INTEGRATED SUSTAINABLE PORT DESIGN

FRAMEWORK DEVELOPMENT PORT MASTERPLAN

MSC THESIS – PUBLIC VERSION

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By

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PREFACE

This document is proposed in partial fulfillment of the requirements for the degree of MSc. Civil Engineering at Delft University of Technology and the National University of Singapore. The research was performed in cooperation with the Maritime department of Royal HaskoningDHV in Dubai. This document is the end product of my research to develop a sustainable port masterplanning framework in order to obtain a sustainable port.

I see sustainable port development as an enormous and complex jigsaw puzzle. This puzzle is far from finished, but little by little the puzzle pieces are fitting together. A puzzle piece could represent e.g. more knowledge of coastal processes, integration of the location choice in the overall design process, early and transparent stakeholder involvement, awareness of sustainable measures and their benefits, etc. I see this document as a puzzle piece as well; it may not complete the puzzle, but it contributes to the completion of the bigger jigsaw puzzle. In order to complete it, i.e. to have a fully implemented sustainable port development resulting in a sustainable port, all these puzzle pieces need to be integrated into one complex puzzle. I hope this document will give you this key message.

This document is the public version of my research. During the research, I have employed many literature of Royal HaskoningDHV. Due to confidentiality reason, this literature which is referred to throughout the report, cannot be used for confirmation by public.

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Finally, I owe a special word of thanks to the maritime department of RHDHV in Dubai for providing me the opportunity to perform this research in a professional environment. They gave me a great experience in Dubai, by welcoming me and providing support when needed despite their busy schedules. To be more specific I would like to thank Nigel Easterbrook, Brad Froyland and Patrick Paragua for sharing their port planning knowledge with me in interesting conversations and for showing me 'the good life' of Dubai. In addition, special thanks to Maggie Morris and Lilian Orias for their daily conversations and moral support in Dubai.
Lastly I am grateful to my family and friends, who supported me throughout the research, in particular, Zhenja Zheng for her amazing last minute coloring skills.

Zhen Zhen Zheng
Delft, September 2015

EXECUTIVE SUMMARY

Ports have evolved into an essential part of a nation's economy [Schipper et al., 2015]. In order to obtain economic growth and prevent loss of trade and competitive position, the worldwide growth in port development will not stop [PIANC 2014a]. At present the port development process typically results in environmental mitigation and/or harm. This translates into a need for integrated sustainable port master planning [PIANC, 2011].

The aim of this research is to develop a practical tool for sustainable port masterplanning in the form of a framework which can be employed by the port planner in order to systematically guide him/her towards a sustainable port. Developing this framework requires knowledge of the traditional planning process and its missing elements, a clear understanding of what exactly defines a sustainable port and how this port can be obtained through a sustainable process, and various existing knowledge about sustainability of ports through the means of existing sustainable philosophies and well-known global maritime organizations. Case studies can be used for the purpose of enhancing and testing the degree of applicability of the framework.

To start with, the question should be asked: *Why does traditional port planning result in environmental harm/mitigation, and hence does not result in a sustainable port?* By analysing the traditional port process, it shows that its main objectives aim to integrate the economic, environmental, safety, technical and social aspects and consider enough flexibility to support the long term development. It therefore would be expected that the traditional approach would not result in environmental harm. However somewhere along the process, several elements are missing which limits the achievement of these main objectives. It turns out that in general the port authority selects the port location and an engineering company is responsible for the design process on that specific location [Schipper et al., 2015]. Here it can be found why the main objectives of the traditional approach are not obtained in the end: although the traditional process indeed considers all relevant disciplines, the party responsible for the location selection does not base its choice on the same disciplines and therefore disciplines such as the environment, will only be considered after the location is selected. If the traditional process does not have the most suitable location for sustainability as starting point, it perhaps inevitably will result in environmental harm from the start. Clearly a new sustainable framework is needed that includes the location choice in the design process, so all the disciplines can already be considered early during the location choice.

Developing a sustainable framework requires a clear understanding of a *sustainable port* and a *sustainable port masterplanning process* towards this port. The issue encountered with the existing definitions, is that both definitions are intertwined and no clear distinction is made which characteristics belong to *the sustainable process* and the resulting *sustainable port*. *A sustainable port* has obtained and maintains a balance of the economy, environment and society now and in the future, where it also anticipates and considers the needs of future generations, besides their own benefit and the prosperity of the surrounding regions. Furthermore, the definition of *a sustainable process* can be characterized by the following process ambitions: the location choice as part of the design process, the consideration and search of the multiple perspectives balance of the interlinked economy, environment and society in an early stage, active and early stakeholder involvement, consideration of long term uncertainties and a continuous learning process.

I propose a framework including all the characteristics of a sustainable port planning process which unlike the traditional process, already integrates the significant important location selection in the design process to develop a sustainable port: Integrated Sustainable Port Design (ISPD). The ISPD framework is focused on system level and is aiming to find sustainable opportunities while socio-economic values are created as well. This can be achieved by considering and integrating the physical, environmental, governmental and socio-economic disciplines in order to find the most suitable location for these opportunities. With the consideration of long term uncertainties and the help of stakeholder involvement, it provides a framework for the port planner to achieve and maintain a balance of the economy, environment and society now and in the future, resulting in a sustainable and future-proof port. The ISPD framework adopts relevant aspects from existing sustainable philosophies (such as Building with Nature) and fills in the missing aspects of the traditional framework. From start to finish, this framework follows seven basic steps: (1) Define the project needs and objectives, (2) Find physical suitable locations, (3) Understand the systems and select most suitable locations, (4) Develop alternative designs based on key values, (5)Test the alternatives, (6) Evaluate the qualities of each alternative and (7) Create the final design.

Three real life case studies have been used for the enhancement of the ISPD framework: the Jebel Ali New Container Terminal (Dubai), the Badagry Port Project (Nigeria) and the New Doha Port (Qatar). Their port planning processes and resulting masterplans were analysed, to discover the extent of influence of the planning process on the sustainability of the masterplan. These cases dealt with critical challenges such as limited expansion area due to bad masterplanning of surrounding projects and coastal erosion. Besides the encountered limitations in practice, they also provided several good examples of sustainable planning measures. These learned lessons were used to enhance the framework for better implementation in practice.

The degree of applicability of the ISPD framework was investigated through the application on the Badagry Port Project, which was selected as most suitable to serve this purpose. The illustrative case was designed to follow all seven basic steps of the framework and to discover which (dis)advantages will be encountered along the way. The most significant issue which was encountered is the general thought that sustainable measures require higher costs and bring along more risks than traditional measures. Therefore they require more research, and thus more time and money than traditional measures. These limitations however will always be present in real life and hence should be dealt with in this research as well. For example the important initial location choice, it is up to the port planner to decide if he/she wants to take the risk of possible resistance and limitations of the location on the port design and operation resulting from a rather incomplete initial research, or if the port planner decides to consider this uncertainty by investing more time and money in the research for the most suitable location. It is the responsibility of the port planner to make grounded decisions and the port planner, besides the environmental benefits, should convince the client of the socio-economic benefits of sustainable measures as well. Furthermore, other limitations of the case study were the limited data available of other locations and limitations set by RHDHV. In order to continue the ISPD despite these limitations, the location system of Badagry was analysed and the values, opportunities and challenges of Badagry were specified. The values were prioritized into key values and possible sustainable planning measures were developed. Systematically and focused alternative development based on these key values and planning measures, is a significant advantage of the ISPD framework because less optimization may be necessary in later stages. Three alternatives were developed and after testing and evaluating them, one final alternative masterplan layout is recommended. Since this research does not cover the more detailed design on construction and material level, the final step is not executed.

In the evaluation, the resulting ISPD masterplan is compared with the existing Badagry Port Project masterplan based on predefined criteria which represent the main environmental issues currently resulting from port projects. Despite the limitations of the evaluation, such as the inability to discuss several criteria due to a lack of more detailed level design, subjectivity and exclusion of socio-economic aspects and a quantitative evaluation method, it turns out that the ISPD masterplan shows less negative and more positive impacts concerning these environmental criteria and hence this masterplan can be considered more sustainable than the existing masterplan resulting from a traditional process. A very rough cost analysis is also performed and it shows that based on only the large investments, the costs of the ISPD and existing masterplan are approximately from the same order of magnitude. Finally the application of the ISPD framework itself is evaluated: it shows that the extent of successful implementation of the ISPD framework in practice depends on mainly the port planner, the available capital and time for the project, the client, category of port, global and local context and the proof of feasibility and benefits of sustainable measures. The lessons learned from the evaluations are used to finalize the ISPD framework in the form of an ISPD user guide.

Concluding this research, the Integrated Sustainable Port Design framework can be successfully implemented in practice and despite the presence of limitations, the framework results in a more sustainable port masterplan. Although there are many recommendations for further development, great potential is expected for the application of the ISPD framework in the future.

LIST OF ABBREVIATIONS

APP	Adaptive Port Planning
BCD	Badagry Chart Datum
BPDL	Badagry Port Development Limited
BPP	Badagry Port Project
BwN	Building with Nature
CD	Chart Datum
DEWA	Dubai Electricity and Water Authority
DPW	Dubai Ports World
Dubal	Dubai Aluminum
DUGAS	Dubai Natural Gas Co. Ltd.
EBM	Ecosystem-based management
EIA	Environmental Impact Assessment
ESIA	Environmental and Social Impact Assessment
ESPO	European Sea Port Organization
EWN	Engineering With Nature
GC	General Cargo
GSC	Geotextile Sand Containers
H_{m0}	Significant Wave Height
ISPS	International Ship and Port Facility Security Code
JANCT	Jebel Ali New Container Terminal
LCD	Lagos Chart Datum
LCDA	Local Council Development Area
LNG	Liquefied Natural Gas
MCA	Multi Criteria Analysis
MoE	Ministry of Environment
NDP	New Doha Port
NDPP-SC	New Doha Port Project Steering Committee
NGO	Non-governmental organization
NOC	No Objection Certificate
PIANC	Permanent International Association of Navigation Congresses
PPIAF	The Public-Private Infrastructure Advisory Facility
PPRGM	Public Participation Representative Group Meeting
QENFB	Qatar Emiri Naval Forces Base
QEZ3	Qatar Economic Zone 3
RAS	Recirculating aquaculture systems
RHDHV	Royal HaskoningDHV
SCBA	Social Cost/Benefit Analysis
SDM	Self Diagnosis Method
T_p	Peak Period
UNEP	United Nations Environment Programme
USACE	U.S. Army Corps of Engineers
WWF	The World Wide Fund for Nature
WwN	Working with Nature

CONTENTS

1 INTRODUCTION

1.1 Problem description

Ports have evolved into an essential part of a nation's economy [Schipper et al., 2015]. Growing trends such as the increase in world population, the resulting global trade growth, the increase in vessel sizes, and the need for modernization of existing ports, require essential investments in ports [PIANC 2014]. Not keeping up with this growth will result in loss of trade and competitive position, and hence worldwide growth in port development will not stop. At present the port development process – regardless how well it is implemented – typically results in environmental mitigation and/or harm and hence cannot be regarded as sustainable. Since environmental impacts also affect the economic and social welfare, there is a need and motivation for integrated sustainable port master planning which focuses on a win-win opportunities, rather than merely minimizing environmental loss [PIANC, 2011].

The current major obstacles in the traditional port master planning process are: scarcity in prime locations and (sustainable) expansion, increase in environmental constraints, and uncertain impacts resulting from climate and technological change [Schipper et al., 2015]. These obstacles might be caused by the fact that in general, in traditional port development the location selection and design process are performed by different parties. This disconnection often results in issues in later stages, because these two aspects are closely interlinked and have a significant influence on port operations [Schipper et al., 2015]. In order to solve these challenges port development needs to, first of all, integrate the location selection in the overall planning and design process. Since the location is the initial basis for a port which determines the physical limitations for the design and operations, it is of significant importance to select the most favorable location. In order to achieve this, research is required not only from a technical and economic perspective like in the traditional process, but a full understanding of the most favorable location can only be achieved by integrating all the disciplines in this process. Port masterplanning needs to fully integrate the technical, physical, environmental, governmental and socio-economic disciplines in one framework [Cork et al., 2014]: this will be the base for the Integrated Sustainable Port Design (ISPD) framework. Furthermore, existing sustainable philosophies have already been set up. These existing philosophies already provide proof of the benefits of sustainable measures, nevertheless these philosophies are still not fully implemented in practice yet. Hence besides developing a new sustainable port masterplanning framework, the main motivation of this research will also be to create a user-friendly guide for a port developer in the form of a flowchart to make the framework more applicable in practice. The application of the ISPD framework can result in innovative solutions and creating more value for the economy, environment and society. To achieve this, a thorough comprehension of the system as a whole is required: not only from a technical and economic perspective, but also from an environmental and social point of view.

1.2 Scope

The fundamentals of the port industry start with answering the question: "Is *a port needed there?".* It is already mentioned in the previous paragraph that ports negatively impact the local and regional ecosystems. These negative impacts and the benefits resulting from the port need to be considered in order to conclude if the port should be built or not, perhaps resulting in the conclusion where all the negative impacts might be avoided in the first place. Hence from the start, for each case it should be considered if the establishment of a port really is necessary. However the population and (desired) economic growth and their associated growth in demand of products and services inevitably lead to the worldwide necessity for ports. Therefore, once the definite decision is made to build a port, the goal is to reduce these

negative impacts to the utmost degree and possibly change them into benefits. This research is starting from this point. In order to formulate a clear objective, the scope of this research needs to be narrowed down and specified in more detail.

The expected result from this research is in the form of a general port master planning framework for sustainable ports in the port development process. From the general to the more detailed approach, a distinction can be made in the system, construction and material level [Vellinga et al., 2014]. As the goal of this study is to formulate a general framework, it makes sense to focus on the *system level* in this case. This framework focuses on the broad lay-out of a port by specifying and locating the main port elements, supplemented by possible opportunities in the local environment. This master planning will not go into detail concerning terminals. This framework can be applied for both a new port as an expansion of a port.

A masterplan is a document which explains how a port needs to grow and adapt according to the development in maritime transport. Many ports face obstacles in expanding their area and cargo handling facilities due to a lack of long term planning which make further development very difficult. A masterplan aims for the long term, approximately *25 to 30 years*, and preferably includes flexibility for unplanned extensions beyond this time period [Cork et al., 2014]. Hence this study focuses on a *long term* strategy.

In figure **1-A** the general port development cycle adapted from Ligteringen (2012) is illustrated. The process can be divided in the preparation, construction and operation phase. It should be noted that the dismantling & removal phase is not included. This research will focus on the *preparation phase*, from where the framework ideally should be implemented, and specifically the *port planning* and *design phase*. Flexibility is still available in these phases of project development and the results will be maximized.

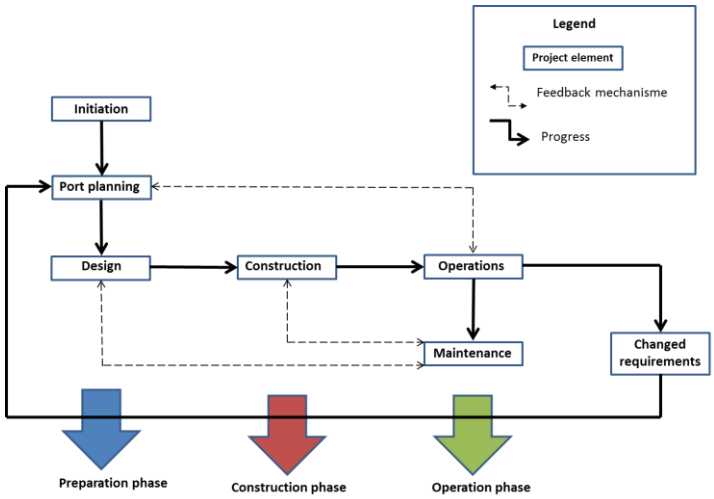


Figure 1-A Port development cycle

The aim in the new framework is to create more value for all involved parties in the port masterplan. Different countries have different values, so a value specification on global level would not be suitable (TEEB, 2010). Although ports have a great influence on both the national and regional economy [The Public-Private Infrastructure Advisory Facility (PPIAF), 2007], in this research mainly the values of the

local stakeholders will be defined, hence the value specification will be on *regiona*l level. If values are defined on a different level, this will be indicated for that specific value.

1.3 Objective

Sustainable port master planning is a broad process and a lot of research is still necessary for the application of the general guidelines of sustainable port development in practice. This research can be seen as one of the multiple puzzle pieces to help and create the final realization of the general guidelines. In other words, the goal of this study is to further develop the concept of sustainable port development and to translate this into specific general guidelines which can be applied on ports in different situations with different boundary conditions. The aim is to have an outcome that clearly shows the benefits of a sustainable port development framework. The main objective of this research can be formulated as follows:

- **Design a general framework for sustainable port master planning and apply this framework on a specific case study to examine, analyze and evaluate its impact.**

It is important to note that this framework is just a helpful guidance for the port planner towards a sustainable port by systematically raising awareness of all important aspects in sustainable port development and it definitely should not be seen as guidelines to strictly adopt. On the contrary, due to multiple restrictions and negotiations in collaborative design and different local situations it might not even be possible to strictly follow the framework. Therefore the involved people are stimulated to further develop the port masterplanning process and make valid decisions in their own freedom.

In order to achieve this primary objective, it can be divided into the following smaller secondary objectives along the process of framework development:

1. *Research the state of the traditional port master planning, its main and missing elements;*
2. *Differentiate between 'the sustainable port master planning process' and 'the sustainable port', and give their definition criteria;*
3. *Study the existing philosophies regarding sustainable port development and the gab to application in practice;*
4. *Set up a new sustainable port masterplan framework and formulate its key guidelines with the attained literature study;*
5. *Enhance the framework by analyzing the masterplanning process of existing ports;*
6. *Apply this framework on a selected case study with an existing masterplan;*
7. *Evaluate the resulting masterplan and the framework and set up recommendations for future use.*

1.4 Methodology & Report structure

To ensure this reader is easy to comprehend for the readers, the method of research is described and the structure of this report is elaborated as well. This research can be divided into four sections: (I) the initial framework based on literature study, (II) the enhanced framework based on practical examples, (III) the case study section and (IV) the evaluation section. All these four sections are required to obtain the main objective of this research and figure **1-B** illustrates a visual representation of this methodology in this order, with the content of each chapter explained below.

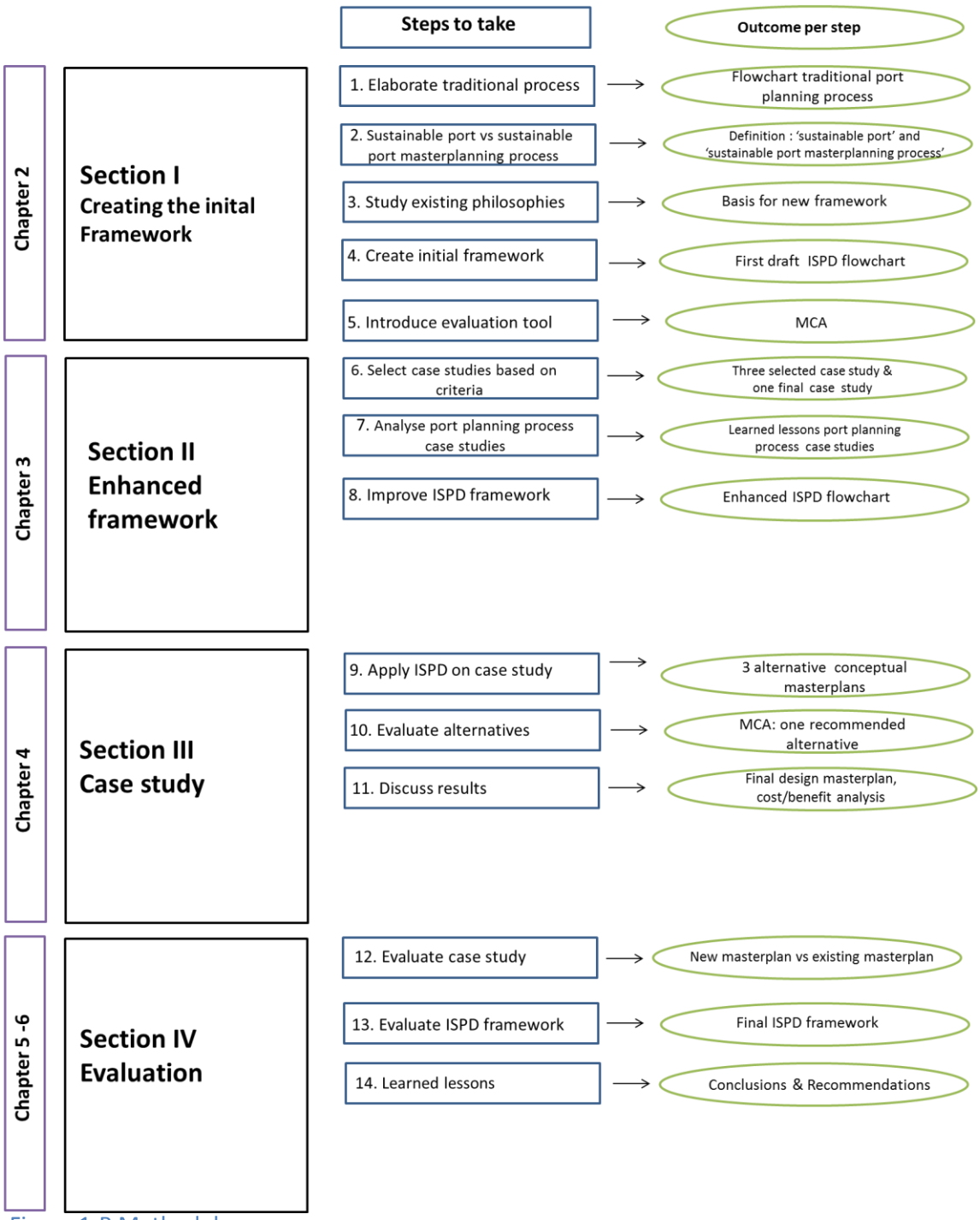


Figure 1-B Methodology

Section I focuses on literature study and here the basis of the Integrated Sustainable Port Design (ISPD) framework is created in the form of an initial framework. Before the sustainable masterplanning is studied, first the problem should be found out why the traditional port master planning process results in environment harm. The questions '*What is the traditional port planning methodology? And what aspects are missing in this traditional approach that it does not result in a sustainable port and where in the process do these aspects need to be implemented?* ' should be answered. Then as the main objective of this research is to develop a sustainable port masterplan framework towards a sustainable port, a clear distinction needs to be made between the *sustainable port masterplanning process* and the result-

ing *sustainable port*. If a clear definition is known of the goal (sustainable port), then it becomes possible to develop a method (sustainable process) to achieve that goal. Hence, their definitions are specified in Chapter **2** after discussing the existing definitions of well-known global maritime organizations. The reason why these organizations are chosen and how their definitions are interpreted by me is indicated in the concerned paragraphs. The chapter continues by studying the relevant aspects of existing sustainable port philosophies and consequently, the initial ISPD framework can be established in the form of a flowchart. In order to evaluate the degree of sustainability of the new masterplan compared with the existing masterplan, the chapter ends with the evaluation methods of three evaluations: the first evaluation is the assessment of the three alternatives resulting from the ISPD framework. The chosen evaluation method is the MCA in order to recommend the most suitable alternative based on predefined evaluation criteria. The second evaluation is performed after one alternative ISPD masterplan is chosen and evaluates if the existing masterplan of the case study or the new ISPD masterplan is more sustainable based on the predefined definition criteria. The last evaluation assesses the degree of applicability of the ISPD framework and will be evaluated by summing up all the (dis)advantages of each step which are encountered during the implementation of the framework on the case study. These evaluations are performed because a framework can only be considered successful if it results in a sustainable port and is applicable in practice. These evaluation methods are explained in paragraph **2.6**.

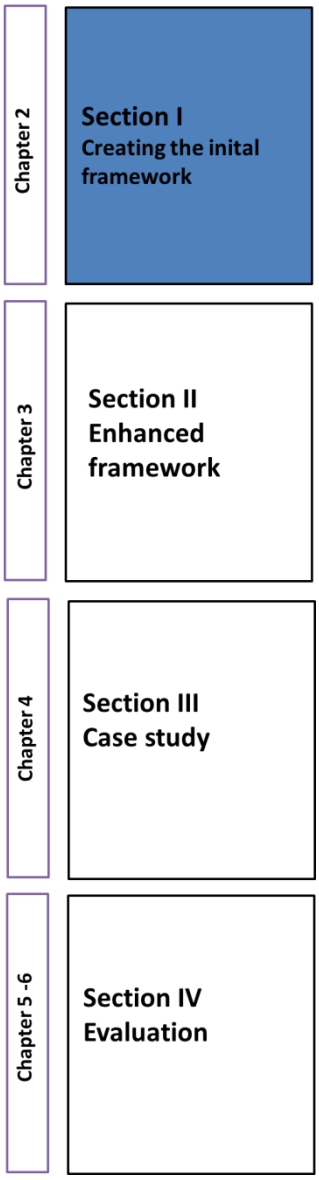
Section II contains the practical part of this research and continuing from section I, the ISPD framework is further enhanced in Chapter **3.** The chapter starts with a selection criteria process to choose the three most suitable ports to enhance the ISPD framework and the most suitable port for the final case study, which are all in the interest of RHDHV. For the former, three ports are selected and by analysing these ports, the following main questions needs to be answered for each port: '*What are the existing masterplan and its main issues? And to what extend are and could these issues be influenced by the existing port planning process compared to the ISPD framework?'* These questions need to be answered because it should be learned what limitations are encountered in real life and thus essentially tests the degree of applicability of the ISPD framework. Lessons learned from these analyses will be used to enhance the initial ISPD framework. The first draft of the ISPD approach will be supplemented, adapted and improved with the information learned in practice. The outcome of this section, is the enhanced version of the Integrated Sustainable Port Design framework.

Section III starts immediately with the implementation of the enhanced sustainable port masterplan framework on the selected case study. The reason to use a case study in this research, is to test the applicability of the ISPD framework on a practical case. And on top of that it also shows if, despite the limitations in real life, ISPD still could result in a more sustainable port than the existing traditional masterplan of the case study. For the case study the same starting conditions and design parameters are assumed as during the time and place of the situation of the existing masterplan. This is necessary in order to have the most accurate comparison between the two masterplans during the evaluation. The main difference is that this research already has immediate access to the RHDHV data base. This on the other hand, can also be considered as a disadvantage since the research is also limited by this available data, as there is no time or money to perform extensive analysis in this research. When data of RHDHV is used, then this will be specifically mentioned in the concerning section. Furthermore, since limitations will always be presents in real life, these will ascend and treated along the case study as well. The ISPD framework starts by defining the needs and objectives of the project and based on the design parameters, several potential locations can be found. These locations will be studied by studying the system as a whole and the opportunities and challenges of the local physical, environmental, governmental and socio-economic environment are pointed out. With the help of stakeholder involvement their values and the opportunities and challenges of each location can be determined and eventually the preferred

location can be chosen. The values of the stakeholders then can be prioritized in the form of key values of this project. Three alternative masterplan lay-outs are developed fulfilling both the basic design parameters and the key values. The feasibility and impact of these alternatives will be elaborated and eventually the alternatives are evaluated by the means of a MCA, resulting in one final design. The outcome of this section is one selected conceptual port masterplan which will not be treated further into more detail because that is outside the scope of this research. This section does include a roughly performed cost analysis of this conceptual masterplan compared to the costs of the existing masterplan of the case study. This is required to give a more quantitative insight in the economic rationales of port development, which might be the convincing reason for the client to stimulate the use of sustainable measures. An explanation of the used tools MCA and stakeholder analysis can be found in respectively paragraph **2.6** and paragraph **4.5**/Appendix **C**.

Section IV elaborates the evaluation of both the final masterplan of the case study and the Integrated Sustainable port design framework in Chapter **5**. Here it concludes whether the new or the existing masterplan is more sustainable based on predefined criteria, and the feasibility and practicability of the sustainable framework is assessed as well in the second evaluation. This second evaluation can be performed by answering the following question: *'What problems were faced during this process and how can they be solved in order to improve the ISPD framework?'*. The lessons learned from this evaluation will be summed up and translated to obtain the final ISPD framework for generic use. Chapter **6** begins with a conclusion of the evaluation of Chapter **5**. This conclusions consists of two parts: conclusions concerning the case study (selection) and conclusions about the development of the ISPD framework and hence the objectives specified in Chapter **1** will be reviewed and answered. Finally recommendations are given for both the development as the implementation of the ISPD framework for suggested further research.

SECTION I CREATING THE INITIAL FRAMEWORK



2 CREATING THE INITIAL FRAMEWORK BASED ON LITERATURE STUDY

2.1 Introduction

In this theoretical part of the research the initial framework of the Integrated Sustainable Port Design (ISPD) process is given form. In general, traditional port masterplanning typically results in environmental mitigation and/or harm [PIANC, 2011]. Hence in order to achieve a sustainable port, this report focuses on the masterplanning process: the main objective of this research is to develop a new sustainable port masterplan framework and to evaluate it by applying the framework on a case study. In order to achieve this, first the problem needs to be specified in paragraph **2.2**, i.e. the traditional port masterplanning process needs to be elaborated and discussed why it results in environmental harm; hence, missing aspects in the traditional process need to be found in order to create a sustainable process. Before a new sustainable framework can be developed, first it is necessary to define what sustainability exactly is. For this a distinction needs to be made between the desired sustainable port and the sustainable port masterplanning process towards this port. Hence, first the definition criteria are given of *the sustainable port* and *the sustainable port masterplanning process* in paragraph **2.3**. The chapter continues with paragraph **2.4** by studying the relevant aspects of existing sustainable port philosophies and by partially adopting their basic guidelines, consequently, the initial ISPD framework can be established in paragraph **2.5**. In order to evaluate the ISPD framework, the chapter ends with paragraph **2.6** where the MCA is introduced as the evaluation tool for the final design selection and the criteria are introduced for the evaluation of the new masterplan with the existing masterplan.

2.2 Traditional port masterplan approach

Before a new sustainable framework is developed, it is necessary to first analyze the traditional design process in order to find out why a sustainable framework is needed and what aspects are currently missing. As is specified in paragraph **1.2**, the scope of this study is focused on the port planning and design phase of the port development process, hence in this section the traditional port planning and design process will be treated in more detail.

A traditional port masterplan indicates in what way port operations could be organised. It does not include a construction plan, but should provide guidelines and policies to oversee the future development of a port and accommodate safe local and international waterborne freight. The most relevant products of a masterplan are the port layout and the description of investment in infrastructure. The main objectives of a port masterplan in general are as follows [Cork et al., 2014]:

- Promote the ‘vision’ for the port by active stakeholder engagement
- Develop the port in line with (inter)national legislation and guidelines
- Combine and integrate economic, environmental, safety and technical aspect in the overall plan
- Support long term development and growth of the port by creating functional port facilities and operational areas
- Allow enough flexibility for the port to react to changing forecasts, technology, regulations and legislation and port competition

The provided main objectives include the environmental and social (stakeholder engagement) disciplines and consider enough flexibility to support the long term development. It therefore would seem that the traditional approach would not result in environmental harm. However somehow the traditional process is not entirely achieving all these main objectives. In order to find out where these objectives are not achieved in the planning and design process, the traditional port masterplan approach will be studied in more detail. The traditional approach can be divided into the following four main elementary design cycle steps [Ligteringen, 2012]:

1. **Analysis** – Data concerning the location and (expected) situation of the port is collected. Forecast are made of the cargo flow and the fleet composition, the environment and safety aspects are studied and physical site data is required as well such as bathymetry, wave conditions, currents and horizontal tide, water levels and vertical tide etc.
2. **Synthesis and Simulation** – With the acquired knowledge of the analysis, several alternative concepts can be created and translated into two to three most favorable alternatives. These alternatives can be tested with the help of simulations.
3. **Evaluation** – After the test results are known of the alternative designs, these alternatives can be compared to each other by the evaluation of specified aspects regarding the designs.
4. **Selection** – With the results of an evaluation method, one masterplan alternative is selected.

With an increasing level of detail, a feedback loop exists between these four steps. This happens after the evaluation, when several rough lay-out concepts are produced and are translated into two to three possible alternatives. With more accurate data, these alternatives can be elaborated into more detail and consequently evaluation and selection will take place again. After the most desired masterplan is selected, the elementary design cycle is followed by the fifth step:

5. **Finalisation** – By selecting the most desired masterplan, the general objective is fixed as well as the direction of solution. The selected design however still needs to be optimized concerning nautical, hydraulic, financial and environmental aspects. This can be done with detailed site investigations.

Figure **2-A** below shows the flowchart of the traditional masterplanning process.

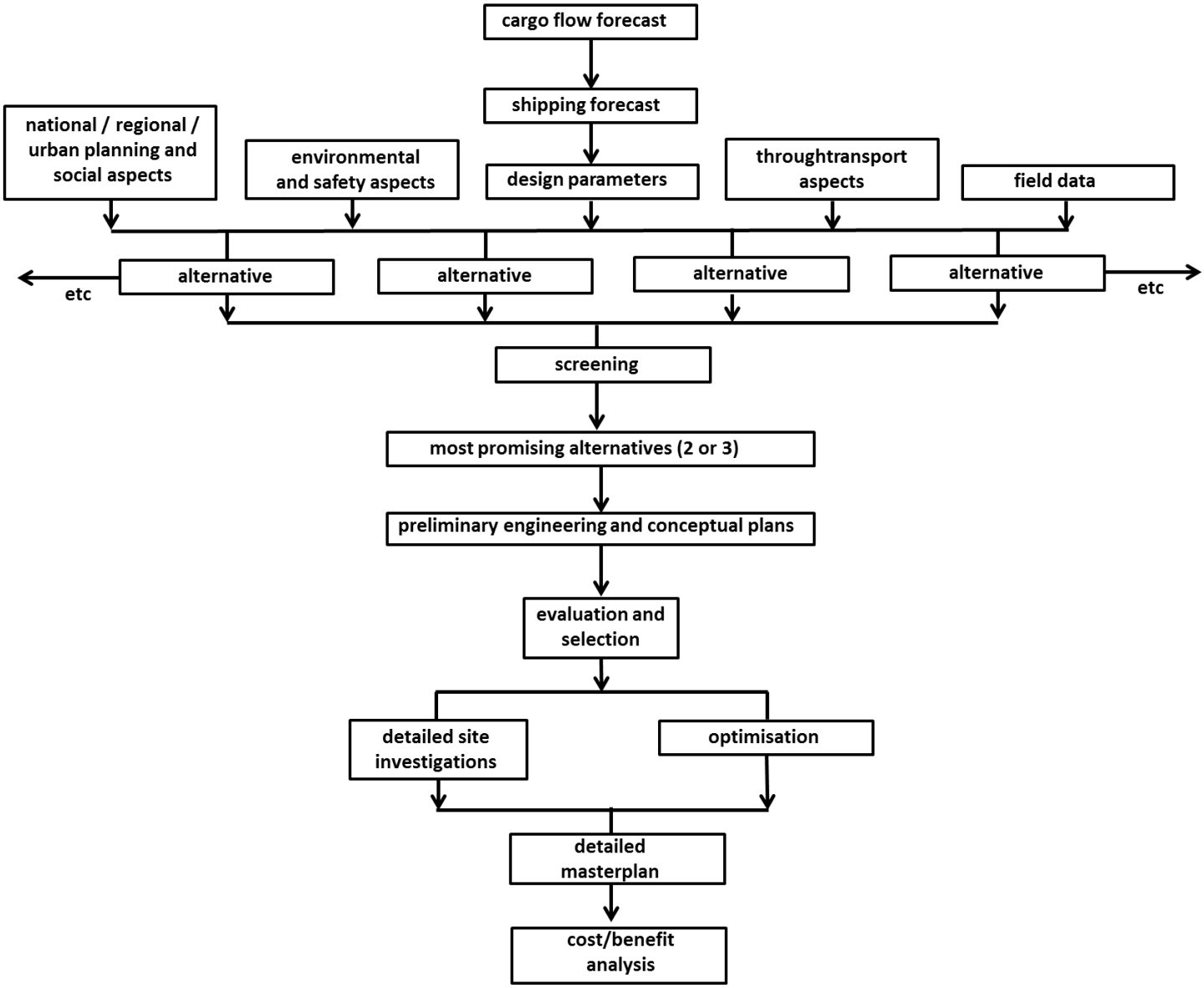


Figure 2-A Flowchart traditional framework [adopted from Ligteringen, 2012]

What can be seen immediately is that there is no location selection in the traditional design process. To be more specific, the traditional port development often does not consider location as a variable but it is often the starting point. In general the port authority selects the port location and an engineering company is responsible for the design process on that specific location [Schipper et al., 2015]. However the party who is responsible for the location might base its choice on different values than the party responsible for the port design: for example if the main goal of port authorities is to obtain high economic benefits from the port, then this can be supported by selecting a port location with excellent hinterland connectivity. The port authority however may not consider the negative (environmental) consequences of port operation on this location, which is taken into account by the party responsible for the port design. This disconnection often results in (environmental) issues in later stages [Schipper et al., 2015]. Here it can be found why the main objectives of the traditional approach are not obtained in the end: although in figure **2-A** the traditional flowchart does indeed indicate research of all relevant disciplines, the prior performed location selection (by another party who is not responsible for the rest of the design process) is not considering all these disciplines (e.g. only economy and government) and therefore

the rest of the disciplines (e.g. environment and society) are considered too late in the port masterplanning process. Since the traditional process has this prior selected location as starting point, it perhaps inevitably will result in environmental or social issues from the start. All the disciplines therefore should already be considered during the location choice.

It is important to mention that the traditional framework shows the essential elements required to develop a functional port masterplan. Therefore in order to create a sustainable framework, the basis of the traditional framework should be largely followed: after all, the current ports are mainly based on the traditional framework and are not completely inefficient or unusable. The goal however is to develop a masterplan that fulfils the functional ánd the sustainable requirements, in other words, the traditional framework needs to be adapted and complemented with sustainable elements. This will result in a different order of processes for the new sustainable framework compared to the traditional process. The main missing aspect which is found in the traditional framework and which should be included in the new sustainable framework is to ***include the location choice as part of the design process performed by one party.*** Due to this missing aspect the main objectives of port masterplanning are often not obtained, because the prior chosen location already brings limitations for the sustainability of ports.

Before I can start with developing a new sustainable framework, more detailed information is required of sustainability of ports. Hence in the following paragraph the exact definition of sustainability in ports will be discussed.

2.3 Definition sustainability of ports

From the start I think it is necessary to mention that a port cannot be considered sustainable in terms of only the *local* environment. This sounds peculiar as this document has the goal to create a sustainable framework eventually in order to create a *sustainable port*. But with the implementation of a port, the proposed site needs to make place for the entire port complex undoubtedly resulting in negative impacts on the local ecosystems. From this perspective sustainability in ports can never be achieved. Therefore this research is looking at sustainability beyond the local scale, i.e. on the *regional* scale. To be more specific, the regional scale does not only treat the local impacts, but should capture the bigger picture of the area surrounding the port including the entire hinterland which is dependent of the import and export of the port. For example, locally the port seems to only cause emissions at the port itself, but on the regional scale these impacts are less significant as less emissions are coming free due to the shift of truck towards maritime transport. The scale is of significant importance regarding sustainability.

This research is based on the thought that sustainability of ports is possible to obtain on a larger, regional scale and to continue from this point, the next step is to find out how to obtain this sustainability concerning ports. In order to find out, first a distinction is made between *the sustainable port* and *the sustainable port masterplanning* process to understand both definitions. By first defining *the sustainable port*, it becomes clear what goal should be achieved and only then it will be possible to define *the sustainable port masterplanning process* which contains characteristics of how to obtain that goal. This will also show the close connection between both definitions. Both their definitions will be given in the form of criteria and characteristics, which are based on the definitions of international well-known and accepted maritime organisations who are aware of sustainability issues in waterborne infrastructures. These organisations should have experienced many works related to sustainability of ports in the form of projects, report guides and other publications. Worldwide acknowledged port organisations which fulfil these requirements are PIANC and ESPO, hence the definitions in this report are based on their

definitions and are discussed below. Furthermore, since the environmental harm caused by a port affects its sustainability [PIANC, 2011], a worldwide nature protection organisation is also involved: the World Wide Fund for Nature (WWF) is a worldwide operating organisation for protection of nature since 1961. I have chosen WWF because it is one of the most well-known nature protection organisations which has the main goals to preserve the biodiversity and to keep the world's environmental footprint within the capacity of the earth. These goals are exactly the problems which are faced in sustainable port development and in collaboration with Deltares, the report *'Port of the future'* is covering these aspects. This report will be used to determine the definitions of sustainability of ports as well.

2.3.1 THE SUSTAINABLE PORT DEFINITION

According to many associations, such as the Modern Language Association, the definition of *sustainability* is given the two following adopted descriptions:

"1. The ability to be sustained, supported, upheld, or confirmed.
2. Environmental Science: the quality of not being harmful to the environment or depleting natural resources, and thereby supporting long-term environmental balance."

[Modern Language Association, 2015]

Sustainability can be seen from a conventional point of view (1) and from an environmental perspective (2), which both need to be taken along for its definition. I initially would think of a definition of a sustainable port which is based on only the environmental perspective, since currently port development results in ecological harm/mitigation, as is specified in the problem description. This environmental definition of sustainability describes the degree of impacts on the environment and its ecosystems caused by the construction and operation of a port. However when only the environment is taken into account, the often forgotten conventional definition of sustainability is not supported, i.e. the ability to sustain. The economic aspect has a significant impact on this ability to sustain. If the costs of a port are too high, financially the port cannot sustain. It may be assumed that the investment costs of a sustainable port might be higher compared to a traditional port, otherwise currently ports would already exist with these characteristics. After all, the final choice of building a port depends on the fact if it makes sense from an economic and financial perspective [Schipper et al., 2015]. It is important to include the social values as well, as in the end, people are the decision makers who decide the degree of sustainability. Hence, to enable to sustain a port for the long term, other important influencing factors need to be considered for the development of a port as well. This is where the economy and society are interlinked with the environment: impacts of ports on the environment and its ecosystems also affect the economic and social welfare, which challenges the ability to sustain a port. Likewise, vice versa the economy and society also impact the degree of sustainability of the port, since high costs and resistance of people limit a port to sustain for the long term. People may not always and directly care about the environment but they do care about their own economic and social welfare which will be affected by it in the short and/or long term, hence I think that the constant aspiration for socio-economic welfare will be the main driving force to desire, create and maintain a *sustainable port*. Port (development) impacts on the socio-economic welfare vary in scale. The scale which is considered for this thesis is the overall socio-economic welfare. This includes cost savings, increasing employment (direct and indirect) and benefits from other objectives.

The above-mentioned is in line with the green growth strategy of PIANC [Vellinga et al., 2014]. Another definition of sustainability in ports is provided by The World Association for Waterborne Transport Infrastructure, PIANC founded in 1885. In March 2014, PIANC Working Group 150 published the report '*Sustainable Ports – A Guide for Port Authorities'*. This report has its focus on the sustainable development

and green growth of ports and the related logistic chain and added value activities. According to this report a sustainable port or green port can be defined as *"one in which the port authority together with port users, proactively and responsibly develops and operates, based on an economic green growth strategy, on the working with nature philosophy and on stakeholder participation, starting from a long term vision on the area in which it is located and from its privileged position within the logistic chain, thus assuring development that anticipates the needs of future generations, for their own benefit and the prosperity of the region that it serves."*

[Vellinga et al., 2014]

According to PIANC, sustainability can be obtained with the economic drive towards green growth. This means that economic and sustainable development should no longer be seen as two conflicting disciplines, but on the contrary, they should be seen as complementary factors. This research agrees with the green growth strategy but instead of only seeing it as an economic driver, I see sustainability as a socio-economic driver. First of all because people are the decision makers who decide the degree of sustainability, as is mentioned before. And second, because socio-economic welfare belongs to the domain of the government as well: since sustainable development can benefit the socio-economic welfare, the government might provide subsidies for this development.

Furthermore, the above mentioned definition of a sustainable port by PIANC is extensively explained, but it actually mainly includes characteristics of the sustainable port development process which are required to create a sustainable port. However in order to create a sustainable framework, I need to make a clear distinction between the two definitions: once I know what I want to achieve (sustainable port), it becomes possible to create a framework to this goal (sustainable process). Hence, although I agree with the definition of PIANC, for the purpose of this research I will treat the port process characteristics in PIANC's definition, such as the green growth strategy, in the following paragraph. Furthermore, another sustainable port definition is required after the framework is developed, in order to practically asses if the resulting masterplan is sustainable. Hence from the above I can conclude that for this research, two kinds of sustainable port definitions are required. One which is necessary to develop a sustainable framework and one after the development which practically can test if the framework results in a more sustainable port. The former definition will be given in this paragraph in order to support the development of the sustainable framework. The sustainable port is constant in operation and therefore it requires a continuous process to maintain a sustainable port. In other words, a port can be considered sustainable now, but requires money and permits of people to maintain being sustainable in the future. Therefore it should be aimed to obtain a balance of the economy, environment and society now and in the future. With the aim on the future, I refer to the part of the PIANC definition where it mentions the anticipation and consideration of the needs of future generations, besides their own benefit and the prosperity of the surrounding regions.

After the sustainable framework is developed, a second definition of a sustainable port is required as is mentioned above. The definition of PIANC is ambiguous in the sense that it cannot be practically evaluated if a port is sustainable, and therefore it needs interpretation and operationalisation in practical guidelines. To start with, a more practical definition of *the sustainable port* can be found in terms of the *EcoPort port* [ESPO,2012] and the *no-impact port* [Schipper et al., 2015]. According to ESPO, a port achieves the status of *EcoPorts port* after successfully completing the so-called Self Diagnosis Method (SDM) [ESPO, 2012]. SDM is a user-friendly consist checklist which port managers can use to self-assess the environmental management programme of the port in relation to the performance of both the sector and international standards and addresses a variety of fields such as environmental policy, communication, operational management, monitoring, etc. This checklist is a practical method to evaluate how

sustainable a port is but since it is not publicly available, the practical definition of an 'EcoPort port' is not known. On the other hand, in the report *Port of the future* of Deltares and WWF (2015), there is a definition provided for the *no-impact port* as follows: *"A port that has no negative impact on the ecosystem and recognizes environmental systems as a mix of elements that interact with each other in oceans and coast areas".*

[Schipper et al., 2015]

This research does not focus on the question if a 'no-impact port' really is feasible to achieve (currently or in the future) so I will not use the definition of a *no-impact port* for this research. But what I will use is the relevant basis of this port to create my own definition to asses if a port is sustainable or not. One of the relevant aspects is to determine the sustainability of a port from an *impact* angle which in this research is recognized to be very practical. So instead of defining a sustainable port as one which has no impact on the environment at all, this research considers that the less negative impact on the environment, the more sustainable the port is. Furthermore, this research agrees that the assessment of sustainability of a port is based on only the impact on the environment: in the above it is mentioned that maintaining a port to be sustainable, is a continuous process where a balance between the economy, environment and society is required. However the assessment if a port is sustainable in this research, essentially only covers a moment or a relative short period of time: this means that you only need to consider the economic, environmental and social impacts present in that moment. However the environmental and socio-economic impacts cannot be translated to one and the same unit yet, which makes it difficult to equally assess them (see ecosystem services and TEEB in paragraph **2.3.2**). Hence only the environmental impacts will be considered since the initial problem description is based on ports resulting in environment harm/mitigation. Based on this environmental impact definition, the exact definition which will be used to evaluate the sustainability of a port will be treated in paragraph **2.6** *Evaluation process*.

The sustainable port definition
Based on the above, the definition of the sustainable port which will be used in this research is:

"A sustainable port is a port which has achieved and is maintaining a balance in economic, environmental and social extent for the surrounding local region. A sustainable port uses the Earth's resources for its own benefit without affecting its capacities for future generations."

This definition of a sustainable port will be referred to throughout the following chapters.

2.3.2 THE SUSTAINABLE PORT MASTER PLANNING PROCESS DEFINITION

Since it is clear what a sustainable port is, it is possible to discuss strategies and tools of the planning process in order to achieve it. This starts with a definition of the sustainable development process, which is provided by the European Sea Ports Organisation (ESPO), founded in 1993. Their definition of a sustainable development adopted from the Brundt-land report [1986] is as follows: *"Sustainable development is development that meets the needs of the present without compromising the ability of future generation to meet their own needs"*

[ESPO, 1986]

This definition is very general as it does not provide specific guidelines or a framework to follow for the port planner in order to create a sustainable port. The definition needs to be more specified in detail in the form of the port development process characteristics and tools which should considered and used to obtain this final goal. In order to provide a more specified definition first of all, regarding *sustainable*

port masterplanning process in this research, two main questions need to be answered: '*How to develop a sustainable port masterplanning framework?*'. *'And how to convince port planners and clients to implement this framework in practice*?'. This thesis mainly focuses on the first question, but since the questions are closely related, the second question will be treated a bit as well. A significant important aspect to answer the second question can be found in the *no-impact port*: this port is based on the ecosystem-based management (EBM) concept which focuses on the revival and protection of the health, function and resilience of ecosystems, benefitting all organisms [UNEP, 2011]. In this EMB approach, Deltares and WWF recognize that the health of the environment and people's socio-economic welfare are connected: ecosystems bring forward services which benefit people. The ecosystem services are divided in four categories: provisioning services (e.g. food, water), regulating services (e.g. regulation of floods drought, land degradation and disease), supporting services (e.g. soil formation and nutrient cycling) and cultural services (e.g. recreational, spiritual, religious and other nonmaterial benefits [the Millennium Ecosystem Assessment, 2005]. General encountered ecosystem services during port construction or expansion and their physical and welfare effect can be found in the *Port of the Future* from WWF and Deltares [Schipper et al, 2015, p.44/45, table 5.1]. In order to provide a better understanding of the values of the ecosystem services, the globally renowned initiative *The Economics of Ecosystem Services and Biodiversity* (TEEB), is initiated in 2007. TEEB draws attention to the economic benefits of ecosystems and biodiversity and aims to express them in monetary values in a liable way [TEEB, 2008]. However some ecosystem services, such as the supporting services are less expressible in monetary value compared to the provisioning services. Nonetheless, the ecosystem services could be the biggest motivation for people to implement the sustainable framework in practice. Traditional port development however negatively affects the local environment and therefore EBM has concerns about the changing processes within ecosystems and to sustain the services that healthy ecosystems generate for the human population [Schipper et al., 2015]. In order to protect or restore well-functioning ecosystems, it is required to have a good balance between processes in logistical morphology, economy, environment and society. The element that connects all of these disciplines is the location [Schipper et al., 2015]. Figure **2-B** shows the involved disciplines in both the traditional and the sustainable port development. The initial goal of a port is to obtain financial benefits and economic growth of a nation by the transfer of goods between sea and shore. Traditional port development therefore ensures that economy and government are considered, but it does not guarantee to deliver a sustainable port since the essential location selection and all the involved disciplines are not explicitly taken into account, as is mentioned in paragraph **2.2**. A sustainable port design development framework should therefore include the location selection in its design process so that all its connected disciplines (morphology, government, environment and socio-economics) are considered from the start.

