A METHODOLOGY FOR DEVELOPING A GREEN PORT. CASE STUDY: AMATIQUE PORT IN GUATEMALA.

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PREFACE

This document is written in partial fulfillment of the MSc. Civil Engineering at Delft University of Technology. The research was carried out in cooperation with the consultancy firm Port Consultants Rotterdam.

It is the result of the research on Green Port developments. In particular, the purpose was to better describe what Green Ports are and analyze how they could be designed and implemented, given that it is a recent topic that would perhaps gain more importance over the years. The lack of guidelines for their green developments that include a systematic and straightforward approach from the planning phase boosted that my attention during the research centered on proposing a complete methodology from conception to the end of the life cycle, which was successfully tested with a case study for the planning phase.

One of the main highlights of the research is that Green Ports are planned and designed to avoid negative impacts from the first development phases and maximize benefits regarding economy, society and environment. This is the key concept of the proposed methodology in which every measure to be taken towards a green development is based on.

This is the public version of my thesis. During the case study, documents from Port Consultants Rotterdam about the project, under development, were used. Due to confidentiality reasons, public access is not given to this literature which is referred to throughout the report.

Acknowledgments

First of all, I would like to thank Port Consultants Rotterdam, for giving me the opportunity of doing my research in their company, which has allowed me to focus on a topic with a combined theoretical and practical approach, as I always was interested in. I owe special thanks to Pedja and Daan, who have read my draft reports more than anybody else, and who were always willing to help me and provide me with feedback (although they are always busy).

I am also grateful for the graduation committee who agreed to guide me throughout my research: Prof.ir. Tiedo Vellinga, dr.ir. Poonam Taneja, dr.ir. Heleen Vreugdenhil. I could see that they were always interested in my topic and my progress, by always reading the reports that I sent them, providing me with their feedback, willing to have a meeting to answer my questions or discuss anything whenever I needed and giving me suggestions for improvement during the meetings. I would like to thank them for their guidance, support and feedback, and for making me feel comfortable and enthusiastic.

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Alejandra Ares Moreno
Rotterdam, October 2018

SUMMARY

Sustainability is one of the concepts that has gained more popularity during the last decade. The awareness about the importance of acting in a sustainable way is increasing over the years, being promoted by decision-makers to reach all members of society. On a daily basis, measures that can be taken towards being sustainable are clear. However, there are sources of high negative environmental and social impacts for which a methodology to be followed for sustainable development has not been defined. This is the case of Green Ports. The concept is used regularly; nevertheless, an agreed-upon definition does not exist, leading to the rise of questions about what they are and how to develop them.

The aim of this research is to analyze and define what a Green Port is and to compare it with a traditional port, in order to develop a clearly-defined, specific complete and timeless methodology to facilitate port planners to get to a sustainable solution. The purpose is that the proposed methodology covers all phases of development, from planning to operation, not only to minimize but to avoid impacts and to maximize benefits. A case study is used to refine it, with the objective of making it applicable to other port projects around the world.

By analyzing the existing varied definitions for Green Ports and the current sustainable practices in ports around the world, the proposed definition of a Green Port in this document is a port which is designed, constructed and operated integrating an environmental, social and economic philosophy, balancing between the port's benefit and future generations' needs. A Green Port also follows a long-term mentality, stimulating green technologies, innovation and energy and resources efficiency, minimizing (negative) impacts and maximizing benefits by creating added value for the environment and society through a stakeholders' co-creation. A Green Port can be compared to a traditional port in terms of the cooperation with stakeholders, the economic driver, the relation with nature, the scope of mentality, the use of technology, the role of the Port Authority, the source and consumption of energy and resources, the quality of air, the biodiversity conservation, the type of cargo, the vision of sustainability, the site location, the growth approach, the way of minimizing environmental impacts, the extent of sustainable actions extent, the management of future uncertainties, the design decisions and the mentality towards the end of the life cycle.

The proposed methodology for developing a greenfield Green Port is based on several top green philosophies: understanding of the system, ecosystem services, stakeholders' co-creation, long-term mentality, green growth strategy, building with nature, and Circular Economy. Each criterion that contributes for a green goal in any development phase is based on one or more of these philosophies. The methodology has been separated into four different stages: planning, design, construction and operation (and management). Each phase is divided into several subjects and green goals have been defined. Different criteria are proposed to achieve these goals. The purpose of this methodology is obtaining a future-proof port where the negative impacts are minimized, and the benefits to society and the environment are maximized. An evaluation framework is also developed in order to give a final score that provides an answer on whether the port is green or not, being a practical tool that gives a general insight, which as the same time gives freedom to be applied to different port projects around the world.

The proposed methodology and evaluation framework have been evaluated with a case study: Amatique port (in Guatemala), which the port planners aim to develop in a sustainable way given that the site is located in a protected area, as a means of compensation. However, the

methodology was tested from the site selection, and some of the findings include that there are other more beneficial sites for the project. The existing masterplan has also been assessed and given possible optimizations in terms of the proposed methodology.

After the refinement, several implementation issues of Green Ports have been found, which mainly refer to the economic feasibility, the competition among ports, and the lack of legislation and financial incentives. Some possible solutions for the success of the sustainable option are, apart from the promotion for the elaboration of dedicated legislation and to increase financial incentives, a green approach towards the business case, the development as a means for anticipation to future circumstances, and, in general, a shift in mentality.

To conclude, it can be considered that the development of Green Ports is important for the port sector and the future. It has been seen, however, that their definition and methodology for their development are complex. Due to this complexity and the specific conditions of each project, a checklist that indicates whether the port is green or not is an idealistic situation. The concept is broader and the philosophy behind, which includes the search for a continuous improvement, is necessary for their success. Through this research, I hope to have made the concept more comprehensive and practical, so that their implementation increases around the world in the future.

LIST OF SYMBOLS AND ABBREVIATIONS

A1	Alternative 1
A2	Alternative 2
A3	Alternative 3
A4	Alternative 4
BHD	Backhoe Dredger
BwN	Building with Nature
CAPEX	Capital Expenditure
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilization
CO_2	Carbon dioxide
COMUDE	Consejo Municipal de Desarrollo Urbano y Rural (Spanish)
CONAP	Consejo Nacional de Áreas Protegidas (Spanish)
CSD	Cutter Suction Dredger
e.g.	For example
EIA	Environmental Impact Assessment
ESG	Environmental, Social and Governance
ESI	Environmental Ship Index
ESPO	European Sea Ports Organization
FEPORTS	Fundación Instituto Portuario de Estudios de Cooperación de la Comunidad Valenciana
FUNDAECO	Fundación para el Ecodesarrollo y la Conservación (Spanish)
FUNDARY	Fundación Mario Dary Rivera (Spanish)
GD	Grab Dredger
IDEG	Infraestructura de Datos Espaciales de Guatemala (Spanish)
i.e.	In other words
IMO	International Maritime Organization
IFC	International Finance Corporation
IT	Information Technology
IUCN	International Union for Conservation of Nature
km	Kilometer
LNG	Liquefied Natural Gas
m	Meter
m/s	Meter per second
MAGA	Ministerio de Agricultura, Ganadería y Alimentación (Spanish)
MSL	Mean Sea Level
n.a.	Non-applicable
NO_X	Nitrogen oxides
OECD	Organization for Economic Cooperation and Development
OPS	Onshore Power Supply
PCR	Port Consultants Rotterdam B.V.
PIANC	Permanent International Association of Navigation Congresses
SD	Suction Dredger
SO_X	Sulphur oxides
TBL	Triple Bottom Line
TNC	The Nature Conservancy
TSHD	Trailing Suction Hopper Dredger
WCPA	World Commission on Protected Areas
WwN	Working with Nature

CONTENTS

1. INTRODUCTION

Sustainability is, at the present, one of the most important guiding concepts for society. Recently, there has been an increase of environmental awareness due to the negative consequences of the high amount of unsustainable practices during the last century which are leading to global warming, climate change and rise in sea level. The Paris Agreement adopted in 2015 by 195 countries contributes to the avoidance of these consequences, by setting the goals of "holding the increase in the global average temperature to well below 2ºC above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5ºC" (United Nations, 2015). Therefore, authorities and institutions have been stimulating sustainability by following sustainable development strategies.

The concept of sustainability was formalized in the early 1990s (Abood, 2007). From then, the United Nations and agencies have promoted sustainable development and environmental awareness among leaders and society. Both the United Nations Environment Programme (UNEP) and the World Commission on Environment and Development were subsequently created for this purpose. The concept of sustainable development was defined for the first time by these agencies in the report called "Our Common Future: A global agenda for change" (United Nations, 1987). The definition has been used until the present and adopted by many institutions: "development which meets the needs of the present without compromising the ability of future generations to meet their own needs".

Moreover, sustainability is directly linked to the concept "Triple Bottom Line" (TBL), which has been first attributed to John Elkington (Carroll & Buchholtz, 2014). The TBL (Figure 1) states that a sustainable solution is based on three pillars: economic, social, and environmental. In other words, any business should perform equally well from an economic, social and environmental point of view, and only with a balance of these three elements, sustainable development can be achieved. It makes clear that sustainability is a wider concept and goes beyond the environment. These three pillars relate to a large number of aspects of life, but are especially relevant for transport infrastructure, due to its high impact on the environment and high investments. In the transport network, ports are nodal points which also contribute significantly to the impacts on the environment.

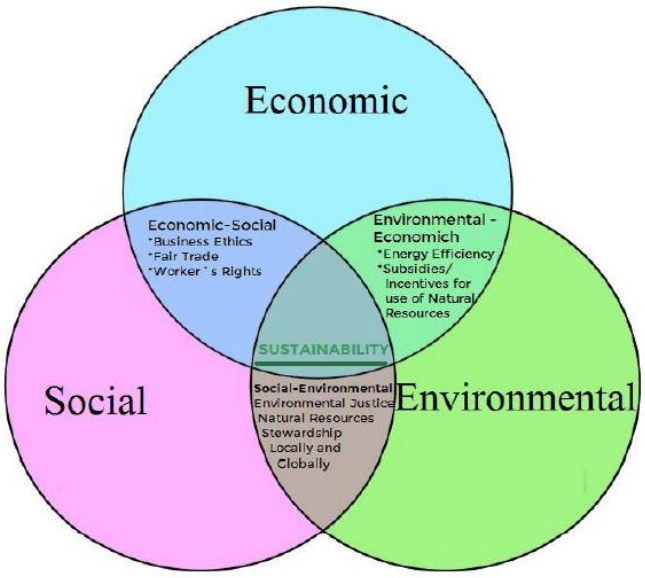

Figure 1 Triple Bottom Line (TBL) (Adopted from Ayers,2011; Vanderbilt University, 2014)

Being aware of the importance of sustainable develoments, authorities and insitutions promote it by means of initiatives or environmental regulations. The United Nations Sustainable Development Goals (United Nations, 2015) is an example, which is taken as a base to improve the environmental performance of numerous companies around the world. Environmental regulations are also a requirement for any civil construction with a considerable size, including port developments, both before construction and during operation. A new project involves the approval, among other licenses, of the Environmental Impact Assessment (EIA) as defined in the EIA Directive 85/337/EEC (European Comission, 1985), which includes all different environmental implications and impacts to the environment, during construction and operation. Nevertheless, a positive EIA does not mean that the new infrastructure is environmentally friendly or sustainable, so a new concept that deepens further in sustainability arose, which does not only minimize the negative environmental impacts but enhances nature-friendly solutions: the "Green Port".

1.1. PROBLEM DEFINITION

The importance of sustainability in recent years has been made clear and, in particular, both the definition of sustainable development and the general approach to follow to obtain it are clear and adopted by numerous institutions. The reason is that the concept became relevant at the end of the 1990s.

On the other hand, the "Green Port" is still a relatively new concept that became significant in the last decade, originated from the EU Sustainable Development Strategy (European Commision, 2001), which is the framework for a sustainable vision in the long-term to improve quality of life.

Different authors and organizations had tried to define what a Green Port is and tried to develop frameworks and ideas about it. However, after doing a literature study, it has been proven that there is a lack of a Green Port methodology or systematic approach to be followed by the decision-makers (i.e. port authorities) to directly implement into port systems, like there are, for example, rules, formulas and steps for the design of port layouts.

Different papers give a general framework (PIANC, 2014a; Zheng, 2015; Vrolijk, 2015; Boer G.G., 2016), but they are vague in the complete set of measures that could be taken (Zheng, 2015; de Boer G.G., 2016). Other papers give concrete actions, but they focus on operation and management stages and leave out the planning, design, and construction phases (Wakeman, 1996; Bailey & Solomon, 2004; Abood, 2007; ESPO, 2012; Yang & Chang, 2013; Klopott, 2013; Lirn, Wu & Chen, 2013; Darbra *et al*., 2013; Chiu *et al.,* 2014; Hiranandani, 2014), centering the attention on how to implement the green concept in already existing ports rather than in greenfield ports. Moreover, none of them cover all the criteria that could be implemented to obtain a Green Port. For instance, none of them consider flexibility as an aspect towards sustainability and, on the other hand, it is closely related. If a port is not adaptable (future uncertainties are not considered into the design) and external circumstances change considerably, some terminal may need to be demolished, which is one of the most unsustainable practices that could be executed. A more detailed literature review is found in Appendix A.

The Green Port goal shall also have a specific method, and for that reason, this master thesis will focus on developing it, covering this gap in literature. The Green Port philosophy and green

opportunities will be compiled in one document, giving a methodology that can be followed for greenfield port or expansions of brownfield ports.

1.2. OBJECTIVE OF RESEARCH

The objective of this master thesis is to develop a better and clearly defined methodology for designing and implementing a Green Port, based on learning from a case study, with the purpose of applying the method to other port developments around the world. In other words, the aim is that this straight-forward methodology could be used and easily followed by port authorities, stakeholders, contractors, and engineering and consultancy firms to develop a sustainable port. Although the most sustainable choice might often be not to construct a new port, the port developed through this methodology would be more sustainable than the development that follows the traditional approach.

To test, prove, and refine the developed methodology, in order to make recommendations to future projects, Amatique port project, a greenfield port located on the Atlantic side of Guatemala, will be used. It is a project in which Port Consultants Rotterdam (PCR) is involved with and which is familiar from an internship in the company previous to the thesis period, and from where the research topic arose. The objective of the project is to provide world-class port services in Guatemala for containerized and bulk import/export operations, given the lack of port capacity on the Atlantic coast of Guatemala.

The reasons for the selection of this project as the case study are three. First, it is a greenfield port, so it is an opportunity to make choices with regard to sustainability. Second, the stakeholders ask for a green approach, as the site is located next to a Nature Reserve and the access channel will cross part of this area, so this green approach can be seen as a necessity for stakeholder support of the project. And third, the port will mostly handle bananas, which is a challenging product because of the energy consumption during transport and storage, and it can be compensated with sustainable decisions. Overall, it is a good opportunity to maximize sustainability and to become a reference for the region and for the world.

Figure 2 Site location of Amatique Port

1.3. RESEARCH QUESTIONS

The main research question of the master thesis is:

How can we design and implement a Green Port?

To answer the main research question, several research sub-questions should be first answered:

 # 1 What is a Green Port and what are the differences with a traditional port?

 # 2 What opportunities can be identified in each phase of a port project for the development towards sustainability?

 # 3 What green goals can be set for each opportunity for sustainable development?

#4 What are the issues regarding the implementation of Green Ports?

1.4. METHODOLOGY AND REPORT OUTLINE

The thesis will be carried out at Port Consultants Rotterdam, a Rotterdam-based independent consultancy firm with an international reputation in the field of strategy, management, infrastructure, and logistics development in ports and hinterland.

The thesis development and outline will follow the methodology summarized in the flowchart of Figure 3 and described below.

