INNOVATIVE TENDERING AND PROCUREMENT FOR ADAPTIVE DESIGNS

MSC THESIS

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[Diagram and images related to innovative tendering and procurement for adaptive designs]

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“Innovative tendering and procurement for adaptive designs”

How can flexibility and adaptability be incorporated in the business case and the resulting contractual agreements for construction?

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COLOPHON

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The report before you is the end result of my study Civil Engineering: my master thesis. An accomplishment reached, that I dreaded for years. It was quite the challenge to set up the research approach, but once started and got me more and more excited. Now looking back upon this period, I learned lots and more with very few days of reluctance.

I would like to thank my committee of graduation for pointing me in the right direction and helping me focus, the Port of Rotterdam for providing me with a workspace with nice extras (i.e. a morning tagging along with a Port Authority patrol vessel) and the department Sustainable Development for the sociability. Last but not least my family and friends for their support even though I slightly neglected everybody due to being so busy with my thesis and work.

Writing the thesis and doing the research was not easy and took a lot of time thinking and staring out of the window. Luckily my view was excellent!

Enjoy your reading,

Pim Vermerris
II. ABSTRACT

Fast technological and economic developments result in early adaptations to port infrastructure due to the changing functional requirements. This results in more downtime, for every party around the infrastructure a disadvantage, as time is money. This is mainly a problem for customer oriented infrastructure, the majority of the infrastructure in the Rotterdam port district.

The Port of Rotterdam (PoR) is searching for improvements in tendering and procurement to decrease the time between commercial and technical lifetime of the infrastructure. Adaptable infrastructure and better incorporation of the actors’ knowledge are pointed out as possibilities to create future-proof infrastructure. Adaptable infrastructure is interpretable in multiple ways: flexible infrastructure, that is designed in such a way that it can be rebuilt without high expenses and downtime. A (partially) robust design is another option. The idea behind robust designing is that a marginal additional investment in building materials, equipment and time can save a significant amount of money when this avoids extensive rebuilding. Startup, design and demolition costs outweigh the price of the initial investment for a robust design.

The research for improvements starts by pointing out the current limitations in the procurement process.

1) A lean & mean trend in infrastructure business cases. Business Cases contain short term agreements with the customer and corresponding cash flows. The high efficiency rate allows little opportunities for innovation or investments. After the business case, the infrastructure has no residual value even though the business case lifetime doesn’t correspond with the technical lifetime.

2) Strict European tendering rules. Innovative or alternative solutions by a contractor are difficult to reward once the tender specifications are published. An open question towards the employer reveals the idea or information to the competition. A private question prevents this, but an employer cannot reward this innovation without restarting the tendering process.

3) Increasing variety of developments change processes in the port area. What is the best way to anticipate? Risk management is already part of the construction process, to monitor building time and costs. However long term risk management is not yet applied.

A fourth conclusion follows from studying the current infrastructure. Terminals in a port can be divided roughly into two groups. On the one hand robust quay walls, heavy cranes and heavy platform loads, the container and bulk import terminals. On the other hand jetties for bulk export, oil and gas. It shows that terminals cannot be transformed just in any other function or build multifunctional.

As the Port is bound to the European Tendering rules, the solution must be searched within its possibilities. A Program of Requirements should have a certain buffer for innovation with more functional requirements without harming the usefulness of the construction. In depth financial evaluation of these projects is not the intention of this thesis. Discussing the value of investing in uncertainty is, creating awareness that a small investment during construction may be an advantage in the future. To create a future-proof design, the first thing the employer needs to obtain is as much information as possible. where can the uncertainty be expected and where flexibility can improve the lifetime of the infrastructure. Incorporating margins and flexibility at random creates economical unrealistic designs. Before PoR publishes the Program of Requirements for a project, clarity of the large cloud of uncertainty around that project is essential. On what issues is uncertainty and which actor may have influence on the course of the uncertainty?
Clarifying the unknown and discussing the developments with different actors, supported by statistics and prognoses from knowledge institutes (universities, TNO and CBS1) can transform uncertainties. From don't knowing what is unknown to knowing what is known and unknown. Anticipation can be incorporated in the Program of Requirements.

The research for uncertainty around a port infrastructure project results in a small number of possible physical changes to the infrastructure as a result of changed requirements, mainly forces by ships, cranes etc. Adding this uncertainty in the methodology as written below will transform uncertainty or developments into a revised specification or requirement.

1) Actor analysis. Which parties have influence in a development affecting port infrastructure.
2) A top down approach of developments and evaluating all uncertainty.
3) Actor consultation accompanied by the uncertainty portfolio (step 2) reducing its size by discussing its topics.
4) Extending the long term risk portfolio with probabilities and impacts of the resulting uncertainty followed by an anticipative measure or precaution.
5) Adding the measures to the first version of the Program of Requirements. What part of the design can be improved by incorporating flexibility or robustness.
6) A value comparison of this extended Program of Requirement with the first version. How much more must be invested and what extra possibilities does that generate?

Until this point, only functional requirements have been drawn up. The next step is formulating a technical design based on the required functionality. The possible ways of tendering and contracts are evaluated which of these is most suited to effectively apply the methodology. An interactive tender procedure allows the employer to discuss the project with contractors and important design decisions made together. Contractors experience can be fully utilized with a proper discussion. A DBM contract is best suited for large infrastructure projects as maintenance is included with a resulting Life Cycle Costs approach. This only applies when the magnitude of the project is enough for sufficient amount of maintenance work for the contractor to be beneficial. This is rarely the case for client projects in the Port of Rotterdam, where a D&B contract is better suited.

An example to demonstrate the theory as stated above is given with the case study of redeveloping a terminal in the PoR district. The ECT city terminal was selected and the methodology was applied to specify the requirements for a new function for this terminal (a reefer hub) Supported by the methodology is advised not to dedicate the design purely on refrigerated, but a multi-purpose terminal instead. Besides formulating the requirements for tomorrow for new infrastructure, this method also suits existing infrastructure for which new functions are searched for.

Concluding one sees multiple ways resulting in future-proof infrastructure. Flexibility, robustness or a combination of both. The presented methodology does not exclude any solutions, but is aimed for broader insights for the employer of an infrastructure project how to formulate the requirements for tomorrow. This leads to a new way of working together with different actors, a mutual trust in sharing information that needs time to develop. The emphasis is on the mutual benefits of infrastructure being able to adapt to changing requirements, an important recommendation towards all parties surrounding the project. The more downtime, the more money is wasted. In addition to this, the employer itself has to master sufficient technical and statistic knowledge being able to understand and calculate the impacts of certain changes to the infrastructure.

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1 TNO: Netherlands Organization for Applied Scientific Research TNO. CBS: Statistics Netherlands
III. SAMENVATTING

Technische en economische ontwikkelingen gaan sneller dan ooit. Dit levert een grote onzekerheid omtrent de functionaliteit van haveninfrastructuur op, zeker op lange termijn. Hierdoor liggen commerciële- en technische levensduur van de infrastructuur vaak verder van elkaar, resulterend in vaker en langer niet beschikbaar zijn van de infrastructuur. Dit is met name een probleem voor klantgerichte infrastructuur, het merendeel van de infrastructuur binnen de haven van Rotterdam.


Het onderzoek naar verbeterpunten start met het onderzoeken waar de huidige beperkingen van het gehele aanbestedingsproces liggen. Wat moet er veranderen om de gegeven oplossing mogelijk te maken? Hieruit volgen drie opvallende zaken:

1) Lean & mean trend in de business case. De hoge rendementsfactor laat weinig ruimte tot innovatie of investeringen over. Daarnaast heeft de infrastructuur na de business case geen restwaarde meer.

2) Strikte Europese tenderregels. Innovatieve oplossingen of een goed alternatief door een aannemer kan binnen de huidige tender zoals die gespecificeerd wordt, maar beperkt worden beloond. Via een open vraag wordt het idee openbaar gemaakt en via een gesloten vraag wordt de innovatie niet extra beloond en is het idee bekend. Of de hele tender moet worden herschreven door de opdrachtgever.

3) Groeiende mate van ontwikkelingen en onzekerheid. Er gebeurt van alles rondom te haven. Hoe is daar nu het beste op te anticiperen? Hoewel risico management al standaard wordt toegepast op de uitvoeringsfase van een project om de bouwtijd en bouwkosten te bewaken, wordt er nog weinig met risico management op lange termijn gedaan.

Een vierde conclusie volgt uit het bestuderen van de huidige infrastructuur, dat terminals grofweg in twee groepen gesplitst kunnen worden op basis van karakteristieken. Aan de ene kant de zware kademuren, grote kranen en zware bovenbelasting op het terrein horend bij containerterminals en bulk import terminals. Aan de andere kant de steigers voor bulk export of olie en gas. Hieruit blijkt dat terminals niet zonder meer tot een andere functie omgebouwd of multifunctioneel ontworpen kunnen worden.

De haven is gebonden aan Europese tenderregels. Binnen die spelregels moet de oplossing dus vallen. Vandaar dat het Programma van Eisen een zekere ruimte tot innovatie moet open houden en de eisen functioneel specificeren, maar in zoverre duidelijk dat de opdrachtgever straks niet met een onbruikbare oplossing zit. Het is ook niet de intentie van dit afstudeeronderzoek om diep op de financiële beoordeling van de projecten te gaan. Het is daarentegen wél de bedoeling om op een andere manier naar investeringen te kijken.
Het bewustzijn kweken dat een kleine investering tijdens de aanleg wellicht veel voordelen kan bieden in de toekomst.

Om tot een toekomstbestendig ontwerp te komen is het eerst van belang te inventariseren wáár de onzekerheid speelt en dus flexibiliteit te verwachten is. In het wilde weg een ontwerp opstellen wat geheel aanpasbaar is, of dusdanig over gedimensioneerd dat iedere mogelijke functie uitvoerbaar is, levert economisch onhaalbare ontwerpen op. Voor het Havenbedrijf derhalve een Programma van Eisen uit gaat vragen bij de aannemers, is duidelijkheid in de grote wolk van onzekerheid een vereiste. Wat voor onzekerheid speelt er en welke partijen zijn van invloed op deze zaken. Door dit duidelijk te krijgen en gedachten uit te wisselen met deze partijen over de ontwikkelingen, al dan niet gesteund door statistieken en prognoses van kennisinstellingen als universiteiten, TNO of CBS, kan een (groot) deel aan onzekerheid tot half zekerheden geformuleerd worden. Met de input van de markt (de verschillende actoren) is het huidige risicobeleid, dat tot nu toe vooral uitvoeringsgericht is, uit te breiden met lange termijn risico's. Risico management derhalve uitbreiden van risico geleid bouwen tot risico geleid ontwerpen in zoverre dat de opdrachtgever van niet wetende wat onbekend is tot wetende wat bekend en onbekend is. Hiermee kunnen anticiperend maatregelen voor opgesteld worden die mogelijk aan het Programma van Eisen (PvE) zijn toe te voegen.

Het onderzoek naar alle onzekerheden omtrent haven infrastructuur vanuit alle mogelijke verschillende achtergronden resulteert in slechts een klein aantal resulterende fysieke gevolgen op de infrastructuur. Voornamelijk verandering in krachten door ander materieel (schepen, kranen e.d.) Door het invullen van onduidelijkheden in de hieronder beschreven methodiek, kan onzekerheid / ontwikkelingen vertaald worden naar andere specificaties of herziende eisen.

1) Actor analyse. Welke partijen beïnvloeden onzekerheid en ontwikkelingen om de haven heen.
2) Ontwikkelingen en onzekerheidsportfolio invullen ( top down approach) Welke veranderingen kunnen de functionaliteit in de toekomst in gevaar brengen?
3) A.d.h.v. die onzekerheidsportfolio de verschillende actoren benaderen en zoveel mogelijk in proberen te vullen met de opgedane kennis uit deze gespreksronde.
4) Het lange termijn risico dossier uitbreiden met de kansen en gevolgen van de onzekerheden/ontwikkelingen met een anticiperende maatregel
5) Die maatregelen toevoegen aan het bestaande programma van eisen. Waar is flexibiliteit in te zetten, of wordt het juist robuust?
6) Kostentechnisch het uitgebreide PvE vergelijken met het eerste PvE. Wat kost het extra en wat beidt het extra?

Tot zover het functionele deel wat mee te nemen is in het Programma van Eisen. De volgende stap is dit PvE vertalen naar een technische oplossing. Hiervoor is gekeken naar de meest effectieve vorm van aanbesteden en contract om deze methodiek optimaal te kunnen benutten. Een interactieve manier van aanbesteden geeft ruimte om met de aannemers te kunnen overleggen en belangrijke ontwerpstappen samen te beslissen. Als contract is voor een groot nieuw werk een DBM contract gezien de onderhoudscomponent en de daaruit volgende Life Cycle Costs benadering aan te raden. Hier staat wel als belangrijke kanttekening bij dat het areaal groot genoeg moet zijn dat een onderhoudsperiode wel genoeg werk op levert. Hetgeen bij de vele losse projecten in het havengebied zelden het geval is, waar een D&B contract geschikt is.

Om al deze theorie invulling te geven is naar de herontwikkeling van een terminal in het Rotterdamse Havengebied gekeken tijdens een casestudy. Hiervoor is de ECT City terminal als onderwerp gebruikt. De methodiek is doorlopen voor een nieuwe functie (reefer hub) waar met de methodiek beargumenteerd wordt om niet blind te staren op refrigerated overslag.
maar rekening te houden met multifunctioneel stukgoed overslag. Naast dat er voor een nieuw project beter over de specificaties van morgen nagedacht kan worden met deze extra stappen in het inkoopproces, is het ook zeer goed toe te passen op bestaande infrastructuur waar een nieuwe functie voor gezocht wordt.

Concluderend kunnen we vaststellen dat er meerdere wegen naar een toekomstbestendig Rome leiden. Dit kan door flexibele-, robuuste infrastructuur of een combinatie van zijn. De methodiek in dit afstudeerverslag sluit niets uit, maar is opgesteld om de opdrachtgever meer inzicht te geven om een programma van eisen voor morgen op te stellen. Dit zal een nieuwe manier van samenwerken met de verschillende actoren betekenen, een vertrouwensband die tijd nodig heeft om te ontwikkelen. Het moet benadrukt worden dat iedere partij voordeel heeft bij infrastructuur die mee kan ontwikkelen met de vereiste functies. Hier schuilt ook een belangrijke aanbeveling in, ten opzichte van de houding van alle partijen. Hoe vaker infrastructuur niet beschikbaar is, hoe meer geld wordt verloren. Daarnaast is zowel statistische als technische kennis zeer belangrijk om ook in het huis van de opdrachtgever te houden. Het is belangrijk te kunnen begrijpen en berekenen wat een dergelijke verandering voor impacts om een constructie heeft.
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1. INTRODUCTION

The thesis at hand is going to discuss a revised procedure to formulate the Program of Requirements for more future-proof infrastructure. The research is mainly approached through the Port of Rotterdam’s point of view. In this chapter, the challenge is introduced with some examples followed by the thesis outline.

1.1 INTRODUCTION

Infrastructure of today is planned under conditions of uncertainty, but is required to remain functional over its technical lifetime. Due to all kind of developments, functional requirements for the infrastructure change soon and often. A challenge that the Port of Rotterdam is aware of, especially after the global economic crisis that started in 2008 the operational conditions have changed dramatically. Premises that held up decades, for instance the ports of call for the hinterland changed when Chinese investments in the Greek port of Piraeus claimed a significant part of the hinterland. Just one of the developments that illustrate that things are changing in the logistics world and that this requires accompanying infrastructural changes.

The Port of Rotterdam (PoR) is with a total throughput of 440 million tons in 2012 the fifth largest port of the world and the biggest in Europe. PoR has the ambition to become the most sustainable and efficient port in the world. (Port of Rotterdam Authority, 2013) One of the ways to achieve this is to incorporate more flexibility in its infrastructure. With a total port area covering 12.500 ha, 90 km of quay wall and 40 jetties, PoR manages and maintains a lot of infrastructure.

The majority of infrastructure projects at Port of Rotterdam are custom designed for the client, so-called customer oriented projects. This used to be by approaching an interesting client, or PoR itself was approached by a client, after which a contract was drawn up. Nowadays the available plot is tendered on the open market. First, potential customers present their business plan for that certain plot. PoR evaluates the different proposals on investment costs, revenues and strategic fit. The focus of a business case is mainly on the financial component. Is the investment earned back within the years of this business case?

Due to changing requirements, often the infrastructure has to be adapted or even rebuilt long before its technical lifetime, and business case has passed. Increase of ship size, use of different energy sources, a shift in economic power or the change of materials are examples of uncertainties surrounding port infrastructure projects.
Lifetimes of infrastructure.

Technical lifetime for infrastructure was introduced in section 1.1. In total, four different definitions of infrastructure’s lifetime can be distinguished (Dongen, 2011):

1) Technical lifetime: the period of time in which the infrastructure is able to safely fulfil its requirements.
2) Economic lifetime: the period of time in which the infrastructure is cost-effective to fulfil its requirements.
3) Commercial lifetime: the period of time in which the infrastructure is able to fulfil its original requirements. It can be economic and technically fine, when requirements change and there is no need for a certain part of infrastructure, the commercial lifetime is over. Ideally, this lifetime should match the duration of the business case.
4) Compliance lifetime: the period of time in which the infrastructure operable in the framework of laws and regulations.

For this thesis the different definitions of lifetime are very important, the research question that will be introduced in section 1.3 is addressing the challenge of decreasing the gap between technical and commercial lifetimes.

The following examples are to illustrate some expensive adaptations as a result of these changing requirements in the recent past that could have been much less or even unnecessary.

THE EMO TERMINAL. In the business case a necessary minimum depth was calculated. Before and during the construction of the quay wall, PoR’s projects department raised their concerns about this minimal depth and advised a larger depth. Financially that would not be profitable and not result in a business case to continue with, so both parties (PoR and EMO) stuck to the original design. However the terminal is less than three years operational and the customer realizes that they do need the extra depth. The reserve that was advised to take into account while designing is not there so deepening this basin is not possible with this quay wall. A new one must be built to address this problem according to Erik Broos during the brainstorm session. (Personal communication September 3, 2013)

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2 Europees Massagoed-Overslagbedrijf. The largest transshipment terminal for coal and iron ore in Western Europe.
THE AMAZONEHAVEN. The ECT Delta Terminal became operational in 1985 (ECT) and designed for ships up to 6795 TEU\(^3\). Nowadays vessels with twice this capacity are regularly calling at this terminal. Due to this enormous increase of scale in vessel sizes in the last decennia, the navigational area, known as the “Amazonehaven” must be widened. PoR has chosen to do this by decreasing the size of the EMO terminal. Around 25 years ago PoR started building the deep quay walls for the EMO terminal, before all contracts were officially signed explained by Maurits van Schuylenburg (personal communication August 16, 2013). After completion, the client (EMO) called at this (part of the) terminal with much smaller vessels than the design ship. Now for the Amazonehaven expansion, this over dimensioned and perfectly functioning quay wall is demolished and a new one is build 55 meters to the south. This can be seen in the picture below.

![Figure 2: Preparations of the build of the new EMO quay wall (left) (Source: POR Beeldbank)](image)

THE EUROMAX TERMINAL. It became operational in 2008 and after thorough research, the design vessel was set at 12,500 TEU. However, even before the terminal was finished the E-class of Maersk (over 14,700 TEU) became operational. How was it not possible to foresee the scale up of container vessels?

![Figure 3: Elly Maersk calling at POR (Source: POR Beeldbank)](image)

\(^3\) Twenty feet Equivalent Unit. An inexact unit of cargo capacity to measure vehicle capacity.
THE BRAMMEN TERMINAL was a concept custom build for handling Brammen\(^4\) and the specific ships transporting them. However this concept was not a success and the customer retreated. PoR was left with infrastructure that was purpose built and required expensive adaptations to be able to issue this plot.

These four examples raise the question: Could this early adaptation have been prevented and how can we improve new infrastructure and the specification of its requirements in such a way that it remains functional under changing circumstances? Changing requirements for infrastructure is not something new. Multi functionality for public places as for instance railway stations are common by now. Office buildings are another example of designing under uncertain conditions. Since the 2008 crisis, new office buildings are designed in such a way that adaptation to, for instance, residential purposes is possible without severe costs (Wouden, 2012). Adaptable infrastructure due to a design that allows easy reconstruction to be more suited for the current requirements.

The problem of uncertainty and how to deal with changing requirements when designing port infrastructure is described in The Flexible Port (Taneja, 2013). She concludes that PoR should not focus on short term customer demands, but more at long term developments. The problem definition of this thesis continues on this basis and how flexibility of infrastructure can be incorporated in the business case and resulting Program of Requirements.

### 1.2 PROBLEM DEFINITION AND RESEARCH OBJECTIVES

**1.2.1 PROBLEM DEFINITION**

As stated in previous paragraph, all kind of (uncertain) developments are affecting the functionality of infrastructure and can lead to expensive adaptations. The problem definition therefore is:

*Due to the increasing frequency and shorter notice of required changes to the infrastructure, the Port of Rotterdam wants to change from a customer oriented infrastructure to a more future-proof infrastructure.*

The above examples illustrate that flexibility, infrastructure being able to adapt to changing requirements, can be a solution to achieve more sustainable infrastructure. To incorporate flexibility, the employer has to revise the specifications of a project towards the contractor. On top of that, to recognize the importance of future-proof infrastructure, its value must be evaluated differently. The solution is more or less already given in the work of (Taneja, 2013):

*The commercial lifetime and the technical lifetime can be better matched by incorporating flexibility in infrastructure.*

It is clear that there are broadly two possibilities: increase the commercial lifetime or decrease the technical lifetime, two different strategies that result in different types of design. The sticking point lies in the current ways of tendering and procurement that are short term appointments between PoR and the client, based on a business case and cash flows. Transitioning towards future-proof (long term) implies a shift in responsibilities and requires a new way of procurement and the formulation of requirements.

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\(^4\) Brammen are slabs of steel, the first step in the process of iron ore into steel products
1.2.2 RESEARCH OBJECTIVES

The transition means a necessary new approach to the business case. The research objectives are as follows:

1) Gain insight in the current procurement procedures.
2) To identify the bottlenecks in these current procedures that limit the adaptive functionality of infrastructure, the gap between commercial and technical lifetime.
3) Compose an extended procurement procedure that decreases the gap between commercial and technical lifetimes and apply this to a case study concerning a port infrastructure project.

1.3 RESEARCH QUESTION AND SUB QUESTIONS

1.3.1 RESEARCH QUESTION

The thesis’ research objectives are generally applicable to all types of infrastructure projects. Since this research opportunity is commissioned by the Port of Rotterdam, the research approach is based on the PoR’s major infrastructural needs, a transition from dedicated customer oriented towards future-proof infrastructure. The research question is:

*How can flexibility and adaptability be incorporated in the business case and the resulting contractual agreements for construction?*

**FIGURE 4: SCOPE OF THIS THESIS GIVEN THE PROBLEM DEFINITION**

In Figure 4 visualizes the part of the infrastructure process this thesis covers. The objective is to identify the bottlenecks and overcome these with a revised procurement method.
1.3.2 SUB QUESTIONS

To be able to answer the problem definition above, the following sub questions are defined including the approach to answer these questions in Italic:

1) What are the drawbacks of the current tendering procedures with a business case?
   *Literature study, brainstorm session and interviews*

2) Which uncertain developments apply to port infrastructure projects?
   *Literature study, Port Compass, interviews.*

3) Which of these can you take into account as Port Authority by incorporating flexibility in the Program of Requirements?
   *By the authors study and research based on research data, interviews.*

4) What will be the timespan of the business case?
   *By the authors study and research.*

5) How to specify a port infrastructure project in a tender such that the contractor can fully utilize his knowledge creating innovative solutions without compromising the usefulness of the solution?
   *By the authors study and research and tests by one or multiple case studies.*

6) How to evaluate and compare these innovative solutions?
   *Evaluation of the results from the case study.*

7) Is the current balance of responsibilities between employer and contractor optimal or can this be approved?
   *By the authors study and research and interviews.*
The steps that need to be taken to obtain this solution, a revised way of tendering and contracts that are the main objective for this thesis. These steps from the challenge to the solution can be visualized in the following flowchart (Figure 5):

Before discussing improvements, the main types of port infrastructure are described when starting this research. Flexibility in infrastructure is mentioned in the introduction, but what exactly is flexible infrastructure? This background information can be found in the next chapter (Background). In chapter 3, the current tendering and contracting procedures are revealed to have a couple of issues that limit the possibilities for innovative tendering. Before identifying them, general infrastructure procurement theory is discussed, later zooming in on the procurement process used at PoR. In this paragraph, the different steps and reasoning for using this method or contract will become clearer.

As the bottlenecks are pointed out, the research approach is discussed. Which of the bottlenecks can be addressed and which can’t? Further elaboration of the scope is discussed, which will be connected to the different relationships between actors surrounding a project and formulating a long term risk portfolio. Gathering the necessary information for this risk portfolio is discussed in chapter 5, uncertain developments for port infrastructure. What uncertainty surrounds a port project exactly, and how does the asset owner / employer obtain the most information to reduce this amount? The final step is evaluating the effects of uncertainty on the specifications/requirements for port infrastructure.

Chapter 6, updating the program of requirements for a port project continues with the implementation of the obtained information in the procurement process.

Thus far, only theory is discussed. An example of how a Program of Requirements could look like with this revised method - a partially fictive case study - can be found in Chapter 7.

The thesis concludes by answering the research questions and providing recommendations regarding necessary follow-on research.
2 BACKGROUND

To start of the research, this chapter provides the reader with some basic knowledge of the direct objects of the thesis, the infrastructure itself, together with the definition of flexibility in infrastructure beholds.

2.1 INTRODUCTION

Before talking about uncertainty surrounding port infrastructure, let us first give a proper outline of the infrastructure that is used in the port. This chapter starts with the perspective of a cargo ship sailing on the ocean towards the customer (and the other way around from source to ships). The specifications of the cargo require different infrastructure for its terminal. A distinction between the main types of cargo is discussed and the corresponding infrastructure that is required to off-load the ship. It must also be noted that there is a difference between import, export and transshipment terminals. Differences and similarities between terminals are pointed out, since the requirements can be decisive for the infrastructures alternative value.

The second part of this chapter focusses on the definition of flexible infrastructure. As flexibility is an extensive concept, it is necessary to describe what this means for infrastructure, and specifically for port infrastructure. The next paragraph starts with a "charter" entering the port making the final part of the trip on route to the customer.