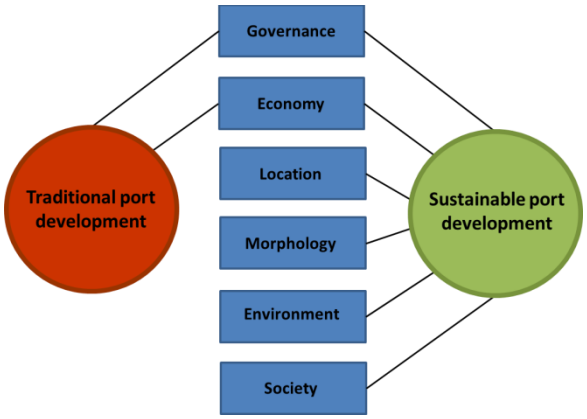


Figure 2-B Involved disciplines in traditional (left) and sustainable port development (partially adopted from Deltares, 2015)

It is of common sense that a port affects the physical as well as the environmental and socio-economic environment. However it must not forgotten that the opposite also occurs, namely that a port is also affected by its location/environment. A suitable location should not encounter too much negative influence from the physical environment on the port. For example, with a port located at a sandy coast, frequent dredging activities are required to maintain a minimum depth. This is not required for a rocky coast, which on its turn has its own drawbacks. Certain locations could form a barrier towards a sustainable port, thus, the selected site location of the port is of significant importance for its design and operational management. However in paragraph **2.2** it is already mentioned that in the traditional process the location selection and port design process are often not executed by one party which results in issues in later stages [Schipper et al., 2015]. Since the choice of location has such a significant impact on the port design and operations, it makes sense to *interlink the location choice and port design and operations in one process performed by one main party* [Schipper et al., 2015]. This can be achieved by first performing initial research to get a basic understanding of all suitable locations where it is necessary to discuss the role of the geographical location, morphology, government, environment (ecosystem services) and socio-economics for each location. By doing so the sustainable framework is one step ahead of the traditional framework by initially obtaining a great amount of information which can reduce later risks. Since the same party is responsible for the location selection, the design is also based on the same disciplines and values and therefore the selected location is the most optimal for the future port design and operation based on these disciplines. Research of all these disciplines for several possible locations can initially be time consuming and expensive, but the entire port planning process will go smoother in later stages as the decisions made are based on a larger supporting foundation. This can be simply explained based on figure **2-C**, which shows a rough representation of the traditional and sustainable process and their biggest difference. Both schemes result in the final masterplan (top of the schemes), but the traditional process does not consider the location as variable but it is often the starting point. Along the process, research which is initially required will be performed later and therefore this process encounters more resistance in later stages (indicated by the wider width). The sustainable process, on the other hand, starts with a research to get basic understanding of the critical parameters of all locations which decreases the risk for resistance along the process. Hence, the initial research can be seen as the functional foundation of the entire process (indicated by the stable pyramid shape).

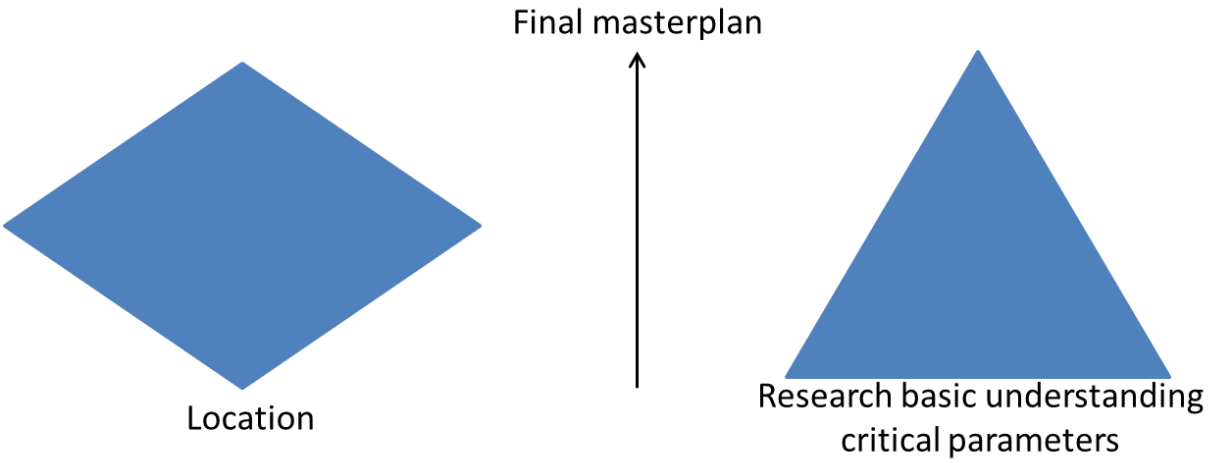


Figure 2-C Representation of traditional (left) and sustainable port planning process.

PIANC's Working with Nature (see paragraph **2.4.2**) agrees with this: the location and design should not only consider the technical and economic objectives of the port, but also include the environmental and

social disciplines. In doing so, involved people need to be stimulated by the creation or increase of their own welfare through ecosystem services. Hence during the development process, sustainable opportunities should be sought while simultaneously creating economic or social values as well: *a balance for the port location should be created from the perspectives of economy, environment and society.* This balance of environmental and socio-economic values also represents a sustainable port (see paragraph **2.3.1**) and can be achieved by a green growth strategy (PIANC) and with the help of active and *early stakeholder involvement*. Both PIANC and ESPO agree that this latter can be used as a tool to find out the needs and requirements of the environment and since the focus is to create value for the stakeholders, it is expected that the co-operation of the stakeholders will increase during the port development process and risks of resistance in later stages are reduced. This research however also recognizes the negative impacts of early stakeholder involvement: it might bring along the risks of early and unnecessary panic for the involved people. This can be prevented by promoting the transparent goal of creating value together for both parties and to make sure that all parties understand this.

Furthermore, PIANC, ESPO and WWF/Deltares, all emphasize on the long term vision as project aim. I however would rephrase this according to *The Flexible Port* of Taneja (2013) that port planners should plan under long term uncertainties. Planners in the traditional process are thinking in terms of short term uncertainties, and therefore propose designs and plans which are based on deterministic forecasts resulting in inflexible port and infrastructure designs which lose their function under changing conditions. According to Taneja, nowadays ports are subject to many uncertainties regarding their future, which is most significant during the port planning phase [Taneja, 2013]. They have to deal with new demands in terms of functions and scopes, new exogenous limitations and changing forecasts and expectations. The incapability to appropriately meet these demands could results in expensive port adaptations, loss of cargo and influence their competitive position. Therefore ports need to become more flexible since flexibility could increase the value of a port project. In response Taneja proposes *Adaptive Port Planning* (APP), an approach that covers the missing aspects in traditional port planning by consideration and incorporation of uncertainty and flexibility factors. It supports a framework where the port planner should produce reasonable alternatives in line with his/her planning objectives and definition of success. Planning under uncertainties requires more initial time, but will may become very profitable in the long term. This research agrees with Taneja (2013) that uncertainty is here to stay: therefore recognition, preparation for, adaption to and management of uncertainties are necessary to profit from it in the long term. Only then is it possible to create a flexible port which is able to stand the test of time and hence enables later generations to still adapt the port for their own objectives [Taneja, 2013].

Lastly, this research tries to create a sustainable port masterplanning process framework with the current available knowledge and information. This means that in the future, undoubtedly new situations will be encountered and more information will come to one's disposal to improve the framework. Therefore this research should consider this sustainable framework as a *continuous learning process*: by implementing the sustainable framework on case studies, each port development process can be seen as a learning process which provides new knowledge to enhance the framework or to indicate the limitations of the framework. New knowledge to adapt the framework can also be obtained through innovation, e.g. by the development of breakthrough of new technology. This means that the framework resulting from this research is valid for the current available knowledge and technology, but adaptation of the framework might be required for practical implementation in the future.

The sustainable port masterplanning process definition

The definition of the sustainable port masterplanning process which will be used in this research is:

"A sustainable port masterplanning is a continuous learning process which is designed to create a balance in economic, environmental and social extent for the surrounding local region. This can be achieved by including the location choice in the overall port design process, while through early, transparent stakeholder involvement and the consideration of long term uncertainties, flexible and future-proof development and operation can be achieved."

The characteristics in this definition are considered the ambitions of the sustainable port planning process to develop a sustainable port and are described below.

- **The location choice as part of the design process** – The location of a port is crucial for different port related disciplines and thus it is desirable to include the location selection in the design process which should be performed by one main party. After all, these two aspects are closely interlinked and have a significant influence on port operations [Schipper et al., 2015]. Since the port location, i.e., the environment is the initial basis for a port and has a significant influence on the degree of sustainability, research is required from the start to have a basic understanding of the critical parameters of all suitable locations. Initially this research will be very time consuming and expensive, but the obtained information can be expected to provide the most suitable location for a specific port (Schipper et al., 2015], which translates in the largest support of location and design choice and a smoother development process in later stages.
- **The consideration and search of the multiple disciplines balance of the interlinked economy, environment and society in an early stage** – The environment is linked to the socio-economic welfare in the form of ecosystem services [Schipper et al., 2015] and the two should be seen as complementary factors. Opportunities should be sought where these different disciplines in port development are positively interlinked. In other words, sustainable measures should be found with the aim to improve one discipline and do not negatively impact other disciplines but, on the contrary, benefit these disciplines as well. Hence during the development process, sustainable opportunities should be sought while simultaneously creating economic or social values as well. For example, creating or conservation of coral (environment), may lead to increase of tourism, recreation and employment (socio-economic welfare) [Vellinga et al., 2014].
- **Active and early stakeholder involvement** – In order to fulfil this balance of economy, environment and society, first of all it should be learned how to create sustainable measures and socio-economic value simultaneously by the means of active and early stakeholder involvement. Communication and co-operations with and between stakeholders is essential in the port planning strategy. As people are the decision-makers, it makes sense to learn the wishes and demands of the people by active stakeholder involvement from an early stage to understand how to create value together. The aim to create value together helps to decrease the possible presence of resistance in later stages and establishes a smooth port development process with less unexpected risks and more stakeholder co-operation. Active and early stakeholder involvement is therefore an essential tool to look one step ahead in the planning process.
- **Planning under long term uncertainties** – Port planning under short term uncertainties results in inflexible port and infrastructure designs, which no longer can perform their function under changing conditions. The incapability of a port to appropriately perform its functions consequently results in expensive port adaptations, loss of cargo and their competitive position. Therefore ports should be planned and developed under long term uncertainties: the aim is to create a flexible port which is still able to function despite changes over time and hence enables later generations to still adapt the port for their own objectives [Taneja, 2013]. A sustainable port planning framework should be developed which can be employed by port planners to identify and incorporate flexibility throughout the entire planning process.

- **Continuous learning process** – The sustainable framework in this research is created with the current available knowledge and information. However new situations may be encountered or new knowledge is coming to one's disposal in the future, hence the framework should be adapted or fine-tuned for future use. The sustainable framework therefore should be considered as a *continuous learning process*: the implementation of the framework on each new case study can be seen as a learning process which provides new knowledge to enhance the framework or to indicate the limitations of the framework. Hence with new knowledge available in the future, the sustainable framework is continuously under construction.

This definition of a sustainable port masterplanning process will be referred to throughout the following chapters and will be used to point out the difference with the traditional port masterplan approach and the suitable elements of the different philosophies in the following paragraphs. In order to develop a new sustainable port masterplanning framework, more knowledge is required than only its definition. Several sustainable philosophies already exist and are still in development. There however is still a gap between creating a sustainable philosophy and actually implementing it into practice. Therefore, existing sustainable philosophies will be studied in the next paragraph to figure out what this gap is and how they can be overbridged for implementation in practice.

2.4 Existing sustainable port masterplan philosophies

This paragraph analyses the gap which hinders the implementation of existing sustainable philosophies into practice. By doing so, the three existing sustainable port masterplan philosophies *Building with Nature*, *Working with Nature* and *Engineering with Nature* are being studied how they differ from the traditional framework and the relevant and missing aspects for successful implementation in practice will be summed up in order to create the basis of the sustainable framework.

2.4.1 BUILDING WITH NATURE

Building with Nature (BwN) is a Dutch research program for infrastructure projects and is founded by EcoShape in 2008. The main difference with the traditional process is that the BwN program has the elemental thought to deliver and use ecosystem services and opportunities while establishing engineering services. Instead of just building and then minimizing the negative effects on nature as much as possible, Building with Nature is aiming for the shift from building *in* nature to actually building *with* nature. BwN is a new form of sustainable development planning with active stakeholder engagement for issues such as safety, environment, economic potential, viability and sustainability. The general guidelines of BwN should be applied as early as possible in the project development process for greater potential results [EcoShape, 2012] and consist of the following five-step process:

1. *Understand the system: include ecosystem services, values and interests.*
2. *Identify realistic alternatives which use and/or provide ecosystem services.*
3. *Evaluate the qualities of each alternative and preselect an integral solution.*
4. *Fine-tune the selected solution: consider practical restrictions and the governance context.*
5. *Prepare the solution for implementation in the next project phase.*

This process is a cyclic process where a feedback loop is possible from step 4 back to step 2. BwN is a learning-by-doing approach by implementing it on experimental projects and the learned lessons are all compiled in the *Building with Nature Design Guideline*. With the help of several practical case studies, EcoShape shows that new opportunities of sustainable maritime infrastructure are possible. However according to this research, this is not enough; the aim is to actually make it happen. For this philosophy

the gap to implementation in practice lies in convincing port planners and clients with help of the ecosystem services to use sustainable measures.

2.4.2 WORKING WITH NATURE

One of the important philosophies of PIANC's future navigation approach is the Working with Nature (WwN) philosophy, first presented in 2008 in the PIANC Position Paper and most recently revised in 2011. This paper is focused on the project level.

Working with Nature is emphasizing on the important shift in thinking in the approach towards maritime development projects. Here lies the difference with the traditional project development, where WwN aims to focus on obtaining project objectives while working with natural processes rather than mitigating the impacts of a predefined project design. Hence the focus is on finding win-win solutions instead of just minimization of environmental impacts. Essentially, therefore, the following steps need to be implemented in this new order:

1. *Establish project need and objectives*
2. *Understand the environment*
3. *Benefit from stakeholder engagement; identify possible win-win solutions*
4. *Develop project proposals and designs which benefit navigation and nature*

The WwN process follows a logical order where the *needs (1)* are specified first, then emphasis is put on understanding the environment in order to figure out what is valued and how *value (2)* can be created on the location itself and lastly *priorities(3)* can be set with the help of stakeholder engagement. With this information project designs can be developed. WwN needs to be practiced early in the process, while flexibility is still attainable and where delays, extra costs and frustrations can be reduced.

2.4.3 ENGINEERING WITH NATURE

The third initiative dealt with is developed by the U.S. Army Corps of Engineers (USACE) and is called the Engineering with Nature (EwN) program. This approach engages in more sustainable opportunities of economic, environmental and social benefits related with hydraulic infrastructure through collaborative processes. In order to achieve so, the EwN-approach is working with the following nine guiding principles adopted from the official website [U.S. Army Corps of Engineers, 2015]:

- *Holistic* – an ecosystem approach for planning, designing, constructing and operating projects where economic, environmental and social factors are equitably weighed in the decision-making process.
- *A systems approach* – reflecting the reality that USACE projects exist in the complex physical and social/cultural systems, and that a single action influences many other parts of the system.
- *Sustainable* – focused on the long-term sustainability and resilience of project solutions and the benefits streams provided by the system over time.
- *Science-based* – build on first understanding, then working deliberately with natural forces and processes to accomplish engineering goals.
- *Collaborative* – based on effective partner and stakeholder communication, engagement and collaboration through the entire life cycle of a project, beginning at the earliest conceptual stages.
- *Efficient and cost effective* – reducing time and rework, while minimizing social friction.
- Socially responsive – aligned with the values, objectives, interests and priorities of USACE, Partners, stakeholders and society at large.

- *Innovative* – embracing new and emerging technologies and incorporating continuous learning, technology transfer and adoption of new and leading practices.
- *Adaptive* – demonstrating adaptive attitudes, structures and processes that enable a living, evolving and sustainable practice.

More research and development is still going on and workshops and presentations are given to spread this EWN-philosophy to the public.

2.4.4. COMBINING PHILOSOPHIES

In this paragraph, several relevant aspects of each philosophy will be adopted and by combining these together with elements from the traditional framework, the new sustainable port masterplan framework can be created.

In the previous it can be seen that the three mentioned philosophies have a lot in common. This could be expected since there currently is a strong emphasis on sustainable development which translates in the fact that several organizations broadly share each other's philosophy [PIANC, 2011]. The most important concept they all have in common, is that they have an integrated port development process which clearly deviates from the traditional framework: instead of reducing negative impacts on environment and/or mitigating them, the focus needs to be on pursuing and aiming for the positive values and opportunities of the environment. What all three philosophies have in common as well are the several examples available which proof sustainable measures can bring benefits, but there is still a gap in fully implementing these philosophies in practice. It turns out that over bridging this entire gap is beyond the scope of this research, but it is possible to tackle and over bridge a small part of this gap in this research. The full list of gaps according to me is still provided in Appendix **B**, but it is merely a reminder of the long way a sustainable framework still has ahead for successful implementation in practice. The gap which will be tackled in this research is the following one:

- **Gap in practical guidelines** – The width and content of this gap differs for each philosophy. Practical tools are provided by each philosophy, but WwN and EwN do not have practical and specific guidelines yet. BwN does provide these practical guidelines for the user entering from three different perspectives and its gap to application can be considered the smallest. However what all three philosophies have in common, is that there is still no practical framework which can be followed by the port planner, each step specifically considered. This framework will be created in this research.

In order to create this framework, relevant principles of these existing philosophies will be adopted and are used to adapt the traditional port development framework resulting in the initial version of a new sustainable framework in the next paragraph. Based on the definition of a sustainable port masterplanning process in paragraph **2.3.2**, the following similar principles can be recognized with all three philosophies:

- The consideration and search of the multiple disciplines balance of the interlinked economy, environment and society in an early stage
- Active and early stakeholder involvement
- Planning under long term uncertainties
- Continuous learning process

The only process characteristic which also could not be found in the traditional process, is that the location choice should be part of the design process performed by one party. The processes of the three philosophies have the location as starting point where there should be an *understanding of the entire system* of only that location. The new framework agrees with the fact that the entire system should be fully understood before a design can be made, but this understanding should be achieved for all suitable locations. Hence there is an even *earlier implementation of the framework* required, namely already during the location choice for the port. Furthermore, the Building with Nature philosophy already has specific guidelines for a project in different phases and locations and also covers the triggers and obstacles regarding government features. As this philosophy is the most similar to this research, the guidelines of this framework will be based on the BwN guidelines supplemented by principles of the other two philosophies. These supplementing principles are provided below, where sometimes they are combined to one principle.

- Define (1) needs, (2) values and (3)priorities in this order
- The focus on project level (system level)
- The aim to benefit nature rather than mitigating the negative impact on the environment
- Creating an holistic approach
- The aim for a sustainable result in a science-based manner
- Adaptive port development

2.5 The Initial Integrated Sustainable Port Design framework

With the essential basis of the traditional port development framework and the obtained relevant elements from existing sustainable philosophies, in this paragraph the new sustainable framework can finally be set up and introduced. In this framework, all the steps of sustainable port development are treated as integral parts of the sustainable port. Hence, this framework will be called the Integrated Sustainable Port Design (ISPD) framework. The initial ISPD framework created in this paragraph will be elaborated by separately explaining each basic guideline and a better overview of the framework is provided in the form of a flowchart.

2.5.1 THE ISPD FRAMEWORK: BASIC GUIDELINES

Figure **2-D** gives the basic guidelines for the Integrated Sustainable Port Design framework from bottom to top. The explanation of the guidelines is provided below.

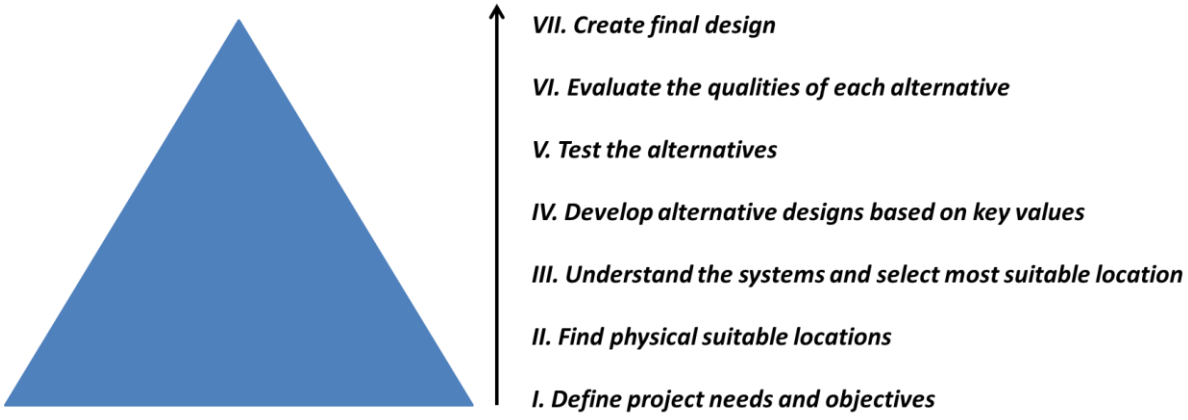


Figure 2-D Integrated Sustainable Port Design guidelines

In ***Step I*** the needs and objectives if the port project are specified. Because there is a large variety in ports, there is also a large variety in project needs and objectives. However all ports have the same main purpose which is to enable the transfer of goods between sea and shore, and by its very nature they are an interchange between sea and land [Haralambides, 2002]. To enable this main purpose, a port needs to provide the four functions in table **2-A**, where the required design parameters for each function are provided in the right column. In order to determine the design parameters for a port project, step I starts by analysing the past and current cargo flow, shipping, urban and industrial development to create feasible cargo flow and shipping forecasts for the future. These forecasts should be valid for the design life of the port and include long term uncertainties. The design parameters for the port will be based on these long term forecasts and the demands of the client. They are required in order to select potential suitable port locations in the next step and can be seen as limitations for the location choice.

Table 2-A General port functionalities and their required design parameters [adopted from Haralambides, 2002]

Functionality	**Required design parameters**
The ability for vessels to arrive and enter the port	minimum water depth, margin to manoeuvre, wave motion
The ability to moor the berths	design vessels, wave motion, margin to manoeuvre within the harbour area
Transhipment of people and products	Required demand market
Connection to hinterland	possibilities multiple modalities, upper limit of the search scale to serve its intended hinterland

Port objectives can be set based on evaluating the success of the project in the form of deadlines, financial and qualitative objectives [Taneja, 2013]. In line with Adaptive Port Planning [Taneja, 2013], the objectives should include planning under long term uncertainties to make the port more flexible and future-proof. Reaching for these future-proof objectives requires more initial time and investment, but it may become very profitable in the long term if flexibility is needed in the future scenario. The port planner is responsible to conclude the extent of the inclusion of these future-proof objectives. This requires knowledge of various aspects of uncertainty which could be encountered during the planning phase and a comprehension of prevailing and emerging trends that have direct or indirect influence on the chosen goals, plans and planning approaches. Examples of such trends are the emerging globalization and containerization, climate change, breakthrough in new technologies, and increasing emphasis on the environment [Schipper et al., 2015].

Step II can be seen as a prefeasibility study in order to find physical suitable locations for the port. This pre-selection is required since it would cost too much time and money to get a basic understanding of too many locations in the next step. A physical suitable location is one that fulfills the design parameters and where the entire port structure is assured from stability and safety with the least negative influences from the physical environment. (Un)favorable local conditions should be considered and can be found in the report *Port of the Future* from WWF and Deltares (Schipper et al, 2015, p.25, table 3.1) in the form of location elements of the physical environment which in general impact a port's design and operation and hence these factors need to be considered during the location selection. Some of these location elements already include the consideration of long term uncertainties, but the port planner should consider the long term uncertainties for all location elements to select locations where flexibility can be implemented.

Step III concerns the basic understanding of the overall system in all potential suitable locations. This understanding is required in order to select the most suitable location based on the integration of environmental, morphological, governmental and socio-economic disciplines [Schipper et al., 2015]. In order to get a basic understanding of each location, long term uncertainties need to be considered in the form of plausible developments which might happen in the time horizon of the project and influence the success of the project [Taneja, 2013]. Positive development for the project can be called an opportunity and otherwise the development is considered a challenge. The factors which influence the success of the project and hence can be seen as opportunities and challenges, can be found in the report *Port of the Future* (Schipper et al, 2015, p.58-59, table 6.1). Another tool which can be used to identify why one location is more suitable than the other is stakeholder analysis. Stakeholder involvement is required to find out what is valued by the involved people, which values are aligned or conflicting and hence which locations bring along more opportunities and challenges in later stages. The location which encounters the least challenges and resistance or has the best opportunities for the port, can be considered the most optimal for the future port.

In ***step IV*** several alternatives are being developed for the port. The location and stakeholder analyses in the previous step provide the port planner what is valued by the involved actors. In order to systematically develop the alternatives, the port planner needs to prioritize these values in the form of key values of the chosen location. These key values represent the economic, environmental and social most important aspects of opportunities and concerns. The focus of this step is based on finding possible planning measures as a response to these opportunities and concerns. The planning measures can be divided into three strategies: (1) avoiding, (2) minimising or (3) mitigating the environmental impacts, while at the same time creating socio-economic value. These planning measures and their future impacts act as a brief impact assessment and they provide better consideration for the future alternative designs on system level: the aim is to create alternatives which all fulfil the needs and objectives of the port while at the same time consider the key values of the stakeholders as well. This results in three different alternatives which are developed according to the predefined economic, environmental and social key values.

Step V deepens in the testing of the developed alternative designs in step IV. Any method and model required can be used to perform this testing and to gain insight in the feasibility of the alternatives. This step is performed to investigate and discover the potential of the alternatives and to assess the possible economic, environmental and social impacts of each alternative in a brief impact assessment. The acquired results can be used during the evaluation of the alternatives in the next step.

In ***step VI*** the three alternatives will be evaluated with an evaluation method. The pre-defined criteria are the key values specified in step IV based on the location and stakeholder analyses and their individual weighing factors are determined by experts in this step. By comparing the alternatives based on these criteria, one alternative will attain the highest score and represents the most optimal alternative. A sensitivity analysis also needs to be performed to determine if the best alternative is still the utmost favourite in situations with different weighing factors. The outcome of this step provides useful advice for a possible fine-tuning of the masterplan: in this case a feedback loop to step I or III is provided when the results are not satisfactory. When a feedback loop is followed to optimise the alternatives, it should also be checked if the cargo flow and shipping forecasts are still valid. It is recommended to review and update these forecasts (and all other assumptions), at least every three to five years. However, in case of rapid and significant global impacts, such as an economic crisis, yearly updates are required [Arecco, 2015]. Once the port planner is satisfied with the alternatives and their evaluation, the alternative with the highest score will be recommended to the client.

Step VII gives the conclusion of the evaluation which alternative is the most suitable for this specific situation and becomes the most optimal and final design. This step is also were the transition can be made to the more detailed design on construction and material level. Since this research only focuses on the system level in the planning and design phase as is specified in paragraph **1.2**, this step will not be treated in this research. However as stakeholders still prefer to see a monetary value to conclude the financial feasibility of a project, the step ends with a rough cost analysis. Although the final design step is not treated in this research, it still will be briefly mentioned to provide the reader a complete process of the planning and design phase.

Figure **2-E** shows the flowchart of the initial Integrated Sustainable Port Design framework. This framework will be taken to the next section, where it will be enhanced with examples of ports in practice. In this flowchart several elements are encircled with red colour to quickly see where the difference are compared to the traditional framework. It can be seen that the differences can be found particularly in the beginning of the development process; this could be expected as now the location choice is included in the process and research of several locations is performed early in the process. Since *step VII Create the final design* is outside the scope of this research, this step is shown in dotted lines. The difference with the traditional framework is that in the initial ISPD framework, *the location choice is part of the design process.* This includes the following differences with the traditional framework:

- **Analysis of physical, environmental, governmental and socio-economic disciplines of different potential suitable locations**
- **Early stakeholder involvement during the location choice**
- **Focus and systemically outline the values, opportunities of each potential suitable location**
- **And prioritizing the values into key values after the preferred location is chosen**

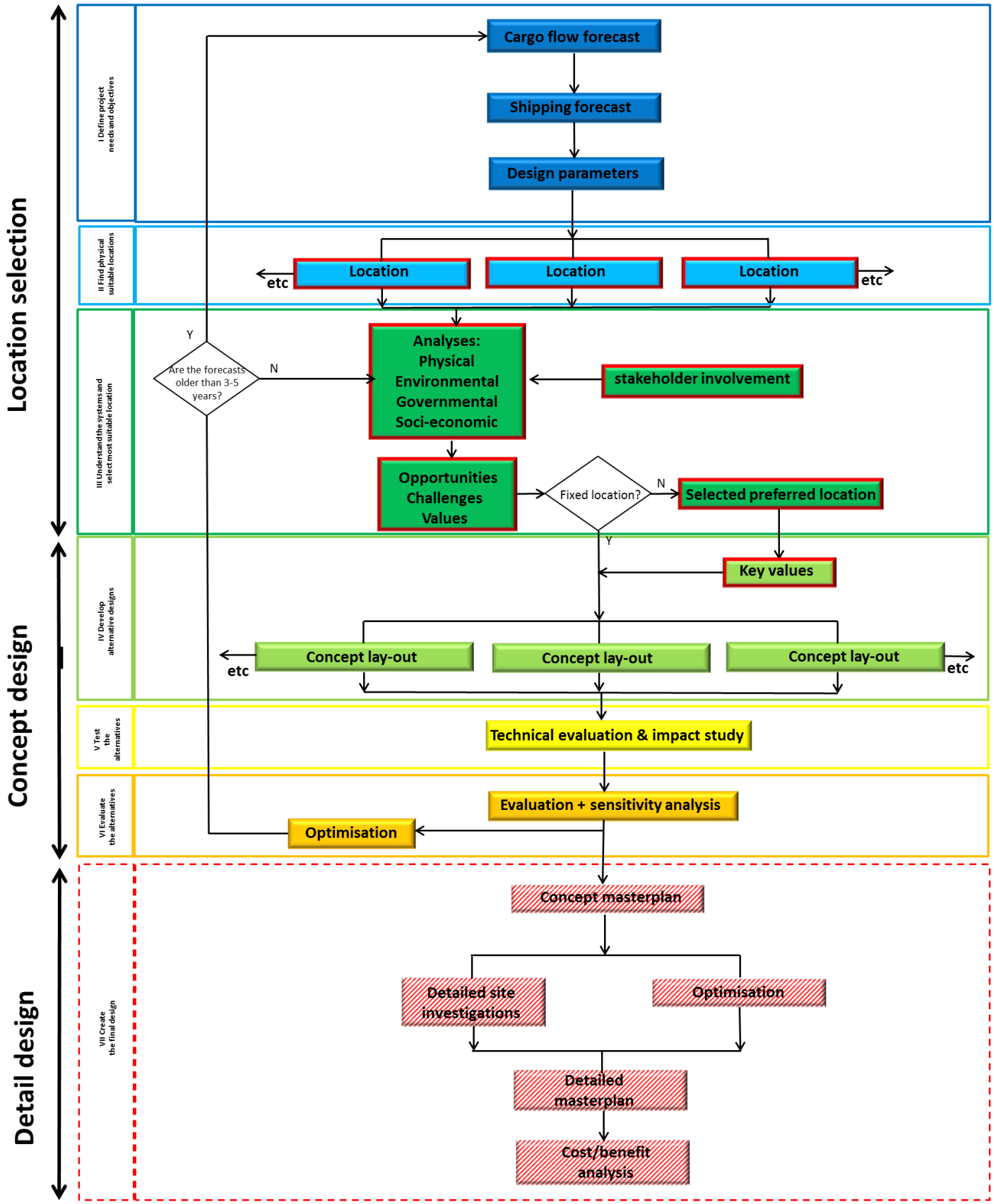


Figure 2-E Flowchart initial ISPD framework

2.6 EVALUATION PROCESS

This research has two evaluation processes. The first evaluation will be conducted during the case study section in Chapter 4 where several alternatives will be evaluated to result in one final conceptual port masterplan. The chosen evaluation tool for this first evaluation is the well-known Multi Criteria Analysis (MCA) [Center for International Forestry Research, 1991].

Multi Criteria Analysis

A Multi Criteria Analysis (MCA) is an evaluation tool which is developed to aid the decision-making with a qualitative and/or quantitative multi criteria problem [Center for International Forestry Research, 1991]. In this case it concerns the decision to select the most suitable alternative based on various criteria. Each criteria is given a certain weighing factor, since not all criteria are considered of equal importance. The weighing factors are determined by a group of experts, stakeholders and/or the decision-makers. Then the alternatives are evaluated: each alternative will be given a standardized score for a criteria. The final score of each alternative is the sum of the standardized score times the weighing factors of each criteria. Depending on the definition of the standardized score and weighing factors, the highest or lowest score represents the best alternative.

The benefits of a MCA are as follows:
1. Ability to consider multiple criteria in the assessment
2. Capability to accommodate mixed data and no need for data-intensive research: both qualitative and quantitative data is allowed
3. Direct involvement of stakeholders (e.g. multiple experts, client, interest groups, etc.)
4. Transparency to stakeholders
5. Inclusion of feedback mechanisms regarding the constancy of the judgements

However concerning the assessment of sustainability, the MCA deals with the following issues:
1. Inability to cover the full range of ecosystem services provided by the ecosystems
2. Assessment of sustainability requires both qualitative and quantitative data. It is hard to obtain quantitative data for e.g. environmental and social aspects.
3. There is widespread agreement that sustainability needs to be measured, but no consensus is reached yet in terms of how sustainability can be measured and what criteria should be included in the evaluation. [Center for International Forestry Research, 1991].

In the MCA a choice can be made between alternatives based on several criteria. The reason I chose the MCA as evaluation tool is because criteria from different disciplines need to be considered and direct and transparent stakeholder analysis is necessary. Another reason and advantage to choose a MCA is that the criteria do not have to be expressed in terms of monetary units. This however can also be seen as a drawback of the tool: clients often prefer to see project evaluations expressed in monetary terms. Paragraph 2.3.2 already introduced the ecosystem services and TEEB, which tries to express the ecosystem services in the same monetary units. However as already mentioned there, it is not possible yet to value all the ecosystem services in monetary units. The aspects which currently are expressed in monetary values are mainly the costs for required land, material and construction for the port project. I however do not think that only these aspects will give a good representation of a sustainable port, because social and environmental benefits cannot be included yet. I therefore have chosen to set qualitative criteria. In order to satisfy the client as well, a rough cost analysis will be provided after the evaluation.

The criteria used for this MCA will be the predefined key values of the port project. These key values will be specified in paragraph 4.5 and they are chosen because they represent the prioritized values of the involved stakeholders in the project. In addition, these criteria will be specified before the alternatives are developed and all the alternatives are developed based on these key values. Since all the alternatives are based on the same key values, the assessment of the alternatives based on these key values criteria would also be more relevant and equal. It should be considered that the set criteria, weighing factors and scores are subjective. In this research however it is assumed that the person performing the MCA, tries to evaluate the alternatives as objective as possible. The final part also includes a sensitivity analysis where the weighing factors will be changed: this shows if the results of the MCA are sensitive to changing parameters. In order to make the assessment more objective, the results of both the MCA and sensitivity analysis will be double checked by an experienced port planner from RHDHV.

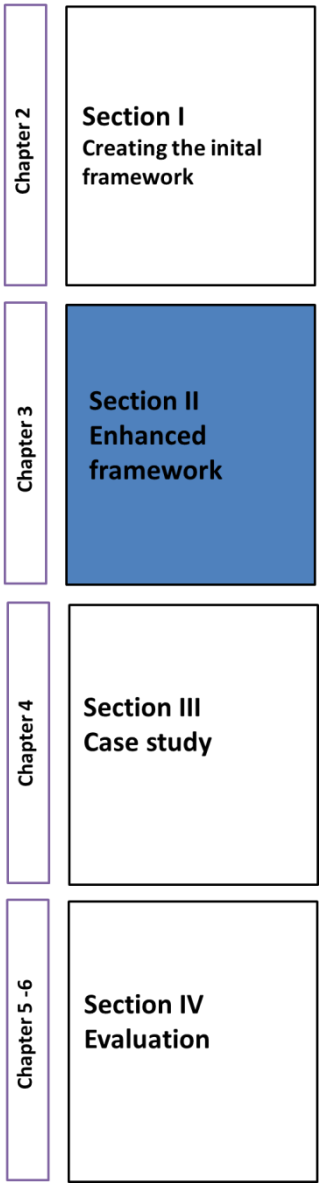
The second evaluation, which will be performed in Chapter 5, is required to achieve the main objective of this research. Since the main objective aims to design a general framework for sustainable port masterplanning, to apply it on a case study and then to evaluate it, this objective in essence wants to obtain (1) an applicable sustainable framework which results in (2) a sustainable port. This means that this evaluation should also be divided into two parts: the first part involves the evaluation which masterplan (new or existing) is more sustainable. And the second part of the evaluation includes the applicability of the framework on the case study.

In the first part of the evaluation it becomes clear if the new masterplan is more sustainable than the existing masterplan and hence, answers the question if the ISPD framework really results in a more sustainable port. Since in this research the second definition of a sustainable port is based on the environmental impacts (see paragraph 2.3.1), the degree of sustainability of a port should be evaluated based on environmental impacts criteria. These criteria can be found in the form of a list of environmental and sustainability issues (impacts), which currently play an important role in port operations and the associated logistic chains. These criteria are provided by both PIANC and ESPO in respectively the *Sustainable Ports – A Guide for Port Authorities* (2014) and the *ESPO Green Guide* (2012). It should be mentioned that the provided lists cover the *current* main environmental issues caused by ports, so in the future these issues may be adapted, added or removed and an entire different list may appear. As the list of PIANC (2014) is the most recent, its current main issues will be used for this research. This research recommends that these issues should be used as evaluation criteria in order to qualitatively measure the impact on the environment per criteria. A table of this adopted criteria list can be found in Appendix A, including their adapted explanation by me for each criteria in order to make them more suitable for the scope of this research. Because it is recognized in this research that impacts of the port project on the environment are interlinked with the socio-economic welfare, the potential effects of each criteria on welfare (during port construction/expansion and operation) are provided as well. This way it shows that when no sustainable measures are taken, it potentially has significant impacts on the socio-economic welfare of people. Since this research in the end compares the new masterplan with the existing masterplan of the case study to determine which masterplan is considered more sustainable, the following rule applies: ***The port with the least negative impacts resulting from the port project on the environment concerning predefined* environmental *criteria, is considered the most sustainable port.*** Hence a conclusion can be made how sustainable a port is. Actually, quantitative standards need to be set to evaluate the impact of ports concerning the environmental criteria. However quantitative standards will not be used in this research as the goal here is to set up a sustainable framework and evaluate if this sustainable framework compared to the traditional framework results in a more sustainable port. By comparing the new masterplan to a reference situation, that is, the existing masterplan, it becomes

possible to determine which masterplan is considered more sustainable. A qualitative evaluation will therefore suffice to achieve this goal.

The second part of the evaluation in Chapter **5** assesses the degree of applicability of the ISPD framework to the case study. The advantages and challenges encountered in the ISPD framework during the implementation on the case study will be treated step by step. In addition, this section will also treat the limitations and challenges which could be encountered in real life and discusses how to deal with them. The learned lessons will be used to finalize the framework.

SECTION II ENHANCED FRAMEWORK



3 ENHANCING THE FRAMEWORK BASED ON EXISTING PORT PLANNING PROCESSES

3.1 Introduction

In this chapter the initial theoretical ISPD framework is further enhanced with examples of three traditional ports in practice. It starts by defining the selection criteria in section 3.2 to narrow the scope of interesting ports for this research. Not all ports are relevant for this framework and due to time constraints, three ports are selected for further study. This section also provides the selected port for the final case study in Chapter 4, as most of the selection criteria are the same for both the ports in this chapter and the case study. The chapter continues by analysing the port planning processes of each of these three ports in sections 3.3 – 3.5, where a brief introduction of each port is given first. Before their port development processes are analysed, first it should be questioned why this is necessary: In other words, *"what are the issues with the existing design?"*. Hence the existing masterplans need to be depicted first while indicating its current main issues. Subsequently, the port planning processes will be analysed in order to find relevant aspects which influence the issues of the existing masterplan. To make this process easier to follow for the reader, a flowchart of the planning process is provided where after the planning process is treated step by step according to the initial ISPD framework. Problems encountered and sustainable measures applied in practice will come forward and might be relevant for the ISPD framework. The chapter ends with section 3.6 by implementing all the learned lessons in the initial framework, resulting in a more concrete and enhanced ISPD framework.

3.2 Selection criteria

In order to select suitable ports to enhance the ISPD framework, various criteria need to be determined first. In the following part, the selection criteria will be elaborated one by one. These selection criteria are largely in accordance with the selection criteria for the final case study. Hence at the end of the paragraph the three selected ports ánd the selected final case study are announced.

3.2.1 List of criteria

Criterion 1 Scope

This research is executed in cooperation with and on behalf of Royal HaskoningDHV and partially performed in the RHDHV office in Dubai. The concerned ports should be in their interest and as a result, the scope of this research is narrowed down to the ports in the RHDHV database of Dubai. This however also brings limitations along, since other potential interesting ports are not considered.

Criterion 2 Data

Due to time constraints, there should be sufficient available data concerning the port planning processes. This aspect also forms the connection with the previous criteria *scope*, since this data is made easily accessible by RHDHV. When information is incomplete, assumptions need to be made which degrades the research and should be refrained from when possible. The highly preferred available data in the port planning process of the selected ports should include:

- The clear order of the planning process towards the existing masterplan

- Taking into account of clearly specified values
- Encountered conflicts/issues to avoid or strategies how do they deal with them
- Multiple studies preferably carried out concerning the environment and the society, such as an Environmental Impact Assessment (EIA) and a society analysis (such as stakeholder information and social situation)

Criterion 3 Project phase
Since both the project planning process and the resulting masterplan are analysed for each port in this chapter, the selected ports should reside in a phase where both the planning process and masterplan are completed. This means that the ports cannot be in the preparation phase anymore and thus the ports should be in or between the two remaining phases: the construction or the operational phase. It is also possible to select a port which is in between the preparation and construction phase, residing in the tender process.

Criterion 4 Category port
Different port categories follow different processes in port planning. A distinction needs to be made between the three following port categories clarified with a brief explanation:

Category A: New ports
This category treats the ports that do not exist yet and still have to be designed and constructed. This category of ports possesses the most flexibility and are most preferable to work with. However the downside is that for new ports, little data and information about the local ecosystem are accessible: large amount of time is needed for research and development of alternative measures. Assumptions can be made but with high uncertainty. A special form of a new port is called a *Greenfield port*: as an addition, these ports lack any constraints imposed by pre-existing work. That means that no buildings or infrastructure network is developed in the surroundings. Another form is the entire renovation of a port. In this case prior study has been performed on the surroundings, but not all information may still be valid.

Category B: Expanding ports
This category focuses on existing ports that need to be expanded due to e.g. insufficient capacity. Little or no hindrance will be passed on to the existing port as the expansion is located outside the operating areas. This means that the existing port can be expanded, constructed and operated at the same time.

Category C: Operating ports
This category focuses on ports with no construction activities involved. Improvements concerning sustainable measures in the development process can be made during the operational phase as well. These improvements will not be in terms of a different lay-out, but focus on management and operational actions in ports.

As the developed framework in this research is restricted to *new* and *expanding ports*, the selected ports must be from these two categories.

3.2.2 Selected ports
After defining the above-mentioned criteria, several ports have been proposed by RHDHV from their database in Dubai. The following three ports fulfil all the four criteria and are selected for further research in the following paragraphs to enhance the ISPD framework:

- **The Jebel Ali New Container Terminal, Dubai**
- **The Badagry Port Project, Nigeria**
- **The New Doha Port, Qatar**

The three above-mentioned ports are suitable for the final case study as well and, in consultation with RHDHV, the port selected for the final case study which will be elaborated into detail in Chapter 4 is:

- **The Badagry Port Project, Nigeria**

The most important reasons for the choice of this port are first of all because the Badagry Port has serious *issues affecting sustainability* (economic, environmental and/or social perspectives) and it shows the most *potential in opportunities* to improve that current situation. This also includes that the involved stakeholders show *potential interest in the implementation of a sustainable framework*. In addition the port in Nigeria is a *Greenfield Port* project, which provides more flexibility since there is less limitation by existing infrastructure. These aspects are important since they provide higher chances for excellent results. This is important because excellent sustainable masterplans resulting from a sustainable framework could be used as frontrunners to attract other ports to implement the sustainable framework as well [PIANC, 2011]. With these reasons it may be concluded that the Badagry port is the most interesting out of the three ports to implement the ISPD framework on.

In the following paragraphs, I will elaborate the port masterplans and the planning processes of the Jebel Ali New Container Terminal, the Badagry Port project and the New Doha Port in this particular order. I chose this order to first show the importance of proper long term masterplanning for a port and surrounding projects in general, then an example will be provided of a fairly good port planning process which still can be up to improvement, and lastly a port will be shown which has no significant impacts on the environment due to an excellent planning process despite the presence of limitations.

3.3 Jebel Ali New Container Terminal

3.3.1 Introduction

Jebel Ali port situated in Dubai, in the United Arab Emirates (UAE) has been experiencing a fast development in the recent years. At the moment Jebel Ali Port is the biggest port in the Middle East and even the largest man-made harbor in the world. Between Rotterdam and Singapore it is also the largest container port. The continuous expected container growth of 10.7m TEU/annum in 2007 towards 56.2 TEU/annum in 2030, will eventually lead to insufficient capacity of the existing Jebel Ali port and requires a long term expansion plan of the port. Due to land scarcity along the coastline, this expansion includes the construction of new terminals in the offshore direction by 2030, also known as Jebel Ali New Container Terminal (JANCT). Dubai Ports World (DPW) who is in charge of the project, has announced that the expansions in principle only include container terminals and one LNG terminal, but flexibility is still present for any future changes.

The JANCT will be located on the coastal side of the existing container terminal of the Jebel Ali Port. Figure 3-A shows a brief overview of this part of Dubai's coastline where the future new terminals (indicated with a red circle) are located between Palm Jebel Ali and Palm Jumeirah. In the current state the project is in the middle of the tender process.

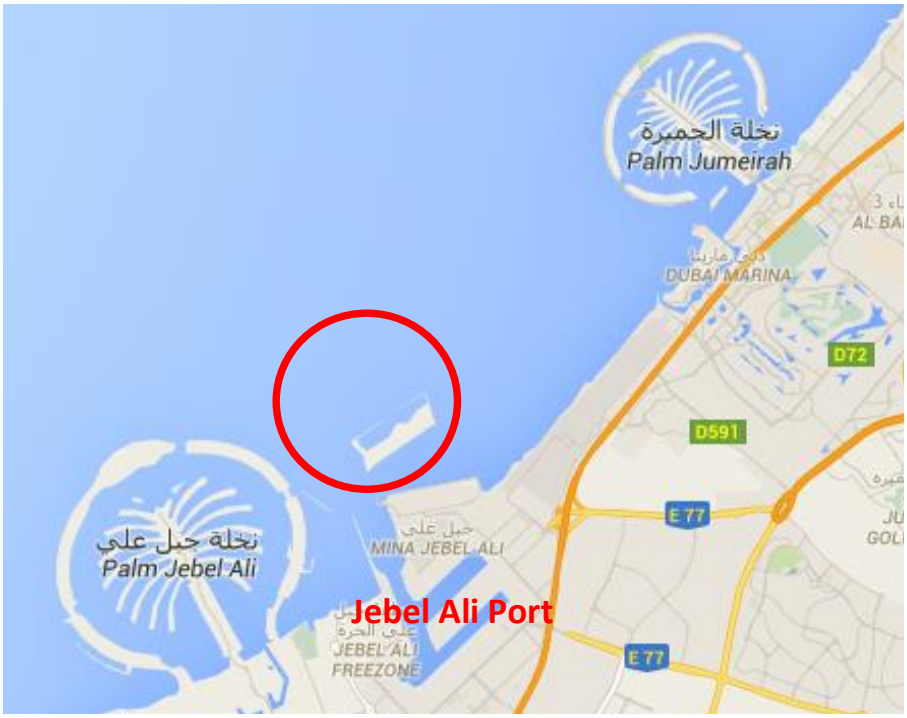


Figure 3-A Location of future JANCT [Google maps, 2015]

3.3.2 Existing masterplan and its main issues

The existing proposed masterplan of the Jebel Ali New Container Terminal is depicted in figure **3-B** below. The JANCT is connected with the existing port by a bridge, connecting CT2 and the CT4/CT5 island and continues its track towards the CT10/CT11 island.

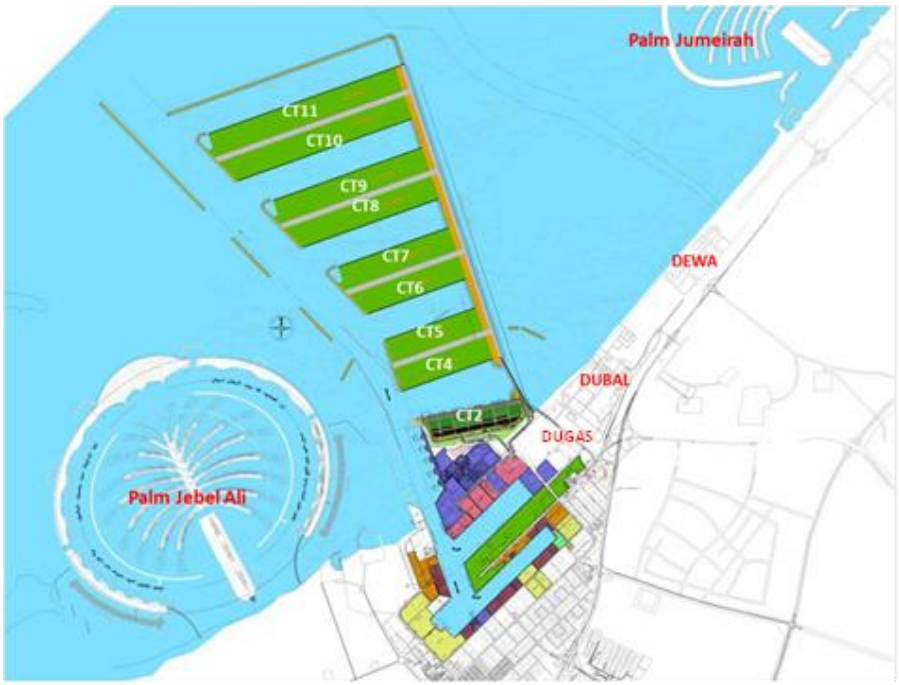


Figure 3-B Masterplan Jebel Ali New Container Terminal [Royal Haskoning, 2007]

Analysis of the area and consultation with RHDHV resulted in the following main sustainable issues for this masterplan which could be up to improvement:

- *Impact on surrounding projects and companies* – The selected location for the JANCT is located along a very crowded coastline. Other projects and companies such as the Palm Islands project (Palm Jumeirah and Palm Jebel Ali), Dubai Electricity and Water Authority (DEWA), Dubai Natural Gas Co. Ltd. (DUGAS) and Dubai Aluminum Co (DUBAL) will face significant impacts from the construction of the new terminal, especially since they also have ambitious plans for development and expansion.
- *Relocation of FSRU berth* – There currently is a Floating Storage & Regasification Unit (FSRU) berth located between the CT2 and CT4/CT5 island. This FSRU berth was built *with* the knowledge that the Jebel Ali port would be expanded in the offshore direction. When the JANCT will be in use, this berth needs to be relocated which will be relative expensive.

This port is mainly used to indicate the importance of long term integrated masterplanning process of the coastline of Dubai. The elaboration of the JANCT planning process will therefore be linked with the masterplanning process of the entire coastline. Furthermore, due to the Non-Disclosure Agreement of RHDHV, the availability of information is limited. Therefore most information below is based on personal communication and interviews with RHDHV.

3.3.3 Port planning process

In this paragraph the port planning process of the Jebel Ali New Container Terminal is elaborated and categorized according to the seven basic steps of the initial ISPD framework, in order to find out where and to what extend this process deviates from the ISPD framework. The flowchart of the overall port planning process of the JANCT is shown in figure 3-C. The element represented in red are a quick indication of the differences with the initial ISPD framework. It can be seen that the flowchart mainly shows differences in the beginning of the process and therefore the remaining steps in the process which do not show significant differences with the ISPD framework will be briefly described.