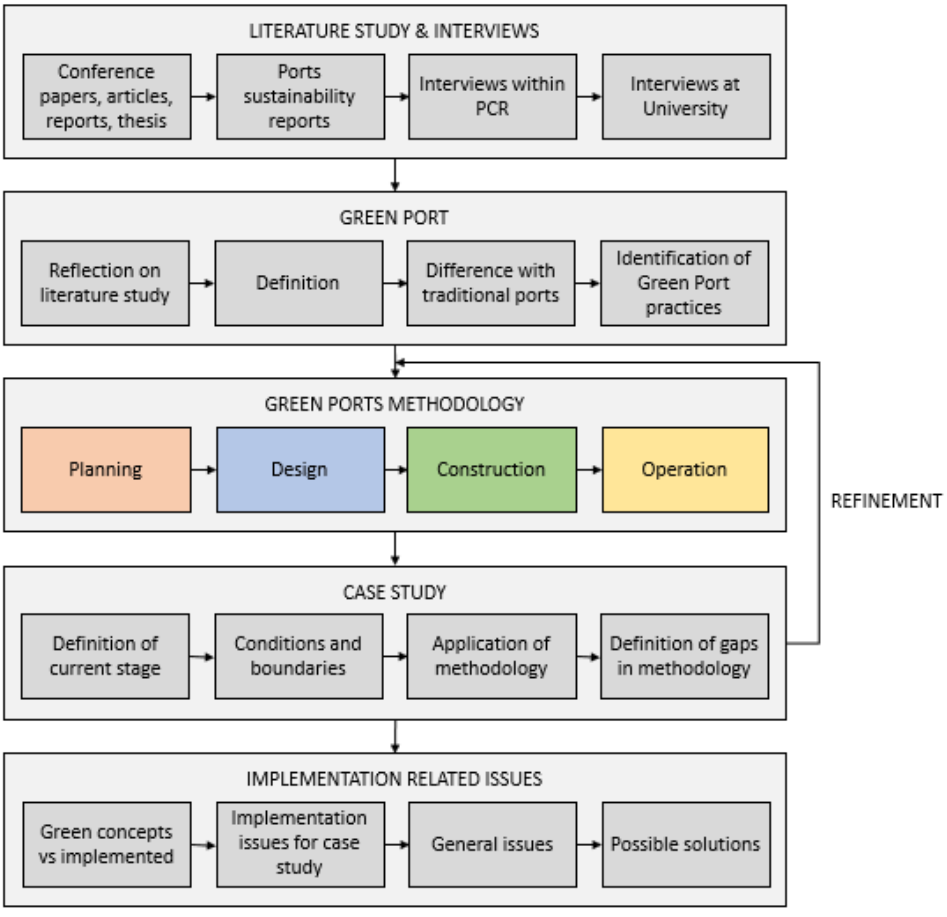

Figure 3 Thesis methodology

The first step will be the literature review, along with interviews with experts of PCR, professors from University and maybe experts from other organizations. The purpose of the literature study is to gather information about the approach of other authors of the Green Port concept and to identify Green Port practices of different ports in the world, via their sustainability reports. The aim of the interviews is to get valuable information from experts with experience in the field that cannot be found in literature.

Focusing on the report outline, the first part of the thesis will include a description of the Green Port, the difference with traditional ports, a summary about green port practices and a reflection on the current green port frameworks based on the literature study.

The second part of the thesis will focus on the Green Port design methodology. It will be based on the literature study and the interviews. Current green port practices will be included in the methodology, together with other sustainable opportunities that are not usually adopted by ports up to the present. A reflection on the philosophy that port authorities shall adopt to obtain a Green Port will also be included, as it is an essential part of the process of shifting from a traditional port to a Green Port.

With this information, the different aspects where the Green Port concepts can be applied will be identified. A distinction will be made between the planning phase, design, construction, and operation. Every green opportunity/criterion will be subdivided in sub-criteria and will be further elaborated on, considering the different sustainable alternatives that can be followed.

The third part of the thesis includes the application of the Green Port methodology to the case study, Amatique port, applying the green port concept to the current port layout in the actual stage of the project, and optimizing the design with green opportunities. Environmental and social issues will be considered, as well as the interests of the community and stakeholders. The site location and boundaries of the project are fixed; however, a better solution in terms of sustainability will be sought, by following the proposed methodology.

The Green Port methodology will be refined after focusing on the case study, identifying gaps or issues in the methodology when applying it to a port project. An in-depth study will be made of the most relevant green opportunities.

The final part of the thesis will list various challenges or difficulties with the implementation of the Green Port opportunities, including a reflection on the implementation issues in Amatique Port. Along with these challenges, possible solutions will also be given.

2. THE GREEN PORT

Due to the importance that authorities and institutions are giving to sustainable development during the last decades, the concept of "Green Port" is becoming very relevant. Port authorities, stakeholders, port users and society in general, ask for and are aware of the importance of green port developments. In other words, they are interested in ports that follow a green port approach (with nature) instead of the traditional approach (replacing nature) (Rijks, Vellinga, & Lescinski, 2014), and considering sustainability in all phases of the port development.

The drivers and pressure that makes decision makers develop ports that follow a more sustainable approach, which also leads to a more opportunistic driver of faster implementation, are the following (Cusano, 2013):

- Increasing society's awareness of the negative impacts of port operations, especially in the communities close to ports, who are pressuring their representatives to take the topic into account and act consequently
- Stricter regulations are being applied around the world, requiring mitigation and compensation measures of the impacts
- Greener supply chains require ports to adapt to the circumstances and follow a sustainable strategy, as they are part of the chain
- Maintaining competitiveness related to sustainability enhances ports into sustainable efficient development, including the balance between social, economy, and environment in the policies and decisions

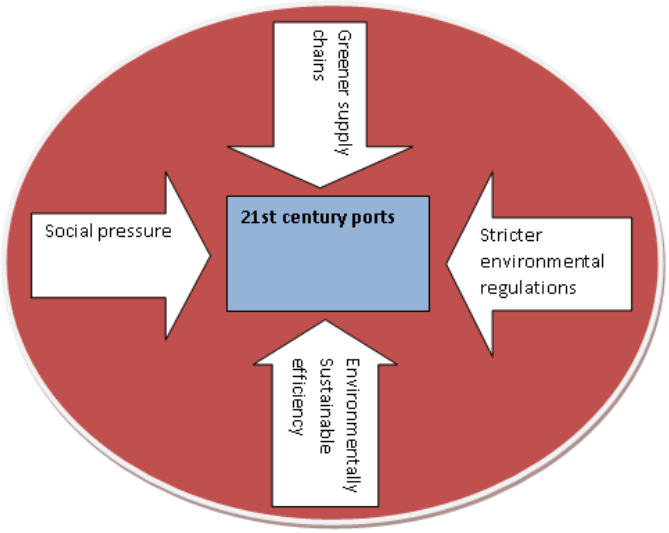

Figure 4 Drivers of 21st century ports (Cusano, 2013)

These drivers contribute to a shift of mind towards sustainable port development. However, they are not sufficient to make a port green and deviate from the traditional port approach towards the green port approach. For that reason, different papers which create awareness about the advantages of following a green port philosophy appeared (PIANC, 2014; FEPORTS, 2008; ESPO, 2012; OECD, 2011), extending beyond existing environmental regulations like the EIA which forms part of the traditional port approach due to its limited contribution towards the Green Port goal.

Nevertheless, there are some relevant questions that are still not clearly answered. The concept of Green Port is commonly used in a generic way. But, what is a Green Port? What are the differences compared to a traditional port? Which is the green port approach? The following section will discuss that topic and provide answers.

2.1. DEFINITIONS OF GREEN PORT IN LITERATURE

The Green Port concept originated from the EU Sustainable Development Strategy (European Commision, 2001), which is the framework for a sustainable vision in the long-term to improve quality of life. Yet, the concept was not defined then, but was derived from this sustainable European strategy. There are a few definitions of the Green Port in literature. These definitions have some similarities; however, they are not the same. Is a Green Port a port that complies with all these definitions? Shall a new and complete description be defined? To answer these questions, the definitions found in literature will be analyzed, considering both their similarities and differences to arrive at a new definition of the Green Port.

The first explanation of the Green Port (PIANC, 2014a) is the following: "*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*."

A Green Port is also defined in literature (Green Energy Ports Conference, 2013) as: "*one which develops its activity considering not only to the economical scope but also the environmental and social scopes or in other words, in a sustainable way: developing its activity causing the minimum possible impact, contributing with improving and control measures for the quality of the air, water, noise and waste. At the same time, a Green Port is one which is able to provide power supply to the ships onshore (OPS) and is provided with facilities for renewable energies and measures for energy efficiency*".

The last definition of Green Port (Zheng, 2015), less adopted globally 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.*"

A first insight into the definitions could show that they only have some common keywords, and they do have many different concepts in them. Table 1 displays the keywords included in them that could be comparable and the ones that are exclusive for each definition.

Table 1 Comparison of keywords between the Green Port definitions

GREEN ENERGY PORTS CONFERENCE, 2013	PIANC, 2014	ZHENG, 2015
Environmental, social & economical scope	Economic green growth strategy	Environmental, social & economical extent
Sustainable development	-	*(Implicit)*
Minimum possible impact	Working with nature philosophy	Uses the Earth's resources without affecting future generations

Measures for quality of air, water, noise and waste	-	-
OPS, renewable energies, energy efficiency	-	-
-	Port authority together with port users	-
-	Stakeholder participation	-
-	Long-term vision on area and position	-
(Implicit in contribution with measures for quality of air, water, noise and waste, OPS, renewable energies and energy efficiency)	Needs of future generations	Without affecting its capacities for future generations
(Implicit in economical scope)	Own benefit	Own benefit
-	Prosperity of the region	Balance for the surrounding local region

After making this comparison, one can arrive at different conclusions. First of all, the definition of the PIANC group is more general and extends further, because it implies new concepts like "working with nature" or "green growth strategy" that shall be studied in depth to fully comprehend the definition, and it also gives general ideas that shall be further elaborated on to understand what they refer to, like "long-term vision on the area".

Second, the definition derived from the Green Energy Ports Conference is more specific and indicates concrete attributes that Green Ports shall have: OPS, renewable energies and measures for quality of air, water, noise, and waste. It also names the concept of sustainable development, while the PIANC report refers to the concepts referred above (working with nature and green growth strategy) instead of sustainability.

Third, Zheng's definition does not give specific characteristics as the former, being more general. Nevertheless, it does not include concepts that need further elaboration as it happens in PIANC's definition. So, it is more comprehensive without having to make a further literature review of certain broad and complex concepts.

In order to give a better and refined definition of the Green Port based on the definitions of literature, the two unclear concepts in PIANC's definition shall be examined in more detail. A short description to make the definition understandable and to verify if it is appropriate to include them in it are shown below. The concepts are broader, but only the useful key elements for this purpose have been included.

Green Growth Strategy

The PIANC group, in their report 150, where the definition of Green Port is given, makes aware of the importance of developing towards Green Growth, as in the report *Towards Green Growth* by the Organization for the Economic Cooperation and Development (OECD). This report states the need for strategies to achieve green growth that ensures climatic and environmental sustainability, defines a policy framework, promotes the transition towards green growth, and defines methods for measuring progress and delivering on green growth.

The green growth strategy that green ports shall be based on involves growth through the following routes (OECD, 2011):

- Enhancing productivity with incentives for efficiency in the use of resources and natural assets, like for instance, reduction of waste and energy consumption
- Creating opportunities for innovation, that allow for new ways of addressing environmental problems
- Stimulating the demand for green technologies, goods and services; creating then new markets and potential for new job opportunities

Working with Nature

The PIANC group defined the concept of Working with Nature as (PIANC, 2014b): "an integrated process which involves working to identify and exploit win-win solutions which respect nature and are acceptable to both project proponents and environmental stakeholders". It gives importance to developing this approach in early stages of the project, to select the design according to environmental issues in order to avoid sub-optimal solutions with a considerable amount of mitigation and damage limitation, instead of maximizing opportunities when possible. The order of the project development is therefore inverted compared to the traditional project development approach, as follows:

1. Establish project need and objectives
2. Understand the environment
3. Make use of stakeholder engagement to identify win-win opportunities
4. Prepare initial project proposals/design to benefit navigation and nature

In order to have a clear understanding of what a Green Port is, identifying the definition in literature is just the first step. More specific green actions ports follow in order to be Green shall also be identified, as the definitions are not specific enough and they cannot cover all green aspects. This will be made in the following section.

2.2. CURRENT GREEN PRACTICES

In order to understand in a more specific way how a green port can be designed and implemented, attention shall be put on the current green practices of different ports in the world. These practices may serve to formulate a new definition and to make a clearer comparison between a green port and a traditional port.

Special attention will be given to ports with a certain relevance in sustainability aspects, like the ones awarded with “Green” Awards or the ones that usually promote green initiatives, but also, they are selected taking into account their location and size, so that a comparison of their green approach can also be made regarding these characteristics.

2.2.1. HAROPA Port

First of all, the focus will be put on HAROPA Ports, in France, which is the fifth largest port complex in Northern Europa, being an alliance between Port of Le Havre, Grand Port of Rouen and Ports of Paris (HAROPA, 2017). The choice for the selection of this port as a reference for green practices is, nevertheless, the award it received for the third time as the “Best Green Seaport” by the port stakeholders and experts in the supply chain of the Asia Pacific zone due to its sustainable economic approach and environmental policy.

HAROPA port counts with an Environmental Strategic Plan that focuses on:

- Forward-looking management of wilderness areas and natural resources
- Control of the environmental impacts due to port activities
- Integration of environmental issues from the design stage of projects
- Integration of the port into their natural and urban environment

Some examples of green practices included their sustainable development approach are the following (HAROPA, HAROPA is committed to climate, n.d.):

- Encouraging low emissions from ships by making financial rewards to the greenest calls.
- Incentivizing the operation inside the port boundaries of innovative industries committed to reducing their environmental impact.
- Helping their customers develop environmentally-friendly logistics projects, like, for instance, the energy recovery process from an incineration and reprocessing plant for industrial waste in Le Havre to heat homes and public facilities in near towns or industrial sites in the neighborhood.
- The “Sand in Seine” charter, under which companies at the port undertake to improve their facilities in terms of environment.
- The “Green and Blue Belt network”, a programme designed to preserve and restore the ecological continuity of the land within its surroundings.
- The experimentation of dumping methods to define a procedure to operate that minimizes the ecological impact and allows the resettlement of marine fauna on the seabed.
- The operation of automatic electrical terminals on the docks so that barges can be powered directly.
- A control management system that monitors and measures changes in the quality of air, water and soil.
- It’s Natural Areas Management Plan, which includes actions to manage biodiversity within the port.
- The constant dialogue with local stakeholders and businesses, hosting around a dozen public consultations a year.

2.2.2. Port of Long Beach

The port of Long Beach in Los Angeles is another example of a port with green initiatives and was also awarded several times with the "Best Green Seaport" reward. Among others, its green practices include (Port of Long Beach. The Green Port, n.d.):

- A Clean Truck program, that has reduced air pollution by 90% over three years, by banning the older, more polluting trucks and through funding programs to operators seeking to upgrade to cleaner trucks with newer engines with zero or near-zero emissions.
- Dialogue and meetings with stakeholders and communities to reduce social and environmental impacts.
- Investing in Shore Power to minimize air pollution and stop diesel spills.
- A Green Flag Vessel Speed Reduction program that makes vessels slow down at a distance of 40 nautical mile distance, thus reducing air emissions as slower ships burn less fuel.
- A Green Ships Award given to encourage greener ships (with reduced emissions), rewarding them with lower docking fees.
- An Energy Island Initiative, which consists on having an "island" of renewable energy technologies and self-generation systems, using low carbon technologies, in order to reduce the port's carbon footprint and provide reliability through its ability to operate in an interconnected mode or in isolation.
- Other sustainable practices include LED buildings, environmental purchases (from pens to fleet vehicles), a recycling program, landscaping projects, a pilot solar car port, etc.
- The "Port of Long Beach sustainable design and construction guidelines" were developed to establish sustainable opportunities from port design stages.

2.2.3. Port of Rotterdam

Due to the proximity of the Port of Rotterdam to the Technical University in Delft, the close relation between the port authority and Port Consultants Rotterdam and given that it is the largest port complex in Europe, which is continuously seeking towards green growth, its green initiatives will also be studied in more detail (Port of Rotterdam, n.d.):

- The port counts with several green areas, that are the natural habitat of animal and plant life. It counts with the "Green Gateway", a riverbank nature of 20 hectares and with the "Bird Valley", a nature area of 21 hectares.
- Longitudinal dams were constructed with the purpose of restoring the natural tidal habitat, as they allow the dredged sediment to deposit there and benefits birds, crabs or fish.
- To reduce carbon emissions, a pipeline is being constructed through the port area so that businesses can connect to it and capture and deliver CO_2 emissions to the pipeline, ending up in empty gas fields under the North Sea.
- Another measure to reduce CO_2 emissions in the city and the port is the "heat alliance". By this means, residual heat from the port is being used via heat networks to supply heat to private households, obtaining a sustainable, reliable and affordable heating solution. Companies located in the port's industrial cluster can also make use of each other's residual heat to reduce emissions and increase efficiency.

