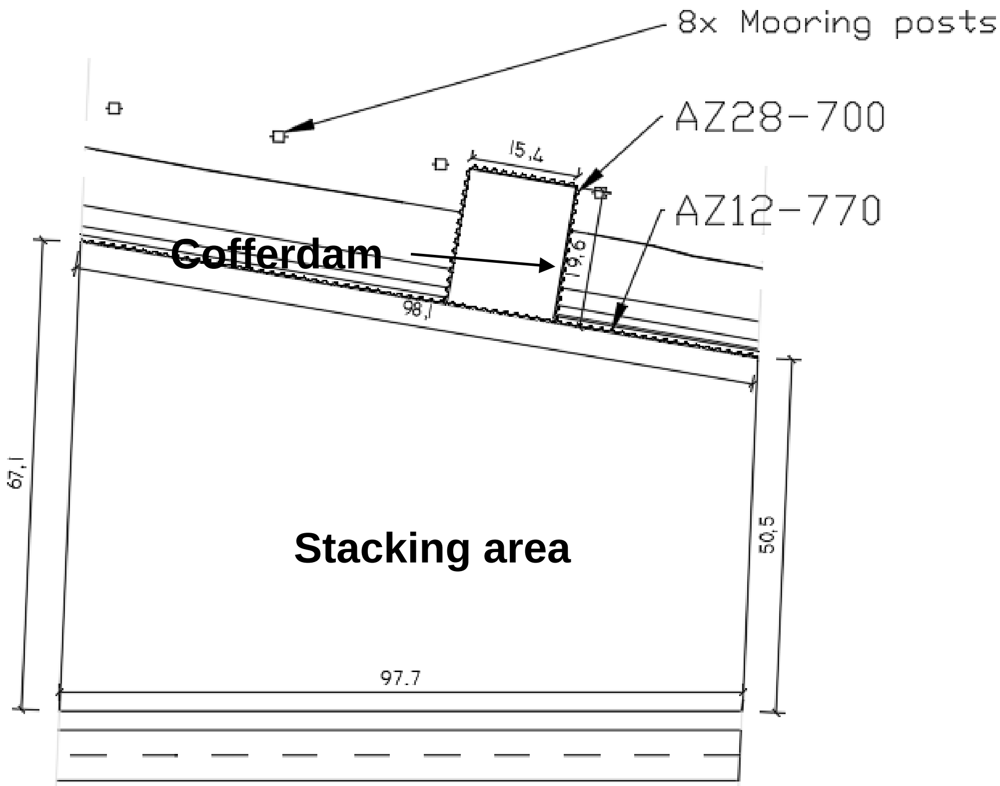


Figure 0-17. Layout of the terminal solution ‘Cofferdam at embankment'. All units in meter

Cofferdam structure:
For the sheet pile design, the steps following CUR 166 have to be followed. First a hand calculation was performed, followed by several calculations in D-sheet for the fine-tuning of the chosen profile and anchorage.

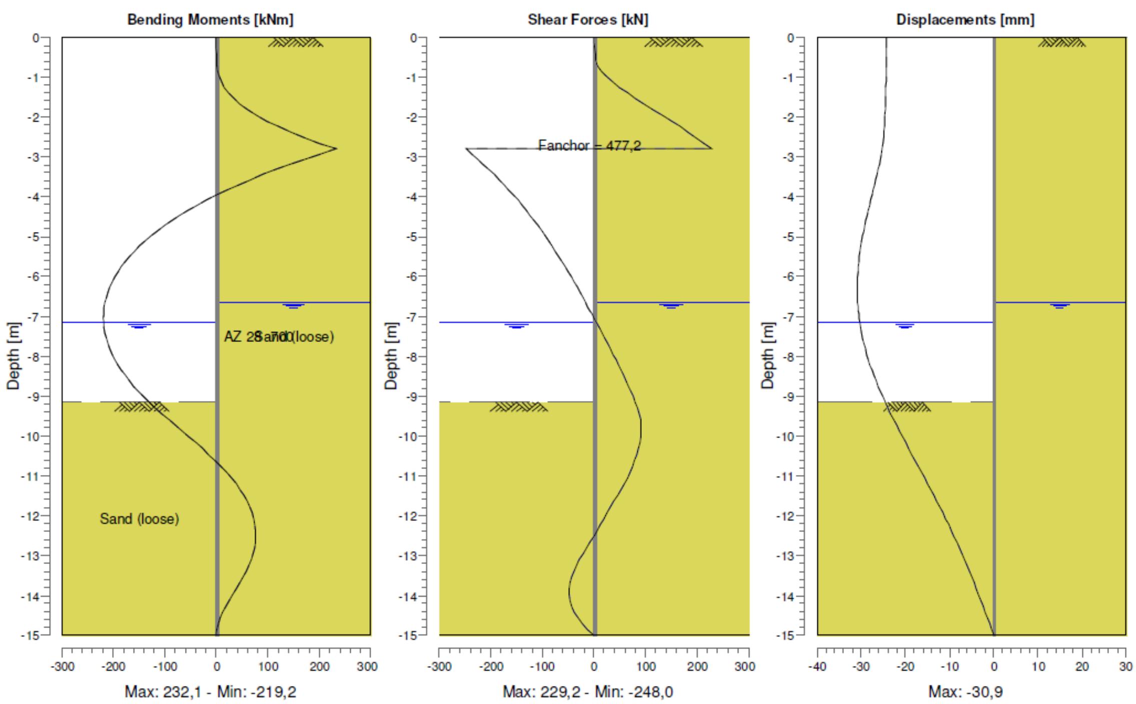
In the picture, the surface level (located at NAP +9.15m) is used as a reference level at 0.00 m (referred to as MV). Two governing situations were considered, for low water (LW) and high water (HW) situations.