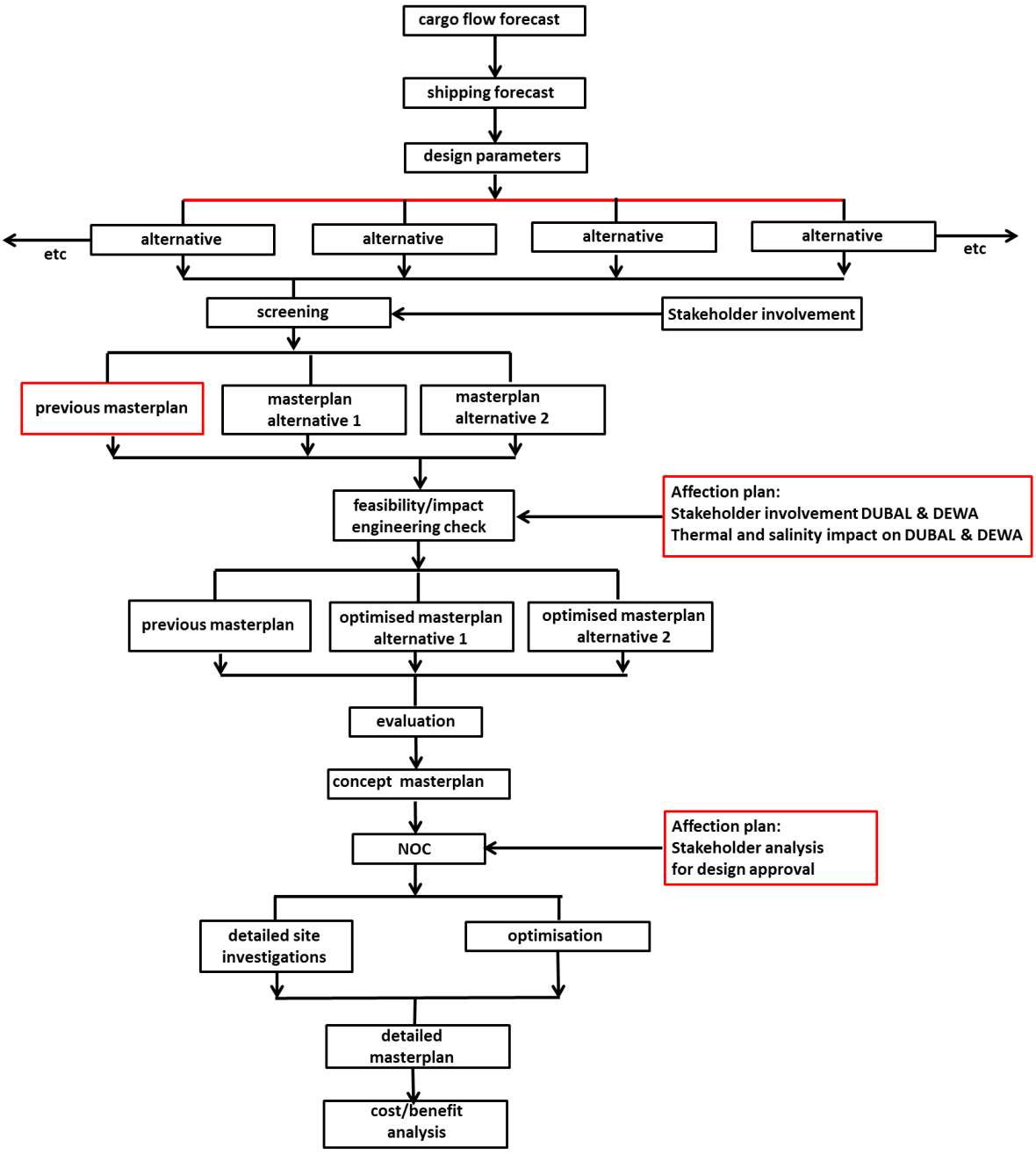


Figure 3-C Flowchart development process JANCT

The differences with the initial ISPD framework in short are as follows:

- Lack of location choice in the process since the expansion is limited by the surrounding projects
- A previous masterplan is considered as an alternative (this project was previously started and is resumed again by another party)
- Late public stakeholder involvement

Step I **Define project needs and objectives**

Several parties already started with the JANCT process several years ago but it was not finished due to for this research unknown reasons. As most information is confidential, it is assumed that the cargo flow and shipping forecasts were performed traditionally for this previous masterplanning to able to define the port user requirements. It is also assumed that for the new JANCT process, which involves RHDHV, these forecasts have been reconfirmed.

Step II **Find physical suitable locations**

When analysing the location of the JANCT, the surrounding projects and companies also need to be considered in the bigger picture. As can be seen in figure **3-B**, JANCT is located relatively close to Palm Jebel Ali and Dubal and therefore it seems quite unusual to locate the JANCT there. However JANCT is an expansion of the existing container terminal and therefore it is desired to attach it to the existing port of Jebel Ali, so the existing approach channel and hinterland connections can be used. Due to this limitation the implementation of the ISPD framework, which requires a pre-selection of suitable locations in this step, would not have resulted in a different location choice.

Step III **Understand the systems and select most suitable location**

Once it is decided to locate the JANCT close to the container terminal, the exact site could be selected through basic understanding of the location's critical parameters. To understand the importance of active stakeholder involvement and public participation in an early stage of port planning, the bigger picture around the JANCT will be analysed. As Palm Ali Jebel is already constructed, it may seem that its plan was already present before the plans of the JANCT. However, the plans for expansion of the Jebel Ali port in the offshore direction existed long before the previous plans and were well known to other parties. In spite of this knowledge, it was still decided to build Palm Ali Jebel on that location [Personal communication and interview RHDHV, 2015].

With the success of Palm Jumeirah, Dubai also strives to book the same or even better results with Palm Jebel Ali and tries to financially benefit from it. Due to this goal on short term, the public participation was not valued during the location selection of the Palm Jebel Ali in the long term: active public participation would most likely result in the fact that with the future nearby JANCT, the overall majority will not like the views of the terminals from their beach in Palm Jebel Ali. Pollution and other environmental nuisance (e.g. odour, noise) during both the construction and operational phase will also affect the daily lives of the surrounding inhabitants. Another large project is the new Al Maktoum International Airport, complementing the existing Dubai International Airport. It is important for a port to have good connections with other transport means, such as airports and therefore the location of this new airport is approximately 15 km southeast from Jebel Ali port. The relocation of the airport to this location was expected, but it was still decided to construct Palm Jebel Ali at the current site. Inhabitants of Palm Jebel Ali will most likely complain about the future noise of the relatively low airplanes which will fly over this area on daily basis. Together with the JANCT nearby, this could mean a difficult road to success for the

Palm Jebel Ali [Personal communication and interview RHDHV, 2015]. Considering this input from stakeholders, it may have led to a different location for Palm Jebel Ali.

The above shows that public participation in an early phase is a critical factor to learn the wishes, demands and values of the public. Besides the opinion of experts, it could still be useful to discover unseen perspectives by the means of public participation. However, although this valuable information might be known (which was the case here), it is still not certain that this information will also be considered and used adequately during the location selection of the port. In the end it all depends on the country itself and its rules and regulations if great value is given to the role of these public stakeholders. After all, in Dubai the stakeholders were only involved during the No Objection Certificate (NOC) process, after the masterplan concept was designed. Furthermore, the stakeholders who are involved the most are the parties with high authority and financial means. Although other stakeholders made comments about the issues regarding Palm Jebel Ali, no mitigation or solution is mentioned in the plans so far [Personal communication and interview RHDHV, 2015]. Hence according to this research the use of the ISPD framework, with the early and active stakeholder involvement, would not have significantly changed the results.

If there was a more integrated planning process aimed for the long time vision in Dubai, the process of the JANCT would not encounter all these limitations. Due to land scarcity along the coastland and inland areas, it was difficult to expand the Jebel Ali terminal land inwards. Another option would be to construct entirely floating terminals; this site option however would require a large distance in offshore direction and therefore will lead to relatively high costs and long transportation distances [Personal communication and interview RHDHV, 2015]. Hence although the final chosen location close to the land does not seem logical in the first place, it might be the best possible option in the existing limited situation. The nearby projects and companies in the surroundings of the JANCT (mentioned at the main issues) however also have ambitious plans to develop or expand in the future. These projects and companies will likely be influenced by the expansion of the new container terminals and therefore the possible impacts on the local environment should be taken into account during the design. Other important limitations of this location by the north east coastline are the existing pipelines coming from DUGAS to offshore area, several intakes/outfalls for DUBAL and DEWA along the coastline and the existing approach channel to the Jebel Ali port. The costs of relocating these pipelines and intakes/outfalls is extremely expensive, and in some cases may not be achievable. According to the ISPD framework, a basic understanding of the critical parameters of the location is required to select the most suitable site. The surrounding projects however were not planned under long term uncertainties: this results in future negative impacts on these projects, and an inflexible and limited situation for the JANCT. With the provided information and existing limitations, the framework agrees with the current chosen site for the JANCT.

Step IV **Develop alternative designs based on key values**

The JANCT is a very relevant project to indicate that flexibility and planning under long term uncertainties are very important factors during the port planning process. In figure **3-D** the current state of the JANCT is depicted: the red circle indicates the existing CT4/CT5 island. However compared to the final design in figure **3-B**, the islands CT2 and CT4/CT5 are further from parallel than is conceived in the final design. That is because the previous masterplan, dated from 2005, had a different angle for the terminal islands. The current existing island in figure **3-D** is the only island which is constructed of the previous design.

Figure 3-D Current situation JANCT with one existing island [Google Earth, 2015]

The previous design is provided in figure **3-E** and one of the major problems with this design is that the port layout was not optimal during intermediate stages. The construction of the terminals starts with the terminals closest to the coastline. With the second approach channel (light blue line) between the terminals, the construction of the later terminals would cause complex vessel maneuvering for the terminals closer to the coastline which are already in use [Royal Haskoning, 2007]. Hence during both the construction and operational phase at the same time, the port layout lacks flexibility. Flexibility is not only needed in the sense of the possibilities to expand the port in the future, but it is also important during the intermediate stages. This needs to be taken into account when designing the port.

Figure 3-E Previous masterplan layout from HPA [Royal Haskoning, 2007 and Google Earth, 2015]

Another important problem which is generally encountered during port design is the negative impact on water quality near the connection of the port to the mainland. As a port obstructs the water flow at its location, it is necessary to prevent stopping the water flow in order to maintain the water quality. The JANCT is not entirely connected to the shoreline in contrast with most ports. As a result the water flow is not completely disrupted and this has positive effects on the water quality. However the JANCT needs to be connected with the coastline for further transport of the cargo in the hinterland. This connection is the access bridge between CT2 and the CT4/CT5 island in figure **3-B**. The reason to build a bridge instead

of a dam is to have optimal water circulation. The bridge is relatively low and thus is not intended for shipping underneath but only to maintain and/or improve the water quality in that location. Port planners often tend to design a port fully attached to the land, but the ISPD framework recommends the connection by a bridge in the JANCT process.

***Step V* Test the alternatives / *Step VI* Evaluate the alternatives**
A total of 20 brief alternatives where developed, but eventually this number was put down to two alternatives. Including the previous masterplan provided in figure **3-E**, in total three alternatives are considered for further testing. These three are selected for the first modelling which is performed to discover the extent of the thermal and salinity impacts of the alternatives on the DUBAL plant and DEWA seawater intakes [DP World, 2009]. The modelling resulted in no significant differences in the impacts of all three alternatives and more modelling was performed to study the impacts of several bridge options (between CT2 and the CT4/CT5 island) on the Dubal plant and DEWA seawater intakes. These tests would also recommend changes of the bridge length (hence the opening of the water flow beneath the bridge) which may improve the local water conditions. Eventually one alternative is selected where the length of the bridge is minimized to the extent that the conditions at the seawater intakes of Dubal and DEWA were not compromised. This resulted in less construction costs and increases the shelter area provided at the CT2 berths.

***Step VII* Create final design**
The final design is designed in such a way that the existing pipe lines coming from DUGAS do not have to be relocated, it considers the existing approach channel and therefore costs are saved.

3.3.4 Lessons learned
This paragraph summarizes the lessons learned from the JANCT masterplan and development process. This includes an analysis as to where and to what extend this framework deviates from the ISPD framework and to what extent this difference could have influenced the existing JANCT masterplan and its current issues. The paragraph ends by selecting and motivating which aspects are selected for enhancing the ISPD framework. The differences between the JANCT process and the ISPD framework are treated along the order of the seven basic steps of the ISPD framework.

Step I – Assumed no significant differences.

Step II – Due to the fact that the JANCT is a port expansion instead of a new port project, a huge limitation is put on the choice for suitable locations. This shows that the success of the ISPD framework also depends on the category of ports: an expansion port has more limitations on the location choice compared to a new port, since an expansion is often located near the existing port. Due to this limitation, the selection of the current location of the JANCT would not have resulted in a different location choice.

Step III – After analysing the coastline and more inland areas of Dubai, it can be concluded that the masterplanning process of these areas is focused on short term objectives and did not integrate the existing projects and long term uncertainties of new projects. Although stakeholders made comments about the issues regarding nearby projects, no mitigation or solution is mentioned in the plans so far. Hence according to this research the use of the ISPD framework, with the early and active stakeholder involvement, would not have significantly influenced the results.

Step IV – Despite the present limitations, the JANCT is developed in such a way that the impacts were kept to a minimum: the existing pipelines were avoided and the same existing approach channel is used.

The layout also includes a bridge connecting the CT4/CT5 island with the shore. This improves the water flow between the island and land and hence improves the water quality there. This sustainable planning measure is recommended by the ISPD framework.

Step V – Assumed no significant differences

Step VI – Assumed no significant differences

Step VII – Assumed no significant differences

From the above it can be concluded that even if the planning process of the JANCT would be more according to the ISPD framework, RHDHV could not have significantly changed the resulting issues of the current masterplan. This is caused by the short term and the not-integrated long term masterplanning process of the entire coastline of Dubai and by the resulting limitations it brings to the JANCT process. This port therefore is mainly used to indicate the importance of an integrated masterplanning process under long term uncertainties in general and which negative impacts it could have when this is missing. A lesson learned from this process, is the somewhat unusual decision to attach the JANCT with the land by a bridge to benefit the water quality.

Actions to enhance ISPD framework

- **Offshore location or no complete port-land connection** – This lesson is more detailed than the lessons learned in the other two port examples, but since a fully land-based port design is so embedded in the traditional port design, I decided to put this more detailed lesson here and it should be a part of the possible solutions and possible impacts. Building a mainly land-based port is so common that most port planners are too careful to build the port in a more seaward direction or even offshore. As a result, the common issue of bad water quality in port basins will even increase due to bad water circulation at the end of the basins. ISPD acknowledges that it might be worth to consider (partial) seaward port development, in order to enhance the water quality inside the port basins. This sustainable planning measure should be considered more often by port planners and will be put in a table of possible planning measures. More benefits of an offshore located port according to Bakermans (2014) will be treated in Chapter **4** during the alternative development and can be found in the *Port of the Future* [Schipper et al., 2015].

3.4 Badagry Port Project

3.4.1 Introduction

Nigeria holds the largest economy in sub-Saharan Africa and is one of the world's largest oil manufacturer. Due to these enormous natural resources, Nigeria has undergone an exceptional growth during the last half century. Despite the improvements and upgrades to its port infrastructure, this immense growth in demanding capacity will outgrow the supplying capacity by 2017. This capacity shortage will be especially noticeable around the Lagos area, where today almost 85% of Nigeria's non-oil imports and exports are being passed [Royal HaskoningDHV, 2015]. Hence Badagry Port Development Limited (BPDL) has plans to construct a multifunctional port situated nearby Lagos. This project is also known as the Badagry Port Project (BPP). This new mega port should provide enough capacity for:

- Containers;
- Dry bulk & liquids;
- Ro-Ro;
- Oil & gas supply services;
- Logistics park;
- Free trade Zone.

The BPP aims to incite the sustainable economic development of Lagos and the rest of the Nigerian economy. The main competitive features for the port are that the multi-purpose facility provides the deepest water in West Africa and excellent hinterland connectivity. It will consequently solve the shortage of multi-cargo capacity and guarantee the quality infrastructure of the Lagos State to cater the growing West African markets in the nearby future [Royal HaskoningDHV, 2015].

The selected site of the Badagry Port is depicted in figure **3-F**: located midway between Lagos and Cotonou, nearby the city of Badagry. With exception of the F100 passing through the site, all infrastructure, utilities and hinterland connections will need to be constructed to support this project, turning the Badagry Port Project into a Greenfield development. In the current state, the masterplan is completed and waiting for permission in the tender process. The current concept masterplan is still being researched for any improvements [Royal HaskoningDHV, 2015].

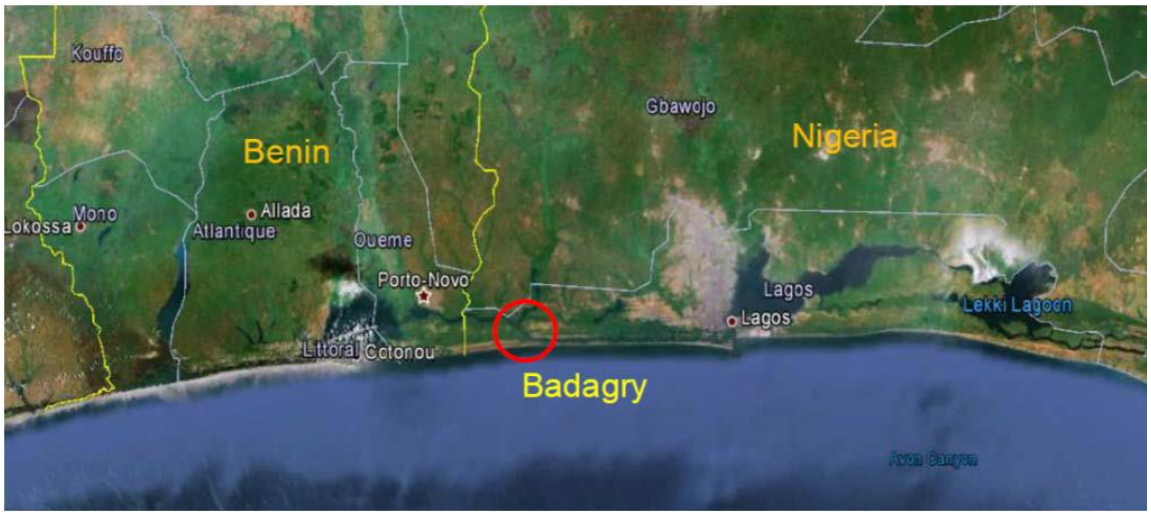
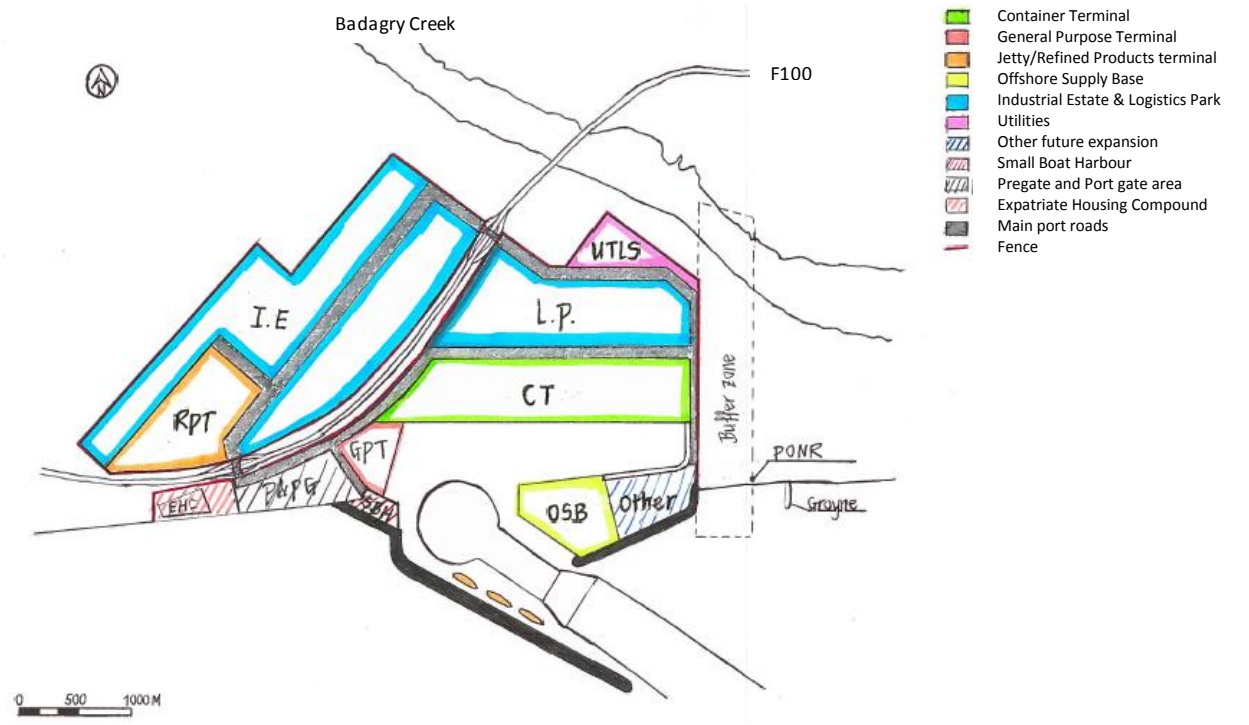


Figure 3-F Location of Badagry port [Royal HaskoningDHV, 2015]

3.4.2 Existing masterplan and its main issues

The existing proposed masterplan of the Badagry Port Project is depicted in figure **3-G** below. The boundaries of the selected site are the Badagry Creek along the north-east edge of the site, the F100 coastal highway along the north-west side and the beach to the south side of the site. The development of the port basin parallel to the coastline is based on the wish to not relocate the F100 coastal highway. The F100 now passes through the port area, resulting in the distribution of the terminals and facilities in two separate areas. The container terminal is by far the largest terminal and is aligned to the logistics park for more convenient operation. North of the port area there is allowance to create a potential barge terminal in the future. It is also assumed that a rail terminal will be constructed in the future which probably will be located north of the Creek: this requires a container shuttle from the container terminal to the rail terminal. East from the port, there is a 500 m wide buffer zone, which indicates the minimum distance between the port and Point of No Return monument. In order to protect this monument from erosion, a groyne will be placed east from it.



3-G Existing masterplan Badagry Port [Based on Royal HaskoningDHV (2015) but drawn in this format for this research]

Analysis of the area and consultation with RHDHV resulted in the following main issues which could be up to improvement for this masterplan:

- *Community resettlement* – At the proposed site location over 4600 inhabitants have to move elsewhere due to the arrival of the port. Their main issues are the loss of their own land and their employment due to the loss of coconut plantation and farm land. The port also might affect fishery in the Creek and the sea.

- *Coastal erosion* – The establishment of the Badagry port causes a disturbance of the long shore sediment transport, resulting in sedimentation and erosion respectively west and east of the port. The coastal erosion is critical for the historical Point of No Return (PONR) monument approximately 500 m east of the port. Badagry was a major slave outpost and market until the late 1800's. When slaves were sold, they had to walk the Slave Route, which is a track that leads from the Badagry Creek to the coastline. The PONR at the seaward end of the Route was the last stop before the slaves were shipped [Royal HaskoningDHV, 2015]. Since the PONR is a significant important reminder of this history, the erosion impacts on that coastal area should be minimised. The existing masterplan includes a sand retaining groyne at the eastern side of the monument. This however is not a sustainable solution: groynes prevent local erosion, but only relocate the erosion problem to a more downstream location. To solve this problem, yearly sand nourishment and maintenance dredging campaigns are included in the masterplan but this will result in frequent disturbance of the local ecosystems and/or provide less time and chances to build up new ecosystems.
- *Historical/cultural impact* – The cultural and historical significant PONR monument is located on the beach 500 m east of the proposed port. With a distance this nearby, the port development will undoubtedly have impact on the PONR.
- *Fresh water contamination* – The further inland the port develops, the larger the risk of salt seawater intrusion into the fresh water of the Badagry Creek. Currently the Badagry Creek can be considered as a fresh water system. Figure **3-G** shows the position of the port basin relative to the Creek. If the salty water in the basin comes in contact with the Creek, there would be a permanent change of the morphology resulting in a significant impact on the local environment.
- *High costs breakwaters* – One of the most expensive capital costs is the construction of the breakwaters. The breakwaters and the revetments are made up from approximately 6 million tons of rock which need to be imported from surrounding areas relatively far away. With this enormous amount of rock transported with trucks, the breakwaters will become a very expensive construction. Besides the financial aspect, the supply and transportation of rock also brings other issues such as a high demand on the market of rock supply (potentially abroad), the bad conditions of the roads and the high traffic intensity within Nigeria.

3.4.3 Port planning process

In this paragraph the port planning process of the BBP is elaborated and categorized according to the seven basic steps of the initial ISPD framework, in order to find out where and to what extend this process deviates from the ISPD framework. The flowchart of the overall port planning process of the Badagry Port is shown in figure **3-H**. The elements represented in red are a quick indication of the differences with the initial ISPD framework. It can be seen that the flowchart mainly shows differences in the beginning of the process and therefore the remaining steps in the process which do not show significant differences with the ISPD framework will only be briefly described.

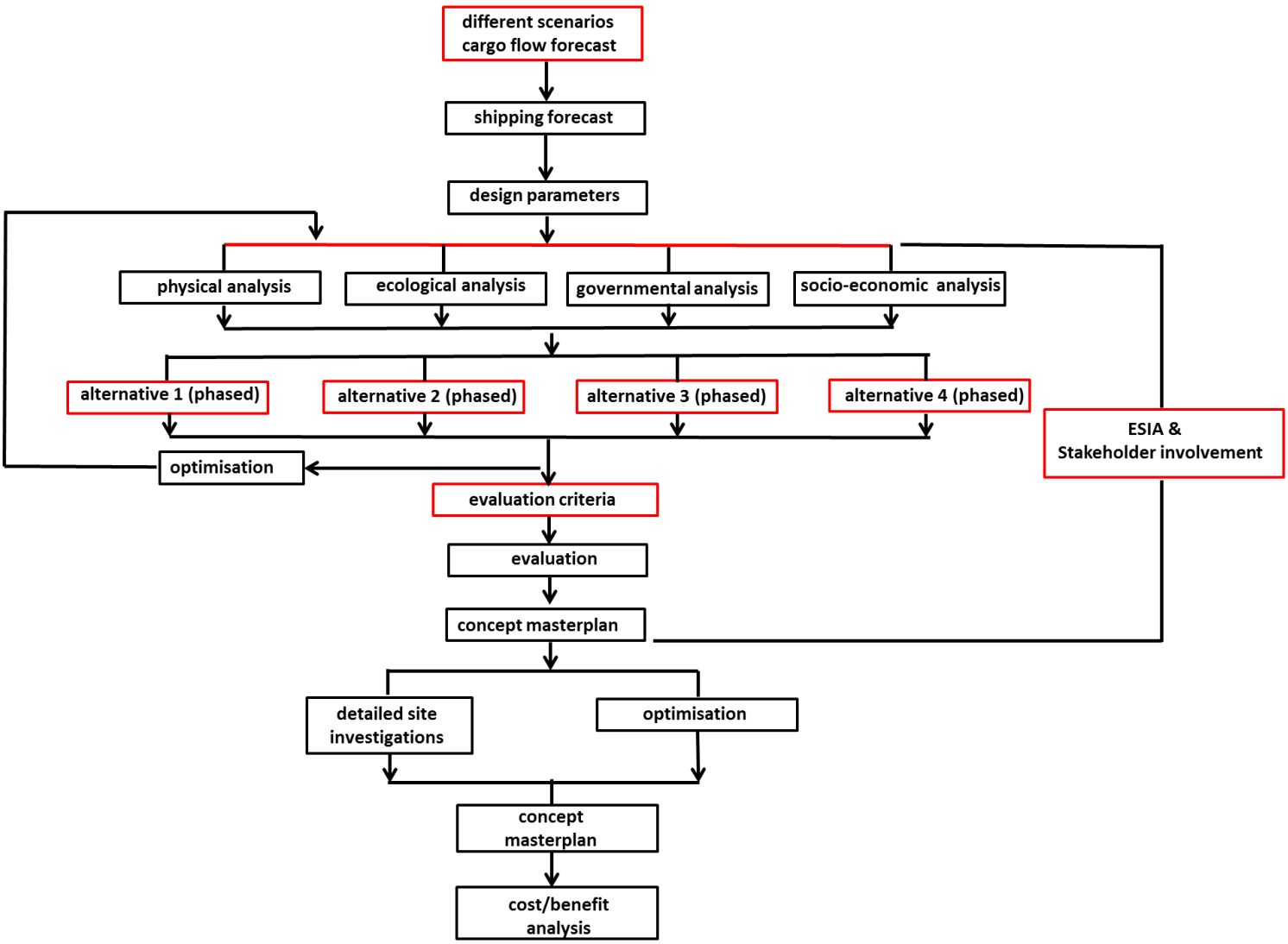


Figure 3-H Flowchart development process Badagry Port

The differences with the initial ISPD framework in short are as follows:

- Inclusion of different cargo flow scenarios for flexible future terminal use
- Lack of location choice by the same party
- Phased alternatives
- The evaluation criteria are specified after the alternatives were developed
- The EIA starts parallel with the analysis of the chosen location

Step I **Define project needs and objectives**

The port development process of the Badagry Port starts with the usual cargo flow and shipping forecasts, where after the port user requirements can be determined. An exception however can be detected with the forecasts for the future General Purpose Terminal (GPT). The areas and capacity reserved for

the terminal are based on the forecasts of the throughput for this terminal. These forecasts are from a long term perspective and therefore might be different in practice. In order to gain more flexibility for this terminal, beforehand there are three throughput scenarios set up for the GPT. Based on the proposed terminal layout, the GPT could potentially cater the following cargo volumes [Royal Haskoning-DHV, 2015]:

- Scenario 1: 100% General cargo
- Scenario 2: 50% General cargo / 50% RoRo
- Scenario 3: 100% RoRo

The consideration of different throughput scenarios is typical for a traditional port development process, but the BBP process brings the different scenarios to a higher level by considering them for different terminal use scenarios. This is an excellent example of *Adapting Port Planning* [Taneja, 2013] mentioned in paragraph **2.2.1**, by increasing the flexibility of terminals: with changing cargo flows, the GPT terminal keeps its function within the three specified scenarios instead of one scenario and it enables future generations to use the terminal for different purposes. Furthermore, during the determination of the design parameters of the BPP, the expected future sea level rise caused by climate change is also considered. Including long term uncertainties in the objectives is significantly recommended by the ISPD framework in order to create a more future-proof port.

Step II **Find physical suitable locations**
After the design dimensions are determined, suitable locations need to be found. In the BPP process however, the location of Badagry is already determined beforehand. BPDL has given the responsibility to Royal HaskoningDHV to undertake a feasibility study for the proposed new port development. This feasibility study starts after the location of Badagry is already determined, which means the undesired fact that another party was responsible for the location choice during the prefeasibility study. Hence this step of finding physical suitable locations is not presented in the development process of the Badagry Port by RHDHV. ISPD however emphasizes on the location choice as part of the design process performed by one main party as both processes are strongly connected.

Step III **Understand the systems and select most suitable location**
Continuing the process, another party evaluated several potential port development locations and Badagry eventually was selected as the most suitable location for the following reasons [Royal HaskoningDHV, 2012]:

- Proximity and accessibility to the existing main F100 coastal highway, with plans for upgrade;
- Immediate accessibility to the existing Badagry Creek as navigation channel, which allows for barge transport of containers between the new Badagry Port and the existing port of Lagos;
- Availability of adjacent land for future industrial and logistics area development, including a free trade zone; and
- Suitable ground conditions (based on a visual assessment).

The research for the most suitable port project location is very limited and the choice is mainly based on the economic aspect of port development; thus the new port location may be the most suitable from only an economic perspective. However this might not be the most suitable location based on the physical, environmental, governmental and social disciplines: this assumption can be supported by i.e. the community resettlement mentioned previously as one of the main issues of the existing masterplan, and

can bring resistance to the project which may result in higher costs. The location which initially seemed the most profitable, might not be that at all due to unknown knowledge. However, according to the ISPD framework this can be avoided, minimized or mitigated by a basic understanding of each potential location. Hence RHDHV should carry out initial research to get a basic understanding of the critical parameters of the physical, governmental, environmental and socio-economic disciplines for all potential locations. With the help of stakeholder involvement, it becomes clear what they value, what the opportunities and challenges of each location are and thus it shows which location has the most potential to find a balance between the values of multiple different stakeholders and the economic need of the hinterland. Only then a fully supported decision can be made for the most suitable location.

Although it is determined that the port will be built in Badagry, the exact final site was not decided yet. Figure **3-I** shows the two potential sites at Badagry for the new port development.

Figure 3-I Potential port development site options [Royal HaskoningDHV, 2015]

This is where the Environmental and Social Impact Assessment (ESIA) starts. ESIA is a tool to systematically examine and assess the impact on the environment and society resulting from the project development. However in the BPP process the purpose of the ESIA study is to abide by the environmental procedures of the Nigerian Authorities and with the social and environmental sustainability performance standards of the International Finance Corporation, in order to obtain environmental permits and funding approvals for construction of the port project [Royal HaskoningDHV, 2012]. This is not a good mind set, because the goal of the ESIA should be to avoid, minimize or mitigate the negative impacts on the environment, like in the ISPD framework.

The ESIA starts with the baseline study which exists of existing data collection and new surveys about the physical, environmental, governmental and socio-economic environment of the two potential sites. The analyses also include several trips to the site locations: during these site visits a walk-over survey of the project sites themselves and the surrounding potential affected areas is conducted. Contact should also be sought with stakeholders (e.g., governmental authorities, the public, and indigenous communities): for informing them and obtaining their input to capture their relevant wishes and concerns. This can be associated with discussions with local government officials and other stakeholders regarding potential effect on their situation, as this assessment is guided by policies, guidelines and processes of international agreements [Royal HaskoningDHV, 2012]. Once the baseline study is performed the potential environmental and social impacts resulting from the project are identified and their significance is evaluated. The more detailed the masterplan, the better these impacts can be identified. Therefore this procedure will continue till the masterplan is fully developed. When the impacts are known, it is possible

to come up with environmental and social mitigation measures for these impacts and management plans can be set up to implement these measures. An indication of the costs of these mitigation measures is also developed.

Based on all the collected information, the two sites are compared with each other based on the relevant environmental and social impacts. The main advantages of site option 1 are the excellent existing hinterland connections (road and barge), relative independence on development of infrastructure by other parties and sufficient adjacent areas for development of industrial and logistic area in the future. The biggest disadvantages however are the nearby presence of the valued PONR monument and the larger risks of fresh water contaminations due to the Creek [Royal HaskoningDHV, 2015]. Site option 2 on the other hand, has no clear boundaries and from a physical perspective there are less limitations. This site however also includes more communities and therefore will result in more community resettlement. In addition, with the construction of a port at site option 2 it is very likely that the F100 coastal high way needs to be relocated further inland. This will require more time and costs, but it also brings much more flexibility to the port design and any future expansion. As it becomes clear that this project very likely will result in community resettlement for both sites, it was necessary to prepare a Resettlement Action Plan (REP), parallel with the ESIA [Royal HaskoningDHV, 2015].

Because both sites have been assessed rather limited, no decision could be made and hence both site options are considered for the development of alternative layouts for the BPP. Therefore the selection of the preferred site option and selection of the preferred alternative are intertwined. ISPD advices to perform extensive research on both sites, because although this baseline study can be compared with step III *Understanding the systems* of the ISPD framework, the analysis in this process is too limited to really understand the system. With the help of stakeholder analysis, the set of opportunities and challenges affecting the BPP on each site location becomes clear and it would be possible to conclude which site is the most suitable. In the BPP development process, stakeholder involvement is regarded as very important because Badagry is located in an area with safety risks (figure **4-B**) and resistance of the local communities is not desired [Royal HaskoningDHV, 2015]. However most communication regarding the port is focused between only BPDL, terminal operators and suppliers, which are seen as the main stakeholders. According to other stakeholders (interest groups, communities etc.) there is no clear communication involving them. In the ISPD framework all the involved stakeholders should be taken into account during the process as much as possible.

Step IV **Develop alternative designs based on key values**

So alternative layouts are developed on two different site locations: three alternatives are located at site option 1 and a fourth alternative is located at site option 2. The four alternatives are first of all designed based on the wishes of the clients [Royal HaskoningDHV, 2012]. In a process of optimisation they are revised concerning the wishes of the other stakeholders as well. This process of optimisation is relatively long and could be avoided by prioritizing the wishes of all stakeholders (obtained from the baseline study) in the form of key values. Once the port planner develops the alternatives based on the key values, he/she can confirm from the start that all relevant stakeholders are structurally involved in the alternatives and less optimizing is necessary.

The BPP has a phased development and consists of four phases: initial development (operational 2020), medium term (operational 2028), medium to long term (operational 2034) and the long term development (2040). Since the time period of the second till fourth phase still need to be confirmed in the future, the port planner has translated this phased development in an initial and long term port development layout for all four alternatives. Phased development is in line with *Adaptive Port Planning* which

enables future generations to adapt the current masterplan for their own use [Taneja, 2013]. Since the port lay-out can still be adapted under long term uncertainties, the flexibility of the port increases for future use.

Step V **Test the alternatives**
While the four alternatives are being optimized, more modelling and study is performed. When more knowledge becomes available, the alternatives are being tested on their feasibility. If an element of an alternative is not feasible or a better alternative is found, then a feedback optimization loop can be drawn back to the environmental analysis. When new knowledge is available, the alternatives can be optimized till the point the port planner is content and decides they are ready for the final evaluation.

Step VI **Evaluate the alternatives**
After the creation of the alternative layouts for the Badagry Port Project, a MCA is selected as the evaluation tool which provides a good assessment of the alternatives based on different criteria. The evaluation criteria are determined after the development of the alternatives, it however makes much more sense in the ISPD framework to use the prior defined key values as the evaluation criteria. Evaluation criteria are aspects of the port project which are considered the most significant by relevant stakeholders and this is exactly what the key values represent. The sensitivity of the outcome of the MCA is tested with a sensitivity analysis, which resulted in one alternative with the highest score. This alternative is recommended for further optimisation.

Step VII **Create final design**
The evaluation of the alternatives resulted in one recommended alternative. This alternative is optimised based on several detailed modelling results. The end result is a detailed conceptual masterplan.

3.4.4 Lessons learned
This paragraph summarizes the lessons learned from the BBP masterplan and development process. This includes an analysis as to where and to what extend this framework deviates from the ISPD framework and to what extent this difference could have influenced the existing BBP masterplan and its current issues. The paragraph ends by selecting and motivating which aspects are selected for enhancing the ISPD framework. The differences between the BBP process and the ISPD framework are treated along the order of the seven basic steps of the ISPD framework.

Step I – The BBP process considers long term uncertainties, in the form of climate change and different cargo flow forecast scenarios for flexible future terminal use, during the determination of the design parameters. Since a sustainable framework aims for planning under long term uncertainties, it is of significant importance to include aspects such as climate change aspects and flexibility in the project objectives to develop a future-proof port. These objectives are strongly recommended in ISPD.

Step II – The location choice is not part of the design process in the BBP process, while this is considered the basis of the ISPD framework and hence this can be seen as the biggest difference between the two frameworks. The ISPD framework emphasizes on the significant aspect that one party should be responsible for the design process including the location selection to assure that the same values are considered. In this way, during the pre-selection based on physical potential locations, the main issues *coastal erosion* and *fresh water contamination* could be avoided by selecting e.g. a rock environment or a location far away from fresh water sources.

Step III – The location choice, which was outside the scope of the BPP development process by RHDHV, is based on brief knowledge and economic objectives. If the entire system was analyzed for all potential locations, then it might result in another location more suitable concerning all disciplines. The main issues of the existing masterplan *community resettlement, coastal erosion, historical/cultural impact, fresh water contamination and high costs breakwaters* might have been avoided or minimized. Furthermore the baseline study of the two site options only resulted in a brief understanding of the environmental system and there was no clear communication involving other stakeholders besides BPDL, the terminal operators and suppliers. Active involvement with all stakeholders in the ISPD framework might result in less resistance of the local communities.

Step IV – After the location study, the values of the stakeholders were not prioritized in the form of key values which resulted in a long optimisation process of the alternatives. The reason for more initial research in the ISPD framework is to give strong foundation and a smoother process for decisions in later stages. If more initial research was performed and prioritized according to the ISPD framework, then developing the alternatives becomes more structured as it enables the port planner to mainly focus on the key values which represent the most significant values of the stakeholders. With more focus and less optimization, the BPP process could have been faster in this step. A positive element of the BBP process is the phased development of the alternatives. This measure is in line with Taneja's *Adaptive Port Planning* [2013] because it brings more flexibility to the terminals when unexpected scenarios happen in the future. This results in a more future-proof port and therefore it should be added to the ISPD framework.

Step V – No significant differences

Step VI – The evaluation criteria for the MCA are only determined in this step of the BBP process. Since the alternatives are developed before these criteria are known, it would be an unequal evaluation as not all alternatives are based on the same criteria. In the ISPD framework the alternatives are developed based on the key values, which are also used as the evaluation criteria for the MCA. By using this aspect of the ISPD framework, the evaluation of the four alternatives would be more unbiased (till a certain extent, since the MCA is rather subjective on its own: see paragraph **2.6**).

Step VII – No significant differences

From the above it can be concluded that changing the biggest differences between the BBP process and the ISPD framework, i.e. the location choice as missing part of the design process and the limited environmental research of the locations, might have avoided or minimized the main issues of the existing masterplan significantly. Positive elements found in the BBP process were mainly measures which are in line with *Adaptive Port Planning* to plan under long term uncertainties and therefore to make the port more future-proof.

Actions to enhance ISPD framework

- **Adaptive planning strategy –**Port planning under long term uncertainties is already briefly mentioned in paragraph **2.3.2** with *Adaptive Port Planning* from Taneja (2013). In the BBP process, multiple examples of adaptive planning are found in several stages of the process. Therefore a strategy is required to identify the uncertainties and to develop measures to increase flexibility of port projects. This adaptive planning strategy is based on Taneja's *Adaptive Port Planning* (2013) and is integrated throughout the entire port planning process. *The Flexible Port* includes a questionnaire which helps the port planner to identify flexibilities in projects [Taneja, 2013,

P.89, table 4.5]. Important flexibility measures which always should be implemented are adopting different shipping forecast scenarios and phased development. Since these measures are considered of significant important which should be adopted in every planning process, they are specifically mentioned below to enhance the ISPD framework.

- **Different shipping forecast scenarios** – In order to create more flexibility in ports on future terminal use level, it is encouraged to not limit the shipping forecast to only one scenario. Two or three different forecast scenarios would already be sufficient to increase the flexibility in terminal use. When different forecast scenarios are adopted, the port lay-out can be designed in such a way that with unexpected future changes, the port is still capable to use the terminal for different purposes. The more different scenarios the lay-out of the port can adapt to, the more flexible the port is. Too many scenarios however would lead to unnecessary high costs.
- **Phased development** – Ports are part of long term planning and because of the long time span, it is essential to plan under long term uncertainties. A port lay-out needs to be divided into several phases: the long term masterplan is based on the cargo flow forecast before the port is constructed, but this original long term forecast should be checked again as short term cargo flow forecasts are much more accurate. Therefore the port lay-out should be developed in phases: for every new phase a short term cargo flow forecast should be predicted and hence the port lay-out can still be adapted in case of any changes in the original long term forecast.
- **Start ESIA parallel with planning process** – In traditional processes the ESIA is only performed after the masterplan is known. However the strategy of *1. Avoid, 2. Minimise, 3. Mitigate/Compensate* the impacts, cannot adequately be implemented anymore as only minimising and mitigating measures can be performed during this stage. Hence the process of ESIA should be performed parallel to the planning process and the assessment should already start during the baseline study which can be used for the purpose of the ESIA as well. In this way the potential impacts of every aspect will be seen along the entire developing process and while developing the alternatives these impacts can be avoided first before minimisation or mitigation of impacts needs to take place. This is actually also part of the Adaptive planning strategy.

3.5 New Doha Port

3.5.1 Introduction

The Government of Qatar, represented by the New Doha Port Project Steering Committee (NDPP-SC), is currently relocating the country's main commercial port from the centre of Doha to a new location approximately 25 kilometres south of the city. The New Doha Port (NDP) will replace the existing port and is located south of the town of Al Wakrah and north of Mesaieed Industrial City, as indicated in figure 3-J. Additional development to the NDP has also been planned by the Government of Qatar: the new Industrial Canal for the Qatar Economic Zone 3(QEZ3) will be located north of the NDP location and the new base for the Qatar Emiri Naval Forces (QENFB) is located south of the NDP site. These additional developments however are considered as separate masterplan studies and will not be covered in this paragraph [WorleyParsons & Royal HaskoningDHV, 2013]

The NDP is a major investment in the future economy of Qatar and as world-class facility its vision is [WorleyParsons & Royal HaskoningDHV, 2013]:

- To cater the expanding future trade requirements for Qatar up to 2030 and beyond, including to act as a stimulant for the development of Qatar's export industry;
- To greatly compete with ports in the region to serve the wider Gulf market and
- To assist the progress of market entry by global port operators and to support counteracting dominant regional port industries.

The port planning and development will aim for the following keystones (literally adopted from WorleyParsons and Royal HaskoningDHV [2011]):

- *Efficiency and Reliability*
- *Flexibility & Future Proofing*
- *Sustainability, Safety & Security*
- *Architectural Identity*

The aim is to follow these leading keystones throughout the entire design phase and even beyond, where they also should be adopted during the construction and operational phase by the future Port Authority, terminal operators and management companies and terminal operators

The construction of the New Doha Port is divided into three phases. At current state, the NDP is in the middle of the construction phase I [Royal HaskoningDHV, 2015].

Figure 3-J New Doha Port Location [WorleyParsons & Royal HaskoningDHV, 2013]

3.5.2 Existing masterplan and its main issues

The existing proposed masterplan of the NDP is depicted in figure **3-K** below. The NDP is an inland port with a Y-shaped basin. This design has the advantage over a linear basin because the shorter length of each arm, reduces the vessel transit times. The port is mainly focused on container transport and planning, while it still provides for other types of marine transport and services. Another important element for the overall development is the presence of a logistics support area. The logistics area is mainly supporting port-related businesses and hence this area is surrounding the port. Further it is also assumed that a new highway will be constructed along the western boundary of QEZ3 (north of the NDP) which will be the primary access to the port. The masterplan also includes a proposed rail terminal in the future, linked to the proposed Gulf Cooperation Council railway which connects all the surrounding countries. This layout is designed in such a way that further expansion beyond 2030 is also possible at the areas reserved for this purpose. It is not clear yet what expansion will occur, thus this area can be used for both the port itself (expansion of the basin(s)) and for the adjacent hinterland (expansion of port-related industries). Furthermore a buffer zone is implemented around the port area in order to minimise the environmental impact.

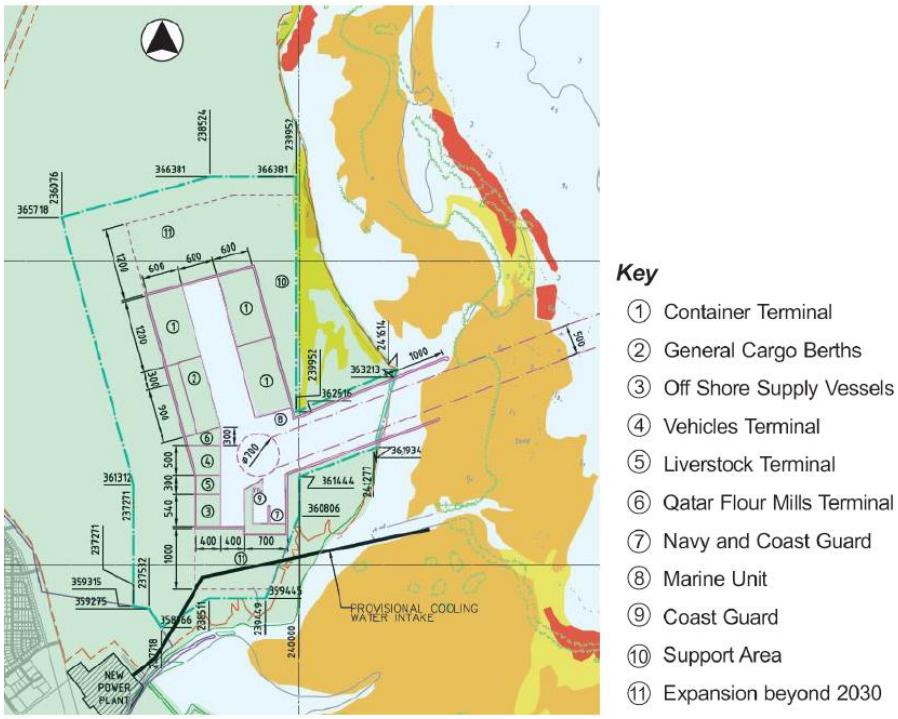


Figure 3-K Masterplan New Doha Port

Not many significant issues could be detected which are caused by the NDP masterplan itself, due to its location at an empty site with no communities living in the very near vicinity. But it should be mentioned that issues still might be present which are caused by masterplans of surrounding projects such as the Qatar Economic Zone 3. This section however only treats the NDP and the following relatively small issue could be found for this masterplan which is not up to improvement:

- *Small loss of coastal lagoon* – The access channel will go through ecological sensitive area (see figure **3-N** and inevitably will result in the loss of lagoon habitat. The reduction of the impact on the lagoon and its loss is essentially unmitigatable. However the magnitude of this impact should be seen in perspective: the loss of lagoon area is already kept to a minimum and can be

considered relatively small. Since the government is determined to build a port in this study area, the only solution to avoid this loss is to abandon the port project.

At first sight, its seems quite questionable to analyse the NDP masterplan and process since few issues can ben found. However if this process, which results in what seems a port with few major negative impact, significantly deviates from the ISPD framework then relevant lessons might be learned from this practical example to enhance the framework.

3.5.3 Port planning process

In this paragraph the port planning process of the New Doha Port is elaborated and categorized according to the seven basic steps of the initial ISPD framework, in order to find out where and to what extend this process deviates from the ISPD framework. The flowchart of the overall port planning process of the NDP is shown in figure 3-L. The element represented in red are a quick indication of the differences with the initial ISPD framework. It can be seen that the flowchart mainly shows differences in the beginning of the process and therefore the remaining steps in the process which do not show significant differences with the ISPD framework will not be discussed.