- To contribute to achieving a sustainable port, the port authority uses hybrid patrol vessels, running on electrical power and diesel.
- To incentivize the contribution of the shipping industry towards sustainability, the port authority gives discounts on port dues to cleaner vessels. For this purpose, they make use of the Environmental Ship Index (ESI), established together with other ports, which indicates the vessel's environmental performance regarding their nitrous oxides, sulfur oxides and carbon dioxide emissions. The corresponding discount is given taking this index into account. The port authority also gives discounts to oil, LNG or product tankers with a Green Award, issued by the Green Award Foundation to vessels and shipping industries that have made an extra investment in vessels and crew to increase their sustainable performance. The discount also applies to inland vessels whose propulsion engine satisfies some requirements, surcharging them if they do not comply.
- To contribute towards energy efficiency, solar panels have been installed in many buildings in the port. Moreover, many buoys, dolphins, and waterway markings are powered by their own solar panels.
- Wind turbines are installed all over the port area. A capacity of 200 megawatts is reached up to now, and through the 'Convenant Realisatie Windenergie in de Rotterdamse haven' (2009) (Agreement on Realisation of Wind Energy in the port of Rotterdam), it is pursued to increase with at least 150 megawatts by 2020.
- LED lighting is being installed in all port areas, being another measure of energy efficiency, as they last longer and consume 50% less electricity.
- The Port Authority has reserved a 40 hectares site for innovative chemical companies that work with renewable feedstock, like power stations that co-fire biomass (the Maasvlakte Power Plant 3), which emit a 25% less CO_2 compared with a coal-fired power plant. This bio-based plant in the Maasvlakte supplies power, cooling water and heat to nearby businesses. In exchange, the surrounding plants provide it with residuals that are used as biomass for power generation.
- The Port of Rotterdam is also the number one European hub for liquefied natural gas (LNG), because of being a frontrunner in facilitating a logistic chain for LNG, to use it as an energy source for households and industries and as a clean fuel for shipping and road transport, as it has no sulfur emissions. Bunkering is also allowed and promoted.
- In the last expansion of the ports, Maasvlakte 2, sustainable measures in the design were followed, designing the reclamation with a streamlined, rounded-off shape with minimal effects on the North Sea. It was also given a compact shape to minimize nature loss and needed sand. The effects on nature were also compensated by means of new dunes of enhanced nature conservation.

2.2.4. Port of Vancouver

The Port of Vancouver claims to be "the world's most sustainable port" (Port of Vancouver, 2016). The sustainable priorities developed during the years focus on governance, culture, leadership, performance, and reporting. For this purpose, they promoted project and environmental reviews about their green approach. Some of their green contributions are the following:

- For the quality of water, they adopted a stormwater management to prevent pollutants from flowing seeping into groundwater and ultimately ending in the sea.

- The port also forms part of the ECHO Program, created to mitigate the impact of shipping on whales along the southern coast of British Columbia.
- The port is committed to reducing air emissions to a minimum, through the Northwest Ports Clean Air Strategy. The strategy includes performance targets for each of the main port emissions sources: vessels, trucks, terminal equipment, and locomotives. They monitor the emissions using satellite technologies and incentivize greener vessels through reduced harbor dues. They are also involved in an initiative to provide Onshore Power Supply and to use LNG as marine fuel, which significantly reduces air pollutants. In addition, they restrict the type of container trucks entering, having requirements for engine age, idle reductions, and emissions control.
- The Port Authority is also committed to the search for cleaner and renewable energies and for that reason, they partnered with BC Hydro, a 93% cleaner energy supplier to meet their increasing energy demand.
- The port forms part of the EcoAction Program, offering discounts on harbor dues to vessels that reduce their emissions and improve their sustainability performance.
- The Port Authority responses to community feedback to minimize the port activities impacts. For instance, they monitor noise in different stations around the port to address concerns efficiently.
- The port is involved in the Habitat Enhancement Program, to restore 10 hectares of habitat and add recreational and natural areas that attract public.

2.2.5. Port of Singapore

The selection of the Port of Singapore as a reference for its green practices is done for two reasons. First of all, it is one of the largest ports in the world with the highest throughputs, having a clear responsibility regarding green actions. And second, because it is located in Asia, a comparison can be made between the green practices of the studied ports regarding their location. The port of Singapore counts with the "Maritime Singapore Green Initiative" (MPA Singapore, 2011), which seeks for a reduction of environmental impacts due to shipping. It comprises five programmes which promote and incentivize companies to adopt cleaner and greener shipping practices above the minimum requirements of regulations:

- Green Ship Programme: it encourages vessels to reduce their emissions of CO_2 and NO_X by reducing their Initial Registration Fees and a rebate on their Annual Tonnage Tax. They also provide the ship and company owing it with a Green Ship Certificate. The qualification of the vessels is based on the possession of an International Energy Efficiency Certificate that is awarded through the Energy Efficiency Design Index, that shall be higher than the IMO's requirements. The ships can also opt for incentives if they have adopted Sox scrubber or LNG technologies.
- Green Port Programme: it encourages vessels to reduce their emissions of pollutants by reducing their port dues. It applies to vessels that declare the use of abatement technology, LNG or clean fuels (defined as containing less than 0.5m/m of sulfur content). They shall also stay five days or less in the port to qualify.
- Green Technology Programme: it encourages local maritime companies to develop and adopt eco-friendly technologies that reduce the emission of pollutants by offering a grant that covers up to half to the cost to develop and adopt the technology, with a maximum of $3 million for projects that achieve 20% lower emissions. The companies

that apply must be registered in Singapore and remain there for a period after finalization of the project.

- Green Awareness Programme: it encourages the maritime industry to explore new possibilities towards sustainable shipping, with regular workshops to share best practices. The port authority co-funds companies in the generation of their sustainability reports.

The port also follows some other sustainable measures (Maritime and Port Authority of Singapore, 2016) such as:

- A strong partnership with stakeholders in terms of safety and sustainability.
- Cleaner fuels such as LNG and promotion of bunkering services.
- Conservation of biodiversity and management of materials.
- Incorporation of sustainability into port design and construction.
- Enhancement of new technologies, development and innovation to enhance operations and environmental sustainability, by a funding support in form of the Maritime Innovation and Technology Fund.
- Ballast water and oil spill management.
- Energy efficiency and use of renewable energies.
- Terminal automatization as one of the measures to control emissions

2.2.6. Conclusions

Many ports around the world are developing policies that include sustainable opportunities, challenges and objectives. In most of them (HAROPA, 2017; Port of Long Beach. The Green Port, 2017; Port of Rotterdam, 2017; Port of Vancouver, 2016; MPA Singapore, 2011; Port of Amsterdam, 2017; Algeciras Bay Port Authority, 2016; Puerto de Vigo, 2016; Busan Port Authority, 2014; Sustainable Port of Antwerp, 2017; Twrdy & Hämäläinen), the improvement in quality of air and water is one of the major objectives, as it involves a direct impact towards the environment and communities. In addition, the search for alternative and green options for energy supply and use of natural resources, waste management solutions, and measures for the switch towards sustainable transport both maritime and inland is common in many of the ports sustainability reports, and they are considered indicators of a green port approach.

Focusing on the analyzed ports, a comparison is made in Table 2, marking the green practices with an 'X' if the port takes any action that contributes towards these sustainable opportunities.

Table 2 Comparison between Green practices of analyzed ports

GREEN PRACTICES	HAROPA	LONG BEACH	ROTTERDAM	VANCOUVER	SINGAPORE
Attention for natural areas & biodiversity	X		X	X	X
Reduction of environmental impacts in port activities	X	X	X	X	X
Use of shore power supply facilities		X		X	

	HAROPA	LONG BEACH	ROTTERDAM	VANCOUVER	SINGAPORE
Promotion of LNG			X	X	X
Inclusion of environmental Issues from design	X	X	X		X
Incentives for low emission ships	X	X	X	X	X
Incentives for sustainable companies/clients	X		X		X
Integration of port into the environment	X		X		
Involvement of stakeholders	X	X	X	X	X
shifting towards sustainable transport		X		X	
Compensation measures for reduction of carbon footprint		X	X		
Use of renewable energies			X	X	X

There are several conclusions that can be derived from this table. First of all, the five analyzed ports take actions to incentivize the reduction of ship's emissions, being the reduction in port dues the main promoter. Another similarity is the involvement of stakeholders and the reduction of environmental impacts during operations. The latter measures especially relate to equipment emission's reduction via automatization, hybrid machinery or cleaner fuels. Shore power supply and use of LNG are also contributors to lower port activities emissions, however, they have been separated in the table to identify which are the ports that have adopted these specific sustainable measures. Haropa port, for instance, has not taken yet any of these measures. The third conclusion is that sustainable measures in the planning stage are not included, and only some of the design actions are mentioned. The reason is that these ports were developed before the recent environmental awareness and concept of Green Port. Therefore, their measures focus on improving the environmental performance in the operation phase.

Through this table, a comparison regarding the type of measures the ports follow can be made. However, the greenest port cannot be chosen if only these criteria are considered. It can be seen that the Port of Rotterdam takes a wide variety of measures, but it could be possible that the measures contribute with a lower benefit than for instance the measures of Long Beach port, with a narrowed variety but with a possible higher weight. However, the purpose of this analysis is to obtain an idea of what the focus of sustainability is for the main ports in the world. The information will be used in the following sections to compare a traditional port with a Green Port and to arrive at a comprehensive definition of the latter.

2.3. DIFFERENCE BETWEEN GREEN AND TRADITIONAL PORTS BASED ON LITERATURE

After having analyzed through literature how a Green Port is defined and taking into consideration the sustainable practices of important ports around the world, the green measures can be differentiated from the traditional or unsustainable measures. A comparison can be made, for different criteria, between what the characteristics are for Green Ports and traditional ports (Table 3). This overview is executed considering the criteria and definitions found in literature and will be refined at the end of the research. In other words, a Green Port goes beyond the existing definitions in literature and current green port practices, which Table 3 is based on, and at the end of the master thesis, the complete picture and difference with traditional ports will be given.

Table 3 Comparison between the traditional port and the green port based on literature

SUBJECT	TRADITIONAL PORT	GREEN PORT
Stakeholders	Not meaningful participation of stakeholders or community and normally only during EIA	Co-creation with communities and stakeholders to generate an added value
Economic driver	Benefits/Economy	Green growth/ Economy, social & environment
Relation with nature	Replacing nature	With nature/develop nature along with port
Mentality	Short term (current benefits)	Long-term (future benefits)
Technology	No use of new and innovative technological developments	Involvement of technological and societal developments to enhance transition towards green growth
Port Authority role	Re-active landlord	Pro-active landlord in the development of the region and the logistic chain
Energy	Energy obtained from fossil fuels	Energy efficiency from renewable sources
Resources	“Take, make and dispose”	Reuse of resources
Quality of air	No special measures for reducing the quality of air during operation	Improving environmental performance through programmes to reduce emissions to a minimum during operation
Biodiversity	Reduction of negative impact on biodiversity	Enhancement of biodiversity and conservation areas

2.4. PROPOSED DEFINITION OF GREEN PORT

After having understood and analyzed the definitions of the Green Port existing in literature, having identified green port practices and having analyzed the difference in characteristics of a traditional port compared to a green port, a refined and new definition can be formulated.

This definition shall include the important keywords of the three definitions in literature. It has been made clear that there are common keywords or ideas when comparing the three, so these shall be definitely included in the new definition. Other keywords that have not been mentioned in the other two definitions may be omitted if they are considered not to be sufficiently relevant. For instance, including that a Green Port shall provide OPS to the vessels is too specific and may become an obsolete measure in a certain time, if a new technology starts to be in use and vessels are developed in a more sustainable way.

In addition, other important aspects found out while identifying green port practices and when comparing the different aspects which a green port has compared to a traditional port shall also be included in it.

The Green Port can be then defined as "***one which is designed, constructed, and operated integrating an environmental, social and economic philosophy, balancing between the port's benefit and future generations' needs. A Green Port also follows a long-term mentality, stimulating green technologies, innovation and energy and resources efficiency, minimizing (negative) impacts, and maximizing benefits by creating added value for the environment and society through a stakeholders' co-creation"***

The reasons for the selection of this definition are the following:

- The port shall be "green" in all stages of development, not only during operation. It is certain that it the longest phase of a port's lifecycle; however, the green concept shall be applied before it is constructed when most green opportunities can be identified. This statement is included in the first phrase: "*one which is designed, constructed, and operated…".*
- The word "sustainability" had to be included, in an explicit or implicit way, because it is the base for the Green Port/Sustainable Port. It has been included by including the phrase: "*integrating an environmental, social and economic philosophy"*, which is the definition of sustainability.
- A Green Port shall still search for its own benefit, so even if one of the three definitions identified in literature does not mention it, it is a very relevant aspect. A port by itself is not a sustainable infrastructure so the goal is not improving sustainability but obtaining a benefit. However, a Green Port shall also consider the needs of future generations apart from the benefit, as mentioned in "*balancing between the port's benefit and future generations' needs".*
- Having a long-term mentality shall also be one of the most relevant aspects of the Green Port, accounting for uncertainties and promoting new technologies. Current situations can change very quickly, even if it is assumed that they will last for decades. If new opportunities for innovation and green technologies arise, the port shall follow them to keep up being green. This is included in "*A Green Port also follows a long-term mentality, stimulating green technologies, innovation…".* The Green Growth Strategy is also characterized by these aspects, making the concept implicit, but now the concept is not included due to its extent, and reference is only made to the aspects that relate the most to ports decision-makers.
- One of the most important paths that a Green Port shall follow is the search of resources or energy efficiency and elimination of negative impacts on the environment, communities and stakeholders. A port will always make some impact, however, via compensation measures, this impact can turn into positive if these measures contribute

with more benefits or positive impacts than the initial negative impacts (overcompensation or added value). This idea is reflected in "*stimulating… energy and resources efficiency, minimizing (negative) impacts, and maximizing benefits by creating added value for the environment and society"*

- If a Green Port has to be developed in a social extent, stakeholders shall participate and be involved during decision making regarding their concerns, interests or expectations and opening the door for different opportunities in order to enhance the environmental and social value of the project. It is included in the last phrase of the definition: "*through a stakeholders' co-creation."*
- It shall also be noted that the concept of working with nature is implicitly included, as sustainability shall be considered from early stages of design and considering the stakeholders for maximizing opportunities by involving their concerns.
- The prosperity of the region mentioned in the PIANC definition is also implicitly included when referring to local communities, by creating added value for them, and having to perform in a combination of environmental, social, and economic philosophy with a long-term mentality.
- Specific actions to be taken during operation such as Onshore Power Supply, renewable energies or measures for the quality of air, water, noise, and waste, which are mentioned in the Green Energy Ports Conference definition, are not included in the proposed definition as they are measures towards a goal instead of being the goal in itself. In addition, if a port does not make use of OPS or renewable energies, it does not automatically mean that it is not green. When other sustainable measures that follow a green philosophy are taken, there can be a compensation. These are also case specific measures, which may be adequate for certain circumstances but may not be feasible or involve higher negative impacts than benefits in other cases.

3. PROPOSED METHODOLOGY FOR DEVELOPING A GREEN PORT

3.1. INTRODUCTION

In this chapter, the methodology to be followed in order to develop a Green Port will be described in detail, which will be later tested and improved with the case study. The proposed definition of the Green Port is used to develop it, which is the basis and starting point, together with the identified current green port practices around the world and the comparison between traditional and Green Ports based on literature. The methodology offers an extra toolbox to develop a port in the sustainable way; in other words, it is not a methodology for developing a port and can be left apart when doing it if a Green Port is not the goal, which would correspond to traditional port developments.

The methodology will focus on greenfield (and landlord) ports so that it is a complete procedure for all stages of development: planning, design, construction, and operation. In addition, information in literature focuses on the operational (and management) stage. The reasons are that this phase is the longest in the design lifetime of a port and given the recent appearance of the Green Port concept, making current ports to follow the concept from their actual stage: operation. However, the selection of green opportunities from the start could make a difference between a green port and a non-green port, even when corrective measures are taken in later phases. In the planning and design phases the environmental impacts can be avoided and/or reduced if an ecosystem-based design is followed during the site selection, layout selection and selection of port structures and materials, which are the hierarchical levels (after the no-port alternative) of an ecosystem-based design (Boer, et al., 2018). For that reason, it is important to consider sustainable choices in the first development stages, also due to the facility for constructing and implementing these green opportunities from the beginning.

For brownfield ports, the methodology can also be applied if an expansion is carried out. However, the restrictions will be larger, for instance, in the site selection. In general, for brownfield ports, green measures can be taken, but a shift to a Green Port is not straightforward, as the constraints are large. The port is in its operational stage and therefore, the measures in the methodology for this phase can be followed, together with other measures in the design if investments are made to improve the port infrastructure.