LW: Groundwater at -6.65 MV and Surface water: -7.15 MV
HW: Groundwater at -1.65 MV and Surface water -2.15 MV

Applying an AZ28 profile with a length of 15m, the location of the anchor has a major influence in stability of the sheet pile. The placement height of anchor was checked for both high (HW) and low (LW) water levels.

HW: Anchor force 467.5 kN
LW: Anchor force 477.2 kN

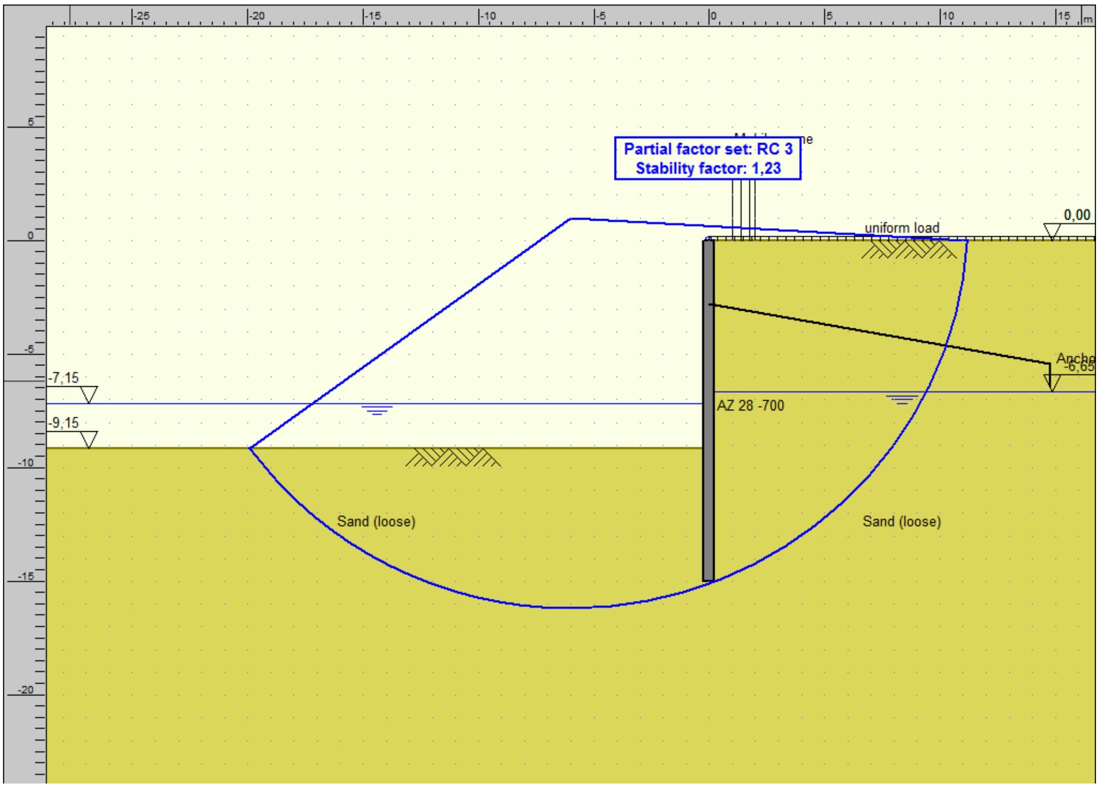
HW Max displacement -28.5mm
LW Max displacement -30.9mm



LW is the governing situation. Provided an anchorage is placed that is able to withstand an anchor force of 477.2 kN at -2.8m below surface level.