2.2 FROM THE OCEAN TO THE CUSTOMER

A ship enters the port via the entrance channel. Often, this is a deepened channel, because the depth near the shore is for the majority of ports insufficient for ocean going vessels. The enormous breakwaters at both side of the port entrance shelter the port area and approaching vessels from currents and high waves. Breakwaters are extended to a water depth at least beyond the breaker zone, where alongshore transport of sediment doesn’t occur anymore (Bosboom & Stive, 2011). This slows down the process of siltation in the harbor mouth. Once inside the port area, the ship continues its way to the terminal via the navigational areas and harbor basins.

Terminals can load or unload ships basically in two ways, with a jetty or at a quay wall. Jetties are berthing platforms on piles that are built from the shore to the required water depth in a certain water body. This is a less expensive solution in shallow fore sea or near shore areas and/or when no heavy loading equipment is required. Quay walls are heavy structures, commonly built with concrete combined with steel sheet piles that are used as earth retaining structures to moor, load and unload ships. Behind the quay or jetty the loading and unloading platform can be seen. This is where cranes place / pick up the cargo coming out of the ship and is sorted for the next step in the transport chain. Container terminals need a large apron behind the quay walls for the maneuvering with the unloaded containers, and sufficient area sorting and storing, where wet bulk terminals don’t need a lot of space near the waterfront. At refineries for instance, the oil can be pumped via pipelines to the storage tanks located more inland.

The harbor basin is the wet area where the ships navigate. Guidelines prescribe the dimensions a basin need to be, for a set design vessel, or the other way around, it prescribes the maximum size vessel that can safely sail and maneuver into the basin. Significant parameters are the depth, navigational width and turning basins. Mooring dolphins are for the majority (a group of) piles that aren’t connected to the shore and help navigate or moor ships.
The hinterland connections are pipelines, road, and railway tracks and inland shipping. By these connections, the hinterland is supplied with the cargo that is being shipped into the port (and vice versa). It is easily understandable that the type of terminal needs to have adequate connections for the cargo to continue its way to the end location. For the Port of Rotterdam, the railway network is spread out to the middle, East and South of Europe.

Thus in short, the port infrastructure can be placed into four categories:

- Navigational areas (breakwaters, harbor basins and entrance channel, bottom/shore protections)
- Mooring facilities (Quay walls, jetties, mooring dolphins)
- Load/unload facilities (gantry cranes, conveyor belts and its foundation)
- Logistical facilities (hinterland connections and apron)

The Port of Rotterdam has more infrastructure in its portfolio (sensors and mooring poles etc.) (Jurgens, 2012) which is not considered significant for this research. The next paragraph will go more into detail in the different types of cargo as each group of cargo requires specialized handling equipment, determining the requirements for a terminal.

### 2.3 TRANSHIPMENT GOODS

The main types of cargo are:

- Dry bulk (ore, coal, grain)
- Liquid bulk (crude oil, petroleum industry products)
- Containers
- Break bulk or multi-purpose/general cargo. (varying from paper, steel, fruit, automotive semi-finished products and RoRo)

Then there are smaller cargo flows, such as LNG and reefer cargo containing fresh products. Each of these cargo flows requires specialized handling equipment. That's why one can find dry bulk terminals, liquid bulk, container terminals, LNG terminals, RoRo terminals in all sizes and shapes throughout the Port and Industry complex. The characterizations of the most common terminals are discussed next.

### 2.4 TERMINALS

#### 2.4.1 DRY BULK TERMINALS

As already mentioned in the last paragraph, dry bulk are raw materials transported in large ships. These ships are basically an open hull where the bulk is dumped in by bucket or grab cranes.

Dry bulk terminals are in two types. The difference is whether the terminal is an import or export terminal. Export can be in its most simple form a conveyor belt on a jetty, dumping the bulk in the ships hold. For the import of dry bulk however, large heavy equipment such as cranes or vacuum installations are needed to empty the hold.
This requires heavy quay walls, to support this heavy rolling equipment. The latter causes heavy quay wall loads, which do not appear at an export-based terminal. It is therefore not likely that an export terminal can be used for import. The other way around should load-wise not create any problems.

At import and transshipment terminals, the cranes unload the bulk onto systems of conveyor belts that transport it to the storage areas. Bulk is stored in the open in big piles (agricultural products are stored in warehouses) generating heavy loads on the surface.

### 2.4.2 CONTAINER TERMINALS

The largest cargo ships of the world are all container vessels. Already up to 400m in length and 59m wide. (Maersk Triple-E) These ships require enormous gantry cranes to reach the outside lane of containers, generating large forces on the quay wall. The quay wall, like for the dry bulk import terminals, must also absorb the mooring forces of such vessels. After the gantry cranes have lifted the containers off the ships, they are placed on trailers or straddle carriers into the storage yard, sorted regarding its next step: transshipment, storage or to the hinterland.

This storage yard requires a large surface, for the vast amount of containers. The size of this area is more important than the number of births, since the unloading rate of containers is so high. The hinterland connections on land are roads en railways. Inland barges and vessels can be loaded at the same quay walls or at a different part of the terminal (inland vessel do not require such large equipment as the ocean vessels).

### 2.4.3 LIQUID BULK TERMINALS

Liquid bulk includes crude oil and derived products. For the Port of Rotterdam, 24% of the total throughput is crude oil. This is blended\(^5\) by the refineries in the port and among other ways via pipelines pumped to the hinterland. Apart from this, a large variety of chemical products goes in and out the port. Liquid bulk terminals are storage tanks or refineries.

Loading and unloading at the terminal doesn’t require heavy equipment as the liquid is pumped from the berthing location via a pipeline (supported on a jetty) to the storage tanks. Therefore, no quay wall or deep water just next to the terminal is required for mooring and (un)loading. To prevent contamination by leaking, the storage tanks are surrounded by a dam that should be able to hold all the content.

\(^5\) Blending is the process of adding different fractions of oil and additives to a specified mixture for the customer.
Transport to the hinterland is done via pipelines or railways. On the topic of uncertainty a refinery is a reliable customer, because the commitment to build a refinery is very high, with high startup / construction costs. However, now that there is a global overcapacity of refineries, nothing is certain and even the well situated refineries in the Rotterdam port area can be terminated. (A. Castelein, CEO of PoR)

A special type of liquid bulk is LNG (Liquid Natural Gas). LNG requires special ships and careful selection of locations for a terminal, because LNG is considered very dangerous, although harmless in liquid form the way it is shipped and a leak would cause a large gas cloud with fire hazard. Therefore a wide safety contour is required for such a terminal. An LNG terminal can be transferred into an oil terminal, the other way around is seldom possible.

2.4.4 BREAK BULK TERMINALS

Break bulk is a variety of individual loaded cargo in bags, boxes or barrels. Most of this is done by containers these days, but break bulk is especially for more specialized cargo on irregular schedules or routes. Cargo going to smaller ports will probably be transported by a general cargo ship and unloaded at a break bulk / multipurpose terminal. Multipurpose terminals are terminals able to handle break bulk as well as containers.

The main disadvantage for multipurpose is the more resources required compared to a dedicated terminal. The cranes must be able to lift containers, dry bulk and break bulk, requiring a solid quay wall with a wide range of mooring configurations. If the terminal also receives a certain amount of containers, a dedicated container berth is necessary. The terminal is than referred to as a multi-purpose terminal.

RoRo is another type of break bulk. Complete trucks drive onto a large ferry like vessel and continue their way at the other port. The main infrastructure is a ramp for these trucks. The hinterland connection for a RoRo terminal is understandably a fast connection to the road network.

2.5 THE DEFINITION OF FLEXIBILITY FOR INFRASTRUCTURE.

The dictionary (Oxford dictionaries, 2014) defines flexibility as the ability to be easily modified. This explanation is fairly accurate in the framework of infrastructure projects. Uncertainty about the future is increasing, the technological possibilities keep increasing and the post-crisis economic balance throughout the world is changing. To prevent expensive adaptations as much as possible, the construction should be designed such that changes can be made easily and cost-effectively. Physical flexible infrastructure is designed in such a way that it can be expanded or reassembled fairly easy without demolishing the construction. Modular building is a possibility. Recent study of (Amarouk, Gijt, & Braam, 2013) demonstrated possibilities of modular diaphragm walls connected by vertical pre stressing, comparable to a Lego construction of concrete blocks that are locked together with steel cables. Another example is a floating crane.
In contrast to flexible infrastructure, robust infrastructure has been designed to stay operational under changing conditions. A robust port has the ability to meet requirements under changed circumstances, without significant impact on the service level and the (re)construction costs are low.

Designing somewhat bigger is relatively cheap compared to a new round of reconstruction years later. As the engineering is done once instead of twice, the equipment and personnel is already at location, roughly stated the only additional costs are the extra material and time. This cannot possibly be more expensive than doing this whole process over again. One of the main principles of standardization is a similar, often robust design for multiple applications. The interchangeability enables the employer to shift functions around without losing functionality. As well as for maintenance, one approach with corresponding material and equipment is enough.

A third option is a combination of robust substructure and a flexible superstructure. An example is a bridge, where the passing traffic size passing a bridge can shrink or grow in the future. The foundation and pylons may be built robust enough to endure a century and to allow expansion while the roadway has been designed for a lifespan of, e.g., 10 years. After 10 years the new roadway can be reconstructed to adapt to the new traffic flows. To illustrate this option, Figure 10 is the placing of the upper part of the Jan Schaeferbrug in Amsterdam. The foundation could be constructed immensely strong and the roadway, could be replaced with another bridge section, should the deck in use, not be able to handle the traffic flows. The cranes lift off the roadway and another one is fixed into position. (It is of course not as simple and economic as just said, but gives an idea of this option.)

**FIGURE 10:** THE CONSTRUCTION OF THE JAN SCHAEFERBRUG OBTAINED FROM: ([WWW.PAROOL.NL](http://WWW.PAROOL.NL))

Flexibility is at the heart of uncertainty management. (Taneja, 2013) states: “A flexible or adaptable port can be altered or employed differently, with relative ease, so as to be functional under new, different, or changing requirements, in a cost-effective manner.” However, flexibility and robustness are much comprehensive concepts and to go back to the problem definition (better matching of commercial and technical lifetime) both concepts mean different aspects for increasing the commercial lifetime on the one hand and decreasing the technical lifetime on the other hand, covering (Taneja, 2013):
Compatibility: The capability to efficiently integrate and operate with other elements in a system without modification.

(De)constructability: Meeting the overall agreements, to which extent can a design or its components of a system easy and economically disassembled or dismantled.

Modularity (-in-design): Refers to use of standardized units or dimensions, facilitating interoperability, interchangeability, and scalability.

Recyclability: The characteristic of design that allows reuse after processing.

Interchangeability: Capability of an element to replace another element (in the same or another system) to fulfill the same requirement.

Durability: Measure of the ability of materials or structures to continue to be useful after an extended period of time and usage.

Interoperability: Ability of a system to work with other systems or an element of the system to work with another element with the same system

Maintainability: Characteristic of design that reflects the ease, accuracy, safety and economy of performing maintenance actions.

Reliability: Characteristic of design that ensures that a system will meet its performance requirements throughout its lifecycle

Resilience: Degree to which a system can recover quickly from a major disruption while regaining, or even exceeding, its original level of performance

Scalability: Characteristic of design that enables the system to be scaled (up or down)

Separatibility: Used in the context of materials, refers to segregation for reuse, ease of extraction and sorting. In case of components it requires realistic tolerances, non-monolithic joints, determinate designs, and appropriate detailing

Standardization: The degree to which designs achieve interchangeability in use

Versatility: Capability of a system to carry out other functions than included in the original requirements.

A port system consists of three layers, the physical infrastructure, the operations and procedures and de products and services. The type of uncertainty determines what type of strategic action can be carried out, flexibility and what kind of flexibility, or robustness. This will be elaborated in the chapter: uncertain developments for port projects.
As the theoretical definition of flexibility for infrastructure is known as well as the differences and similarities for cargo's and the ships and terminal equipment, it is time to address the aspects of terminals that form the functionality and in what way flexibility or robustness increases this flexibility.

The different aspects of the terminal are:

- **Quay wall / Jetty**: absorbance of forces by the ship and cranes determine the max crane and ship size possible for the substructure.
- **Apron**: Maneuvering area container terminals require more space than break bulk because of the reach stackers. The capacity of the terminal depends on the amount of moves per hour can be completed.
- **Storage area**: is also determining for the capacity, partially connected to the hinterland connections. Storage area can be small when the arriving cargo immediately can be transshipped further in the transport chain.
- **In and out connections (hinterland connections)**

The figure below indicates the different aspects on a map of a multipurpose terminal.

![Figure 11: A Standard Layout for a Multipurpose Terminal (Ligteringen 2009)](image-url)
2.7 CONCLUSION

This chapter introduced the world of port infrastructure. Each terminal requires its own dimensions and specifications and can only be compared very broadly. Container terminals, dry bulk import and break bulk all share the need for a heavy quay wall to support the heavy equipment. This equipment is for the majority on rails, needing a solid foundation. Also the storage area must be large and able to sustain large surface loads. Dry bulk export, liquid bulk (and LNG) together also share the same base facility requirements. These do not require a quay wall or deep water near the shoreline. A jetty suffices. Storage space is large as well, but does not have to be explicitly near the shoreline.

This separation of terminals is essential for alternative value of the infrastructure. Each terminal has certain margins to adapt for other use, but an LNG terminal that has to be rebuilt for containers is certainly not an option for a business case for that LNG terminal. Next, the definition of flexible designing of infrastructure was discussed, which meant designing infrastructure that has the ability to be easily modified. There are different options on how to accomplish this. Constructing it in such a way that it can be expanded or changed, building it robust that changing functions within margins can also be accommodated without changing anything. So flexibility can be accomplished by the design itself or by flexible requirements, a bandwidth in between functionality is possible without reconstructing. Third option can be a combination of both. The key of adaptable infrastructure is easy and fast reconstruction and for robust (sub)structures by investing a little extra in material and time and therefore saving a large amount of money on design- and startup costs.

Now as the concept of flexible port infrastructure is discussed, it is time to get insight in the procurement procedures. What is involved in procurement and what are the bottlenecks currently that counteract the implementation of flexibility in the port infrastructure.
3 PROCUREMENT THEORY

The previous chapter has treated the topics of infrastructure and flexibility. As the concept of flexible infrastructure is discussed, the procurement process is next.

3.1 INTRODUCTION

One the research objectives is exploration of the bottlenecks in the current procedures. To define these, the first step is analyzing the current situation. How does procurement work now? What sort of requirements is currently specified?

Infrastructure projects can be divided into two user directions: Customer oriented projects, where a private client gives a functional set of requirements and public projects, where every day users are the client. In the Netherlands, Rijkswaterstaat is employer mostly for public projects. With these contracts, no revenue is to be expected by rent for instance, so lifecycle costs play an important role in the decision making. As this thesis is mainly written for and from the perspective of the Port of Rotterdam, the methodology is developed for customer oriented projects.

First, a clear distinction between the concepts tendering, contracting and procurement (UNDP). These concepts are used regularly, and are important not to mix up.

Contracting is the procedure how the employer determines its role towards the contractor, a partner, supervisor, or designer and the mutual agreements. The way of tendering depends on the contract the employer is going to use. Procurement is the announcement of the works and the public/restricted invitation for contractors to respond with a price and plan of action; simply said the purchase of a service/product. Tendering is a competitive method of procurement, taking price and quality in consideration for the most suited offer.

This chapter discusses the current procurement processes, generally for infrastructure projects and more specifically the policy for Port of Rotterdam. First the ways of procurement, what sort of contracts are used in infrastructure projects and how this all comes together in a business case. What is already done to handle unexpected developments and finally what the limitations are that oppose the incorporation of flexibility.

3.2 PROCUREMENT IN INFRASTRUCTURE PROJECTS

Procurement is the process where the employer announces a new project for which they are searching for a contractor who is going to (design and) execute this project. In the case of infrastructure, this will be a governmental body for public works, the majority of infrastructure projects or in the case of this thesis the Port of Rotterdam Authority. The procurement procedure determines the relation between the employer and the interested contractors and based on what type of contract the project will be executed. The interested contractors can respond to this invitation by handing in their plan of action with a price.
Procurement in infrastructure projects is done in multiple ways and the information up next is compiled by (Rijkswaterstaat), (Havenbedrijf Rotterdam N.V., 2007) and (European Union, 2009):

PUBLIC (UNRESTRICTED) TENDERING. Already shortly mentioned in the introduction of this chapter, public tendering is a public competitive procurement method, when an employer publishes the required specifications. Generally speaking any contractor may enter the bidding process following publication of this form of tendering. The bidding contractor, provided that he meets the requirements, with the most attractive offer is awarded the contract. There is no negotiation between contractors and the employer. This way of tendering is most suited for projects for which a large number of contractors exist.

NON-PUBLIC (RESTRICTED) TENDERING. Same procedure as above, interested parties may register once this form of tendering has been notified. A minimum of five suitable parties are then selected by the employer (Phase 1). In phase 2, the selected parties submit their tender, after which the contract is awarded to the successful bidder. Again, there is no negotiation. Restricted tendering is applicable in monopoly situations with a small supply of contractors. Availability could become an issue. Projects where there is a large supply but also high costs, preselection of candidates keeps the administrative procedures in control as reviewing a large quantity of offers consumes too much time and money.

COMPETITIVE DIALOGUE PROCEDURE. Applied for large or financial/juridical complex infrastructure projects. The employer invites at least three parties guided by selection criteria and with these parties, the solution is discussed by dialogue. The evaluation of the submitted tenders is always according to Economic Most Advantageous Tender (EMAT) criteria.

NEGOTIATION PROCEDURES WITH PRIOR ANNOUNCEMENT. The employer invites parties. PoR selects the contractors that are allowed to hand in their offer, based on upfront announced criteria. No fewer than two may register for this negotiated round. This procedure may be used for large projects where technical specifications and functional expectations are impossible to estimate up front.

LIMITED SUBMISSION. The employer does not announce the project upfront, but awards a contract to a party underhand. This method can be applied in limited situations:

- When public or restricted tendering have failed and the tenders handed in were unusable (every tender budgeted over the pre calculated construction costs).
- Time is of the essence (large calamities such as natural disasters)
- Noncommercial, research related products.

However, PoR is included under a guideline for exceptional sectors, allowing this way of tendering without earlier attempts of public tendering.

BEST VALUE PROCUREMENT. A new and upcoming form of tendering is called Best Value Procurement (BVP) (Aanbestedingsmakelaar.nl, 2012). This is a form of stimulating the contractors to show their capabilities and why they are better than other subscribers. The interesting element in this form is discussing their approach: not only by an impressive plan of action in writing, but more via interviews. BVP is reviewed with more focus on quality and less on price. The contractors do a risk assessment and measures to reduce them. This is an interesting point for PoR, through years and years of port related projects, a lot of experience about risks during certain projects is gathered. It deserves attention to estimate the improved quality of risk management by a contractor. BVP factors such as quality, options incentives etc. can evidently be better evaluated through the contractors' expertise.
Port of Rotterdam selects the right tendering procedure by using the Kraljic-Portfolio. More on the PoR policies later in this chapter and visual in Figure 14: Present Procurement Policy at Port of Rotterdam.

3.3 CONTRACTS USED FOR INFRASTRUCTURE PROJECTS

Until recent years, the traditional form of contract was used. This beholds a strict separation of design and realization responsibilities. The employer provided the design and the contractor only had the responsibility of constructing said design. Nowadays a shift in responsibilities in design and construction towards the contractor is observed. Employers are more and more using contracts like Design & Build. In the contract, the relation between the employer and contractor will be determined: Who is responsible for design, construction and / or maintenance, as well as risks and expected results. Both ways of contracting will be explained in the next paragraph.

3.3.1 TRADITIONAL CONTRACTS

The traditional international known and applied Conditions of Contract (in Dutch: “bestek”) are described in the FIDIC Red Book. The employer is responsible for the design and the contractor executes the works. The traditional contract is mostly applied to smaller - or standard works. Since the employer has a high level of influence in the process and the contractor is only responsible for the execution, this form of contract is very limited in the possibilities of innovative ideas by the contractor.

Traditional contracts can be divided into two forms, performance based, where the employer demands a certain commitment from the contractor and result based (Dutch: RAW-bestek). In a result based contract, the employer has a design that has to be executed, requiring a certain result. Performance based is mostly applied to maintenance works, whereas result based beholds the realization of a new infrastructure project (Havenbedrijf Rotterdam N.V., 2007).

3.3.2 INNOVATIVE CONTRACTS

The traditional division of roles between design and construction hinders the integration of knowledge of both fields and executing parties. Therefore in the last years, a trend is visible towards more integrated contracts in larger one-of-a-kind infrastructure projects. The employer is assigning more work and therefore risks to the contractor by setting out a more functional Program of Requirements, making the contractor responsible for both the design and construction. Internationally, the conditions for such a Design & Build contract are known as the FIDIC Yellow Book.

3.3.2.1 DESIGN & BUILD

The employer sets out a Program of Requirements based on performance specifications and the contractor, or a collaboration between a contractor, architect and/or engineering company will be responsible for both the design and the construction. The employer buys a solution whereas in traditional form the client buys a product set by his own design. This integrated approach has the main advantage that the transition from design to construction is smoother, with only one party responsible. A disadvantage for the employer is the decrease in influence on the design.

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6 The Kraljic Portfolio categorizes products (in this case infrastructure) according to financial impact and supply risks.
7 Fédération Internationale des Ingénieurs-Conseils, the international federation of consulting engineers.
The project is offered as one contract and tenders will be evaluated on up front specified criteria. For maintenance works for public projects, the same principle of contracting is used: Engineering & Construct (Rijkswaterstaat).

### 3.3.2.2 DESIGN, BUILD, FINANCE, MAINTAIN AND OPERATE

Besides giving the contractor responsibility of the design and construction phase, expansions of contract, such as maintenance, are also more and more applied. Below are three possibilities.

**DBM.** The contractor is also responsible for the maintenance of the infrastructure for a certain period. As a result, the maintenance phase of infrastructure will be more integrated during the design and planning, leading to lower life cycle costs of the construction.

A DBM contract is used for the execution of Maasvlakte 2 for the complete project (Havenbedrijf Rotterdam N.V.). After the design and construction of the land reclamation and sea defense, the contractor PUMA⁸ is responsible for five years of maintenance of the sea defense. Part of this contract can be viewed as an alliance, but more on this at the bottom of this page.

**DBFM.** The same as the DBM contract above, but including the responsibility to finance the project for a certain period. The employer pays for a service (an available highway) instead of the product in the traditional contracting way (a double lane highway). Example given by (Rijkswaterstaat)

**DBFMO.** PPP⁹ contracts are DBFMO, they also include the exploitation of the infrastructure over a certain contract period of 20 to 50 years. (Kennisportal Europese Aanbestedingen) A key motivation for governments considering public private partnerships is the possibility of bringing in new sources of financing for funding public infrastructure and service needs.

### 3.3.2.3 ALLIANCE

In projects where the risks and their origin are unknown and high, an alliance between the employer and the contractor can be made. Both parties are responsible for the budget, the risks and the profits. The main advantages are that both employer and contractor are working as a team and share the risks and profits rather than dividing them. The disadvantage of this collaboration is that both parties have to gain trust towards each other, a time consuming process, that off course costs money. An alliance is based on the mutual gains theory.

An example of an alliance in the PoR projects portfolio is part of the sea defense of Maasvlakte 2. The target was on optimal total cost of ownership on a DBM contract. Both PoR and the contractors had advantages in creating an optimal solution. A base solution was prepared, but the contractor came up with a more economical innovative solution for the robust part of the sea defense. The Port of Rotterdam allowed the contractor to build the sea defense this way, on the condition that it was as safe as the "standard design" and that the profit of this innovative design compared to the budget of the standard design would be split between employer and contractor.

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⁸ PUMA: project execution Maasvlakte 2, a partnership between Boskalis and Van Oord.
⁹ Public Private Partnerships
3.4 DEFINITION OF A BUSINESS CASE

The concept *business case* was already shortly mentioned in the introduction. Generally explained, a business case is a tool to provide insight in the costs and benefits of a project to substantiate an investment decision. The objectives are to estimate feasibility, the complexity and duration of a project, in a way that the executive management can set a budget for that project. (Oldenkamp & Veen, 2003)

More often private funding and operation by private parties is taken into consideration for infrastructure projects. For customer oriented projects, a business case can be used by the employer (PoR in this thesis) to make a decision whether or not the advantages and expected revenues from exploitation are worth the required investment costs. The conclusion of a business case should be a compelling argument for implementation. (Rouse, 2012) The above mentioned projects are typically contracted with DBFM(O) contracts. It is used as analysis of all business economic aspects where agreements must be made by the in financing and exploiting involved parties.

Internally in a company, the business case can be used as a financial motivation to realize a project or implement a decision. Therefore, all business cases consist of at least an overview of all cash flows and risks of the project that is being evaluated. Compiled by (Ormont, 2013) and Frans van Hooff (personal communication, November 20, 2013)

3.5 RISK MANAGEMENT IN INFRASTRUCTURE PROJECTS

During every construction project things go wrong, the objective is to limit the faults and their impacts via risk management. To be prepared for the unexpected, and to set responsibilities for the parties involved in a project should undesirable events happen, a risk portfolio for the construction is used (Eelants). For integrated contracts, the contractor supplies the employer with that portfolio and anticipative measures. When a certain event occurs, both employer and contractor know what is expected of them (based on the author’s experience as an intern at Iv-Infra BV, a Dutch Engineering company) In order to improve risk management in construction projects RISNET was founded in 2003, a network sharing information about risk management between multiple parties currently developing guidelines and tools for risk management. As of today, the majority of governmental employers and engineering unions are partners in RISNET (Eelants, kennisplatform CROW, RISNET, 2014).

PoR as well already applies risk management for its projects. Together with the parties that are involved in said project, a risk register or portfolio is set up. In general, risks can be categorized into four groups:

- Investment risks
- Construction risks
- Exploitation risks
- Revenue risks.

The current risk management consists of a portfolio with certain risks elaborated basically on three different aspects (Poppeliers, 2011). First the risk description with among others the probability, consequence, status and the owner of the risk. The owner is the party responsible for dealing with the consequences by this risk. The second part is going more into detail of the consequences, the value of the risk, time and money wise and a possible corrective measure. Again the involved parties point out the manager of the consequence.
The third and final part contains the value of the risk after the corrective measure is applied. This assesses the reduced costs and time loss should the precaution be taken. The risks discussed in such an assessment are for the majority short term risks during the construction period, that jeopardize the deadline and budget of construction.