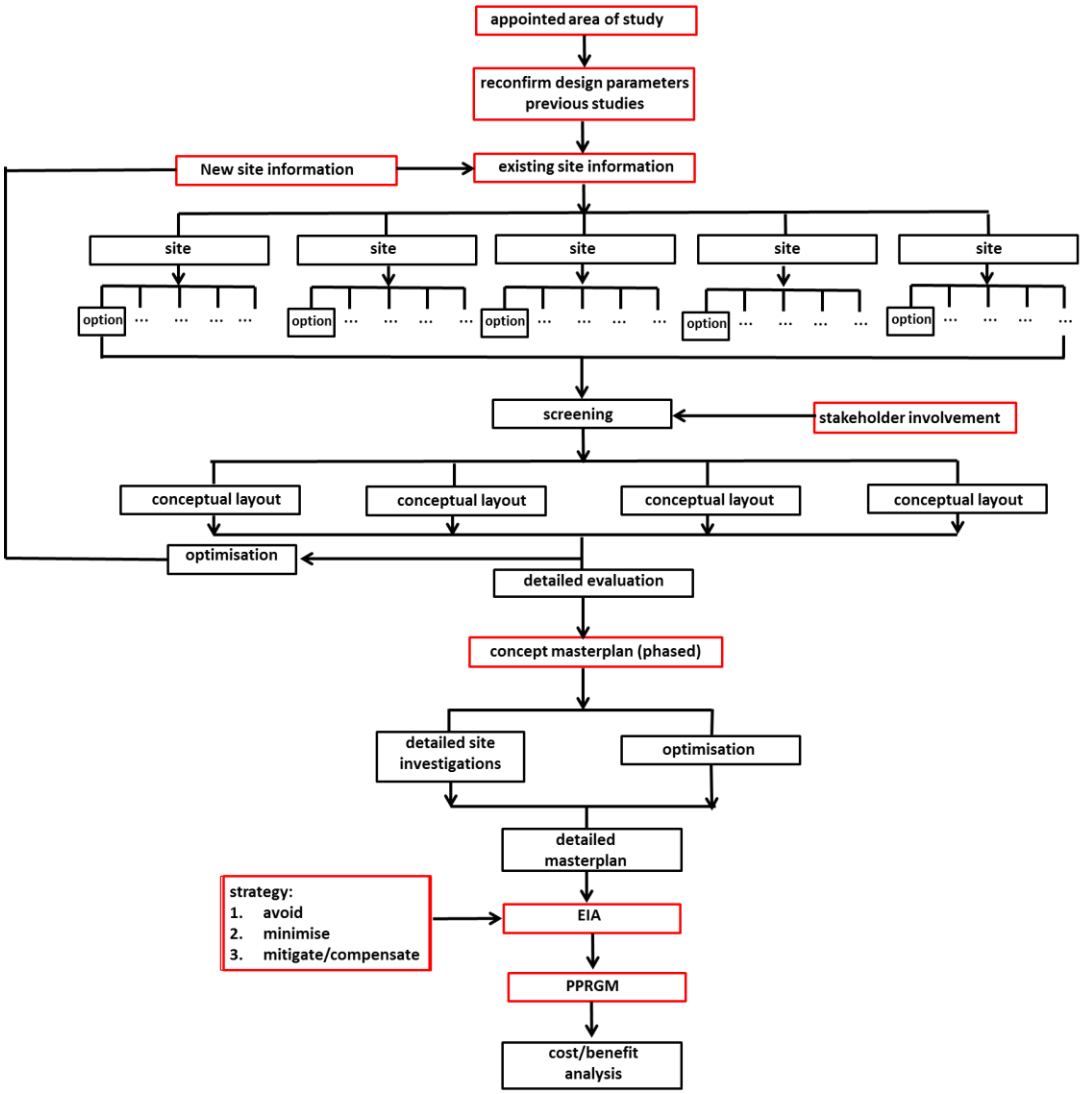


Figure 3-L Flowchart development process NDP

The differences with the initial ISPD framework in short are as follows:

- New area of study is last-minute appointed by another party: this resulted in time constraints for new location analyses and thus existing data is used, and investigations will be performed later for their reconfirmation
- Phased conceptual masterplan
- The EIA strategy is to (1) avoid, (2) minimise, (3) mitigate: (1) avoid however is not possible anymore if the EIA is performed after the detailed masterplan
- Inclusion of rather late public stakeholder analyses

Step I **Define project needs and objectives**

Originally the consultancy firms Scott Wilson and PSA were appointed the validation of the design of the proposed port located at a different location and the arrangement of the tendering and awarding for the follow-on consultancy for Engineering Project and Construction Management (EPCM) services. Cargo flow forecasts were performed to determine the port user requirements for the original location. Since the new location was chosen in a relative short time span, the same design parameters could be used after reconfirmation [Scott Wilson and PSA, 2007]. An interesting element of the design parameters is the aim for the keystones *Efficiency and Reliability*, *Sustainability, Safety & Security*, *Flexibility & Future Proofing* (see paragraph **3.5.1**), which can be seen as project objectives. The last objective is in line with the *Adaptive Port Planning* [Taneja, 2013], to plan under long term uncertainties; the effects of these objectives can be found in later stages. The ISPD framework would not have carried out this step significantly different.

Step II **Find physical suitable locations**

Due to sudden change of location by the government of Qatar, the new task was to select a new site for the NDP, in the area south of Doha between al Wakrah and Mesaieed, and to give recommendations on the preferred location and the conceptual layout. In this case the government already assigned the study area for the proposed port. The entire 18 km long coastal area was visited and the five suitable site options in figure **3-M** were identified as potential site options based on visual assessment.

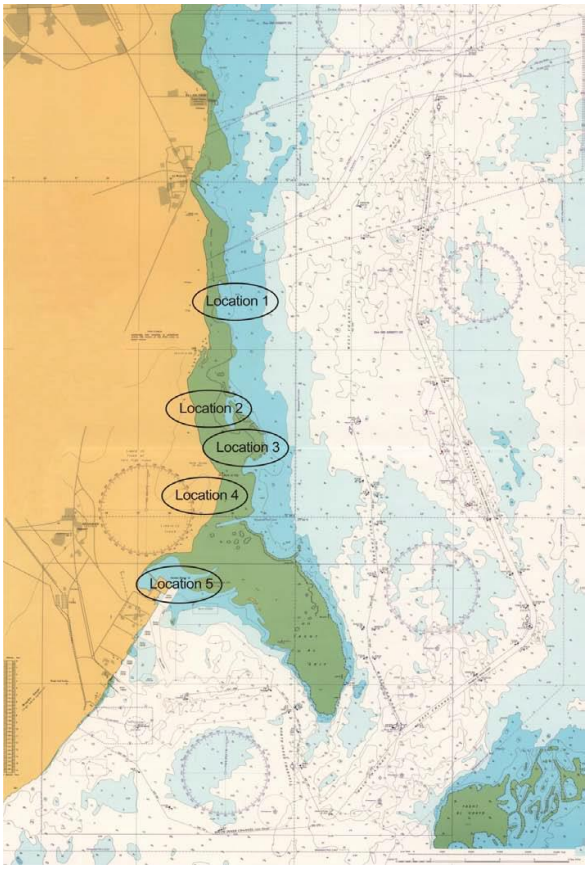


Figure 3-M Suitable site options New Doha Port

In the ideal situation with the ISPD framework, the port planner should select this study area him/herself based on the physical, ecological, governmental and socio-economic impacts of the location on the port. Location choice by the government however is an often seen situation in Qatar and due to this standard limitation there might be no other outcome with the implementation of the ISPD framework.

Step III **Understand the systems and select most suitable location**

After the change of location, it was recognized that the site investigation data for the new site could not be performed before the given deadline and therefore assumptions had to be made based on existing information till confirmatory investigations could be completed in later stages [Scott Wilson and PSA, 2007]. New investigations are scheduled in a later stage to obtain more up-to-date environmental information. With this new obtained knowledge the previous assumptions could be confirmed or adjustments could be made if necessary. This order is obviously not recommended, but due to the sudden change of location and the standing deadline, this was the most suitable decision of the port planner according to the ISPD framework.

Each of the five site options has its (dis)advantages and the choice of the most suitable location is strongly depending on the relation of the port with the surroundings. Figure **3-N** shows the possible impacts of the proposed NDP on the surroundings. After the relations with the environment are known, a long list of 25 different site options from inland to offshore are developed on these five suitable sites. An interesting aspect is that offshore locations are also considered besides the more traditional inland ports. According to the ISPD framework, offshore locations would require less maintenance dredging activities and the environmental sensitive coastal areas (figure **3-N**) would be avoided. This long list is coarsely screened based on criteria including cost, environmental impact, interface with adjacent facili-

ties, land and marine transport links and construction risks. During this site selection a number of stakeholders were involved to discuss the preferred site for the port. Although the consideration of the stakeholders in Qatar did not play a critical part, it is still highly recommended by ISPD to consider them during the site location selection process. The opportunities and concerns specified by the stakeholders, might have provided relevant information about a location from another perspective. This coarse screening resulted in four remaining options which are selected for more detailed optimisation. Since each of the site options also has its own layout, the development of the alternatives goes hand in hand with selecting the preferred site location.

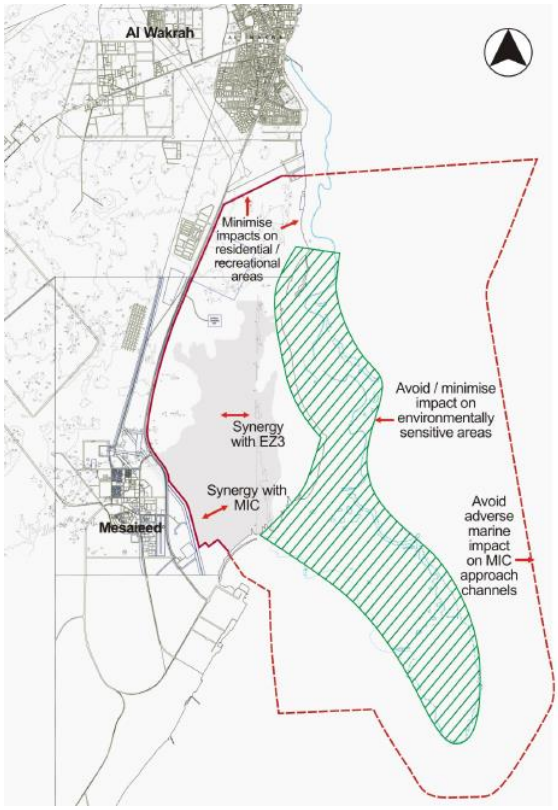


Figure 3-N Possible planning impacts of NDP [Scott Wilson and PSA, 2007]

Step IV **Develop alternative designs based on key values**

The four remaining site options were considered for further detailed development in the form of the port layout. The development of the layout is based on the project objectives, prior defined as the key stones of the NDP project. First of all, several designs have been considered: this process does not only consider the common shaped basins (i.e. linear) but also the more uncommon Y-shaped basin where the terminals are located around two basin (see figure **3-K**). The reasoning behind this design is to minimise the amount of dredging and the vessel travel distance within the port. Hence with the Y-shaped basin, the project objective, *Efficiency and Reliability,* has been taken into account. ISPD recommends considering more possible (uncommon) planning measures, because they might bring along significant economic benefits such as efficiency. The framework further recommends possible planning measures to increase the flexibility of the port in line with *Adaptive Port Planning*, by planning under long term uncertainties. The NDP is designed for a time period up to 2030 including an expansion area to meet the growth requirements for Qatar beyond this time period. Since it is difficult to forecast the developments in shipping, cargo handling and logistics for this long period with precision, the main infrastructure is designed in such a way that in case of possible changing users and incorporation of new technology, the terminals are still functional. For example, the NDP is mainly focused on the expected growth of con-

tainer traffic: if this forecast will deviate from the real cargo flow, then the existing layout is still flexible as the GC terminal is located on the western side of the port basin, so the flexibility of the non-container operations in the NDP is maximized. This is partially possible due to the phased development, which also becomes more flexible by the design of the Y-shaped basin. By dividing the construction of the port in three phases, the masterplan can still be adapted when in the future more precise (short term) forecasts are made. Therefore phased development provides maximum flexibility and can minimise early and (and possibly fruitless) investments. These measures agree with the project objective *Flexibility & Future Proofing* and with the *Adaptive Port Planning* of Taneja (2013) mentioned in paragraph **2.3.2**, to increase the flexibility of ports and enable them to keep their functions despite changing conditions. Possible solutions to make a port more future-proof can be taken at different levels of a port infrastructure system, but the above mentioned planning measures are on terminal level. This step is an excellent example of Adaptive Port Planning and the ISPD framework would not have executed it significantly different.

Step V **Test the alternatives /** ***Step VI*** **Evaluate the alternatives**

As is mentioned before, after a brief screening of the 25 different site options there is one final evaluation of the four remaining conceptual designs. The evaluation was based on several criteria including a refined cost estimate, which resulted in two conceptual plans. These two were presented and the client eventually did not select the cheapest alternative with greater volume of surplus fill, but the alternative with the least environmental impact. This decision was made because in this case there is sufficiently high value placed on preserving the continuous coastal strip to the north and it shows a good example that one of the project objectives, i.e. *Sustainability, Safety & Security* is considered by the client as well. It shows that sustainability in ports is not only determined by the development process and the port planner, but also depends on the final choice of the client. This conceptual masterplan was approved by an Emiri Decree and has been fixed for the purposes of the masterplan.

Step VII **Create final design**

Following the choice of the location and masterplan, the NPP-SC also performed a number of site investigations for further optimization of the conceptual masterplan. This is the point where RHDHV came in the picture. The task of RHDHV is to further develop the conceptual masterplan in more detail which requires the incorporation of the input of all involved stakeholders. An initial masterplan for the port was finished in early 2009 which was updated annually. This means that in order to work with updated information, new short term cargo flow forecasts and other investigations had to be performed.

After the initial masterplan was developed, the Ministry of Environment (MoE) made a request to include the perspective of the public in the socio-economic branch of the Environmental Impact Assessment (EIA) study regarding the NDP. The NDPP-SC has given the instruction to conduct a Public Participation Representative Group Meeting (PPRGM). The participating group is consisting of Qatari nationals who represent the views and concerns of the country regarding the NDP. This PPRGM only took place after the masterplan was designed. Beforehand a structured questionnaire regarding the NPD project has been send to the stakeholders with an aim to understand their perceptions and/or concerns about the NPD project. The outcome of the PPRGM and the questionnaire are that the majority of the stakeholders is in favour of construction of the NDP. However the key concerns which resulted from the meeting and questionnaire were inevitable negative environmental impact, uncomprehensive communication towards local inhabitants, poor water circulation in the dead ends of the basins resulting in waste/floating debris issues within the harbour, and in addition, attention was drawn to improve the existing infrastructure and connectivity between the NDP site and surrounding areas. All stakeholders also agreed that the PPRGM is a good initiative, but they also conclude that it would be more profitable if these meetings are hold during the planning phase. The ISPD framework agrees with this and recom-

mends that the PPRGM should already be performed during the selection of suitable locations. However the question is if an earlier implementation would have a significant difference since not much is done yet with this information.

After the initial masterplan was developed, an Environmental Impact Assessment (EIA) is also performed. And EIA is performed to understand the potential impact of the project on the surrounding environment and in the NDP this assessment has only started with the baseline surveys of the entire environment after the masterplan is known. However to preserve and protect the environment as much as possible, the following strategy should be followed in this specific order of priority (literarily adopted from COWI [2011]):

1. Avoid areas of high environmental value where possible;
2. Minimise adverse impacts through the application of mitigation measures (in the design, planning, construction, and operational phases); and
3. Compensate for significant un-avoidable adverse impacts.

This strategy and the potential impacts should already be implemented and considered during the development of alternatives in the planning phase instead of after the masterplan is known. This however did not significantly influence the masterplan because there were no major impacts on the environment. The only major impact would be the impact on a small part of the mangrove area and coastal lagoons. This however could not have been avoided since the government of Qatar already determined this study area. The only reason to avoid this is to abandon the project.

3.5.4 Lessons learned

This paragraph summarizes the lessons learned from the NPD masterplan and development process. This includes an analysis as to where and to what extend this framework deviates from the ISPD framework and to what extent this difference could have influenced the existing NDP masterplan and its current issues. The paragraph ends by selecting and motivating which aspects are selected for enhancing the ISPD framework. The differences between the NDP process and the ISPD framework are treated along the order of the seven basic steps of the ISPD framework.

Step I – The NDP process used the cargo flow forecasts which were previously made, because there were time constraints. ISPD agrees if this limitation is present, that the best possible solution would indeed be the reconfirmation of the previously made forecasts if they are still relatively recent. The inclusion of objectives where long term uncertainties were considered, proof to be very fruitful in later stages of the process.

Step II – Although the government initially selected the study area of the proposed port, the final site selection and design process were performed by the same party. The only main issue found in this masterplan is *the small loss of coastal lagoon*, caused by the fact that location appointment by the government is common in Qatar. Due to this limitation, the ISPD framework most likely also would not have avoided the loss of this high valued flora and fauna.

Step III – Due to the sudden change of location for the proposed NDP, there were time constraints for new investigation of the locations. In the NDP process the existing information was used until new investigation could confirm them. Due to present limitations ISPD agrees with the decisions made, but certainly does not recommend this. However no significant negative effects of this are noticeable, due to the fact that most existing data is still valid and no social analysis was needed as there are no people

living in or near the project area. The NDP process also considered several offshore locations which is strongly recommended by the ISPD, especially for container terminals which require a deep water depth for their vessels.

Step IV – During the development of the layout alternatives, flexible and sustainable solutions were developed and the alternatives where developed in phases which makes the masterplans more future-proof. ISPD recommends both of this. By taking a less common basin shape, the port resulted in increased efficiency and flexibility.

Step V – No significant differences

Step VI – After the evaluation, the client in this case chose the alternative with the least ecological impact instead of the alternative with the lowest costs. This shows that a sustainable port does not only depend on the development process and the port planner, since in the end it is the client who has the deciding role to select the preferred masterplan. This means that if the ISPD framework is followed in this case without governmental limitations, it still would be possible to result in a less sustainable port if the client does not value sustainability. In this case however, the client significantly values the environment, resulting in a more sustainable port compared to the other more expensive alternative.

Step VII – Only after the initial masterplan was known, the PPRGM and EIA were held. The ISPD framework agrees with both actions, but it is recommended to perform them in a much earlier stage: the PPRGM should already be held during the selection of suitable locations and the EIA should already start during the analysis of the locations. In the NDP process however, the late implementation of the PPRGM and the EIA did not significantly influence the resulting port because the project location was not inhabited and hence no major impacts could be detected.

The biggest difference with the NDP process and the ISPD framework is that the NDP framework missed a lot of initial research due to time constraints. The differences with the ISPD framework however did not have a great impact on the resulting masterplan, because the existing site information and assumptions made were valid and because the chosen location is an empty area which resulted in mostly minor impacts. This means that the NDP process does not significantly deviate from the ISPD framework, because even if the ISPD framework was implemented, in this case the process could not be changed due to the present limitations of the location and country itself. What this practical example shows is that there will always be limitations present with port development and these limitations need to be accepted during the process. However it is still possible to develop a port with no significant issues, as long as the port planner makes responsible decisions along this limited ISPD framework. It shows that despite the limitations subjecting the ISPD framework, a sustainable port still may be created. This is also mainly caused because the NDP process has an excellent incorporation of long term flexibility in line with the *Adaptive Port Planning*. Hence the positive elements found in the NDP are connected with APP, and are translated in the early identification of possible planning solutions and their impacts on the environment.

Actions to enhance ISPD framework

- *Possible planning measures and impacts strategy* – In order to prevent expensive port adaptations, decrease in cargo flow and loss of competitive position, ports need to become more flexible in meeting future uncertainty demands. Before developing the layout alternatives, possible planning measures on terminal level need to be developed as part of the *adaptive planning strategy* (para-

graph 3.4.4) based on Taneja's *Adaptive Port Planning* (paragraph 3.4.4) which considers long term uncertainties to increase the sustainability and flexibility of the port. To focus this search for flexible and sustainable planning measures, these measures should be based on the predefined key values, which represent the most significant values of involved stakeholders. Furthermore, in order to perform an early brief impact assessment as part of the final Environmental Impact Assessment (EIA), it is recommended to include the possible impacts of the planning measures as well. The description of these impacts cannot be too detailed in this stage, but it should help in the consideration of the alternatives. When the possible impacts are known it is also possible to find the flexibility of these planning measures. This brief impact assessment definitely should not be considered as a replacement for the EIA, which still needs to be performed after the development of the detailed masterplan.

3.6 Enhanced framework

The learned lessons in the three analysed port planning processes are implemented in the initial ISPD framework, resulting in a more concrete and enhanced Integrated Sustainable Port Design framework. A flowchart of this enhance ISPD framework is shown in figure 3-O. The additions to the initial framework are encircled in red. The differences with the initial ISPD framework in short are as follows:

- ESIA and stakeholder involvement walk parallel with the design process
- Brainstorming possible planning solution based on the key values, and their impacts
- Consideration of different forecast scenarios and phased developed of alternatives for flexible terminal use

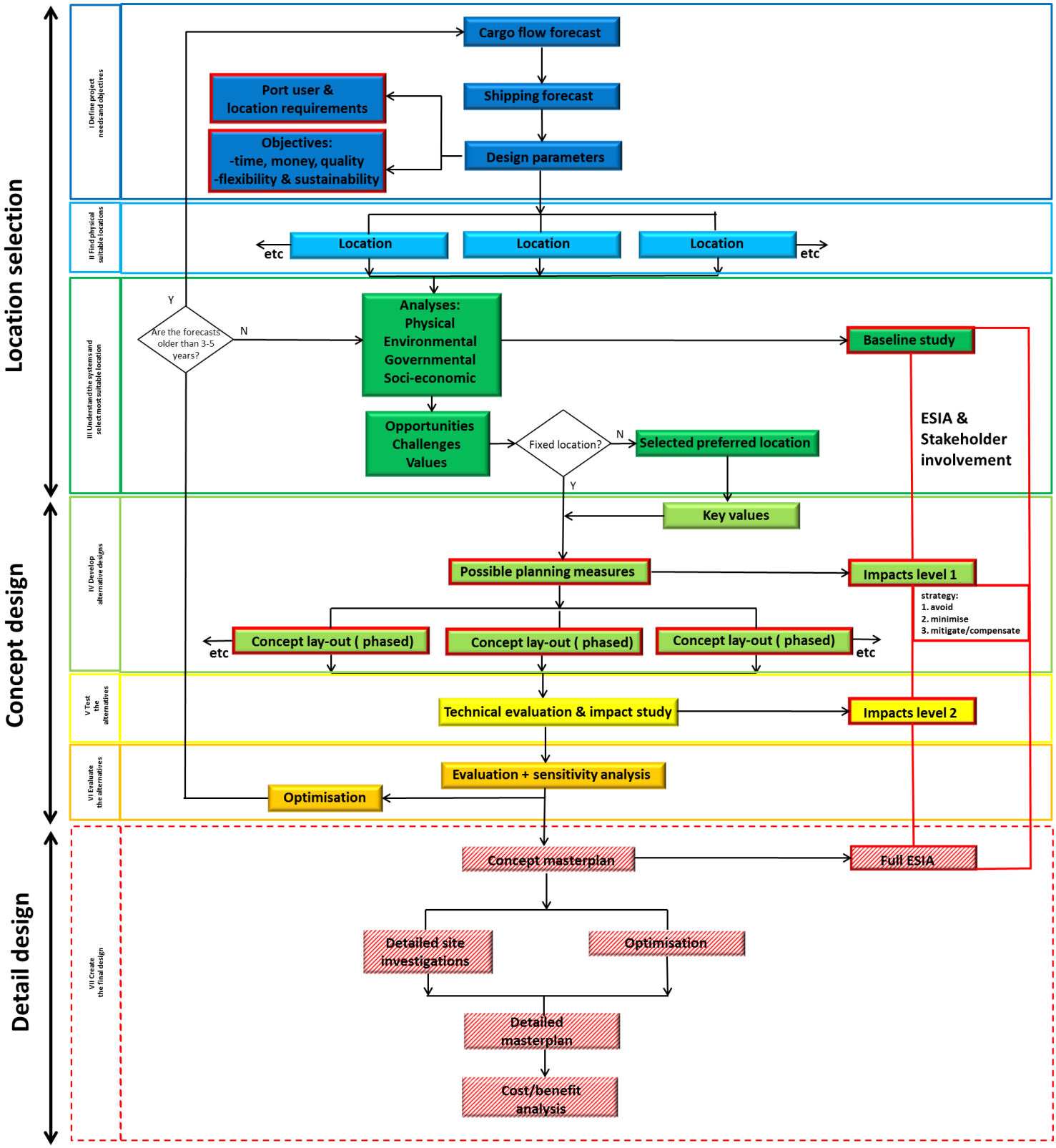
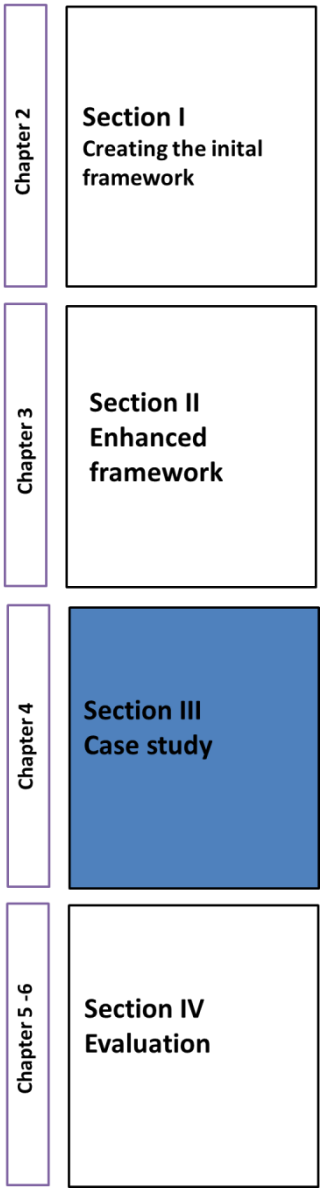


Figure 3-O Flowchart enhanced ISPD framework

The case study in the next chapter will be planned and designed following this enhanced Integrated Sustainable Port Design framework.

SECTION III CASE STUDY



4 CASE STUDY: BADAGRY PORT PROJECT

4.1 Introduction

In this chapter the enhanced Integrated Sustainable Port Design framework is applied on the case study: the Badagry Port Project. The same starting conditions and design parameters are assumed as during the time and place of the situation of the existing masterplan. This is necessary in order to have the most accurate comparison between the two masterplans during the evaluation. The main difference with the starting conditions then and now is that there are more time constraints during this research: for this reason the data collection is already completed and can be used right from the start for this research. When the retrieved information of RHDHV is used, this will be noted. Since the situation of the Badagry Port is already described in paragraph **3.4**, the issues with the existing masterplan and process are known. Hence this chapter can immediately start with the implementation of the ISPD framework on the Badagry Port. First the needs and the objectives of the port are clearly specified in paragraph **4.2**. With this information several physical suitable locations for the BBP can be determined in paragraph **4.3** and by analysing the physical, ecological, governmental and socio-economic environment in combination with a stakeholder analysis it results in the most suitable port location in paragraph **4.4**. The key values of this specific location can be defined and based on these key values, several alternatives for the masterplan are developed by seeking sustainable opportunities which will be tested on their feasibility respectively in paragraph **4.5** and **4.6**. After evaluating the alternatives in the MCA in paragraph **4.7**, ultimately one final masterplan is selected and explained in more detail in paragraph **4.8**. The chapter ends by providing a rough cost-benefit analysis of this final design.

4.2 Define project needs and objectives

The main objective of this case study is to cater the exceptional growth in demand of the Nigerian economy, which will be noticeable especially in the Lagos area by 2017 [Royal HaskoningDHV, 2015]. As the port at Lagos will have insufficient capacity by then, the client BPDL has requested for the construction of another port to incite the sustainable economic development of Lagos and the rest of the Nigerian economy. The process to define the detailed project needs and objectives starts by analysing the economy of Nigeria and its projections for all its cargo streams in order to make accurate cargo flow and shipping forecasts for the port. These forecasts are required to cater the needs and objectives for the proposed port from the start covering a 50 year time horizon.

Long term forecasts bring a high degree of uncertainty, especially when the design life of this port is covering a 50 year time horizon. A port which considers these long term uncertainties from the start, increases its flexibility by the ability to adapt and still function under future changes. ISPD recommends to consider as much long term uncertainties and environmental impacts during the planning as possible. However since different involved/interested parties have a different view of the importance of each other's objectives, the port planner's decision which and how many objectives will be chosen should be based on relevant analyses, the consideration of the limited time and money, and nature of interest and the influence of each party. BPDL is financing the port, so this party relatively has the most influence.

However, the ISPD strongly stimulates the objectives of other parties, such as flexibility, sustainability and social welfare, and the port planner therefore should convince the client of the benefits of these objectives as well: namely that sustainable measures can bring socio-economic welfare as well. Furthermore in order to consider the long term uncertainties, it requires knowledge of various aspects of uncertainty which could be encountered during the planning phase and comprehension of prevailing and emerging trends that have direct or indirect influence on the chosen goals, plans and planning approaches. Since there is not enough time to study all these aspects of uncertainty and emerging trends, I have decided to partially adopt these objectives from RHDHV and hence my chosen secondary objectives are as follows:

- To plan under long term uncertainties to create a flexible and future-proof port
    - To enable the catering of three cargo scenarios for different use of the General Purpose terminal [Royal HaskoningDHV, 2015] (see paragraph **3.4.3)**
    - To consider climate change in the form of imbedding the future sea level rise in the design water level [Royal HaskoningDHV, 2015]
- To aim for sustainable solutions while obtaining socio-economic benefits

One of the above objectives is to consider different forecasts scenarios in order to increase the flexibility of terminal use. I agree with the number of different cargo scenarios because a too high number of scenarios would unnecessarily increase the costs and three different cargo scenarios for terminal use would already increase the flexibility of the port sufficiently. Reaching for the above mentioned future-proof and sustainable objectives requires more initial time and investment, but it may become very profitable in the long term if flexibility is needed in a future scenario. Hence besides obtaining the main objective from a time, economic and qualitative perspective, the secondary objectives are supporting it by including the long term flexibility and environment as well.

The project needs are specified with respect to the port users and location requirements. Since the same starting conditions are assumed as during the time and place of the situation of the existing process performed by RHDHV, the forecasts and the port user and location requirements obtained by RHDHV are still valid and will be used as well for this ISPD process. These cargo flow and shipping forecasts and port user requirements are rather detailed and the process to obtain them does not significantly deviate from the traditional framework. Since the aim of this chapter is to show the benefits and challenges of the implementation of the ISPD framework, therefore mentioning them would not significantly contribute to the aim of this research. Hence I will no mention this information in the main report nor in the Appendices. However the demands made for the future port location will be mentioned here, because they are required and relevant to know for the location selection in the next step. The future port location needs to be located in such a way that the following needs in the form of port location requirements, partially set up by Royal HaskoningDHV [2015], are fulfilled:

- In the vicinity of Lagos
- Reduction of demand pressure on Lagos area's road system
- Sufficient suitable land for future expansion and good natural conditions
- No extremely high construction and operational costs (e.g. relocating an existing bridge)
- Sufficient hinterland demand, potential different hinterland modalities and at least one existing main road connection

The above defined port design parameters are basically limitations for the amount of potential suitable locations for the proposed port, since not all locations are able to fulfil the needs and objectives of the port. Hence in the next step, I can select physical suitable locations for the port which fulfil these design parameters.

4.3 Find physical suitable locations

Now the design parameters of the port are known, the scope of physical suitable locations can be narrowed down. This pre-selection is required since it would cost too much time and money to do research on too many locations in the next step. According to ISPD, a physical suitable location is a location which fulfils all the specified design parameters while it has the least negative impacts from the surrounding physical environment. This might seem as an aspect which should be treated in the following step *Understand the systems and select the most suitable location*. In this step however there is no understanding of the entire environmental system yet, but only the suitability of a location based on the physical environment is considered. These physical impacts caused by specific location elements can be found in the WWF and Deltares report called *Port of the Future* (Schipper et al, 2015, p.25, table 3.1).

The process starts by specifying the area of study which is located along the coastal areas of Nigeria. Other limitations for the area of study are specified in the previous chapter in the form of port location requirements. Then visual potential locations are sought based on existing literature (soft and hard) and site visits. Due to the time and money limitations in this research, site visits cannot performed. Furthermore, the existing available literature for this research is also limited in order to determine in what extend the physical environment will negatively impact the proposed port for each location and in what extend the location fulfills the design parameters of the port project. Despite the limitation I provide figure **4-A** which shows the map of Nigeria and its surroundings with, according to me, visual potential suitable locations for the proposed port.

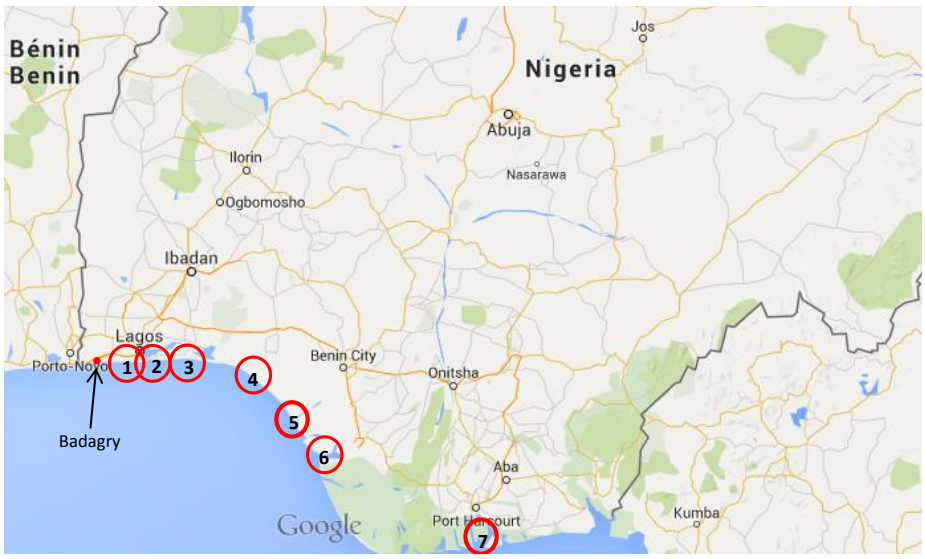


Figure 4-A Potential suitable locations proposed port [background adopted from Google maps, 2015]

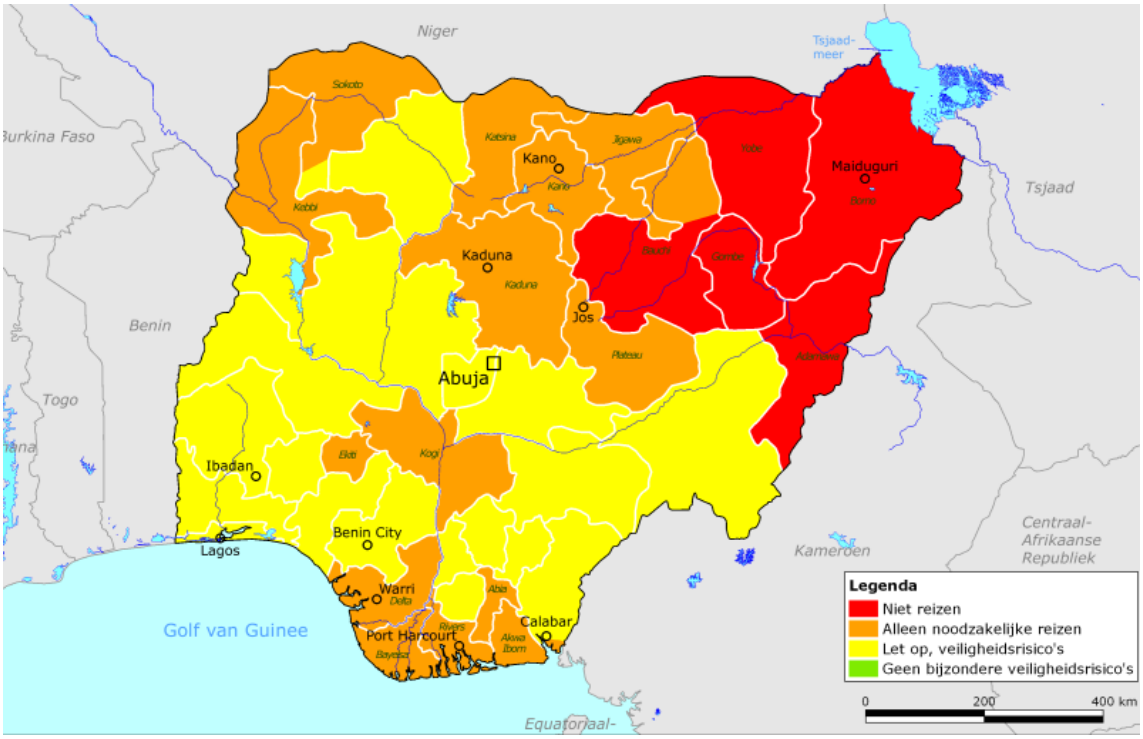


Figure 4-B Travel advice to Nigeria [Rijksoverheid, 2015]

These locations seem potential suitable based on only brief and visual assessment; this includes the significant important consideration of the rather unstable social situation in Nigeria. Figure **4-B** shows the travel advice for several parts in Nigeria by the Government of the Netherlands (Rijksoverheid). It is advised by them not to travel to the red areas, to only travel to the orange areas if necessary and travelling to the yellow areas includes safety risks. Below I provide a list of the seven potential suitable locations indicated in figure **4-A**, including their (dis)advantages based on my own brief assessment.

1.Snake Island
- + Proximity to Lagos
- + Existing main road to Lagos
- + Possibility inland water transport
- + Sufficient new area available
- - Pressure on Lagos area's road system

2.Lekki
- + Proximity to Lagos
- + Existing main road to Lagos and big cities in south/west Nigeria
- + Possibility inland water transport
- + Sufficient new area available
- - Pressure on Lagos area's road system

3. Badore
- + Captive hinterland (no distance related competition from the port in Lagos)
- + Reduction of demand pressure on Lagos area's road system
- + Existing main road to Lagos and big cities in south/west Nigeria
- + Possibility inland water transport
- + Sufficient new area available

4. Aiyetoro-Mahin
    + Captive hinterland (no distance related competition from the port in Lagos)
    + Reduction of demand pressure on Lagos area's road system
    + Sufficient new area available
    - Located far away from Lagos
    - No possibility inland water transport

5. Benin City (Jakpa-Oke)
    + Captive hinterland (no distance related competition from the port in Lagos)
    + Reduction of demand pressure on Lagos area's road system
    + Possibility inland water transport (till certain distance near Benin City)
    + Sufficient new area available
    - Located far away from Lagos

6. Warri (Forcados)
    + Captive hinterland (no distance related competition from the port in Lagos)
    + Reduction of demand pressure on Lagos area's road system
    + Possibility inland water transport
    + Sufficient new area available
    - Located far away from Lagos
    - In the past unstable social situation, however relatively safe since 2006 [Rijksoverheid, 2015]

7. Port Harcourt (Yellow Island / Bonny Island)
    + Captive hinterland (no distance related competition from the port in Lagos)
    + Reduction of demand pressure on Lagos area's road system
    + Existing main road
    + Possibility inland water transport
    + Sufficient new area available
    - Located far away from Lagos
    - Unstable social situation since 2006 [Rijksoverheid, 2015]

According to the ISPD framework, locations are considered potential suitable after fulfilling the design parameters and by checking all the location elements in the report called *Port of the Future* (Schipper et al, 2015, p.25, table 3.1) to select suitable locations with the least negative impacts from the location as possible. However due the lack of information, site visits and time, it is not possible to test if the seven above mentioned locations indeed are suitable since multiple aspects cannot be tested and confirmed; the ISPD framework is therefore limited. Another issue which would be encountered in this step and in the following step, is that this location selection requires more initial research and thus more time and money as well, than the traditional process. The reason for this elaborated location selection is to select the most suitable location which brings the least limitations for the future port design and operation. It is up to the port planner if he/she wants to deal with risks of resistance and limitations of a location resulting from a rather incomplete initial research, or if he/she decides to consider this uncertainty by investing more time and money in the research for the most suitable location. However in this case study this choice does not have to be made because there is limited time and data of other locations, and in addition, ISPD emphasizes on the importance of grounded location selection based on a good understanding of the critical parameters of that location. Hence in order to continue this research I have decided to analyse a possible location which offers access to sufficient baseline information to fully sup-

port my decision of the location choice. In this research the only location which offers this is Badagry, the location of the existing masterplan. It is important to mention that although this location is not considered in the previous, in the end there is still a possibility that Badagry might be the most suitable location. Hence I have decided that in the next step the area along the coastline of Badagry will be studied into more detail.

4.4 Understand the systems and select most suitable location

The ISPD framework emphasizes on the importance of location choice as part of the design process. This is considered the basis of the framework because the location, design and operation of a port are strongly interlinked. A location must be chosen in such a way that it complements the design and operation of a port. As the design will only be developed after the location is chosen, it is not known yet how a location will influence the port and its operations. However it is possible to find out how a location would react on and influence the potential arrival of the port: this can be found out by initial research to get a basic understanding of the critical parameters of each location. Before the locations can be studied, it is first necessary to clearly define the area of study. Since in this case study I have to work with the available data of the location of Badagry, the area of study is already been decided for me by RHDHV. Furthermore if the entire design process including the location selection is performed by one party, then the same disciplines and values can be considered for both. By analysing the physical, environmental, governmental and socio-economic disciplines, a basic understanding can be obtained of the critical parameters of each location. These critical parameters decide which location is the most suitable and can be found in the report *Port of the Future* (Schipper et al, 2015, p.58-59, table 6.1) in the form of the general encountered factors in port development for each discipline and their impacts. By considering these general influencing factors in each discipline analysis, it becomes clear what opportunities and challenges the proposed port will face on a location. The challenges also include the identification of uncertainties which might be encountered in the future. By using the tool of stakeholder involvement, it also becomes clear what the concerns are of the local stakeholders and what they value. These values, opportunities and challenges of each location need to be found concluding the research and they decide which location is the most suitable for the port design and operations (the project objectives). The location which encounters the least negative impacts and shows the best opportunities for the port, can be considered the most suitable location for the port. It is up to the designer to decide which location that is. The biggest issue which will be encountered in practice is already explained in step II: namely that although the understanding of the critical parameters of potential suitable locations will result in the most suitable location for the future port design and operations, it however requires more time and money than in the traditional process.

This is also the part where the Environmental Social Impact Assessment starts. This assessment first requires baseline investigation and information. Once the existing situation is known the potential impacts of the port on the environment, resulting from understanding the system in this step, can be specified: these main impacts can be found in the form of the opportunities and challenges of the location. In a later stage when the layouts are developed and all the measures are known, the impacts on the environment can be more specified in detail: this will be performed when the alternatives are being tested.

It is important to note that in the following location system analyses, several information is excluded from this research because they do not contribute much to this research and therefore are not relevant

to mention here. I consider information resulting from surveys irrelevant, if no unusual aspects are found which would benefit or challenge the arrival of the future port.

4.4.1 Physical site conditions

i. Existing development

Figure 4-X shows Badagry with respect to Nigeria and Benin. The area is mostly undeveloped and with the exception of the F100 expressway connecting Lagos and Benin, the Badagry Port project could be considered a Greenfield development. The roads consists of dirt and sand, there is no transport system and the transport is primarily by motorbike and boat. Furthermore, there is also no evidence of piped water and the housing is basic and build from wood, mud with zinc or thatched roofs. Telecommunication is available, however the service by electricity is not well. Along the coastline there are several small communities, some palm plantations and small-scale tourism. The largest part of Badagry is located along the northern banks of the Creek and the few remaining small villages are distributed along the south side of the Creek. The suitable area for the Badagry Port is bordered by the F100 expressway in the north, the Badagry Creek in the east, the coastline in the south and the Benin border in the west [Royal Haskoning, 2015].

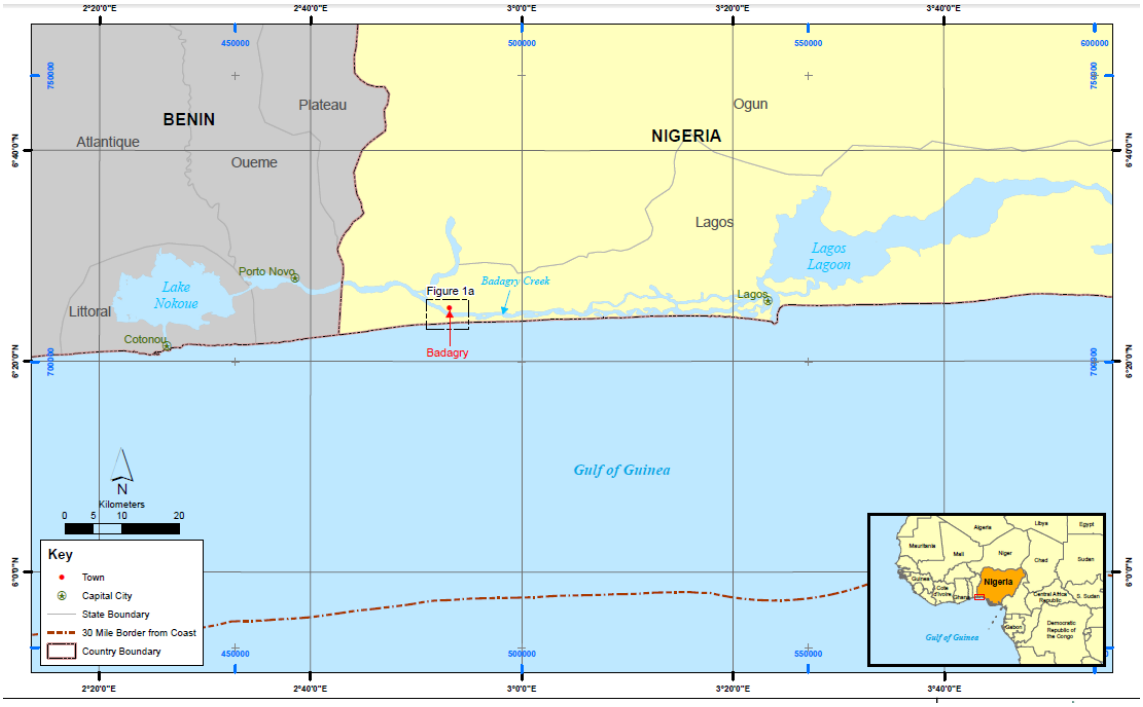


Figure 4-C Location of Badagry Port project within Nigeria [Environmental Resources Management, 2012]

The only major road in the surroundings is the F100 expressway. This main hinterland connection moves parallel to the Nigerian coastline, connecting Cotonou and Lagos. Currently the F100 provides two lanes in both directions and is in the process to increase the capacity to five lanes in both directions between Badagry and Lagos. In the surroundings there is no formal waste management established. Another upgrade which is in process is the light rail infrastructure for passenger transport: this connection is currently being built between Badagry and Lagos but will not be suitable for cargo transport. Detailed information about its development and schedule is not known yet and needs to be confirmed by the governmental authority [Royal HaskoningDHV, 2015].

Multiple surveys and investigations are performed by Royal HaskoningDHV from 2011 till 2014 in order to get a better understanding of the geotechnical and marine soil conditions, water levels (tidal levels and design water levels), wind, currents, topography and vegetation conditions. The found land soil conditions are suitable for the construction of a port and the marine soil ground conditions can be used for reclamation purposes after dredging [Royal HaskoningDHV, 2013]. Furthermore, the predominant wind near Lagos is coming from a south-west direction and in general has a low speed of about 3 – 8 m/s [Royal HaskoningDHV, 2011]. The design water levels are based on the observations of the tidal levels, surge levels and future sea level rise [Royal HaskoningDHV, 2012] and the longshore current at Badagry is always set to the east with overall speeds less than 1 m/s with a maximum of 1.5 m/s measured in July [Royal HaskoningDHV, 2011]. In short, no unusual information was found during these studies which would significantly benefit or challenge the arrival of a future port along the coastline of Badagry. The surveys and investigations which did encounter possible opportunities and challenges for the future port are elaborated below.

i. Bathymetry

In October / November 2012 a bathymetric survey was carried out by Royal HaskoningDHV. Due to shallow areas near the coastline, dredging will be required for the proposed port. Furthermore, a bathymetric survey along the Creek has been performed during the period of December 2013 to February 2014 [Royal HaskoningDHV, 2014]. The results showed that, besides the existing F100 coastal road and the future rail terminal, a third hinterland modality is possible in the form of barge transport along the Creek, connecting Badagry to Cotonou and Lagos.

ii. Wave Conditions

Numerical wave modelling indicates that the 1 in 100 year swell wave condition consists of a significant wave height (H_{mo}) and peak period (T_p) respectively of around 2.0 m and 20 seconds. The design waves will arrive at the proposed port site from approximately 180° relative to North. The results of detailed measurements of wave conditions at Badagry [Royal HaskoningDHV, 2014/2015] verify that long waves are also present, particularly during the summer months where the wave height can rise up to 10 cm [Royal HaskoningDHV, 2014]. These long waves should be taken into account during port design.

iii. Long Shore Sediment Transport

The net long shore sediment transport along the western part of the Nigerian coastline goes from west to east. With the construction of breakwaters, accretion is expected on the updrift side (west of the main breakwater) while erosion will become evident on the downdrift side (east of the lee breakwater). Badagry is approximately midway between Cotonou and Lagos and therefore its longshore sediment transport is assumed to be of the same order of magnitude and is estimated approximately between 0.8 to 1.2 million m3/year from west to east.

Using a morphological sediment transport model [Royal HaskoningDHV, 2015], the longshore sediment transport around the western part of Nigeria's coastline has been analysed. The outcome shows the potential sediment transport and coastline evolution over time periods of 1 year, 2 years, 5 years and 10 years in the current situation if a port would be established [Royal HaskoningDHV, 2015]:

- 1 year : 50m coastline retreat
- 2 years : 80m coastline retreat
- 5 years: 140m coastline retreat
- 10 years: 200m coastline retreat

The results clearly show that with the intervention of a port, the coastline will undergo severe coastal retreat and coastline protection is undoubtedly necessary.

Conclusion physical analysis
Based on the physical analysis, the future port will encounter several challenges at the coastline of Badagry. However, if attention will be paid to find measures in order to solve these challenges, then it can be concluded that from a physical perspective Badagry can be considered a suitable location. The following opportunities and challenges would be encountered with the arrival of a port:

Opportunities

- Besides the existing main F100 coastal road, Badagry has the potential to have other hinterland modalities in the form of a future rail terminal and barge terminal.
- With the arrival of the port the (existing) infrastructure network will be improved. There are already plans to increase the capacity of the F100 coastal road.
- Sedimentation will take place west of the main breakwater; this brings along future opportunities in the form of transporting this sand through a bypass to nourish the eroded coastline east from the port, or possible use of the sedimentation area for future port expansion if this area becomes stable.

Challenges

- The coastline of Badagry would undergo sever coastal retreat with the arrival of a port and therefore coastline protection is of significant importance.
- Since the natural depth of the sandy coastal area is not sufficient, (maintenance) dredging of entrance channels and port basins is required
- Long waves in summer should be considered as they could have an impact on shipping operations inside the port area.

4.4.2 Ecological situation

i. Terrestrial ecology

Currently the proposed site is characterised by the presence of (coconut) plantations, mangroves, coastal scrub, marsh, forested areas, wetlands, small agriculture and illegal sand mining. These habitats will all be disturbed with the arrival of a port, but there are no protected areas in or near this site. In the past several protected faunal species have been encountered, but during the baseline survey none of these protected species were encountered [Royal HaskoningDHV, 2015].

ii. Marine and Creek Ecology

No protected species were found in the Creek, but the Creek and lagoon system are important nursery grounds which is confirmed by the fishermen during the baseline consultations [Royal HaskoningDHV, 2015]. In the project area there are no reports of occurrence of endangered marine mammal species, besides the West African manatee which potentially resides in the Creek. Another important marina animal is the sea turtle: it is reported that along the shoreline of Badagry the green turtle potentially nests between the months March and August/October to December. However during observations between September and December no green turtles were found and therefore the numbers of nesting in the project area are unknown [Royal HaskoningDHV, 2015].

Conclusion ecological analysis

The only relevant information for this research is that in case of impact on the ecology in Badagry, no impacts will be considered serious threats due to the lack of protected areas and species. For this reason Badagry can be considered a suitable location from an ecological perspective. Since the most important message is clear, the above mentioned information is kept rather limited and the complete information about the Terrestrial ecology and Marine and Creek ecology is irrelevant to mention in this research.

4.4.3 Governmental situation

i. Administration

Lagos State consists of 57 local government areas (LGA) and the site of the port is located in the LGA of Badagry. The LGA of Badagry is in a conflict with the Local Council Development Area (LCDA) of Badagry West about the question who the official authority of Badagry should be [Royal HaskoningDHV, 2015].

ii. Private or public project

The Badagry Port Development Company Limited (mainly AMPT) has the plan to privately operate the new port as a common-user, public facility. The project, therefore, will be financed by the Consortium and they will be responsible for the development and operation for this port.