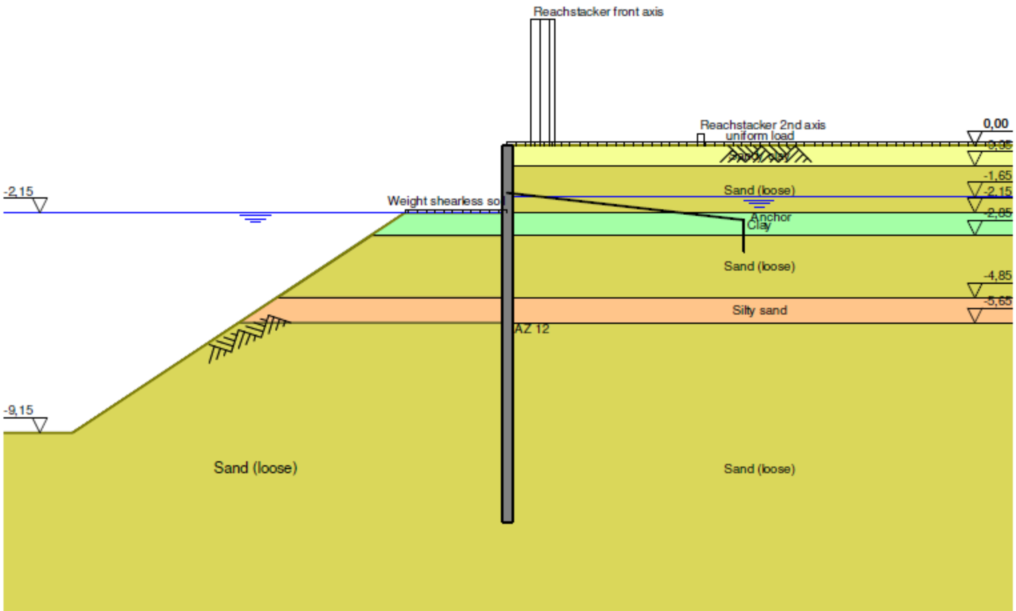
Stability check using Bishop calculation showed this condition was satisfied

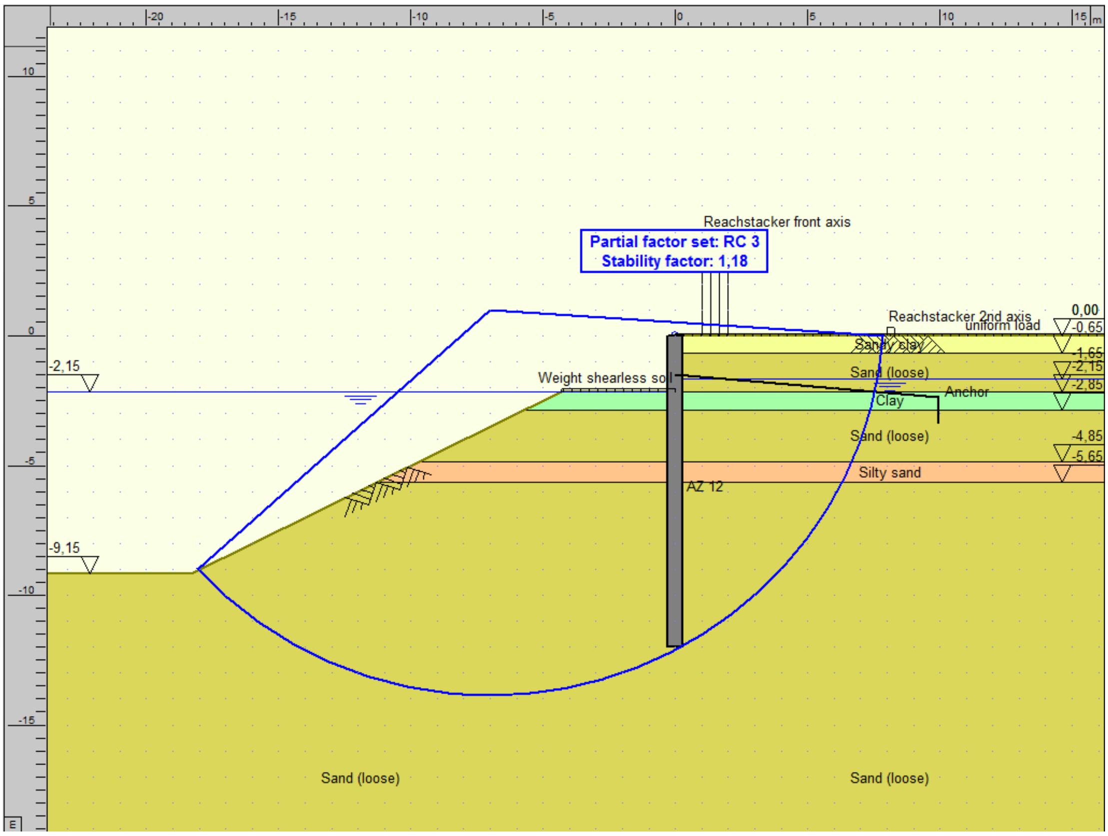
Sheet piling active (Ea) : 669,337 [kN]
Horizontal force (Er) : -408,733 [kN]
Anchor wall active (Eo) : 165,760 [kN]
Cohesion x length (Ec) : 0,000 [kN]
Factor due to angle (Es) : 1,009 [-]
Allowable anchor force = (Ea - (Er + Eo) + Ec) / Es
Allowable anchor force by Kranz : 904,192 [kN