3.2. TOP GREEN PHILOSOPHIES

The methodology for developing a Green Port is based on several top philosophies. This means that all measures that contribute towards a Green Port included in the methodology are based on them. These are described below.

3.2.1. Understanding of the system

A Green Port cannot be developed if only the conditions inside the site boundaries are considered. An analysis at a system level is essential, defining it taking a holistic approach, in order to contemplate all affected elements, to identify opportunities, create added value and enhance Ecosystem Services. The system has to be understood on a physical, ecological, economic, and social level (Vrolijk, 2015). This is the basis for many green measures in every development stage, as it is essential to identify win-win solutions. Depending on the objective, the system to be considered can be wider.

The information about the system can be obtained from different sources, for which the stakeholders' cooperation is crucial, as well as obtaining scientific data from historical records.

3.2.2. Ecosystem services (ESS)

Ecosystem Services are benefits that society obtains from the natural environment, and therefore, from its ecosystems, providing them with an added value. This positive impact is one of the reasons why the ecosystem shall be protected and enhanced during port developments. This requires the involvement of different areas of expertise from early development stages so that these aspects are integrated into the design after the identification, assessment and valuation of the relevant ESS, enhancing them. The negative effect on the delivery of services due to port infrastructures shall be avoided by taking actions during green port developments.

The different categories of ESS are (The Economics of Ecosystems & Biodiversity, 2018):

- Provisioning services, which include material or energy outputs from ecosystems like food, raw materials, water, and medicinal resources.
- Regulating services, which relate to services ecosystems provide when they act as regulators, like for instance regulating air and soil quality and global climate, contributing against the negative effects of natural disasters, reducing soil erosion, allowing pollination, controlling pests and diseases, etc.
- Habitat or supporting services, which refers to the different habitat an ecosystem provides for the species lifecycle, or contribution to navigation, etc.
- Cultural services, including recreational spaces or aesthetic value.

All categories shall be analyzed to evaluate the changes in ecosystem service delivery to humans so that actions can be taken during the development process to maximize them.

3.2.3. Stakeholders co-creation

In a Green Port, apart from economic and environmental aspects, social aspects shall be considered. The concerns, values, needs and interests of stakeholders shall be addressed not only to minimize the impacts a port development may cause to the environment and their communities but also to create an added value to them and to other public and private partners. Through a Green Port, global and regional benefits can be obtained, and it has to be guaranteed that local stakeholders are also benefited, instead of affected in a negative way. This can be accomplished by means of a co-creation, bringing stakeholders together to produce a mutually agreed solution for a common goal: sustainability.

A new port development may involve negative environmental impacts, but it also allows the possibility of creating added value for stakeholders. These are not only dedicated to communities who can benefit, for instance, from recreational areas, but may also be addressed to other stakeholders, who look for added value and who may contribute with the investment. This is especially relevant for Green Ports, because many sustainable measures go along with higher costs, and this could be advantageous for the business case. This will be described further in section 1.

However, the stakeholder's involvement process has to be done in a careful way, selecting the stakeholders by understanding the whole system, for which local knowledge is needed. The

influence of every affected group shall also be considered to address the relevant values for the project and to discard extra information that would not lead to creating an added value for these stakeholders or for the Green Port goal.

The stakeholders' co-creation shall be realized, prior to the port development, through a stakeholder mapping, to identify them, their profile, concerns about the project, expectations from the project, their influence on the project and a rate of this influence. This information can be obtained from workshops, to gather their values and local knowledge from the first stage of development. Local, regional and national authorities, industry, port developers, tourism, nature interest groups, international bodies, and long-time residences are relevant members for these workshops, apart from affected sectors, like for instance, local fishermen. A useful practice for stakeholder engagement to make workshops valuable is the Game structuring methods (Slinger, et al., 2018), with a purpose of not reaching to a consensus but exploring the different groups' interests, values and desirable future circumstances.

During the rest of the port development, a stakeholder inclusive approach shall also be followed, in order to obtain a solution integrated into its social and ecological conditions and creating value for communities, other stakeholders and the environment. Some groups may be relevant for a particular development phase, while some others can allow a cooperative creation from the first phase up to the end of the lifecycle of the port.

3.2.4. Adaptive planning

Adopting a long-term mentality is one of the most important bases for following the Green Port approach, which forms part of its definition (section 2.4). In the first place, it is sought not to disturb future generations' needs, by reserving enough natural resources. But it is also one of the drivers for their development.

Developing a Green Port instead of a traditional port, is the way of anticipating to the future regarding sustainability matters. Many ports around the world relate their activities to fossil fuels and carry out a significant amount of unsustainable actions. Current environmental regulations are not strict enough towards them, but it is possible that there is a shift of mind in the future towards an energy transition, which makes ports close down or transform completely because of old economy activities or industries located in the port, due to new policies or due to the lack of fossil fuels in the earth. The cost of demolishing and constructing again overcomes the cost of green measures in the planning and design phase.

A Green Port shall consider future uncertainties, also in view of the possible fourth industrial revolution, in order to remain functional over the years, which can be placed in project, corporate, market or political context (Taneja, P, H. Ligteringen, M. van Schuylenburg, 2010). This can be done through an adaptive planning, that allows making changes with a minimal investment if there is a change from the initial conditions, enabling to lengthen the lifetime and to receive the payback on the extra investment of green measures.

The adaptive planning can materialize by adopting for flexible and adaptable solutions. Flexibility has been defined as "the ability of the plan to cope with variations and to allow adjustments to the layout of the plan" and adaptability as "the ability of the system to change in response to developments within the system boundary" (Taneja, P., H. Ligteringen, W.E. Walker, 2011), so

the concepts are very related and applicable to port developments to remain functional under new requirements of the future.

Flexible and adaptable ports are linked to sustainability (and therefore, Green Ports) in many aspects. Reuse of elements and materials contributes to flexibility, optimizing the use of natural resources, limiting waste and pollution, and conserving energy. Flexible and robust terminals may also change the demolishing of terminals to just the need of remodeling when changing demands. Flexible masterplans also allow for the reconfiguration of port spaces for new uses without costly modifications (Taneja, Vellinga, & Ros, 2014). The adaptive planning is, however, not only related to the planning or design phase, but also to the rest of the development phases.

3.2.5. Green growth strategy

Green Ports shall follow a green growth strategy to achieve sustainability goals, by promoting innovation, constantly looking for new opportunities for green technologies and seeking for resources efficiency. The concept was further detailed in section 2.1.

3.2.6. Building with Nature (BwN) and Working with Nature (WwN)

The concepts of WwN and BwN are essential for Green Port developments, focusing on respecting and creating value for society and the environment from the first development phases. The concept of WwN was explained in section 2.1.

Building with Nature is a philosophy defined by EcoShape, especially intended for hydraulic engineering projects, that consists on understanding and exploiting nature especially in the design and construction phases of infrastructures to give an added value to society, environment and economy (EcoShape, 2018).

The BwN approach is the transition from “Building in Nature” in traditional port developments, where nature was considered a threat and the unique solution was submission. On the other hand, the BwN approach is in harmony with the behavior of natural systems, utilizing natural processes, and includes the following concepts:

- Sustainability and adaptability as main elements due to the continuous changing conditions in society and the environment
- The natural system as a starting point to satisfy society’s needs while enhancing nature
- Incorporation of nature in infrastructure design to increment flexibility, adaptability, extra functionalities and new ecosystem services (further detailed below)

A BwN guideline is now available at www.buildingwithnatureguidelines.org, with a distinction between different environments (estuaries, sandy foreshores, cities, etc.) with practical examples and building solutions for every application. A distinction between the different project phases (initiation, planning and design, construction, and post-construction) is given, as the opportunities to apply the concept are different depending on what stage the project is in. It is, therefore, a concept that shall be considered in every phase, maximizing natural processes and stimulating nature development, making the project closely related to and embedded in nature instead of forming a breach in nature.

3.2.7. Circular Economy

To ensure a sustainable development, the achievement of the Circular Economy is one of the main goals. The concept relates to an efficient and sustainable use of resources, as many of them are scarce, obtaining benefits for the environment and society. Contrary to the "take, make and dispose" principle, the circular economy ensures a continuous flow of goods and services, enhancing renewable resources and controlling finite stocks.

The circular model is based on three principles (Ellen Macarthur Foundation, 2017):

- Design out waste and pollution
- Keep products and materials in use
- Regenerate natural systems

This shall be part of the focus of Green Port developments and, for that reason, a significant number of measures to achieve the Green Port goal included in the methodology contribute towards a Circular Economy. In port complexes, the Circular Economy especially refers to recognizing the value of waste and residual products. This residual waste could be reused for constructing port infrastructure, such as nature friendly banks, producing less waste and using less raw material (Sangster, 2015). It is also especially relevant because ports facilitate the reuse of energy in the chain by bringing the producing and recycling industries in contact, they accommodate relevant industries for waste management and they are logistical hubs for the handling of waste material (Port of Rotterdam, 2017).

3.3. OVERVIEW OF THE METHODOLOGY

The proposed methodology is divided into four phases, corresponding to the four stages of port development as mentioned before: planning, design, construction and operation together with management. Focus is put on planning, as the case study will be used to refine this development phase. For each stage, different subjects where green opportunities can be adopted are defined. These are the following:

1. Planning:
    a. Port's mission
    b. Site selection
    c. Masterplanning
2. Design
    a. Infrastructure
    b. Materials
    c. Energy
3. Construction
    a. Maritime works
    b. Earthworks
4. Operation and management
    a. Port
    b. Terminals
    c. Vessels
    d. Environmental management system

For each of these subjects, several green goals can be identified, which are based on the top green philosophies described in the latest section. The achievement of these goals depends on different criteria, which can be evaluated by means of a scoring system (Appendix B). An overview of the methodology can be found in Table 4.

Table 4 Overview of methodology to develop a Green Port

PHASE	SUBJECT	GREEN GOAL	CRITERIA
PLANNING	PORT'S MISSION	Green Port purpose	Definition of objective and subobjectives
		Green strategy	Definition of strategy and action plans
		Green standards and behavior	Definition of policy
		Green values	Definition of driver values
	SITE SELECTION	Biodiversity conservation	Impact on protected areas
			Impact on protected species
			Impact on natural habitats
		Minimum negative environmental impact	Use of existing port facilities
			Use of existing hinterland connection
			Use of natural conditions
			Impact on coastal processes
			Impact on water system quality
		Minimum negative social impact	Buffer area to local communities
			Impact on existing recreational areas
			Necessity of resettlement of communities
			Impact on archaeological cultural values
			Employment opportunities to local communities
			Impact on fisheries and aquaculture
			Impact on existing economic activities
	MASTERPLANNING	Efficient port layout	Productivity
			Flexible layout and adaptive planning
			Use of land given type of soil, volumes, and quality
			Compensation measures

			Distribution of port terminals considering communities
			Use of common infrastructure & facilities
			Use of waterfront and water depths
			Use of environmentally friendly transport solutions
		Integration into the surroundings	Integration of the port into the urban or natural environment
			Connectivity
		Added value	Conservation areas
			Recreational areas
			Inclusion of social and economic aspects
DESIGN	INFRASTRUCTURE	Minimum negative environmental impact	Use of Onshore Power Supply technology
			Electrification of terminals
			Measures for mitigation of environmental accidents risks
			Impacts on communities
			Impacts on coastal processes
			Use of carbon capture technology
		Future proof	Flexible and adaptable design
		Added value	Inclusion of ecological and nature enhancement measures
	MATERIALS	Efficient use of material	Use of resources
			Reuse of material
		Materials selection based on sustainability	Source of materials
			Nature of materials
			Performance characteristics of materials
		Efficient waste management	Waste management plan
			Handling of hazardous waste
	ENERGY	Energy efficiency	Energy consumption
			Use of renewable energies
CONSTRUCTION	MARITIME WORKS	Environmentally friendly construction methods	Processing of contaminated material
			Impacts assessment
			Increase of turbidity

			Occurrence of spills
			Use of overflow
			Impact on groundwater quality
			Disposal of material
		Equipment selection based on sustainability	Environmental performance of equipment
	EARTHWORKS	Environmentally friendly construction methods	Construction plan
			Impacts on communities
		Equipment selection based on sustainability	Environmental performance of equipment
OPERATION, MAINTENANCE, AND MANAGEMENT	PORT (GENERAL)	Pro-active port Authority role	Acceptance of terminal operators or companies
			Acceptance of cargo
			Cooperation between companies
		Sustainable hinterland transport	Use of electric trucks
			Implementation of an environmental zoning
		Energy and resources efficiency	Lighting system
			Reuse of resources
			Operational efficiency
	TERMINALS	Hazardous material management	Spills prevention
			Emergency response plan
		Sustainable yard equipment	Environmental performance of equipment
		Efficient waste management	Amount of waste
			Waste processing and disposal
	VESSELS	Emissions reduction	Acceptance of vessels
			Port dues and rewards
			Measures for emissions reductions
		Ballast water management	Ballast Water and Sediments Management Plan
	ENVIRONMENTAL MANAGEMENT SYSTEM	Continuous cooperation with stakeholders	Inclusion of stakeholders to set goals and contribute with ongoing efforts
		Sustainability reporting	Development of sustainability reports as a strategy for improvement

		Control systems and monitoring	Setting of a monitoring program to verify compliance with green objectives and targets
		Continuous improvement	Searching for improvement and optimization of operations, maximizing productivity and eliminating sources of inefficiency
		Stimulation of green technologies and innovation	Looking for opportunities for implementation of green technologies or innovative solutions

The outline of the following subsections will be based on the table. Each phase of the Green Port methodology will be described, dividing it into the different subjects, green goals, and criteria, giving measures on how to perform towards sustainability.

It has to be noted that the proposed methodology is intended to be applicable to any new port development around the world. However, there are factors that are case specific. Some criteria that contribute to a specific goal may not be applicable to a specific port project, while other criteria may have to be included if it is very relevant for the case. Moreover, some criteria may be more important than others, and this shall be addressed somehow. The difference in the local stakeholders between projects contribute to the difficulty of developing a generic methodology, which at the same time is essential to achieve the Green Port goal, as a 'stakeholders' co-creation' is one of the top green philosophies. The way of giving freedom for each case is including in a weighting system for the criteria included in Appendix B and elaborated on in section 3.4.

3.4. EVALUATION FRAMEWORK

The proposed methodology for developing a Green Port, described in detailed from the following section, provides the best practices to obtain this goal. The refined comparison between a Green Port and a traditional port (Table 6) also gives the best practices against the most unsustainable practices compared to traditional port developments. However, in reality, the situation does not fall into one or the other category, complying with all the criteria. A port development is not 100% traditional or 100% green. In addition, the specific circumstances of each port development and technical or economic conditions can make it difficult to comply with all green opportunities in the methodology. The non-compliance with some aspects does not lead to a non-green port if other green aspects compensate or the vision of the developers is clearly green. Therefore, the question that arises is: how could we evaluate a Green Port?

An evaluation framework has been developed, based on the proposed methodology for developing a Green Port. For the port development under study, different criteria can be evaluated. For each criterion, there is a design or decision to make, and this can be done following or not the green goal. The degree to which this decision goes in line with the Green Port goal is evaluated by a system of signs (+ 0 -), and their meaning will be described for each criterion. The scoring shall be summed up at the end, which indicates how green or not the port

is (the higher positive grade, the greener, while if the grade is negative it means the opposite). The purpose of this type of scoring is that the fact of not taking a specific measure compensates if another sustainable measure is taken. That is the reason why it is a scoring system 'on measures' (the score is different if a measure is taken or not) rather than 'on impacts', which could be another possibility of doing it, and because all impacts may not be quantified from the first development phase. The scoring system has been defined with the purpose of being applicable to ports with different characteristics (in location, size, etc.). Most criteria are evaluated objectively, however, some of them count with quantitative figures (e.g. distances or percentages) which have been estimated considering how they would contribute towards the specific green goal for the criteria which is evaluated.

In specific cases, it is possible that some criteria are irrelevant or not applicable. Moreover, stakeholders play a role in defining which criteria are more important for that port development. Given this case dependency, a weighting system has also been developed in a qualitative way, giving guidelines to select the correct weight for that specific situation. This weight has to be multiplied to the score for each criterion.

Before its application to a specific port, it has to be clarified that before applying the evaluation framework to a new port development, the scope of the project has to be defined. In other words, the port requirements shall be defined in advance: total land area needed future developments, functional period, size of maritime infrastructure, required hinterland transport, etc. which comes from a market study that gives the volumes that the port will cater, and which are translated into spatial and functional requirements. The Green Port concept will be evaluated after this base, without considering, for instance, the overall cargo flows that the port will generate, which are harmful to the environment. This overall minimization of flows belongs to a higher level and is not included, focusing only on the port local system.