3.6 REVIEW OF PROPOSALS: LOWEST PRICE VS. EMAT

Once the interested parties have subscribed their tender, or bid, the employer can evaluate these and award the winner by two ways: Based on lowest price or based on most quality for the lowest price.

The lowest price speaks for itself, the contractor that can fulfill the asked requirements for the lowest amount of money, gets the contract. Awarding on lowest price is done because it is less administrative costs, more competition, procedures are quicker and the choice for the winning contractor is easily accounted for. (Hardeman, 2013)

In the last years a shift towards EMAT criteria is visible. EMAT stands for Economical Most Advantageous Tender. Study by EIB (economic institute for building) showed that applying EMAT criteria increases the value of the solution. (Hardeman, 2013) Instead of lowest price only, the offered tenders now will be reviewed on the (relative) highest quality for the lowest price. On average, 61 % is based on price and 39 % on quality based criteria.

The most recent tender for a public project by PoR, (Reconstructie Waalhaven O.Z) the evaluation is done in a 50/50 ratio for price/quality. The price is evaluated with the lowest tender sum as the benchmark. If another tender is 10% more expensive, this contractor will be awarded 10% less points. The quality criteria are appearance of the area (10%) hindrance for passing traffic and residents (20%), approach of unexpected findings i.e. explosives (10%) and sustainability (10%) (Knijnenburg, 2012) Rijkswaterstaat only evaluates by EMAT criteria (Rijkswaterstaat). However, the factual appraisal of quality is not significant enough. The evaluation is still too much translated into risks and therefore lowest price is often the deciding factor. The spirit to evaluate more on quality is something to work on as stated by Arnoud the Bruijne. (personal communication, September 10, 2013).

In general, quality based criteria include necessary time for realization, planning, sustainability, risk management, operations, economic position etc. (Hardeman, 2013)
The port infrastructure of PoR is by European Law seen as utilities and therefore must be procured by the European procurement policy if the tender sum for infrastructure projects exceeds 5,2 million euro (Broesterhuizen, 2012).

Port of Rotterdam procures two types of projects: customer oriented projects, for the terminal operators and public projects, for hinterland connections (roads, railways, bridges etc.) The most complications due to changing requirements occur at customer oriented projects. The main topic is therefore customer oriented projects. How does a customer oriented project originate and what are the following actions that are taken? This is schematized below.

---

**FIGURE 13:** PROCESS OF PROCUREMENT FOR A CUSTOMER ORIENTED PROJECT, INFORMATION PROVIDED BY TIM GADEMAN (PERSONAL COMMUNICATION SEPTEMBER 16, 2013)

The negotiation starts by the client of the projects (for the majority this is a terminal operator) setting out his functional requirements. What is he/she going to do with the terminal? The Port of Rotterdam hands over this program of functional requirements to one of three engineering companies that are part of a framework agreement10. The selected engineering company transforms this into a program of technical requirements. This is the base of the tender for the contractors, who can offer their bid for the works back to Port of Rotterdam.

Public projects are evaluated differently. Instead of rent, the improvement of for instance traffic flow and or infrastructure that is worn and must be replaced, are reasons to execute such a public project. The procurement policy follows the same steps as the customer oriented project in Figure 13: Process of procurement for a customer oriented project but without a client delivering functional requirement. PoR calculates via capacity management the future requirements for the traffic flow.

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10 A framework agreement is used by employers and contractors for a minimum amount of work at a predetermined price and conditions for a certain period.
To go into more detail in step 2 and 3, the procurement policy applied by PoR is covering the following steps:

First, the scope of the works must be determined and then the value of this project. This is done by using the Kraljic Portfolio. The Kraljic Portfolio classifies projects into four quadrants based on the financial impact versus the supply risk. A high supply risk means just a few or only one contractor is able to realize the project. In Figure 14: Present Procurement Policy at Port of Rotterdam the Kraljic model can be found with the type of infrastructure projects for ports per quadrant. Each quadrant has a best fitting tender procedure, as well as a best suitable contracting procedure. Note that this is only relatively, the specification of the client’s requirements can lead to another procedure. On the next page the full policy is schematically rendered.
1. Assess the procurement demand

2. Assess value of the project
   - Leverage projects (roads, <12 m retaining height quay walls, large maintenance works)
   - Strategic projects (Constructions, >12 m retaining height quay walls)
   - Routine projects (public parks, small maintenance works)
   - Bottleneck projects (Specialized dredging, stone revetments)

3. Assess tender procedure
   - Leverage: multiple contractors \(\rightarrow\) (non-) public tendering
   - Strategic: negotiation procedures with/without prior announcement
   - Routine: multiple contractors \(\rightarrow\) (non-) public tendering
   - Bottleneck: negotiation procedures with/without prior announcement

4. Assess contracting procedure
   - Leverage: known process, unknown product \(\rightarrow\) D&B(M)
   - Strategic: unknown process, unknown product \(\rightarrow\) PPP, DBFM
   - Routine: known process, known product \(\rightarrow\) Traditional
   - Bottleneck: unknown process, known product \(\rightarrow\) D&B(M)

5. Compose the selection- and award criteria

6. Award the project

- Execute the whole project at once or in parts?
- Single project / combination of multiple projects?
- Engineering works part of the project or separate tender?
- Who provides materials? PoR or contractor (consequences on price and risk)

- Leverage: Multiple contractors, expensive projects \(\rightarrow\) exploit free market system. Preferred quadrant for tendering.
- Routine: Multiple contractors, inexpensive projects.
- Strategic: Few contractors, expensive projects \(\rightarrow\) Large interests for both parties.
- Bottleneck: Few contractors, inexpensive projects \(\rightarrow\) watch out for a monopoly

For both step 3 and 4, further consideration about the tender and contract is done keeping optimal client satisfaction in mind. Some customers specify very precisely the infrastructure they are looking for (so a traditional contract could be the best match), others use pure functional requirements, giving plenty of space for innovative solutions and contracts.

**FIGURE 14: PRESENT PROCUREMENT POLICY AT PORT OF ROTTERDAM (COMPILED BY AUTHOR BASED ON (HAVENBEDRIJF ROTTERDAM N.V., 2007))**
3.8 BOTTLENECKS IN THE CURRENT PROCESS

Briefly referring to the problem definition again, long-term functionality of infrastructure is getting more challenging. From the last projects an estimated 10-15% (Source: Wim Zwakhals) required reconstruction to maintain functional. Going more into detail on this number is off limit due to customer privacy, but at least gives a feeling of the problem.

To face the challenge of reducing this percentage, the bottlenecks in the current procurement process have to be pointed out. Three different aspects in the tendering and contracting have been found where improvement can be obtained: The "lean and mean" trend of the business case that is now common to use for determining the go-ahead for the project,

The limitation of fully utilizing contractor's knowledge and potential due to strict tendering rules, the uncertain future and possible developments and the financially A business case is the translation of the client's fixed requirements by PoR into fixed costs and the expected revenues (partially fixed by rental agreements). What aspects are can be improved and in what ways is it possible to include them?

3.8.1 LEAN AND MEAN

The first is the financial evaluation of the infrastructure. A landlord port such as PoR generates revenues via two sources, harbor dues and rent for the terrain. Harbor dues need to be paid by sea going vessels entering the port and some inland vessels using certain facilities. The amount depends on the size of the ship and amount of transshipment and is used for the facilities for safe and quick navigation and mooring. Rent for the terrain is calculated for every plot in the port area. The amount of rent is determined for the area used and the required infrastructure. When setting up a business case for a new contract, with a set efficiency rate the rent must enough for the required investment in infrastructure. Now this efficiency rate is quite high in order to maximize profit as the port, but the possibilities for innovation are therefore limited. Innovation means exploring unfamiliar territory and this results in risks. A risk is automatically translated into money. In short: risks are expensive.

On top of that Port of Rotterdam doesn't include residual value in the calculation of the Net Present Value (NPV)

This means that at the end of the term of the business case (25 years normally) the infrastructure has no economic value anymore, while it may be technical still in good shape. When this residual value is taken into account, the NPV of a project can be much higher, allowing more budget for more innovative designs or flexibility. And by improving the structure, the technical lifetime extends. However, residual value is a risk in itself as well. On top of that, instead of residual value, more attention should be given to alternative value. What is accomplishable with the infrastructure when its current function is no longer required?

This "lean and mean" style, a high efficiency rate combined with designing infrastructure just spot on the requirements is very effective for maximizing profit. But this strategy is a risk as well. Keeping the investment as low is possible by a design exactly suited for the current purpose gives a significant chance that a rebuild is necessary for slightly changing requirements.

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11 Efficiency rate is Benefit / Return. This must exceed a certain rate for a project to make it profitable.
12 NPV is the cash balance of costs and benefits that compares the present value of money today to the present value of money in the future, taking inflation and returns into account.
13 Lean manufacturing became known by car manufacturer Ford. By optimizing the production process of their cars in more efficient steps and minimizing spillage. From now on it was possible to produces more types of car from that same production line.
3.8.2 STRICT TENDERING POLICIES

The second point of interest is the possibility for contractors to come up with creative and innovative ideas. The requirements and scope of the project are determined up front and evaluated on price and quality. Now a contractor sees innovative possibilities to improve the construction, durability or operation of the infrastructure that are possibly outside the scope of the project. The contractor then has two possibilities:

- **Open Question** (addressed to employer)
- **Closed Question** (addressed to employer)

**Contractor has innovative idea**

**The competition becomes familiar with the idea**

**Result**

- ** Contractor protects his idea and is not going to suggest this.**
- **It can be implemented.**
- **Tender has to be adapted**
- **Innovation can not be rewarded**

**Employer must ascertain if its possible within the rules of the tender.**

**Result**

- **Delay of the project**
- **Employer doesn’t like that**
- **Contractor won’t spend too much resources on the elaboration**

**FIGURE 15: FLOW CHART OF THE CURRENT PROCESS OF HANDLING INNOVATIVE IDEAS**

As seen in Figure 15 in most of the cases of the tender, innovation resulting in major changes in the scope, in short term is a costly proposition, for both the employer and the contractor. Based on equality and transparency principles in the European Tender policies, changes in requirements or rewards are prohibited once they have been published. The transparency principle states that the criteria are fixed once published. In that way contractors can estimate what is expected and the possibility that the scope of the project is determined based on the proposals is out of the question as well (Transparantiebeginsel, Kennisportal Europese Aanbestedingen) The same applies for the equality principle. Contact between employer and contractor is prohibited when this results in an advantage for this contractor. This applies to the bottom part of the flowchart above (Inschrijven op een aanbesteding, Kennisportal Europese Aanbestedingen).

Broader design possibilities lead to more risks, leading to higher costs. The Program of Requirements should become an optimum between functionality, room for innovation and taken into account as much uncertainty as possible.

3.8.3 UNCERTAINTY AND DEVELOPMENTS

Third point of attention is the increasing amount of- and the speed at which changes and developments are coming towards us. To be able to write a Program of Requirements as an employer, for future proof infrastructure, more preparatory work is needed to establish trends, developments and the uncertainties surrounding the port infrastructure. Risk management, introduced in section 3.5, is common to apply during (infrastructure) projects due to a more and more dynamic society.
Financial consequences of undesirable events and delays are increasing drastically. (Deloitte Consultants B.V., 2009) The focus so far is on the construction part of the project. In order to establish a more future-proof Program of Requirements, it is important to improve the uncertainty and risks knowledge and to add this long term section to the risk management portfolio before formulating the Program of Requirements.

It is not said that no development and expectation management in PoR is done at all. For management and maintenance, asset management gathers information from three different departments that provides the input regarding the availability of assets:

1) Port Planning
2) Capacity management: A sub department of Asset Management (Asset Management Havenbedrijf Rotterdam N.V.). Based on the expected cargo flows, transport movements can be calculated. In these models, possible bottlenecks can be signaled early, based on which renovation or expansion can be planned.
3) CBL and PIM\textsuperscript{14}: These departments supply accessibility programs for road, rail, inland shipping and pipelines.

The essence of this long-term addition the risk management is to change procedures from risk based construction to risk based designing. Section 3.5 introduced four categories of risks: investment, construction, exploitation and revenue. The investment part is covered with a business case and construction risks are the short term risks monitored mostly by the contractors. The attention to exploitation- and revenue risks (long term risks) is the main bottleneck for improving commercial lifetime with the Program of Requirements for new projects.

3.9 CONCLUSION

Infrastructure projects can be public or customer oriented. Procurement and contracting procedures are chosen to be the best match for the concerned project. The possible procurement processes differ in in the number of moments of contact between employer and the amount of contractors that take part. Then the contracts were compared. Where in traditional contracts the only responsibility for the contractor was the construction of the project, in new contracts, the responsibilities are more integrated in one package that is expected from the contractors.

Port authorities in Europe have for the majority a procurement policy and above a certain expected tender sum, PoR is obligated to the European procurement policy. The most common ways for European procurement are by public or restricted tendering. Tenders are evaluated based on lowest price, or highest quality for the lowest price (EMAT)

The bottlenecks in the process towards more future-proof infrastructure are the current lean and mean trend of evaluating investments in a business case, combined with strict European procurement rules that limit innovative solutions opted by contractors or the alternative value of that infrastructure. This combined with more and sooner changing requirements due to all kind of developments results in some cases to early reconstruction of the infrastructure.

The next chapter will discuss the methodology how to accomplish a more future-proof way of procurement and which of these bottlenecks can be addressed during this thesis.

\textsuperscript{14} CBL: Container, Breakbulk and Logistics and PIM: Process industry and Bulk. The two departments responsible for commercial policies
4 RESEARCH APPROACH

The necessary background about port infrastructure and the definition of flexibility has been discussed as well as the current procurement in the previous chapter, which concluded with three aspects that form a bottleneck in these current processes. This chapter treats the research approach. Which of these bottlenecks form the scope of the research and which is beyond?

4.1 INTRODUCTION

For a well-defined research objective one must get significant insight in field of study, the current processes and policies. This gives the theoretical framework of the research field. How is tendering and procurement done in infrastructure, in general and by PoR specifically? What exactly is flexible infrastructure?

The principle of this thesis is adding or changing steps in the process of formulating a Program of Requirements for a new project. Visualizing this research objective as a formula:

\[ ax + by = Z \]

in which “Z” represents the gap between commercial and technical lifetime, variables “x” and “y” are requirements. These are constantly changing, therefore represented as variables. The aim thus is finding specifications “a” and “b” in such a way that Z is as small as possible, with a minimum of zero, when commercial lifetime is equal to the technical lifetime.

The theoretical study proved that the possibilities can be sought in the risk management and changing the formulation of the project requirements. The consideration which possibility or bottleneck is the scope of the research is discussed later in this chapter.

The approach is a broad risk assessment and the actions PoR can take in the design followed by a closer look at the requirements in order to create Early Contractor Involvement and creating opportunities for innovative ideas.

Once the improvement is elaborated in theory, it must be tried out and demonstrated by working out a case study. The results of the case study are the foundation for the conclusions and recommendations.

4.2 STEP 1: EXPLORATION OF THE FIELD OF STUDY

An analysis will be made on the topics of procurement, contracts and of course the possibilities of flexible infrastructure. What exactly is flexible infrastructure is already explained in the chapter “Background” and the limitations to incorporate flexibility in infrastructure on the field of contracting in the previous chapter. Gathering this information is done in different ways:

- Desk study: A literature study to gather as much relevant information as possible about procurement theory, European Tender policies, port infrastructure, flexibility etc.
- Getting up to speed by a brainstorm session held at PoR
- Additional in depth research: Interviews and literature study based on new knowledge and tips.
From different angles, ideas for improvement of the efficiency of infrastructure already have been made. The government of Ireland has set up a 10 step guide for buying innovation by making more use of the knowledge of the contractor (Departement of Enterprise, Trade and Employment, Ireland).

Different port/dredging related magazines have had publications on Early Contractor Involvement (International Association of Dreding Companies, 2012) and (Mink, 2013) so part of this step is bundling the information that is available and information that is not.

4.2.1 DESK STUDY: LITERATURE RESEARCH

As mentioned as one of the starting points, first an analysis must be done to know how the current tendering procedure is and what ideas to incorporate flexibility into infrastructure are there. Answering the first five questions forms the base of the theoretical framework and formulating the answer for the first sub question “What are the drawbacks of the current procurement procedures with a business case?”

The focus of the research regards:

1) What are the current procurement and contracting procedures? What is a business case? How is procurement process in general and specifically by PoR now?

2) Defining flexibility in this thesis. What is flexible infrastructure? What else can be done to make infrastructure future-proof?

3) What is port infrastructure? In what way is port infrastructure combinable with flexibility.

4) What beholds the current risk management for PoR infrastructure projects.

5) What are the possibilities for improvement?

6) What requirements does PoR lay down? In what way is this functional specified or exact?

7) Which risks and uncertainties apply to port infrastructure? What developments are known or can be expected? Which of those can you take into account as Port Authority and what will be the horizon of the business case?

8) Are other fields of civil engineering working on flexibility and incorporating this in contracts? What are their ideas?

Theory is one thing, usage in everyday routines is another. The best source of information for this question is talking to professionals who are working every day in the procurement processes, both the employer as the contractor side. Based on experience, what do they see as possibilities or limitations? Interviews with different people were taken to broaden the theoretical study and to gather more in depth knowledge.

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4.2.2 GETTING UP TO SPEED: BRAINSTORM SESSION.

At the start of this research, the research question “How to apply flexible infrastructure in the tendering and procurement process?” and a lot of ideas were available. To get up to speed on the latest situation and to gather as much information as possible about the current state of mind within different departments of PoR and Rijkswaterstaat, Mr. Zwakhals invited some people for a brainstorm session in which the latest ideas and opinions on flexibility in infrastructures could be discussed. I set up a framework for the brainstorm subject, as seen in Figure 16. The contract was the center of the discussion and both flexibility at the front (voorkant) meaning the terms and conditions and the back (achterkant), meaning the design. A list of topics was drawn up to let the participants discuss their ideas.

![Figure 16: The layout of the brainstorm](image)

The summary and outline of this brainstorm can be found in Appendix B: Brainstorm session.

Information obtained during the brainstorm session helped converging the directions to focus the research on, what obstacles there are and what possibilities are thought of at this moment.

4.2.3 IN DEPTH: EXPERT INTERVIEWS AND LITERATURE STUDY

The aim of the research is formulating an improvement or recommendations for an existing problem. Besides theoretical studies, practical information given by people having lots of experience with tendering and procurement is very valuable. This information is gathered in the first round of interviews. Questions following the brainstorm and literature research are discussed during interviews with several different parties to go more in depth on these questions. Since the topic of incorporating flexibility in the business case is new and unknown, the interviewees merely talked about their expectations from the point of view of their specialty. They are familiar with the current process and can spot limitations or improvements by this thesis’ proposals. Often the interviewee introduced one or more other persons with more experience with the discussed topic to talk to.
Interviews are taken from:

**TABLE 1: INTERVIEWS**

<table>
<thead>
<tr>
<th>Person</th>
<th>Function</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maurits van Schuylenburg</td>
<td>Port Development</td>
<td>Orientation</td>
</tr>
<tr>
<td>Giel Jurgens</td>
<td>Asset Owner PoR</td>
<td>Asset management PoR</td>
</tr>
<tr>
<td>Arnoud de Bruijne</td>
<td>Innovations RWS</td>
<td>Flexibility / alliance contracts</td>
</tr>
<tr>
<td>Wouter Bredemeijer</td>
<td>Port Development</td>
<td>Port Compass</td>
</tr>
<tr>
<td>Tim Gademan</td>
<td>Procurement PoR</td>
<td>Tendering and Procurement</td>
</tr>
<tr>
<td>Cees Pons</td>
<td>Port Development</td>
<td>Tender Maasvlakte 2</td>
</tr>
<tr>
<td>Frank Wolkenfelt</td>
<td>Environmental management</td>
<td>Tender TEW terminal</td>
</tr>
<tr>
<td>Jelle Peddemors</td>
<td>Port Development</td>
<td>Port Compass</td>
</tr>
<tr>
<td>Kees van de Graaf</td>
<td>De Boer Dredging Procurement</td>
<td>Tendering a contractors view</td>
</tr>
<tr>
<td>Frans van de Hooff</td>
<td>Investment &amp; Risk Management</td>
<td>Financial side of the business case</td>
</tr>
<tr>
<td>Mark Franken</td>
<td>Project Development</td>
<td>Business Case</td>
</tr>
<tr>
<td>Karin de Boo</td>
<td>Business Analysis &amp; Intelligence</td>
<td>Goods flows estimations and dealing with uncertainty</td>
</tr>
<tr>
<td>Joost Bos</td>
<td>Wet Infrastructure</td>
<td>Tendering process with the contractors</td>
</tr>
<tr>
<td>Jarit De Gijt</td>
<td>Advisor Quay walls</td>
<td>Possibilities for future-proof infrastructure</td>
</tr>
</tbody>
</table>

A short summary and the intention of these interviews is given in Appendix C: Interviews.

4.2.4 CONCLUSION: BOTTLENECKS

The literature study and interviews indicated three bottlenecks in the current procurement process (see section 3.8), but for completeness they are repeated here briefly:

- Lean & Mean trend for infrastructure business cases. No residual value left after the timeframe of the business case has passed, combined with a high efficiency rate for the investments, leaving little room for a design that can cope with major changes in the requirements.
- Speed and variety of uncertain developments. The main cause for this thesis. All kinds of technological-, economic- and sustainable developments result in changing requirements for the infrastructure.
- Strict European Procurement rules that complicate creativity by contractors and make altering the tender impossible once it has been published.

The next paragraph goes more into detail what is in the scope and what is beyond.
After analyzing the current situation first the attitude of the different parties stands out. Instead of strict dividing of risks and responsibilities, it can be in anybody's interest to join forces and knowledge in order to create more future-proof infrastructure optimized to create a better hub port than the competition.

4.3.1 BEYOND THE SCOPE

The European Procurement policies are fixed boundary conditions. It is not likely that this is going to change and lies well beyond the scope of this thesis. The same applies for the financial in depth evaluation of the business case. The research is drawn from an engineering point of view and therefore financial and juridical knowledge is not extensive enough for quality research. However in the recommendations, these will be the topic of discussion for further investigation based on this thesis’s research and findings.

4.3.2 SCOPE

Regarding the challenge that lies ahead to decrease the time between technical- and commercial lifetime that is hindered by all kind of developments, not every solution is valid. Designing infrastructure that can handle any possible change in the requirements and beyond is financially not a wise decision. As employer, it should be emphasized that doing more preparatory work to get the requirements sorted out by taking into consideration these developments as well, takes away a significant part of uncertainty, resulting in a more accurately specified tender.

The scope of this research centers around the assessment of uncertain developments, how to acquire such information, how to handle this delicate information and in what way this can be incorporated in the procurement process.

Designing infrastructure that is remains functional under changing requirements, starts with estimating what can be expected and narrowing down the spectrum of uncertain developments in order to anticipate more accurately with the Program of Requirements. This thesis is going to formulate a revised procurement process, focusing on including this uncertainty and recommending some changes in the relation and attitude of employers and contractors.

In the next paragraph, the approach based on the obtained information and after defining the scope as treated above is discussed next.

4.4 APPROACH

The two main topics regarding this improvement are uncertainty (and risk management), the formulation of functional requirements thinking beyond the design specifications what alternative usage the design has and the incorporation in the procurement process. The second topic is dedicated to the relation with the other actors, the contractors as well as the shipping companies for instance.
4.4.1 STEP BY STEP SCHEME TO INCLUDE UNCERTAIN DEVELOPMENTS INTO THE PROCUREMENT PROCESS

The major question is: Which of these uncertainties can be dealt with in the procurement process? This can be divided into more specific sub questions and the answer is going to be answered from the PoR’s point of view:

- What sort of uncertainties and developments are surrounding port projects? In order to fully understand what kind of developments are of influence to a port, a top down inventory is started approaching the port and all relevant processes around it. What different markets are supplied, what types of cargo are transported and what kind of shipping companies transport this. What sort of equipment is being used etc. Then, possible developments based on news and reports are written. The result will be an uncertainty tree, that includes everything that the most recent uncertainty study for PoR has drafted (NGI/TNO/TU Delft/TRL, 2014).

- Which of these developments jeopardizes the functionality of the current design? Next, developments that have an effect on functionality on port infrastructure are elaborated based on qualitative reasoning. This development, together with probability and possible consequence can be added to the long term risk management, that also has a column for an anticipating measure which can be incorporated in the Program of Requirements.

- Which precautions can be incorporated in the tendering procedure and what is out of control for the employer? To be completely risk avoiding, all precautions can be added to the design. The result will almost certain be financially unrealistic. Therefore, strategic options about what and what not to implement are suggested.

- How can functionality be influenced in these situations? Again, by suggesting strategic options. The next step is discussing technical possibilities with the contractors during the procurement phase.

- Who is going to pay for flexibility? The client, PoR itself or maybe innovative solutions by the contractor won’t cost any more than traditional designs. The emphasis is on the value of designing differently. The additional financial burden is up to the employer to deviate.

- How can you formulate your demands in such a way that the contractor will actively participate in the design phase? An interactive procurement method, together with an integrated contract and evaluation by EMAT criteria that stimulate innovation.

The outcome will be a risks- and uncertainties inventory with possibilities on how to eliminate or reduce them. The other part of the solution is the already mentioned. Early Contractor Involvement and market consultation. The requirements of the project must be an optimum between innovative possibilities, functionality and a reasonable price. The outcome of the formulation of functional demands is dealing with these risks.
Both these elements will be included in the current procurement process resulting in a revised process with a different step scheme.

4.5 SIMULATION BY A CASE STUDY

For a given practical problem in the infrastructure network of PoR, a proposed method to reduce uncertainties or be able to adapt to changing requirements is tested.

The ECT Cityterminal in the Eemhaven is selected as topic for the case study. When this 65ha terrain get another function, what are the possibilities and what will the Program of Requirements look like? The elaboration of the case study will be determined together with mr. Zwakhals and mr. de Gijt of PoR.

As soon as the theoretical improvements are formulated for the project that is the topic of the case study, a second round of interviews takes place with some of the experts mentioned above for the in depth interviews, to evaluate the proposed improvements. This should be the validation step of the proposed improvements and will be reflected on during the conclusion and recommendations.