Conclusion governmental analysis

Due to the challenge of conflicting local official parties, it is not sure if Badagry is a suitable location from a governmental perspective and further research is recommended for this aspect. The two challenges found are as follows:

Challenges

- Due to the conflicting situation between the LGA of Badagry and the Local Council Development Area (LCDA) of Badagry West, difficulties might arise later in the process when permits are required.
- The main objective of private investments is a positive business case (economic profit maximization) and in addition, they usually do not obtain government subsidies. Policies of sustainable development in this case are therefore more difficult to impose if they are not supported by governmental subsidies.

4.4.4 Socio-economic situation

i. Demographics

Badagry is a coastal town with a local government in Lagos State. Lagos State has the highest population of all Nigerian states and has the population of 17.5 million [Lagos State Government, 2011]. For the chosen location of the port in Badagry, 5 communities (over 4,600 people) need to be resettled as is indicated in figure **4-D**. These communities have a rural lifestyle consisting of predominantly fishermen and farmers. Of this population a higher port is female and the majority of the population is under the age of 25 [Royal HaskoningDHV, 2015].

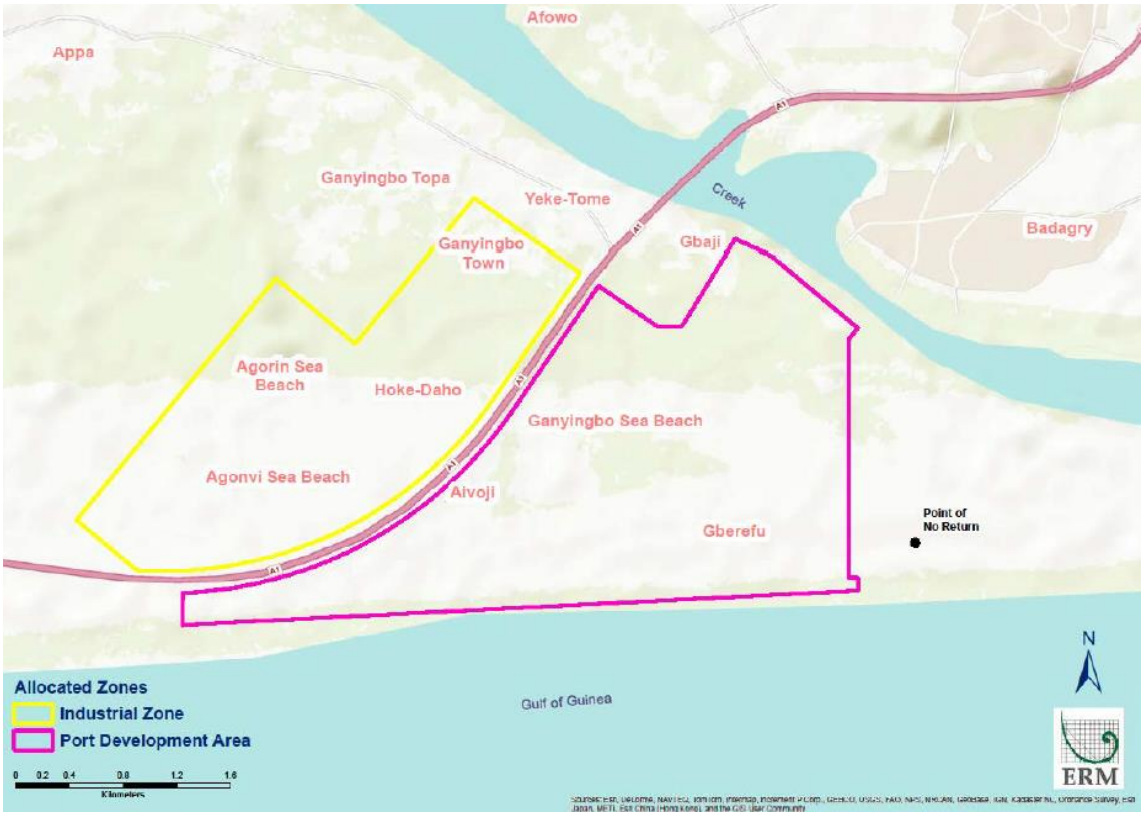


Figure 4-D Communities in the project area [Royal HaskoningDHV, 2013]

ii. Cultural Heritage

Badagry was established in the early 15th century and was one of the first establishments of contact for the trade between the Oyo Empire and Europe. This town could be seen as an important slave trading post until the late 1800's. An important reminder of this period can be found in the form of Badagry Heritage Museum situated on the northern side of the Creek. Other important cultural heritage include the Slave Route, a track that leads from the Badagry Creek to the coastline and ends at the Point of No Return monument. These sites are located along the eastern side of the proposed port site, and on the proposed site itself there is the presence of several shrines, graves and locally important cultural heritage sites. Hence measures should be taken for the protection of this heritage.

The Point of No Return national landmark site is of critical importance for Nigeria's cultural heritage. This PONR monument is located directly east of the project site as can be seen in figure **4-D**. As a proposed port would cause an obstruction of the long shore sediment transport, erosion will take place east from the port and consequently this could harm the PONR. Therefore it is of crucial importance to maintain stable beach conditions at this landmark site: any negative impacts resulting from the port project on the site of the PONR monument, hence to the adjacent eastern coastline, should be avoided where possible and mitigated where unavoidable [Royal HaskoningDHV, 2015].

iii. Education

The majority of the population in the surroundings have attended primary school and only the minority also had senior or tertiary education. This results in a low literacy rate, especially under women [Royal HaskoningDHV, 2015].

iv. Land Use and Tenure

The establishment of the project requires an acquiring of land of approximately 1200 ha. Within the boundaries of the project there is the presence of 386 structures. Currently the land is mainly used for fishing, farming activities and the collection of non-timber forest products. The largest village is situated next to the F100 bridge and its surface consists of approximately 400 by 300 m at the east side of the road and an extra 350 by 150 m at the west side of the road. There are also several smaller fishing villages are scattered along the coastline. The land is owned by local communities and families [Royal HaskoningDHV, 2015].

v. Health and Healthcare

In the near surrounding of the proposed site there are no hospitals or clinics present. Malaria is the most prevailing disease in the area, inhabitants are confronted with malnutrition and HIV/AIDS, and on top of that there are issues concerning poor water quality [Royal HaskoningDHV, 2015].

vi. Economics, Livelihoods and Employment

In the surrounding areas multiple livelihoods/occupations can be found where the key ones include fishing, farming, markets and petty trading. Loss of land and negative impacts on the local water systems will affect the local trade, which primarily consist of fish, palm oil, cassava, coconuts, kernels and corn [Royal HaskoningDHV, 2015].

vii. Hinterland market

Badagry is located relatively close to the ports in Lagos and Cotonou. The reason that Badagry is considered is because the new port should cater for the future overcapacity in the port of Lagos. However the significant risk with closely located ports is that they will share the same hinterland which would mean that there is a contestable hinterland market: this means that no single port has a definite cost advantage over other competing ports which results that the ports need to compete over market share in these areas [Langen, 2007]. However this might not be the case as can be seen in figure **4-E.** The figure shows that since Badagry is located West of Lagos, Lagos needs to be bypassed in all cases to transfer the cargo to the port's hinterland in Nigeria. This indeed fulfills the criteria that the demand in Lagos will be met, but it also brings extra pressure on the already busy traffic network around Lagos. Furthermore, if the cargo will pass by Lagos in all cases, it perhaps would still be cheaper and more sustainable to directly navigate to the port in Lagos by vessel despite the potential longer waiting times caused by overcapacity in the future. On top of that, the cargo transport between Cotonou and Lagos is also already connected by the F100 coastal way, hence the hinterland on both sides of Badagry is already covered by these two ports. This might result in insufficient hinterland demand for the proposed port at Badagry. However it is of significant importance to mention that this is only my own impression based on incomplete information. There is a very good possibility that there may be sufficient hinterland demand at Badagry, but due to the lack of information and time, I cannot confirm that in this research.

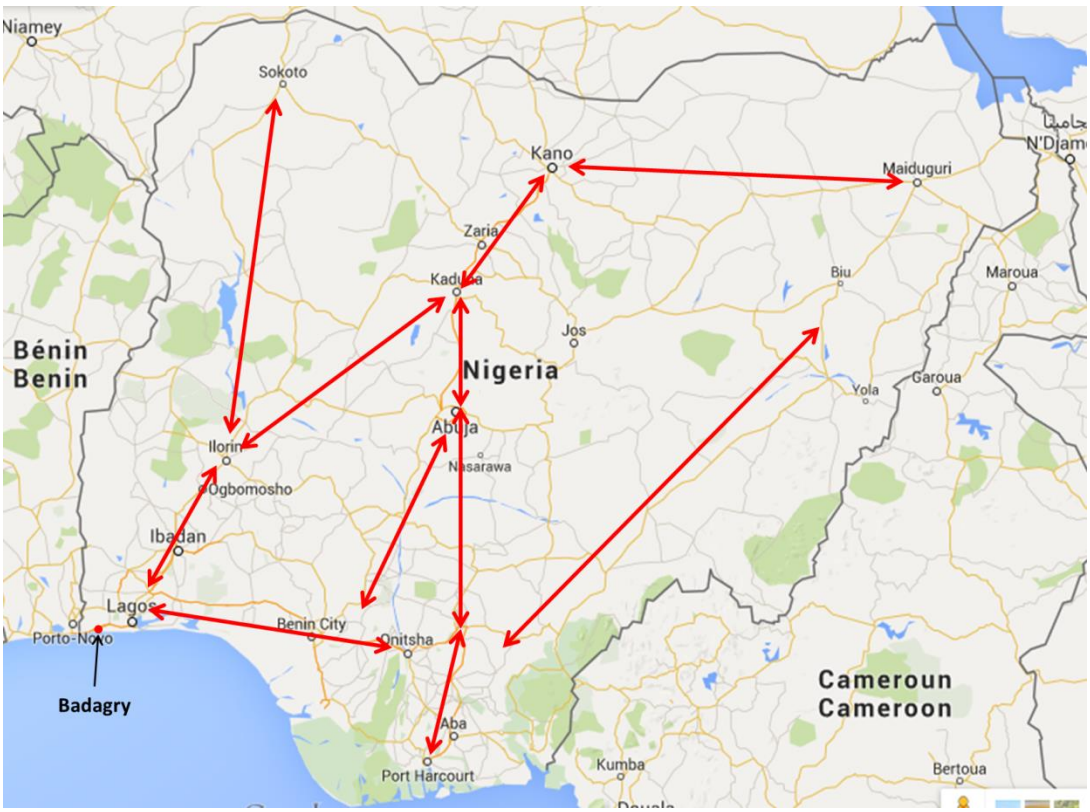


Figure 4-E Hinterland transport of Nigerian coastline [background adopted from Google maps, 2015]

Since the port in Lagos will provide cargo for other large cities in Nigeria, it would make much more sense to build a port more east of Lagos: this would be closer to the rest of Nigeria and it would relieve the traffic pressure around Lagos. A port east from Lagos would also be closer to provide cargo transport between Nigeria and Chad (which is not bounded by any water) and parts of Cameroon.

Conclusion socio-economic analysis

From a socio-economic perspective it is not clear if Badagry is a suitable location due to the many challenges it might encounter. Although the arrival of the port will bring a rapid economic development along for the entire area, further research is required for the following opportunities and challenges:

Opportunities

- The arrival of the port will start the rapid economic development of the Badagry area.
- The arrival of the port will bring new (in)direct employment inside and outside the port.
- The arrival of the port might also bring along a better health care system.

Challenges

- With the port of Lagos and Cotonou in a relative close distance, it is not clear if the proposed port will obtain sufficient hinterland demand due to the port competition of the port in Lagos. The expected container demand might also grow slower or faster than forecasted.
- The arrival of the port will inevitably result in community resettlement and negative impacts on the marine systems. This would result in the loss of land and livelihoods of the local inhabitants. If a port would be developed at Badagry, then a resettlement plan must be set up which provides compensation and new land, houses and livelihoods for the involved communities. Since the education level is relatively low, a different form of livelihoods need to be offered which does not significantly deviate from their current livelihoods. Re-schooling is also an option. Due

to the high number of women in the area, this plan should also take this vulnerable group into account.
- The arrival of the port will undoubtedly result in loss of cultural heritage. The most important heritage according to the stakeholders is the PONR monument in the eastern area relatively close to the coastline. It should be avoided that this PONR monument needs to be relocated or will be affected by coastal erosion caused by the port.

Stakeholder analysis

In order to discover what the concerns are of the involved stakeholders in the area of Badagry, a stakeholder analysis needs to be performed. A stakeholder analysis is a two-way communication process between the party proposing the project (i.e. BPDL) and the parties who are influenced by the project (i.e. stakeholders). A stakeholder analysis is a tool for the involved stakeholders to not only indicate their perspectives concerning the project, but knowledge and information should also be transparently shared so the different stakeholders are aware of each other's interest, worries and the future plans for the proposed project. The stakeholder analysis can also be used by the client to build synergetic relationships with all stakeholders, by transparently involving and considering them throughout the development process and trying to create value together with them. For these reasons, this tool is considered one of the key aspects of the ISPD framework. In order to perform a stakeholder analysis, the port planner should follow the following steps:

1. Specify maximum area to consider involved stakeholders (area of influence)
2. Identify a good representation of the stakeholders
3. Send a structured questionnaire beforehand to record the views and concerns of the stakeholders and let them prepare for it
4. Meet with the stakeholders in person to confirm the views and concerns of the stakeholders and for additional updates
5. Define their values and concerns in a summary

Due to the time constraints and the limited date, I could only perform a brief stakeholder analysis involving mainly the stakeholders living in the project area. Furthermore, step 3 and step 4 could not be adequately performed either due to this time limitation. Step 4 however is executed with the help of the available data of RHDHV and my own input. The entire process and the full stakeholder analysis are provided in Appendix **C**. Step 5 is executed here by summarizing the main concerns and values of the involved stakeholders resulting from this analysis and they are as follows:

- Loss of biodiversity
- Community resettlement (including vulnerable groups such as women, elderly and disabled persons)
- Loss of livelihoods
- Coastal erosion
- Cultural impact
- Fresh water contamination
- High project costs
- Economic growth of the area
- Increase connectivity surrounding areas
- Improvement health situation and education
- Need for security

- Port competition with Lagos
- Impact on tourism
- Transparent process
- Engagement with other affected communities

The above lists shows a lot of opportunities and concerns as well. Many of these concerns are the same as the challenges found during the system analysis. However despite the presence of these concerns the chances of the establishment of the projects is still considered considerably high because many of these concerns can be avoided, minimized or mitigated/compensated. If possible measures can be introduced to adequately mitigate and compensate the negative impacts, then the stakeholders mainly agree with the construction of the port.

4.4.5 Most suitable location

Due to mainly the socio-economic challenges, I have doubts if Badagry is a suitable location for the proposed port with the potential insufficient hinterland demand and resistance of the local communities. According to the ISPD framework, these challenges should be further studied and investigation should be performed to analyse if another location would be more suitable. Due to the lack of information, it is of great relevance to mention that in the end there still is a possibility that Badagry might be the most suitable location for the proposed port since there also is no full supported proof that Badagry would not be. However due to time constraints and the lack of site information of other possible locations, a grounded location choice is not possible in this stage of the research. Since the goal of this chapter is to discover the (dis)advantages of the ISPD framework in practice in order to adapt the framework, I have decided for this case to further implement the framework on the Badagry location with the available information. Besides considering the socio-economic perspective, it can be concluded that from the perspectives of the other disciplines, Badagry overall can be considered a suitable location and hence this research will continue with selecting Badagry as the location for the proposed port.

In order to find the most suitable site location in Badagry, the port should first of all offer excellent economic opportunities in order to achieve the needs and objectives of the port. Furthermore the chosen location should keep the negative impacts on that location to a minimum in order to fulfil the sustainable and social part of the port objectives. The main concerns concluding from the system and stakeholder analyses which should be considered and kept to a minimum are:

- Community resettlement
- Loss of livelihoods
- Need for security
- Coastal erosion
- Cultural impact
- Impact on tourism
- Fresh water contamination
- Loss of Biodiversity
- High project costs
- Port competition with Lagos

If it is physical allowed by the sea conditions, it is first of all recommended to select an offshore site. For this topic I refer to the report '*Open ports of container vessel*' of Bakermans (2014) which researches the possibilities for offshore and exposed container ports. This report is relevant because it partially focuses

on an open container port in the offshore location in West Africa, more specifically Lagos. An offshore location has several benefits which are valid for the Badagry location: first of all, regions which expect steep growth in transport with large containers vessels require large depths at the berths, which can be provided easier at an offshore location [Bakermans, 2014]. Another benefit is that an offshore location brings more possibilities for future port expansion, which makes the port more flexible for future changes. Furthermore, the coastal zone including the high valued PONR monument will be protected since there will be no sedimentation and erosion issues due to the absence of structures which disturb the coastal longshore sediment transport. Hence there is less impact on the morphology [Bakermans, 2014]. Lastly, due to the absence of communities in the seaward direction of the Badagry coast, this location would also cause less negative social impacts. However since the water depth deepens relatively fast from the coast into the seaward direction [Royal HaskoningDHV, 2012], this would also mean that the port would be a large floating island which is connected to the shore by a causeway on piles. Mainly these two elements (i.e. the large volume of the floating island and the causeway on piles) lead to higher initial construction costs of the offshore port compared to the initial construction costs of a traditional port [Bakermans, 2014]. However it is also observed that a high terminal productivity and little downtime, which are valid for an offshore port, significantly and positively influence the payback period. Finally, it is interesting to mention that the benefits for the environmental and morphological environment are not fully considered during the financial analysis, which might underestimate the value of an offshore port [Bakermans, 2014]. Many concerns of the stakeholders would be avoided, but the potential extreme high costs of an offshore location resulted in the specific indication by RHDHV that an offshore port is not a desired option. According to the ISPD framework, an offshore port can still be considered by further research or by developing an offshore port in the next step which proofs that its (construction) costs do not significantly exceed the costs of an inland port. However since this research is performed for RHDHV, I have decided not to further consider the offshore location in the following.

Since I have decided that the proposed location will be on land along the coastline of Badagry, it is impossible to avoid any impact of the considered main concerns of the stakeholders, as is mentioned before. However there are sites which would experience less impact of these concerns compared to other sites. First of all, the western and middle part of the coastline include more communities compared to the eastern area and therefore will result in more community resettlement and loss of livelihood. Furthermore, small cultural heritage is scattered all over the area: the most important heritage according to the stakeholders which also attracts the most tourism is the PONR, located east of the port relatively close to the coastline. It should be avoided that this PONR monument needs to be relocated or will be affected by coastal erosion. Regarding the coastal erosion it should not matter where the port will be situated as erosion will undoubtedly take place at the downstream side of the port location and therefore erosion protection measures should be implemented for every location. The same goes for the security of the area: it does not matter where the port is location, since the safety level in the area is approximately the same. Furthermore, the fresh water contamination can be avoided by not extending the port development too much land inwards, there are no locations with high valued biodiversity and high costs of breakwaters can be avoided by keeping their length to a minimum and by using locally present material instead of obtaining huge amounts of rock from distant locations. Finally, the port competition with Lagos cannot be avoided but in order to strengthen the competitive position of Badagry, it is necessary to invest in infrastructure for excellent hinterland connections in the form of road, train and barge transport. Besides the aim to minimise the negative impacts on the location based on the main concerns, the most suitable location should also offer facilities or opportunities which support the economic objective of the port project. Finally the location along the Badagry coastline that fulfills these demands the best and therefore is identified by me as the most favorable site location, is shown in figure **4-F**. This location is the same selected location for the existing masterplan. The area is shaped like a triangular,

bounded by the F100 highway along the northwest, the Badagry Creek along the northeast and the coastline in the south. The main issue would be the nearby presence of the significant valued PONR monument. Relocation of this monument should be avoided at all cost and the aim is to minimise the impacts to a minimum. The ISPD framework agrees with the following adopted economic key benefits of this site [Royal HaskoningDHV, 2015]:

- Excellent existing hinterland connections for road (F100 express way) and inland waterway (Badagry Creek to and from the Lagos port)
- Relative independence on development of infrastructure by other parties
- Sufficient adjacent areas for development of free trade logistic zones and future expansion
- Good ground conditions

Figure 4-F Propose site location [Royal HaskoningDHV, 2015]

In the next step, I will continue the ISPD process with the development of different alternatives on this selected site location.

4.5 Develop alternative designs based on key values

4.5.1 Key values

Based on the previously conducted stakeholder analysis it is clear what concerns the stakeholders in the chosen site location, and hence what they value. When creating a port design, it is impossible to take all these values of all the stakeholders into account as some values are conflicting. Therefore in order to enable a more focused development process, these values need to be prioritized in the form of key values. The alternative layouts can then be developed based on these key values which represent the most important values of the relevant stakeholders in that location. In addition, these key values are also used as evaluation criteria for the MCA in paragraph 4.7.This is recommended because it would be a more equal evaluation if prior to the alternative development the criteria are already known, on which they are going to be assessed. Table 4-A shows the table with key values which, after consultation with RHDHV, I have determined for the Badagry Port project development. The key values can be divided into

the three different disciplines of economy, environment and society, and a brief explanation of each key value is provided as well. More key values can be introduced but that would also mean that the alternative development needs to take more (conflicting) values into account. This however is not necessary for this case because I believe that these nine key values in principle represent the concerns of the involved stakeholders.

Table 4-A key values of Badagry Port development and their explanation

Key value	Description
Economy	
CAPEX/OPEX	The degree of invested cost for the construction and operation of the project. This mainly consist of the cost for the breakwaters, the (maintenance) dredging costs, sand nourishments with a by-pass and the construction method.
Connectivity	The degree of the accessibility of the system from and to other transport means. Increasing the connectivity includes e.g. optimisation of the hinterland transport systems and usage of various hinterland transport modalities.
Environment	
Biodiversity	The degree of variety of life forms (e.g. species and their habitat) within a given ecosystem, biome or planet. Biodiversity often may be used as a measure to indicate the state or health of an ecosystem.
Coastal and marine ecology	The degree that the coastal and marine ecology is impacted as a result of the project. This mainly considers the erosion of the coastline and the possible resulting salt water intrusion.
Pollution	The degree of usage of (fossil) resources which are or will be scarce in the future and/or have a negative impact on the local and surrounding environment (e.g. water ways, air, soil etc.).
Society	
Health, Safety and Security	The degree that someone or something is safeguarded of dangerous situation and their impacts (e.g. ship collisions, fire, port state control, diseases etc). This includes the safe housing of future employers and the well-being of the persons who are related or surrounding the project.
Employment	The degree that the current employment of the communities in and surrounding the project or a new livelihood is guaranteed. This includes the permanent economic opportunities related to the port and new suitable livelihoods.
Cultural heritage	The degree of how many graves and sacred site need to be relocated in order to continue the project, where the area of the PONR monument should be respected and cannot be encroached.
Population resettlement	The degree how many people need to resettle due to the establishment of the port and how their new situation is compared to the old location. This includes transparent adequate

	compensation and the preservation of livelihoods of all groups in the affected communities.

The key values from the economic discipline are usually conflicting with key values from the other two disciplines. This is caused by the fact that sustainable and social measures often require more investments which conflicts with the key value *CAPEX/OPEX*. However the key values of the economic discipline do not conflict with the key value *Employment*, which does not require further explanation. If key values can conflict, they can also positively reinforce each other in certain planning measures. These measures of course are wanted in the alternative designs and hence before starting the development of alternatives, a brainstorm session should take place to come up with these possible planning measures which have positive effect on more than one key value. It is of course also possible that the chosen location comes along with limitations unable to implement these measures. In this case, the alternatives should consider different key values. The table of possible planning measures based on the key values is provided in Appendix **D**. The strategy used to implement these measures is to avoid (1), to minimise (2) and to mitigate (3) negative impacts on the environment. That means that in the first place these measures should strive for avoidance of any negative impact to system. When this is not possible minimising or mitigating/compensating measures should be provided. Therefore in the same table the possible impacts of these solutions are provided as well. It is desired to conduct an impact assessment (i.e. a full ESIA) as soon as possible, but this is a rather difficult procedure as the masterplan needs to be determined first. Hence, considering the possible impacts of the alternative planning measures can be seen as a brief impact assessment in order to help the selection of the most beneficial and sustainable measures, which eventually will be implemented in the three alternatives. This is actually also part of the adapted port planning strategy, to consider the long term uncertainties of possible planning measures in order to create a flexible and future-proof port.

Alternative development

From this point the development of alternatives starts. The alternatives are developed in such a way that they fulfil the needs and objectives of the port (design parameters) and take the key values into account to the utmost degree. The alternatives should be described in several development phases: this is recommended by ISPD in order to guarantee more flexibility for the port for unexpected future changes. One of the socio-economic challenges for example is that the container demand might grow slower or faster than forecasted. With the phased development, the port can react on this uncertainty, by respectively delaying or speeding up the construction of the next phases. The port planner should choose the number of phases: the more phases, the more flexible the masterplan becomes. This however requires a significant amount of time and due to the lack of detail in this research, the phased development will be reduced to an initial and a long term phase.

All three alternatives have a different lay-out of the terminals, but they all consist of the same components and measures (indicated if this is not the case), because they are based on the same port needs, objectives and key values. The desired terminal requirements are already specified by Badagry Port Development Limited, as part of the port needs and objectives, but the following measures which are developed in this step still need explanation: *Aquaculture/Rice farming, Sand Motor, Buffer zone with landscaping, Sand filled geotextile containers, Relocation of the F100 highway* and *bridge connection island with shore*. The development of these six measures will be explained by providing a short problem description, the key values on which the measures are based and the chosen solution/measure. This process is described below.

1. Problem description – With the establishment of the port, over 4600 local inhabitants need to relocate to other places in the surroundings. The loss of their (farm) land and plantations, and negative impacts of the project on the marine and inland water system, would affect their livelihoods as well. In order to accelerate their cooperation, suitable alternative livelihoods need to be offered. Hence it is important to first analyse their current livelihoods and educational level: it turns out that the main livelihoods in the project area are small scale agriculture, fishery, markets and petty trading, and that the majority of the community people has a relatively low education level [Royal HaskoningDHV, 2015]. Due to this low education level, the same or alternative livelihoods need to be introduced which do not significantly deviate from their current livelihoods. Another option would be re-schooling.
Key values – **Employment** and **Population resettlement**
Chosen solution – **Aquaculture and rice farming**. Aquaculture is the cultivation of particularly food fish and shell fish under controlled conditions, and would be a good replacement for fishery. Both aquaculture and rice farming can be easily performed after short education and it does not significantly differ from the current livelihoods. More information about these measures can be found in paragraph **4.6.1**.

2. Problem description – The arrival of the port will disturb the longshore sediment transport along the coast which results in sedimentation and erosion at respectively the western and eastern side of the port. With no preventative measures, the eastern side of the coastline adjacent to the port, including the high valued PONR monument will be eroded away. Traditional countermeasures require materials outside the project area or would bring frequent disturbances to the local ecosystem.
Key values – **Biodiversity, Coastal and marine ecology** and **Cultural heritage**
Chosen solution – **Sand Motor**. A Sand Motor is a new coastal maintenance strategy which basically means highly concentrated sandy nourishments. The difference with the traditional medium volume of sand nourishments, is that a lower frequency of nourishments is required which results in less frequent disturbance of local ecosystems. More information about this measure can be found in paragraph **4.6.2**.

3. Problem description – As indicated before, the PONR monument located east of the port is a significant valued cultural heritage in the project area. In order to avoid any impact on this monument, the port should keep a minimum distance from the PONR. However, due to the lack of space at the chosen location, this distance cannot be large enough that no visual sight of the port will be experienced standing at the PONR. The industrial sight therefore should be replaced by a more desired natural sight.
Key values – **Biodiversity** and **Cultural heritage**
Chosen solution – **Buffer zone with landscaping**. The buffer zone will avoid direct contact between the port and the PONR, and the width differs per alternative. In order to avoid the visual sight of the port, the buffer zone will be used for landscaping. This landscaping is performed in such a way that the view of a person standing at the PONR, will not be disturbed by the view of the port. In other words, a person located at the PONR should not see the highest point of the port. More information about this measure can be found in Appendix **E**.

4. Problem description – The proposed port needs to be protected against the negative impacts of weather and the intensity of the waves near the shoreline to arrange safe harborage. Breakwaters are usually build at the entrance of the port to provide a sheltered approach channel for the incoming and outgoing vessels and to create a quiet wave environment in the port basin. Traditional breakwaters are made from rock, however there are no rocks in the near surroundings of the project site. Transporting the rocks from somewhere else by truck would result in high costs and more chance on road accidents. It would be more sustainable to use materials for the breakwater which are already present in the project area.
Key values – **CAPEX/OPEX, Biodiversity** and **Health, Safety and Security**

Chosen solution – **Sand filled geotextile containers**. A breakwater made of geotextile sand containers is a more sustainable, easily reversible and soft solution compared to the hard breakwaters. This soft breakwater has the same purpose as a traditional breakwater, but can be considered more environmental friendly as it uses large amounts of sand which are already abundantly present in the surroundings. More information about these measures can be found in paragraph **4.6.3**.

5. Problem description – The chosen location for the proposed port is bounded by the F100 highway in the north-west. This means that the F100 would proceed through the port complex, dividing the secured area into two separate areas. The F100 however requires free access as not port-related activities make use of the road as well, which results in a complex security arrangement of two separated port areas. In addition the connectivity within the port would be strongly influenced by the two separated port areas.
Key values – **Connectivity** and **Health, Safety and Security**
Chosen solution – **Relocation of the F100 highway.** Due to the relocation of the F100, there is one entire port complex which increases the connectivity and security within the port. The relocation of the F100 also provides some flexibility for the new location of the road.

6. Problem description – Traditional port masterplans are often entirely connected to the shore. This results in bad water circulation in the end of the basins and therefore issues with bad water quality arise.
Key values – *Pollution*
Chosen solution – **Bridge connection island with shore.** If the lay-out allows it, the alternatives should include a short bridge connecting an island (a port area which is not attached to the shore) with the shore which increases the water circulation in the end of the basin. This will increase the water quality inside the basin and results in less polluted water. Due to the positioning of the terminals, this measure could only be implemented in alternative 3.

Hence several measures are developed based on the nine key values. In total I have developed three alternative port lay-outs which include the same port components and also include the above mentioned measures. Alternative 1 is based on the development in such a way that the existing F100 does not need to be relocated. In combination with the shortest breakwaters, this alternative has the lowest CAPEX/OPEX. Alternative 2 and 3 are developed to create better connectivity within the port by relocating the F100. Other implemented measures in alternative 3 are mainly focused on the environmental and social key values and therefore this alternative has the highest costs. Alternative 2 can be seen as the average of the two other alternatives and this alternative almost never includes the best or worse implementation of key values. This alternative however does affect the most communities in the project area. In the next paragraph the three alternatives will be explained one by one based on the key values.

4.5.1 Alternative 1

Alternative 1 is based on the key values in table **4-B**. It can be seen that several implemented measures are reinforced by more key values, which are given a color. The key value which is not considered for alternative 1 is *Pollution*. Due to the layout no opportunities could be found to implement related solutions.

Table 4-B Key values used in alternative 1

Key value	Measure	Reinforcing measure
CAPEX/OPEX	-The port is developed in such a way that the existing F100 coastal road does not need to be relocated	

Connectivity	-The CT and GPT are aligned as they both have the same operators. The entire logistic park is aligned to these terminals and the F100 highway, which results in more convenient operation within the port and to the hinterland roads. -There are possibilities for future expansion by a rail and inland water terminal	
HSS	-The RPT and Industrial Estate are located downwind of the EHC; in case of leakages the EHC will not be affected.	
Biodiversity	-The southern part of the buffer zone is reserved for a landscaping area	-A Sand Motor (concentrated sandy nourishments) is placed behind the lee breakwater where erosion will take place. Due to the concentrated volume, there is less frequent disturbance of the local ecosystem compared to traditional smaller nourishments. The nourishment will mitigate the local erosion and therefore protects the PONR as well
Coastal and marine ecology		
Cultural heritage	-The development is parallel to the F100 in order to create a bigger distance with respect to the PONR monument -An access road is leading to the new tourist centre and PONR	
Employment		-The northern part of the buffer zone is reserved for aquaculture/rice fields in order to mitigate the loss of livelihoods of the communities.
Population resettlement		

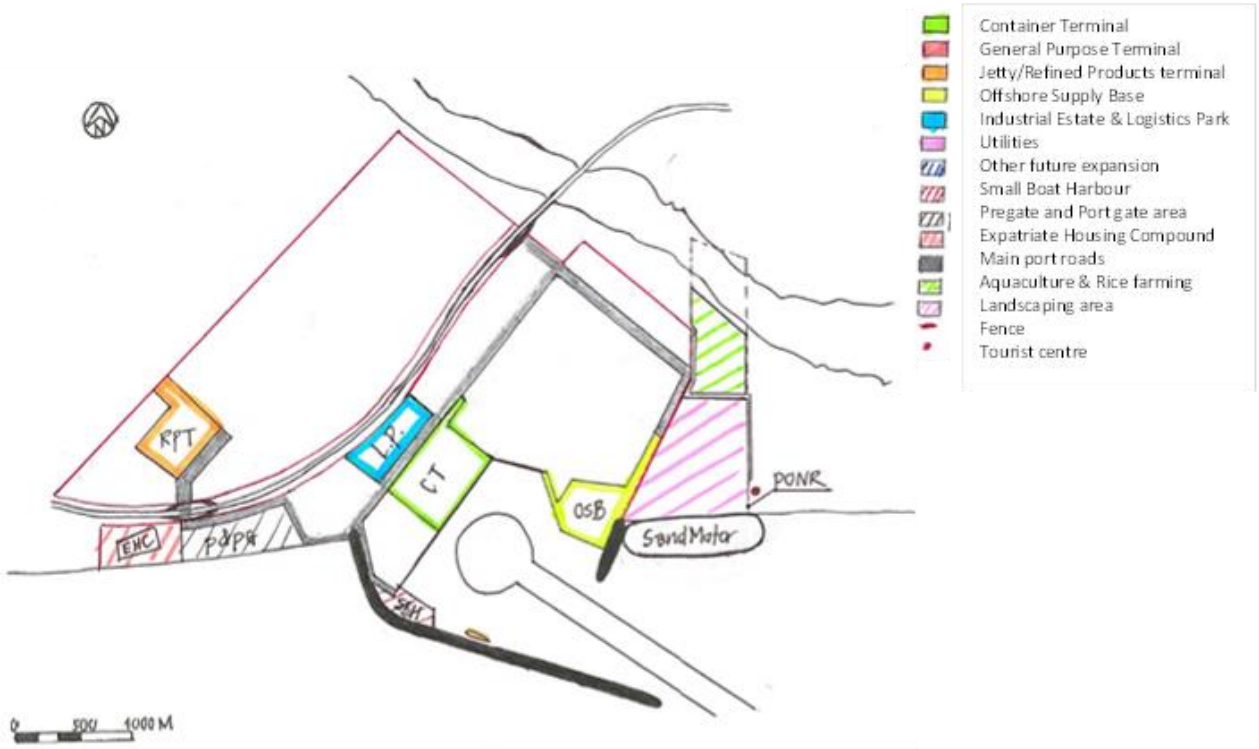


Figure 4-G Alternative 1 initial development

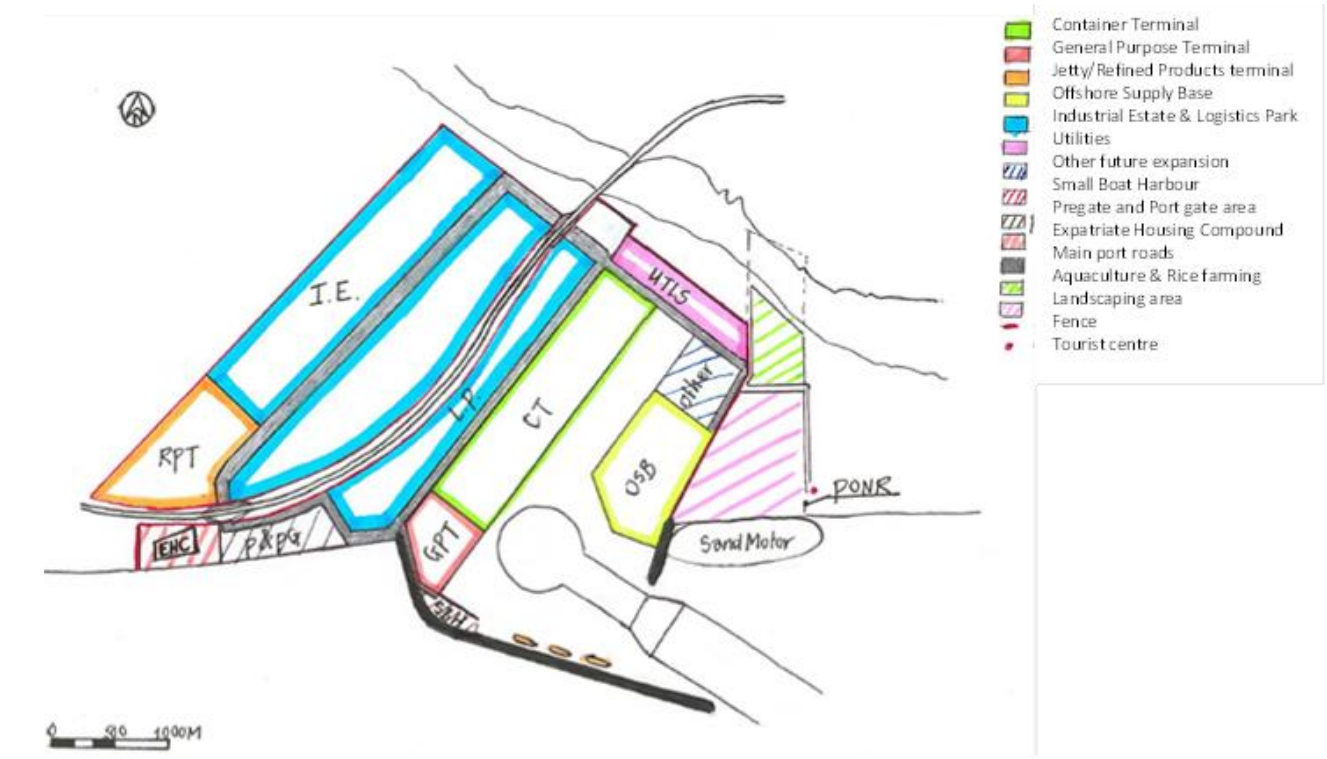


Figure 4-H Alternative 1 long term

4.5.2 Alternative 2

Alternative 2 is based on the key values in table 4-C. It can be seen that several implemented measures are reinforced by more key values, which are given a color. The key value which is not considered for alternative 2 is *Pollution*. Due to the layout no opportunities could be found to implement related solutions.

Table 4-C Key values used in alternative 2

Key value	Alone	Reinforcing
CAPEX/OPEX	-The layout is developed in such a way that the length of the breakwaters could be decreased	
Connectivity	-The CT and GPT are aligned as they both have the same operators. The entire logistic park is aligned to these terminals results in more convenient operation within the port -There are possibilities for future expansion by a rail and inland water terminal	-Due to the relocation of the F100, there is one entire port complex which increases the connectivity and security within the port -The relocation of the F100 also provides some flexibility for the new location of the road
HSS	-The RPT and Industrial Estate are located downwind of the EHC; in case of leakages the EHC will not be affected.	
Biodiversity	-The southern part of the buffer zone is reserved for a landscaping area	-A sand motor (concentrated sandy nourishments) is placed behind the lee breakwater where erosion will take place. Due to the concentrated volume, there is less frequent disturbance of the local ecosystem compared to traditional smaller nourishments. The nourishment will mitigate the local erosion and therefore protects the PONR as well
Coastal and marine ecology	-The basin is developed far away from the Creek to prevent inland water contamination	
Cultural heritage	-An access road is leading to the new tourist centre and PONR	
Employment		-The northern part of the buffer zone is reserved for aquaculture/rice fields in order to mitigate the loss of livelihoods of the communities.
Population resettlement		

Figure 4-I Alternative 2 initial development

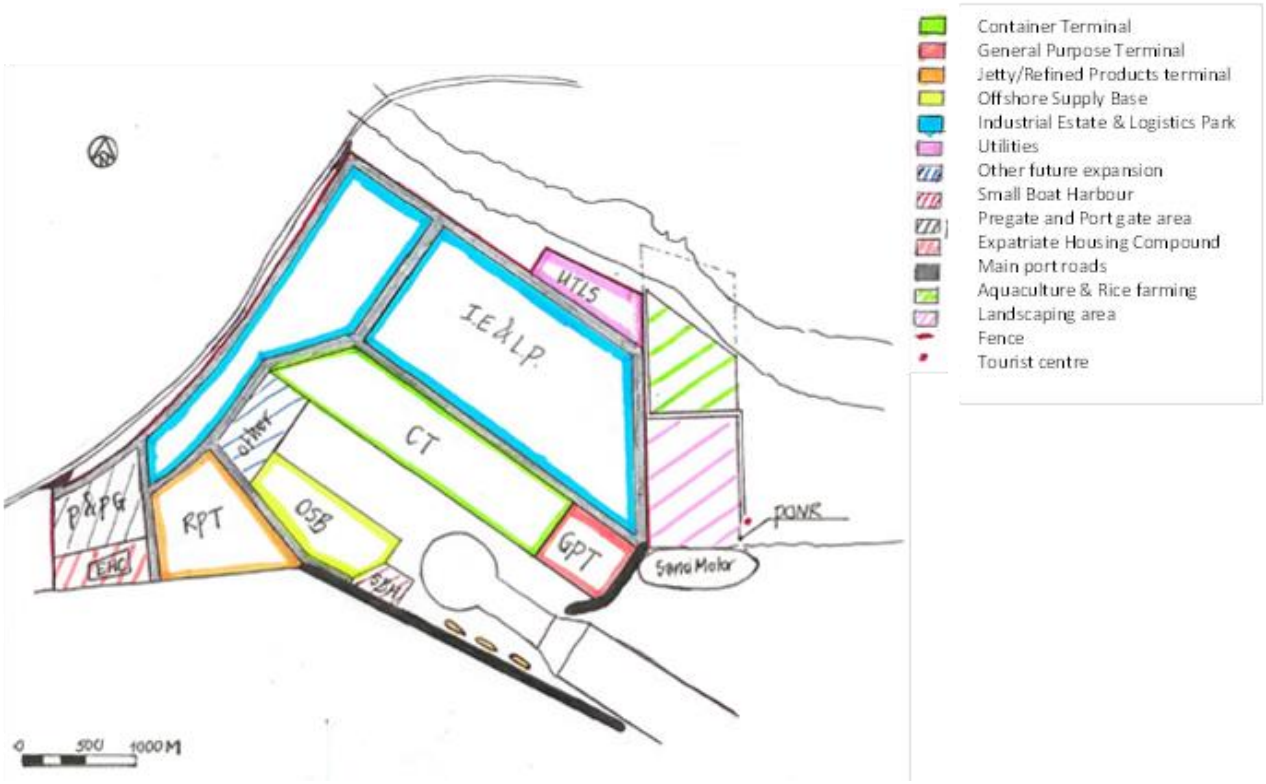


Figure 4-J Alternative 2 long term

4.5.3 Alternative 3

Alternative 3 is based on the key values in table 4-D. It can be seen that several implemented measures are reinforced by more key values, which are given a color. The key value which is not considered for alternative 3 is *CAPEX/OPEX* since due to the relocation of the F100, this is conflicting with the key values *Connectivity* and *HSS*.

Table 4-D Key values used in alternative 3

Key value	Alone	Reinforcing
Connectivity	-The CT and GPT are aligned as they both have the same operators. The entire logistic park is aligned to these terminals, which results in more convenient operation within the port -There are possibilities for future expansion by a rail and inland water terminal	-Due to the relocation of the F100, there is one entire port complex which increases the connectivity and security within the port -The relocation of the F100 also provides some flexibility for the new location of the road
HSS	-The RPT and Industrial Estate are located downwind of the EHC; in case of leakages the EHC will not be affected.	
Biodiversity	-The southern part of the buffer zone is reserved for a landscaping area	-A sand motor (concentrated sandy nourishments) is placed behind the lee breakwater where erosion will take place. Due to the concentrated volume, there is less frequent disturbance of the local ecosystem compared to traditional smaller nourishments. The nourishment will mitigate the local erosion and therefore protects the PONR as well
Coastal and marine ecology	-The basin is developed far away from the Creek to prevent inland water contamination	
Cultural heritage	-An access road is leading to the new tourist centre and PONR	
Pollution	The long term development includes a short bridge connecting the area reserved for expansion with the coastline which increases the water circulation in the end of the basin. This will increase the water quality inside the basin	
Employment		-The northern part of the buffer zone is reserved for aquaculture/rice fields in order to mitigate the loss of livelihoods of the communities.
Population resettlement	The layout is located in such a way that less communities need to resettle (avoid instead of mitigate)	

Figure 4-K Alternative 3 initial development

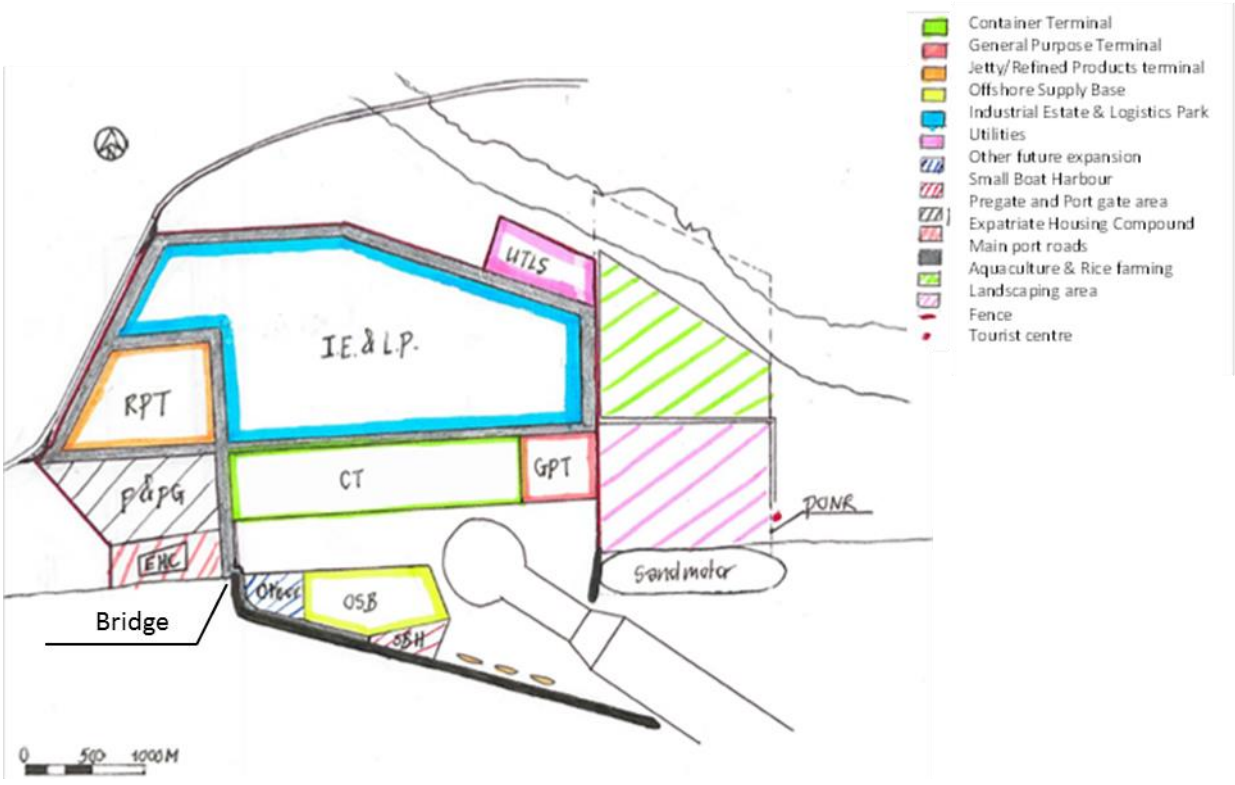


Figure 4-L Alternative 3 long term

4.6 Test the alternatives

The evaluation in the following step is based on the assessment of the technical feasibility, the potential impacts and the cost estimation of the developed conceptual alternative layouts. In order to prepare for this evaluation, the technical feasibility and potential impacts will be treated in this step. Since the three alternatives do not include significant complicated layouts, it is expected that no major issues will arise with the overall port configuration and its feasibility therefore will not be treated here. However there are three sustainable rather innovative measures which are implemented in each alternative which still require a lot of research and hence there are still significant challenges in order to successfully implement them in practice. Therefore the feasibility and the possible impacts of the following sustainable measures will be treated in more detail: *Aquaculture & Rice farming, Sand Motor* and *Geotextile Sand Containers.* First the measures (a) will be explained, then the feasibility (b) of the measure is checked including providing aspects for further research and eventually the possible impacts (c) of the measure on the economic, environmental and social environment will be treated in the following. Since the three measures are rather new and not commonly used in practice, BPDL (client) will also take a lot of risk to agree with these measures and hence this paragraph hopefully informs and helps BPDL to seriously consider the measures.

4.6.1 Technical evaluation and impacts: Aquaculture & Rice farming

The arrival of the port inevitably results in the resettlement of several communities to other places in the surroundings. One of the biggest worries of the inhabitants is the loss of their livelihoods caused by the loss of their farmland and plantations, and by the negative impacts of the project on the marine and inland water system which might affect the fishery. If construction and operations of the port project indeed affect their livelihoods, it is important to introduce alternative livelihood opportunities to satisfy the inhabitants and accelerate their cooperation. A good and feasible alternative is the combination of aquaculture and rice farming.

a. Measure

Aquaculture or aquafarming, is the cultivation of aquatic organisms, particularly food fish and shellfish under controlled conditions. The cultivated organisms can be both fresh- and saltwater populations and could be compared to agriculture, whereas fishery is comparable with hunting [Fisheries and Aquaculture Department, 2015]. It stands as a potentially sustainable alternative for the dangerous overfishing and decline of wild fish population at several places in the world. Currently as perhaps the most rapid developing food-producing division, it represents close to 50 percent of the world's food fish [Fisheries and Aquaculture Department, 2015]. Aquaculture can be performed both inlands as in the sea and has several positive socio-economic impacts: it supports jobs throughout the seafood supply chain. The jobs related to aquaculture tend to be centred in coastal, rural communities and provide as a wage-effective livelihood. The positive economic impact of the industry extends beyond the aquaculture companies: "Upstream" industries supplying aquaculture include agriculture hatcheries, veterinary services, equipment manufacturers and feed manufacturers. "Downstream" industries supplied by aquaculture involves processing, wholesale, retail, transport and food services [National Oceanic and Atmospheric Administration, 2015].

Although aquaculture can be seen as a sustainable solution for overfishing, it currently still has several negative impacts on the environment. These impacts are mainly in the form of importing huge amount of salt water inlands, the environmental impact of the use of medicine and other inputs in fish farms, the demand of space and fish feed [Fisheries and Aquaculture Department, 2015]. In order to develop

more sustainable conditions, the following alternative measures in aquaculture are introduced [Reynolds, 2012]:

1. Integrating rice-and-fish farming

Fish and rice fields accidentally know a history of coexistence, as various fish species ended up swimming into flooded rice fields and as a matter of fact prefer these circumstances to inhabit and reproduce [N. Ahmed, S.T. Garnett, 2011]. For this reason farmers have been intentionally import fish into their rice fields and the results are very promising: the increased availability of phosphorous and nitrogen in the soils cause by the fish, resulted in nutrient-rich and productive rice crops. Another reason for the nutrient-rich rice is the decrease in algae and disease-carrying aquatic weeds, which is a favored food for fish. In the integrated systems the yield is found to be higher and less fertilizer and pesticide inputs are required. On top of the improved and increased rice harvest, the farmers also receive an extra source of income for the fish in their fields [N. Ahmed, S.T. Garnett, 2011].