It shall also be noted that the stakeholders' support or opinion shall be sought and listened in all phases of development, even if it is not included as a separate criterion for each of them. Their involvement is included as a criterion in the crucial moments of the development, which is done by means of workshops, interviews, etc. from which decisions will be made according to their views.

The evaluation framework follows the same structure as the Green Port methodology, therefore, the scoring system is given to each criterion defined in the methodology. It is included in Appendix B, together with the criteria weighting system.

3.5. PLANNING

The planning stage of a port is crucial for a successful and sustainable development. If the correct choices are made in this phase, a huge amount of environmental impacts can be avoided together with its corresponding damage mitigation in future phases. In order to follow a green approach, sustainable actions shall be taken regarding the port's mission, the site selection, and the masterplanning. These will be elaborated on below.

3.5.1. Port's mission

The port authority has a clear responsibility in all development phases and its organization shall be adequate for this purpose. The first step for a port development is to understand "where you

are", "where do you want to get", and "how to get there". These questions are answered when defining the port mission, and in order to achieve a Green Port, a green philosophy shall be part of it.

For the definition of the port's mission, and prior to the conception of the project, stakeholders shall be involved, in order to understand their needs. A stakeholder mapping can be created for this purpose, including them, their profile, concerns about the project, expectations from the project, their influence on the project, and a rate of this influence. The understanding of the whole system is important, to include all stakeholders that can contribute to the Green goal. Examples are local, regional or national authorities, tourism groups, nature interest groups, operators, etc. Based on this information the port mission can be defined, considering from the start how the benefits of all stakeholders and communities can be maximized.

The Ashridge Mission model (Parts, 2012) is used by companies to define its mission and could be also used to better define the port's mission and objectives, facilitating the project course from the beginning. The model includes four mission statement dimensions (Figure 5), that are further detailed in the following subsections.

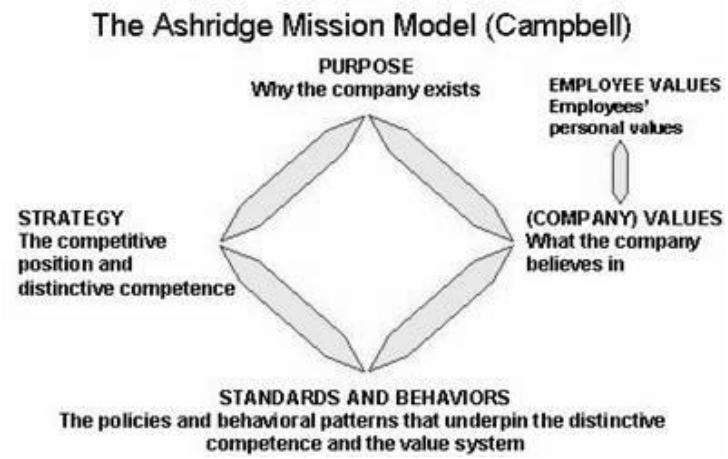

Figure 5 The Ashridge Mission model (source: 12manage.com)

a. Green Port purpose

In order to achieve a Green Port, the Port Authority must define it as a purpose and support its development, or the goal will never be reached. Therefore, reasons for following a sustainable approach need to be identified rather than barely complying with current regulations, which is possible when adopting a long-term mentality. The port owners shall search for their own benefit but also for the benefit of society and the environment. This shall be done at the beginning of the process in order not to lose opportunities, when roles and responsibilities shall also be defined, and it shall be maintained along the complete development process by means of sustainability reporting, to better identify sustainable goals (PIANC WG174, 2017).

The objective of a Green Port is, therefore, to develop a sustainable port (benefiting economy, society and environment). For this purpose, several subobjectives have to be defined, based on the identified stakeholder's needs, which are:

- Developing a future-proof port (adaptable and robust)
- Minimizing negative impacts

- Maximizing benefits and creating added value to society and the environment

b. *Green strategy*

To achieve the purpose defined by the port authority, a strategy is needed, which defines how to achieve those objectives with the current resources. The following actions shall be carried out to define a green strategy:

- Define the (sustainable) principles around which the port authority's performance shall be based on, corresponding to the top green philosophies described in section 3.2.
- Identify resources and competence of the Port Authority
- Define action plans towards the port's purpose

c. *Green standards and behaviors*

The port authority shall define guidelines or a policy to follow to translate the purpose and strategy into actions, together with stakeholders, including port users. To develop a Green Port, a set of sustainable standards shall be used, however, they shall extend beyond actual environmental regulations, which only focus on minimizing some impacts instead of avoiding them from earlier phases. For instance, the sustainable actions to follow can be based on achieving the 17 Sustainable Development Goals set-up by the United Nations (United Nations, 2015), applying the concepts to port development. The means to reach these 17 goals (Figure 6) and the Green Port goal shall be included in the port's green policy. The actions to be carried out are, therefore:

- Define a set of sustainable standards or goals bases on stakeholders' needs
- Set targets based on these goals
- Include a port policy including them

Figure 6 Sustainable Development Goals (United Nations, 2015)

d. *Green values*

These are the beliefs and moral principles of the organization that give a meaning to the standards and behaviors that are followed. The values lie behind the organization's philosophy, which are the drivers and motivators of it and are also based on the port users and stakeholders' values. The values that drive the Green Port approach to extend further than the ones for the traditional port approach, as not only economy is considered, but also social and environmental aspects. The values may include responsibility, respect, empathy, effort or solidarity all of them towards the environment, communities, and future generations. The values of the industries

and companies located and operating in the port shall also be in accordance with the values of the Port Authority. The actions to carry out are:

- Identify values based on the Green Port goal
- Set the values as a driver for decisions making

3.5.2. Selection of the site

For greenfield port developments, a common practice of the traditional approach is selecting the project site as per land ownership from the Port Authority or private landowners. Moreover, the selection is primarily not based on minimizing negative environmental or social impacts, and even less adding value. This results in suboptimal solutions from the start of the port development that cannot be easily solved. This happens when having a short-term plan of the port, and therefore, not green. On the contrary, Green Port developments start from the selection of the site along sustainability principles and the top green philosophies. The green goals and criteria to consider towards them during the site selection process are elaborated on below.

It has to be noted that this phase focuses on comparing different site alternatives. Therefore, the criteria will serve to choose the best option in terms of sustainability. It is assumed that all the alternative sites are located in an efficient area, considering options at a maximum distance of 50km to cities. The reasons are first, that ports are predominantly constructed to serve cities, so they shall be located relatively close or the cities would have to move towards the port; and second, because of the considerably high environmental impacts of hinterland transport as the distance increases.

Difficulties

There might be some difficulties during the site selection process, due to the numerous constraints that appear. During the port planning, it is possible that all below requisites for a Green Port do not comply. Nevertheless, non-compliance with any of the aspects do not necessarily lead to a non-Green Port, if other green opportunities are followed and there is a net benefit. The evaluation framework in Appendix B is created for that purpose.

Moreover, another difficulty arises when combining sustainable measures with economic and technical feasibility and public acceptance. This issue could lead to leaving sustainable actions behind and giving more importance to the other factors. However, to achieve the Green Port goal, the importance of all of them shall be balanced, by for example using a Multi-Criteria Decision Analysis and giving a higher weight to green aspects.

Stakeholders

From the site selection phase, communities and stakeholders needs shall be heard. In order to maximize their benefit. It is also a means to better understand the area and its specific characteristics, added value, heritage issues, cultural significance and what do communities give special importance to. Every region counts its unique conditions that have to be identified and analyzed to consider them in the port planning, and it could only be possible with the co-design together with stakeholders and communities in the region, for instance, via meetings, workshops, questionnaires and public hearings; as well as with information about the distribution of the population in the area, cultural heritage, etc.

Based on this information, decisions can be made regarding the most convenient port location. Groups such as municipalities, cargo producers, nature interest groups, tourism groups, local scientists, and other authorities shall be included. For each green goal and criteria of the proposed methodology, the relevant stakeholders shall be included, which may lead to the considering that criteria as a priority or consider it relevant. This makes the methodology case specific, which is materialized via the weighting system in Appendix B, which gives importance to the criteria that stakeholders also find important.

a. Biodiversity conservation

Green Ports developments search for minimum negative impact (or zero impact if compensated with other measures) to the environment during all phases, which includes biodiversity. Therefore, it is reasonable that this is taken into account from the planning stage, when the project site is not yet chosen, so that these impacts can be avoided from the beginning, following a Working with Nature approach. Biodiversity and natural habitats conservation shall be one of the most important criteria for this selection, vital for long-term sustainable development, which is the basis for Green Port developments. The criteria which determine the optimal site selection are the following.

- Impact on protected areas and species:

The first step towards a Green Port approach is locating the site outside the boundaries of any of any of the Protected Area Management Categories (Table 20 in Appendix 0) developed by the International Union for Conservation of Nature (IUCN) (Dudley, N., 2008) through its World Commission on Protected Areas (WCPA). The categories refer both inland and marine areas. Even if the legislation in the region permits the construction of a port in some of these categories, the best practice for a Green Port is that it shall not be located in them. This also applies to other related protected areas such as World Heritage Sites, Ramsar Sites and Natura 2000 Sites or other categories of nature areas applicable to specific countries instead of globally[1]. Nevertheless, this can involve excessive restrictions for new port developments. For that reason, in cases where there is an impossibility of selecting an alternative site outside the boundaries of these areas, the location inside them will only be allowed when the integrity of the natural system is not at stake. For that purpose, the ecological conditions of the area need to be analyzed and understood, to act in a responsible way[2]. Territories with special needs for conservation because of the degree of threat of the animal species shall also be included in the analysis.

- Impact on natural habitats:

For any site, but especially in the cases where the site cannot be located outside protected areas, given the community needs, the lack of available space, the hinterland connection, etc., conservation of nature and biodiversity and rehabilitation of degraded natural habitats is essential, and the port shall be developed with the extra involvement of nature protection stakeholders. The site shall be selected avoiding sensitive environments which could be negatively impacted. Convenient tools for the identification of important natural habitat sites can be found in Appendix 2.

[1] E.g. the Areas of Outstanding Natural Beauty (AONBs) exclusive for the United Kingdom

[2] Ramsar manuals and handbooks can be used for this purpose (e.g. *Handbook 1 Wise use of wetlands* (2010))

In general, a Green Port shall consider and follow action plans towards protection, maintenance, and rehabilitation of natural habitats. Desk studies of the ecological characteristics of the project area shall be carried out from the beginning to understand what the impacts to the local aquatic or terrestrial biodiversity are in order to mitigate them and create added value, by adding a nature development scope to the project. Because of the loss of biodiversity that a new port will produce, reforestation activities and rehabilitation of degraded natural habits are important practices to obtain a net benefit to biodiversity. Preservation and restoration of the ecological continuity of the land are essential, which could be done by developing ecological corridors (PIANC, 2014a).

b. Minimum negative environmental impact

Protection and enhancement of environmental values is an essential factor to achieve a Green Port and shall be considered from the site selection, basing the election in a sustainable strategic policy that supports long-term decisions, as explained previously. Negative environmental impacts shall be avoided in the site selection process by selecting a site considering the criteria discussed below in detail. For this purpose, local knowledge is essential, which can be obtained from stakeholders' workshops. This knowledge, together with tools, may predict the behavior of the local environment after the port construction and shall be considered in the site selection process.

It has to be noted that to minimize future negative environmental impacts, the site selection shall be based on a long-term mentality, choosing a sufficient area both for future development phases which take uncertainties into account. Otherwise, if circumstances change, the port may need a larger area and if not available, it would require the development of a completely new port to satisfy the demand, something to be avoided because it requires a high investment and high environmental impacts.

- Use of existing port facilities:

First of all, before a greenfield port is developed, a consideration shall be made regarding the use of existing nearby port infrastructure instead of selecting a new site for a new port development. This also includes the transformation of an industrial area into a port. The construction of a whole port complex usually involves a higher environmental impact, than an expansion or adaptation of an existing one, unless the area is in a very vulnerable environment. Therefore, unless there are constraints for use other established ports (lack of capacity or space, adverse impacts to close communities or environment because of its current location or future expansion activities, etc.) the new port activities shall benefit from existing ports and be realized in them. A justification of developing a new port or expanding an existing one shall be the first step when selecting the site, and stakeholders shall be closely involved in this decision.

- Use of existing hinterland connection:

If the use or expansion of an existing port is not an option, given the local conditions, the second step is to consider the use of an existing hinterland connection. This will also reduce considerably the impacts associated with materials, local biodiversity or construction. If one of the alternative site counts with an already existing hinterland infrastructure it shall be selected.

- Use of natural conditions:

The selection of the optimal site shall consider the use of natural conditions to reduce impacts. This includes considering areas with larger water depths to minimize dredging or locating the

port in areas protected (e.g. by a bay) or sheltered water areas to avoid impacts related to breakwater (during construction, to marine biodiversity, to coastal processes, etc.).

Another aspect which is closely related to the consideration of natural circumstances is the avoidance of locations that may lead to higher negative impacts in construction and operations. This may lead to choosing upon a different typology of port, like the consideration of a deep-sea port against a shallow-sea port or direct loading versus barging operations. The dredging volumes may be lower in deeper seawater; however, this location may produce a higher negative impact related to other aspects, like marine biodiversity. For that reason, an in-depth study shall be carried out to determine the advantages and disadvantages of all options and to consider environmental costs and opportunities.

Another desktop study to be made before the land obtention relates the optimization of material. This refers to the cut and fill volumes, that shall be balanced to obtain a sustainable solution, avoiding excessive volumes of one or the other practices because of choosing a suboptimal location. Selection of a site where the excavation of high terrains consisting of hills or mountains is needed shall be avoided, both because the landscape would be considerably affected, and because they form a natural barrier against noise, light or odor that would be beneficial for the operational phase if they are kept close to the port site instead of flattened in order to be part of the port areas.

- Impact on coastal processes:

The impacts related to coastal processes shall also be taken into account when selecting a site, making use of all the scientific data available or considering the use of hydrodynamic models to assess the impacts in morphology, seabed, etc., because of locating a port in that area. Changes in current patterns and littoral drifts are probable, but efforts must be made so that the impacts are not negative, for instance, for shipping. Locations which may induce high sedimentation in the harbor, leading to high maintenance dredging efforts, shall also be avoided, as they would have a direct impact on the system, disturbing the soil and biodiversity continuously. If these impacts are considered to be adverse, the corresponding port site shall not be selected. This green aspect in site selection completely contrasts with traditional port planning, as no preliminary studies are carried out to make the site selection decision for sustainability reasons; if they are made, they focus on functionality purposes instead of green objectives.

- Impact on water system quality:

A location which may affect the quality of the overall water system shall be discarded, which especially refers to river ports, when much dredging is required.

c. Minimum negative social impact

For a Green Port, the selection of the site shall not only be based on the environment, but also on society, as per the definition of sustainability (Triple Bottom Line). This can be achieved by considering several criteria, explained below.

- Buffer area to local communities:

A Green Port shall not be situated in a location significantly close residential areas or communities, especially if the future port involves operations with a high noise, vibration, dust, and odor impact, as it will directly affect the nearby community in a negative way. Therefore, when considering the different site alternatives, an analysis shall be made to forecast the levels

that the community would perceive if these alternatives are relatively close to residential areas and discard any options if they are considered to be high. A buffer area shall be available, to limit the maximum levels in certain locations. If the level is higher, a mitigation measure shall be developed from the first stages of the project, to ensure that it will be carried and avoiding restraints in further development phases. The buffer area is also intended not to block the residential or industrial developments.

Another significant aspect to consider in the port location is the visual and air quality, affected by the port facility, operations, lighting, etc. A natural landscape may be converted into an industrial scenario, leading to the dissatisfaction of nearby residential areas. Visual barriers shall be adopted to avoid this effect, like for instance, a green belt zone.

- Impact on existing recreational areas:

Existing recreational areas for nearby communities shall not be eliminated in order to construct the new port. This includes parks, beaches, natural lookouts, etc. Otherwise, a new recreational area with the same nature shall be developed as a compensation measure. The reason is that the communities benefit indirectly from the port activities but directly from these areas and they shall not be taken away from them, also to gain public acceptance for the port project.