4.6 OBJECTIVES

The objective of this thesis is recommendations how to incorporate flexibility in infrastructure design and contracts and a choice model of opportunities/possibilities in a project to deal with uncertainties. A comparison of an alternative with and without flexibility can compare and demonstrate how flexibility improves the construction.

What is possible with the revised Program of Requirements that was not possible before? That is the question that can be answered illustrated by the case studies.

4.7 CONCLUSION

As this is a theoretical research caused by bottlenecks pointed out in the “real world”, a significant part of the work is literature research, both superficial and in depth, together with in depth knowledge by professionals based on everyday experience. As the European Procurement policies are fixed and financial assessment is beyond the field of expertise, the scope is set for anticipating on tomorrow’s requirements. It should be in every party’s interest involved in the logistical chain that the infrastructure is part of, to pursue maximum availability of the infrastructure. To achieve this, new steps have to be added to the procurement policy.
5 UNCERTAIN DEVELOPMENTS SURROUNDING A PORT PROJECT

Concluding the research approach chapter, the main focus is aimed at gathering knowledge to anticipate on the requirements of tomorrow. In this chapter, this process on how to do that from the Port’s point of view is elaborated.

5.1 INTRODUCTION

The background chapter shows that traditional port infrastructure is very rigid. In order to design infrastructure that is able to anticipate on possible changes in the future, the physical construction itself has to be designed differently. Should one decide to stick to traditional designs requires more time doing research in trends and developments and taking these into account when formulating the Program of Requirements. The current procedures focus on customer’s current requirements accompanied by cash flows, the input for the business case. For future-proof infrastructure anticipation on what happens during and after this business case is an essential step in the form of long term risks.

In this chapter we start by introducing the Port Compass of PoR; the scenario based expectations for the Rotterdam harbor. This is the future view, discussing four possible scenarios of what the port will look like in 2030. Anticipating on long term future estimations is already done, by the pursuit of the port’s position in four possible scenarios. These estimations and the responsible developments form part of the base for this chapter. The process of this data is done in a new way by translating them in long term risks and measures.

To start with this process, all uncertainty surrounding port infrastructure is discussed and broken down into sections in a top-down approach. Who can provide this information? What does this process looks like for a port infrastructure project. First, the sort of uncertainty one can expect around port infrastructure and the “domino-effect” one development has on another is treated.

5.2 ORIGIN OF UNCERTAINTY FOR PORT INFRASTRUCTURE PROJECTS

“Complete certainty is the situation in which we know everything (...) Walker et al. (2003) define uncertainty as any departure from the unachievable ideal of complete determinism. They categorize uncertainties by their location, level and nature.” (Taneja, 2013)

In the modern day transport sector, there is much uncertainty. Change in clients and transport networks. Change of demand, change of technology or requirements, all can be causes for incapable infrastructure. The chain of uncertainty (Figure 17: Chain of uncertainty for port infrastructure uncertainties) starts with value. This is a catch-all term for the value that a change of product, process or service is worth. Money (in many forms i.e. investments, savings, size of scale) causes almost every change. It can change the energy market, causing other goods flows (oil/coal/LNG) and volumes going in and out the port. It changes the size of ships, terminal equipment, if handling goods can become more efficient or size of scale. It changes the hinterland demand. So in short, money changes the type of goods and their volumes, which in turn changes the type and size of equipment. The equipment is the main thing, next to the required space for storage, which determine the requirements for the infrastructure.
Uncertainty starts with the balance of value / money around the world. Financial limits of hinterland determine what import / export products and volume of throughput will be handled. Type of goods determines the volume and what kind of operators will be client of the port. The terminal operator and throughput determine the operations on the terminal. The operations determine what kind of infrastructure is optimal.

**FIGURE 17: CHAIN OF UNCERTAINTY FOR PORT INFRASTRUCTURE (COMPILED BY AUTHOR)**

### 5.3 CURRENT FORECASTING AT POR: PORT COMPASS

To maintain its leading position in Europe, Port of Rotterdam is constantly adjusting the expectations of the near future to keep the port and industry complex up to date. The most recent estimations for the coming twenty years are called the Port Compass, written in 2011 (Havenbedrijf Rotterdam N.V., 2011). Port Compass are the ambitions of PoR containing its view on uncertainties and the business plan, based on forecasting, estimates of cargo flows and industrial development, for PoR for the coming twenty years. The estimations are based on forecasting of the development of power plants, refinery capacity, global economic balance etc.

This leads to four scenarios which are:

1. **Low growth.**
   Limited economic growth and no real price jump for crude oil. Therefore fossil fuel remains dominant and shrinkage of dry bulk throughput.

2. **European Trend.**
   The oil price rises slightly and the usage of LNG, biomass and other cleaner energy sources increases.

3. **Global Economy.**
   Continuing globalization and economic growth and a low price for oil resulting in high consumption of fossil fuels and limited sustainability policies. The volume of the container sector increases a lot.

4. **High Oil Price.**
   Large investments in sustainable energy sources, and environmental policies. The economic growth of Europe is limited.

The scenarios include expectations and quantities for all different cargo flows through the port, as discussed in Chapter 2. Already at first glance the large diversity in possible developments becomes clear. This is not yet adapted in the Program of Requirements for infrastructure. Including this new step in the way of thinking is the challenge to be faced in this chapter.
5.4 DEVELOPMENT ASSESSMENT

The information that is used to formulate the four scenarios above is for the significant part a chain reaction of different developments leading to another. To simplify this chain reaction in order to find out on which aspect the Program of Requirements and procurement can improve the functionality, it can be divided into different angles of uncertainty towards the port. But how does the port obtain this information?

5.4.1 WHICH ACTORS ARE INVOLVED.

The shift towards the new form of contracting, Design and Build, implies less work for the employer of a project. More risks and design tasks fall under the responsibility of the contractor. Early Contractor Involvement is a new way of combining the contractors knowledge before instead of after the major design decisions. Since the knowledge from contractors is combined with the employer's should simplify the tender even more in order to come up with the best suiting solution. More on this subject in the next chapter. It deserves attention to extend this theory of actor involvement to more actors that are somehow related to the infrastructure project. The contractor is one of the (significantly important) actors, but there is a lot of uncertainty that can be reduced and developments estimated by involving the knowledge of the large diversity of other actors that the port knows. It is therefore important that as an employer not to look away at changes, but to anticipate on them. Questions that arise in the early stages of new projects are for instance the standard decisions of using traditional infrastructure, who's to say that this remains the commonly used technique?

For instance, a new container terminal has to be build. The terminal operator delivers its functional Program of Requirements. The port, as employer in a landlord port model, is responsible for realizing the infrastructure to accommodate that terminal operator's routine. But instead of focusing on the client's (the terminal operator) short term requirements for that given period of time of the contract, the port authority is wise to take its own precautions and explore more in the world of container transport. The first step to do this is doing an actor analysis. Which parties play a significant role in future developments and what know-how is already available. With this information known, the possible developments and uncertainty can be assessed more specific for that project and actors involved. This in-house assessment is the next step and will be discussed in the next paragraph. Clearly, by doing an actor analysis, the work is not done. Step 3 in the process is combining this actor analysis with the uncertainty portfolio. Discuss with the different parties in their level of expertise and influence these uncertainties:

- Consultation with crane constructors. What are the developments in crane sizes and (un)loading processes.
- Consultation with shipping companies. What are their expectations of container shipping and routines.
- Consultation with shipyards. What are trends in the development of ships. Are their limits in the ever increasing scale of size of container vessels.
- Consultation with knowledge institutes and universities. Based on statistics and lab tests, is a new technique being developed that requires drastic changes in the port infrastructure? What is the economic prospect of the hinterland, and what is the prospect on energy consumption for the coming decennia.
- Instead of consultation of each party individually, a brainstorm session can be very effective to obtain even more questions and answers. Actors also start discussing topics among themselves enlightening information that the employer did not thought about.
The first topic of discussion is getting clear objectives for the project and possible alternatives. Within these objectives, the uncertainty should be dealt with as much as possible.

The central question for this information exchange with the different actors is: "What does your (part of the) terminal look like in 20 – 30 years?" In other words, what developments do you know of or expect? Aspects such as confidentiality interfere with gathering accurate knowledge. Commercial companies are reluctant to show all cards they have in hand. To get as much useful information as possible, managing the information without making details unwantly public, discretion is advised. It is also valuable to verify certain information at multiple sources.

**Actor vs. Stakeholder**

In this thesis, the definition actor instead of the more commonly used term "stakeholder" is used. The reason for this is that with stakeholders everybody affected by, or involved in a project are meant. Actors on the other hand are parties that can influence the result or functionality of a project. They have active roles in the project. When assessing the developments that may have influence on the functionality of some infrastructure, we are only interested in parties that can influence the usage or functionality of said infrastructure.

Not meeting this description but very useful for research: knowledge institutes for technological possibilities, statistics and economics.

### 5.4.2 INTELLECTUAL PROPERTY

Now the big issue that has to be encountered in this phase is actors not really revealing all their knowledge and leave trivial parts of knowledge out of the discussion. Major innovations must be kept in house to keep it away from the competition in the understandably opinion of the owner of this idea, in this case an actor. The employer must agree with all parties to use the information confidential. Confidentiality agreements do not have to limit the discussion of developments. PoR can use this information in specifying the requirements for for instance the loading platform or mooring configurations without revealing the exact specifications or the source of this information. Besides the competition, the employer himself also can use or disclose said information. Agreements on the intellectual property of the idea are necessary as well. In the ten step Innovation procurement guide (Departement of Enterprise, Trade and Employment, Ireland) this is suggested by royalties from possible future contracts should the employer be partial owner of the idea. It also states: "Intellectual property rights should ultimately rest with the party who is best able to exploit it”

A proposal to emit licenses for the usage of the innovation by Rijkswaterstaat is based on the same principle. The aim of this adaptation is better protection of intellectual ownership and stimulating the development of innovative technologies, ideas etc. (Rijkswaterstaat et al., 2011) With the usage of licenses, the information remains property from the original owner, but the license allows the employer to apply the information once. When the information is used more often, royalties are due.

All parties must be persuaded to join knowledge. The emphasis rests on the mutual gain principle.
This cannot be done without complete clarification of the possibilities of providing information. Under the protection of Intellectual Property this may lower the barrier to share knowledge. If the employer knows about developments that can result to extensive rebuilds in the future, anticipates on these developments to avoid possible rebuild, the availability remains optimal. Both shippers, operators and customers know that time is money.

Changes are being made sooner and sooner by the increase of developments in the near future and today. This implies a lot of uncertainty for long term developments. By involving the knowledge of more actors, this wide spectrum of uncertainty can be narrowed down. Some expectations become certain that it will happen or maybe it will not due to physical or economic limitations. The direction in which the Program of Requirements needs to be flexible should be much more evident.

5.5 Uncertainty

The next step in formulating a Program of Requirements for future-proof infrastructure is assessing on what fields or aspects of processes connected to the port changes can happen. Of course nothing is certain in the future and anticipating on it will always be based on guessing, but the level of likelihood of events can be higher by doing market research as described in the last paragraph. This assessment is valuable. Start with a very broad approach and then narrow it down by taking away uncertainty by either market consultation or by filtering away aspects that are unpreventable by tendering.

The following top down approach is dividing uncertainty as already introduced in Figure 17: Chain of uncertainty for port infrastructure (compiled by author) the chain of uncertainty into the different varying categories, with causes and the following consequences. This information is a brief summary and is discussed in more detail in Appendix D.
FIGURE 18: TOP DOWN APPROACH UNCERTAINTY

The diagram illustrates the top-down approach to uncertainty with various factors influencing energy market, economy, hinterland capacity, external interference and demands, competition, type of cargo, terminal operators, shipping companies, change in construction materials, and surroundings. Each factor and its effects are detailed as follows:

**Energy Market**
- Terrain destination
- Transhipment goods
- Import/export ratio
- Routines
- Shift in global economic balance
- Import/export ratio
- Shifted global products in raw materials

**Economy**
- Labor market
- Competition
- External interference and demands
- Hinterland capacity
- Economy
- Energy market

**Hinterland Capacity**
- Rail/road connections
- Economic power
- Environmental laws
- CO2 emission
- Public opinion
- Safety demands
- Climate changes

**Labour Market**
- Changing job requirements
- Available work force
- Capacity enlargement surrounding parts
- Higher demands clients
- Changing regulations
- Routines

**Competition**
- Terminal capacity (tons/yr)
- SoE (oil/bulk/container)
- Terminal and shipping operators
- Routines
- Equipment
- Duration of residence
- Bankruptcy

**Type of Cargo**
- Terminal operators
- Shipping companies
- Change in construction materials

**Terminal Operators**
- Routines
- Type of ship
- Reliability

**Shipping Companies**
- 3D/4D printing
- Availability raw materials
- Fibre reinforced constructions
- Construction methods

**Change in Construction Materials**
- Permits / appeals
- Location of the plot
- Strategic surroundings management
- Image PoR

**Surroundings**
- Effects:
  - Less coal and oil, more LNG, biomass or solar power.
  - 1st step of processing raw materials closer to source.
  - Less import and processing fossil fuels
  - More electrical equipment, slow steaming
  - More export to Asia, Brazil.
  - Possible trade war US-China
  - Import semi-finished products/chemicals
  - High quality European made products
  - Take-up amount
  - Change to other import ports
  - Type of transhipment goods
  - Change of energy source
  - Change of production processes
  - Sustainability awareness
  - Increasing safety levels
  - Sea level rise
  - Change of river water level
  - More computerization
  - Highly educated employees required
  - Diminishing labour force
  - Unemployment
  - Shippers or terminal operators move to other ports
  - Increase availability
  - Increase flexibility
  - Broaden portfolio of capabilities
  - Possible building in subsoil
  - Energy market
  - Type of terminal
  - Type of ships
  - Amount of movements/hr
  - Heavier cranes
  - More equipment
  - Reliability on the destination of the terminal
  - Switching costs -> oil refineries or computerized container terminals are very expensive to build and won’t likely move.
  - Slow steaming
  - Amount of calls/yr
  - Dimensions of ships
  - Questionable loyalty shippers and terminal operators
  - Higher demand of materials in Asia
  - Steel price rising
  - More use of composites, other build techniques
  - Different type of constructions and lifetimes.
  - Stakeholders can slow procedures down
  - Hindrance in the surroundings
  - Is this location useful for other purposes?
  - Public opinion about PoR can win/loose clients
5.6 FROM UNCERTAINTY TO DIRECT IMPACTS

Figure 18 shows that the diversity of uncertainty is large. The majority of uncertainties are indirect effects, only a few result to directly on the infrastructure. The first question is: When do the requirements for said infrastructure change? This basically happens in two cases: The infrastructure serves its function/purpose but external developments (i.e. unloading equipment) change in such a way that other infrastructure is required. The other case is that this infrastructure loses its intended function for a new one.

Secondly a distinction is made between direct effects for port infrastructure and indirect effects. Direct effects are for instance changes in cargo, whereas the global economic balance is an indirect effect, but leads to changing throughput in the port.

![Figure 19: Deviation in Direct and Indirect Effect for the Infrastructure]

The interesting fact is that eventually the domino-effect of uncertainties and processes all come down to a couple of direct impacts mainly the type and volume of cargo flows and innovation on the transport sector itself. The discussion of this uncertainty assessment can be found in Appendix D.

Summarized, the following stands out:

- Less throughput of raw materials and more semi-finished products. The can lead to more multipurpose cargo shipping or container transport
- Crude oil throughput is going to decrease
- More throughput of mineral oil products, biomass and steel
- Unless the global economy doesn't recover, LNG will increase
- More chemical products
- Increase of container transport.

However, although anticipation of these developments are highly interesting, these aren’t conclusions that directly change the requirements of the infrastructure. All elaborated uncertainty and its impacts above can be summarized into changes in the cargo flows and innovation in transport chain itself. At least these are the common resultant that is relevant to deal with in the Program of Requirements.
Directly influenced by these changes are:

- Type of cargo
- Cargo volume
- Type of ships
- Number of calls per terminal
- Terminal equipment
- Required services by PoR
- Laws and regulations

So all uncertainty is now reduced to impacts in the cargo, the equipment used for transport and handling and services/limitations by third parties.

5.7 CHANGES REQUIRED

The next step in the process is making these impacts even more abstract into changes in physical impacts on the port infrastructure. We have concluded that the type and volume of cargo is where it all comes down to. Different cargo is resulting in other ships and equipment used or services required. Physical challenges that change the functional requirements are:

- Mooring Forces: Bollard forces by mooring lines, kinetic energy of the ship
- Mooring Configuration: Quantity and position of bollards and dolphins
- Nautical accessibility: depth and width of harbor basins.
- Terminal capacity: Storage / handling area, number of berths
- Vertical forces on the quay wall / jetty: Cranes and other handling equipment such as trains of carriers.
- Hinterland connections: Connection to road, rail an inland shipping network.
- Required space around the terminal: Hindrance / safety contours

These physical changes form the margins that need to be taken into account when formulating the Program of Requirements. What risks are there, what is the probability and the physical impact and what specification can limit this.

5.8 PRECAUTIONS TO INCORPORATE IN THE TENDER

Uncertainty is now brought back to the variations in requirements for the infrastructure. With this knowledge, the already introduced actors can be approached for a discussion on future developments. With that new information taken into consideration, the level of uncertainty can be assessed including a possible measure can be included in the requirements. Not all risks are apply to every infrastructure project or can to be specified in the functional demands. The increase of container vessels for instance is not a primary risk for the rail connection; the increased throughput is, but this will be specified in this paragraph.

What exactly changes in requirements should a physical change is required? Some examples pointing out altering requirements that jeopardize functionality of the terminal on macro level or more specified on some infrastructure itself:
- **Design vessel**

A Larger ship than the set design vessel. For illustration, the enormous upscale in size between the newer generations of container ships see Figure 20:

- Increased basin depth
- Larger mooring forces

Smaller ships require another mooring configuration

(Part of the) solution which could overcome certain changes and would therefore be wise to specify in the tender: flexible mooring facilities.

---

**FIGURE 20: SUPER POST PANAMAX CRANE, WITH THREE SUCCESSIVE GENERATIONS OF CONTAINER SHIPS (WWW.RACHELEDMONDS.COM)**

- **Terminal equipment**

Upscale of gantry cranes:

- Larger reach
- Multiple containers / volume in één cycle.
- Wider crane tracks

In order to accommodate the unloading possibilities, the gantry cranes needed to grow accordingly to the upscale of the ships. As an example, Super Post-Panamax cranes weigh over 1600-2000 Ton and can be seen in Figure 20 compared to the earlier generation Panamax and the now necessary Triple E size in Figure 21. In this picture, the increase of container ships is also interesting to observe for the challenge of determining the design vessel.

A solution which could overcome certain changes and would therefore be wise to specify in the tender: Robust substructure: Wider and thicker platform able to resist higher forces.
- **Variable loads on terminal deck**

Variable loads determine the forces that the surface of the terminal can accept and where foundation is required.

**Equipment:**

- Railway tracks with bulk carriages
- Conveyor belts
- Straddle carriers / lorries

**Cargo:**

- Bulk
- Stacks of containers
- Tanks

**Hinterland connections:**

- Bulk import / containers / break bulk → Road, railways and inland shipping
- Liquid bulk / gas → railway, pipelines and inland shipping

So based on the examples above, as a tender has to be composed for terminal infra, the Program of Requirements can take uncertainty into account when calculating the needed quay wall depth or storage space and load.
A trend with the current Design and Build contracts is the employer passing most of the responsibilities onto the contractor. In order to formulate the Program of Requirements for future-proof infrastructure, more preliminary work by the employer (whether or not in combination with the contractor(s) or research institutes such as TNO or universities) is necessary. Without this preliminary work, the direction in which the flexibility must be applied is very hard to determine. It should be emphasized that the technological knowledge at the employers is important to maintain. This means that the trend of passing more responsibilities of to the contractors is questionable. Currently in DBFM contracts, the employer consults the market (contractors) to establish possibilities and dividing risks, whereas the whole idea of market consultation used in this revised methodology is based on sharing responsibilities rather than dividing them with the big picture of future-proof infrastructure in mind.

Summarized in one single figure is the conclusion of this risk inventory. For the content on the boxes marked as “direct” and “indirect”, see Appendix D. It has been noted that although developments from all kind of angles are changing the requirements and functionality, this can be scaled down to a limited amount of direct effects that lead to a physical changes to the infrastructure.

With the physical changes known for the infrastructure, the next step is implementation in the procurement process, more specifically in the Program of Requirements.

![Figure 22: Conclusion of the Risk Portfolio](image-url)

In the next chapter we take a closer look at the Program of Requirements given the information that could lead to these physical changes. What strategic options can PoR choose by asking higher specifications and what exactly are these specifications?
After the uncertainty is evaluated, it can be transformed in a risk and the possible influence parties in contracting can have on these risks. Using the knowledge of the actors for the project and combining this with an uncertainty analysis, a step scheme resulting in a more future-proof Program of Requirements can be written.

### 6.1 INTRODUCTION

The framework as talked about so far is rather abstract. In this chapter these steps are made more amenable. For procurement, contract engineers and civil engineers it is key to keep this very important information clear and brief, the responsible person for the port has to make the investment decision. The front of the contract matter of speech, is determining the requirements and agreements with the client. In the revised method, this will now also be dedicated to take away as much uncertainty as possible with these requirements. The part of the uncertainty tree that cannot be estimated with the available knowledge remains, a more clear view of what we don’t know. With this information the authors of the Program of Requirements for the tender can discuss solutions in the design together with the contractors that can be build flexible for instance in order to anticipate on residual uncertainty. To accomplish the most beneficial relationship for both PoR and contractors, the most suited tendering en procurement procedures will be discussed later on in this chapter.

### 6.2 FORMULATING THE PROGRAM OF REQUIREMENTS

#### 6.2.1 ADAPTED RISK PORTFOLIO

The base for this development anticipation is adapted from the current risk portfolio, so basically the risk, probability, impact and countermeasure. In this table, the knowledge of the actors is included.
A fictive example of this table is:

**TABLE 2: FICTIVE EXAMPLE OF THE RISK: GROWTH GANTRY CRANES.**

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Continuing growth gantry cranes</strong></td>
<td>Gantry cranes keep growing in order to keep up with increasing growth of ships. The cranes remain dominant in unloading routines.</td>
<td>In 10 years, most container ships are 18 000 TEU, already 10 ships of 22 000 TEU Unloading by 4 containers in one cycle.</td>
<td>High</td>
<td>Major</td>
<td>Quay wall design that is able to withstand forces of a crane of this proportions. A trend is visible that most terminal operators switch up to Super-Post-Panamax (SPP) cranes already. -Rail tracks wide enough - Robust foundation able to handle SPP cranes (a rail load of 137.5 T/m)</td>
</tr>
</tbody>
</table>

What information can be retrieved from its contents:

1. **Development:** In this column the uncertainty or development that can be expected that may be jeopardizing the infrastructure's functionality is added. In this example no categories in which to arrange uncertainties have been added. A completely computed portfolio could divide uncertainties based on capacity issues, location, navigational depth or forces on the landside of the terminal etc.

2. **Expectation:** What is most likely going to happen concerning this development based on in house knowledge.

3. **Added information by market consultation:** What relevant information helping to determine a strategic action after market consultation can be added.

4. **Probability of the event is divided into three options.** Low, medium and high.

5. **The impact of that certain development, should it occur is also divided into three categories:**
   a. **Minor:** Productivity or capacity changes somewhat, but the infrastructure will not lose its functionality.
   b. **Medium:** slight adjustments are required to the infrastructure in order to keep it functional. These adjustments are not expected to exceed more than 10% of the building costs
   c. **Major:** Adding changes to the design of the infrastructure or rebuilding it is necessary. The construction will not function anymore. These drastic adaptations will cost more than half of the initial construction budget.

6. **Preventing or anticipating measure in the tender.** Based on financial and engineering knowledge the project team can make a decision on what possible adaptation of the requirement in the Program of Requirements can be made in order to anticipate on that specific development. For instance, the original Program of Requirements of the client demands a quay wall for 15 m water depth. Developments predict larger ships within 15 years that need at least 16 m of water depth.
7. The measure would state: *water depth: 16 m.*

Briefly referring to the origin of this project, adapting the way of tendering in such a way that flexibility can be incorporated in the business case, three possible ways to do this can be distinguished. This is schematized in the figure below.

![Figure 23: Model of Choice for the Functional Requirements](image)

**Figure 23: Model of Choice for the Functional Requirements**

Concluding, each requirement in the tender has to be dealt with as a small business case. What extra costs does this anticipating factor in the requirement bring and what extra possibilities does it create? Even more important: what are the consequences if this development does occur and no anticipating measure was added.

Based on the example given in Table 2 the possible adaptation for this tender could be that the rail track of the cranes should be wide enough for a Super Post-Panamax crane weighing 2200 tons instead of the now sufficient Post-Panamax crane of 1600 tons. The design rail load is for four wheels per corner:

**Table 3: Anticipating Measure Crane Rail Load**

<table>
<thead>
<tr>
<th>Client’s requirement</th>
<th>Anticipation</th>
<th>Requirement + anticipating measure:</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 T / m</td>
<td>137.5 T / m</td>
<td>137.5 T / m</td>
</tr>
</tbody>
</table>

Off course this advice must be substantiated by the extra costs and benefits.

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### 6.2.2 Methodology to Draw Up Strategic Options

The results from this anticipation tool form the basis of the revised Program of Requirements. It was already mentioned in the theoretical framework that the common way of looking into investments has not included a long term view enough. The financial departments and the responsible people for deciding what investments are done, need to comprehend the value of anticipating investments. The employer (in this case the Port Authority) has to change its way of thinking about the choices being made, what these will cost and ultimately what possibilities are left open. By updating the Program of Requirement with the freshly obtained information from the anticipation tool, a number of strategic options can be presented to the persons making the investment decision. How can the Program of Requirements as proposed by a client be extended in such a way that it does not have to be (much) more expensive to aim for future-proof infrastructure and what the consequences can be, when developments are not taken into account.
The whole process as discussed in chapter 5 and 6 can be schematized as a flow diagram in Figure 24.