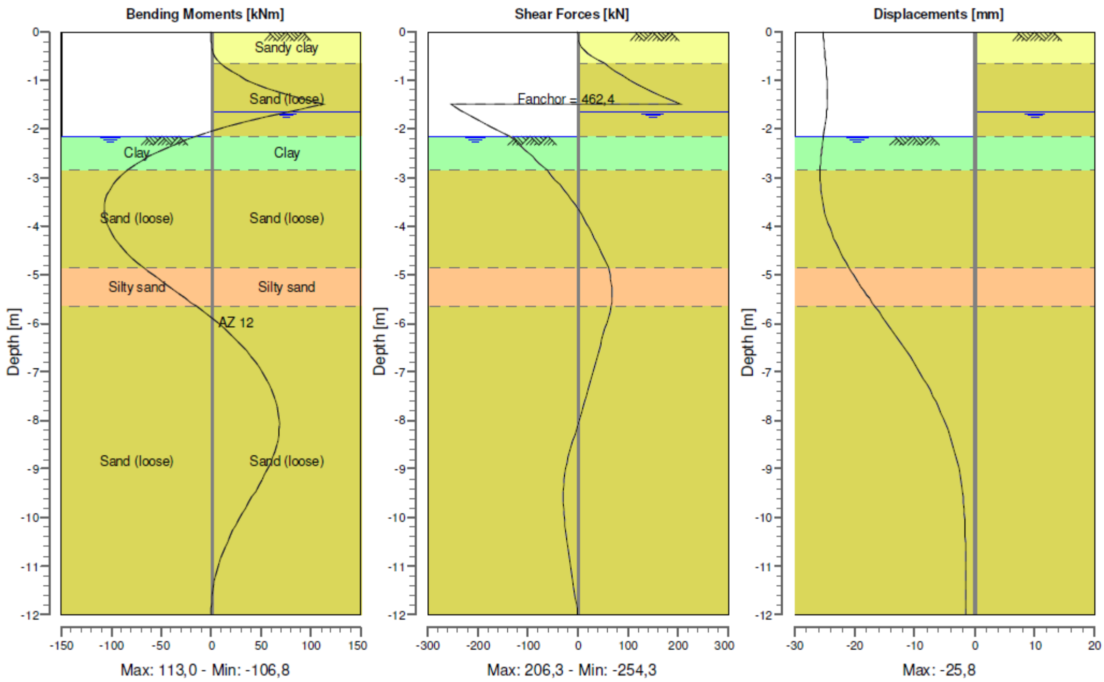
Reachstacker on embankment, storage area
The existing embankment has to be reinforced with sheetpiles as well to withstand the wheel load of the reachstacker. The retaining height is again 9.15 m, with an embankment slope of 1:2. The governing load of the reachstacker is 790 kN/m2 at 1 m from sheet pile. In addition, a uniform load kN/m2 was taken into account over the entire stack area.

A similar calculation as for the cofferdam was performed for both LW and HW situations. The HW situation appeared to be the governing situation here. A stable construction was found when an AZ 12 profile with a depth of 12 m was applied, with an anchorage that is able to withstand an anchor force of 462.4 kN.





Moments/Forces/Displacements - Stage 1: Heightening surface level



Appendix G Assessment of financial feasibility

This appendix shows the results of the assessment of financial feasibility of the proposed terminal solutions. The feasibility framework from chapter 4 was applied with the in chapter 5 identified potential cargo volumes. It was concluded that for the identified cargo volumes, no positive NPV could be found for any of the proposed terminal solutions. The appendix concludes with the circumstances that need to change in order to obtain a positive NPV.

G.1 Feasibility assessment of the three proposed terminal solutions

Table 0-21. Results of the optimal NPV for terminal solution 'Mobile crane at existing quay'

NPV for optimal tariffs		Sailing frequency	Growth scenario		
			Low (-1%)	Medium (0%)	High (2%)
Service level	Very low	1	€ -6.603.481	€ -6.621.230	€ -6.404.401
	Low	2	€ -6.050.947	**€ -5.158.040** *	€ -4.475.424
	Medium	3	€ -10.048.684	€ -10.707.961	€ -8.488.797

*) Corresponds to the optimal NPV calculated in the illustrated procedure in subsection 6.1.2