- Necessity of resettlement of communities:

In many cases, a port construction involves the relocation of local communities, that may cause ethnic, tribal, cultural or religious conflicts, both because of the relocation and the new activities that will be carried out in the area. A Green Port shall search for non-resettlement of communities, especially in the case of traditional communities whose life can be disturbed significantly when doing it. In when it cannot be avoided, a suitable resettlement plan shall be prepared to minimize commotion to local people and a smooth transition towards the industrialization and modernization shall be ensured. It shall be allowed only when an improvement in their quality of life is given, and never if it is not the case.

- Impact on archaeological cultural values:

Sites with significant archaeological cultural value, even if the region is not protected, shall be avoided.

- Employment opportunities to local communities:

A consideration when selecting the site to enhance communities' benefits is to select a site location at maximum 20 km from regions where skilled labor can be found. Employment opportunities shall be given to local communities with the development of a Green Port, and if these are available at a large distance it will cause a disruption to them instead of add value, being possible that the city relocates close to the port.

- Impact on fisheries and aquaculture:

Sites in an important area for fisheries and aquaculture shall be avoided. The loss of a significant amount of fishing grounds, stock or aquaculture areas is not acceptable in a Green Port, which shall seek for no impact to fisheries. It is possible that there is a temporary and reversible loss of fishing grounds during construction, which is more acceptable than a permanent loss, but it shall be compensated to fishermen and avoided in any case.

- Impact on existing economic activities:

On the land side, a Green Port shall not affect existing economic activities like agriculture or farming, becoming even more important if the livelihood of the affected people only depends on these activities. If part of the onshore part of the port has to be located on them, because it is the only alternative, the affected people shall be compensated.

3.5.3. Masterplanning

Once the location of the port has been set, an efficient masterplanning seeking towards environment conservation and minimum community impacts is one of the most important aspects of a Green Port development. The limited availability of land and water areas is one of the main issues and drivers to do it in the most efficient way. Apart from economic and functional aspects also considered in traditional port developments, social and environmental aspects shall also be taken into account.

Traditional port masterplanning includes a trade and traffic forecast, a translation of forecasted volumes into port and infrastructure requirements, and the definition and technical detail of the layout and future development phases given boundary conditions (cargo and nautical standards, physical conditions, existing port and hinterland connections, legal framework, etc.). Green port masterplanning shall also consider matters like the integration of the port into natural or urban areas and environmental protection and management. This is possible when the environmental features are identified in early stages.

Stakeholders

Stakeholders and communities shall participate in this process, in order to obtain a design that fulfills the needs of the port and these groups (Zheng, 2015). The different design alternatives shall be elaborated on based on key values derived from a stakeholder analysis. They could include cultural heritage, biodiversity, coastal and marine ecology, pollution, etc. This process is essential for developing a Green Port and shall be planned and carried out carefully to discard not relevant information and focus only on what is actually important for the communities and stakeholders, providing them with an added value. Terminal operators, cargo producers, logistics/supply chain managers, municipalities, nature interest groups, and industries are some relevant stakeholders for this phase.

a. Efficient port layout for minimum impact

There are several means through which the layout can be designed efficiently, minimizing negative environmental impacts while at the same time creating added value. The criteria to consider for this purpose are elaborated on below.

- Productivity:

The distribution of the port areas and uses shall be done in the most efficient way, maximizing productivity to minimize the required total area of the port, and therefore, minimize the negative impact on the local environment. This is especially relevant if the site is located in an important area for biodiversity, if after the site selection process, it was concluded that this was the only alternative. When the port is partially located in these special areas, the masterplanning has to be done in a more responsible way, and the port activities to be carried out in these areas shall be the ones with less impact. The maximization of productivity also refers to the transport

flows inside the port and to the hinterland, which shall be minimized. The sharing of infrastructure facilities between terminals could be an option for this purpose.

- Distribution of port terminals considering communities:

The port configuration shall also be based on nearby communities, for which the different stakeholders shall be involved. Noise, dust, and odor impacts shall be minimized, and the location of the different terminals is essential for this purpose. Wind studies shall be carried out if the specific terminals of the port can be harmful in this sense, to locate the origin of the impacts in a suitable place. If the impacts are still noticeable, other mitigation measures shall be considered, like buffer areas around the port, which also contributes towards visual quality. This latest aspect is also to be considered when designing the port layout through landscaping measures, considering the option of locating the most visible parts of the port out of the view from residential or recreational areas. 3D visualizations are a convenient method to analyze these impacts. A buffer area shall also be given between communities and terminals with potentially dangerous activities (e.g. handling or storing hazardous material), which serves as a safety distance to minimize risks of reaching communities, for instance, in the case of a spill.

- Use of land given type of soil, volumes, and quality:

The distribution of the port areas and uses have to be done considering the type of land and its quality. In order to obtain an optimized solution, geology desk studies shall be carried out from the beginning. If the site counts with a combination of non-adequate soil and soil with good quality, it is recommendable that the terminal areas are located on the adequate soil, because an improvement of the soil can be avoided, leading to less alteration of the environment, both regarding nature and landscape and emissions during construction. The less adequate soil can be dredged and use the excess of material for instance, as visual barriers. It can also be the case that it is beneficial (or inevitable) to locate the terminal on top of soil with less quality and use the better-quality soil as a top layer that also serves for compaction. An analysis regarding these volumes shall be made to obtain the best solution in terms of environment.

- Flexible layout and adaptive planning:

The layout shall be based on a long-term mentality, being one of the principles of Green Port developments. Therefore, this shall be included by means of an adaptive planning, opting for a flexible layout that accounts for future uncertainties and developments, making it robust (Taneja P. , 2013). Standard or modular terminals shall be used when possible, minimizing the risk of future impacts to the environment if there are changes in throughput that require the demolition and construction of a completely new terminal. With modular terminals, if the type of cargo a terminal handles changes, the investment will be minimum, focusing especially on the onshore equipment. A phased development shall also be planned, reserving spaces for future terminals and avoiding restricting the expansion of the port, to minimize construction works for expansion plans.

- Compensation measures:

Compensation measures to port development impacts are essential and shall be considered during the masterplanning to obtain a zero-sum impact or net benefit, being the latter the best practice. This could be achieved by developing compensation sites to create new habitats in and/or around the port (see example in Appendix A). Port planers shall decide upon them in a smart way, using resources and materials efficiently, considering the reuse of dredged or

excavated soil, also to reduce sailing or trucking times to the disposal area and therefore, following the concept of the circular economy. The size of this compensation areas shall be comparable to the size of the impact of the port: biodiversity loss, impact to protected areas, etc.

- Use of common infrastructures and facilities:

Another aspect to consider in the masterplanning is the use of common infrastructure and facilities between terminals. Material will be saved, and impacts will be reduced during construction and probably because of a lower total port area required.

- Use of waterfront and water depths:

A considerable amount of impacts can also be avoided if an efficient use of the waterfront and water depths is made. Terminals which require larger vessel draughts, and therefore, larger water depths, shall not be located at the end of the harbor basin, because in that case, the whole basin would have to be dredged at that larger depth, when it is possible that not all terminals require so much dredging. Opposite to this, these terminals shall be located near the entrance of the port, so that from then, the basin can be dredged up to a lower depth for other terminals. The same principle applies to the use of the waterfront. Only facilities which need direct water access shall be located close to the harbor basin, with quay wall. The savings in environmental impacts of quay wall length are very high and shall be minimized in Green Port developments.

- Use of environmentally friendly transport solutions:

A crucial aspect for a Green Port is that the onshore transport infrastructure is based on environmentally friendly solutions, by means a modal shift or electric trucks. The purpose of a modal shift is to reduce emissions from trucks when handling the cargo to and from the hinterland, being the most common type of transport in traditional port developments and also the most harmful to the environment. Nevertheless, this can only be achieved when a new transport infrastructure is developed or trucks with no emissions are used.

In the masterplanning phase, to shift modality, the potential for expansion of rail tracks, berths and transshipment shall be analyzed. Developing a pipeline system up to the cargo destination is an interesting option when the port handles liquid or gaseous cargoes, for which the best practice would be to make use of electric pumps from renewable energy.

The other option, which is not considered as modal shift, is to develop a road infrastructure for trucks with an overhead line (Wuppertal Institut, 2018) such as the ones used for trains. This would contribute to a more efficient and less harmful way of transport, resembling trucks to the more efficient railway transport, especially if the power is obtained from renewable sources instead of fossil fuels. Zero emissions and lower levels of noise and the reduction of energy required comparing the electric and diesel drive are the main benefits.

If these green opportunities cannot be implemented due to physical conditions, the last option is to develop a road infrastructure. However, in order to compensate for the use of this non-efficient mode of transport, alternative environmentally friendly fuels or electric vehicles shall be sought. This will be detailed in section 3.8.1 for the operation phase green measures.

b. Integration into the surroundings

In general, the design of the layout shall be based on understanding the local environmental conditions and having a clear overview of the whole system, in order to make decisions that

preserve instead of damage it (following Working with Nature philosophy). The system cannot be restricted or disrupted due to the port development, and only at this system level, the port can achieve its objectives. To obtain a solution which is integrated into its surroundings, some criteria shall be considered during the design.

- Integration of the port into the urban or natural environment:

Landscaping contributes to the integration of the port, but it is not the unique measure. The layout must fit into the landscape, and special attention shall be given to the skyline and how the port would be perceived from different points. The interface shall be integrated gradually and in a "friendly" manner to the local environment, taking special measures for that purpose. This integration also refers to ensuring connectivity, both between natural spaces (for biodiversity flows) and between urban areas. An example of non-integration in the surroundings is the Port of Ferrol (Spain) and it can be found in Appendix G.

The minimization of the change in the surroundings condition shall also be sought. For instance, disruptive effects for the marine environment or coastal processes shall be minimized, regarding the entrance shape and location in dig-in ports or regarding the overall shape of the port if the port area is reclaimed to the sea. Scale models and simulations are methods to be used in the masterplanning phase to arrive at the optimal solution.

- Connectivity:

Ensuring the actual connectivity of the whole system is also a way to integrate the port into the natural and urban environment. The existing flow and connectivity between species and communities (transport flows) must be guaranteed, avoiding creating a breach or fragmentation between them and therefore, allowing the movement. As mentioned above, ecological corridors are a measure for this purpose. In the case of communities, measures to prevent congestion due to the port transport shall be taken, developing the adequate transport infrastructure.

c. Added value towards society and the environment

In addition to an efficient port configuration that minimizes impacts, a Green Port shall also create added value to society and the environment. Two types of areas, apart from those directly related to port's operations and activities, shall exist. These will be elaborated on below.

- Conservation areas:

The first type of areas is designated for the environment: conservation areas. These areas are protected from development spaces for the port. Conservation areas count with significant environmental values, like for instance, wetlands, mangroves, mudflats, and other coastal habitats, and have the purpose of habitat conservation, enhancement or restoration. If the area does not count with these type of habitats, but there are areas with opportunities for enhancement of environmental values through vegetation, planting with native species shall be carried out. Moreover, compensation areas are included in this group, having the purpose of restoring biodiversity due to the loss of it from the new port.

- Recreational areas:

The second land type is designated for social (communities) use: recreational areas. Their purpose is enhancing and conserving the aesthetic appeal of spaces inside the port: cultural values, biodiversity, etc. in order to attract communities. This is an important factor because of

the fact that a port removes some values for people when being constructed and shall be compensated. These areas include green spaces, viewing areas, pedestrian paths, bikeways, etc. Recreational areas can also be developed using natural processes, which goes in line with BwN concept. For instance, a beach can be created by using a natural sediment trap, rather than through dredging and nourishment, which involves more impacts.

- Inclusion of social and economic aspects

The creation of added value goes beyond communities (recreational areas, employment, connectivity, integration of the port into the urban environment, etc.), extending to other stakeholders such as terminal operators, industries or municipalities. During the stakeholders' co-creation process, not only their issues shall be addressed but also their benefit shall be maximized (which also improves financing, as it is explained afterwards in section 5). Therefore, ways to create added value to these groups shall be defined in the masterplanning phase, to later implement them in future phases.

3.6. DESIGN

After the planning, the next phase in a port development is the design phase. This phase is carried out by engineering, consultancy or construction firms. Nevertheless, the role of the Port Authority or private investor is essential because this design will be based on the port's mission (purpose, strategy, policy and values), defined by the organization. If the port's mission includes a green development, the design will also be developed along these lines.

As the planning stage, the design phase is crucial to implement green measures, assuming that there are lower constraints compared with the operation phase, when the port is already constructed. Most of the environmental impacts during construction and operation can be avoided if a design that considers sustainable aspects is carried out and at the same time, it gives the opportunity of maximizing positive effects and create added value.

Stakeholders

The decisions during the design phase shall be taken, therefore, not only to avoid, minimize or mitigate impacts but also create an added value towards the environment and society. For example, creating or conservation of coral (environment), may lead to increase of tourism, recreation, and employment (socio-economic welfare) (PIANC, 2014a). The obtention of energy from renewable sources inside the port boundaries also create an added value to the region. The inclusion of stakeholders is essential for this purpose, in order not only to address the issues raised by them, but also to provide them with the maximum benefits. Apart from communities, some relevant stakeholders in the design phase include terminal operators, safety organizations, local industries, nature interest and tourism groups, etc. Based on them, a stakeholder-inclusive design can be developed, contributing towards the Green Port goal. The added value given to the stakeholders is implicitly included in the green decisions that can be taken, which are elaborated on below. They are divided into three groups: infrastructure, materials, and energy.

3.6.1. Infrastructure

The design of the complete port's infrastructure shall be in accordance with the green principles. This means that the design shall seek for the minimization of the negative impact to the

environment and maximization of the social, economic, and environmental value. The green opportunities for these two purposes are elaborated on below.

a. Minimum negative environmental impact

- Use of Onshore Power Supply technology:

Shipping transport is the main source of emissions for activities related to ports. The scope of port authorities towards a shift to vessels with less emissions extends up to the port boundaries, but it may contribute in the long-term to the construction of cleaner vessels. For the design phase, the measure to be consider is Onshore Power Supply. While being berthed, the use of onboard-generated power is not a requirement because the vessel does not have to sail, and therefore, can be avoided. With this system, as an alternative to onboard power, vessels can be hooked up and connected to the main grid. The benefits include reduced emissions, noise and vibrations, lower wear of the auxiliary engines and therefore lower maintenance costs and better image of the shipping company and possible reduction in port dues. Therefore, it is a benefit towards the port and the vessels. However, this requires the necessary infrastructure and facilities in the terminal, quay wall, and vessel (cabling, frequency converters, transformers, etc.) which involves high costs.

- Measures for mitigation of environmental accident risks:

The risk of environmental accidents shall be mitigated by developing safety measures in design. This refers especially to terminals with potentially hazardous materials (flammable products, toxic substances, radioactive materials, etc.) or which are vulnerable to spills (e.g. oil or LNG terminals), bunkering procedures, ballast waters or possible chemical contaminants. Safe and careful use shall be ensured during operation, but this has to be guaranteed through the design. Adequate storage and handling facilities shall be designed, taking extra measures for risks with major frequency or consequences. For instance, the distance between the water bodies and the storage facilities shall be maximized, or an area with a point for spill collection shall be designed in the terminal or jetty to retain a spill with the volume of the storage facilities and to prevent it from flowing into the water.

- Impacts on communities:

During the design phase, decisions shall be made to eliminate communities' impacts in operational phases. These measures relate specifically to preventing the environmental impacts of the port activities from reaching nearby communities. When there are nearby communities located at a distance from which the port is visible, noise and visual barriers shall be developed. This could be done through landscaping with local vegetation or reusing excess material from excavation or dredging. These impacts could be assessed by a 3D model visualization. In addition, if the type of cargo and terminals being operated in the port emit high levels of vibrations, dust or odor, measures to eradicate these levels in residential areas must be carried out. If port roads are located close to residential areas, silent asphalts shall be considered.

- Impact on coastal processes:

Regarding the marine side, an important consideration in the design is the minimization of change in coastal processes and hydrology because of new port infrastructure such as sea walls, jetties, breakwaters or due to the shape of a reclamation area. It also applies to the dredging activities, so it has to be designed in an adequate way to produce a limited impact. The use of soft solutions instead of hard solutions for the port protection is also a sustainable alternative

that follows the principle of BwN and which helps maintain the natural conditions and processes (water and sediment flows) compared to the situation without the development. Soft solutions also involve challenges in complying with technical requirements as well as requiring higher maintenance or larger space. On the other hand, they might be constructed with local materials by local people, which in the end may be less expensive than hard solutions and beneficial for the business case. The advantages and disadvantages of these solutions shall be analyzed.