1. The client specifies what kind of equipment will be used and what ships are expected to start the project. What are the current requirements?
2. Which actors are involved in this project (i.e., shipping companies, terminal operators, crane manufacturer)
3. In-house assessment developments and long-term uncertainties
4. Discussion with actors about developments and expectations of long-term uncertainties. The part is called market consultation, in which PoR can share its thoughts and expectations with the different actors and vice versa.
5. Include this new information in the risk portfolio.
   Some are not relevant; others are added.
   (Note that step 2, 3, and 4 are a continuing process, resulting in a constantly updated risk portfolio.)
6. Possible precautions can be added to the Program of Requirements.
7. What strategic options are to be taken:
   - Investments and possibilities with the client's stated requirements
   - Fully risk averting precautions and corresponding possibilities on top of clients requirements
   - Economic optimal precautions with corresponding possibilities on top of clients requirements (max for less)
   - Client's requirements with corresponding infrastructure and a number of adaptive possibilities
   In the distinction between functional and technical part of the Program of Requirements, the technical part is now entered.
8. With the strategy chosen for its functionality, the technical challenges are discussed with the contractor.
   (optional is outsourcing of technical detailing by an engineering company as it is in the current procedure)
9. Via competitive dialogue tendering, the plan of action by the participating contractors is handed in and evaluated.
10. Based on investment costs, the financial department can calculate the costs for the client and if there is a mutual agreement, the project continues.
11. According to the agreements with the client, functional and financial, the final Program of Requirements can be formulated.
12. By using a D&B contract, together with interactive tendering, optimal usage of early contractor involvement can be realized.

This revised way of tendering and procurement includes two new aspects: Functional challenges are discussed with the different actors and technical challenges can be discussed with the contractors. Public procurement in Ireland is attempted to create innovative incentives with a ten-step scheme that shares similarities with the schedule as proposed in this thesis. Defining and refining requirements together with actors and procurement with performance-based specifications. (Department of Enterprise, Trade and Employment, Ireland) Preparing the information and a well substantiated discussion with the different actors requires significant technical knowledge at the employer. An employer should at least be familiar with the processes and technologies possible for that project as ignorance will not help in the willingness to share information. Up next, the technical challenges discussed with the contractors where again knowledge of the contents is important for an optimal result.
10. Rent and agreements

9. Evaluation of tenders

Updated Program of functional requirements
Long-term perception

Strategic options
Decision by Management Team

11. Loop procedure, input for final Program of Requirements

12. D&B contract with final program of requirements

Interactive Tender procedure with Program of Requirements

FIGURE 24: THE UPDATED PROCESS FOR TENDERING AND CONTRACTING.
In the methodology until this point, attention was given to reduce the uncertainty as much as possible by incorporating margins in the requirements. The part that remains unclear may be absorbed by the technical solutions. The technical realization needs to be discussed with the contractors and the design decisions with them instead of for them by the employer. This paragraph is discussing the type of contract and way of procurement in order to maximize the value of the resulting infrastructure by working together. In short, what is the best fitting form of procuring the project and what type of contract can be used in order to make the steps above possible. Up next, a discussion of the different procurement forms and contracts that were earlier introduced in Chapter 2, based on its suitability. In the schedule of Figure 24, this paragraph contains step 8 to 12.

### 6.3.1 EARLY CONTRACTOR INVOLVEMENT

Preparation of large infrastructure projects often consumes an extraordinary amount of time, money and human resources and is not particularly cost-effective. (Mink, 2013) A part of this inefficiency is caused when using traditional contracts that divide the design and construction responsibilities between two parties. The employer, responsible for designing the infrastructure brings contractors late into the process after many key decisions have been made concerning the design. The contractor's task is calculating the costs and the one with lowest price is granted to execute the works. But often the contracting authority is not familiar with the latest technology or possible solutions and the clients and consultants are asked to make design decisions with insufficient information and know-how. More specialized knowledge is available at the contractor, who in the end is also responsible for the actual construction operations.

Early Contractor Involvement (ECI) is in short bringing in the expertise of the contractors before the important design decisions are made. Contractors can fully utilize their knowledge in finding the best solution. ECI provides an efficient means of designing and planning infrastructure projects, more cost-effective, efficient and with a broader knowledge of construction risks. Using ECI with a properly executed contract that reflects a partnering relationship with the employer according to (Lingguang Song, 2009).

An example of a successful ECI partnering relationship can be found in the steel construction. The design changes and errors were reduced and the schedule was tightened. Another advantage noticed were better fitting prefab elements delivered on daily bases, reducing material delays and waste. (Lingguang Song, 2009) In the next paragraph the different ways of procurement that are introduced in chapter 3.2 are compared and discussed on the amount of contact moments between the employer and contractors. The amount of contact moments for discussing the technical challenges of creating future-proof infrastructure are vital when employing the contractor's knowledge and opting for ECI and dialogue. The other way around is as important, to ensure the functionality of the design.

### 6.3.2 PROCUREMENT PROCEDURE

Contractor involvement is best utilized by selecting an interactive procurement method. The important design decisions can be made together during the meetings, in which the contractors can present the technical possibilities and the employer can emphasize the requested solution and its principles. The possibility of Early Contractor Involvement, as already explained in the previous paragraph is an example of a method to accomplish this. When considering the Kraljic-portfolio again (Figure 14) the projects that profit the most in the revised form of tendering are
strategic projects: expensive, with a long life span; exactly the major port infrastructure projects. Ideally this could be done with “negotiation procedures with/without prior announcement” but in order to legally apply this form of tendering, a lot of conditions must be fulfilled. In practice, mostly it cannot be applied. Therefore, let’s take a look at the alternatives (Kennisportal Europese Aanbestedingen).

PUBLIC TENDERING enables every contractor that has innovative ideas beneficial for the employers long term view to submit an offer. The disadvantage however is that tendering has one contact moment between employer and contractor, so contractor involvement cannot be fully utilized.

RESTRICTED TENDERING. The main difference with public tendering is the pre-selection phase added to restricted tendering. But the same as for public tendering, there is no negotiation phase and that negotiation phase is what is needed for the employer and the contractor to combine their knowledge for the optimal design.

THE COMPETITIVE DIALOGUE procedure is more suited than the tendering procedures as described above, because of the dialogue element included. The difference with negotiation procedures with(out) announcement is that the requirements for the project are stated upfront as base and the negotiation aimes for improvement of those, whereas at the outset of the dialogue, the actual solution is not clear yet. This form of tender is mostly applied for large, financially complex projects. During the dialogues the employer can discuss risks and challenges with the contractor(s) and the most suited solution is incorporated in the Program of Requirements. Both the just explained procurement methods are mentioned by (Mink, 2013) in Terra et Aqua discussing ECI.

BEST VALUE PROCUREMENT. ECI can be a useful instrument for BVP (International Association of Dreding Companies, 2012) as BVP is based on interviews with the contractors rather than solely on their plans of action. The downside of this method is still a clear devision of risks and responsibilities rather than sharing them, as the contractors are being awarded on their risk management. With the methodology as just presented, assessing the long term risks is the responsibility of the employer. In theory it enables the best of contractor involvement, but stands or falls based on the quality of the questionnaire during interviews and used EMAT criteria to assess the proposals.

Concluding, the most important element of the tendering and procurement phase is the interactivity to explore possibilities of design and the requirements. The type of contract is in this regard less decisive. Nevertheless, one variant is much more suited than the rest as will be explained next.

6.3.3 CONTRACTS

Each of the different forms of contract that establish the relationship between the contractor and the employer of the project is discussed with pros and cons to opt for that way for the proposed method of formulating the Program of Requirements.

TRADITIONAL CONTRACT. With a traditional contract, the role of designing and the role of constructing are strictly separated. The employer is responsible for the design, the contractor “only” executes the construction based on the employer’s calculations. For an innovative contract with early contractor involvement, one should understand immediately that these two circumstances don’t mix.
If the pre-conceived design is a standard design and the precautions are taken in the built-in reserves (standardization of quay wall designs for instance) a traditional contract can provide the best fitting contract, although this could be much more expensive when the employers’ knowledge does not match the contractors feeling for the tricks of the trade.

DESIGN & BUILD. The majority of “innovative contracts” contains Design & Build procedures. In order to bring all the in this thesis introduced elements together that can be added to the current tendering en contracting procedures with future-proof infrastructure as its aim, this form of contract provides all possibilities to realize this. Contractor’s knowledge can utilized by leaving the technical design and build open for them. By evaluating the proposals as handed in by the different contractor parties via EMAT criteria, more attention can be given to life-extending subjects, as life cycle costs, possibilities for easy adaptation, etc.

DBM. When aiming for sustainable and future-proof infrastructure, paying attention to the life cycle costs is crucial. Whereas in a D&B contract, the focus is only on design, with DBM the life cycle, meaning maintenance routines and expenses are taken into account as well. Therefore a DBM contract stimulates the contractor to come up with a more sustainable design. He does not want to come back every year for maintenance. However, PoR has maintenance under its own administration. Most projects, such as quay walls en terminals are too small to be beneficial as a maintenance job. Therefore, DBM is only interesting with a significantly large project with enough maintenance work to provide a steady workload. The new, integral approach of a port area could be an option for such a contract.

DBFM(O) is a valid solution for public projects. For client projects (which are the majority of the PoR infrastructure projects) the investment costs are recovered on the long term by rent and harbor dues. The construction budget at the start of the project is loaned by PoR itself. Benefitting its BBB+-status (stated by Ronald Paul, COO of PoR during “De Brug”, April 2014), acquiring borrowed capital is in most cases cheaper than done by the contractor(s). Some large contractors may benefit the same financial rating as well, explained by Giel Jurgens (personal communication, February 27, 2014), requiring this responsibility for the contractor during the tendering phase, the number of contractors able to submit for that kind of tender is rather limited. For the operating part, no contractor is required, as the client of the infrastructure will be operator for as long as the contract lasts. Therefore, for client projects, the F and O component are not applied.

ALLIANCE. To share risks and knowledge in order to successfully execute a difficult project, an alliance formed by the employer and contractor can deliver good results. The downside is, that no competition is possible between contractors once the alliance is formed. A tender phase before the actual design phase starts can help the employer determine the best partner using selection criteria what teaming up with that partner would yield.

However, an alliance is mostly adopted for situation with unknown technical complexities or risks. This is not necessarily the case for the port projects, the risks consists the developments and future requirements, unless PoR as the employer specifically demands technological innovative solutions (concerning the possibility of flexible infrastructure)

Stimulating the effectiveness and creativity of the contractor can be acquired by sharing the benefits (mutual gains principle). This however can also be included in a D&B contract, not specifically an alliance. Already introduced in Chapter 5.4.2, are intellectual property rights. In order to receive full cooperation by the contractor, innovative ideas are protected by the same principle.
The aim of this thesis was to formulate a methodology to anticipate on the ever growing uncertainty and developments around ports and the necessary infrastructure. A new way of formulating the Program of Requirements and contracting procedure can form a solution. Both at front of contracting (requirements) as at the back (technical specifications with the contractor) already discussed for the front are an uncertainty and development assessment and an actor analysis. In order to derive a more future-proof Program of Requirements for infrastructure the employer must extend its view beyond the client’s requirements at external developments and gathering as much knowledge as possible that is available.

This chapter introduces a methodology to include the obtained information by market consultation and uncertainties to clarify the anticipation measures that are possible and to what extra costs this will result. As soon as these measures are clear, they can be included to the Program of Requirements after which a decision can be made based on more knowledge whether it is wise to take the risk or act preventing.

This is the functional part of the Program of Requirements. At the back of the contract, the “remaining” uncertainty can be grappled by an innovative technical solution. Early Contractor Involvement is a possibility of joining knowledge and forces. In order to value active contractor cooperation EMAT criteria valuating innovative ideas are important, as well as an interactive procurement procedure. From the more familiar procurement policies, the competitive dialogue is the most useful way. The accent of a suiting procurement method is on the number of discussion moments between employer and contractor in which the design solutions are made. The relationship between employer and contractor is arranged in a DBM contract should the quantity of infrastructure be sufficient for an economic maintenance procedure for the contractor. In practice, for PoR this will not be the case, besides PoR has its own maintenance facilities. Therefore, PoR infrastructure projects are best arranged in a D&B contract.
This concludes the theoretical part of this research. The current infrastructure and procurement are investigated and the bottlenecks for implementing flexibility in the infrastructure are pointed out. The focus was then aimed on reducing the amount of uncertainty and using as much information as possible to set up a Program of requirements for tomorrow rather than for today. The previous chapter discussed the revised procurement steps in which the incorporation of this Program of Requirements.

The subject of the following chapter is a case study to demonstrate these revised steps on a partly fictive situation. Whereas the Program of Requirements of the client was adopted by PoR to translate that in the required infrastructure, with the revised method, the specifications can partly be revised with the added anticipative measures.
7.1 INTRODUCTION

The aim of this case study is to illustrate and test what the proposed methodology in this thesis beholds by applying it to a real situation. An example like this clarifies much more than just a theory. Therefore, the subject is a terminal in the PoR area, treating each step of the method one by one, explaining the advantages and how information was gathered. The objective is discovering whether or not the Program of Requirements as set by the client (A and B) results in A’ and B’ based on anticipations due to procuring via the revised procurement steps.

Choosing the subject for the case study is done under certain conditions:

1. Currently interesting for PoR.
2. Plain example. Otherwise, the illustrative value decreases.
3. A new or dedicated concept, or at least beyond reasonable expectations that this project will go through changes. A project that has a zero-risk purpose results in exactly the same requirements in this revised methodology as well.
4. A disclaimer that nor the time or capabilities to consult the actors as introduced in this case study was available. What could be the reply is assumed by the author.

The subject is the ECT City Terminal. For this case, this actual moment is used. With the shift of deep sea container transport to the Maasvlakte 1 & 2 areas, alternative functions for the area are sought. For illustration of the Program of functional Requirements, the current specifications now, used by ECT are assumed as the first step. An overview of this terminal is given up next.
The subject of this case study is the ECT city terminal, a container terminal situated at the south end of the Eemhaven area. Its location can be seen in Figure 26. The terminal was constructed halfway the last century. The most frequent ships calling are around 3500 TEU often sailing along North- South trades (i.e. Europe – (South-)Africa) (ECT, 2014). The terminal is however able to handle ships up to 8000 TEU, which are in the "Post Panamax" category up to half way the Jumbo class. (Lijtingen, 2009) In 2012, the plan was developed to create Rotterdam Coolport (Heijboer, 2013)\(^\text{15}\). This terminal should fortify Rotterdam’s leading position in perishable cargo throughput. Reefer cargo volumes are increasing and fast hinterland connections are essential. Coolport is a transshipment hub from the ocean to short sea and train connections. As of today, no location is certain, but the ECT city terminal is one of the top nominees.

Coolport is supposed to be operational January 2015. As this is a fairly new concept and very dedicated terminal facilities, there are some risks attached to this idea. One of them for instance already happened when one of the partners withdraw from the project. (Heijboer, 2013) The Coolport specifications are the starting point of the steps.

\(^{15}\) By PoR amongst others. For the sake of the example, an outside party has the Coolport proposed rather than PoR.
For the sake of simplicity, a keynote for this case study is that the substructure of the quay wall is in good technical shape and rebuilding the terminal would purely be as a result of unsuited new requirements. In case of a new destination for this terrain, following the steps of the methodology introduced in the previous chapter: what developments can be seen, what uncertainty is there and what kind of anticipation is possible?

One of the first, most important aspects to establish are unmovable physical boundaries for this area: The Benelux tunnel. The sailing depth for the tunnel is decisive for the maximum depth land inward. Until this time and probably the near future as well, this remains a boundary, but currently studies are done for the possibility of lowering the tunnel. At the conclusion of this case study, it should become clear that by approaching the terminal, and its function by this reconsidered procurement procedure, results in a revised Program of Requirements with some precautions for a future-proof design.

ECT City terminal (ECT, 2014)

- Capacity: Max 8000 TEU ships
- Surface: 650 000 m²
- Quay wall length: 1400 m
- Quay depth: 14,15 m
- Built in: 1966 – 1971

In the late 1960, the Willem Alexander basin, the southwest part of the Eemhaven and the basin around which the current ECT is situated, was dug. Container transport was scarcely out of its egg for continents other than the USA. The USA already transported war equipment with containers with success. It was in 1966 during the construction of the Eemhaven that the first container arrived from the States. The Port of Rotterdam, back then a municipal authority, was aware of the rise of container transport. The terminals in the Eemhaven however were all laid out for break bulk. Containers required much more storage and handling area and a wider apron. The freshly deepened “Magriethaven” was filled in order to create this area and 171 m dedicated container quay was constructed. ECT was formed in 1966 as well by five stevedores and the Dutch Railway company. It welcomed its first call by a container ship 31 August 1967 (Stella Container Logistics B.V., 2014)

The technical data for the quay walls is retrieved from the archive. A cross section of the South side of the terminal can be found in Appendix E. Information granted by Asset Management about the original construction in the late 1960’s brought interesting and advantageous facts to light. For the North side of the terminal, prefab quay wall floors were used that were destined for another terminal, which was designed for break bulk. The contract for the ECT City Terminal (at the time destined for Interforest) had to be closed quickly. In order to make that happen, the available relieving platforms and piles were used. Being able to absorb the required forces, the relieving platform was extended land inward and due to insufficient bearing capacity of the original amount of piles, more were used.

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16 With special thanks to Aad Zevenbergen
For the south side, the originally designed crane tracks were not used and during construction the now used back rail including foundation was added. In the next table, relevant technical data are presented:

**TABLE 4: TECHNICAL DATA ECT QUAY WALL**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contract depth north side</td>
<td>12.65 m (construction depth 13.00 m)</td>
</tr>
<tr>
<td>Contract depth south side</td>
<td>14.15 m (construction depth 14.65 m)</td>
</tr>
<tr>
<td>Relieving platform design load</td>
<td>25 kN/m²</td>
</tr>
<tr>
<td>Bollards</td>
<td>500 kN</td>
</tr>
<tr>
<td>Crane track width north side</td>
<td>8.85 / 15.24 m</td>
</tr>
<tr>
<td>Crane track width south side</td>
<td>8.85 / 15.24 / 30.48 m</td>
</tr>
</tbody>
</table>

### 7.3 STEP 1: COOLPORT’S PROGRAM OF REQUIREMENTS

The elaboration of the requirements for Coolport are confined to the basic equipment and facilities required. As no actual data is known at this point, the following will be assumed by studying other perishable goods terminals:

- **Ships:** The arrival of cargo will be done by dedicated reefer ships and Short Sea container ships.
- **Facilities:** 1500 Reefer plugs and 10 ha refrigerated sections (warehouses).
- **Terminal equipment:** Ship to shore (STS) break bulk cranes and gantry cranes.
- **Apron:** Yard cranes, reach stackers, forklifts.
- **Hinterland transport:** By road and rail.
- **3 berths for the design vessel:** Resulting in a quay length of 593 m based on the formula from Ports and Terminals:

\[
L_q = 1.1 \times n \times (L_s + 15) + 15 = (1.1 \times 3 \times 175) + 15 = 593 \text{ m}
\]

These are the functional specifications as set out by the client. At the conclusion of this case study, the advised strategic actions added to this specifications forms the revised Program of Requirements and will be compared to the original version (above). First, the important actors are discussed.
Here the major actors for the ECT City terminal and possible future operations are defined. The actors are described, together with what aspect they could influence and the weight of that influence. Actors that have a key role in functionality of this infrastructure are:

- Port of Rotterdam
- Shipping companies. Reefers, containers and break bulk
- Terminal operator(s). Reefers, containers and break bulk
  Operators of hinterland connections
- Law and regulation institutes
- Knowledge institutes
- Contractors

PORT OF ROTTERDAM. PoR strives to remain the number one hub in Europe for all cargo flows. As most refrigerated facilities are spread out over multiple small areas, clustering them in one “cool” hub is more efficient. Another trend is visible: deep sea container shipping, the intercontinental lines, are calling more and more at the seaward terminals on Maasvlakte 1 and 2. The logical result from deeper water and lesser travel time inside the port area. For the older port areas land inward, this results in a decrease of the cargo throughput. In the area development plans for the Waalhaven and Eemhaven, most terminals are nominated to be transformed to multipurpose terminals when the current contracts end. Clearly, dedicated terminals are being transformed into more multi-purpose terminals. Now PoR itself is a landlord port and facilitates for its clients. It is for the port’s own benefit to take its own developments into the process of designing infrastructure. Therefore, PoR will not be an actor that comes up with surprises.

SHIPPING COMPANIES. The current container trades that use the City terminal as port of call are very diverse. Some of the traders include: OOCL, Unifeeder, Eucon an OPDR. With current trends such a slow steaming and ever growing container ships, dedicated reefer transport is gaining terrain. Perishable goods require less travel and waiting time than other goods transported in containers. The question is to which point can reefer shippers compete with the big trade lines? More and more alliances are formed between the larger shipping companies. This will lead to hub to hub transport lines with ever growing ships. What’s not to say that reefer ships will continue to grow in order to compete.

Reefer ships are smaller and maintained in mint condition. They can accommodate containers, break bulk on pellets or even tanks with concentrated juices. Most have their own cranes on board and some have side doors through which cargo can be (un)loaded. An example can be found in Figure 29. The big question for Coolport is off course: what percentage of ships will be dedicated reefer ships?

The other trend currently visible is short sea transshipment as a replacement for deep sea shipping. Short sea container ships have a capacity of around 600-850 TEU with one exception destined for the Baltic Sea trades of 1700 TEU. Increasing the size of feeder ships, as ships used for short sea are called, would be impractical for the UK trades, as most of the ports there are tidal basins with restricted draught. Shipping companies themselves do not expect drastic scale changes for feeder ships.
TERMINAL OPERATORS. What primary handling equipment is used now, and what is the future? Currently ECT uses 11 quay wall container cranes, multiple reach stackers and container lorries. The terminal is completely paved. As of 2020, the contract for ECT ends. After this, the question is whether ECT remains in charge of operating Coolport or leave it to the Short Sea container shipping. If they leave, do the cranes remain?

The company now responsible for the reefer cargo is subsidiary company Home Reefer Care BV. Reefer cargo is unloaded via conventional quay cranes or gantry cranes when reefer containers are used.

Short sea operations are cooperated with the terminal’s neighbor, Rotterdam Short Sea Terminals. A possible expansion of this terminal could already be noted as an option after approaching Rotterdam Short Sea Terminals.

What are the plans of the Coolport operator is important to know.

HINTERLAND CONNECTION OPERATORS. The ECT City terminal is connected to the railways to the hinterland via Rail Service Center Rotterdam. By waterways, numerous small companies and independent shippers transport the goods further inland. The same follows for road transport. The terminal is connected to the road network with easy access to the highway. The functionality of the terminal does not be affected significantly by changes on this part.

Large distribution centers for supermarkets etc. benefit from a central import location of perishable goods. They could be attracted by the good road and rail connections, therefore the availability of plots nearby with good access can result into new customers.

LAWS AND REGULATIONS is a group of varying authorities. DCMR is responsible for all environmental affairs around the port area. The congregation of Rotterdam and the governmental executive company responsible for all infrastructure Rijkswaterstaat

A percentage of multipurpose cargo could contain flammable/toxic or in another way dangerous goods. The terminal is situated nearby some residential areas. For safety contours, not every part of the terminal can be used for dangerous goods, which is no issue with perishable goods.

As well as safety, other aspects of well-being in and around the port play a role in determining the functionality of said terminal. Smell, emissions, noise etc. all are cumulated with a maximum acceptable amount.
KNOWLEDGE INSTITUTES. CBS, DUT and other universities are familiar with the latest developments, what innovations are on its way, construction materials and methods, new ways of transport/transshipment.

Knowledge about the Selling Market is vital for estimations of cargo flows. What economic prognoses can be established based on the population growth/shrinkage, economic power, trends in cargo flows, more European production? For this statistics of CBS or modeling by the Club of Rome are tools to set the course for the coming decades.

CONTRACTORS. The technical possibilities for a multi-functional design are discussed after the functional specifications are clear and with good assessment of the angle of uncertainty expected to which can be anticipated technically in the design.

7.5 STEP 3: UNCERTAINTY AND DEVELOPMENTS

Step 3 is the inventory of possible uncertainties and developments. As starting point, the top down approach that is discussed in Chapter 5 is used. To this assessment, aspects especially applicable to this terminal are added. Recent in-house uncertainty assessment at PoR is done during a project called Project Masterplan +. On top of that input used from a report that the Club of Rome\textsuperscript{17} that takes into account more negative trends visible in the global trade for PoR.

\textsuperscript{17} The Club of Rome is a think tank composed by experts from different expert fields all over the world that address global challenges.
Developments and results:

- Increase of gas price (Ukrain conflict)
- 1st step of processing raw materials closer to source.
- Less import and processing fossil fuels
- More electrical equipment, slow steaming
- Clustering refrigerated terminals is sustainable and more effective.
- More export to Asia, Brazil.
- Import is getting more expensive.
- Possible trade war US-China
- Import semi-finished products/chemicals
- High quality European made products

- Unemployment and population shrinkage refuse take-up amount
- Restroring → production in Europe
- Less import exotic food due to price increase
- Change to other import ports
- Type of transhipment goods

- Change of energy source
- Change of production processes
- Amount of investment in public infrastructure by the government
- Sustainability awareness
- Increasing safety levels
- Sea level rise
- Change of river water level

- More computerization
- Highly educated employees required
- Diminishing labour force
- Unemployment

- Shippers or terminal operators move to other ports
- NL is dominant on the refrigerated import
- Increase availability
- Lots of distribution centres of supermarkets nearby
- Increase flexibility
- Broaden portfolio of capabilities
- Shipping companies invest in competing ports in South Europe (Greek port by Chinese investments)

- Possible building in subsoil
- Energy market
- Type of terminal
- Type of ships
- Less deep sea, more short sea transshipment

- Amount of movements/hr
- Heavier cranes
- More equipment
- Reliability on the destination of the terminal
- Switching costs → oil refineries or computerized container terminals are very expensive to build and won’t likely move.

- Slow steaming
- Amount of calls/yr
- Dimensions of ships
- Questionable loyalty shippers and terminal operators
- Form of large alliances resulting in bundling of flows
- Rise of more Chinese shippers

- Higher demand of materials in Asia
- Steel price rising
- 3D printing eliminates advantages of cheap labor by outsourcing
- More use of composites, other build techniques
- Different type of constructions and lifetimes.

- Stakeholders can slow procedures down
- Hindrance in the surroundings. Less pollution allowed
- Is this location useful for other purposes?
- Public opinion about PoR can win/lose clients
- Deepening of Benelux tunnel increases max draft

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The main conclusion from developments and market consultation is a decrease in deep sea container flow in this port area.