		Handling tariff [€/move]							
	€-5.158.040	€ 35	€ 40	€ 45	€ 50	€ 55	€ 60	€ 65	€ 70
Sailing tariff [€/TEU]	€ 35	€-9.250.963	€-8.643.403	€-8.498.796	€-5.744.128	€-5.397.453	€-7.450.294	€-9.180.607	€-11.832.635
	€ 40	€-8.502.073	€-8.637.177	€-9.440.218	€-5.158.040	€-7.160.202	€-9.033.733	€-11.405.778	€-6.831.610
	€ 45	€-8.775.559	€-9.388.760	€-5.275.258	€-7.038.246	€-8.264.305	€-11.456.247	€-6.872.311	€-7.104.072
	€ 50	€-9.527.142	€-8.971.347	€-6.792.574	€-7.969.364	€-11.288.348	€-11.512.500	€-7.121.743	€-7.950.643
	€ 55	€-8.919.890	€-6.909.791	€-7.856.960	€-10.563.071	€-11.562.968	€-7.162.443	€-7.742.257	€-8.132.982
	€ 60	€-6.711.690	€-7.606.584	€-10.251.070	€-11.391.535	€-6.799.094	€-7.768.015	€-8.165.542	€-9.470.117
	€ 65	€-7.723.802	€-10.172.122	€-10.673.777	€-6.849.563	€-7.808.716	€-7.957.155	€-9.220.500	€-9.684.501
	€ 70	€-9.905.350	€-10.359.036	€-6.711.256	€-7.430.334	€-7.987.228	€-9.253.060	€-9.787.036	€-10.558.771
	€ 75	€-10.285.437	€-10.960.308	€-7.480.802	€-8.027.928	€-9.044.674	€-9.520.056	€-10.583.191	€-11.284.831
	€ 80	€-10.640.905	€-7.336.515	€-7.641.609	€-9.099.550	€-9.552.616	€-10.998.262	€-10.558.771	€-10.373.288
	€ 85	€-6.563.569	€-7.692.077	€-9.140.251	€-9.344.229	€-10.575.014	€-10.583.191	€-11.284.831	€-10.363.520
	€ 90	€-7.544.736	€-8.709.310	€-9.411.509	€-10.607.574	€-10.998.262	€-10.558.771	€-10.373.288	€-11.545.314
	€ 95	€-8.759.779	€-9.452.209	€-10.399.187	€-10.575.014	€-10.583.191	€-11.284.831	€-10.363.520	€-7.677.731
	€ 100	€-8.999.565	€-10.553.282	€-10.607.574	€-10.998.262	€-10.558.771	€-10.373.288	€-11.545.314	€-7.677.731
	€ 105	€-10.593.982	€-10.399.187	€-10.575.014	€-10.583.191	€-11.284.831	€-10.363.520	€-7.677.731	€-7.677.731
	€ 110	€-10.553.282	€-10.607.574	€-10.998.262	€-10.558.771	€-10.373.288	€-11.545.314	€-7.677.731	€-7.677.731
	€ 115	€-10.399.187	€-10.575.014	€-10.583.191	€-11.284.831	€-10.363.520	€-7.677.731	€-7.677.731	€-7.677.731

Table 0-22. Results of the optimal NPV for terminal solution 'Crane vessel'

NPV for optimal tariffs		Sailing frequency	Growth scenario		
			Low (-1%)	Medium (0%)	High (2%)
Service level	Very low	1*	€ -7,613,961	€ -7,289,545	€ -6,649,312
	Low	2	€ -12.532.955	**€ -12.567.625**	€ -10.604.651

* Costs based on continuous sailing

Table 0-23. Results of the optimal NPV for terminal solution 'Cofferdam at embankment'

NPV for optimal tariffs		Sailing frequency	Growth scenario		
			Low (-1%)	Medium (0%)	High (2%)
Service level	Very low	1	€ -8.170.137	€ -8.168.482	€ -7.972.974
	Low	2	€ -7.025.337	**€ -6.938.040**	€ -5.860.227
	Medium	3	€ -11.522.901	€ -10.320.101	€ -7.851.692

		Handling tariff [€/move]							
	€-6.938.040	€ 35	€ 40	€ 45	€ 50	€ 55	€ 60	€ 65	€ 70
Sailing tariff [€/TEU]	€ 35	€-11.030.963	€-10.423.403	€-10.278.796	€-7.524.128	€-7.177.453	€-9.230.294	€-10.960.607	€-13.612.635
	€ 40	€-10.282.073	€-10.417.177	€-11.220.218	€-6.938.040	€-8.940.202	€-10.813.733	€-13.185.778	€-8.611.610
	€ 45	€-10.555.559	€-11.168.760	€-7.055.258	€-8.818.246	€-10.044.305	€-13.236.247	€-8.652.311	€-8.884.072
	€ 50	€-11.307.142	€-10.751.347	€-8.572.574	€-9.749.364	€-13.068.348	€-13.292.500	€-8.901.743	€-9.730.643
	€ 55	€-10.699.890	€-8.689.791	€-9.636.960	€-12.343.071	€-13.342.968	€-8.942.443	€-9.522.257	€-9.912.982
	€ 60	€-8.491.690	€-9.386.584	€-12.031.070	€-13.171.535	€-8.579.094	€-9.548.015	€-9.945.542	€-11.250.117
	€ 65	€-9.503.802	€-11.952.122	€-12.453.777	€-8.629.563	€-9.588.716	€-9.737.155	€-11.000.500	€-11.464.501
	€ 70	€-11.685.350	€-12.139.036	€-8.491.256	€-9.210.334	€-9.767.228	€-11.033.060	€-11.567.036	€-12.338.771
	€ 75	€-12.065.437	€-12.740.308	€-9.260.802	€-9.807.928	€-10.824.674	€-11.300.056	€-12.363.191	€-13.064.831
	€ 80	€-12.420.905	€-9.116.515	€-9.421.609	€-10.879.550	€-11.332.616	€-12.778.262	€-12.338.771	€-12.153.288
	€ 85	€-8.343.569	€-9.472.077	€-10.920.251	€-11.124.229	€-12.355.014	€-12.363.191	€-13.064.831	€-12.143.520
	€ 90	€-9.324.736	€-10.489.310	€-11.191.509	€-12.387.574	€-12.778.262	€-12.338.771	€-12.153.288	€-13.325.314
	€ 95	€-10.539.779	€-11.232.209	€-12.179.187	€-12.355.014	€-12.363.191	€-13.064.831	€-12.143.520	€-9.457.731
	€ 100	€-10.779.565	€-12.333.282	€-12.387.574	€-12.778.262	€-12.338.771	€-12.153.288	€-13.325.314	€-9.457.731
	€ 105	€-12.373.982	€-12.179.187	€-12.355.014	€-12.363.191	€-13.064.831	€-12.143.520	€-9.457.731	€-9.457.731
	€ 110	€-12.333.282	€-12.387.574	€-12.778.262	€-12.338.771	€-12.153.288	€-13.325.314	€-9.457.731	€-9.457.731
	€ 115	€-12.179.187	€-12.355.014	€-12.363.191	€-13.064.831	€-12.143.520	€-9.457.731	€-9.457.731	€-9.457.731