- Use of carbon capture technology

The use of Carbon Capture technology is an efficient method for reducing carbon dioxide emissions to the atmosphere. However, this measure acts on the destination of the CO2, and Green Ports measures shall reduce emissions by acting on the source. But in any case, it is an option that reduces the negative impact on the environment. The option of relocating or reusing the emitted CO2 has to be linked with measures to reduce emissions.

Two different Carbon Capture technology could be used. The first one is Carbon Capture and Storage technology. The process involves carbon capture, compression, transport, storage and monitoring, together with suitable storages. These storages are mainly underground and include gas and oil fields or deep saline formations, to where the carbon dioxide is transported by pipelines or by ship. This resembles the natural process of storing oil and CO2 over time.

The disadvantage is that a complete CO2 infrastructure has to be built-up for the use of this technology. Moreover, a safe infrastructure has to be guaranteed, to avoid the leakage from pipelines, failure of the system (with its consequence of a high amount of CO2 released in a short period of time), or seismic events due to the built up of pressure. In addition, there are uncertainties regarding the consequences of this storage for future generations.

The other option is the use of Carbon Capture and Utilization (CCU) technology. It has become an interesting alternative compared to CCS, because not only the climate change is mitigated by reducing the amount of CO2 in the atmosphere, but it also allows the reuse of waste CO2 emissions to convert them into valuable products, like for instance, chemicals and fuels. It could also be directly supplied to relevant industries that use it as raw material, like for instance, to greenhouse growers, to the food and drink industry or to the pharmaceutical industry. This option creates a greater profit, because the products can be sold, and especially if there are no incentives for the use of the technology.

The weakness of the process is that the current global demand for chemicals will only consume a small percentage of the global emissions. For instance, the annual production of methanol and urea only consumes 0,5% of the total global emissions per year (Cuéllar-Franca & Azapagic, 2015). Moreover, the reuse of CO2 for fuel production only delays the emissions rather than removing them completely from the atmosphere.

b. Added value

- Inclusion of ecological and nature enhancement measures:

To develop a Green Port, it is essential to understand the local ecology and at the same time analyzing which ecosystem services are provided if they are enhanced, to select the best alternative. After then, the design can be optimized, following the philosophy of Building with Nature. Ecology and nature can be enhanced by means of the materials selection, developing soft instead of hard solutions of roughness of surfaces. Specific measures that can be taken are

included in Appendix D. This enhancement does to necessarily involve higher costs or less effectiveness and can also give new ecosystem services and added value to communities.

c. Future proof

- Flexible and adaptable design:

One of the ways of making a port robust and future proof, which was defined as one of the objectives of the Green Port in the port mission, is by means of a flexible design, which can be modified without significant investment for a new requirement that appears with time. There are several concepts related to provide flexibility to infrastructure (Taneja P. , 2013) such as accessibility, capacity, compatibility, durability, maintainability, modularity, recyclability, resilience, standardization, usability, versatility, etc. Measures that contribute to these concepts are also contributing towards making a port future proof. In addition, using prefabricated or standardized elements can contribute both to make the port future proof and to the reuse of elements to other new constructions when the port reaches the end of its life time. It is probable that, after the operative period, the port counts with elements which are not and the end of their lifetime and can be reused. It is out of the scope of the port developers to what extend these elements are reused, but they shall give facilities to contribute to the circular economy.

3.6.2. Materials

A relevant opportunity to achieve green solutions relates to the use, the source and the type of materials. This refers both to the existing land resources and to extra material needed for construction. Materials require large amounts of energy and water for their extraction and transportation; therefore, the design of a Green Port shall be based on an efficient use of materials, which are environmentally-friendly, to minimize impacts. These green criteria are closely related to the circular economy, one of the key aspects for a sustainable development.

a. Use of materials

- Efficient use of resources:

Using materials and resources in an efficient way, reducing the amount of required volumes, leads to a reduction of the negative impact to the environment, so it shall be sought in every Green Port design. These materials relate to the existing materials in the port site and to extra material needs for the construction of the infrastructure. Therefore, both the local environment and other environments from which the materials are obtained from can be benefited, leading to a lower disturbance if the required volumes to be obtained are lower.

- Reuse of material:

Reuse of materials is a very important practice, which is in line with the Circular Economy principle. It mainly refers to the excess of excavated or dredged soil which could be reused in other port areas; for instance, to level terminal areas, as a means for compaction, as building materials, for shelter of waves, to create noise and visual barriers, for landscape purposes, recreational areas, for enhancing biodiversity, etc. Through this practice, waste, natural resource consumption and emissions are reduced. Cost savings would be probably achieved, but the challenge lies in the quality of the excess material, which may not satisfy engineering specifications.

The reuse of sand is usually more straightforward than the reuse of other materials like clay. Innovative solutions to do it with the available material shall be sought, even if at first sight there is no other possible application rather than disposing them as waste. The reuse of local material becomes even more relevant in certain countries or location where the hinterland transport is very expensive, due to the cost savings that could be achieved.

The reuse of materials does not only refer to the reuse inside the port boundaries. A mapping including obsolete ports or other type of constructions up to a certain distance could be elaborated, in order to obtain materials or elements from them that could be reused for the port.

b. Materials selection

- Nature of materials:

When selecting the required materials, environmentally-friendly, biodegradable or recycled materials shall be considered. Materials from non-renewable sources also damage valuable natural resources, and therefore, shall be avoided. For instance, the use of cement shall be limited as far as possible because of the damage to the environment by the high levels of carbon dioxide emissions during production, and also because of the impact to the local soil. The same applies to PVC plastic, being non-biodegradable material that emits high amounts of dioxin during production, which is harmful to society.

The type of materials shall be based, therefore, on a sustainable basis, considering quality, durability, and energy conservation criteria, apart from the direct impact on the environment of that specific material. Materials that enhance ecology shall also be selected, which are, for instance, materials with rough surfaces instead of smooth. The use of alternative materials compared to the most globally used shall also be considered, always ensuring the compliance with standards.

- Performance characteristics of materials:

Low maintenance and durable materials shall be used. When the lifespan of the material increases, and the maintenance requirements decrease, a reduction in waste generation and emissions could be achieved. The capital cost of the material may be larger but the costs during the lifetime are lower. In general, the criteria to consider are quality, durability, and energy conservation.

- Source of materials:

The source of the materials is also an important consideration. It is recommendable to obtain them locally (if available), from nearby sources. This leads to a reduction in emissions during transport and brings benefits to local industries. Obtaining the material from nearby obsolete constructions is also a sustainable measure. A good practice is also giving preference to suppliers with certified environmentally friendly supply chains.

c. Waste materials

- Waste management:

In a Green Port, a waste management plan shall be implemented, with the purpose of reducing the amount of waste material being disposed. This practice goes in line with the circular economy principle of Green Ports. Through this plan, new opportunities of reusing materials can

be identified. Prefabricated materials with standard sizing can be used instead of the ones fabricated on-site, to avoid generating waste from offcuts. Moreover, a dedicated storage area shall be designed for separation and recycling of waste. These measures would involve higher costs, but they are compensated for the reduction of disposal procedures.

3.6.3. Energy

Energy transition to more efficient and sustainable is one of the main objectives of a Green Port in comparison with traditional ports. This relates to the energy efficiency, and in particular, the energy consumption and the source of obtention, as traditional ports base their operations on fossil fuels, which are one of the main sources of emissions to the atmosphere leading to global warming and climate change.

a. Energy efficiency

- Energy consumption:

Energy consumption is in the first positions of the top 10 environmental priorities of European ports in the last years (ESPO, 2017). Therefore, it shall be studied in detail for Green Port developments to come up with measures for the total consumption. Lighting is the main energy consumer in the port, and therefore, actions can be taken to reduce its consumption. One way of achieving this is through an effective lighting system or improving the lighting technology, for instance with the use of LED lights or automated systems (sensors). Other activities for energy efficiency which could be planned form the design phase are the use of smart grids, the storing energy, and waste energy minimization and recovery.

Most of the measures for the reduction of energy consumption can be taken in the operation phase, and therefore, will be described in section 3.8.1.

- Use of renewable energies:

Power generation from renewable energies as an alternative to fossil fuels such as natural gas, oil, and coal, is another means towards a reduction of emissions to the environment. The percentage of sustainable energy generation is still significantly low throughout the world, and it is an undoubted sustainable practice applicable to a wide variety of sectors. In order for a port to be green, it shall also contribute to CO_2 emissions reduction by using renewable energies for the supply of electricity, fuel, heat, and light during port operations. Also, to anticipate future circumstances when these fossil fuels are not available anymore.

If the national grid is located nearby, the energy shall be obtained from it, from which green energy shall be bought. On the other hand, when the national grid is located at a large distance, the connection would involve high negative environmental impacts. In this case, the own production of energy through renewable sources shall be considered. However, these sources of energy are not as reliable as solely connecting to the main grid generated by fossil fuels, due to the fluctuations in its obtention, depending on specific conditions to fully exploit their capacity. Therefore, an intensive analysis shall be made, which mainly depends on the specific characteristics of the site location. A combination of renewable and non-renewable energy is an option when the physical conditions are not favorable enough.

The different renewable energy alternatives that can be beneficial in a seaport if the physical conditions are adequate are solar power, biomass, wind, geothermal, ocean, and hydropower

energy. The description of them, including advantages and disadvantages for their implementation in ports is included in Appendix E. The obtention of energy from some of these sources is direct and the technology is already proved and used worldwide. On the other hand, the obtention of energy from waves, from instance, is not such a common practice in port complexes as the obtention from wind, but it has a high potential. As Green Ports search for sustainable innovation, ingenious ways shall be studied and designed, for instance in breakwaters and quay walls.

Energy efficiency could also be obtained from other sources of energy, which are not commonly named as "renewable" but they are based on the principle of Circular Economy. The waste of certain business inside the port may form the source of energy for others or to supply local communities. This analysis is an important step in a Green Port development and shall be carried out from the first stages. A possible option is the use of the excess of steam from waste.

3.7. CONSTRUCTION

The construction phase involves a large amount of negative environmental impacts in a short period of time. For that reason, if a Green Port is aimed, the construction methods, equipment and transport flows shall be selected and planned to mitigate them while creating socio-economic value when there is an opportunity. For that purpose, and to minimize the negative impacts the relevant stakeholders shall be included before and during construction, adapting the construction plan or methods when necessary. Some stakeholders include, for instance, nature protection groups, communities or other affected groups (e.g. fisherman), safety organizations, local scientists, etc.

A distinction is made between the maritime works and the earthworks, which are elaborated on below.

3.7.1. Maritime works

There are several maritime works, or construction activities realized in the water, which are carried out in a port construction. Pile driving, breakwater and quay wall construction and dredging are the main ones. The attention will be given to the dredging activities, which are the most harmful construction activities, to the global and local environment, but the measures to be taken are also applicable to other maritime works.

Dredging is an essential practice both for the construction of a new port (capital dredging) and for the maintenance of the required depths during the lifetime of the port (maintenance dredging). As it is one of the construction activities with higher cost, larger time period required and higher environmental impacts in port developments, it is important to analyze it to find the green opportunities that will contribute towards the Green Port goal.

One of the reasons for the high environmental impacts of dredging is turbidity. Large amounts of sediments become in suspension during the operations (dredging and disposing) because of disturbing the existing substrates. This may affect marine biodiversity, especially to some natural habitats which are more vulnerable, like coral reefs.

a. Environmentally friendly methods

The construction method determines to a high extent what are the impacts to the local environment. Several criteria shall be considered to minimize it.

One of the most sustainable practices that could be considered during dredging operations is the reuse of the dredged material, which was already described in the design phase as a measure to reduce hinterland transport. It may also be a measure to reduce transport of the dredgers to the disposal site, also contributing to maintaining the livability of ecosystems.

- Processing of contaminated material:

For their reuse, contaminated materials shall be cleaned, or otherwise, they shall be placed in Confined Disposal Facilities, to mitigate the risk to the water and natural habitats. The potential uses for CDFs are, for instance, a site for windmills for energy production, barrier islands for shoreline protection or for certain kinds of agriculture (non-edible plants) (International Association of Dredging Companies, 2010). A survey of contaminated bottom sediments shall be therefore carried out before dredging, and if they are found, special measures shall be taken to prevent dispersion of the contaminants. A correct monitoring and design shall be made to avoid the loss of contaminated material during placement.

- Impacts assessment:

Another important aspect to consider in order to develop a Green Port is to create an environmental management plan to improve the environmental performance and to predict the impacts of dredging or reclamations. These activities count with associated high environmental risks, which can be mitigated by an adequate impact assessment, in order to minimize them and evaluate them, which is equally important for the project business case and for ecology. Together with stakeholders' participation, alternative practices can be examined.

One of the measures to be taken is the modeling or additional studies to understand the physical changes and impacts, given the physical conditions in the area. The most common dredging impacts are described in Appendix F. The method of dredging and disposal shall be therefore selected according to the possible impacts. The natural processes, like tide and currents, can also be used to improve the efficiency of the construction method and shall also be analyzed by means of additional studies. When the impacts are predicted to be large, measures to mitigate them shall be carried out, such as altering the rate of sediment removal, constraining the activities to certain time periods (i.e. environmental windows) (Netzband & Adnitt, 2009) or considering deep sand extraction pits (to 10-20 meters below the seabed level[3]) to limit the disturbed seabed.

- Increase of turbidity:

When the location counts with vulnerable sensitive aquatic ecosystems, specially to (large) fluctuations in turbidity or to a high reduction of light penetration, special attention shall be put during the dredging activities. These habitats shall be identified, and turbidity shall be controlled and reduced in the cases when the predicted levels are high compared to the situation before construction, in order to protect and not to disrupt the marine environment (International Association of Dredging Companies, 2010).

- Use of overflow:

An adaptive planning is essential to minimize negative impacts during dredging activities. This allows to take measures when certain conditions are met. For instance, overflow could be

[3] As per dredging for construction of Maasvlakte 2 (Port of Rotterdam)

restricted where vulnerable ecosystems are identified. On the other hand, it could be acceptable in other type of environments.

- Disposal of material:

The offshore disposal of material shall be done in done in areas without environmental significance, like protected areas, which also applies to the sand dredged for reclamations. And generally, it shall be ensured that the disturbance of ecological systems is minimum.

- Impacts to communities:

Specifically for pile driving, apart from determining the impacts to habitats and water pollution, measures for reducing noise pollution and vibrations shall be considered, as these are the main impacts. The minimization of the construction period becomes very relevant in this case, especially when there are nearby communities. A good construction plan is essential for this purpose. For other maritime works such as breakwater construction, there is another negative impact apart from the ones identifies in pile driving, which is dust pollution, both in quarries and the site. Measures to minimize dust impacts on communities shall be taken, like creating barriers or pouring water or chemical components that help retain it.

b. Equipment selection based on sustainability

The construction method is the most important factor which can influence the impacts during construction. However, an extra contribution relates to the selection of the equipment, especially in sensitive environments. Apart from an environmental management plan, several measures can be taken that relate to the equipment or tools used.

- Environmental performance of equipment:

The equipment shall be selected to minimize the physical changes and impacts assessed before construction, especially when these are predicted to be negative to marine ecosystems. The best practice is to use the latest developments in dredging technology which improves efficiency and contributes to sustainable dredging. However, these measures involve higher costs and it may be possible that there is still a limited understanding of their effectiveness, which happens with silt screens or curtains to control turbidity (Netzband & Adnitt, 2009). Closed grab dredgers can also be used when there are nearby vulnerable species, as they involve a lower impact.

In the case of contaminated sediments, the equipment shall be selected with special measures to control the dispersion, like automatic control, positioning systems, or degassing systems (Vellinga & M.Geense, 2004).

Moreover, the selection of the type of dredger or equipment for other maritime works shall be done considering sustainability criteria apart from economic and technical criteria. Some considerations for dredgers can be resuspension, spills, precision when there are nearby vulnerable habitats, contamination level of sediments, etc. The environmental performance of standard equipment is shown in Table 5.

Table 5 Environmental performance of standard equipment

DREDGERS	SAFETY	ACCURACY	TURBIDITY	MIXING	SPILL	DILUTION	NOISE
TSHD	+/0	-	-/0	-	0	-	+
SD	+	-	+	-	-	0	+
CSD	+	+	0/+	0/+	0	0	+
GD	-	-	-/0	0	+	+	+

BHD	-	+	-/0	+	+	+	+

Using environmentally friendly dredging and other marine equipment is the best practice for a Green Port construction. Modern, clean and energy efficient vessels shall be selected. Some LNG-fueled TSHD vessels are already available and others are being constructed, so it is an option to improve the environmental performance.