But what if the possibility of lowering the Benelux tunnel becomes a reality. The draft increases to possibly 18.5 m. This has huge consequences. ECT might stay and attract Super "Post Panamax" container ships with the necessary STS gantry cranes.

The main short term uncertainty is the level of success of this dedicated Coolport and if not successful what alternatives are possible.

On the topic of loading and unloading studies already are being done for the possibilities of unloading up to 9 containers in one cycle. This implies other loads on the quay wall.

For the reefer shipping companies, the main concern is competing with the alliances of the major container companies. It could be possible that dedicated reefer transport doesn’t outweigh the disadvantages of the major trading lines anymore. Reefers could be unloaded at the terminal by the large ships or a shuttle service might be a solution.

Due to the economic crisis and the growing unemployment in Europe, more homegrown food could be gaining terrain on the exotic foods, leading to less import.

These are the main risks that follow the uncertainty assessment.

7.6 STEP 4: MARKET CONSULTATION

Of all actors useful information about what is going to happen to the more inland situated terminals is gathered by discussing this with the terminal operator and the shipping companies.

The most important trend to anticipate on is the reduction of the container flow from deep sea to short sea and the change of deepening the Benelux tunnel might have as a result. The timeframe in which this is possible to realize can be decisive here. The next question is whether or not deep sea containers / break bulk might regain at this location.

For Coolport, apart from building a giant cooled warehouse, most refrigerated products still arrive in reefers (which are standard size containers) Handling equipment and/or ships are not likely to change significantly. The size of reefer ships (for instance the Hansa-class, used by Seatrade) is around the average general cargo ship size of 160 x 23 m with a draught of 8,1 meter. Exceeding forces or depth by reefer ships is not likely to happen, but the success of Coolport pretty much depends on the transport of perishable goods in break bulk and via reefer containers.

Another trend is the transition to break bulk terminals in this area. As today’s largest container vessels call mainly at the Maasvlakte 1 and 2 terminals, less and less containers are being brought into port at the more inland ports. The discussion of these developments should formulate a clearer Program of Requirements.

7.7 STEP 5: UPDATE RISK PORTFOLIO

The updated inventory of possible uncertainties and developments after the market consultation results in the following table with anticipating measures if possible. The next pages display the risk portfolio for this case study.
<table>
<thead>
<tr>
<th>Uncertainty/ Development</th>
<th>Expectation</th>
<th>Added information by market consultation</th>
<th>Probability</th>
<th>Impact</th>
<th>Preventing/ Anticipating measure in tender</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decrease cargo flow for inner port terminals</td>
<td>Deep sea transport arrives more at the MV1 and MV2 terminals. More short sea transshipment at Waalhaven and Eemhaven.</td>
<td>Expected cargo numbers</td>
<td>High</td>
<td>Medium</td>
<td>Quay wall design has fortunately multiple crane track foundations. As well as “Post Panamax”, smaller tracks are able to handle multi-purpose cranes. Make sure they remain in good condition</td>
</tr>
<tr>
<td>Coolport is only part of the terminal capacity</td>
<td>Coolport is expected to take up 10% of the terminal initially with possible expansion of another 10%</td>
<td>Expected cargo numbers. Handling equipment data for break bulk</td>
<td>High</td>
<td>Medium</td>
<td>–Build crane tracks that can also accommodate break bulk cranes and other equipment. - Position Coolport at the smaller Northside of the harbor basin.</td>
</tr>
<tr>
<td>Container crane ➔ Smaller container cranes</td>
<td>Does ECT leave and takes the cranes with them or are they sold?</td>
<td>Plans of ECT and Coolport partners</td>
<td>Low</td>
<td>Minor</td>
<td>Multiple crane tracks are available. Removing cranes is expensive and quite the operation. Advise new terminal operator to use the existing cranes should containers still be (un)loaded at this terminal</td>
</tr>
<tr>
<td>Container crane ➔ multi-purpose crane</td>
<td>Percentage of Break bulk depends how many container cranes are replaced</td>
<td>Percentage of Coolport usage and alternatives</td>
<td>High</td>
<td>Minor</td>
<td>Quay wall design has fortunately multiple crane track foundations. Make sure they are in good condition</td>
</tr>
<tr>
<td>Residual value of retracted heat becomes higher</td>
<td>Energy transportation through the port becomes more interesting</td>
<td></td>
<td>Medium</td>
<td>Medium</td>
<td>In terminal layout, pipe line tranches have to be taken into account. The companies that will benefit of this idea are likely to come up with the fundings to execute this.</td>
</tr>
<tr>
<td>Ship size changes significantly</td>
<td>7000 TEU ship - L(^\times)W(^\times)D: 318<em>42.8</em>14 Reefer ship: L(^\times)W(^\times)D: 160<em>23</em>8.1</td>
<td>Reception of container ships and or general cargo</td>
<td>Large</td>
<td>minor</td>
<td>Include more bollards and fenders in the design.</td>
</tr>
<tr>
<td>Reefer ships expand to 6000 TEU or larger</td>
<td>Benefits of scale could result in larger reeferes of container vessels dedicated for reeferes</td>
<td>Dedicated short sea or deepsea? Scale of size vs. transport duration and interval</td>
<td>High</td>
<td>Maintain max depth with maintenance dredging</td>
<td>Are dredging costs worth being able to receive that max ship size</td>
</tr>
<tr>
<td>Coolport concept fails</td>
<td>Shipping companies still transport reeferes at the common trades with the largest ships,</td>
<td>Are special reefer trades worth the extra money and if not: are the shipping companies going</td>
<td>Medium</td>
<td>Remain able to receive 8000 TEU ships Shuttle services</td>
<td>Keep the harbor basin up to max depth for the first period, keeping it accessible for larger ships to test the concept. Alternative functions</td>
</tr>
</tbody>
</table>
because that is cheaper to set up shuttle services from the deep sea terminals to Coolport?

New techniques for ship to shore handling

As every container terminal is investing in larger but conventional gantry cranes, indicates that new techniques are not ready any time soon.

A possible scenario is direct unloading of the “mothership” in to feeder ships and inland barges.

Low

Major

The design load of terminal flooring is rather conservative, much options are possible. Could result in heavier quay wall designs

New techniques for shore to shore handling

As every container terminal is investing in larger but conventional gantry cranes, indicates that new techniques are not ready any time soon.

What is the terminal operator working on? What engineering innovations could lead to other ways of handling?

Low

Minor

A conservative load factor is used in order to design relieving platform and foundation of crane tracks. A totally new concept that would exceed these forces, would be such a large design and test period that no immediate actions needs to be taken now.

Additional loads on relieving platform

Break bulk terminals are common to have railway tracks for trains underneath the cranes.

Is the terminal operator likely going to construct a railway for trains. What loads are expected of this train

Low

Medium

More equal spreading of load or additional foundation

Design platform load is 25 kN/m². Depending on the train load, action can be taken (additional foundation)

Benelux tunnel is lowered

Not possible within 15 years. Increase d possibilities for Waal- Eemhaven area. 18000 TEU ships will call for this terminal

Is this physically possible? (Knowledge institutes) If so, does the terrain provide possibilities for container terminal / bulk etc.

Low

Major

A new quay wall is required for the largest ships and equipment

If possible: Quay wall design of at least “Euromax” specifications required for container ships up to 18000 TEU.

TABLE 5: UPDATED RISK PORTFOLIO

7.8 STEP 6: UPDATED PROGRAM OF REQUIREMENTS AND STRATEGIC OPTIONS

The anticipating measures according to the anticipation tool result in (part of the) requirements rewritten. The aim of these options is to convince the employer and the executive decision makers of PoR (who have to finance the investment) that the extra investment is worth it. In short: What does the client require? What does the employer see as developments and possibilities and what is possible in this situation with the given requirements?

There are roughly three possibilities.

1) Fully adopt Coolport requirements
2) Anticipating requirements added to the Coolport requirements. Design a multipurpose terminal on which Coolport can be located.
3) Fully risk adverse. The Benelux tunnel is lowered within 15 years. Deep sea containers could be the new purpose for this terminal. Specifications of the Euromax terminal are required.
The first option is already introduced in step 1 of this case study.

Option 2, the more strategic option would be designing a multipurpose terminal, as the concept of Coolport is new and the throughput numbers might not be enough to successfully exploit Coolport. In order to secure as much and diverse cargo throughput as possible to maintain profitable infrastructure, the focus should be on multi-purpose terminal instead of dedicated short sea container or reefer transport. Below the most obvious alternatives are lined up and compared based on design vessel and unloading equipment. In grey, the specifications of the original ECT City Terminal are highlighted.

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>6000 TEU design ship</th>
<th>Reefer ship</th>
<th>Short Sea ship</th>
<th>General Cargo</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOA [m]</td>
<td>320</td>
<td>160</td>
<td>134</td>
<td>80-160</td>
</tr>
<tr>
<td>Beam [m]</td>
<td>32</td>
<td>23</td>
<td>21</td>
<td>30 max</td>
</tr>
<tr>
<td>Draught [m]</td>
<td>14 max</td>
<td>8.1</td>
<td>9</td>
<td>10</td>
</tr>
</tbody>
</table>

**TABLE 6: COMPARISON OF SHIPS**

Ship dimensions will not likely form an obstacle for alternative functions.

Crane comparison. The main parameters that are responsible for a match with the substructure of the quay wall are the weight and the portal width. The now used cranes are used as input for the container crane and need to be at least "Post Panamax” size cranes in order to unload the bigger vessels, as well as the optimal size for Short Sea container ships (Feeder/Panamax size) and a general cargo crane able to handle Handymax size vessels, i.e. the Liebherr LHM 280, (Liebherr)

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Container crane</th>
<th>Short Sea containers</th>
<th>Sea containers</th>
<th>General Cargo / reefer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight [T]</td>
<td>1760</td>
<td>1440</td>
<td>1440</td>
<td>241</td>
</tr>
<tr>
<td>Portal / Rail Width [m]</td>
<td>22-35</td>
<td>17</td>
<td>17</td>
<td>11</td>
</tr>
<tr>
<td>Lifting capacity [T]</td>
<td>65</td>
<td>65</td>
<td>65</td>
<td>84</td>
</tr>
</tbody>
</table>

**TABLE 7: UNLOADING EQUIPMENT COMPARISON**

The total weight is based on the individual wheel load multiplied by the number of wheels (32 in total) The weight of container cranes is by far larger than general cargo cranes.

The Program of Requirements as formulated as the client does not have to be adapted much, for the second option that followed by the revised procurement method. The possible alternative scenarios all can be applied on this terminal’s substructure. The only uncertainty is the size of the ships that will be calling at this terminal. Therefore, possibilities to adapt fender and bollard positions are the main point of adding to the requirements. Regarding the uncertain throughput volume of Coolport, PoR should suggest to situate it at the north side of the terminal. It is slightly less deep and has less dedicated container infra. The south part can still be used or used again as a short sea container terminal. The reefer plugs can be designed in such a way that taking them away easily and reusing them would be possible.

The third option is fully risk adverse. When the boundary condition that the Benelux tunnel determines expires, the basins and terminals are accessible and interesting for deep sea container shipping or even dry bulk. In that case, the current design vessel of 400 m long with the required Super Post Panamax gantry crates to reach the outer row of containers (around
2200 T) form the governing design loads. For the quay wall design, this at least results in a “Euromax” design.

As for hinterland connections, the terminal has good access to road, railways and inland waterways. The only option that is not available is pipelines, but this will result in drastic rebuilding of the complete terminal. On top of that, hazardous chemical cargo on this location is not advisable due to residential areas nearby.

7.9 COMPARISON AND DISCUSSION

Luckily for this terminal, the substructure is robust due to the design with former expansion to such an extent that the most alternative functions, in between certain boundary conditions such as the crane portal width, are possible without significant changes to the Coolport requirements. Alternatives such as short sea and general cargo, even containers are an opportunity. Demonstrated by simple comparisons between ships and cranes, the current substructures are more than able to handle every possible function within the possibilities of this terminal. The uncertainty must be sought in the type and volume of cargo and in totally new ways of (un)loading procedures and equipment.

To conclude this case study, it has become clear that not only for new infrastructure projects, the requirements are clarified and improved by adding the new steps to the procurement procedure, also for existing infrastructure that is going to fulfil a new function the employer can benefit in the focus of requirements.

From engineering point of view, the second option is the one to put out for tendering. It is in this case very beneficial to create room for alternative use and also the current substructure enables this without any drastic reconstruction. After all, the terminal serves as a significant container terminal at this moment.

Accepting the Coolport requirements is what used to be done and the uncertainties of Coolport would be contractually secured. If Coolport would fail, the financial consequences would be the responsibility of the client. It also consumes a significant amount of time to rebuild for a new destination and should the Coolport go bankrupt, the contractual agreements can’t magically appear the funding. Taking matters into own hand and anticipate on other possibilities for the terminal by a minor investment and continue with option 2 would from an engineering point of view be wisest.

Option 3, anticipating on deep sea transport establishing on this location in the future results in all probability to a conclusion that the quay wall and basin provides insufficient capacity and a more robust design is required. No practical calculation have been made, but it can be assumed that based on the facts that deep sea is shifting seawards for the space and time savings, is not going to migrate inlands even if it would be possible once the tunnel is being lowered. It would be very future proof, yes, but with the current versatility of the available infrastructure, it is an enormous financial risk to take for little extra opportunities.

This concludes the case study that demonstrated that by scouting beyond the client’s requirements and acquiring information of the surroundings of this project, small investments result in a large variety of alternative possibilities.
8 CONCLUSIONS & DISCUSSION

8.1 CONCLUSION

Port infrastructure today is planned under more and more conditions of uncertainty. The challenge to design a well-functioning design for the timespan of its technical lifetime is getting bigger. Port of Rotterdam is searching for a strategy to close the timespan between commercial (functional) and technical lifetime of (client-) infrastructure so that the alternative value of the construction increases. More alternative value means the ability to remain functional in the event of other cargo type or volume, or different equipment.

The aim of this thesis was formulating a procurement methodology that enables the application to decrease this timespan. The focus for the projects is the customer oriented projects. Dedicated client infrastructure has less alternative value. The aim is finding possibilities to increase this value by a new way of formulating the Program of Requirements. It was soon established during research that risk management is the key ingredient here. Risk management is already a common part of the planning during construction, but not for risks of changing requirements. Therefore the proposed addition with this method to the procurement procedure is integrally combining the short term and long term uncertainty and developments for port infrastructure projects in a risk portfolio.

Planning under uncertainty by plunging headlong into all kinds of measures and buffers results in far too expensive designs. The essence of the method is narrowing down all uncertainties by gathering as much information as possible in order to make more accurate estimations of those uncertainties and developments. A future-proof Program of Requirements for a project is one thing; it is another to find a future-proof and economically attractive Program of Requirements. The emphasis on the benefit of constructing flexible or robust is spending a small percentage extra on smart design and or material and time in order to prevent possible high reconstruction costs.

By assessing uncertainty and developments around the project of interest, consultation of the different actors may converge the amount of uncertainty that applies for the project. The risk portfolio can be thinned out and the risks remaining can be prevented by anticipative measures proposed to include in the clients requirements.

Concluding the steps of the process contain the following questions:

1. A project is started. The client announces requirements
2. Which actors can be responsible for changing requirements (actor analysis)?
3. What are possible changing requirements (uncertain development assessment)?
4. Which possibilities can be ruled out (update risk portfolio)?
5. What changes can be anticipated on and prevented in the design (anticipating measures)?
6. Which risks is the employer willing to take and which risks to prevent? (strategic options)

Uncertainty can be reduced in the functional part of formulating the contract and Program of Requirements, by interactive procurement, the technical challenges and applying the precautions in the design can be discussed. As well as the functional and the technical part of the procurement process results in a revised Program of Requirements that can provide innovative solutions for port infrastructure.
Innovative solutions do not mean a high-tech solution by all means. An effective execution procedure or the usage of material leading to a much more robust design without extra costs can be an innovative solution as well. The goal was to achieve maximum future-proofness.

The whole process can be summarized in the following illustration. With the question, do we design with clients requirements A and B or with the aim of extending commercial lifetime or easy rebuilding possibilities A' and B'?

**FIGURE 29: DESIGN A&B OR A’&B’?**

That was in short the steps that can be added to the existing procurement policy in order to create flexible infrastructure. To establish a practical example what this beholds in the real world, a case study that drafts the requirements for a reefer hub on an existing container terminal was done. Where by current procurement, a more dedicated Coolport design is tendered, the added value of this methodology became clear immediately when demonstrating the risks and possible alternatives. When studying the substructure, accommodation of more functions could as easily be incorporated. From this case study, it has become clear that not only for new infrastructure projects, the requirements are clarified and improved by adding the new steps to the procurement procedure, also for existing infrastructure that is going to fulfill a new function the employer can benefit in the focus of requirements.

Next, the research questions will be answered with the obtained information.

### 8.2 RESEARCH QUESTIONS

The sub research questions were formulated as follows and also globally point out the different steps that were taken to come up with this method:

**What are the drawbacks of the current tendering procedures with a business case?**

- Lean and mean style of business cases. No margins for extra loads for instance are taken into account, that is a risk because only a slight change in requirements can result into incompetence of that infrastructure and costly reconstruction.
- European tendering rules prohibiting changes in the requirements or awarding criteria after initial publishing of the tender. This complicates awarding an innovative design idea or changing the projects requirements as a result of new information.
- A large range of uncertainty and developments result in various changing requirements, by type and volume of cargo and the equipment used to transport and (un)load. The infrastructure must be suited for the requirements at all time.
Which uncertain developments apply to port infrastructure projects?

On many different terrains are occurrences, developments and discoveries that lead to changes in a port. Via as many different ways this finally reaches the port infrastructure by physically changed functions in:
- Type of cargo
- Throughput volume
- Mooring forces
- Mooring configuration
- Width & depth harbor basin
- Number of berths
- Storage area
- Vertical forces on quay wall
- Vertical forces on loading platform
- Hinterland connections
- Hindrance/safety contours

Not all uncertainty directly leads to changes. But economic shifts, upscale of size or new ways of transport do result in the direct and physical changing requirements above. This tones it down as a start to incorporate in the Program of Requirements.

Which of these can you take into account as Port Authority by incorporating flexibility in the Program of Requirements?

It is possible to incorporate some kind of buffer for every possible development there is. However this would result in an excessive over-dimensioned construction and not approved by the financially responsible party. This party will indirect by harbor dues and rent of the terminal pay for the construction costs that are required for his requirements. PoR can pay for the additional costs, but that is not realistic as well. Therefore in the method a so called moment of Strategic options is introduced. The intention of this method is adding extra preparatory work for the employer (PoR for the majority of this thesis) to narrow down the scope in between which the requirements can be expected. This may be possible with minor adaptations but lead to huge functional spreading gains for slightly higher costs.

What will be the timespan of the business case?

The horizon of the business case depends on the strategy chosen:
Should the employer choose for a robust solution, it would be wise to extend the business case to 30/40 years creating more budget for a robust design, or even better in order to leave everything the same at the front of the contracts. In other words, the timespan of the business case should remain 25 years, which is the familiar timespan in the Port of Rotterdam. The depreciation period of the construction can be extended however. A robust design should remain functional after these 25 years. Part of the construction costs can be earned back in the next business case for the plot where this particular part of infrastructure is attached to.

Should the requirements be likely to change within a significant short period of time, the employer can choose for flexible infrastructure. In this case, a shorter business case is recommended, because the infrastructure is easily adapted to the at that point actual requirements.
How to specify a port infrastructure project in a tender such that the contractor can fully utilize his knowledge creating innovative solutions without compromising the usefulness of the solution?

First rule out as much uncertainty as possible before setting up the requirements. The contractors itself said it: in order to work together successfully on an integrated contract, the employer must know exactly what he wants. The methodology is set up to do exactly that. We want to build something that is future-proof within a realistic budget. Therefore we need to know what can be expected in the future.

Next the technical and design challenges are discussed with the contractor instead of handing them over. This is called Early Contractor Involvement. Working together with the most ambitious contractor is done by Best Value Procurement. BVP stimulates to really demonstrate their best.

How to evaluate and compare these innovative solutions?

The research more or less focused on the steps in the methodology to accomplish implementing flexible infrastructure. Therefore, answering this question lacks a solid base. Based on the information available, the suggestion is: lowest price with additional quality criteria for extra depth / configuration usage within the budget. The designs can easily be compared based on the options of placing mooring bollards and fenders. Flexibility in receiving a large variety of ships depends on besides the basin depth at the quay wall on mooring configuration and forces. Three parameters that can easily be compared. Next, application of crane tracks and the absorbing of loads can be compared on availability.

The focus of the methodology however is not only on comparing the different proposals, therefore a guideline following the procurement process on evaluating the level of flexibility is admitted in the recommendations.

Is the current balance of responsibilities between employer and contractor optimal or can this be approved?

Currently more responsibilities are shifted from employer to contractor. This means more risks for the contractor enlarging the distance between hem and the employer. For the methodology as proposed here, more preparatory work is required from the employer to obtain as much information for long-term risk management as possible. This leads to more responsibilities back under control of the employer. As technological challenges are discussed together with the contractor (Early Contractor Involvement) where the attention lies at sharing risks rather than dividing them, the current balance of responsibilities needs improvement.

And finally the answers of the sub questions should now provide enough material to answer the main question:

How can flexibility be incorporated in the business case and the resulting agreements for construction?

After establishing the theoretical framework of procurement and port infrastructure, the method to look beyond that client’s requirement helps answering this question now. The reason to add flexibility to the port infrastructure is by being able to withstand changing requirements without significant reconstruction time and costs. In order to incorporate flexibility to absorb these changes, it is advised to first converge these uncertainties. What uncertainty could result in changing requirements? The next step is to rule out as much uncertainties as possible by gathering as much information as possible.
This transforms uncertainty into (half)certainty and can be included in the long term risk portfolio. In this risk portfolio, the development, expectations, probability and impact are assessed based on the obtained knowledge. Based on the impact, an anticipative measure that can be added to the Program of Requirements, is proposed. This results in a couple of options the employer has which is the main difference between this new and the current way of procurement: Adapting the client's Program of Requirements or not. Financial, strategic and technical evaluation of the situation and possibilities can determine the strategy of the employer in order to withstand the fast changing requirements.
8.3 DISCUSSION

8.3.1 RESEARCH APPROACH

At the beginning and formation of the research, the accent was more at the contractor’s side. More responsibilities to come up with innovative designs. During the research for the future requirements, it soon became clear that in order to create future-proof infrastructure, more preparatory work is required by the employer. The employer depends for a significant part of the information on the actors involved in that particular project. The methodology as proposed in this thesis therefore stands or falls at the willingness of sharing information. The employer can make all arrangements possible to secure classified information, as long as an actor is not willing to share its knowledge, making the risk portfolio more accurately is a much bigger challenge.

This thesis only provides qualitative arguments. Proving that this extended method is better with calculations or numbers remains very difficult, since every project is different and whichever strategy is chosen is a risk itself as the future remains uncertain for everyone. What it can do better than the current method is providing strategies to enlarge the project’s future-proof, by gathering more information than just the customer’s, and via risk assessment incorporating this into the Program of Requirements. Quantifying the extended method could be accomplished by calculating the additional investment of the precautions on top of the customer’s requirements. This can be compared to the costs of rebuilding the construction with the customer’s requirements to the then required specifications. This still only provides a comparison between additional investment at the start and a necessary rebuild in the future, financial parameters such as inflation, interest rates etc. still make the validation of this comparison a challenge.

All in all this method is far from proven, but it does provide a well substantiated answer to overcome the challenge of designing infrastructure under uncertain conditions: More and diverse input for the risk portfolio and incorporating this into the Program of Requirements, changing the perspective of investing minimally as it is done currently. Its philosophy is “a stitch in time saves nine.”

The case study demonstrated an improvement for customer oriented projects at a port by this adapted procurement procedure, the last interesting question to answer now is:

8.3.2 IS THE METHODOLOGY GENERALLY APPLICABLE?

The scope of the research to come up with this methodology was converged to new private infrastructure projects in a port. The ideas on which the method is based on, market consultation, development research and extending the risk portfolio with this knowledge, are more widely applicable. For another port, the approach can be largely the same, if the conditions are somewhat alike. A totally different hinterland or physical boundaries can change the perspective of the project entirely. Thus in short, the outline of the method is for private projects, not especially ports, applicable. The interpretation is different, depending on the scope of the project.

Somewhat different are public projects. The users of the project are not the ones assessing the requirements for that project. The requirements of tomorrow are determined based on the perspective of the employer, who is not the user. Therefore, the outline of the method of this thesis can be used for public projects, but obtaining the required information is based on other sources. The maintenance program could benefit from a run through the method once a certain threshold is passed or significant changes are stated by the client.
The purpose again, is gathering as much knowledge of the aspects that can change the requirements in the future and assessing via a risk portfolio in what way a possible anticipative action can be performed. The recommendation is to export the method to public projects and maintenance works to find out feasibility for these types of projects as well.
Besides finding adaptations for the Program of Requirements in order to make it more future-proof, research always raises several more questions or findings that lay beyond the scope and timeframe of this thesis. This is formulated in the recommendations below.

9.1 TECHNICAL EXPERTISE NEEDS TO STAY AT THE EMPLOYER

A trend is spotted in current procurement procedures using integrated contracts where employers rely more and more on the expertise of the contractors.

As discussed in paragraph 6.3, without a certain level of expertise available at the employer (PoR or RWS), it is impossible to formulate clear and accurate requirements. And without "knowing what you want" as employer, the solutions as provided by the contractors aren't as suited as it could have been or much more expensive than necessary.

By interactive procurement procedures, the contractors and employer can discuss requirements and possibilities and both parties know more about the results that are searched for. The recommendation based on the additional work necessary for employers to successfully implement the extended method is to have relevant engineers part of the procurement process.

9.2 SUITABILITY METHODOLOGY IN MAINTENANCE PROGRAM

The focus of this thesis was for the majority on new projects that are customer oriented. However, during a brainstorm session with Giel Jurgens (PoR Asset owner) it became clear that the life cycle of existing assets could be extended by including a brief update of its requirements by the steps of this methodology. Taking into account minor revisions to that asset in order to bring it up to date again, can prolong its lifetime significantly. Visualized in a time line of the asset’s life cycle it could be like this:

![Asset Life Cycles](image)

FIGURE 30: ASSET LIFE CYCLES

Defining these thresholds and a suitable adaptation in existing assets needs further investigation.
9.3 SUITABILITY METHODOLOGY FOR PUBLIC PROJECTS

The outline of the method is for private projects, not especially ports, applicable. The interpretation is different, depending on the scope of the project.