2. Inland recirculating aquaculture systems

A big issue of aquaculture systems is the fact that they require large amount of water for refreshing. A popular solution in recent years for this problem are the so-called recirculating aquaculture systems (RAS). In these systems the used water is going through a treatment tank and then is recirculated to the fish tank and reused [Timmons, 2007], making it possible to use less water up to 99 percent compared to other systems [Timmons, 2007]. Another advantage of RAS is that they are managed in controlled environments, so the waste discharge can be reduced, there is less need for antibiotics and chemicals to fight diseases and the chances of fish and parasite escape is brought to a minimum. RAS are also able integrate the water-based cultivation of plants, as plants develop well in the nutrient-rich water and even benefit its purification for reuse by cleanses it of nitrogen and phosphates [James, 2009]. On top of that, RAS result in less environmental damage compared with the majority of the other aquaculture systems (e.g. open-ocean farms), due to their minimum required space and limited pollution. The recent years there has been successful research, based on RAS in rural communities, on the treatment of human and animal wastewater and turning it into reusable fuel which can be used for providing electricity. This creates possibilities to make these communities self-sufficient for the majority [Reynolds, 2012].

3. Using locally caught fish as feed

A controversial topic in aquaculture is the feed for the cultivated fish. The main question related to this topic is if these cultivated fish consume more fish in the shape of grounded feed than they would generate for human consumption and therefore is decreasing the world's fish supply. This problem is even worsened by an increasing number of farmers which tend to feed the traditionally herbivorous fish with fishmeal in order to save costs. [Naylor and Burke, 2005]. This issue could be solved by letting aquaculture rely on their local fish supply to feed their cultivated fish and therefore reduce the inputs required for this industry. By only using the locally caught fish as feed, many dangers of industrial aquaculture are reduces as the feed is based on natural populations which have low risk (compared to exotic species) to negatively interact with the cultivated fish [Zertuche-González et al., 2008]. On top of that, there is no need to process or transport the fish feed which would significantly reduce the CO2 emissions [Tyedmers, 2009].

4. Involving women in aquaculture

Sustainability in aquaculture could also be sought from the social perspective. On the project site and the surroundings, the women are one of the most vulnerable groups regarding the impact on employment and therefore measures need to be taken to sustain them with alternatives to work. In the project area the women are mainly dependent on land for their income, however it is not allowed for them to

have their own or inherit land under the traditional land management system. This translates in the fact they often will not be included for compensation of land which makes them very vulnerable [Royal HaskoningDHV, 2015]. For this reason these women could play a significant role in sustainable and small-scale home based aquaculture systems, such as a backyard pond. This would not only support them with a dependable source of income, but also benefits the entire family and community from a nutritional and social aspect [Shaleesha and Stanley, 2000]. Around the project site the associated processing, wholesale, retail, transport and food services are already performed by mainly women and therefore should not form in issue [Royal HaskoningDHV, 2015].

Women in aquaculture in practice

In the Keelamakudi Village, in Tamil Nadu State of India, researchers from the M.S. Swaminathan Research Foundation have been training 30 under-privileged women in the project called B*ackyard ornamental fish breeding and management.* The project aims to teach these women to run home-based aquaculture operations where ornamental fish are raised for sale. The choice of crop is fallen on ornamental fish because these species require limited technical skill, time and space, which can be locally sold for approximately USD$9-14 per household, per month. Home-based aquaculture is connecting the women with training, technology, credit, infrastructure, job security and trade, supporting the livelihoods of vulnerable rural women [Shaleesha and Stanley, 2000].

Used aquaculture water is recycled in the kitchen garden [adopted from Shaleesha and Stanley, 2000]

The freshly hatched fry is separated from the parent stock [adopted from Shaleesha and Stanley, 2000]

b. Feasibility

The feasibility and success of (the combination of) sustainable aquaculture and rice farming mainly depends on the requirements for rice cultivation. The first question to answer is if there is any market demand for the two businesses in the local environment to provide the communities of a stable source of income: As fishery is one of the current main livelihoods, only the market demand for rice needs to be analysed. Although Nigeria has one of the largest rice productions in Africa, at the same time it is also one of the world's largest importers of rice which translates into a high national demand of rice [Food and Agriculture Organization of the United Nations, 2015]. Local production of rice is highly attractive due to the high costs related with importing the rice. Rice farming in Nigeria is considered an essential cash crop because the majority are small-scale producers who generally only use 20 percent for their own consumption and sell the remaining 80 percent of their harvest. This results to the fact that rice farming is generating more income for Nigerian farmers than any other cash crop in the country [Food and Agriculture Organization of the United Nations, 2015]. This translates in a great opportunity for the livelihoods of the communities at the port site. Not only in the sense of rice cultivation, but also the

development of the associated markets such as processing and sale of rice, rice mills constructions and wholesale distribution [Food and Agriculture Organization of the United Nations, 2015].

The most important climate conditions which affect rice growth are rainfall, temperature and the hours of sunshine [Agriculture and updates, 2011]. The favorable region should include the necessary warmth and enough rainfall for the cultivation of rice. Rice is a (sub-)tropical plant and requires a relatively high temperature between 20°C and 40°C and an ideal temperature of 30°C. Furthermore sunlight is extremely essential to enable the plants to develop and grow and therefore the area needs to have sufficient hours of sunlight for the rice plants [Agriculture and updates, 2011]. Badagry has maximum and minimum temperature of 29.0°C and 25.4°C, with an average temperature of 27.4°C. And with about 1445 mm of precipitation per year and sufficient hours of sunlight [Climate Data, 2015], the site location is considered to be highly suitable for rice cultivation. Another important aspect for feasibility are the suitable climate and soil conditions required for rice cultivation. Rice can grow under a great variety of soil conditions and it is rather difficult to indicate a soil on which it is not able to grow. However, the ideal rice soils include having a good water retention capacity and a fairly amount of clay and organic matter. The site location in Badagry has a geotechnical profile of sand with clay layers in between, where more land inwards areas contain more clay than the areas near the coastline, providing excellent soil conditions for rice growth [Agriculture and updates, 2011].

Concerning the economic feasibility, it makes sense that it is more sustainable and convenient to build small-scale inland aquaculture systems and rice fields because only land and equipment is required. The latter should not raise any issues because there are relatively small investments needed for small-scale aquaculture systems and rice fields. The former should also not form any problems as the land will already be compensated by the port. The used land for the integrated system of aquaculture and rice fields is preferable located near the Creek: this gives easy access to water and therefore also provide easy fish entrance from the Creek to the rice fields. Another economic (and environmental) advantage of the adjacency of the Creek is the availability of inland water transport.

Further detailed research and attention which needs to be paid to this system is described as follows:

- The current locations for the aquaculture and rice farming near the Creek (see figures **4-G** till **4-L**) are selected based on the initial suitable conditions. However, more detailed research need to be performed in order to find the most suitable land.
- It must be studied which fish and rice species are the most suitable, feasible and profitable to cultivate. As the local circumstances might be limited, the species should require limited time, space and technical knowledge and should be sold for a reasonable price.
- Currently the local inhabitants are not familiar with the practices of sustainable aquaculture and rice farming on large- and small-scale and they need to be properly educated in order to run the systems independently. Training programs should provide the people with sufficient information about technology, credit, job security, infrastructure, trade and detailed business plan.

c. Impacts

Economy

One of the main advantages of aquaculture and rice farming is the resulting boost of the economy and their economic value (in the form of the ecosystem service food) which by far outweighs the capital required for the businesses. The capital required depends on the circumstances, but aquaculture and rice farming in generally require significant initial capital due to the land that is needed. However if the communities get compensation in the form of new land, this initial investment is not an issue anymore. If the aquaculture and rice business may translate in growth for the regional and national economy,

there is a great possibility that the government will partially invest in it as well. According to the site study there were already attempts of aquaculture in Nigeria in the past [Royal HaskoningDHV, 2012], so the potential and investment are definitely present. Furthermore, small scale aquaculture is relatively cheap and can be established in the backyard of inhabitants so this livelihood could also provide for own consumption. In addition, there are possibilities to not only cultivate local fish species but also potentially open the market for fish species which cannot be grown in the natural circumstances. Lastly, with inland aquaculture systems there is low risk that diseases emerged from fish farms cause serious damage to the wild fish populations and therefore the fishing industry also has a low risk to be affected by aquaculture [Food and Agriculture Organization of the United Nations, 2015].

Environment
Aquaculture stands as a potentially sustainable alternative for the dangerous overfishing and decline of wild fish population at several places in the world. The main environmental issues of aquaculture are drastically reduced by the introduction of inland recirculated aquaculture systems [Food and Agriculture Organization of the United Nations, 2015]. There is a lower risk of spreading diseases to wild fish species, less water is used as the wastewater is treated and reused again and with locally caught fish servings as fish feed, the wild fish population should not be significantly affected. If the fish tanks would be sustainable like this, then the impact of aquaculture on the environment can be considered minor. Furthermore, by combining the rice fields with aquaculture, there is a reduced demand for fertilizer and pesticides in rice fields.

Society
The main advantage of aquaculture and rice farming for the local society is the (in)direct generation of a significant amount of new jobs throughout the seafood and crop supply chain. The jobs related to aquaculture and rice farming tend to be centred in coastal, rural communities and therefore are suitable for the livelihoods of the local inhabitants. Aquaculture also results in the fact that the variety of fish accessible to the consumers is greatly enlarged. Furthermore, aquaculture and rice farming do not extremely differ from the current two largest livelihoods at the site location, namely fishery and agriculture. Besides the job opportunities for men, the related jobs also provide many opportunities for more vulnerable groups such as women and elderly who are required to stay at home. Creating profitable new livelihoods has benefits for the resettled inhabitants but has also a positive effect on the acceptation and process of the port project.

4.6.2 Technical evaluation and impacts: Sand Motor
In the event of no preventative measures, there is an extremely high risk that the eastern side of the coastline adjacent to the port, including the PONR will erode away. Traditional countermeasures would consist of hard structures perpendicular to the coastline which require material that is not present in the local surroundings and/or frequent sand nourishments which also frequently disturb the local ecosystems. In order to counter coastal erosion with a more sustainable measure, the Sand Motor is introduced.

a. Measure
A Sand Motor is a new coastal maintenance strategy which basically means concentrated sandy nourishments. The fundamental objective of a sandy nourishment in the traditional approach is to maintain the coastline by the use of a medium volume of sand (approximately 2 to 5 million m^3) with a typical lifespan in the order of 5 years. This results in nourishment repetitions every five years with the associated frequent disturbance of the local ecosystem. The new coastline strategy however has a concentrated nourishment and depending on the situation and the desired lifespan, the nourishment could be

several times the amount of the traditional approach, possibly rising the coastline several meters above MSL. The (temporary) presence of surplus sand establishes new areas for nature and recreation and is gradually redistributed by natural processes (i.e. winds, waves and currents) over the coastline. On top of that by less frequent nourishments, this innovative approach promotes the limitation of disturbances to the surroundings and provides nature more time to develop new ecosystems with enhanced biodiversity. In front of the coastline the areas should also be filled with sand to create shallow areas which are very favorable habitat conditions for small marine species. Initial results at pilot studies (e.g. Delfland Sand Motor (2011)) have already shown that this strategy is effectively counteracting coastal erosion, while at the same time it also provides opportunities for nature and recreation.

The Delfland Sand Motor

The Sand Motor Delfland project is a sustainable and climate-proof solution which counteracts the coastal erosion by exploring the benefits of concentrated sand nourishments in space and time, while stimulating the nature and recreational opportunities. The Sand Motor experiment includes a concentrated sand nourishment of 21.5 million m^3 which will be constructed about 5 meters above sea level. Due to natural processes the sand is gradually divided along the coastline, beach and dunes. This innovative measure aims to reduce the negative impacts on the ecosystems by disturbing them less frequent with sand nourishments (compared to the typical five year return period of the traditional nourishments).

The Delfland Sand Motor is constructed in 2011 and the first results show that this measure is effective in counteracting the coastal erosion as expected, by spreading the sedimentation along the coastline to the new dunes, which experience visits by seals and the growth of flora and fauna. In addition, the Sand Motor also attracts many wind and kite surfers. In the coming five year this project will be monitored and extensive research programmes are set up which both accurately analyse the development of the Sand Motor and the physical, ecological and social driving forces of this measure as well. The Sand Motor experiment is a collaboration between research institutes in public parties and private corporations, which resulted in the fact that the emphasis is put on the Sand motor for coastal research in order to find innovative solutions for coastal protection and management. [Ecoshape, 2015].

The Sand Motor in Delfland after construction in 2011
[adopted from Ecoshape, 2015]

The Sand Motor in Delfland in 2015
[adopted from Ecoshape, 2015]

b. Feasibility

The net longshore sediment transport along the Nigerian coastline is approximately 0.8 million m^3 per year from west to east. With the establishment of the Badagry port, accretion will take place at the west of the main breakwater and erosion will take place at the east of the lee breakwater. Based on a simple sediment equilibrium, the assumption could be made that if there is 0.8 million m^3 accretion, then the

coastline adjacent east of the port should erode with 0.8 million m^3 per year as well. This means if a nourishment with a lifespan of 20 years is desired, a concentrated sandy nourishment of approximately 20 x 0.8 million = 16 million m^3 is required once the breakwaters are constructed. The required sand needs to be dredged from the approach channel, basins and can also be retrieved from the sedimentation area west of the port through the means of a bypass. Perhaps it is even needed to dredge areas before the actual planned phase. This is not a significant issue because these basin areas need to be dredged in later phases anyways. If this dredged sand is not enough then it is necessary to dredge more sand in the surrounding sea. The exact location (as well as the volume, frequency and shape) of the nourishment is not known yet, but in all the three alternatives the expected location of the Sand Motor is indicated around the expected location of the erosion (see figure **4-G** till **4-L**). It is of significant importance to mention that despite the promising potential of the Sand Motor, it is still a relative new coastal maintenance strategy and therefore further detailed study is necessary.

Further detailed research which needs to be performed is described as follows:

- To test the concentrated nourishment to a full extend, detailed assessment is needed regarding the optimal location, volume, frequency and shape of the nourishments.
- After these parameters are decided, detailed simulation models should be used to provide predictions of the morphological process development over time, the development of dune formation and the extensive environmental impacts. Currently there is no comprehensive understanding of the complex interaction of all the relevant processes and hence this restricts the prediction of the Sand Motor's impact on the terrestrial ecology.
- After completion, the coastline needs to be closely monitored if the sediment transport and the Sand Motor evolves as predicted.

c. Impacts

Economy

With the concentrated sandy nourishment, there is no need for other coastal protection. The only material required is sand which can be obtained from the dredged port areas and the surrounding sea bottom. Hence, the main costs for the construction of the Sand Motor are the maintenance dredging costs. As initially there is a huge amount needed for the Sand Motor, more initial dredging is needed. This probably does not result in a good cut and fill balance, but it is a cheaper solution than getting rocks from a faraway location to create a hard structure, such as groynes. Furthermore, the sedimentation which will take place west of the main breakwater will bring along future opportunities in the form of transport of this sand through a bypass to nourish the eroded coastline east from the port. Another opportunity would be the possible use of the sedimentation area for future port expansion if the area becomes stable. As this local coastal erosion problem is a result of the port construction, the Sand Motor should be financed by a collaboration between public authorities and private companies. The potential of the Sand Motor is very promising and of significant importance for future coastal erosion problems and hence there is a high possibility that research institutes might partially finance it as well.

Environment

The largest negative impact of the Sand Motor is the disturbance of the ecosystems during the nourishment itself. Sand nourishments in general influence the coastal geomorphology as well as the abiotic conditions of the beaches and dunes. The critical changes in the structure of the shore caused by the local concentrated nourishment are expected to have major impacts on the local biodiversity and ecosystem, potentially affecting the environment for the long term. This significant impact, however, is mitigated by less frequent concentrated sand nourishment compared to the traditional more frequent and smaller nourishments. Local ecosystems would face less frequent disturbances and are provided with

more time to develop new ecosystems (such as shallow water habitats) and perhaps with even more enhanced biodiversity. The time period of the nourishments is also of great importance: the shoreline along Badagry is used as a nesting site by the Green Turtle. The potential nesting period of Green Turtles is between the months March and August/October to December. Although during observations between September and December no green turtles were found, these periods still should be avoided for sand nourishments in order to have a negligible impact on the nesting process. Another sustainable aspect of the Sand Motor is that it requires material which is already abundantly present in the local surroundings, namely sand. By using the local materials there is no need to obtain material from other distant areas which prevents a significant amount of CO2 emissions in the air resulting from transporting that material.

Society

Besides favorable circumstances for nature, the (temporary) presence of surplus sand also provides opportunities for recreation for the local community and the future employers. Furthermore, the Sand Motor maintains the coastline by preventing further erosion: this does not only protect the PONR monument from damage and/or relocation, but it also decreases the chances of possible salt water intrusion in the fresh water Creek and lagoon system. As these water systems are important nursery grounds for (shell)fish, disturbance of these water systems can have a significant impact on the (shell)fish and indirectly on the local communities who largely depend on the livelihood of fishery in the Creek and lagoons. The flip side however might be that although the Sand Motor theoretically should provide enough safety to maintain the coastline transport, this however might not be enough from the safety perspective of the people. For this purpose, perhaps in the end it is also necessary to build a groyne.

4.6.3 Technical evaluation and impacts: Geotextile sand containers

The port needs to be protected against the negative impacts of weather and longshore drift. Breakwaters can reduce the intensity of waves near the shoreline and consequently arrange safe harborage. Breakwaters are usually build at the entrance of the port to provide a sheltered approach channel for the incoming and outgoing vessels and to create a quiet wave environment inside the port basin. The principle of breakwater is rather simple: the waves originating from the sea are broken or reflected at the outer side of the breakwater, which results in a smooth wave climate inside the breakwaters. It is common to build hard breakwaters made of rock, but as there are no rocks in the near surroundings of the project site, a more sustainable solution should be introduced, such as sand filled geotextile containers.

a. Measure

Traditional breakwaters are hard structures made of rock. However as rock is becoming more expensive and difficult to acquire, it is very interesting to consider a more sustainable, easily reversible and soft solution such as a breakwater made of geotextile sand containers (GSC) [Hornsey et al., 2003]. The concept of GCSs has already been discovered decades ago by applying it for a dike line closure and since then they are mainly used to serve as temporary protection because long term constructions did not yet had sufficient stability under wave loads [Hornsey et al., 2011]. Recent years however a number of significant GSCs projects have been performed in Australia [Hornsey et al., 2011].The early geotextile containers mainly consist of tubes with a variety of lengths and perimeters fabricated essentially from woven geotextiles (which would depend on the manufacturer). The GSCs now however can be manufactured in a variety of forms, such as elliptical and rectangular cross section [Hornsey et al., 2011]. GSCs have the same purpose as a traditional breakwater, but are more environmental friendly as they use large amounts of sand which is already abundantly present in the surroundings. To make the GSCs more environmental friendly there is a possibility to perform landscape architecture on top of the containers.

Lime burners breakwater, Geelong, Victoria, Australia

The Lime burners Point boat harbour was subject to wind waves of up to 0.5 m; this would result in significant damage to the floating pontoons inside the harbour, which would make the launch and retrieval of the recreational vessels very difficult and dangerous. This project aims to reduce wave transmission into the harbour by constructing a 80 m long x 5.5 m high geotextile sand container breakwater, constructed at -4.0 m LAT and situated 40 m from the end of the harbour entrance.

The breakwater was built up of 40 m long by 12 m perimeter and the GSCs consisted of a combination of standard duty staple fibre geotextile for the bottom and sides, and a composite staple fibre geotextile on the exposed surface as serious exposure to UV radiation can be expected.

Satellite view of Lime Burners Point harbour [adopted from Hornsey at al., 2011]

To date the project is catering the required harbour protection by reduction of the maximum wave heights at the pontoons. The breakwater offers limited danger to small craft vessels, and in the unlikely event of collision with the breakwater the damage to the small craft is expected to be less significant compared to an impact with a hard traditional structure [Hornsey et al., 2011].

Lime burners breakwaters timeline [adopted from Hornsey at al., 2011]

b. Feasibility

As there is sufficient sand present in the surroundings, the feasibility of the GSCs breakwater mainly depends on the stability and durability of the GSCs.

Stability

The stability of the traditional hard rock breakwaters can be tested with the Hudson's formula [Hudson, 1953], but it was acknowledged for a long time that this formula could not be used for the assessment of GSCs. One of the main key factors influencing the stability of a container structure is the global/wave stability. There are experiments performed regarding global stability GSCs on small scale, but currently

the large scale wave flume testing of GSCs to apply it in practice is still absent due to the high associated costs. However without the accurate data obtained from full scale GSCs modelling, it is also not possible to ensure accurate scaling of the GSCs and consequently accurate forecast of the GSCs performance could not be made. Research is performed regarding the stability of smaller container options which represent the small GSCs used in practice [Water Research Laboratory of the University of New South Wales, 2008]. The four most important components in this research are scaling of the containers, preliminary wave flume modelling, comprehensive flume modelling and developing the design curves and methodology.

Another key factor influencing the stability of the containers is sand retention. As is mentioned above, the fill capacity of the GSCs play an import role in its stability and hence it is of critical importance that this fill capacity will be preserved for the entire structure's life time. However designers often overlook one important aspect, namely the sand retention capacity of the geotextile which has a significant impact on the fill capacity of the GSCs in the long run. As the GSCs including the sand within are under exposure to quite aggressive flow conditions, the geotextile has a high probability to deform during both the installation of the container as sand movement due to wave attack. For some woven geotextiles this deformation translates into a change in the pore size and the retention capacity of the GSCs and this should be avoided as much as possible.

The last key factor influencing the stability of GSCs is the scour protection. In order to maintain the endurance of the GSCs structure, like with all coastal structures, the toe stability is of crucial importance. Therefore the location of the toe should be at a level where it has a minimum chance to be damaged. In general if base of the structure is established at 0 m LAT the performance of the structure is sufficient but in every case an accurate site assessment is required. On top of that during extreme storm event large scale erosion might develop at the toe of the structure, so in order to prevent damage on the breakwater it is advised that an additional scour container should be implemented in the structure (figure **4-M**). Furthermore the toe GSC should not be too small compared to the wave conditions as it still might damage the structure and eventually leads to failure of the design.

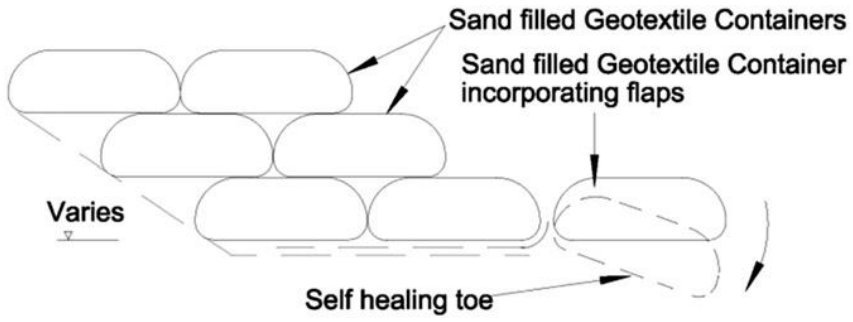


Figure 4-M Flexible toe container detail [adopted from Hornsey et al., 2011]

Durability

One of the key factors influencing the durability of the GSCs is the damage resistance, which can be divided in the incidental damage (i.e. boat or driftwood impact) and vandalism (i.e. knife cuts and punctures The first category of damage can be significantly reduced by the choice of a suitable geotextile which is less affected by damage. The survivability of a geotextile depends on the elongation, this means that a geotextile needs to be chosen with high elongations in order to have a lower damage potential. The second category of potential damage, i.e. vandalism consists primarily of knife cuts. The standard (non-)woven geotextiles have limited resistance to this kind of vandalism and would result in failure of

the system. A possible solution for this problem is the usage of a composite geotextile (figure 4-N). A composite geotextile has the standard inner geotextile plus a coarse fibre geotextile fastened to the outside. Besides the outer layer serving as a course protection, it also contains trapped sand within the geotextile which contributes to additional protection from knife cuts. The lower the outer layer geotextile mass, the less sand it can contain and the lower the damage resistance. Experiments have shown that the ideal outer layer geotextile should have a mass of 900 g/m^2 in terms of a good cost and protection ratio. If there is still damage after these two methods, then maintenance of the GSCs will be performed which primarily consist of patch work of potential wholes or damage to the containers.

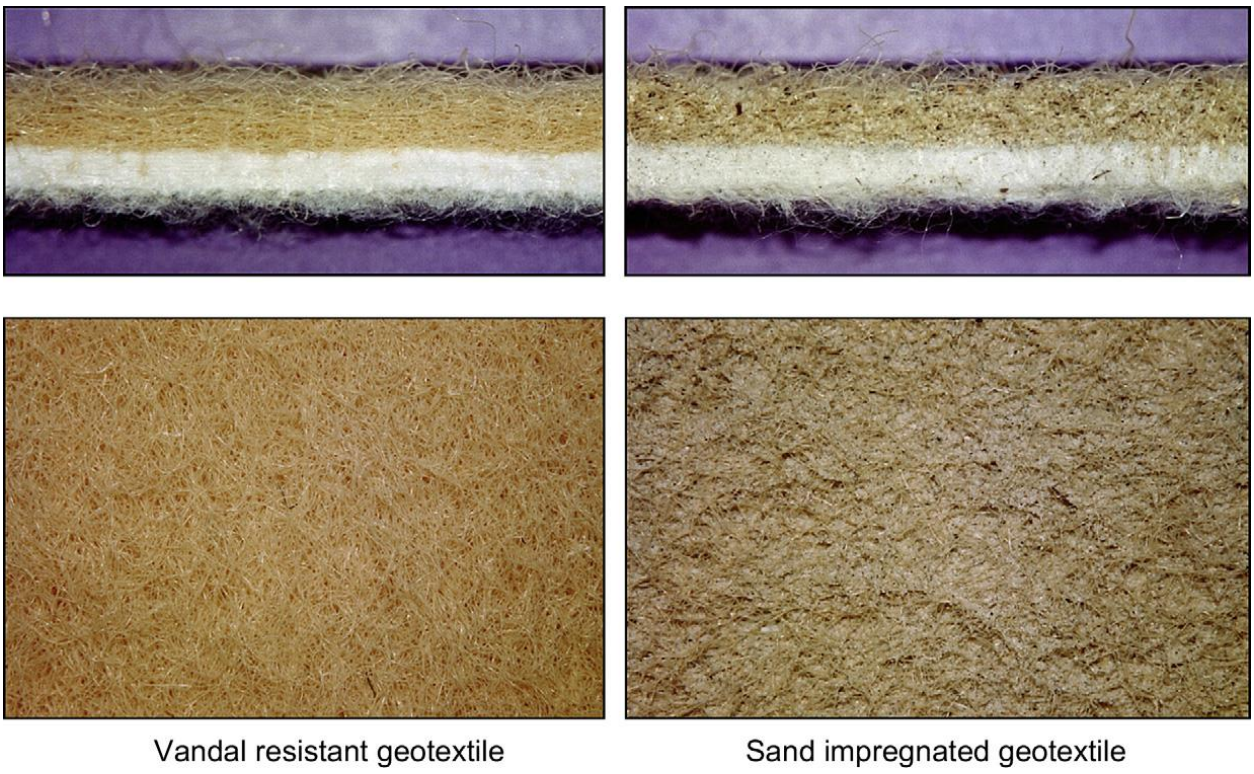


Figure 4-N Composite geotextile [adopted from Hornsey et al., 2011]

Another key factor affecting the durability of GCSs is UV degradation. Since standard geotextile can only withstand a maximum of 2 to 3 months of UV radiation, it is expected that the GSCs should withstand the exposure to UV for many years. Experiments have resulted in the medium term possibilities of the GSCs (Russell Heads groyne, 1993. Stockton Beach revetment, 1996) [Restall et al., 2002], but it still should be determined if the containers are also suitable for long term performances. It is expected that with the improvements in the technology of polymers, the durability of the GSCs is also improving [Hornsey et al., 2011].

The last key factor which plays an important role in the durability of GSCs is the abrasion resistance. As the surrounding seawater contains sand, shell and coral fragments, the containers are under the threat of abrasion and its life durability will be limited. This abrasion particularly has its most significant impact near the sea bed level, where the movement of coarse material reaches its maximum. It is advised to

select a generic geotextile class which provides a minimum strength retention of 70% after 80,000 abrasion cycles [BAW Federal Waterways Engineering and Research Institute, 1994].

The above information shows that there still is a long way to go before the GSCs can be implemented in practice. The containers still require a lot of research and hence there are still significant challenges in order to successfully implement this measure in practice; not only is this measure not so commonly used and rather new, the client also takes a lot of risk and therefor it will be a hard decision for the BPDL to consider this measure.

So in order to make a suitable design of the GSCs breakwater, further detailed research which needs to be performed is described as follows:

- Detailed assessment of the stability (i.e. wave stability, scour protection and sand retention) and durability (i.e. damage resistance, UV degradation and abrasion resistance) of the GSCs.
- After completion, the breakwater needs to be closely monitored if the containers are staying on their place and are protecting the harbor for the long term as intended.

c. Impacts

Economy

In general the breakwaters are one of the largest capital investments in a port masterplan. In this alternative for the breakwater there is a huge amount of sand required. This sand is already in the surroundings and no other materials need to be transported from elsewhere, which would make this alternative cheaper than a breakwater made from another material. The geotextile however, needs to be fabricated and transported from outside the project area. The construction costs are also lower as the main tasks are to fill and place the containers, and the containers also have a minimal construction timeframe. As the GSCs breakwater is easier to reverse than a hard structure, it also offers more flexibility for the masterplan for any possible future seaward expansion of the port.

The maintenance mainly consists of patching possible holes and damage to the containers and therefore is less expensive than repairs conducted at hard structures. However it is expected that more maintenance is required as the geotextile has less strength than the rocks. This problem can be minimised by selecting a stronger geotextile which naturally would also increase the costs.

Environment

As the required sand is already present in the surroundings, this soft breakwater is more environmental and user friendly. On top of that the sand filled geotextile containers provide habitats for marine species and it is also possible to create a gradual natural connection with the land. It is perhaps possible to create a landscape on top of the soft breakwater where small animal species can reside. The negative impact caused by dredging is disturbing several ecosystems, however this does not need be done regularly.

Society

As the PONR monument is near the coastline, the sand containers could definitely be viewed from this position. However the view of the sand containers might not be disturbing if a nature landscape is built on top of it which basically looks like long island of beach and/or nature. Besides environmental purposes, landscaping the sand containers also provides a social purpose by creating a recreational view from the coastline.

4.7 Evaluate the qualities of each alternative

4.7.1 Criteria and weighing factors MCA

A Multi Criteria Analysis (MCA) is an evaluation methodology to aid the selection of the most suitable alternative based on various criteria. As is already explained in paragraph **2.6**, the criteria used for this MCA are the previous defined nine key values as these key values are considered by the stakeholders to be critical for the project. The difference with the existing port development process is that different criteria are used in this evaluation. These criteria were also known beforehand as the key values so the alternatives are developed on these criteria, which makes the assessment of the alternatives more relevant and equal. The exact aspects which will be included in each key value for this MCA will be explained in the following paragraph. First a weighing factor needs to be assigned to each criterion as not all criteria are valued of equal importance. This will be done placing all the criterion in the first column and row of a table as can been in table **4-E**. By comparing each criterion in the column with another criterion in the row, a 0 or 1 should be given. If the criterion in the column is given an 1, then that means that the criteria in the column is more important than the criteria in the top row. The total score of each criteria in the first column is the sum of that row. The weighing factor is the total score plus 1, or else it would mean that one criteria has a weighing factor of 0 which basically means that criteria does not play a role at all. The higher the score means the more important the key value. This weighing factor table is filled in with the help of experts involved in the project who are familiar with the perspectives of the stakeholders.

Although the research is mainly focused on sustainability and tries to emphasize less on the costs of the project, the situation however should be considered to be as realistic as possible. In other words sustainability from an environmental and social perspective might be regarded as important, but the financer of the project still has more decision power and therefore costs will always play one of the largest roles in a new project, as can be seen in the highest weighing factor given to the key value "CAPEX/OPEX". The thesis however is an excellent opportunity to show that key values such as *costs* and *biodiversity* should not have to be independent and could have a positive impact on each other.

Table 4-E Weighing factors base case

	CAPEX/OPEX	Connectivity	Biodiversity	Coast/Marine	Pollution	HSS	Employment	Cult. heritage	Resettlement	**Total**	**Weighing factor**
CAPEX/OPEX	x	1	1	1	1	1	1	1	1	**8**	**9**
Connectivity	0	x	1	1	0	0	0	1	1	**4**	**5**
Biodiversity	0	0	x	0	0	0	0	0	0	**0**	**1**
Coast/Marine	0	0	1	x	1	0	0	1	0	**3**	**4**
Pollution	0	1	1	0	x	0	1	1	1	**5**	**6**
HSS	0	1	1	1	1	x	1	1	1	**7**	**8**

Employment	0	1	1	1	0	0	x	1	1	**5**	**6**
Cult. heritage	0	0	1	0	0	0	0	x	0	**1**	**2**
Resettlement	0	0	1	1	0	0	0	1	x	**3**	**4**

Now the weighing factors are known, the three alternatives can be assessed based on the nine key values. Each value will be assigned a score ranging from a minimum of 1 up to a maximum score of 5. With 1 and 5 as respectively the worse and best possible scores. These scores are relative as the alternatives are compared with each other. Furthermore it is also possible that alternatives will get the same score for several values, because the differences of the alternative regarding these values are not very significant. Finally the scores of each value will be multiplied by the previous assigned weighing factor and the sum of the results is the total score of the alternative. The alternative with the highest total score indicates the most suitable masterplan for the Badagry Port Project.

4.7.2 Results MCA for each alternative

Criteria 1 CAPEX/OPEX

Considering the minimum difference in quay wall lengths, terminal areas for each alternative and the (dredging) maintenance and operational costs, the evaluation of the Capital Expenditure is primarily based on the cost of the breakwater, the cost for relocating the F100 coastal road and construction of a new bridge, which indicate the differences in the alternatives.

Alternative 1 has the shortest breakwater of approximately 4000m, alternative 2 follows with a breakwater length of about 4200m and Alternative 3 contains the longest breakwater of approximately 4700m. In Alternative 2 and 3 the F100 coastal road needs to be relocated: the estimated cost for relocation of the road and construction of a new bridge are equivalent to about 1400m length of breakwater. This is a significant amount and therefore these costs may not be neglected. Based on these costs, Alternative 2 and 3 have respectively about 25% and 35% higher CAPEX.

Alternative 1 – 5 points
Alternative 2 – 3 points
Alternative 3 – 2 points

Criteria 2 Connectivity

Connectivity indicates accessibility of the terminal (within the port area) and the interlinkages with the hinterland (road, rail, inland waterways). This also include the possibilities to construct a rail and inland water terminal in the future.

All three alternatives have the possibility for expansion by a rail and inland water terminal and their associated linkages. Alternative 1 has the entire Logistic Area along the Container Terminal and F100 high way, which results in the shortest access route to the hinterland roads. The entire port of alternative 2 and 3 is one port complex and is located at one side of the relocated F100 coastal way, which makes the connectivity within the port much easier. The relocation of the F100 also provides some flexibility for the new location of the road.

Alternative 1 – 3
Alternative 2 – 4
Alternative 3 – 4

Criteria 3 Biodiversity
Since it is expected that the impacts on the local and surrounding ecosystems resulting from the project do not significantly differ between the alternatives, the assessment of the biodiversity is primarily based on the area of the buffer zone and the possibilities to protect, preserve and/or create ecosystems there. It also includes the possible risk of impacting the ecosystems.

Alternative 3 has by far the largest buffer zone size to create biodiversity. In Alternative 1 and 2 the reserved area for the buffer zone is respectively 60% and 54% with respect to the buffer zone in Alternative 3. All alternative include a sand motor which decreases the frequency of impacts on the ecosystems.

Alternative 1 – 3 points
Alternative 2 – 2 points
Alternative 3 – 5 points

Criteria 4 Coastal Erosion and Marine Environment
Coastal Erosion and Marine Environment predominantly includes the erosion of the coastline directly east of the port and the possible inland water contamination with salty seawater.

Alternative 1 has the highest chance of inland water contamination as this design is dredged furthest land inwards. However, there is still a distance of approximately 750 m between the Creek and the basin which is not under the high risk of salt water intrusion. No major risks could be identified for Alternative 2 and 3.

Alternative 1 – 3 points
Alternative 2 – 5 points
Alternative 3 – 5 points

Criteria 5 Pollution
Potential impacts on the environment should be identified in more detail during the Environmental and Social Impact Assessment (ESIA). Pollution in this part describes the use of resources which would obviously affect the local and surrounding environment.

The establishment of the Badagry Port brings along pollution of the environment. Since the required operations are the same for each alternative, it is expected that there are no significant differences regarding the pollution of the environment and the impact on the environment in alternative 1 and 2 which are considered moderate. Alternative 3 also has the same port operations, but its long term development includes a short bridge connecting the area reserved for expansion with the coastline which increases the water circulation in the end of the basin. This will increase the water quality inside the basin and therefore alternative 3 owns a higher score.

Alternative 1 – 3 points
Alternative 2 – 3 points
Alternative 3 – 4 points

Criteria 6 Health, Safety and Security
There are no significant differences between the alternatives regarding this criteria, because the Health, Safety and Security of the involved people are of critical importance to a certain degree that the same required measures need to be implemented in every alternative. The evaluation of the HSS therefore is

based on the locations of the Refined Product Terminal and the Industrial Estate relative to the surroundings and the main security control of the port area.

In Alternative 1 the F100 is proceeding through the complex, dividing the secured area into two separate areas east (terminals and Logistics Park) and west (RPT and Industrial Estate). Obviously the F100 needs free access as not port-related activities make use of the road as well. The entire port complex, i.e. the port, Industrial Estate and Logistics Park, has a joint security organisation in order to prevent unauthorized entry and activities throughout the entire area. The security arrangement of two separated port areas is more complex compared to one port area. Alternative 2 and 3, after relocating the F100, exist of one port complex and therefore do not face this problem. The RPT and Industrial Estate are located downwind of the EHC in all alternatives; In case of leakages the EHC will not be affected. However if calamities really were to happen, due to the predominant south-western wind the impact will be felt at Badagry town. As alternative 3 has the RPT and Industrial Estate located most to the west, it will affect Badagry the least.

Alternative 1 – 3
Alternative 2 – 4
Alternative 3 – 5

Criteria 7 Employment
Employment includes preservation of the current livelihoods of the affected population and the creation of new permanent livelihood opportunities for the local and surrounding population. Due to the resettlement, land used for their livelihoods (e.g. farming, fishing near the Creek, coconut plantations etc.) will be lost and new areas need to be reserved for this purpose. This criteria primarily assesses the area reserved for aquaculture and rice farming in the buffer zone.

Alternative 3 has by far the largest area reserved for aquaculture and rice farming. In Alternative 1 and 2 the reserved area for the buffer zone is respectively 20% and 58% with respect to the area reserved in Alternative 3.

Alternative 1 – 3
Alternative 2 – 4
Alternative 3 – 5

Criteria 8 Cultural Heritage
Since the alternatives are located around the same area, they approximately also have similar impact on historical and cultural sites. The evaluation of Cultural Heritage therefore only depends on the impacts on the most significant monument, namely the PONR.

Alternative 3 has the distance between the port and the PONR of 1500m. Followed by respectively alternative 1 and alternative 2 with and distance of respectively 1100m and 850m. It should be noted that with the smallest distance of 850m, no noise impacts will be heard at the PONR. The sight of the port will differ per alternative.

Alternative 1 – 4
Alternative 2 – 3
Alternative 3 – 5

Criteria 9 Population resettlement

As it is already agreed on that it is not possible to avoid the resettlement of the population residing in the project area, the aim should be to impact these inhabitants as least as possible in their process to move to a new location. This includes assigning a new location for them to live, the guarantee of their livelihood (discussed under criteria 7 "Employment"), transparent stakeholder engagement and an adequate compensation. These aspects need to be described in a systematic and transparent plan. This plan does not indicate any differences between the alternative. Therefore the assessment of Population resettlement is predominantly based on the number of affected communities.

Alternative 3 affects the least of communities namely Ganyingbo Sea Beach, Aivoji, Ganyingbo Town, Hoke-Daho, Agorin Sea Beach and Agonvi Sea Beach. In Alternative 1, in addition the community of Yeke-Tome is partially affected, but the community of Gberefu is affected less. Alternative 2 affects the most communities: besides the communities mentioned in Alternative 3, the communities of Yeke-Tome and Ganyingbo Topa also need to be partially resettled.

Alternative 1 – 2 points
Alternative 2 – 1 points
Alternative 3 – 4 points

Table 4-F Total score base case

Criteria	Weighing factor	Alternative 1		Alternative 2		Alternative 3	
CAPEX/OPEX	9	5	45	3	27	2	18
Connectivity	5	3	15	4	20	4	20
Biodiversity	1	3	3	2	2	5	5
Coast/Marine	4	3	12	5	20	5	20
Pollution	6	3	18	3	18	4	24
HSS	8	3	24	4	32	5	40
Employment	6	3	18	4	24	5	30
Cult. Heritage	2	4	8	3	6	5	10
Resettlement	4	2	8	1	4	4	16
Total		29	**151**	29	**153**	39	**183**

4.7.3 Sensitivity analysis

In order to provide more reliability to the outcome of the MCA in the previous paragraph, the score needs to be checked for its sensitivity to a change in weighing factors. A sensitivity analysis needs to be conducted to discover if the same alternative will rank first if the weighing factors are regarded differently. Next to the existing weighing factors of the base case (previous paragraph), three other weighing factors sets A, B and C will be tested. Set A gives all criteria equal weighing. Set B is based on giving higher importance to the criteria *HSS* and *Resettlement*. Set B is chosen particularly for this case in Nigeria, as the local communities and the health, safety and security issues play an important role. And finally set C is based on giving *CAPE/OPEX* the least importance and therefore more weight to the sustainability factors which keep the same order as the base case. Although this situation would not be realistic

as costs always play a significant role, it is interesting to find out how the alternatives score based on the sustainability factors.

The outcome of the sensitivity analysis point out that in all three scenarios with different weighing factors, alternative 3 is also by far the alternative with the highest score, followed by alternative 2 and 1. As is mentioned above, the goal of this analysis is to check in what extent the outcome of the base case scenario is sensitive to different weighing factors. Since only this conclusion is important, the full sensitivity analysis will not be provided here but can be found in Appendix **F**.

4.7.4 Recommendation alternative

In this paragraph the results of the MCA and the sensitivity analysis are summed up and a recommendation is given to select an alternative to develop further. Table **4-G** provides a summary of the results of the evaluation.

Table 4-G Results MCA and sensitivity analysis

	Alternative 1	**Alternative 2**	**Alternative 3**
Base case	151	153	183
Set A	29	29	39
Set B	143	144	187
Set C	135	155	204

Alternative 1 obtains the lowest score, but there is not a clear difference with the score of Alternative 2. The main benefit of Alternative 1 are the lowest costs due to shorter breakwaters (*economy*), but it has lost points largely due to the required larger community resettlement and the two separated port areas which affect the connectivity and security within the port (*society*). This alternative could be preferred from a financial point of view, but is definitely is not the best solution with regard to the other criteria.

Alternative 2 has obtained the second highest score and ends just before Alternative 1. The main benefits of this alternative over alternative 1 are the larger land size contributing to the local livelihoods and one entire port area resulting in higher connectivity and security within the port. The negative aspects compared to the other alternatives are the smallest distance between the port and PONR, the most affected communities in the project areas and the high costs of the relative long breakwaters and relocation of the F100. This alternative is not preferred from a social point of view.

Alternative 3 has obtained the highest score and is the clear and outright favourite, which is proved even more during the sensitivity analysis. The alternative has lost points due to the longest breakwaters and the need to relocate the F100. However this alternative is preferred due to its larger distance to the PONR, affecting less communities, the least impacting the security of the people in and surrounding the port and excellent connectivity within the port. Alternative 3 is despite its costs preferred above the other two alternatives.

Table 4-H Results MCA multiple perspectives balance

	Economy	**Environment**	**Society**
Alternative 1	++	+	+/-
Alternative 2	+	+	+
Alternative 3	+/-	++	++

Before recommending an alternative, it should be mentioned that the above performed evaluation may be rather subjective, since I both developed and evaluated the alternatives. Furthermore, most evaluation criteria based their score on the differences between the three alternatives; however since all three alternatives are still conceptual masterplans on system level, it was assumed that most aspects on construction and material level do not significantly differ. In order to adequately evaluate each criteria, it would require more detailed designs. Despite these limitations, according to figure 4-H, alternative 2 seems more in balance from an economic, environmental and social perspective. However alternative 3 shows much more benefits from and environmental and social perspective and although this alternative has the highest costs, **based on the assessment and sensitivity analysis, it is recommended to BPDL that alternative 3 should be developed further in more detail as part of the port master plan.**

4.8 Create final design

Following from the MCA and the sensitivity analysis, alternative 3 is the most suitable design and therefore recommended to the client. However since this alternative also has the highest costs, I cannot simply assume that the client would agree on this recommendation. For this reason I have decided to add a rough cost analysis: this costs analysis will provide the required costs of alternative 3 compared to the costs of the existing masterplan. Since alternative 3 is more expensive than the other two alternatives, the client BPDL maybe can be convinced to choose alternative 3 if I can proof that this masterplan does not require significantly more investments than the existing Badagry Port masterplan. Furthermore, as this research struggles with time constraints, it is not possible to provide a full ESIA analysis which in practice should be performed at this stage. Since this research is not mainly focused on performing the final ESIA, the potential impacts of alternative 3 described above in paragraph 4.6 would be sufficient for this case.

4.8.1 Rough cost analysis new masterplan

The costs of the project are of significant importance for the parties financing the project. In this paragraph a rough cost analysis of the recommended long term masterplan of alternative 3 will be provided. It is chosen to provide these long term costs relative to the costs of the existing masterplan, as it will be practical and interesting to compare both costs during the evaluation in the next Chapter. The costs of the elements and services are already known for the existing masterplan [Royal HaskoningDHV, 2015] and can be used as a rough indication of the costs of the new masterplan. Elements like the quay wall lengths and terminal areas have significant costs, but these elements show minimum differences between both lay-outs. When costs are relative to each other, the only costs which need to be considered are the significant differences between both masterplans. These differences are as follows:

- Breakwaters – The breakwaters in the new masterplan are made from geotextile sand containers and therefore the costly purchase and transportation of the rocks for a hard breakwater are not required anymore. However with a breakwater made of mostly sand, there are new dredging activities required for the sand containers. Another difference with the existing design is the absence of a groyne the east side of the lee breakwater. Taking this all into account the costs of the sand container breakwater and the absence of the groyne are estimated on *€ 240 million*.
- Relocation F100 highway – In the new masterplan the F100 needs to be relocated more to the west of the project site. With this relocation there is also a need for a new bridge to cross the Badagry Creek. The costs of this relocation and the new bridge is estimated on *€ 70 million*.

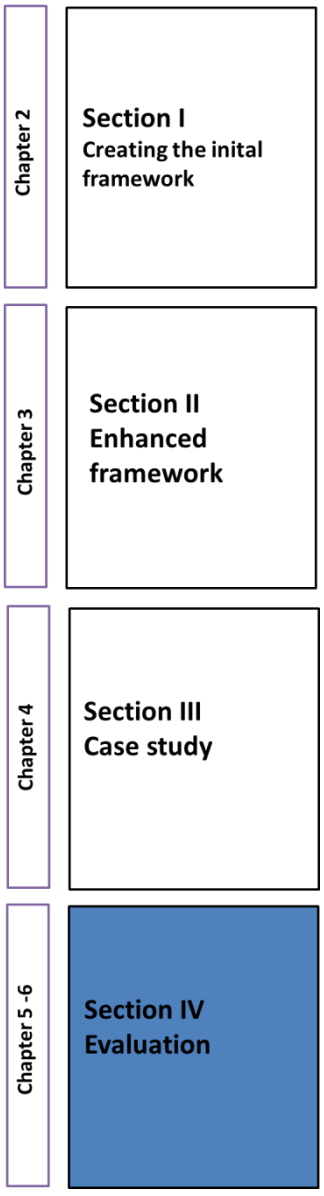
Hence the total costs of the new masterplan are *€310 million*. From the data of RHDHV, I could find that considering the same elements, the costs of the existing BPP masterplan are estimated on *€311 million* [Royal HaskoningDHV, 2015]. It should be specifically noted that this estimation is very rough and only the highest costs have been considered and the costs of research of the innovative sustainable measures are excluded. Despite these aspects, the costs of both masterplans may be considered approximately from the same order of magnitude.

So according to this rough cost analysis, alternative 3 does not require more investments than the existing traditional masterplan. If it is assumed that the client agrees with alternative 3 now, then this alternative is selected for further detailed design on construction and material level in this step. However the existing BBP masterplan is still a conceptual design and the information of this detailed research was not available yet and thus the chosen alternative could not be optimized for this case study. Furthermore as is specified in paragraph **1.2**, this research only focuses on system level and the more detailed level design of the chosen alternative is outside the scope of this research. However I will briefly explain what actually should be done here;

- Detailed design and construction and material level in such a way that the final detailed is ready for approval and can be connected to the construction and material phase.
- After construction, set up a monitoring system for the sustainable measures *Aquaculture, Sand Motor* and *Geotextile Sand Containers* which are still rather new and therefore bring along uncertainties and risks.
- Prepare actions which can be under taken when undesired or unexpected observations are obtained. This could be a feedback loop back to the design phase where an alternative solution can be found.

It should be mentioned that the first bullet point still involves the planning and design phase, but the following two bullet points show that planning under long term uncertainties actually does not finish at the end of the planning and design phase. Since the goals of considering these uncertainties and risks is to create a flexible and future-proof port, this also involves the construction and operational phase which are outside the scope of this research; these are the phases where the port can be adapted under unexpected changing circumstances in order to still keep its function. Hence the development of the ISPD framework for the more detailed planning and design phase, the construction phase and the operational phase are recommended for further research, which will be mentioned in Chapter **6**.

SECTION IV EVALUATION



5 EVALUATION

5.1 Introduction

This chapter covers the final evaluation of the research and consists of two parts: in the first evaluation the existing Badagry port masterplan is compared with the new resulting ISPD masterplan of the case study. In this section it becomes clear which masterplan is considered to be more sustainable and hence, answers the question if the ISPD framework really results in a (more) sustainable port. This evaluation is performed by using the predefined criteria of *the sustainable port* in Paragraph **2.6** and the two masterplans are qualitatively compared based on these criteria in paragraph **5.2**. The second part evaluates the degree of applicability of the ISPD framework to the case study. This will be performed by looking at the advantages and challenges encountered in every step of the ISPD framework during the implementation on the case study in paragraph **5.3**. The chapter ends with a conclusion in paragraph **5.4** where the lessons learned from both evaluations are summed up.

5.2 Evaluating the new masterplan versus the existing masterplan

In this section the resulting masterplan of the ISPD framework is compared with the existing masterplan of the Badagry Port. The criteria used for this evaluation are the predefined criteria in the evaluation of a sustainable port in paragraph **2.6**. For better explanation of these criteria, I refer to Appendix **A**. Since no distinction is made in importance between the criteria in this definition, all the criteria are considered of equal importance. Furthermore, the two masterplans do not go into detail of several criteria because these criteria require more detailed designs beyond the system level, which is outside the scope of this research. Therefore not all criteria can be discussed during the comparison of both masterplans. The masterplans can be assessed now based on the defined criteria and referring back to paragraph **2.6**, the following rule applies: the less negative impact is caused by a port on the environment regarding these criteria, the more sustainable the port is regarded. For these reasons, a full MCA is not required here. To give a quick reminder the existing masterplan of the Badagry Port and the new ISPD masterplan are shown again in figure **5-A** below.