G.2 Minimum required growth of potential cargo volumes

By adding a parameter to the spreadsheet that adds a growth percentage of the potential cargo volumes, an iterative procedure was followed to find the required additional volumes for a positive NPV. For growth scenarios ‘Low’, ‘Medium’ and ‘High’ a growth of the potential cargo volumes of respectively 295%, 250% and 173% is required. See the corresponding calculation sheets:

NET PRESENT VALUE	Variable input	Fixed input	Output

TERMINAL SOLUTION	Embankment	Service level frequency	2	Annual growth	-1%	Growth of potential cargo volumes
First year	2018	Operational years	25	Handling price [€/move]	€ 50,0	295%
Years of cap. expenditure	1	Discount rate	6%	Sailing price [€/TEU]	€ 52,0	
CAPEX	€ 3.623.750					
OPEX terminal	*€ 450.000*	*Max. Handling revenues*	*€ 981.279*	Moves/year	19625,58	Best NPV
OPEX sailing	*€ 1.010.142*	*Max. Sailing revenues*	*€ 837.584*	TEU/year	16107,39	€ 6.546
OPEX total	€ 1.460.142	Max. Annual revenues	€ 1.818.863	Average TEU-factor	1,64	

	Year	Speed of modal change	Annual Revenues (Sailing + terminal)	CAPEX (terminal)	OPEX (Sailing + terminal)	Total (Revenues - CAPEX - OPEX)	NPV
0	2018	0%	€ -	€ 3.623.750	€ -	€-3.623.750	€-3.623.750
1	2019	50%	€ 909.432	€ -	€ 1.091.676	€-182.245	€-171.929
2	2020	75%	€ 1.364.147	€ -	€ 1.275.909	€88.238	€78.532
3	2021	88%	€ 1.591.505	€ -	€ 1.368.025	€223.480	€187.638
4	2022	94%	€ 1.705.184	€ -	€ 1.414.083	€291.101	€230.579
5	2023	97%	€ 1.762.024	€ -	€ 1.437.113	€324.911	€242.793
6	2024	98%	€ 1.790.444	€ -	€ 1.448.627	€341.816	€240.967
7	2025	100%	€ 1.818.863	€ -	€ 1.460.142	€358.722	€238.570
8	2026	100%	€ 1.818.863	€ -	€ 1.460.142	€358.722	€225.066
9	2027	100%	€ 1.818.863	€ -	€ 1.460.142	€358.722	€212.327
10	2028	100%	€ 1.818.863	€ -	€ 1.460.142	€358.722	€200.308
11	2029	100%	€ 1.818.863	€ -	€ 1.460.142	€358.722	€188.970
12	2030	100%	€ 1.818.863	€ -	€ 1.460.142	€358.722	€178.274
13	2031	100%	€ 1.818.863	€ -	€ 1.460.142	€358.722	€168.183
14	2032	100%	€ 1.818.863	€ -	€ 1.460.142	€358.722	€158.663
15	2033	100%	€ 1.818.863	€ -	€ 1.460.142	€358.722	€149.682
16	2034	100%	€ 1.818.863	€ -	€ 1.460.142	€358.722	€141.209
17	2035	100%	€ 1.818.863	€ -	€ 1.460.142	€358.722	€133.216
18	2036	100%	€ 1.818.863	€ -	€ 1.460.142	€358.722	€125.676
19	2037	100%	€ 1.818.863	€ -	€ 1.460.142	€358.722	€118.562
20	2038	100%	€ 1.818.863	€ -	€ 1.460.142	€358.722	€111.851
21	2039	100%	€ 1.818.863	€ -	€ 1.460.142	€358.722	€105.520
22	2040	100%	€ 1.818.863	€ -	€ 1.460.142	€358.722	€99.547
23	2041	100%	€ 1.818.863	€ -	€ 1.460.142	€358.722	€93.912
24	2042	100%	€ 1.818.863	€ -	€ 1.460.142	€358.722	€88.597
25	2043	100%	€ 1.818.863	€ -	€ 1.460.142	€358.722	€83.582
26	-	100%	€ -	€ -	€ -	€0	€0
27	-	100%	€ -	€ -	€ -	€0	€0
28	-	100%	€ -	€ -	€ -	€0	€0
29	-	100%	€ -	€ -	€ -	€0	€0
30	-	100%	€ -	€ -	€ -	€0	€0
Totals			€ 43.681.138	€ 3.623.750	€ 35.778.125	€ 4.279.263	€ 6.546