Somewhat different are public projects. The users of the project are not the ones assessing the requirements for that project. The requirements of tomorrow are determined based on the perspective of the employer, who is not the user. Therefore, the outline of the method of this thesis can be used for public projects, but obtaining the required information is based on other sources.

The purpose again, is gathering as much knowledge of the aspects that can change the requirements in the future and assessing via a risk portfolio in what way a possible anticipative action can be performed. Rijkswaterstaat can formulate the requirements for a new project with this methodology, input for instance about grow capacities. The recommendation is to export the method to public projects for feasibility.

9.4 WILLINGNESS OF SHARING INFORMATION

Part of this methodology rests on good faith of sharing information by market parties. Not everybody wants to share information that could jeopardize the company (or developments that are a step ahead of the competition)

This takes time and confidence. Intellectual property such as this knowledge needs protection. As already said, RWS is working on a strategy to better protect innovative ideas and knowledge that is generated by the market. How this can be applicable in market parties such as shipping companies and terminal operators is subject for further investigation.

9.5 FINANCIAL AND TECHNICAL DEPARTMENTS WORKING IN UNISON

Depreciation of construction as quay walls can be spread out over a longer time than the business case of 25 years. This forms extra budget for investing in high quality infrastructure that can last much longer than a business case now. Also slightly higher investment than as necessary for the client may result in much longer operational infrastructure.

However, the financial view on such investments narrows technical playroom down. Convincing all parties around such projects that investing in making a construction future-proof is very important, otherwise, many good measures that could lead to considerable savings in the future are wasted.

9.6 PHYSICALLY FLEXIBLE INFRASTRUCTURE ONLY FORMS IN LIMITED SITUATIONS A VALID SOLUTION

Multiple sources shared doubts during interviews and conversations about the application of physically flexible infrastructure such as floating quay walls, or modular built quay walls. The claim was that physically flexible infrastructure is beneficial not until it has been reused for four times. Whether or not this number of reconstructions actually occurs for port infrastructure is doubtable, the proof of the pudding is in the eating and so far no valid situation has occurred where that many reconstructions happened. In depth financial evaluation of this alternative is necessary in order to provide a well-founded argumentation.
The flexibility as introduced at the start of this thesis is more aimed at flexible usage of that infrastructure. Port infrastructure such as quay walls are robust constructions that are built for longer periods of time and it is quite difficult to really make such a construction flexible. So a rigid construction that is flexible in use. This is possible by a robust substructure with adaptable possibilities in the superstructure.

9.7 VERIFICATION OF THE METHODOLOGY

All results in this thesis are based on a desk study and theory. Information and feedback based on experience by professionals is used as a check for the suitability and content of this thesis. However to fully validate the improvement of procurement by this methodology, it must be applied to a real project. Then it is possible to really compare the client’s Program of Requirements with the updated version. And after the construction comes the real test. What developments were anticipated, and is the construction really flexible?

9.8 EXTENDED FINANCIAL EVALUATION OF THE PROPOSED METHODOLOGY.

As the research approach already excluded the financial evaluation of the business case, the rate of return, timeframe etc. it is recommended to investigate the possibilities of flexible infrastructure when the timeframe of paying of the infrastructure can be spread out over a longer period of time. In section 3.8.1 it was stated that the technical lifetime and the depreciation time of the infrastructure does not match. In order to further investigate the possibilities of investing in future-proof infrastructure, this should be found out.

9.9 CONTRACT AND EVALUATION CRITERIA

As competition between contractors not always brings out the best in commercial parties, EMAT criteria must be proposed that emphasizes the focus to quality instead of lowest price. This cannot be accomplished when the employer itself is not prepared to invest some extra in future-proof infrastructure, referring to recommendation 9.5. As risk management and debalancing of risks is getting more important, from currently used contracts D&B provides the best solution, but a completely new form of contract may even be better. As the knowledge of contracts and law is not sufficient for a detailed answer, the recommendation following this is further research in contracts for the proposed methodology.


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APPENDICES
A. LITERATURE RESEARCH

This Appendix summarizes the main findings of the consulted literature that form the base of the plan of action for this thesis. Note that this is not the entire literature research, just the part used to formulate the research approach.


   Flexibility helps a port to adapt to a wide range of exogenous developments. Adaptable Port Planning incorporates uncertainty and flexibility in traditional port planning methods.

2. **Thesis “Sustainability as a tender criterion in port infrastructure projects”, E Broesterhuizen**

   Incorporate sustainability as a criterion in a port infrastructure project. The layout of this research has similarities with this research (flexibility as criterion instead of sustainability)

3. **Thesis Flexibility in DBFM contracts J. Roosjen**

   A flexible contract should in principle be prepared for a change and is characterized by options in the contract.
   Flexibility of the DBFM contract depends on interpersonal flexibility
   Take into account the contracting parties’ perspective in flexibility

4. **Quay wall designs, C. Chen**

   Container vessels are getting larger and larger, the current port infrastructure won’t be able to handle this

5. **Port Compass 2030 + Trends/Developments + Estimations of goods flows.**

   Port of Rotterdam has based on a number of trends and developments four scenarios of its harbor in twenty years.
   
   1) Global Economy
   2) European Trend
   3) High Oilprice
   4) Low Growth

   All scenarios imply changes in goods flow and shifts in certain direction

6. **Asset management, G. Jurgens**

   Asset management is a new way of approaching the whole life cycle and its costs of infrastructure assets.

7. **Buying Innovation, Department of Enterprise, Trade and Employment, Ireland**

   A 10-step guide of public procurement to stimulate research and innovation.

8. **Early Contractor Involvement, International Association of Dredging Companies.**

   Explanation of Early Contractor Involvement and in what sort of projects this can be useful.
9. *Aqua et Terra* Article about Public Procurement Rules in the EU and Early Contractor Involvement.

It is in the interest of all parties that optimal solutions can and should be discussed. As an employer, use the knowledge of the contractor and share the complexity and risks of infrastructure projects.

10. *Faalkostenvrij bouwen: het kan*, Arent van Wassenaer, Allen & Overy LLP

Rijkswaterstaat has formed an alliance with the contractor to share the risks of a project instead of dividing them, with success.

11. Workshop toekomst vaste infrastructuur (sustainable infrastructure)

Dealing with uncertainty can be done in two ways: Robustness or flexibility

Use Asset Management

Shorten the technical lifetime of an asset

Standardization

Robust substructure, flexible superstructure(s)

Scenario thinking

12. *European procurement for concession works (PoR and European parliament)*

Infrastructure projects with a budget over 5 million Euro must be tendered publicly on the European contracting market.

13. *Design and Construct in Civil Engineering Reader* by Prof. H.A.J. de Ridder BE MSc PhD and J.P. Noppen BE MSc

Insight in the forms of contracts and collaboration in the civil engineering industry.


This tender document provided information about the specifications asked for a certain project as well as the EMAT criteria and weight.

15. *Aanbesteden doe je zo, richtlijnen voor het aanbesteden van infrastructuurele werken bij het havenbedrijf Rotterdam, Inkoop en contractmanagement, oktober 2007*

Tendering, procurement and contracting policy applied by Po Rand the motivation.

16. *De feiten rond aanbesteden, gebruik van EMVI, Economisch instituut van de Bouw.*

Research of four years of tenders evaluated by EMVI, the main criteria, proportion, advantages and disadvantages

17. *Rijkswaterstaat, zakelijk, aanbesteden.*

Information about tender, contracting and procurement procedures by Rijkswaterstaat.
B. BRAINSTORM SESSION

A brainstorm session is a very effective method to gather lots of information in limited time. During this brainstorm, the objective was for me to find out what general ideas, possibilities and limitations of flexibility in contracts there are, from different perspectives. Therefore, people of different departments involved in business cases and/or innovation within PoR and Rijkswaterstaat were invited to discuss the topics from their role.

The contract was the center of the discussion and both flexibility at the front (voorkant) meaning the terms and conditions and the back (achterkant), meaning the design (Figure 31). I draw up a list of topics and let the participants discuss their ideas.

![Figure 31: Lay Out of the Brainstorm](image)

For this session the departments, port projects, port development, procurement etc. could discuss the following topics:

- Is the conventional form of contracting still applicable?
- What are the possibilities of collaborations between PoR and ship designers or crane builders in exchanging expectations / knowledge of the future?
- How to incorporate flexibility into contracts?
- What are possible qualitative criteria for flexibility in contracts?
- When are you going to set functional demands as the employer?
- What is the importance of assets (standardization etc.)
- Possible case studies

Off course, this was a rough outline of the brainstorm. Below is the summary of the brainstorm in Dutch:
Aanwezigen:
1. Wim Zwakhals Duurzaamheid en Innovatie
2. Erik Broos Projectleider nieuwe projecten
3. Maurits van Schuylenburg Projectmanager Logistiek
4. Giel Jurgens Port Development, Asset Owner
5. Tim Gademan Procurement, inkoop v. projecten
6. Arnoud de Bruijne RWS, Innovatie & Markt
7. Poonam Taneja PhD Flexible Port
8. Pim Vermerris TUD

Connectie tussen RWS en POR: In het kader van duurzaamheid, wat kun je nog meer vragen van een aannemer?

Dit is een vervolgstap op het de CO2 prestatieladder → betrek de aannemer niet alleen in de business case, maar laat deze actief meedenken. Dit komt ten goede van het eindresultaat

1e vraag: hoe flexibel is flexibel?

Heeft het terrein nog wel dezelfde bestemming (bijv. container → container) of een totaal andere inrichting?

Wat is de horizon? Business Cases zijn zo’n 25 jaar. Als die tijd volbracht kan worden zonder de constructie aan te passen ben je al een heel eind.

Maar er zijn genoeg voorbeelden waarin binnen 5 jaar weer aangepast moet worden. Dit moét te overzien zijn.

**Emo terminal**, door Erik Broos benoemd. De klant is nu de kade slechts anderhalf jaar in gebruik is voor de derde keer bij hem langs geweest omdat de kademuur aangepast moet worden. Halverwege de bouw ook en in de aanbestedingsfase.

Ander voorbeeld: **Brammen terminal** Hier is een terminal op maat gemaakt voor de klant. Dit concept is vervolgens niet aangeslagen en moet voor een volgende klant de terminal weer omgebouwd worden.

Hoe langer de termijn van de business case is, hoe meer de onzekerheid toeneemt.

FIGURE 32: LEVEL OF UNCERTAINTY IN TIME

100
Om onzekerheid aan een business case toe te voegen, is het mogelijk risico’s aan aanpassingen/onzekerheden (in techniek en bedrijfswaarden) toekennen.

Flexibiliteit is omgaan met onzekerheden (gebruik, materialen, klant enz.)

Deze “elementen” kunnen dan een economische en technische risicomatrix vormen.

Onzekerheid proberen te minimaliseren kost geld. Onzekerheden zijn nog op te delen in eisen en wensen. Wat is het je waard om als opdrachtgever je zaken op orde te hebben? Hierbij is ranking te geven aan de wensen.

Wat wil je aan toekomstbestendig toerekenen en wat past in een business case?

Wat vormt nu de onzekerheid voor haveninfrastructuur? Het begint bij welke stoffen/producten ingevoerd worden. Hier zijn de schepen en laad/los systemen van afhankelijk. Inzicht in de productmarkt is de beste start om om te gaan met onzekerheid.

Rijkswaterstaat is al meer naar de scheiding tussen aanleg- en onderhoudskosten aan het kijken vs. de levensduur. Bij de aanleg wordt weinig tot geen rekening gehouden met faalkosten. Problemen tijdens de aanleg komen vaak pas naar voren in de onderhoudsfase. Door één budget voor aanleg en onderhoud te hebben, wordt beter nagedacht over de gebruiksfas.

Eigenlijk: D&B \rightarrow DB(F)M

De functionele vraag kan maar tot op zekere hoogte, want tot op welk niveau heeft de opdrachtgever nog voldoende kennis om de ontwerpen te vergelijken.

**Samenwerkingsverbanden**

RWS is ook alliantieprojecten opgestart. De traditionele rol van OG en ON los proberen te laten en als een gezamenlijk projectteam het doel proberen te behalen. Dit onder meer door gezamenlijk het benodigde budget ophoesten. Winst/verlies wordt door alle partijen gedeeld.

Havenbedrijf Rotterdam is verplicht Europees aan te besteden boven het drempelbedrag, dus het werken met één vaste ON werkt helaas niet (dit zou de onderlinge vertrouwensband wel te goede komen)

Zijn bijvoorbeeld de terminaloperators erg terughoudend met hun visie op de toekomst qua schepen/kranden is het wel mogelijk om bij scheepsbouwers te informeren wat bijvoorbeeld de limiet is aan schroefafmetingen/langzamere vaarsnelheden etc. Wat betreft onderzoek doen naar ontwikkelingen van de markt is het raadzaam om verwachtingen van de theorie (onderzoeksinstituten e.d.) én de praktijk (scheepsbouwer e.d.) Van beide kanten inzicht krijgen in de algemeen aanvaarde limieten, de theoretisch logische bedachte grenzen.

Meer vrijheid toekennen aan opdrachtnemers / de markt

Helder doorgeven wat je als opdrachtgever wilt.

Meer in functies specificeren ipv. Letterlijk het product/materiaal benoemen. Dit wordt nu vaak nog niet gedaan omdat de OG “bang is iets te krijgen wat hij niet wilt” bijvoorbeeld onbruikbare afmeerconfiguraties tijdens het dagelijks gebruik van kades.

Functionele specificaties en eisen formuleren en de “markt” hier vervolgens met oplossingen voor laten komen
Waar zit de winst voor de aannemer in? Ontwerp van de hoofdconstructie? Door de aannemer meer ruimte te geven, komt deze misschien tot een totaal andere oplossing, waar hij/zij meer ruimte voor winst in ziet.

Interessant voorbeeld: **remwerk EMO terminal.** Hier is voor staalvezelbetonplaten gekozen. De uitdaging hier was om verschillende soorten schepen, waaronder duwbakken, af te laten meren. Duwbakken bonken conventionele houtfenders kapot.

**Standaardiseren**

Standaardiseren kan tegenstrijdig zijn met openbaar aanbesteden/ vrijheid markt. Is dit wel conflicterend?

Momenteel is zo’n 10% van de totale kosten door engineering. Standaardisering kan dit percentage omlaag schroeven.

Faalkosten worden ook minder

Algehele mening om tijdens de EMVI beoordeling minder op geld voor de aanleg alleen te gaan beoordelen. Meer focus richting onderhoud/ maintenance kosten. Dit vragen aan de makrt en de basistaken omzetten in EMVI criteria

De vraag vervolgens is: zit de markt (dus de inschrijvers op een tender) wel op al dit onderhoud te wachten. Voorbeeld van regelmatig terugkeren om onderhoud te moeten plegen aan constructies.

Een mogelijk beoordelingscriterium van inschrijvingen is de mate van hinder door onderhoud.

**Concluderend:**

Er hoeft nog niet direct iets aan het contract te veranderen. Kijk vanuit flexibiliteit, wat moet veranderen? Eerst is het van belang om als opdrachtgever de markt te verbreden en inzicht te krijgen in wat deze marktpartijen (aannemers, klanten) **wollen**.
C. INTERVIEWS

In this Appendix a brief summary per interview is given. Since the subject of this thesis is new and the process not (fully) developed, the amount of available literature is fairly small. It is not a mathematical problem for which formulas or approaches are already (whether or not partially) available. Information gathered from these interviews is input by professionals for the analysis. It is a multi-angle approach of the challenge of incorporating flexibility into the business case and to get a complete and actual picture of the current tendering/procurement process, also the opinions of different professionals in this field about short comings in possible improvements.

FIGURE 33: DEPARTMENTS INVOLVED IN THE BUSINESS CASE OF A POR PROJECT

The process of a port infrastructure project can be found in Figure 33, which illustrates the different departments the interviews were taken. PoR has in essence two sides, the engineering side (Asset management, projects and port development) and the financial side (Investment, Risk management and Procurement) As already explained, the proposals of incorporating flexibility can be evaluated with these departments based on their experience with port projects and business cases.

Every interview had the same lay out:

- What beholds your job
- From your point of view, what do you think of the idea to use more flexible infrastructure.
- From your point of view, what possibilities or limitations do you see for incorporating flexibility. Why or why not and where or where not?
- In every interview another person was mentioned to talk to for more information about a specific topic or documentation about the discussed topic was obtained.

The interviews will be taken in different stages of the research process to use the input from the professionals as optimal as possible.
First, for the theoretical framework to become familiar with the research objectives and will be repeated as soon as the risk inventory and functional requirements are revised to discuss the updated version. Before starting with a case study, a first validation is useful, to adapt it, should this be necessary.

ROUND 1

The interviews were taken from:

Interviewee: Wim Zwakhals & Erik Broos
Function: Project manager Environmental Management & Project leader Port Development
Subject: Problem identification and introduction
Interesting points:
To incorporate flexibility in contracts → Direction of Asset Management
→ Specifications in the contract
Clarity about the challenge of flexibility in contracts via a brainstorm session (including Rijkswaterstaat, who are also interested in this challenge)
incorporation of the yet to be found solution on a Green Field development (i.e. Porta Central, Brazil)

Interviewee: Maurits van Schuylenburg
Function: Project Manager Logistics
Subject: Problem identification and introduction
Interesting points:
Example of the Amazonehaven about uncertainties costing a lot of money. The Port Compass discusses uncertainties in the future and different scenarios for the port as a strategy to respond.
Look into the Maasvlakte 2 tenders, this was a new way of tendering for PoR

Interviewee: Giel Jurgens
Function: Asset Owner
Subject: Asset Management PoR
Interesting points:
Insight in Asset Life Cycle Management which focusses on a balance between build- and maintenance costs. Looking beyond the financial aspect.
Standardization could be a solution and is something the quay wall-department is interested in.

Interviewee: Arnoud de Bruijne
Function: Sr. Advisor of Innovation and Market, Rijkswaterstaat
Subject: Alliance contracts, Rijkswaterstaat’s view on flexibility in contracts
Interesting points:

The key for functional demands is: Specifically know what you want as an employer. With your demands, did you cover all the bases so that you don’t end up with unwanted or unusable solutions.

Rijkswaterstaat is also experimenting with shortening the technical lifetime of constructions to cope with uncertainties.

Alliance contracts were introduced in projects where risks and their owners are unclear. In this way, risks and profits are shared, not divided.

Interviewee: Tim Gademan
Function: Procurement
Subject: Procurement PoR
Interesting points:

The risk of setting out functional demands getting a solution that is not useful.

The tendering laws set out by the EU limits the employer in awarding the contractor who comes with innovative solutions. As soon as its outside the scope, no significant reward can be given.

An option for innovative solutions can be an internal business case for future-proof infrastructure. Can PoR add some budget to every project/business case to make it more future-proof?

Interviewee: Wouter Bredemeijer
Function: Environmental Policies and Zoning
Subject: Port Compass and expectations
Interesting points:

Clustering and redistribution of terrain is a continuous process. The PoR zone has 3 different regions (Maasvlakte 1, Europoort and the Botlek area) each looked at individually. One aspect is the contract duration

For the future, to accommodate the economic growth, the goal is to intensify the use of existing port area, not another expansion.

Talk to Jelle Peddemors for more details of the Port Compass.
Interviewee: Cees Pons
Function: Port Development
Subject: Container terminal Maasvlakte 2 tender

Interesting points:

Why a tender? A tender simply to get the best offer for this plot.

With the growth of the container industry, PoR realized that this plot should be a container terminal. The dimensions of wet- and dry area were given, quay wall design and hinterland connections. Interested parties could make an offer and were evaluated on financial, sustainable, innovativeness and commercial strategy criteria. The next step was a tender for the works itself.

Functional demands: Depth, lay out, max cross current, phased building. The “Euromax” quay wall was given as reference.

The contractor had to be able to verify that their design met the functional demands.

An innovative contribution by the contractor was possible by clever staging the works and handling the sand.

Interviewee: Frank Wolkenfelt
Function: Environmental Advisor
Subject: Tank terminal Europoort tender

Interesting points:

Due to its location and market research, the plot had to be a tank terminal.

A basic lay out was given, as were the nautical safety conditions. The potential clients were challenged to come up with an alternative. It had to be a state of the art terminal.

PoR already looked at the tenders beyond this customer. Should he leave, what else is possible with this terminal.

Interviewee: Jelle Peddemors
Function: Port Development
Subject: Port Compass

Interesting points:

Procedures to come up with the scenarios for Port Compass. A confidential report on the cargo expectancies and the names for some other people to help me with more details.
Interviewee: Frans van Hooff
Function: Investment and Risk management
Subject: Financial side of the business case
Interesting points:
Standard payback period is 25 years with possible expansion of another 25 years.
Every project must have a positive outcome after the payback period and must have a certain efficiency rate.
Residual value of infrastructure isn't taken into account

Interviewee: Mark Franken
Function: Project Development
Subject: Business cases, evaluation and awarding them.
Interesting points:
Customer – PoR selection bases on objective measurable criteria. Financially on NPV and efficiency rate. Every group of criteria (technical, financial, sustainability, strategic) is evaluated by a specialized team.
A lower boundary is set as important demand
Every BC is looked into as a business plan. What is de NPV of the plot after 25 years. What are the revenues. Is the investment needed for this plot worth it.
Interesting for me: Look into every case both as an economist and an engineer. Engineers don't know much about aspects as uncertainty, port dues, bankruptcy and accountancy rules such as write-off

Interviewee: Kees van der Graaf
Function: Managing Director De Boer Dredging
Subject: Tendering, a contractor's view.
Interesting points:
Taking risks as a contractor is normal, but they have to be calculable. Not calculable risks are the responsibility of the employer.
Employer often doesn't know what he/she wants. Therefore requirements are often formulated vague. More clarity is wished.
European procurement rules are mainly lived up to by the Netherlands. A critical look into applying them can be useful.
Interviewee: Karin de Boo  
Function: Business Analysis and Intelligence  
Subject: How to deal with uncertainties  
Interesting points:

Long term estimates are left alone as much as possible, unless external long term effects, such as closing of blast-furnaces in Germany or the cancellation of the development of an LNG terminal in the port area.

What input is used for the scenarios and goods flows: Capacity hinterland, what developments are there (factories opening or closing?) A certain bandwidth is given in between the ports transshipment rates are expected to be.

Check: Are investments now financially as interesting as you think. Is that money 25 years making interest not worth more than by investing it straight away.

Interviewee: Joost Bos  
Function: Project leader wet infrastructure  
Subject: Tendering process with contractors  
Interesting points: For the superstructure of the quay walls, PoR makes functional demands (ladders, fenders etc.)

The substructure is specified by norms and guidelines, as well as functional demands.

The responsibility for over dimensioning lies with the project team. They come up with a proposal for the quay wall.

In a tender, innovative ideas are limited. When the contractor comes up with an innovative proposal, there are two ways: an open question or a confidential question

Open question → the idea is known by all other competitors

Confidential question → is the idea within the scope of the tender → if not, the specifications of the tenders must be adjusted, which you want to prevent as employer.

So how to specify your demands, with room for innovation and contractor involvement. What part of the project is set, what part is open for the contractors creativity? How can you valuate this.

This conversation was very useful for clarification of the problem definition.
Interviewee: Frans van Hooff

Function: Investment and Risk management

Subject: incorporation of risks in the business case. Risk management PoR

Interesting points:

Refined definition of the business case

Uncertainty inventory looks good. We added surroundings and strategic surroundings management

Categorized risks
1. Introduction to research steps that have been taken over the last months
2. Observed as one of the limitations is the exclusion of residual value, Maurits shared the thought that with residual value taken into account could create more financial possibilities to include flexibility
3. The top down approach converged into direct effects was good. Project Masterplan + was introduced. In this report sort of the same list is used to define different sources of uncertainty. Bringing back developments and uncertainty to physical changes on the infrastructure is good, but is should not be ignored what the source of the change is. What causes it and why?

Extra examples include the sudden increase of bulk carriers after shears of having reached a certain limit. Bigger vessels, intended to transport iron ore to China are now deployed on the Brazil - Rotterdam route. This is done since China can’t produce enough depth in its harbor basins

Another example is the Fukushima disaster leading to an enormous increase in purchasing LNG by Japan. As a result, the LNG throughput at PoR is much less.

In the maintenance phase, it can be valuable to define certain triggers. Should an important parameter for the infrastructure (for instance increased ship size) exceed a certain value, action has to be taken and what kind of action

4. A shift at the Port development from individual projects to an overall "bigger picture" for a complete harbor area. What are physical limitations on this area? When setting up a tender for a new project, more attention to the potency of that plot is helpful. If the new client's requirements are not matching the plot's potency, is that client located on the right place? Talk to Cees Pons for these developments.

5. Some addition to my procurement policy in chapter 6.2.2 is given about the different phases of validating the usefulness of a new project. Phase 0 is a quick scan to assess if a project is valid for further investigation by the three-way discussion by Port Development and commercial executives of Manager process industry / bulk and containers/break bulk logistics. Phase 1 is a business case by a project team. This business case is reviewed by the project board determining what specifications are set for the project in hand.

6. Extra details for the examples used in my introduction, specifically for the Amazonehaven.

7. What kind of physically flexible infrastructure is considered in Project Masterplan +? The main problem for using flexible infrastructure is that it will only be beneficial when the structure has to be removed or adapted in say 10 years. For example at the city harbors, where zoning plans can limit operational time for infrastructure, or small natural reserves that will be depleted.

Another problem is that its competitor is sand. And sand is cheap and also flexible in a way that is can be dug out and dumped somewhere else.
A test has been done with containers and concrete floors (Containerland) as a test for temporary infrastructure, but is not applied commercially. Caisson quay walls is another example for flexible infrastructure.