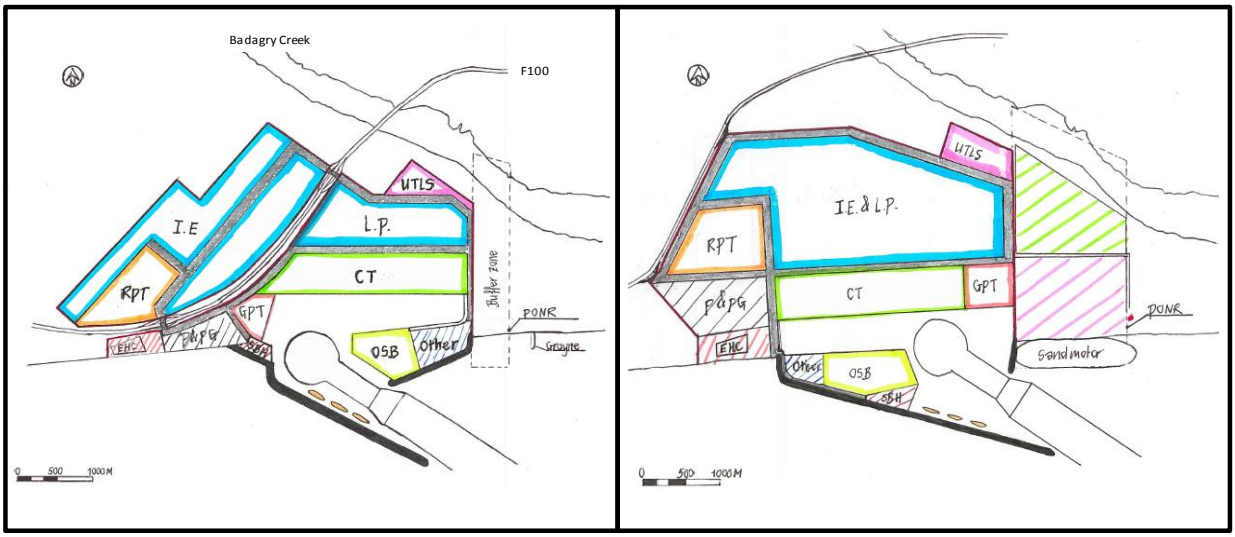


Figure 5-A Existing BBP masterplan (left) and ISPD masterplan

Table 5-A shows the comparison of the two masterplans based on the defined criteria of a sustainable port.

Table 5-A Evaluation existing BBP masterplan and ISPD masterplan based on definition criteria

Criteria	Existing BBP masterplan	ISPD masterplan
Land use planning	-Good use of land for continuous long term operability of the port from economic (increase (in)direct employment inside and outside the port), social (attraction people recreation and cultural purposes) and physical/ environmental perspective (coastal erosion protection by a groyne and frequent sand nourishments). Good port-city interaction is expected -Flexibility due to phased development and taking into account of multiple scenarios for different terminal use in the future	-Good use of land for continuous long term operability of the port is increased from an socio-economic perspective (increase employment and less resistance from the resettling communities by the introduction of aquaculture and rice farming and their downstream markets as replacing livelihoods) -Flexibility due to phased development and taking into account of multiple scenarios for different terminal use in the future
Modalities and Connectivity	-Convenient operation within the port (due to alignment CT and Logistics Park -Possibility several hinterland transport modalities (road, rail and barge)	-Better connectivity compared to the existing masterplan within the port due to relocation of the F100 and alignment CT and GPT (with the same operator) and Logistics Park - Possibility of several hinterland transport modalities (road, rail and barge) - Flexibility for new location F100
Air quality	-High CO2 emission from the transport of large amount of rocks for the breakwater by trucks from Lagos area and the faraway Calabar area (south east of Nigeria, near the border with Cameroon). Supply by inland water and seagoing barges is also considered, but at this stage these modalities are considered unlikely from an economical, practical and time delay viewpoint. Barge transport is still considered for later stages.	-Less CO2 emission by the use of locally present material for the breakwater
Surface water and sediment quality	-No relevant impacts on system level design	-Increase in water quality in basin due to the water circulation in the end of the basin caused by a bridge
Soil and groundwater quality	-No relevant impacts on system level design	-No relevant impacts on system level design
Dredging impacts	-Reuse of dredged material for reclamation areas -Frequent disturbance of ecosystems due to sand nourishments at eroded coastline -No sand nourishment during breeding seasons	-Reuse of dredged material for reclamation areas -Less frequent disturbance of ecosystems due to very large sand nourishments (sand motor). This provides more time to form new ecosystems or to rebuild the existing ones -No sand nourishment during breeding seasons
Sound impacts	-A 500 m wide buffer zone will decrease the future sound impacts of the port construction and operations, for a person (e.g. tourists) located at the PONR monument and beyond	- A 1500 m wide buffer zone and the additional landscaping will decrease the future sound impacts of the port construction and operations even more, for a person (e.g. tourists) located at

		the PONR monument and beyond
Energy and climate change mitigation	-No relevant impacts on system level design	-No relevant impacts on system level design
Climate adaptation	-No relevant impacts on system level design	- No relevant impacts on system level design
Habitat and species health	-No loss of valuable natural habitats -No sand nourishment during breeding seasons (e.g. nourishment needs to be supplied once every 5 years, then this action may not be performed during the breeding seasons)	- Less loss of fish species by introducing aquaculture. A natural environmental system can be built for the breaded fish. - Less frequent disturbance of ecosystems due to very large sand nourishments (sand motor). This provides more time to form new ecosystems or to rebuild the existing ones - No sand nourishment during breeding seasons e.g. if concentrated nourishment needs to be supplied once every 20 years, then this action may not be performed during the breeding seasons)
Landscape management and quality of life	-Less visual impact of the port located from the PONR monument by a 500m wide buffer zone -Seven local communities need to be resettled -A resettlement plan is set up to adequately guide the resettling communities. This includes assigning a new location for them to live, the guarantee of their livelihood, transparent stakeholder engagement and an adequate compensation.	-No visual impact of the located from the PONR monument by a 1500m wide buffer zone and landscaping of this buffer zone. -Five local communities need to be resettled -A resettlement plan is set up to adequately guide the resettling communities. The guarantee of their livelihood is covered by the introduction of aquaculture and rice farming
Ship-Related Waste Management	-No relevant impacts on system level design	-No relevant impacts on system level design
Sustainable Resources Management	-Use of large amounts of rock for the breakwaters, which is scarce in the local surroundings	-Use of sand for the breakwaters, which is abundantly present in the local surroundings

Conclusion

From table **5-A** above it first of all shows that the ISPD masterplan has less negative and more positive environmental impacts based on all relevant criteria on system level. This however does not consequently proof that this masterplan is more sustainable than the existing Badagry masterplan, because, as is specified above, several criteria could not be discussed during the comparison of both masterplans: these criteria require a more detailed design level which is beyond the scope of this framework and research. Since the weight of all criteria is of equal importance, the missing evaluation of these criteria is necessary in order to make a more valid conclusion.

The last criterion *Sustainable Resources Management* could only be partially treated. This criterion treats the usage of scarce material resources within and beyond the port and closing material loops as is specified in Appendix **A**. However first of all, this research treats port masterplanning on system level; many required natural resources and material for construction of the port is important to mention, but they are all linked to the more detailed construction and material level design which is beyond the scope of this research and the ISPD masterplan. Second, the closing material loops should cover the entire port life cycle that besides the planning and design phase treated in this research, also includes the construction, operation and demolition phase. This last phase for example covers an important sustainable strategy of recycling and re-usage, since the large quantity of port debris provides excellent cost effective

opportunities after recovery [Vellinga et al., 2014]. Since these phases and design levels are not included, this criteria could not be adequately discussed in this evaluation. The majority of the criteria however could be adequately discussed on system level, and all point out that the ISPD masterplan seems more sustainable.

Furthermore, the masterplan evaluation above only considers the qualitative impacts from an environmental perspective and hence the socio-economic and quantitative monetarisation evaluation are excluded. In paragraph **2.3.1** and **2.6** it is already explained why I chose for the above performed evaluation. However it may be possible that some researchers, port planners or BPDL will not extremely value this evaluation from only an environmental perspective, and therefore a brief cost assessment of the ISPD masterplan relative to the existing masterplan has been added in paragraph **4.8.1**. This cost assessment proofs that the ISPD masterplan is cheaper than the existing one, based on only the highest costs. Furthermore, if the socio-economic perspective would be included in the evaluation of sustainability of both masterplans, then the ISPD should also result in a more sustainable port; the ISPD framework is aiming to find sustainable planning measures which create socio-economic benefits as well, while the traditional framework mostly focuses on economic benefits [Deltares, 2015]. It should be mentioned however that these analyses exclude the investment costs for research and the risks which come along with rather innovative measures.

Lastly, since this research is aiming to create a sustainable framework which results in a (more) sustainable port, it should be questioned if my judgment as the author is too subjective regarding the research preference. Although I have tried to perform the evaluation as unbiased as possible, it still may be possible that another researcher or port planner would have a differing conclusion. However the ISPD masterplan is systematically developed based on key values resulting from carefully performed location analyses, while emphasis is put on sustainable measures and socio-economic benefits as driving force. For this reason I strongly believe that, despite a different judgement by another researcher /planner per criterion, the overall conclusion (i.e. the ISPD masterplan can be considered more sustainable) would be the same.

Considering the results of the masterplan evaluation and the discussion about the limitations of this evaluation treated above, I can conclude that according to the criteria of this research the ISPD masterplan can be considered more sustainable than the existing masterplan of Badagry.

5.3 Evaluating the applicability of the ISPD framework to the case study

The second part of the evaluation assesses the degree of applicability of the ISPD framework on the chosen case study of the Badagry Port Project. The advantages and challenges encountered during the planning process in each step will be treated in the order of the seven guidelines.

I. ***Define project needs and objectives***

The application of the ISPD on the case study starts by studying the country's economy and projections and forecasting the future cargo flow and shipping in order to cater to the needs and objectives of the requested port by the client BPDL. This also includes increasing the flexibility of the port by adopting different shipping forecasts for flexible terminal use. In order to do so, it first of all requires knowledge of various aspects of uncertainty which could be encountered during the planning phase and comprehension of prevailing and emerging trends that have direct or indirect influence on the chosen goals, plans and planning approaches. Due to time constraints, all these aspects of uncertainty and trends could not be studied; RHDHV however already adequately set objectives based on long term uncertainties and hence this information could be adopted while another objective could be added concerning

sustainable measures and socio-economic benefits as driving force. A reconfirmation of the data is not necessary because it was assumed that the planning process started at exactly the same time and with the same conditions as the RHDHV case. Problems which could be encountered in this step in practice concern the difference in view of the importance of each other's project needs and objectives by different involved/interested parties. For example BPDL as client would specify its needs and objectives based on a positive economic business case and the government aims for regional/national socio-economic welfare, while nature organisations want to achieve sustainable objectives. In order for all the parties to agree, in the end the port planner is responsible to adopt reasonable project needs and objectives: his/her decision should be based on relevant research and analyses, and the consideration of the limited time and money, and nature of interest and the influence of each party. Since the client finances the port, this party relatively has the most influence. However, in the ISPD framework the objectives of other parties, such as flexibility, sustainability and social welfare, should be stimulated by the port planner and he/she should convince the client of the benefits of these objectives as well.

II. ***Find physical suitable locations***

After the port location requirements are known, the port planner can search for physical suitable locations to narrow the scope of researching the amount of locations in the following step. After specifying the area of study, the visual suitable locations had to be selected. This was quite difficult from only a map because this basically only provides information of the existing surrounding nature, development, infrastructure and boundaries. This information is too limited to conclude if the physical conditions of the location fulfill the needs and objectives of the proposed port. It is advised to perform site visits for this purpose. Since it is not clear if the visual suitable location fulfilled the criteria of BPDL, more investigation of the location is required. The aspects to investigate are the suitability of the locations regarding the design parameters (specified in *step I*) and a list of important location elements which influences the port design and operation (can be found in the WWF and Deltares report called *Port of the Future* (Schipper et al, 2015, p.25, table 3.1)). Due to the lack of information and measures to obtain the required location information, the pre-selection of the potential suitable locations could not be confirmed. However in practice this problem would be encountered less: of course in general information will always be limited, but at least the locations can be visited and research can be performed on possible suitable locations. However the issue which undoubtedly will arise is that this location selection (step II and III) will require far more initial research, and thus time and costs, than in a traditional approach. However where the traditional process often separates the location choice and design process, along the process the research might encounter more challenges in later stages if the location brings resistance to the port design. The ISPD process, on the other hand, performs more initial research resulting in the most optimal location for the design because the same values are used by one party for both processes. This decreases the risk for resistance along the process since the chosen location provides a larger supporting foundation for the design and operation of the future port: a significant amount of design and operational costs might be saved and sustainability might be easier to implement due to the suitability of the location. It however of course also can be the case that both the traditional and ISPD process result in the same most suitable location while the latter requires more time and money for initial research of other locations. Therefore it is up to the port planner to decide if he/she wants to take the risk of resistance and limitations of the location resulting from a rather incomplete initial research or if the port planner decides to consider this uncertainty by investing more time and money in the research for the most suitable location. In the end, this decision will depend most on the client who is financing the project. However since the port will contribute to the regional and national socio-economic welfare as well, subsidies of the government might also finance these extra initial costs of research. In this case study, Badagry was the only location with sufficient location information and

hence the research continues by analysing Badagry to get a basic understanding of the critical parameters of this location in order to assess if it is a suitable location for the proposed port.

III. ***Understand the systems and select the most suitable location***

This step starts with researching the physical, environmental, governmental and socio-economic aspects to get a basic understanding of all the critical parameters of the potential suitable locations. By considering general influencing factors of the port development of each discipline, it is possible to have a more focused search for the critical parameters of each location: a table of these influencing factors and the possible solutions which can be chosen to prevent their impacts can be found in the *Port of the Future* (Schipper et al, 2015, p.58-59, table 6.1). The outcome of these analyses can be described in the values, opportunities and challenges of each location and the location with the most opportunities or the least challenges will be chosen as the preferred location for the future port. Since for the case study only Badagry could be studied, it is not clear if difficulties will be encountered by the port planner to select which location is the most suitable based on the comparison of the values, opportunities and challenges of each location. Furthermore, the biggest issue which will be encountered in practice is already explained in step II: namely that although the initial research of potential suitable locations will result in less resistance by the most suitable location for the future port design and operations, it however would require more time and money than in the traditional process. Lastly, since the information of the base line of Badagry is already made available for this research, the boundaries of the study area were already determined. However this research realizes that in real life before the location system is being studied, clear boundaries of the study area of each location need to be determined. These boundaries can be determined by the client and the port planner. In the end it is up to the port planner how big the area of study will be: the general rule applies that the larger the area of the study, the less uncertainties about the location will arise in later stages of the process, but this also requires a higher required investment in time and money.

IV. ***Develop alternative designs***

After the location selection, the design process can be started. The design process starts by prioritizing the previous found values of the stakeholders in the selected location into key values. Subsequently by brainstorming possible planning measures based on these key values, the design process is much more organized and focused. These planning measures have to be on system level, but since several measures are strongly connected with a more detailed level it is rather difficult to make a clear distinction of the level of these planning measures. Since the entire planning process is very complex and time-consuming, it turns out that focusing the design process by clearly identifying the key values and a list of their possible solutions was very helpful to keep the bigger picture on system level in mind while considering both long term uncertainties and the values of the stakeholders. I do not regard that this requires extra time, since it might even safe time by developing the alternatives more systematically. Furthermore, I noticed that it is too complex in this stage to already design the alternatives on different levels and it was pleasant and more organised to have a design process on system level only. The more detailed design on construction and material level, is recommended for later stages and outside the scope of this research.

V. ***Test the alternatives***

In order to perform a full evaluation of the alternatives in the following step, this step covers the part of the technical feasibility of the different layout alternatives. As it is the goal to create a sustainable port and keep the impact on the environment to a minimum, the different alternatives include several rather new sustainable measures. Due to time constraints and the lack of modelling tools, these sustainable measures could not be tested on their feasibility. However in practice it should be realized that this step

is rather time-consuming. In order to reduce this required testing (time) to a minimum, the modelling needs to be prepared and executed adequately. This means that beforehand clear objectives for the modelling works need to be determined. However, according to me, the biggest issue which will be encountered is not the testing of the alternatives but to convince the client BPDL to implement the sustainable measures. Although a brief feasibility check is provided with the positive benefits of the sustainable measures, the information shows that there still is a long way to go before some of the measures can be implemented in practice. The sustainable measures still require a lot of research and hence there are still significant challenges in order to successfully implement them in practice; not only are the measures not so commonly used and rather new, but the client also takes a lot of risk if the measures will have the same positive results in this particular situation and therefor it will be a hard decision for BPDL to consider some of the sustainable measures. It is up to the port planner to gather enough proof of the feasibility and the positive benefits of the sustainable measure in order to convince the client to apply them instead of the traditional measures.

VI. ***Evaluate the qualities of each alternative***

The previous defined key values are being used as the evaluation criteria for the MCA: since all the alternatives are developed based on these key values, the assessment is more equal and relevant. However several evaluation criteria could not be adequately assessed due to the fact that the layout alternatives were designed on system level, while several of the criteria are covering a more detailed level. Therefore the evaluation with these criteria should also be performed after the chosen alternative is further developed in more detail. The detailed design can then be equally assessed on these evaluation criteria. The ISPD framework however focuses on the system level design and therefore it is recommended to also make a framework for the more detailed, construction and material level design. Due to time constraints, this should be studied in another research. Furthermore by including a sensitivity analysis the outcome of the evaluation is supported more. However, although the key values/evaluation criteria were selected after consultation with RHDHV, the entire evaluation including the sensitivity analysis is conducted by one person and is therefore rather subjective. This can be considered as a weakness in the evaluation step and hence it is recommended to evaluate the alternatives by more people besides the person who developed the alternatives.

VII. ***Create final design***

After the outcome of the evaluation, one alternative is selected for further detailed design on construction and material level. Based on the above mentioned evaluation of the existing and ISPD masterplan, it turns out that the chosen ISPD alternative masterplan can be considered more sustainable on system level than the traditional masterplan. More detailed modelling and investigation is required for the optimisation of the chosen alternative. However since the existing BBP masterplan is still a conceptual design, the information of this detailed research was not available yet and thus the chosen alternative could not be optimized for this case study. Therefore the challenges which might be encountered during the optimisation of the chosen alternative are not known. Development on construction and material level in the ISPD framework is not applied on a case study yet, so hence this is recommended for further research. Another issue that I encountered is related to the issue found in step V that several sustainable measures are still rather new and therefore bring along uncertainties and risks. This also means that it is unknown how these sustainable measures will develop in the future. It therefore should be mentioned that planning under long term uncertainties actually does not finish at the end of the planning and design phase. Since the goals of considering these uncertainties and risks is to create a flexible and future-proof port, this also involves the construction and operational phase which are outside the scope of this research; these are the phases where the port can be adapted under unexpected changing cir-

cumstances in order to still keep its function. More information about this will be mentioned in the conclusions and recommendations in chapter 6.

Figure 5-B sums up all the above and provides a quick overview of the (dis)advantages of each step of the ISPD framework in practice.

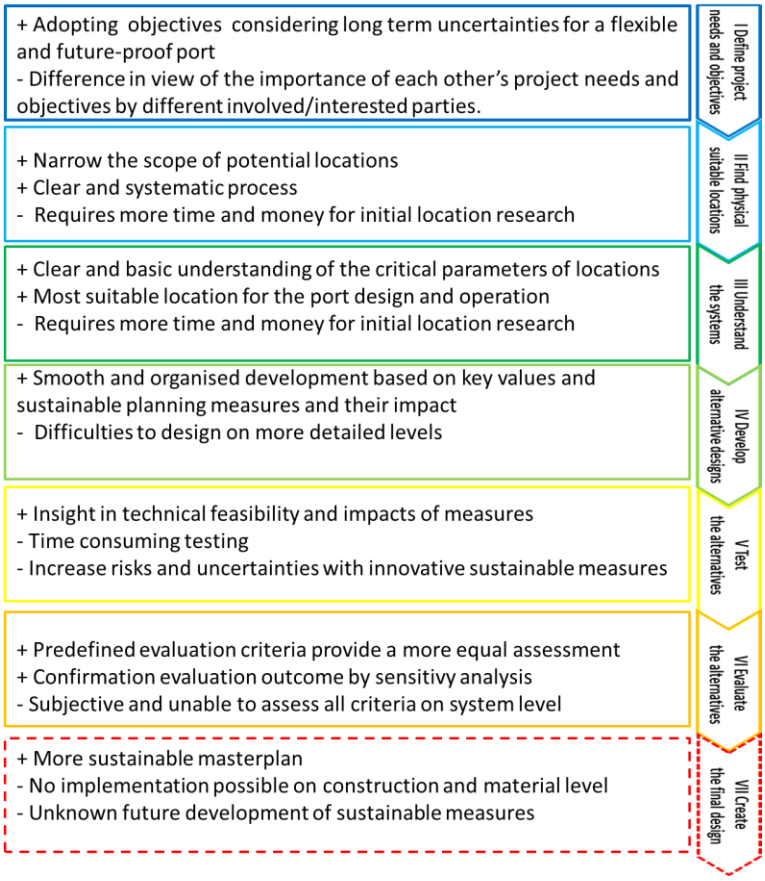


Figure 5-B (dis)advantages of applicability of the ISPD framework

Conclusion

From the evaluation of the application of the ISPD framework to the case study of Badagry Port, it can be concluded that the success of the application largely depends on the case study and its limitations. The limitations are mainly caused by the area in the world, the local context of the location and the client, and hence these factors play a significant role how much resistance can be expected. In this case study the other problems encountered during the application of the framework were mainly caused by the time limit and lack of baseline information about different suitable locations. The key is to take sufficient time for the most optimal location selection, as this is the basis of ISPD. Furthermore it is also of significant importance to include long term uncertainties in the project objectives. Since this research and the framework are focused on the system level of the planning and design phase, the full consideration of these uncertainties cannot be seen in this framework. This would involve more detailed design on construction and material level and includes the construction and operation phase as well. In this case study it turns out that despite the limitations, the resulting ISPD masterplan is still considered to be more sustainable than the existing masterplan. In practice limitations will also undoubtedly always be present during the planning process, but the evaluation shows that the ISPD framework still can be applied resulting in a more sustainable port than the traditional process. Hence, the objective to success-

fully apply the ISPD framework in practice and creating a more sustainable port compared with the traditional framework, is achieved.

5.4 Lessons learned

This paragraph summarizes the lessons learned from applying the ISPD framework to the case study. This includes an analysis as to where and to what extend this framework encounters difficulties in practice and the learned lessons will be listed below. The paragraph ends by selecting and motivating which aspects are selected for enhancing the ISPD framework to the finalized version in the following paragraph.

- In general the implementation of the ISPD framework in a case study is an effective way to test the advantages and limitations of the framework for further optimization. The ISPD framework can be optimally improved by applying it on a limitless case study. In practice however limitations and the lack of information will always be present to some extent, but to improve the ISPD framework it is recommended to choose a less limited case study than the Badagry Port Project. In order to obtain a case study with less limitations, the case study selection in paragraph **3.2** should also be without limitations: that means that the case study selection should not be limited by the data base of RHDHV.
- During the implementation of the framework on the case study, I experienced that the flowchart of the ISPD framework and the brief explanation of the framework in paragraph **2.4** is rather limited: the aspects which should be investigated or considered in each step are not entirely clear. The flowchart needs to be explained in a user-friendly guide where each step is carefully explained. Within this user guide, the port planner is free to make his/her own responsible decisions based on relevant research and limitations of the project.
- Since the entire port planning process is very complex and time-consuming, it is of significant importance to clearly organize and focus the process by setting clear objectives beforehand. Since different parties want to achieve different objectives, the port planner is responsible to adopt reasonable project needs and objectives: his/her decision should be based on relevant research and analyses, and the consideration of the limited time and money, and nature of interest and the influence of each party. These objectives are considered in different stages of the process; e.g. in finding the most suitable location for the port design and operation in *step II* and *III*, in *step IV* by prioritizing the values into key values and specifying possible planning measures and their impacts to create a more focused and systematic development process, and by specifying the exact aim of the modelling tests beforehand in *step V* to reduce the effort and computation time. Hence clear objectives need to be set throughout the entire planning process to obtain a more pleasant and organized process.
- The most important part in the application of the ISPD framework is the careful selection of the most optimal location of the proposed port. The location has a significant influence on the opportunities and challenges of a port and vice versa the port has a significant impact on the location as well. This will give the design process a large supporting foundation and a smoother process can be gained in later stages. The key of location choice therefore is to reserve sufficient time for thorough analyses of suitable locations. To be able to find suitable locations, it is important to have a real life impression of the location and therefore it is advised to have site visits of potential locations in an early stage. Furthermore, besides the increased investment in time and money, the research to narrow down the scope of suitable locations, analysing all of them and considering all their opportunities, challenges and values significantly are raising the complexity compared to the traditional process. In order to deal with this complexity, clear objectives need to be set and tables of factors/aspects/impacts which need to be considered for a

more organised process in *step II* and *III*. In the end it is the responsibility of the port planner to guide this complex process of location choice with the help of a user guide.
- Since the entire planning process is rather complex, the framework is only applied on system level and already on this level the case study demonstrates that it is convenient to start at system level, while keeping the other more detailed levels in mind. These more detailed levels still requires further research.

Actions to finalize enhanced ISPD framework:

- **User guide ISPD framework** – The flowchart of the ISPD framework is rather limited, because it is not clear which aspects the port planner should consider in each step to obtain a more organised and systematic process. Although each designer has the freedom to make decisions based on his/her own reasoning within the framework, the main guidelines and their objectives should be a clear message to all. Therefore in order to make the flowchart more user-friendly, a user guide with full explanation of each step in the framework will be provided. This includes a description of the (dis)advantages of each step and what aspects a port planner should consider to come to a responsible and grounded decision. Within the user guide it is up to the port planner how extensive the ISPD framework will be followed considering the relevant circumstances and limitations of the project.

5.5 Final ISPD framework

The learned lessons of the case study application are implemented in the enhanced ISPD framework, resulting in the more practical final Integrated Sustainable Port Design framework. A flowchart of this final ISPD framework is shown in figure **5-C** below. The additions to the enhanced framework are indicated in red. In order to make the flowchart more user-friendly, a user guide with full explanation of each step in the framework is provided in Appendix **G**.

Figure **5-C** shows that the flowchart of the final framework is the same as the enhanced framework. This would make sense since the case study Badagry Port Project is already used to enhance the ISPD framework in paragraph **3.3** and therefore new lessons should not be learned about the planning and design process itself. However since I have implemented the ISPD framework myself on the case study, I have encountered several issues which need to be decided with careful analysis and consideration of the port planner. The only aspect which therefore will be added to the final framework is the user guide for the ISPD framework in Appendix **G**. Most of the other learned lessons are outside the scope of this research and therefore will be treated in the conclusions and recommendations in the following chapter.

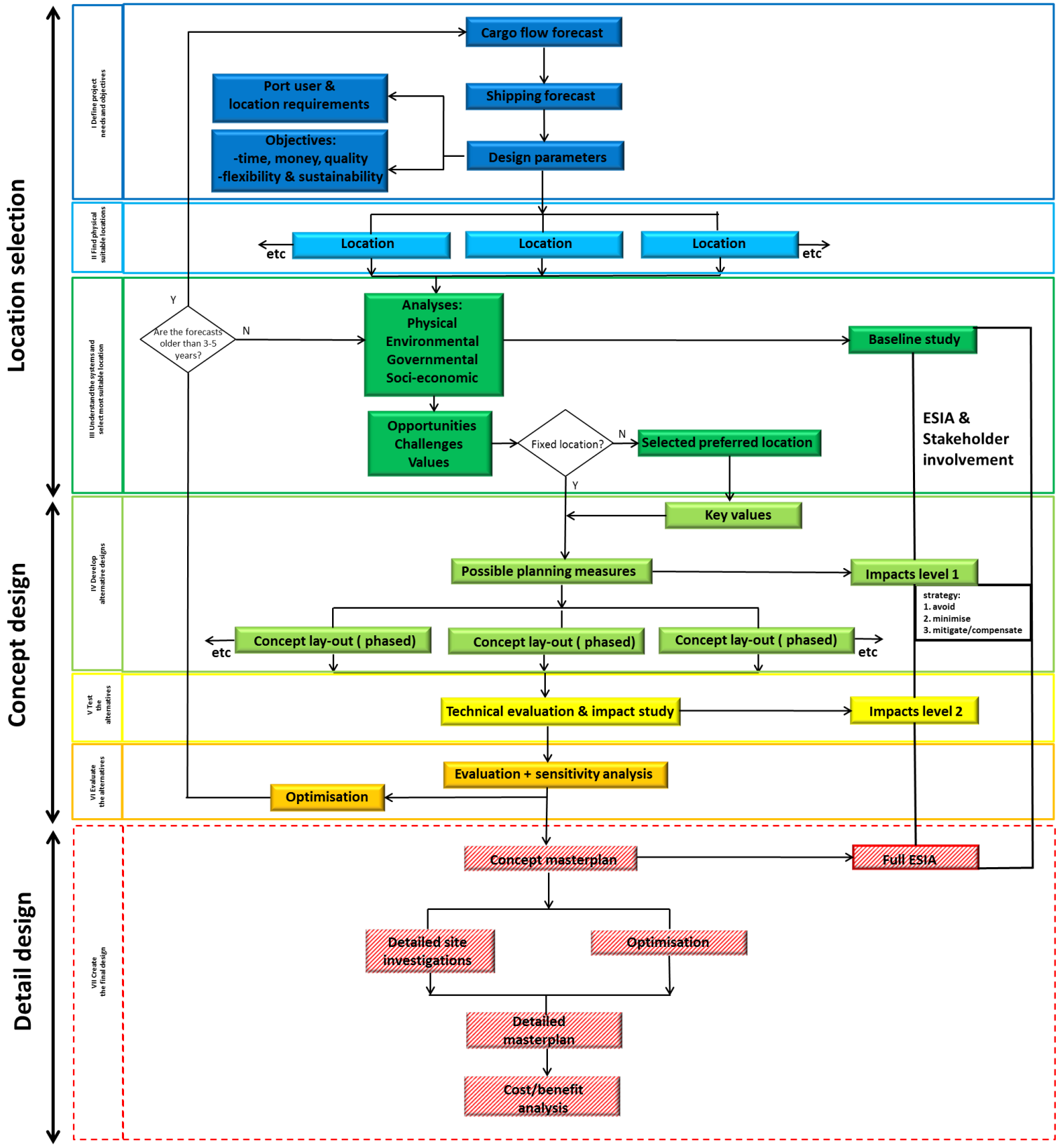


Figure 5-C Final ISPD framework

6 CONCLUSIONS & RECOMMENDATIONS

This chapter describes the conclusions and recommendations of this research. The conclusions can be divided into two parts: the case study and the Integrated Sustainable port Design framework. In paragraph 6.1 the conclusions sum up the obtained relevant results of the research including the evaluation in Chapter 5, for both the case study and the ISPD framework. By recalling the main objective and following through the process of the secondary objectives, it becomes clear if all these objectives have been obtained during this research. Consequently, the problems which are encountered translate into points of improvement for both the case study and the ISPD framework, and better implementation of the framework in practice. Hence this chapter ends with paragraph 6.2 by providing recommendations for further research concerning the problems specified in the conclusions.

6.1 Conclusions

The conclusions exist of two different parts: first the main conclusions will be provided of the case study. This includes the selection of the case studies used to enhance the ISPD framework and also the final case study which is used for the application of the framework. The second part will provide conclusions of the ISPD framework: this includes the development process of the ISPD and eventually it can be concluded if the main objective of this research is achieved by the final ISPD framework.

6.1.1 Conclusions case study

In order to enhance the ISPD framework and to test its degree of applicability in practice, the framework has learned from three case studies and subsequently is implemented in one of these case studies. The case study selection is described in Chapter 3 and the NDP, BBP and the JANCT were chosen as the most suitable case studies for the following reasons:

- Interest of RHDHV
- Availability to data base
- Different category of ports: new port development (NDP and BBP) and expansion (JANCT)

A difference could be discovered when the ISPD framework is applied to the categories *new port development* and *port expansion* project. The latter brings more limitations from the surrounding locations on the full implementation of the framework: in particular, the location choice is rather limited due to the fact that a port expansion is often desired close to the existing port complex, and due to bad masterplanning of the surrounding area. In this research only the different categories of port case studies are treated, but it is not known yet what limitations the framework will encounter with other variations in case studies, such as different development phases, port functions, framework users, etc. The ISPD should also be applied to these varying case studies because it provides valuable information to further improve the framework. The case studies also teach us that although limitations are always present in practice, that it is still possible to create a sustainable port, in particular if the client also highly values sustainability.

The chapter ends with the selection of the BPP as the final case study to test the applicability of the ISPD framework. The interest of RHDHV and the availability to the data base eventually brought along several limitations for the implementation of the ISPD framework on this case study. What exact limitations were encountered will be treated more with the conclusions of the final case study below. The main reasons for the choice of the BPP are as follows:

- The presence of serious issues affecting sustainability (economic, environmental and/or social perspectives)
- Highest potential in opportunities to improve its current situation: this includes the potential interest of the involved stakeholders for the implementation of a sustainable framework and the fact that the port is a Greenfield Port project.

These aspects are important since they provide higher chances for excellent improvement and results. Furthermore, successful masterplans resulting from a sustainable framework could be used to convince and attract future port planners and clients to implement the sustainable framework as well. From this I can conclude that the ISPD framework should be applied to more case studies in order to get more of these excellent examples to implement a sustainable framework.

In Chapter 4, the ISPD framework is implemented in the Badagry Port Project. The process walked through the entire framework starting from the specification of the project needs and objectives in paragraph 4.2. The difficulty for the port planner in this step is integrate the difference in view by different involved parties about the importance of each other's project needs and objectives. It is up to the port planner to set reasonable project needs and objectives based on relevant research and analyses, the consideration of the limited time and money, and nature of interest and the influence of each party. Besides the economic objective, the port planner should convince the client of the benefits of the objectives concerning flexibility, sustainability and social welfare as well. The following location selection process in paragraph 4.3 and 4.4 is often separated from the design process in the traditional process. Here it shows that RHDHV provides sufficient data for the traditional approach, however ISPD requires a basic understanding of other locations besides Badagry as well. Based on this I can conclude that actually all the traditional case studies will provide limited information since they mainly provide data about the final selected port location and therefore the data to understand the critical parameters of other potential suitable locations is missing. In practice however there is still the possibility to analyse other locations including site visits, which is limited by the time constraints of this research. But the most significant issue in this step in practice, undoubtedly is the money constraint: it is up to the port planner to decide if he/she wants to take the risk of possible resistance and limitations of the location on the port design and operation resulting from a rather incomplete initial research, or if the port planner decides to consider this uncertainty by investing more time and money in the research for the most suitable location. In the end, this decision depends most on the client who is financing the project. In addition, due to the limited data available and my own limitations, the governmental analysis could not be treated in much detail. This however is of significant important in order to speed up the process of obtaining permits along the design process and most important, it is also very interesting to analyse the possibilities to obtain governmental subsidies to finance the extra initial costs of location research.

In order to continue the ISPD despite these limitations, only the location system of Badagry could be analysed and the values, opportunities and challenges of Badagry were found. The values were prioritized into key values and possible sustainable planning measures were developed based on the key values for a more focused and organized alternative design process in paragraph 4.5. This is a significant advantage of the ISPD framework, because the systematic and focused development might save time as less optimization may be necessary in later stages. On the other hand, the interests of RHDHV put a significant limitation on the alternative development, for example when RHDHV specifically noted that an offshore located port is not a desired option. Due to this limitation, I have not developed this alternative while it might be a very sustainable option. The reason why RHDHV did not desire an offshore located port, is because they have serious concerns about the high costs involving a floating port complex and

its construction and the increase of risks compared to traditional often used measures which both are not desired by the client. This general thought that sustainable measures require higher costs and the fact that they bring along more risks than traditional measures, will be the most significant problems encountered in practice. Since it is not possible yet to consider the environmental and socio-economic benefits in the same monetary values (see paragraph **2.3.2** for TEEB and ecosystem services), I could not proof that, in this case, the offshore port might not be more expensive than the traditional land located port, if other disciplines besides the economic disciplines are included in the overall valuation as well. Furthermore concerning the higher risks of innovative sustainable measures, paragraph **4.6** shows that they still require a lot of research and it is uncertain how the measures will develop for specific case studies in the future. More research about the feasibility of sustainable measures in general should be performed, so that the port planner can convince the client of their positive benefits. Since each port project is unique, the feasibility of these measures can only be accurately tested in practice where, after implementation, they should be strictly monitored. Once the monitored situation does not elapse as expected/desired, the port should be flexible enough for adaptation in such a way that a feedback loop can be made back to the design phase to develop an alternative solution (Taneja, 2013). This monitoring and adaptation to solve undesired observations are required to create a flexible and future-proof port, but they are performed during the construction and operational phase which is outside the scope of this research. Hence this aspect will be recommended in paragraph **6.2.1**.

Furthermore in paragraph **4.7**, the evaluation of the alternative conceptual masterplans in a MCA based on the predefined criteria, i.e. the key values, resulted in one alternative masterplan with the highest score. This masterplan affects the least communities and includes the largest buffer distance to the PONR and excellent security and connectivity within the port. However not all evaluation criteria could be adequately evaluated because they require more detailed level design, which is outside the scope of this research. Once the detailed level design is performed, then it is important to evaluate the master-plan again based on the same key values in order to obtain a complete evaluation. Another limitation of this research is that the evaluation, including the sensitivity analysis are rather subjective, as I developed the alternatives and evaluated them as well. Other port planners might come to a different conclusion and in order to solve this weakness and to obtain a more objective assessment, it is important to evaluate the alternatives by more experts besides the person who developed the alternatives. Eventually one masterplan is recommended for further detailed design. In this final step in paragraph **4.8**, the same limitation is encountered again: the detailed construction and material level design is missing and therefore this last step cannot be treated in this research. I however experienced that more detailed design is too complex in this stage of the process and it is more organised to have a design process on system level only, which was the scope of this research from the beginning. Hence, the more detailed design on construction and material level, is recommended for later stages and these levels will be referred as a recommendation in paragraph **6.2.1**.

In the above I can conclude that the port planner has a significant task to organize the planning and design process and to consider all the wishes of the relevant stakeholders and the limitation encountered along the way. The ISPD user guide provided in Appendix **G**, tries to support the port planner in this complex planning and design process by systematically identifying each step of the process, its (dis)advantages and what aspects a port planner should consider to come to a responsible and grounded decision throughout the process. Within the user guide it is up to the port planner how extensive the ISPD framework will be followed considering the relevant circumstances and limitations of the project.

6.1.2 Conclusions Integrated Sustainable Port Design framework

In order to conclude if this research if the ISPD framework has obtained its goal, the main objective will be recited again:

- **Design a general framework for sustainable port master planning and apply this framework on a specific case study to examine, analyze and evaluate its impact.**

In order to achieve this primary objective, the process is divided into smaller secondary objectives which serve as the process which should be followed to develop the ISPD framework. The conclusions of this development process will be summarized below by treating the secondary objectives one by one. Once the conclusions are known of the ISPD development process, it can be concluded if the main objective is achieved.

1. *Research the state of the traditional port master planning, its main and missing elements*

Before a sustainable framework will be developed, first I have to explain why it is necessary to do so. In other words, '*what aspects are currently missing in the traditional port process which explains the resulting non-sustainable port?*'. The most important missing element is that the location choice is separated from the design process. Where the traditional process starts with a chosen location as starting point, in the sustainable framework the location selection is considered the basis of the entire design process. Since the traditional process still results in functional ports, it cannot be considered completely wrong, and hence it serves as the basis for the new sustainable framework, where after it still needs to be supplemented with elements from the sustainable port planning process.

2. *Differentiate between 'the sustainable port master planning process' and 'the sustainable port', and give their definition criteria*

Before I can develop this sustainable framework, I also need to know what exactly defines a *sustainable port* and a *sustainable port masterplanning process* towards this port. The issue encountered with the existing definitions, is that both definitions are intertwined and no clear distinction is made which characteristics belong to the sustainable process and the resulting sustainable port. It turns out that this research requires two kinds of definitions for *the sustainable port*: one which is necessary to develop a sustainable framework and one after the development which practically can test if the framework results in a more sustainable port. The former definition of a *sustainable port* has obtained and maintains a balance of the economy, environment and society now and in the future, where it also anticipates and considers the needs of future generations, besides their own benefit and the prosperity of the surrounding regions. The second definition of a *sustainable port* is based on the environmental impact angle, in the sense that the port with the least negative impacts resulting from the port project concerning predefined environmental criteria, is considered the most sustainable port. The predefined criteria are the main environmental issues currently resulting from port project and this definition will be used for the evaluation if the new masterplan is more sustainable than the existing one. Lastly, the definition of *the sustainable process* can be characterized by the following process ambitions: the location choice as part of the design process, the consideration and search of the multiple perspectives balance of the interlinked economy, environment and society in an early stage, active and early stakeholder involvement, a long term vision as project aim and a continuous learning process.

3. *Study the existing philosophies regarding sustainable port development and the gab to application in practice*

Several sustainable port philosophies already exist such as Building with Nature, Working with Nature and Engineering with Nature, which mainly have the same interests: searching for sustainable measures

which both fulfil the technical and socio-economic objectives of a port. They however, just like the traditional process, exclude the significant important location selection in the entire process, which represents the basis of my definition of the sustainable process and thus definitely should be included. Furthermore, I want to analyse why these existing philosophies are not fully implemented in practice yet, since all three have in common that they proof that sustainable measures can bring benefits, but there is still a gap in fully implementing these philosophies in practice. In the end it turns out that over bridging this entire gap is way beyond the scope of this research and my ability and therefore they should be recommended for further study. The full list of gaps according to me is provided in Appendix **B**. Since this topic is a significant research on its own, the gaps need to be tackled one by one. Hence in this research I try to over bridge the gap in practical guidelines by developing a practical framework which can be followed by the port planner, each step specifically considered.

4. *Set up a new sustainable port masterplan framework and formulate its key guidelines with the attained literature study*
After analysing the missing aspects of the traditional framework, defining the sustainable port and planning process and studying the useful principles of the existing philosophies in Chapter **2**, the initial ISPD framework can be created in the form of seven key guidelines and a flowchart. The ISPD framework is an integrated framework, where the location choice is considered the basis of the entire planning process. By setting clear objectives including long term uncertainties from an early stage and with the help of early stakeholder involvement, the aim is to find sustainable opportunities while socio-economic welfare is created as well. This can be achieved by considering and integrating several disciplines of the port location. It is entirely up to the port planner to what extent he/she follows the framework and the people involved are even stimulated to further develop the ISPD framework by applying it on case studies, making it into a continuous learning process.

5. *Enhance the framework by analyzing the master planning process of existing ports*
Treated in paragraph **6.1.1**.

6. *Apply this framework on a selected case study with an existing masterplan*
Treated in paragraph **6.1.1**.

7. *Evaluate the resulting masterplan and the framework and set up recommendations for future use*
The full evaluation of the resulting ISPD masterplan with the existing BBP masterplan is elaborated in Chapter **5**, where the two masterplans are evaluated based on predefined criteria in paragraph **2.6**. In short the limitations of this evaluation are as follows:

- Several criteria could not be discussed because they focus on the environmental impacts on a more detailed level, which is beyond the system level design of the two masterplans
- Exclusion of socio-economic analysis and a quantitative /monetarization evaluation method
- Subjective assessment

Despite these limitations, it can be concluded that the ISPD framework results in a more sustainable masterplan. A second evaluation is also performed in Chapter **5**, by assessing the applicability of the ISPD framework on the selected case study. The conclusions can be found in paragraph **6.1.1**. Several difficulties were encountered during this process and it can be concluded that a bigger variety of case studies with as less limitation as possible could better assess the applicability and success of the framework. The learned lessons have been used to finalize the ISPD framework in paragraph **5.5**. This includes a user guide of the final ISPD framework where systematically every step of the framework is explained.

Finally, it can be concluded that the extent of successful implementation of the ISPD framework in practice depends on mainly the following factors:

- The port planner implementing the framework
- The available capital for the project (public or private investments)
- The values of the client
- Category of port
- Area in the world and local context
- Available amount of time reserved for location analyses
- Proof of feasibility and benefits of sustainable measures

From the above it can be concluded that the main objective is successfully achieved in this research, since the ISPD framework could be applied on a case study and resulted in a more sustainable port masterplan. Based on these conclusions, the resulting recommendations concerning the case study, the ISPD framework and its implementation in practice are provided in the following paragraphs.

6.2 Recommendations for the ISPD framework

In this paragraph the recommendations regarding further development and implementation of the ISPD framework are summed up, based on the issues found in the conclusions in the previous paragraphs. The recommendations can be divided roughly into two groups: recommendations for further improvement of the framework and recommendations for better implementation in practice. Since testing the framework on case studies is part of the framework development, the first group of recommendations entails advice on future application of the framework on case studies and its case study selection as well. The second group mainly includes recommendations to convince governments, port authorities, port planners and other relevant parties to implement the ISPD framework (and sustainable measures in general) in practice.

6.2.1 Recommendations for further improvement of the ISPD framework

This section briefly treats the problems found in the conclusions concerning the development and improvement of the ISPD framework and provides recommendations for further research in order to solve them. Based on the conclusions in paragraphs **6.1.1** and **6.1.2**, the following recommendations for further improvement of the ISPD framework are given:

- The research shows that the ISPD framework can be improved by implementation on case studies in Chapter **3**. However the presence of limitations put on the case studies affect the extent of improvement: the more limitations, the less elements of the ISPD framework can be tested. Hence, first of all it is recommended that the ISPD needs to be applied on more case studies for further improvement of its framework. Furthermore, optimal improvement is expected by the application on a limitless case study. In practice however there are no case studies without limitations, thus it is recommended to choose a case study with as little limitation as possible. In order to obtain a case study with less limitations, the case study selection in paragraph **3.2** should widen its scope for suitable case studies: that means that the case study selection should not be limited by solely the interest of RHDHV and its data base. Another recommendation is to use a set of rather diverse cases studies. The more diverse the case studies are, the more diverse the set of encountered challenges is and the more lessons can be learned for improving the framework from different angels. Examples of diverse case studies include variations in development phases, port functions, framework users, etc.

- In Chapter 4, the ISPD framework is implemented on a case study. Step III of the framework covers the analysis of several disciplines on a location. The analysis of the governmental discipline however, is rather limited in this research and it is recommended to study this discipline into more detail in order to speed up the process of obtaining permits along the design process. In addition it is recommended to study the possibilities to obtain governmental subsidies to finance the extra costs of the ISPD framework caused by the initial extensive location selection.
- During the evaluation of the existing masterplan in paragraph 5.2, several criteria could not be adequately evaluated because the final ISPD framework is focused on implementation on system level planning and design while the evaluation criteria also cover more detailed level planning and design. Although a connection is made to, the more detailed, construction and material level, in the end the encountered problem is that the ISPD framework is not applicable yet for port planning on more detailed levels. Further research on these levels is recommended by e.g. implementing the ISPD framework on more detailed level case studies and using the learned lessons to enhance the framework in such a way that it is applicable on the construction and material level as well. In this way the port masterplan can be developed in such detail that the construction phase can immediately follow after the approval of the final detailed masterplan.
- During the evaluation of the ISPD framework in paragraph 5.3, the objectives of considering long term uncertainties and sustainable measures to obtain a flexible and future-proof port cannot be achieved because the ISPD framework is focused on the planning and design phase. This research does not treat the sustainable application in the other phases which also should be taken into account: since it is still uncertain how several rather innovative sustainable measures will develop in practice, it is necessary to monitor them for several years after implementation. During the monitoring, attention should be paid to find undesired/unexpected observations and consequently, actions can be under taken to develop a(n) (alternative) solution. For further information I refer to *The Flexible Port* [Taneja, 2013]. Since this process needs to be required after the planning and design phase, it is recommended to develop frameworks applicable to the construction, operation and dismantling/removal phase as well, which are connected to this planning and design ISPD framework. Furthermore, since the framework is aiming to create a sustainable port, it makes sense to consider sustainability from the beginning to the end of a port's life. For example the questions which should be treated during the development of the framework for the dismantling/removal phase are: '*How can the leftover and remaining material strategically be handled in order to use them for recycling and re-usage purposes?*' '*And what kind of future land use can be planned for the area of the port?*'. More of these questions need to be answered when creating a ISPD framework for all phases of the design life of a port. In this way, the criterion of *Sustainable Resources Management* in the evaluation of paragraph 5.2, which includes the closing material loops, can also be accurately evaluated.

6.2.2 Recommendations for better implementation of the ISPD framework in practice

In paragraph 2.4.4 it is mentioned that although there is already proof of the benefits of sustainable measures, there is still a wide gap between proofing sustainable measures work and its actual application into practice. These gaps are also encountered during the implementation of the ISPD framework on the final case study. This means that several driving forces should be researched in order to motivate and convince people to implement sustainable measures and to over bridge the gaps of implementing a sustainable framework in practice. A list of these gaps is already specified in Appendix B and this section briefly treats these gaps which are found in the conclusions concerning the implementation of the ISPD framework in practice and provides recommendations for further research in order to solve them. Based on the conclusions in paragraph 6.1.1 and 6.1.2, the following recommendations for better implementation of the ISPD framework in practice are given:

- The ISPD framework covers several aspects of Adaptive Port Planning [Taneja, 2013] in order to create a more flexible and future-proof port. Planning where the port planner needs to think in terms of long term uncertainties is strongly recommended in a sustainable framework, however flexibility is not valued in monetary terms in the ISPD framework while it could be extremely profitable from an economic perspective. It therefore is recommended to research the valuing of the flexibility of ports to a bigger extend, because economic benefits would be a huge driving force to implement flexibility of ports. For further information of this topic I refer to '*The Flexible Port*' by Taneja (2013) where possible valuation methods are treated, and to The Economics of Ecosystems and Biodiversity (TEEB) which is also recommended for further research (see Appendix **B**).
- In the previous it has been mentioned that relevant experts, which are not related to the case study, should objectively perform the same evaluation in order to find out if they come to the same conclusions. Furthermore it is also recommended for other people to implement the ISPD framework themselves on other case studies. For both recommendations it would become clear if this framework and the user guide are understandable for others and if the ISPD framework can be implemented in practice by port planners in general. After all, I have been working on this framework for a time period of 7 months and several elements of the research and framework might be unclear to people who are not related to it.
- One of the project objectives of the case study, is the focus to implement sustainable measures where socio-economic value and welfare in the form of ecosystem services is created for the stakeholders as well. This objective is set because this research considers the socio-economic welfare as the driving force of implementing sustainable measures. However there is no distinction made in the distribution of social welfare among stakeholders. The equal distribution of welfare among stakeholders is of significant importance as equal distribution might be a big support to apply sustainable measures: this might be one of the keys to make the gap for implementation of sustainable measures in practice a bit smaller. Therefore research of creating a more equal distribution of welfare is recommended; for this purpose the quantification of ecosystem services in the form of TEEB needs to be further studied (see Appendix **B**).
- The conclusions of the implementation of the framework on the case study resulted in the fact that rather innovative sustainable measures still require a lot of research. More research is needed and recommended to get an understanding of the feasibility of these measures in order to convince the people of their benefits. This requires not only further understanding of dynamic natural processes, but tools for modelling also need to be further improved and verified. Furthermore since this research resulted in a more sustainable port, it is recommended that the ISPD framework (and sustainable frameworks in general) should be applied to more case studies. When more proof is obtained of the benefits of sustainable measures, strategies should be made to make the people aware of these benefits. A part of this awareness strategy of sustainable measures and their benefits involves the need for frontrunners who have implemented the new measures in practice with positive outcome [Vellinga et al., 2014]. With frontrunners, more people may be convinced to also use sustainable measures (See Appendix **B**). Research is recommend to find out how to convince people to be these frontrunners, e.g. with extra governmental subsidies.
- Lastly, there is a general thought that sustainable measures are more expensive than the traditional measures. Although there is already legislation concerning the environmental impact in maritime infrastructure and sustainable measures are implemented more often, there is still a big gap for full implementation of sustainable measures and frameworks. As is mentioned in the previous recommendation, front runners are essential to raise awareness of the benefits of sus-

tainable measures. Front runners might be attracted with the help of the government, so questions should be asked if the government should subsidize front runners and the implementation of sustainable measures more; or how the government can help in fighting the unequal competition of ports, if it turns out that sustainable measure are indeed more expansive than traditional measures. Do government all over the world need to enforce sustainability of ports? Hence further research is recommended what the exact role of the government should be in sustainable port planning (See Appendix **B**).