NET PRESENT VALUE	Variable input	Fixed input	Output

TERMINAL SOLUTION	Embankment	Service level frequency	2	Annual growth	0%	Growth of potential cargo volumes
First year	2018	Operational years	25	Handling price [€/move]	€ 50,0	250%
Years of cap. expenditure	1	Discount rate	6%	Sailing price [€/TEU]	€ 52,0	

CAPEX	€ 3.623.750				
OPEX terminal	*€ 450.000*	*Max. Handling revenues*	*€ 981.500*	Moves/year	19630
OPEX sailing	*€ 1.010.117*	*Max. Sailing revenues*	*€ 837.564*	TEU/year	16107
OPEX total	€ 1.460.117	Max. Annual revenues	€ 1.819.064	Average TEU-factor	1,64

Best NPV
€ 9.236

	Year	Speed of modal change	Annual Revenues (Sailing + terminal)	CAPEX (terminal)	OPEX (Sailing + terminal)	Total (Revenues - CAPEX - OPEX)	NPV
0	2018	0%	€ -	€ 3.623.750	€ -	€-3.623.750	€-3.623.750
1	2019	50%	€ 909.532	€ -	€ 1.091.658	€-182.126	€-171.817
2	2020	75%	€ 1.364.298	€ -	€ 1.275.888	€88.410	€78.685
3	2021	88%	€ 1.591.681	€ -	€ 1.368.002	€223.679	€187.805
4	2022	94%	€ 1.705.373	€ -	€ 1.414.060	€291.313	€230.747
5	2023	97%	€ 1.762.218	€ -	€ 1.437.088	€325.130	€242.956
6	2024	98%	€ 1.790.641	€ -	€ 1.448.603	€342.038	€241.123
7	2025	100%	€ 1.819.064	€ -	€ 1.460.117	€358.947	€238.720
8	2026	100%	€ 1.819.064	€ -	€ 1.460.117	€358.947	€225.208
9	2027	100%	€ 1.819.064	€ -	€ 1.460.117	€358.947	€212.460
10	2028	100%	€ 1.819.064	€ -	€ 1.460.117	€358.947	€200.434
11	2029	100%	€ 1.819.064	€ -	€ 1.460.117	€358.947	€189.089
12	2030	100%	€ 1.819.064	€ -	€ 1.460.117	€358.947	€178.386
13	2031	100%	€ 1.819.064	€ -	€ 1.460.117	€358.947	€168.288
14	2032	100%	€ 1.819.064	€ -	€ 1.460.117	€358.947	€158.763
15	2033	100%	€ 1.819.064	€ -	€ 1.460.117	€358.947	€149.776
16	2034	100%	€ 1.819.064	€ -	€ 1.460.117	€358.947	€141.298
17	2035	100%	€ 1.819.064	€ -	€ 1.460.117	€358.947	€133.300
18	2036	100%	€ 1.819.064	€ -	€ 1.460.117	€358.947	€125.755
19	2037	100%	€ 1.819.064	€ -	€ 1.460.117	€358.947	€118.637
20	2038	100%	€ 1.819.064	€ -	€ 1.460.117	€358.947	€111.921
21	2039	100%	€ 1.819.064	€ -	€ 1.460.117	€358.947	€105.586
22	2040	100%	€ 1.819.064	€ -	€ 1.460.117	€358.947	€99.610
23	2041	100%	€ 1.819.064	€ -	€ 1.460.117	€358.947	€93.971
24	2042	100%	€ 1.819.064	€ -	€ 1.460.117	€358.947	€88.652
25	2043	100%	€ 1.819.064	€ -	€ 1.460.117	€358.947	€83.634
26	-	100%	€ -	€ -	€ -	€0	€0
27	-	100%	€ -	€ -	€ -	€0	€0
28	-	100%	€ -	€ -	€ -	€0	€0
29	-	100%	€ -	€ -	€ -	€0	€0
30	-	100%	€ -	€ -	€ -	€0	€0
Totals			€ 43.685.959	€ 3.623.750	€ 35.777.526	€ 4.284.683	€ 9.236

NET PRESENT VALUE	Variable input	Fixed input	Output

TERMINAL SOLUTION	Embankment	Service level frequency	2	Annual growth	2%	Growth of potential cargo volumes
First year	2018	Operational years	25	Handling price [€/move]	€ 44,0	173%
Years of cap. expenditure	1	Discount rate	6%	Sailing price [€/TEU]	€ 58,0	

CAPEX	€ 3.623.750				
OPEX terminal	*€ 450.000*	*Max. Handling revenues*	*€ 884.825*	Moves/year	20109,648
OPEX sailing	*€ 1.013.678*	*Max. Sailing revenues*	*€ 937.499*	TEU/year	16163,784
OPEX total	€ 1.463.678	Max. Annual revenues	€ 1.822.324	Average TEU-factor	1,61