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20-02-2014

Interviewee: Tim Gademan

Function: Project Manager Procurement

Subject: Discussion of the new methodology

1. Introduction to research steps that have been taken over the last months
2. Observed as one of the limitations is the exclusion of residual value, Tim shared the thought that with residual value taken into account could create more financial possibilities to include flexibility, however also noted that building something with a longer economic lifetime is a risk itself. It requires an investment of which you don’t know if it will pay off for a long time. So it cuts both ways.
3. Top down approach was OK
4. A new method of tender is introduced: instead of tendering for an fixed solution, the employer tenders for opportunities in a way contractor involvement, that sometimes is applied by PoR. The scope of the tender provides the basic plan and the contractors get the opportunity the come up with a more successful solution. This is part of Best Value Procurement. PoR’s essence in this is contracting an expert instead of a salesman. The contractor hands in its elaborated risk portfolio and opportunities portfolio with proposed measures. Consultancy Scenter is expert on this topic.
5. In the competitive dialogue procedures, the dialogue is about the completing the Program of Requirements. The most important requirement for port infrastructure is availability. It is off course not the intention of this infrastructure that it requires a lot of maintenance which causes unavailability.
6. Botlek Tank Terminal is an example where alternative usage for that plot already was taken into consideration. The tanks are founded on piles. No further support or landfill around it was technically necessary. However for possible alternatives (the client did encounter financial problems so designing it purpose built was a risk, should that client withdraw) quay walls were built and that peace of harbor basin was filled in. The sand needed consolidation in order to withstand a reasonable deck load. This required a higher investment. At the end, the client did not withdraw, so that packed subsoil did not have to be utilized.
7. What tender procedure is best suitable for my proposed methodology? Public tendering has one contact moment between employer and contractor, so contractor involvement cannot be fully utilized.
   To profit maximal of contractor involvement, an interactive way of tendering must be adapted. The important design decisions can be made together during the meetings.
Ideally this could be done with “negotiation procedures with/without prior announcement” but in order to legally apply this form of tendering, a lot of conditions must be fulfilled. In practice, mostly it cannot be applied. Look for an alternative!

8. For the type of contract, in order to aim for sustainable and future-proof infrastructure, paying attention to the life cycle costs is crucial. Therefore a DBM contract stimulates the contractor to come up with a more sustainable design. He does not want to come back every year for maintenance. However, PoR has maintenance under its own administration. Most projects, such as quay walls en terminals are too small to be beneficial as a maintenance job. Therefore, DBM is only interesting with a significantly large project with enough maintenance work to provide a steady workload. The new, integral approach of a port area could be an option for such a contract. An alliance could be an option.

9. What addition can be done in the steps towards a revised Program of Requirements: Include a loop from the client to the final Program of Requirements. The process will be covered again in order to make it complete. Also the monitoring of developments and uncertainties is a continuing process. Not just done once, but multiple times.

27-02-2014

Interviewee: Giel Jurgens

Function: Asset owner Port of Rotterdam

Subject: Discussion of the new methodology

1. Introduction to research steps that have been taken over the last months
2. Observed as one of the limitations is the exclusion of residual value, Giel also shared the thought that with residual value taken into account could create more financial possibilities to include flexibility. He suggested to view it as alternative value instead of residual.
3. PoR strives to be the most sustainable port in 2030 (Port Compass) But there are two different views on sustainability: Environmental related, but also a long lifespan. The necessity of small extra investments that extend the lifetime of infrastructure positively adds value on the sustainability subject.
4. The top down approach converged into direct effects was good. No additions could be done at the spot.
5. The methodology contains helpful elements towards tendering for future-proof infrastructure. However, the most important obstacle to overcome will be the financial view on the new projects and this way of extra investment in anticipating requirements. It should be empathized that balancing every business case out in a way that the entire investment is paid by the client during its contract is a risk as well. What if that client goes bankrupt, then the redevelopment costs will (partly) have to be covered by PoR.
6. A quay wall is completely written of in 40 years. This is a accountancy “trick” that doesn’t have any connection with the economic- or technical lifetime.
7. When discussing the types of contract that are used during port infrastructure D&B is the best suiting variant. DBM was already discussed with Tim Gademan, and DBF(MO) is not very suited as well. This is not only because PoR earns the revenues by rent and harbor dues, but also because PoR has a AAA-status, meaning it is often cheaper to get a loan for a project by themselves.
In order to explore the possibilities to extend the method to existing infrastructure, Giel invited me to a follow-up appointment.
D. UNCERTAINTY, CAUSES AND CONSEQUENCES FOR THE PORT

This appendix is about the process of defining the uncertainty and development that surrounds a port. It also discussed the causes and consequences that a development or uncertainty may have. Where does it come from, what does it influence, how did it come into existence etc. In Chapter 5, the outcome of the uncertainty research was already reproduced in a top down diagram. Uncertainties and for the completeness of this research for full understanding for the reader, said process is now elaborated.

TOP DOWN UNCERTAINTY ASSESSMENT

The formation of the cloud of uncertainty is by a brainstorm conducting information about actors and processes surrounding port infrastructure

- What influences the cargo flows throughout the world?
- What parties directly participate in the logistics chain?
- What developments in construction and materials apply to port infrastructure?
- Interaction with the public, opinions, laws and regulations
- Global economics and consumption, what are the trends?

The obtained information is gathered in the top down figure on the next page, with different subjects of uncertainty:

FIGURE 34: TOP DOWN UNCERTAINTY APPROACH (NEXT PAGE)
Effects:

- Less coal and oil, more LNG, biomass or solarpower.
- 1st step of processing raw materials closer to source.
- Less import and processing fossil fuels
- More electrical equipment, slow steaming

- More export to Asia, Brazil.
- Possible trade war US-China
- Import semi-finished products/chemicals
- High quality European made products

- Take-up amount
- Change to other import ports
- Type of transhipment goods

- Change of energy source
- Change of production processes

- Sustainability awareness
- Increasing safety levels
- Sea level rise
- Change of river water level

- More computerization
- Highly educated employees required
- Diminishing labour force
- Unemployment

- Shippers or terminal operators move to other ports
- Increase availability
- Increase flexibility
- Broaden portfolio of capabilities

- Possible building in subsoil
- Energy market
- Type of terminal
- Type of ships

- Amount of movements/yr
- Heavier cranes
- More equipment
- Reliability on the destination of the terminal
- Switching costs → oil refineries or computerized container terminals are very expensive to build and won’t likely move.

- Slow steaming
- Amount of calls/yr
- Dimensions of ships
- Questionable loyalty shippers and terminal operators

- Higher demand of materials in Asia
- Steelprice rising
- More use of composites, other build techniques
- Different type of constructions and lifetimes.

- Stakeholders can slow procedures down
- Hindrance in the surroundings
- Is this location useful for other purposes?
- Public opinion about PoR can win/loose clients
Note that a clear distinction between the different angles of uncertainty is not possible. Most happenings are a chain of reactions and impacts and share common ground with one or more other subjects. This top down model is a distinction to keep different aspects conveniently arranged. The first distinction is made between direct and indirect processes for the port. The change in cargo for instance is directly linked to the port infrastructure, whereas the changes of economic balance don’t have a direct link to the infrastructure itself, but do have serious consequences for the port throughput. For the Program of Requirements, the ultimate result are all effects brought down to a number of physical changes for the infrastructure, these changes can then precautionary be incorporated in the requirements. Below the division of direct and indirect angels of uncertainty:

![Diagram](image)

**FIGURE 35: DIRECT AND INDIRECT EFFECTS**

Up next are these angles of uncertainty treated.

**ENERGY MARKET.**

In this thesis the energy market is the collective term for the production, transportation, storage and throughput of materials to gain energy. On the one hand fossil fuels, such as coal, crude oil and LNG, on the other hand sustainable energy sources as solar, wind or biomass power.

Fossil energy is getting more expensive and the reserves are limited. The search and implementation for alternative energy has enormous consequences for the throughput of oil and gas and the usage of land. Naturally this is an interaction. The price of fossil fuels has consequences for the development of sustainable energy sources.

Countries all over the world have higher demands for fuel every day. With the economic boom of China and India, the demand from the East is increasing significantly.

The public awareness about the sources of energy is growing. This already has impacts on the energy market. The Dutch Parliament for instance is already discussing the closing of coal power plants, mainly because the emission of carbon dioxides. However, since the Fukushima disaster, the German public opinion about nuclear power has gotten worse and this boosted the production of fossil power plants. In two scenarios the demand of coal will increase in the future, as alternative for oil, when the price of oil increases drastically or in the global economy scenario, where the global demand of energy rises.
Also, technological advancement can steer energy production two ways: on the one hand, new techniques and possibilities to retrieve fuels from places that were not possible or economically advantageous before. On top of that, filtration of exhaust gasses or CO2 capture and storage (CCS) can improve, in a way that fossil powered plants will be less pollutant. On the other hand, alternative energy sources can become more effective.

One thing is certain. Fossil fuel reserves are limited and sooner or later other sources of energy are necessary, changing the throughput in this port.

+ Technological possibilities increase.
- Public opinion on fossil fuels.
- Energy is getting more expensive resulting in less transportation of raw materials. Less bulk, more general cargo.
- Import is getting more expensive
- Shipping routines can change, slow steaming for instance, resulting in less calls per year but larger ships.

### TYPES OF CARGO

The type of transshipment goods depends, again, highly on the energy market. The economic balance is leading factor in the amount of import and export. With increasing computerization, terminal capacity increases, enabling the terminal to handle more throughput.

The increase in diversity of mineral oil products is also reason to invest in more flexibility in storage.

Coal is already discussed as uncertainty. It can be divided into two groups, cokes (used for steel production) and coal for power plants. The cokes throughput is directly linked to the steel production in NW Europe. As a fossil fuel, coal will keep on playing an important role, especially with higher oil prices and the development of CCS. Biomass is directly linked to the usage of coal for power plants, as it is mixed with coal. Less oil, means more coal and more biomass.

Container transport is the market, where growth is expected, no matter what future economic scenario will occur. As already said, Rotterdam has the advantage of deep water.

The LNG market is growing as well. Shell is almost done with the build of a massive floating LNG production platform (Velzen, 2013), which is a sign that LNG does have a significant future. However, although this trend of growth, totally unexpected events that effect and change LNG throughput occur, such as the Fukushima disaster. As an alternative for a power source, Japan purchased large quantities of LNG, causing significant less throughput in Rotterdam (Totaaltrans, 2013)

### TERMINAL OPERATORS

Each type of cargo has due to years of improvement and working on efficiency largely the same routines and equipment. Still, terminal operators individually have their own routines, amount and size of the used handling equipment. This is also related to the annual throughput and the size of the ships.

The focus so far has been on changes that are reactions on external changes. The terminal operator itself is also looking for ways of innovation and improvement. A container terminal for instance can buy half way in its contract with the port, a new crane that is able to handle more containers / hour.
A trend is visible from iron ore to processed steel, the already mentioned “brammen”. Maybe, the now unused Brammen Terminal can become successful after all?

SHIPPING COMPANIES

The major uncertainty for the shipping companies is the developments in ship sizes. The most used example is off course the enormous increase of the size of containerships.

With the ongoing increase of size, Rotterdam will fortify its position as a hub or main port.

This statement is backed by the sudden increase of bulk carriers that are calling for PoR after years of having reached a certain limit. Bigger vessels, intended to transport iron ore to China are now deployed on the Brazil – Rotterdam route. This is done since China can’t produce enough depth in its harbor basins. Therefore, these larger ships are now destined for Rotterdam.

Another development is the formation of two giant alliances in the container shipment. The first is P3, a formation between Maersk, MSC and CMA-CGM and the other is named the G6 containing: APL, Hapag Lloyd, OOCL, Mitsui O.S.K. Lines and Nippon Yusen Kaisha. These formations can change a lot in mutual competition and sailing schedules. It could also mean more massive 18 000 TEU + ships, since shipment on common routes is combined.

HINTERLAND CAPACITY.

By hinterland capacity one can think of the production, the economic power of the hinterland and the capacity of the infrastructure network. A port can be able to handle billions of tons in throughput, when there is little demand in the hinterland, the port capacity means little to nothing, leaving aside transshipment off course.

Again, energy prices are one of the causes for changes in throughput to the hinterland. Higher prices mean less import or import closer to the end destination of the product/material. For both oil products and iron ore, Rotterdam has the advantageous location. The more inland positioned refineries and blast furnaces are the ones that will close the first. The steel production has a worldwide overcapacity, and the prognosis is with decreasing steel demand, the Duisburg furnace is the only one remaining in Northwest Europe.

Another prognosis is the population decline in NW Europe, resulting in less import on the long term.

+ more export.
- Less import, so more competition in the HLH-range. It is important to have and maintain the best hinterland connection.
- More production in Europe, more export, but significantly less import.

INDIRECT.

Up next, the indirect impacts are discussed and translated into direct risks. Indirect processes cause changes that reflect on for instance the type of cargo or volume, which are direct consequences.

ECONOMY

18 Hamburg-Le Havre Range, from North to South: the ports of Hamburg, Bremerhaven, Rotterdam, Antwerp, Zeebrugge and Le Havre
Economic Balance. China, India and Brazil are upcoming economic powers and have increasing demand for energy, raw materials as finished products. Outsourcing by Western companies is getting less beneficial and more production in Europe can be a consequence.

+ Export of European high quality products.
  - Increasing price of raw materials, less throughput of raw materials.
  - Import is getting more expensive.
  - Terminal productivity decreases.

EXTERNAL INTERFERENCE

By external, one can think of all kinds of interferences that are not directly related to the chain of transport, but can change it. Again the connection can be made to the energy market. Public opinion can change emission laws or even for the closure of power plants or oil refineries. There is also a chance that with stricter environmental laws in the Netherlands / Europe, factories will move to countries in Asia, where environmental laws are much less concerned.

Coal throughput is a topic in almost all topics of uncertainty, but in this topic the effect is limited to closing of German coalmines. Due to the amount of casualties in these mines, most of them are closed by the government. To fulfill the coal demand from the still operational coal power plants, more import of coal is required and this can be an advantage for PoR. Changing opinions on this matter can be reduced to the punctual equilibrium theory\(^{19}\) and shock effects such as New Orleans, Enschede firework factory disaster or Fukushima nuclear power plant disaster. This shock effect creates a whole new point of equilibrium to a certain process of situation.

Also nature can cause problems in the future. The weather conditions are getting extreme, resulting in fiercer storms and longer periods of drought with lower water levels in the rivers and canals connecting the port with the hinterland. Another effect is sea level rise. This can for instance require higher quay walls and higher cranes, but also a higher water level at the river mouth. This can become a problem with bridge passings etc. for inland shipping.

Political changes in Europe can have large effect on the throughput to Europe. Worst case scenario is a collapsing EU and decreasing economic power and nationalization of all the European countries.

+ Export.
  - Less fossil fuels.
  - Less throughput to European hinterland.

LABOR MARKET

Computerization of production and transport processes require different professions in the port area. An already existing problem in the labor market is the decrease in available practical experience. Cutbacks in technical personnel and retirement are the main causes.

For the future jobs, highly educated IT related jobs will be a significant part of the jobs in the port.

Directly, this will not have a noticeable impact on the infrastructure itself. More likely, the changing of infrastructure will have effect on the jobs, not the other way around.

\(^{19}\) Punctual equilibrium means that everything has a certain equilibrium position around which it remains.
COMPETITION

With increasing competition, it is important as PoR to be the number 1 port of call. The connections to the hinterland must be the best and fastest. Therefore it is important to have the best facilities and up to date infrastructure.

In negative economic prognosis's, for oil throughput for instance, the Port of Rotterdam has an advantage with its near shore location for the refineries. The stand-alone inland refineries are the ones that receive the heaviest blow of decreasing throughput. The Rotterdam area refineries have to shift their focus more on the export market. Laws and regulation can weaken or improve the competitive position.

PoR's location is also a big advantage in the container trade. At the point of writing, more than 100 container vessels have a capacity of over 13 000 TEU (Wikipedia, 2013) and Rotterdam is located at deep water, being able to receive these colossus at all time.

Surrounding ports are aiming at the short sea lines and the RoRo market. The rail and waterway connections to the hinterland are very good for PoR, however, the road network is often congested in the port area, reducing its position compared to the competition.

- Export.
- More oil processing in Rotterdam in terms of percentage.
- Less consuming by hinterland means more competition.

9.9.1.1

CHANGE IN CONSTRUCTION MATERIALS.

Steel is getting more expensive and alternatives as composites are gaining terrain. Composites have promising signs, but require new ways of calculating strength and safety.

In the mind of most Civil Engineers, there are three types of material: steel, concrete and wood. Guidelines and safety norms need to be adapted in order to utilize composites.

Another development from the last years gaining territory is 3D-printing. It it already fully functioning for small items, but maybe in the future complete vehicles or buildings can be printed.

Note that this is not really essential for the future purpose for infrastructure and is more a development that the contractors have to address.

SURROUNDINGS.

The location of the plot or terminal is a determining factor what can and what cannot be done at that location. The storage space and possible room to expand behind the quay wall is determining the max amount of throughput that can be handled. Other thresholds are crossing infrastructure. A bridge determines the maximum height of a passing ships or width should it concern a movable bridge. Immersed tunnels form a threshold (literally) on the bottom for the draught, the same applies to locks. Thus in short, the space for the terminal can be enormous, the quay wall depth 25 meters, if a lock, bridge or tunnel limits the size of the passing vessel dramatically, that large terminal won't be able to receive the ocean going vessels that are standard today.
Hindrance contours also can be a possible limitation on the alternatives of a certain location. An ore terminal close to residential area or an LNG terminal for that matter is not an option. Should the plot of this example need another function, certain functions cannot be considered.

Surrounding stakeholders can slow procedures down and on top of that with the modern communication technology, everybody wants to have a word or an opinion about something.

The public opinion about a company is very important. It can make or break that company.

CONCLUSION:

When concluding the expectations of the different cargo flows, the following stands out:

- Less throughput of raw materials and more semi-finished products → multipurpose cargo
- Crude oil throughput will reduce
- More throughput of mineral oil products, biomass and steel
- Unless the global economy doesn’t recover, LNG will increase
- More chemical products
- Increase of container transport.

However, these aren’t conclusions that directly change the requirements of the infrastructure. All elaborated uncertainty above can be summarized into the following direct impacts causing changes on port infrastructure: Interesting is that most results or consequences due to uncertainty converge into a small number of direct effects on port infrastructure. At least, the ones that are relevant for this thesis, which objective is finding additions for the formulation of the Program of Requirements in order to make it more future-proof.
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<th>Direct effects:</th>
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<td></td>
<td>• Less coal and oil, more LNG, biomass or solarpower.</td>
<td>Throughput volume</td>
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<td></td>
<td>• 1st step of processing raw materials closer to source.</td>
<td>Type of cargo</td>
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<td>• Less import and processing fossil fuels</td>
<td>Terminal capacity</td>
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<td>• More electrical equipment, slow steaming</td>
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<td>• More export to Asia, Brazil.</td>
<td>Throughput volume</td>
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<td></td>
<td>• Possible trade war US-China</td>
<td>Type of cargo</td>
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<tr>
<td></td>
<td>• Import semi-finished products/ chemicals</td>
<td>Terminal operations → operators</td>
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<td></td>
<td>• High quality European mode products</td>
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<td>Import / export volume</td>
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<th>External interference and demands</th>
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<td>• More computerization</td>
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<td>• Unemployment</td>
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<td>• Shippers or terminal operators move to other ports</td>
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<td>• Increase availability</td>
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<td>• Increase flexibility</td>
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<td>• Broden portfolio of capabilities</td>
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<th>Competition</th>
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<td>• Type of terminal</td>
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<td>• Type of ships</td>
<td>Type of cargo</td>
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<tr>
<th>Type of cargo</th>
<th>Development and results:</th>
<th>Direct effects:</th>
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<tr>
<td></td>
<td>• Amount of movements/hr</td>
<td>Terminal capacity</td>
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<td></td>
<td>• Heavier cranes</td>
<td>Forces on quay wall and platform</td>
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<td>• More equipment</td>
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<td>• Reliability on the destination of the terminal</td>
<td>Shipping companies</td>
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<td>• Switching costs → oil refineries or computerized container terminals are very expensive to build and won’t likely move.</td>
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<th>Terminal operators</th>
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<td>• Slow steaming</td>
<td>Forces on quay wall</td>
</tr>
<tr>
<td></td>
<td>• Amount of calls/yr</td>
<td>Terminal capacity</td>
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<tr>
<td></td>
<td>• Dimensions of ships</td>
<td>Required depth and width waterways</td>
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<td>• Questionable loyalty shippers and terminal operators</td>
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<tr>
<th>Shipping companies</th>
<th>Development and results:</th>
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<td></td>
<td>• Higher demand of materials in Asia</td>
<td>Flexibility incorporation</td>
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<td>• Steelprice rising</td>
<td>Type of cargo</td>
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<td>• More use of composites, other build techniques</td>
<td>Throughput volume</td>
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<td>• Different type of constructions and lifetimes.</td>
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<th>Change in construction materials</th>
<th>Development and results:</th>
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<td>• Stakeholders can slow procedures down</td>
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<td>• Hindrance in the surroundings</td>
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<td>• Is this location useful for other purposes?</td>
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<td></td>
<td>• Public opinion about PoR can win/loose clients</td>
<td>Alternative value</td>
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<th>Surroundings</th>
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<td>Terminal capacity</td>
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<td>• Location of the plot</td>
<td>Type of cargo</td>
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<td></td>
<td>• Strategic surroundings management</td>
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<td>• Image PoR</td>
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The top down approach on the last page was filled in with the direct effects that could cause problem for the functionality of the infrastructure. Summarizing, all uncertainty can be brought down to the following relevant effects:

- Type of cargo
- Cargo volume
- Type of ships
- Number of calls per terminal
- Terminal equipment
- Required services by PoR
- Laws and regulations

The next step in the process is making these impacts even more abstract into physical changes on the port infrastructure that are necessary for the infrastructure to maintain its (level of) functionality. These are:

- Mooring Forces
- Mooring Configuration
- Terminal capacity: Storage / handling area, number of berths
- Vertical forces on the quay wall / jetty: Cranes, other handling equipment such as trains of carriers.
- Hinterland connections
- Required space around the terminal (hindrance / safety contours)

These physical changes form the margins that, if relevant, need to be taken into account when formulating the Program of Requirements. What risks are there, what is the probability and the physical impact and what specification can limit this?
E. CROSS SECTIONECT CITY TERMINAL QUAY WALL
SOUTHSIDE
F. LIST OF DEFINITIONS

Actor: A party having influence on the project or requirements for the project

Anticipative measure: (Also: precaution) Adapting a requirement such that it is suitable for the causing change.

Asset: A component of a facility with an independent physical and functional identity and age (quay wall, channel section, fender etc.)

Best Value Procurement: Procurement focusing on quality. Via interviews the contractor can show its capabilities with more design liberties, the employer states less requirements.

Bottlenecks: Restrictions that cause delay or limitations in a process

Bollard: Mooring device to fix mooring lines

Business Case: A decision tool for a project or a plan, which include a cash flow projection. It addresses the question what the expected benefits are and whether these are worth the required investment given a certain rate of return.

Client: The company for whom the infrastructure project is executed, mostly the terminal operator in the case of port infrastructure. Also used in this thesis: customer

Concession: Public authorities use concession contracts to engage private firms to supply services or to perform works. (European Parliament, 2013)

Contractor: The party whose proposal has been accepted by the Employer and who is responsible for the realization of the infrastructure project (Ridder & Noppen, 2009).

D&B contract: Design & Build (Also Design & Construct [D&C]) The contractor is responsible for the design and the execution of an infrastructure project. The client buys a solution. (Ridder & Noppen, 2009)

DBFM(O) contract: Design, Build, Finance, Maintain and (Operate). Procurement procedures with the contractor. Expansions of the D&B contract including:

Finance: The contractor is also responsible for financing the project
Maintain: The contractor is also responsible for maintenance during the timespan of the project
Operate: The contractor is responsible for operating the project.
(Ridder & Noppen, 2009)

DUT: Delft University of Technology

Early Contractor Involvement: Involving the contractor and his knowledge earlier in the design process of large unknown projects to increase the quality of the solution.
Efficiency rate: Benefit / Return. This must exceed a certain rate for a project to make it profitable

EMAT: Economic Most Advantageous Tender (EMVI in Dutch)

Employer: The party who receives and accepts the tender and who is responsible for the site and paying the contractor. (Ridder & Noppen, 2009)

Flexibility: The ability to respond to changes. Can be used interchangeably with adaptability.

Flexible infrastructure: Infrastructure that allows changes to the structure along with changing requirements

Functionality: The effectiveness of the infrastructure in fulfilling its purpose

Future-Proof: Sustainable, able to maintain functionality during a longer unknown time in the future

Gantry Crane: Cranes that lift objects with a hoist that can be moved horizontally along the crane beam.

Hub: A junction where multiple trade lines end/begin

Infrastructure project: The preparation, design and build of a part of infrastructure.

Innovation: Development or delivery of a new or significantly improved product, process or service, or a new organizational method in business practice. Innovation can be linked to performance and growth through improvements in efficiency, productivity, quality, response times, competitive positioning and flexibility. (Departement of Enterprise, Trade and Employment, Ireland)

Jetty: (un)loading platform on piles extended into the water until the required mooring depth, connected to the shore via a walkway.

Kraljic Portfolio: Categorizes products (in this case infrastructure) according to financial impact and supply risks

Mooring: (un)load

NPV: Cash balance of costs and benefits that compares the present value of money today to the present value of money in the future, taking inflation and returns into account.

Plan of action: Document describing the design and construction of the proposed solution with a planning and budget

Port infrastructure project: A project concerning port infrastructure.

Port Infrastructure: Port related infrastructure such as waterways, quay walls, fenders, etc.

Port of Rotterdam (PoR): Port area of Rotterdam, a privatized company, publicly traded with the government as only shareholder. The port authority operates the port as a landlord model.
PPP: Public Private Partnership. Joint business venture between authorities and economic operators

Procurement: Announcement of the works and the public/restricted invitation for contractors to respond with a price and plan of action

Program of Requirements: A complete document of all demands and requirements that the solution must fulfil.

Public Procurement: Projects ordered by the government.

Quay Wall: Hard boundary between land and water. Foundation for gantry cranes and mooring equipment.

Reefer: Refrigerated container, also used for refrigerated transport

Risk Portfolio: A compilation of all risks pointed out surrounding a certain project

Risk: The chance something (undesirable) happens times the consequences this event will have.

Robust: Over-dimensioning as strategy to be prepared for uncertainties in the future

Tendering: Competitive method of procurement, taking price and quality in consideration for the most suited offer

Terminal: Area where interchanging of cargo from ship to hinterland happens.

Traditional contract: The client sets out the conditions and design, the contractor executes this. Result-based (Dutch: RAW-bestek: Rationalisatie en Automatisering Grond-, Water- en Wegenbouw.) or performance-based.

Uncertainty: Any deviation from the ideal intended situation by the real situation. The main difference between a risk and an uncertainty is that the probability of occurrence is unknown with uncertainty

Works An order for the realization or design and realization for a project in the construction industry.