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*Due to confidential reasons the literature made available to me by Royal HaskoningDHV, which is referred to in the main report cannot be used for confirmation by public.

APENDIX A DEFINITION CRITERIA FOR THE EVALUATION OF A SUSTAINABLE PORT

Table A-I Definition criteria evaluation sustainable port, their potential effect on welfare and explanation*

Definition criteria	Potential effect on welfare without sustainable measures	Explanation
Land use planning	-Increase of employment rates -Increase of economic attractiveness of the region, resulting e.g. in more turnover	The degree that the chosen location (land and water area) is suitable for a feasible long term operability of the port, regarding the overall socio-economic (hinterland, employment, recreation, port-city interaction etc.) and environmental (nature, sedimentation/erosion, wave/flooding, etc.) circumstances. The degree to assign, change or adapt the current function of the area for future use and/or expansion while the natural processes will be maintained or enhanced (flexibility). This includes efficient land and water area utilization with respect to scarcity and limitation of space in the future.
Modalities and connectivity	-Increase or decrease of air pollution caused by trucks (depending on the use of different modalities) resulting in impacts on human health -Increases connectivity which leads to a reduction of inland transport costs and consequently lower product prices.	The degree of optimisation of the hinterland transport systems and cargo transfer efficiency, usage of several hinterland transport modalities and reduction of external traffic impacts (minimise environmental footprint) to accommodate the increased transport volume growth in marine world trade.
Air quality	-Increase health costs -Loss of productivity loss -Decrease value quality of life -Decrease biodiversity (ocean acidification effects) -Increase in amount of CO2, resulting in the increase of the market price for carbon	The degree of the release of any substance that pollutes the atmosphere and therefore the well-being of the humans/creatures living in it in the short- and long term, resulting from the project. (e.g. PM10, Sox, NOx, CO2, etc.)
Surface water and sediment quality	-Increase of health costs -Decrease profit tourist sector -Decrease biodiversity, resulting in decrease of quality of life -Decrease fish catch, price effects determine loss of profit	The degree of degradation or improvement of the quality of the water in and surrounding the port due to port operations.
Soil and groundwater quality	-Increase of health costs -Decrease profit tourist sector -Decrease biodiversity, resulting in decrease of quality of life	The degree of release of any substance in the soil, sediment and ground water which is harmful for the well-being of the humans/creatures who are in contact with it, resulting from the project (e.g. petroleum, poly-nuclear aromatic carbons, hydrocarbons, waste, etc.).
Dredging impacts	-Increase cost dredging activities -Decrease biodiversity (disruption of sea-	The degree of managing integrated dredging activities developing opportunities for creating or improv-

	floor, turbulence and coastal erosion), resulting in decrease of quality of life	ing ecosystems and impacts on the local and surrounding environment in the short- and long term caused by the project.
Sound impacts	-Increase in health costs -Loss of productivity loss -Reduced value quality of life - Reduced biodiversity -Decrease fish catch, price effects determine loss of profit	The degree of sound nuisance (permanent) on the local and surrounding environment caused by the project, which may cause reduction of life quality, bring health hazards and great disturbance in ecosystems.
Energy and climate change mitigation	-Increase in amount of CO2, resulting in the increase of the market price for carbon	The degree of energy consumption in terms of the usage of fossil resources which are or will be scarce in the future (e.g. coal, oil or natural gas), the usage of renewable energy and the creation of new energy. The amount of Greenhouse gas (GHG) pollutions (such as CO2) are related to global warming and are released by burning fossil resources.
Climate adaptation	-Decrease safety for floods, extreme weather conditions etc. -Slightly higher potential damage for floods	The degree of preparation for future climate changes affecting the project, such as sea level rise (increased storm surges), extreme weather conditions, increase of floods, water excess and shortages etc.
Habitat and species health	-Decrease profit tourist sector -Decrease fish catch, price effects determine loss of profit -Decrease in intrinsic value biodiversity	The degree of integration of the natural and port system regarding the project objectives. This includes habitat and species managements as well as coastal change and loss of marine environment.
Landscape management and quality of life	-Decrease profit tourist sector -Decrease value people attribute to the ecosystem	The degree of impacts on the existing landscapes and consequently on a person's quality of life. Decreasing impacts should go along without significantly increasing the project footprint.
Ship-Related Waste Management	-Increase of health costs -Decrease profit tourist sector -Decrease biodiversity, resulting in decrease of quality of life -Decrease fish catch, price effects determine loss of profit	The degree of proper handling the collection, transportation and disposal of ship-related waste to port reception facilities. At all cost it should be prevented that waste will be disposed in nature (i.e. sea) and affects ecosystems.
Sustainable Resources Management	-Decrease of scarce resources, resulting in increase in price -Increase in pollution, resulting in increased health costs and reduced value quality of life	The degree of usage of scarce material resources within and beyond port areas. This includes closing material loops, resulting in avoidance of significant waste flows.

* Table A-I provides the current environmental and sustainability issues. In other words, this list might change in the future as other issues might arise and is not completely valid for future use. This should not cause any problems as the list could be adjusted when necessary. Furthermore it is not possible to define the exact connected logistical morphological, economic, environmental and social processes as this is case specific; these exact processes which apply for separate cases can only be determined once the specific port and situation are known.

APPENDIX B GAPS IN SUCCESFUL IMPLEMENTATION OF SUSTAINABLE MEASURES IN PRACTICE

- **Gap in awareness of sustainable measures and its benefits** – Coordinated effort is necessary in order to raise awareness of sustainable measures its benefits [PIANC, 2011]. Every port which might be involved in port projects are required to be engaged in this transit: from port authorities and government to environmental stakeholders and local communities. This process will not go without difficulties, but perseverance and patient are the key. The awareness of sustainable measures should be positive and therefore, proof should be shown of their benefits. Sustainable measures cause less environment harm than traditional measures. People should be aware that environmental harm translates into negative impacts on their socio-economic welfare as well. On the other hand, good health of ecosystems also result in the increase of socio-economic welfare. This increase in welfare can be shown in the form of ecosystem services (see paragraph **2.3.2**), which can be seen as the driving force to implement sustainable measures. Since a private party and/or government needs to finance these sustainable measures, the value of the ecosystem services should be expressed in the same monetary unit, according to TEEB (see paragraph **2.3.2**). It is not possible yet to express all the ecosystem services in the same monetary unit, hence it is recommended to invest more time in this research.

- **Gap in knowledge and understanding** - Although there already is reasonable understanding of sustainable measures, they still bring along more risks than the traditional measures. This is caused by the fact that the sustainable measures are still rather new and not commonly used in practice and monitored after implementation. Although research is ongoing, a better understand of dynamic natural processes is required. Tools for modeling also need to be further improved and verified in order to strictly monitor the sustainable measure after implementation. These gaps in knowledge and understanding however should not be the main reason for hindering the application in practice.

- **Gap in frontrunners** – Even if there is proof that sustainable measures work, people still might be doubtful to actually implement them due to the fact that these measures are more expensive and/or there is less proof of success compared to the traditional measures. People tend to be rather reserved when it comes to new innovative measures which are not commonly used in practice. To enable common implementation of new methods, there is a need for frontrunners first who successfully implement the new measures in practice [Vellinga et al., 2014]. With frontrunners, more people may be convinced and dare to also use sustainable measures. In order to attract frontrunners, research should be performed what role the government should play in subsidizing and promoting sustainability of ports.

- **Gap in governmental legislation** – There is already legislation that limits the environmental impact in maritime infrastructure, but this research promotes that governments around the world initially should maximize this sustainable legislation. This legislation might be required to raise awareness of the benefits of sustainable measures and to fight unequal competition. Once the first successful results in practice are becoming clearer, a shift might be possible from legal obligation to socio-economic trigger.

- **Gap in management** – Due to administrative procedures, many recent waterborne infrastructure projects experience delay [PIANC, 2011]. This can be expected since environmental regulations do not trigger the process of development and innovation due to the inflexible nature of its application. Therefore it is of significant importance to focus on the intention of the legisla-

tion instead of adopting an authoritative approach to its application. A shift from a ‘control’ to a ‘management’ philosophy is required and the disciplining differences between ecologists, engineers, planners and politicians similarly need to be treated in order to actually implement WwN in practice [PIANC, 2011].

A stakeholder analysis can be defined as a two-way communication procedure between the one who proposed the project (i.e. APM Terminals) and the involved stakeholders. It is considered as one of the key aspects of the sustainable port development framework, providing the stakeholders to indicate their perspectives concerning the project. This includes transparent share of knowledge and information, trying to understand each other's interest and worries and establishing collaborative relationships where the stakeholders are allowed to fully understand the possible impacts and opportunities concerning the project with the goal to achieve positive results. In the following I have devised my own step plan for a brief stakeholder analysis, which is suitable for this research and case study. I have followed the following process:

1. Specify maximum area to consider involved stakeholders (area of influence)
A port project will always impact its surroundings and therefore should take into account the impacted stakeholders. However it is impossible to consider all the impacted stakeholders and therefore a stakeholder analysis should start by specifying the maximum area in which the impacts of the stakeholders are still considered, the so-called area of influence. Considering the time and money constraints, the area of influence specified for the stakeholders for the Badagry Port Project includes the following:

- The entire area reserved for the port and its facilities, defined as the project site, including the current inhabitants
- Shipping activities and services from and to the harbour and the hinterland connections with an upper limit of approximately 100 km [Haralambides, 2002]
- The surrounding communities, such as the town of Badagry and other nearby communities

2. Identify a good representation of the stakeholders
In order to define a good representation of stakeholders, according to me the following questions need to be asked:

- Who is interested in, affected by or can influence the masterplan and its outcome?
- Understand the goals of the stakeholders regarding the masterplan
- Prioritise (by their level of interest, influence, impact and attitude), focus attention and resources to target areas with the highest risk

A good representation means that stakeholders need to represent the physical, environmental, governmental, economic and social aspects of the surrounding locations which are impacted by the port project. In total the following seven groups of stakeholders (including the discipline of interest they represent) can be found:

i. **Environmental Regulators:**
Physical, Environment, Government
ii. **Other Government Decision Makers / Regulators**:
Physical, Environment, Government, Society, Economy
iii. **Government Authorities Responsible for Land Matters**:
Environment, Government, Economy
iv. **Traditional Leadership and other community institutions**:
Government, Society, Economy

v. **Affected Communities**:
Environment, Society, Economy
vi. **Economically Interested Parties:**
Economy
vii. **NGOs / Civil Society / Research or Academic Institutions:**
Physical, Environment, Society, Economy

I believe that the seven mentioned group is a good representation of the stakeholders; this also means that the group of stakeholders is divers in terms of age, gender, area of residence, level of education, field of education and occupation. These stakeholders and their interests can be found in table **C-I** below.

3. Send a structured questionnaire beforehand to record the views and concerns of the stakeholders
Due to time and money constraints of this research, no structured questionnaire could be send beforehand. In real life however, this part is essential in order to give the stakeholders sufficient time to prepare for the real stakeholder meeting in the following step and to let them attentively think about their views towards the project. It is assumed that in this research, the stakeholders are fully prepared for the stakeholder meeting in the following step.

4. Meet with the stakeholders in person to confirm the views and concerns of the stakeholders and for additional updates
Due to time and money constraints of this research, no meeting could be planned with the stakeholders in person. However if a real meeting is taken place, the following question needs to be asked: *Is the meeting structured to be informal to encourage open discussion among the stakeholders and the port project team?* Furthermore, the views and concerns of the stakeholder should be obtained from a structure questionnaire (step 3) and from the meetings, where the stakeholders can add additional views or ask questions something is unclear. A transparent and peaceful process is required. This could lead to new information for all parties and might lead to less resistance in a later stage. However in real life I should also consider that the caution of early stakeholder involvement is that it might raise panic in an early stage: therefore the transparency of the project should be considered relatively and making information public to several stakeholders should be done adequately.

Since no meeting and additional updates could occur, the stakeholder analysis is based on the existing data of Royal HaskoningDHV (2013) and my own input. The stakeholders, their interests and their resulting concerns and opportunities regarding the future port project in Badagry can be found in table **C-I** below.

5. Define their values and concerns in a summary
The main concerns of the involved stakeholders resulting from this analysis are the following:

- Loss of biodiversity
- Community resettlement (including vulnerable groups such as women, elderly and disabled persons)
- Loss of livelihoods
- Negative impacts coastal erosion
- Cultural impact
- Fresh water contamination

- High project costs
- Economic growth of the area
- Increase in connectivity with surrounding areas
- Improvement of health situation and education
- Need for security
- Port competition with Lagos
- Impact on tourism and recreation
- Transparent process
- Engagement with other affected communities

Table C-I. Stakeholder analysis

Stakeholder group	**Interest in project**	**Concerns & opportunities**
i. Environmental Regulators		
-Federal Ministry of Environment Housing & Urban Development (FMEnv) - Lagos State Environmental Protection Agency (LASEPA) -Lagos State Ministry of Environment	Provide national and state expertise about environmental impacts, and responsible for environmental permits and exercising national and regional control over environmental aspects.	•The resettlement is very likely and desire to give useful advice on resettlement practices on the basis of the Nigerian legislation •The PONR monument was confirmed as a culturally significant heritage site •Appropriate plans for wetlands and nature conservation and mitigating erosion •Concerns about the encroachment of illegal activities and the need for security •Need for clear permitting and resettlement processes •Desire transparent stakeholder engagement during the entire process, communication and partnering with NGOs and other agencies •Need for environmental mitigation measures •Pollution resulting from port construction and operation
ii. Other Government Decision Makers / Regulators		
-Nigerian Navy Hydrographical Office (NNHO) -Nigerian Maritime Administration and Safety Agency (NIMASA) -Lagos State Ministry of Waterfront and Infrastructure Development -Nigerian Institute for Oceanographic and Marine Research (NIOMR) -Badagry Local Government Area (LGA)	National, state and local government groups or individuals of primary political importance to the project and have permitting requirements that must be met by the Project.	•Concerns negative impacts of the project on maritime safety, navigation and the need for breakwaters •Concerns discovery of the potential ship wrecks and antiques •Potential conflict with an earlier tourism proposal for the Badagry area •Desire of clear identification of potential risks to the Project and areas to be aware of

-Badagry West Local Government Area (LGA)		
iii. Government Authorities Responsible for Land Matters		
-Lagos State Lands Use and Allocation Commission -Lagos State Lands Bureau	National, state and local government groups or individuals with primary responsibility for matters related to land management	•Desired transparent land acquisition process •Increase in connectivity with surrounding areas •Opportunities to improve health situation, education and local economy
iv. Traditional Leadership and other community institutions		
-Akran of Badagry -Alapa of Apa -Council of Chiefs -Women -Fishermen -Fisherwomen -Youth -Community Development -Committees	Traditional leadership may include individuals or groups that lead in the traditional government structure including heads, councils and leaders of sub-groups (e.g. women, fishermen). Other community institutions are those that exist to support specific interest groups such as market traders, fishermen and fisherwomen, farmers, artists, etc.	•Preference for other project location •Expectation continuous transparent stakeholder engagement: wish to be the first point of contact to be informed of the project •General acceptance of project •Concerns potential negative impacts to fish stocks and the related livelihood at a national level • Concerns population resettlement and the impact on earmarked tourism projects, particularly the protection of the PONR monument • Opportunities in engagement with other affected communities • Political tension as the Alapa contested the authority of the Akran of Badagry over villages in the Project area
v. Affected Communities		
Communities in the footprint of project: -Gberefu -Ganyingbo Sea Beach -Aivoji -Hoke-Daho - Agonvi Sea Beach Communities in the immediate vicinity: -Agorin Sea Beach -Gbaji-Yeke Tome -Ganyingbo Topa -Ganyingbo Town	Groups or individuals who are affected or likely to be affected (directly or indirectly) by the Project such as households and communities that would receive impacts (positive or negative) as a result of the Project. Those physically and/ or economically using the land.	•Preference for other project location in order to protect heritage and agricultural lands • Expectation project brings development to the region, improves the local living standard and employment for youths •Project is generally accepted but concerns about impacts on communities, cultural heritage areas (particularly the PONR monument), proposed tourism project, inward migration, loss of livelihoods, traffic and noise, environmental impact, resettlement and compensation •Expectation continuous transparent project

Other affected communities nearby: -Appa -Afowo -Joforo -Sakpo -Agonvi -Badagry Town		engagement (information desired of the experience of APM Terminals) •Clear assurance plan with mitigation measure for the following impacts: resettlement; compensation; loss of livelihoods; and environmental damage •Concerns conflict between communities and companies concerning adequate compensation •Concerns increase population affecting the community's security •Increase in connectivity with surrounding areas
vi. Economically Interested Parties (business)		
-BPDL -Investors -Commercial businesses that will use the port or free zone -Local businesses that may supply goods and services	Individuals or companies with direct interest in the project. This may be through gaining contracts or providing supplies. They may also be potential business partners and finance institutions.	•High investment costs for construction, operation and maintenance •Opportunities for investments and growth within the port and the surrounding areas •Concerns of port competition with Lagos and insufficient demand of hinterland •Increase in connectivity with surrounding areas
vii. NGOs (International, Regional or Local) / Civil Society / Research or Academic Institutions		
-Nigerian Conservation Foundation (NCF) -Community Conservation Development Initiative (CCDI) -Pro-Natura International	NGOs, researchers and associations working within the Project area, such as fishery associations, farmers groups and co-operatives. Social NGOs will include those representing the interests of vulnerable groups (e.g. disabled people, women, orphans)	• Potential risks to biodiversity, protected species, forests, wetlands and coastal areas •Loss of the local livelihoods •Concerns about vulnerable groups such as women, elderly and disabled persons •Opportunities to improve health situation, education and local economy •Pollution resulting from port construction and operation

APPENDIX D POSSIBLE PLANNING MEASURES BASED ON KEY VALUES

Table D-I

Key value	Possible planning measures	Possible impacts
Economy		
CAPEX	❖ Floating breakwater;	❖ Cheaper solution but probably does not break the long waves resulting in unsafe conditions inside the basin;
	❖ Sand buffer breakwater;	❖ Cheaper and more sustainable solution by using local materials, but feasibility needs to be checked;
	❖ Sand Geotextile containers breakwater;	❖ Cheaper and more sustainable solution by using local materials, but feasibility needs to be checked;
	❖ 'Groynes' breakwater;	❖ Cheaper solution, but feasibility needs to be checked;
	❖ Phased development;	❖ Flexibility when container demand grows faster or slower than expected;
Connectivity	❖ Create good road, rail and barge hinterland connection;	❖ Highly desired for future hinterland connection. Switching from road to rail and barge is more sustainable and causes less congestion. It also strengthens the competitive position of the port;
	❖ Relocate F100;	❖ Delay of port construction due to need to relocated the F100 first, but probably needed for future expansion;
Environment		
Biodiversity	❖ Creation of artificial reef structures (to create fish aggregation structures which function in a similar way to coral reef);	❖ Sustainable way to increase habitats for marine species;
	❖ Sloping shallow water areas near coast;	❖ Sustainable way to increase habitats for small marine species, sand is required;
	❖ Development of a fish release program (i.e. release to the wild of raised juveniles);	❖ Mitigates the disturbance of fish population during construction phase and preserves the fishery;

Coastal Erosion & Marine Environment	❖ Sand Motor; ❖ Groynes;	❖ Less frequent disturbance of local ecosystems and sustainable due to the use of local present sand, but less safe feeling without a hard structure; ❖ Higher safety feeling, but more expensive sand nourishments are also necessary;
Pollution	❖ Offshore location or no complete port-land connection More connected to the operational phase and actually falls outside the scope of this research, but several examples: ❖ Cold ironing ❖ Discount for cleaner ships; ❖ Public transport for inside port(shuttle busses for employers/staff); ❖ Maximise use of green energy; ❖ Energy recovery from container cranes; ❖ Energy-neutral buildings (underground thermal energy storage); ❖ Aim for ultimately < 35 % road transport to hinterland; ❖ Bridge connecting (partial) offshore port with main land	❖ Enhanced water quality inside the port basin, due to the distance between land and port which might result in increased water circulation inside the basins ❖ Cleaner emissions at port location because CO2 emissions of ships are less clean than during the generation of electricity); ❖ Encouragement of cleaner ships; ❖ Relatively less CO2 emissions compared to cars; ❖ Less use of fossil fuels and less emissions; ❖ Less use of energy required; ❖ Less use of energy required; ❖ Relatively less emissions and less road congestion; ❖ Increase in water circulation in or near the port. Depending on the length of the bridge, dredging costs might be saved due to natural depths
Society		
Health, Safety & Security	❖ Expatriate housing in guarded and bordered compound, in upwind direction of dangerous products and services; ❖ Regulation plan against local corruption; ❖ Create one port area (relocate the F100); ❖ Resettlement of communities from	❖ Higher safety (feeling) for the expats; ❖ Better safety and security for local population and the new employers; ❖ Better security control and overview of the entire port; ❖ Preferably no resettlement, but

	Creek;	probably wise to move away from Creek for community's health (i.e. malaria), but increases the distance for fishery;
Employment	❖ Port activities direct and indirect including education (minimum percentage jobs for affected communities after education, diversity in this percentage men and women); ❖ Aquaculture/fish farming for affected communities (part of compensation if they need to resettle or if eventually the Creek bursts resulting in water contamination); ❖ Increase national and regional tourism: - Historical heritage more attractive for tourists as social commitment by port (small tourist centre, good access road to PONR monument, regular cleaning of site;	❖ Less resistance of the affected communities is expected and they get more educated; ❖ The two biggest livelihoods are covered, hence less resistance of the affected communities is expected. These livelihoods also have possibilities to grow and provide future assurance; ❖ For relatively low costs, regional and national tourism of Badagry can be improved;
Cultural Heritage	❖ Landscaping area as buffer zone between the port and the PONR monument;	❖ The sight of the gantry cranes will be avoided standing at the location of the PONR. For relatively low costs the cultural worth of the PONR could be increased;
Population resettlement	❖ Structured compensation plan: -Transparent stakeholder engagement; -Appointment new location; -Employment, See "Employment"; -Vulnerable groups (See Appendix **F**)	❖ More time required, but I should result in a smoother collaboration with the affected communities regarding the project. A structured compensation plan might also result in a regional economic growth and better facilities for the affected resettled communities.

Landscaping of buffer zone

The most important cultural heritage in and around the project area is considered to be the PONR monument, located approximately 1500m east of the port. In order to avoid any impact on this monument, the buffer zone between the port and the PONR will be used for landscaping. This landscaping is performed in such a way that the view of a person standing at the PONR, will not be disturbed by the view of the port. In other words, a person located at the PONR should not see the highest point of the port.

As the PONR monument is located at the beach, it is unavoidable to have sight of the breakwaters from this location so the focus is to apply landscaping of the buffer zone to avoid the sight of the gantry cranes (i.e. highest point of the port) used in the container terminal. The cranes are assumed to have a height of approximately 100m. On the other side, a person needs to stand at the PONR which should be unable to see these gantry cranes. An assumption is made that the PONR monument is attracting mainly regional and national tourism, so the chosen height of this person is the average height of the Nigerian male. The average height known is 1.638m, but was last measured in 1994 [Nation Master, 1994]. For this reason an average height will be assumed of 1.70m. Figure E-I gives an impression of the landscaping relative to the height of the gantry crane and the average Nigerian male. The distance from the nearest crane to the buffer zone still needs to be specified in more detailed design. The width of the buffer zone varies for each alternative with alternative 3 possessing the widest buffer zone (1500m) and alternative 2 with the smallest buffer zone (850m). Alternative 1 stays in the middle with a buffer zone width of 1100 m.

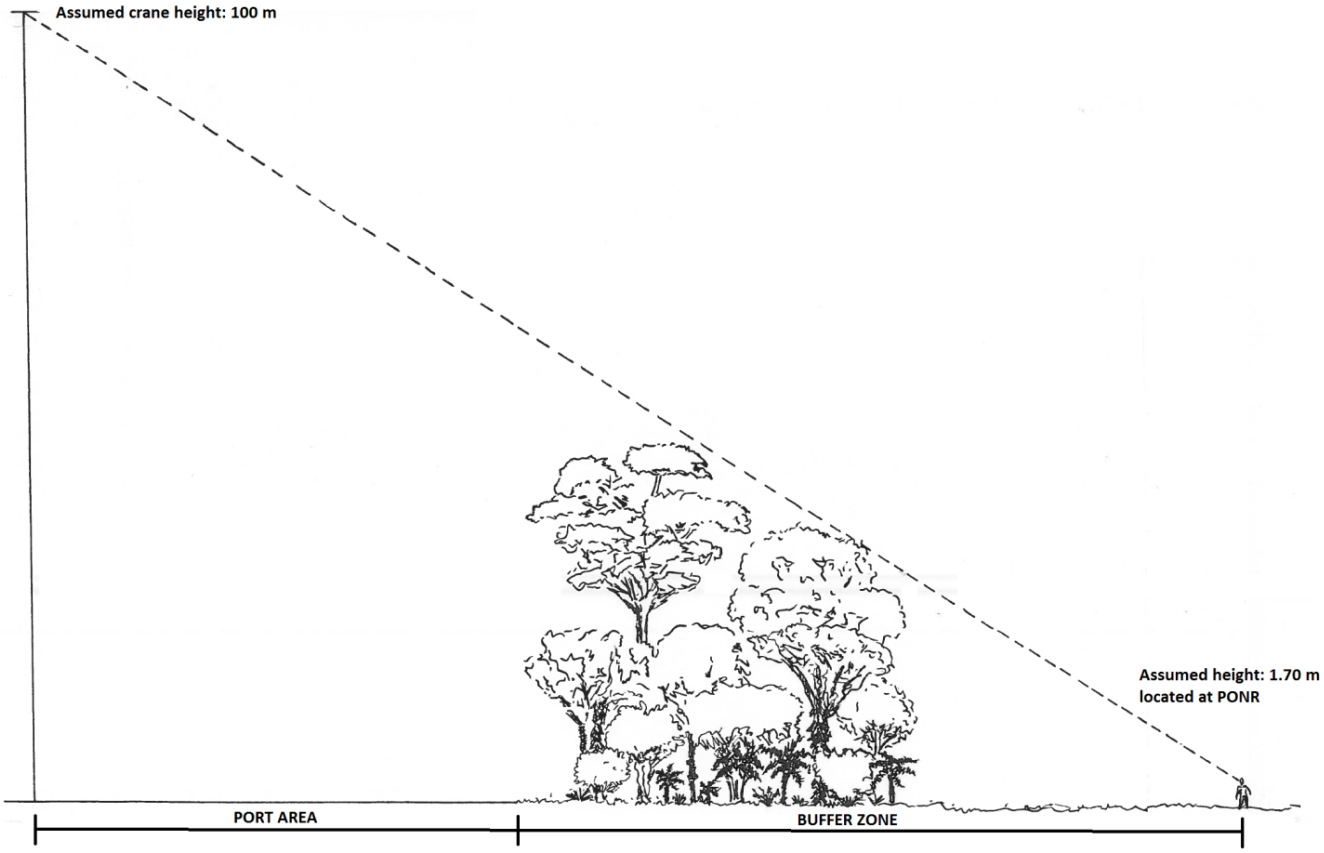

Figure E-I Impression landscaping buffer zone (not to scale)

Population resettlement

In the selected port area, a total of five to six communities need to move (depending on the alternative). In order to treat the affected communities with satisfaction and therefore preventing any resistance from them towards the project, an adequate and structured compensation plan needs to be developed. This compensation plan should include the following aspects:

- *Transparent stakeholder engagement* – *Besides* the fact that affected communities need to be informed sufficiently regarding the project, they also need to be adequately informed about the compensation plan. For example it is very attractive to accept new and better offered accommodation, however the monthly costs of the new house might not be affordable for the inhabitants (e.g. electricity bill). Therefore a transparent plan is needed, where the inhabitants should be informed about important aspects without causing unrest.
- *Appointment new location, land and other possessions* – If affected communities need to be resettled, then they need to be located to a new place where their original amount of land and possessions are also compensated. Structured bookkeeping of the land and all other possessions of each family is required, which is a very long process. This new location should provide the same quality of life as the previous location or offers an even better quality of life.
- *Employment* – A structured plan is needed which covers the assurance of new employment or the conservation of the current livelihoods by providing the suitable areas required for performance. This could be translated into compensation of every palm tree in the plantation, good accessibility to the river and sea for fishery, guarantee a minimum percentage of jobs inside the port and/or new possible livelihoods (i.e. aquaculture and rice farming). As a result the local communities do not need to be afraid of migrating people from elsewhere to the port area seeking jobs. On top of that, creating new possible livelihoods could also result in a regional or national economic growth.
- *Vulnerable groups* – In the affected communities there are several people more vulnerable for the resettlement than others, e.g. women, elderly and handicap. Including compensation for the most vulnerable groups (i.e. women and elderly).

Table F-I weighing factors set A (same weighing factors)

	CAPEX/OPEX	Connectivity	Biodiversity	Coast/Marine	Pollution	HSS	Employment	Cult. heritage	Resettlement	**Total**	**Weighing factor**
CAPEX/OPEX	x	1	1	1	1	1	1	1	1	**8**	**1**
Connectivity	1	x	1	1	1	1	1	1	1	**8**	**1**
Biodiversity	1	1	x	1	1	1	1	1	1	**8**	**1**
Coast/Marine	1	1	1	x	1	1	1	1	1	**8**	**1**
Pollution	1	1	1	1	x	1	1	1	1	**8**	**1**
HSS	1	1	1	1	1	x	1	1	1	**8**	**1**
Employment	1	1	1	1	1	1	x	1	1	**8**	**1**
Cult. heritage	1	1	1	1	1	1	1	x	1	**8**	**1**
Resettlement	1	1	1	1	1	1	1	1	x	**8**	**1**

Table F-II Total score set A (same weighing factors)

Criteria	**Weighing factor**	**Alternative 1**		**Alternative 2**		**Alternative 3**	
CAPEX/OPEX	1	5	5	3	3	2	2
Connectivity	1	3	3	4	4	4	4
Biodiversity	1	3	3	2	2	5	5
Coast/Marine	1	3	3	5	5	5	5
Pollution	1	3	3	3	3	4	4
HSS	1	3	3	4	4	5	5
Employment	1	3	3	4	4	5	5
Cult. heritage	1	4	4	3	3	5	5
Resettlement	1	2	2	1	1	4	4
Total		29	**29**	29	**29**	39	**39**

Table F-III weighing factors set B (HSS & Resettlement)

	CAPEX/OPEX	Connectivity	Biodiversity	Coast/Marine	Pollution	HSS	Employment	Cult. heritage	Resettlement	**Total**	**Weighing factor**
CAPEX/OPEX	x	1	1	1	1	0	1	1	0	**6**	**7**
Connectivity	0	x	1	1	0	0	0	1	0	**3**	**4**
Biodiversity	0	0	x	0	0	0	0	0	0	**0**	**1**
Coast/Marine	0	0	1	x	1	0	0	1	0	**3**	**4**
Pollution	0	1	1	0	x	0	1	1	0	**4**	**5**
HSS	1	1	1	1	1	x	1	1	1	**8**	**9**
Employment	0	1	1	1	0	0	x	1	0	**4**	**5**
Cult. heritage	0	0	1	0	0	0	0	x	0	**1**	**2**
Resettlement	1	1	1	1	1	0	1	1	x	**7**	**8**

Table F-IV Total score set B (HSS & Resettlement)

Criteria	**Weighing factor**	**Alternative 1**		**Alternative 2**		**Alternative 3**	
CAPEX/OPEX	**7**	5	35	3	21	2	14
Connectivity	**4**	3	12	4	16	4	16
Biodiversity	**1**	3	3	2	2	5	5
Coast/Marine	**4**	3	12	5	20	5	20
Pollution	**5**	3	15	3	15	4	20
HSS	**9**	3	27	4	36	5	45
Employment	**5**	3	15	4	20	5	25
Cult. heritage	**2**	4	8	3	6	5	10
Resettlement	**8**	2	16	1	8	4	32
Total		29	**143**	29	**144**	39	**187**

Table F-V Weighing factors set C (least importance CAPEX/OPEX)

	CAPEX/OPEX	Connectivity	Biodiversity	Coast/Marine	Pollution	HSS	Employment	Cult. heritage	Resettlement	**Total**	**Weighing factor**
CAPEX/OPEX	x	0	0	0	0	0	0	0	0	**0**	**1**
Connectivity	1	x	1	1	0	0	0	1	1	**5**	**6**

Biodiversity	1	0	x	0	0	0	0	0	0	**1**	**2**
Coast/Marine	1	0	1	x	1	0	0	1	0	**4**	**5**
Pollution	1	1	1	0	x	0	1	1	1	**6**	**7**
HSS	1	1	1	1	1	X	1	1	1	**8**	**9**
Employment	1	1	1	1	0	0	x	1	1	**6**	**7**
Cult. heritage	1	0	1	0	0	0	0	x	0	**2**	**3**
Resettlement	1	0	1	1	0	0	0	1	x	**4**	**5**

Table F-VI Total score set C (least importance CAPEX/OPEX)

Criteria	**Weighing factor**	**Alternative 1**		**Alternative 2**		**Alternative 3**	
CAPEX/OPEX	1	5	5	3	3	2	2
Connectivity	6	3	18	4	24	4	24
Biodiversity	2	3	6	2	4	5	10
Coast/Marine	5	3	15	5	25	5	25
Pollution	7	3	21	3	21	4	28
HSS	9	3	27	4	36	5	45
Employment	7	3	21	4	28	5	35
Cult. Heritage	3	4	12	3	9	5	15
Resettlement	5	2	10	1	5	4	20
Total		29	**135**	29	**155**	39	**204**

Table G-I User guide for final ISPD framework

I. Define project needs and objectives	
	Explanation
Different scenarios cargo flow forecast & Shipping forecast	Perform future cargo flow and shipping forecasts in order to cater to the needs and objectives of a port now and in the future. First choose a planning time horizon (design life of the port). In order to analyse the country's economy and projections for all cargo streams, the following disciplines of the country should be studied: -Population (growth) -GDP -Foreign trade -Cargo traffic -Vessel mix -Existing containerised and other cargo stream forecasts In addition global emerging trends analyses are also necessary in line with the adaptive planning strategy, which include but are not limited to [Taneja, 2013]: - Globalization - Containerization - Climate change - Increasing emphasis on the ecology and sustainability - Innovation technologies - Limitations by physical bottlenecks (Panama canal, Suez canal etc.) - Changing port functions - Increasing scales of port projects - Changing stakeholders in the port sector
Design parameters	A. Define the port needs in the form of (i)Port user requirements: -Functions port (e.g. fishery, industry, traffic/cargo, marina etc.) -Design life of the port -Design vessels -Minimum depth required -Margin to manoeuvre (within the harbour area) -Wave motion -Number of design vessels -Required area (m2, required quay lengths) -Required nautical aspects (ii) Port location requirements: -Demand hinterland market -The upper limit of the search scale to serve its intended hinterland (usually 100 km) -Possibilities multiple modalities, etc.

	B. Define the port objectives which can be set are based on evaluating the success of the project in the form of [Taneja, 2013]: - Time - Economy - Quality In line with Adaptive Port Planning [Taneja, 2013], the objectives should also include planning under long term uncertainties to make the port more flexible and future-proof. Problems which could be encountered in this step in practice concern the difference in view of the importance of each other's project needs and objectives by different involved/interested parties. In order for all the parties to agree, in the end the port planner is responsible to adopt reasonable project needs and objectives: his/her decision should be based on relevant research and analyses, and the consideration of the limited time and money, and nature of interest and the influence of each party. In the ISPD framework the objectives such as flexibility, sustainability and social welfare, should be stimulated by the port planner and he/she should convince the client of the benefits of these objectives as well. Reaching for these future-proof objectives requires more initial time and investment, but it may become very profitable in the long term if flexibility is needed in the future scenario. The port planner is responsible to conclude the extend of the inclusion of these future-proof objectives. This requires knowledge of various aspects of uncertainty which could be encountered during the planning phase and a comprehension of prevailing and emerging trends that have direct or indirect influence on the chosen goals, plans and planning approaches.
Possible methods/tools	Client sessions, Expert analysis, Stakeholder analysis, Trend analysis, SWOT analysis, etc [Taneja, 2013]
II. Find physical suitable locations	
Location	Narrow the scope of physical suitable locations by this pre-selection in order to save costs and time for the next step. A physical suitable location is a location which fulfils all the specified design parameters (previous step) while it has the least negative impacts from surrounding physical environment. These impacts can be found in the report *Port of the Future* (Schipper et al, 2015, p.25, table 3.1)and all visible suitable locations need to be systematically checked based on these impacts caused by the location elements and the design parameters. It should be noted that these location elements are of different scales and an element such as sea level rise does not change within the considered area for port location. Hence from that perspective there is no difference to locate the port somewhere else practical within the area boundaries. The port planner should consider the long term uncertainties for all location elements to select locations where flexibility can be implemented. The issue which undoubtedly will arise is that this location selection (step II and III) will require far more initial research, and thus time and costs, than in a traditional approach. It is up to the port planner to decide if he/she wants to take the risk of resistance and limitations of the location resulting from a rather incom-

	plete initial research or if the port planner decides to consider this uncertainty by investing more time and money in the research for the most suitable location. In the end, this decision will depend most on the client who is financing the project. However since the port will contribute to the regional and national socio-economic welfare as well, subsidies of the government might also finance these extra initial costs of research. ***The following order of actions is recommended:*** **1.Specify the area of study (based on design parameters)** **2.Find visual potential locations by existing literature (soft and hard) and site visits** **3.Check for each location in what extend the physical environment will negatively impact the proposed port, by using the report *Port of the Future* (Schipper et al, 2015, p.25, table 3.1)** **4. Select suitable locations which fulfil the design parameters and which encounter the least negative impact from the physical environment.**
Possible methods/tools	Expert analysis, SWOT analysis, Scenarios, Stakeholder analyses, etc [Taneja, 2013]
III. Understand the systems and select most suitable location	
	Emphasis should be put on the importance of location choice as part of the design process. This is considered the basis of the framework because the location, design and operation of a port are strongly interlinked. A location must be chosen in such a way that it complements the design and operation of a port. Therefore the physical, environmental, governmental and socio-economic disciplines of each suitable location should be researched, in order to get a basic understanding of the critical parameters of each location. These critical parameters decide which location is the most suitable and can be found in the report *Port of the Future* (Schipper et al, 2015, p.58-59, table 6.1) in the form of the general encountered factors in port development in each discipline. Note that this table represents a basic list of the influential factors and impacts encountered in general, hence this list may differ for each specific location and several influential factors can be added by the port planner to the case specific location. By considering these general influencing factors in each discipline analysis, it becomes clear what opportunities and challenges the proposed port will face on a location. By using the tool of stakeholder involvement, it also becomes clear what the concerns are of the local stakeholders and what they value. These values, opportunities and challenges of each location need to be found concluding the research and they decide which location is the most suitable for the project. The location which will encounter the least negative impacts of the factors [Schipper et al, 2015, p.58-59, table 6.1] and shows the best opportunities for the port, can be considered the most suitable location for the port. It is up to the port planner to decide which location that is. The biggest issue which will be encountered in practice is already explained in step II: namely that although the initial research of potential suitable locations will result in less resistance by the most suitable location for the future port de-

	sign and operations, it however would require more time and money than in the traditional process. Furthermore, prior to the location analysis, the port planner should set clear boundaries of the study area of each location, the so-called area of influence. These boundaries can be determined by the client and the port planner, but in the end it is up to the port planner how big the area of study will be. The general rule applies that the larger the area of the study, the less uncertainties about the location will arise in later stages of the process, but this also requires a higher required investment in time and money. **Start ESIA** This is also the part where the Environmental Social Impact Assessment starts: the ESIA should be performed parallel to the design process in order to early identify and avoid negative impacts. This assessment first requires baseline investigation and information, which is obtained through the location analyses. Once the existing situation is understood, the potential impacts of the port on the environment can be specified which result from understanding the system in this step. The following task of the EIA should be performed during this step: **ESIA task 1** – Review all existing documentation and undertake a detailed study of the project area and the complementing infrastructure area (access road and railway routes, electricity, etc), together called the area of influence. **ESIA task 2** – Study the baseline environment. Baseline information needs to be collected, collated and presented on the environmental characteristics of the area of influence. This will require detailed field studies where existing data is insufficient or out of date. The baseline information will be obtained by the following analyses.
Physical analysis	Get a basic understanding of the critical parameters of the physical environment. Things to research for the baseline study include but are not limited to: -topography, land cover, geology, climate and meteorology, coastal morphology, bathymetry, sediment quality, water quality, air quality and noise. **Conclude the opportunities and challenges**
Environmental analysis	Get a basic understanding of the critical parameters of the environment. Things to research for the baseline study include but are not limited to: -flora and fauna types and diversity, endangered species, sensitive habitats, terrestrial, coastal and marine ecology, including a description of the marine habitats and protected areas. **Conclude the opportunities and challenges**
Governmental analysis	Get a basic understanding of the critical parameters of the governmental environment Things to research for the baseline study include but are not limited to: -relevant regulations and standards - both National and International, local and national governmental situation and context **Conclude the opportunities and challenges**
Socio-economic analysis	Get a basic understanding of the critical parameters of the socio-economic environment Things to research for the baseline study include but are not limited to: -present and projected (population, land use, planned development activities, community social structure, employment and labor market, sources and distribution of income, cultural heritage/religious sites and properties, vulnerable

	groups and indigenous populations etc). Gender considerations will be important to ensure that no particular gender group or vulnerable group is disadvantaged or hampered by implementation of this project, agriculture, livestock, fisheries, small scale industries, infrastructure, and connectivity. **Conclude the opportunities and challenges**
Stakeholder analysis	A stakeholder analysis can be defined as a two-way communication procedure between the one who proposed the project (i.e. APM Terminals) and the involved stakeholders. It is considered as one of the key aspects of the sustainable port development framework, providing the stakeholders to indicate their perspectives concerning the project. This includes transparent share of knowledge and information, trying to understand each other's interest and worries and establishing collaborative relationships where the stakeholders are allowed to fully understand the possible impacts and opportunities concerning the project with the goal to achieve positive results. Stakeholder analysis is also a task in the ESIA and can be described as follows: **ESIA task 3** – Stakeholder engagement should be carried out at and will be undertaken to inform regional level authorities, NGOs and local stakeholders about project design and to obtain their key concerns in order to inform the team's development of mitigation measures for the project. ***The following process is recommended to follow for stakeholder involvement:*** **1.Specify maximum area to consider involved stakeholders** **2.Identify a good representation of the stakeholders** • Who is interested in, affected by or can influence the masterplan and its outcome? • Understand the goals of the stakeholders regarding the masterplan • Prioritise (by their level of interest, influence, impact and attitude), focus attention and resources to target areas with the highest risk • Assess the date and duration of any engagement • Is the group diverse enough? (age, gender, area of residence, level of education, field of education, occupation) **3.Send a structured questionnaire beforehand to record the views and concerns of the stakeholders** • Is the meeting structured to be informal to encourage open discussion among the stakeholders and the port project team? **4. Meet with the stakeholders in person to confirm the views and concerns of the stakeholders and for additional updates** • Is the meeting structured to be informal to encourage open discussion among the stakeholders and the port project team? **5.Define their values and concerns in a summary** Stakeholder involvement could lead to new information and might lead to less resistance in a later stage. The designer however should consider that the caution of early stakeholder involvement is that it might raise panic in an early stage: therefore the transparency of the project should be considered relatively and making information public to several stakeholders should be done ade-

	quately.
Values, opportunities and conflicts	Based on the previous conducted analyses the critical parameters of each location can be summarized in the form of values, opportunities and challenges of each location. The task required for the ESIA in this step is as follows: **ESIA task 4** - Determination of impacts of project facilities and activities. All significant changes caused by the project, need to be analysed and described. These would encompass environmental, ecological and social impacts, both positive and negative, as a result of each facility/activity intervention that are likely to bring about changes in the baseline environmental and social conditions discussed in Task 2. This also brings forward the possible impacts on the arrival of the proposed port project on these location.
Preferred location	Once all this required knowledge is obtained to have a basic understanding of the critical parameters of each location, it is important to understand which factors make one location more suitable than the other. The Port of the Future [Schipper et al, 2015, p.58-59, table 6.1] can be referred to for this purpose, which systematically lists all the possible factors of port development for each discipline, a description of their possible impact concerning the port and the possible solutions to counterattack this. The location which is able to include the most possible solutions in its situation, will encounter the least negative impacts or has the best opportunities for the port and therefore can be considered the most suitable location for the port.
Possible methods/tools	Brainstorm, Stakeholder analysis, Delphi, Experts, Focus groups, Scenarios, Technological forecasting etc [Taneja, 2013]
IV. Develop alternative designs based on key values	
Key values / evaluation criteria	Before the port planner can start with the development of alternatives, he/she needs to know what aspects are desired in these alternatives. When creating a port design, it is impossible to take (conflicting) values of all stakeholders into account. To enable a more focused and systematic development process, these values need to be prioritized in the form of key values. These key values are found based on previously conducted stakeholder analysis and the alternative layouts should be developed based on these key values which represent the most important values of the relevant stakeholders of the chosen location. Furthermore, this is a significant advantage of the ISPD framework, because the systematic and focused development can save time as less optimization may be necessary in later stages. In addition, these key values are also used as evaluation criteria during the evaluation in a later stage. This is recommended because it would be a more relevant and equal evaluation if prior to the alternative development the criteria, on which they are going to be assessed, are already known. It is the responsibility of the port planner to decide which values principally represent the concerns of the involved stakeholders. More key values will take into

	account more values of stakeholders, but also results in a more difficult and disorganized process to develop alternatives which satisfy all key values. This means that the port planner should consider both the content and the number of key values. The task required for the ESIA in this step is as follows: **ESIA task 5** – A prioritization of all concerns identified needs to be made, including the differentiation between short, medium, long-term and cumulative impacts during construction, operation and decommissioning. The Consultant shall also identify both temporary and permanent impacts. A detailed outline and discussion of specific conditions that might affect the environment which are unique to the project should be provided.
Possible planning measures and their impact	Brainstorm to come up with sustainable planning measures based on these key values. The **strategy** used to implement these measures is to **avoid (1), to minimise (2) and to mitigate (3)** negative impacts on the ecology. That means in the first place that these measures should strive for avoidance of any negative impact to system. When this is not possible minimising or mitigating/compensating planning measures should be provided. The possible impacts of these measures also need to be described in a table. This table systematically shows all the possible planning measures and their impacts. However this process is not necessary, it is up to the port planner if he/she wants to spend time on this. The task required for the ESIA in this step is as follows: **ESIA task 6** –The analysis will explicitly consider the mitigation measures that are considered necessary including the effect of these measures on the operation of the port and most importantly the environmental benefits. Environmental mitigation plans will also be discussed in terms of the requirements for implementation including procedures and staff.
(Concept) alternative (phased)	From this point the development of alternatives starts. The alternatives are developed in such a way that they fulfil the needs and objectives of the port (design parameters) and take the key values in to account to the utmost degree. As the emphasis in each alternative is put on different key values it likely will result in different alternatives and solutions as well. The alternatives will also be described in several development phases: this is recommended in order to guarantee more flexibility for the port for unexpected future changes. The designer should choose the number of phases: the more phases, the more flexible the design becomes.
Possible methods/tools	Brainstorm sessions with experts, Delphi , Focus groups, Scenarios, Trade-off studies etc [Taneja, 2013]
V. Test the alternatives	
Technical evaluation and impacts	The evaluation in the following step is based on the assessment of the technical feasibility, the potential ecological and social impact and the cost estimation of the developed conceptual layout alternatives. In order to make preparations for

	this evaluation, the technical feasibility and potential impacts will be treated in this step. This step is rather time-consuming and in order to reduce this required testing (time) to a minimum, the modelling needs to be prepared and executed adequately. This means that beforehand clear objectives for the modelling works need to be determined. The biggest issue however which will be encountered is to convince the client BPDL to implement the sustainable measures. The sustainable measures still require a lot of research and hence there are still significant challenges in order to successfully implement this measure in practice; not only are the measures not so commonly used and rather new, but the client also takes a lot of risk if the measure will have the same positive results in this particular situation and therefor it will be a difficult decision for the client to consider some of the sustainable measures. It is up to the port planner to gather enough proof of the feasibility and the positive benefits of the sustainable measure in order to convince the client to apply them instead of the traditional measures. The task required for the ESIA in this step is as follows: **ESIA task 7** – The alternatives need to be detailed analysed, including: -"No project" alternative; -Port size and purpose alternatives; -Siting alternatives; and -Layout alternatives (including rail and road access and breakwater and entrance channel alternatives)
Possible methods/tools	Brainstorm, Delphi, Experts, Focus groups, Modelling and simulation exercises, ROA, Scenarios, Stakeholder analysis, etc [Taneja, 2013]
VI. Evaluate the qualities of each alternative	
aluation + sensitivity analysis	Evaluate the alternatives based on the assessment of the technical feasibility, the potential impacts and the cost estimation. Use the predefined key values as evaluation criteria. The port planner can select a suitable evaluation tool of his/her own choice. A sensitivity analysis needs to confirm the sensitivity of the evaluation outcome.
Optimisation	Since new knowledge is obtained by the performed investigations, it might result in the requirement to change or alter the alternatives. A feedback loop can be followed back to the alternative development for optimisation of the alternatives.
Possible methods/tools	Multi Criteria Analysis, Life cycle costing, Robust Decision Making, Financial techniques (e.g. CBA, DCF, DTA, ROA, Simulations), Scenarios using qualitative methods or EMA, Trade-off studies etc [Taneja, 2013]
VII. Create final design	
Final masterplan	Choose on or a combination of alternatives based on the performed evaluation.

	Follow a feedback loop back to a more detailed design process till the desired degree of detail is achieved. This step is outside the scope of this research, and will therefore not be treated here. The final tasks of the ESIA is as follows: **ESIA task 8** – Analyse and describe all occupational health and safety concerns brought about by activities during all the phases of the project. Recommendations need to be made on corrective and remedial measures to be implemented under the environmental management plan. Other social impacts that have to be considered are the effects on the existing population of a considerable influx of additional workers; during the construction period that could entail problems of housing, water usage and solid waste disposal. Specific impacts should be indicated and mitigation measures defined both for the existing population and for incoming workers. **ESIA task 9** - Develop a comprehensive environmental management plan. The plan should recommend a set of mitigation, monitoring and institutional measures to eliminate, minimise or reduce to acceptable levels of adverse environmental impacts and/or maximize socio-economic benefits. For the proposed mitigation measures, cost outlays should be provided as well as their institutional and financial support, time frame and responsibility. This shall be provided for all the project phases.
Cost/benefit analysis	A monetary method should be performed, because the client desires to know the costs of the project. The port planner is free to choose his/her own monetary method.
Possible methods/tools	Competitor watch, Delphi, Expert panels, Focus groups, Imaging, Media scanning, Stakeholder analysis, Time series analysis, etc [Taneja, 2013]