Best NPV
€ 4.095

	Year	Speed of modal change	Annual Revenues (Sailing + terminal)	CAPEX (terminal)	OPEX (Sailing + terminal)	Total (Revenues - CAPEX - OPEX)	NPV
0	2018	0%	€ -	€ 3.623.750	€ -	€-3.623.750	€-3.623.750
1	2019	50%	€ 911.162	€ -	€ 1.094.321	€-183.159	€-172.791
2	2020	75%	€ 1.366.743	€ -	€ 1.278.999	€87.744	€78.091
3	2021	88%	€ 1.594.533	€ -	€ 1.371.339	€223.195	€187.399
4	2022	94%	€ 1.708.429	€ -	€ 1.417.509	€290.920	€230.436
5	2023	97%	€ 1.765.376	€ -	€ 1.440.593	€324.783	€242.697
6	2024	98%	€ 1.793.850	€ -	€ 1.452.136	€341.714	€240.895
7	2025	100%	€ 1.822.324	€ -	€ 1.463.678	€358.646	€238.520
8	2026	100%	€ 1.822.324	€ -	€ 1.463.678	€358.646	€225.019
9	2027	100%	€ 1.822.324	€ -	€ 1.463.678	€358.646	€212.282
10	2028	100%	€ 1.822.324	€ -	€ 1.463.678	€358.646	€200.266
11	2029	100%	€ 1.822.324	€ -	€ 1.463.678	€358.646	€188.930
12	2030	100%	€ 1.822.324	€ -	€ 1.463.678	€358.646	€178.236
13	2031	100%	€ 1.822.324	€ -	€ 1.463.678	€358.646	€168.147
14	2032	100%	€ 1.822.324	€ -	€ 1.463.678	€358.646	€158.629
15	2033	100%	€ 1.822.324	€ -	€ 1.463.678	€358.646	€149.650
16	2034	100%	€ 1.822.324	€ -	€ 1.463.678	€358.646	€141.180
17	2035	100%	€ 1.822.324	€ -	€ 1.463.678	€358.646	€133.188
18	2036	100%	€ 1.822.324	€ -	€ 1.463.678	€358.646	€125.649
19	2037	100%	€ 1.822.324	€ -	€ 1.463.678	€358.646	€118.537
20	2038	100%	€ 1.822.324	€ -	€ 1.463.678	€358.646	€111.827
21	2039	100%	€ 1.822.324	€ -	€ 1.463.678	€358.646	€105.498
22	2040	100%	€ 1.822.324	€ -	€ 1.463.678	€358.646	€99.526
23	2041	100%	€ 1.822.324	€ -	€ 1.463.678	€358.646	€93.892
24	2042	100%	€ 1.822.324	€ -	€ 1.463.678	€358.646	€88.578
25	2043	100%	€ 1.822.324	€ -	€ 1.463.678	€358.646	€83.564
26	-	100%	€ -	€ -	€ -	€0	€0
27	-	100%	€ -	€ -	€ -	€0	€0
28	-	100%	€ -	€ -	€ -	€0	€0
29	-	100%	€ -	€ -	€ -	€0	€0
30	-	100%	€ -	€ -	€ -	€0	€0
Totals			€ 43.764.249	€ 3.623.750	€ 35.864.784	€ 4.275.716	€ 4.095

Based on these results, it can be concluded that the following minimum cargo volumes are required for a break-even NPV:

TEU/year	16,000 - 16,250
Moves/year	19,500 - 20,000
TEU-factor	1.60 - 1.65

G.3 Effect on business case of improved road connection towards Apeldoorn

When a detour via Deventer is taken, the travel distance is 28km and the travel time 32 minutes. The corresponding costs for pre- or end-haulage between Zutphen and Apeldoorn was calculated to be €100/container. When a hypothetical direct road connection between Zutphen and Apeldoorn would be present, the travel distance is assumed to become 20km and the travel time decreases to 25 minutes, which results in pre- or end-haulage costs of €85/container. This means that a larger share is likely to be captured for the same tariffs.

The feasibility assessment for an improved road connection towards Apeldoorn is now given:

Table 0-24. Optimal NPV for terminal solution 1: 'Mobile crane at existing quay', with improved road connection towards Apeldoorn. Source: own calculations

NPV for optimal tariffs		**Sailing frequency**	**Growth scenario**		
			Low (-1%)	**Medium (0%)**	**High (2%)**
Service level	Very low	1	€ -6.390.137	€ -6.388.482	€ -6.192.974
	Low	2	€ -5.245.337	**€ -4.935.327 ***	€ -4.080.227
	Medium	3	€ -9.742.901	€ -8.540.101	€ -6.071.692

Table 0-25. Optimal NPV for terminal solution 2: 'Crane vessel', with improved road connection towards Apeldoorn. Source: own calculations

	Sailing frequency	**Growth scenario**		
		Low (-1%)	**Medium (0%)**	**High (2%)**
NPV for optimal tariffs	2	€ -11.481.675	**€ -11.369.401**	€ -10.164.104

Table 0-26. Optimal NPV for terminal solution 3: 'Cofferdam at embankment', with improved road connection towards Apeldoorn. Source: own calculations

NPV for optimal tariffs		**Sailing frequency**	**Growth scenario**		
			Low (-1%)	**Medium (0%)**	**High (2%)**
Service level	Very low	1	€ -8.170.137	€ -8.168.482	€ -7.972.974
	Low	2	€ -7.025.337	**€ -6.715.327**	€ -5.860.227
	Medium	3	€ -11.522.901	€ -10.320.101	€ -7.851.692