3.7.2. Earthworks

The earthworks for port developments usually include vegetation clearing, leveling, construction of the terminals and the traffic associated with these activities, together with the traffic for mobilizing the land-based equipment for the maritime works.

a. Environmentally friendly methods

- Construction plan:

An efficient construction plan shall be prepared to minimize the period which is associated with these adverse effects and to limiting working hours to the less harmful hours of the day, also to reduce light impacts to communities, requiring at the same time the less amount of mobilized equipment and traffic flows.

- Impacts on communities:

The main environmental impacts of the work on land that can be reduced, depending on the method or way of execution, are noise, vibrations, and dust. Some methods to minimize dust emissions include using screens around the construction site, temporary pavement of the construction roads and use of conveyor belts for excavated material. For noise reduction, a green belt of plans between the site and communities is a good barrier, as well as sound insulation fences. Noise surveys before construction can be carried out to better assess the impacts.

- Impacts on the local environment:

Land vegetation cleaning also requires special measures to mitigate ecosystem impacts and susceptibility of terrestrial areas to invasive species incursion. Understanding the system and local ecological characteristics is necessary for this purpose. Water quality can also be affected through the earthworks if there is erosion or runoff or material; therefore, special measures to retain this material shall be taken.

b. Equipment selection based on sustainability

- Environmental performance of equipment:

Emissions are another negative impact derived from the construction phase. Therefore, the earthwork equipment (construction equipment, trucks or other vehicles) shall be selected taking into account sustainability considerations. For instance, new equipment with newer engines emit lower volumes of harmful particles, as well as diesel or electric engines, so these shall be the selected equipment for Green Port developments. Moreover, noise nuisance can also be reduced by selecting low noise equipment, by creating temporary noise barriers or restricting the working hours, which shall be done especially when there are nearby communities.

3.8. OPERATION, MAINTENANCE, AND MANAGEMENT

The operation (including maintenance) and management phase comprises the design lifetime of a port; therefore, it is the longest development phase and the green opportunities shall be maximized. The Port Authority has a very important role for this purpose. The best practice towards a Green Port is the support of companies, terminals operators, cargo, vessels and chains with a higher environmental performance, and the non-acceptance of unsustainable clients who base their activities on fossil fuels, in order to contribute to an energy transition to a more environmentally friendly.

The sustainable measures for the operational phase will be described below, distinguishing between general actions to be followed in the port, in the terminals and in vessels. The relevant stakeholders for this phase are detailed in the management section, being the continuous cooperation during operations a specific criterion for this phase towards the green goal.

3.8.1. Port (general)

This section will describe the green opportunities for the common port areas, activities outside the port boundaries and the objectives of the Port Authority in this phase of development.

a. Port Authority role

- Acceptance of terminal operators or companies:

The Port Authority of a Green Port has an important role of being sustainable regarding the terminal operators they allow. Companies inside the port can have a high impact on how sustainable a port is. A Green Port shall be reserved for terminal operators or companies with a sustainable business approach.

Terminal operators which reuse waste materials, include measures for saving energy, promote innovation, are committed to environmental activities, improve efficiency, are committed to reduce noise, dust or air impacts, maintain water and soil quality or engage community shall be sought and preferred to the ones which do not follow any sustainable measures, making sustainability an important criterion for the selection (see example in Appendix A).

A Green Port shall also seek for clients who would increase the employment opportunities of nearby communities and search for a continuous improvement of the productivity of the port facilities, also considering new technological innovations and promoting green markets.

- Acceptance of cargo:

A shift from fossil fuel to renewable energies shall be made, and the first step is betting for green products. The best practice for a Green Port is the unique acceptance of green cargo.

- Cooperation between companies:

The Port Authority shall support and incentivize organization and cooperation between companies to improve their sustainability performance together. Some options are co-siting, designing shared facilities, and reusing waste from one terminal as raw material for another, if possible.

b. *Sustainable hinterland transport*

- Use of electric trucks:

One of the most important measures towards a Green Port is the use of environmentally friendly means of transport. When the hinterland connection consists of a road, electric trucks shall be used. Compared to standard trucks, both emissions and noise are reduced. This measure does not involve the extra investment in infrastructure but in new vehicles. Depending on the available hinterland infrastructure, it is more environmentally friendly to consider this solution or a modal shift. For instance, if a railway system is already available, the use of electric trucks would involve the construction of a complete road infrastructure, involving higher environmental impacts. On the other hand, if a road is available, better options could be the electrification of the road or the use of these electric vehicles.

- Implementation of an environmental zoning:

If all trucks are not electric, there shall be a limitation to entering the port or some areas (through an environmental zoning) only to vehicles with newer or cleaner engines (with maximum emission levels of nitrogen oxide and airborne particles) or fueled by a more environmentally friendly source like LNG. The latter involves lower emissions, savings up to 30-35% over diesel, cleaner burning and does not usually require any after-treatment or specialist NOx abatement measures. Other alternative fuels such as synthetic fuels and biofuels provide the best environmental performance. Their use shall be stimulated in the port. The environmental zoning also applies to noise levels, especially when there are nearby communities close to the transport infrastructure.

c. *Energy and resources efficiency*

There are several ways to use energy and resources in an efficient way, both in terminals and the rest of the port areas. For instance, the use of electric batteries in transport (and terminal equipment) is directly linked to an increase in 72 to 90% of energy efficiency (Wuppertal Institut, 2018), is the preferred solution in terms of energy consumption, which was covered in last section. Other measures to be taken relate to the following criteria.

- Lighting system:

An effective lighting system shall be designed and supplied in a Green Port, in order to contribute to reducing pollution and saving energy. Especially if the type of terminals and operations require operations 24 hours a day. Apart from using photovoltaic panels to generate the light, LED lighting shall also be used all over the port including roads, buildings and equipment, which saves a great amount of energy and improves visual quality. A control system to save energy when it is not needed is another sustainable measure to be implemented, which is also applicable to ventilation or air conditioning. White certificates measure the levels of energy savings and obtaining them shall be one of the main goals during operation.

The impact of artificial light to seabirds is also something to take into account. The installed lighting system shall be adequate for these species, especially if they are vulnerable or protected.

- Reuse of resources:

Ways to use resources in an efficient way shall be taken, while always seeking for new opportunities. The reuse of rainwater is a good option in locations where volumes of precipitations are high and if there are natural conditions to collect this water.

- Operational efficiency:

Operational efficiency is, in general, a very important aspect. Reduction in waiting times or increasing productivity helps towards this goal, reducing also unneeded emissions by running engines while they are not in use. Automation and IT solutions contribute to it, allowing, for instance, to monitor several cranes from a control station. Automation will also reduce the light consumption in the evening and emissions from quay equipment.

3.8.2. Terminals

This section focuses on the sustainable practices in port terminals during their operations. The attention is focused on the hazardous material management, the yard equipment and the waste management.

a. Hazardous material management

During operations, there is a risk of environmental accidents when hazardous material is handled in the terminal or during fueling procedures, which shall be mitigated from the design phase, but also with a safe operation. The measures regarding the design were detailed in section 3.6.1 and now the attention is given to the actions to take during operation. These measures relate to the spills prevention and to the emergency response plan in case there is an environmental accident.

- Environmental accidents prevention:

The prevention of spills can be enhanced, during operation and apart from the adequate and safe infrastructure explained in the design section, through the appropriate application of safety processes, by trained personnel and carrying out regular inspections to look for leakage or damage of the storage facilities and the spill response equipment. This spill response equipment shall be complete and strategically placed around the port, in all vehicles, terminals and in quay walls or jetties being correctly labeled, together with fire extinguishers. The content and nature of storage facilities shall also be indicated. Another mitigation measure is to prohibit smoking in the whole port area or to locate procedures for refueling of vehicles and equipment at a distance from the working area, buildings, other properties, and far from any source that could lead to a fire.

- Emergency response plan:

An emergency response plan shall be carried out in case there is an environmental accident, in order to act rapidly and in a coordinated way in the different phases: spill containment, recovery, clean-up, and disposal (see example in Appendix A). If the soil and groundwater are contaminated, the actions to follow shall be also clearly defined in the emergency response plan. After the accident is mitigated, an investigation to find the cause and to analyze the effectiveness of the emergency response shall be carried out, to act accordingly for future preventions and optimizations of the response.

The environmental emergency plan shall also contain the response for natural disasters, although the cause is independent of the port operations, like earthquakes, tsunamis or flood and also for other accidents like fire or explosions.

b. Sustainable yard equipment

- Environmental performance of equipment:

The goal for a Green Port is the zero-emissions scenario. Because this involves a radical change, it could be started by the minimization of these emissions, which shall be enforced by the Port Aurthority, by electrifying or installing rails in the terminals, which is a measure for the design phase, or by using yard equipment with electric engines, hybrid technology or sustainable fuels, which is a better alternative because employment is not reduced. For zero emissions, fuel cells are an option, offering long operational periods, and also hydrogen fueling, which can be used to store energy produced by renewable sources for its later use. They are currently in use for small equipment, especially for fuel cell-powered forklifts, but in the future, it may be possible that the use of the technology is transferred to other heavy equipment, like trucks. The measures for the shift to zero emissions also contribute to a considerable reduction of the noise levels.

Dust nuisance to communities shall also be avoided by means of the terminal equipment and facilities, if the dry bulk terminal was not located in an adequate position during the masterplanning to avoid this impacts or wind studies were not carried out. These problems can be mitigated with the use of modern bulk handling facilities, sprays for damping, through the stockpiles profile design (for which the prevailing wind conditions are essential) and the use of covered conveyors. Dust impacts from chimneys, can be controlled through dust filters or high chimneys (Vellinga & M.Geense, 2004).

Energy efficiency shall also be included, in terminal equipment, which shall be selected to optimize productivity and in terms of their environmental performance (see example in Appendix A).

c. Waste management

- Amount of waste:

One of the goals of a Green Port is waste prevention during operations, including ship-generated waste and cargo residues. Terminal operators shall be encouraged by the Port Authority to take measures to achieve this.

The performance of vessels in terms of sustainable reception of waste shall also be incentivized in the port, by reducing the port dues. The lower the quantity of waste it, the higher the reduction could be. There shall also be a limit on the amount of waste delivered to the port if it is not reused or recycled, and an incentive when the waste is recycled. An important method to optimize the reception of waste in the port is establishing a communication or notification system with the vessels so that they are able to inform in advance which is the quantity of waste they are delivering

- Waste processing and disposal:

When waste is generated, the objectives are the reuse, recycling, and energy recovery during waste processing. The recycling shall be done by means of adequate reception facilities for different types of waste. The reuse could be done in the same terminal or between terminals.

Waste of different industries or terminals could be used as raw materials for other industries, reducing the dependency on fossil fuels and contributing positively to the environment. For instance, residual heat could be reused as energy source.

In the case where waste cannot be reused inside the port boundaries, terminal operators supported by the Port Authority shall search for new alternatives for reuse outside the port, to other industries. In general, all measures that enhance the circular economy shall be followed and new opportunities shall be sought for this goal.

When waste cannot be reused, the disposal shall be also done in a safe way, not to disrupt the quality of the soil and groundwater.

3.8.3. Vessels

An important part of the environmental harm to the environment regarding port complexes is due to vessels. Even if their design is not a direct task of port developers, the Port Authority can have an essential role in reducing the impacts. These impacts refer to the reduction in air and water quality.

a. Emissions reduction

Maritime transport is the main source of CO_2 emissions from activities related to port operations. The percentage of the total emissions for each source for the Port of Rotterdam is shown in Figure 7, which 87% from the vessels and 13% which comes from the operations in the port.

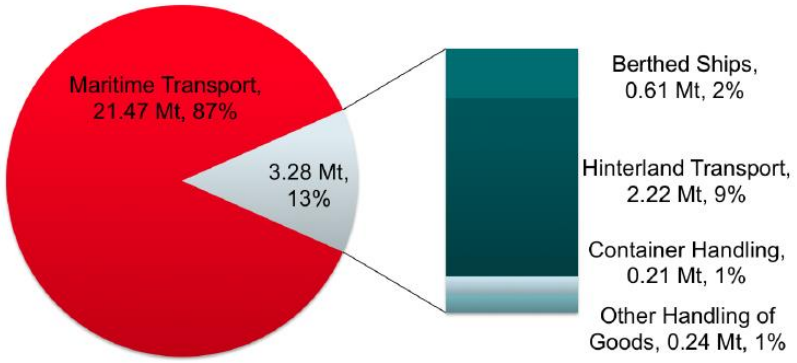

Figure 7 Transport related CO_2 emissions connected to the Port of Rotterdam in 2015/2016 (Wuppertal Institut, 2018)

Ideally, vessels that call a Green Port shall be supplied with alternative and more environmentally friendly fuels than diesel, like LNG or with low Sulphur contents, which reduced pollution and emissions. However, even being the most extended sustainable fuel, it does not contribute to the zero emissions goal, which is the ideal situation. Battery electric and hydrogen-fueled vessels may be an option in the near future, especially for short distances, which are cleaner sources with no emissions. Substitutes for fossil fuels are also synthetic fuels and biofuels.

The construction of more sustainable vessels is out of the scope of Port Authorities. However, some measures can be taken to improve the performance inside the port boundaries.

- Acceptance of vessels:

The best practice is that Port Authorities of Green Ports only accept vessels with a better environmental performance. This can be quantified by means of the Environmental Ship Index (ESI), which "identifies seagoing ships that perform better in reducing air emissions than required by the current emission standards of the International Maritime Organization" (WPSP, 2017). This index evaluates the volumes of nitrogen oxide and sulfur oxide emitted by the ship. Part of the formula gives fixed bonus for a reduction in carbon dioxide emissions and for the use of OPS facilities. The ESI Score ranges from 0, for ships which meet the environmental requirements, up to 100, for ships with zero emissions of SO_X and NO_X. The ideal situation is that a Green Port only accepts vessels with a positive ESI. If all ports took this measure, it would lead to a shift in maritime shipping, and global emissions would be reduced considerably.

- Port dues and rewards:

Only allowing certain vessels in the port can make them lose competitiveness, so a softer measure could be reducing the port dues and incentivizing shipping companies with better environmental performance. It also includes applying fines to vessels with higher levels of noise which affect nearby communities, to incentivize the installation of more silent engines, especially when OPS is not installed.

- Measures for emissions reductions:

Enforcing vessels to slow down at a certain distance from the port, leads to a reduction both in noise and emissions. The Port Authority shall also give example by using marine service vessels with more environmentally friendly fuels, for instance, hybrid boats.

b. Ballast water management

- Ballast Water and Sediments Management Plan:

Untreated ballast water released from ships at a new destination may introduce invasive species to the new location, leading to harmful consequences for the local ecosystem (see Figure 8). This is because this water, used for the vessel's stability, may contain many different species of microbes, plants and animals, coming from other parts of the world. The International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention) entered into force in September 2017 to introduce global regulations in order to control the release of untreated ballast water (International Maritime Organization, 2017). The Convention requires vessels to implement a Ballast Water and Sediments Management Plan, including procedures to control to the water and its sediments and managing it to a certain standard and if necessary installing a ballast water treatment system onboard.

Figure 8 Procedure of release of ballast water (International Maritime Organization, 2017)

In a Green Port, the compliance with this new regulation must be ensured, which also includes rules for ports. For instance, adequate reception facilities must be installed for the reception of waste in ports or terminals where cleaning of ballast tank is carried out.

3.8.4. Environmental management system

Most of the ports around the world count with an environmental management system or a management system where environmental issues are included. This is normally divided into air quality management, energy conservation, noise management, waste management and water management. The objective of the current ports through this environmental management system is to ensure the compliance of the environmental regulations, which are becoming stricter, and therefore requires the reduction of emissions, noise, energy consumption, etc.

For Green Ports, where the minimization of this impacts was considered from the first stages of development, the approach or objective of the environmental management system deviates from the traditional port management system. As stated in the port mission, the objective of a Green Port is not just to comply with the environmental legislation. The objective is in a higher level, with the purpose of obtaining a sustainable complex which is based on the top green philosophies (section 3.2), thinking about the future generations' needs. Therefore, the environmental management system focuses on maintaining the high environmental performance achieved through all stages of development and improving the aspects which were not implemented from the beginning given budget constraints. When the port obtains a return on the investments, new investments could be carried out to further reduce the overall impact of port operations.

The environmental management system shall, therefore, consist of several actions, which are elaborated on below.

a. Continuous cooperation with stakeholders

Since it is one of the top green philosophies, the inclusion of stakeholders shall also be done as part of the management of the port, during the operation phase. The whole group includes internal stakeholders (shareholders, board members, management, employees) and external stakeholders (customers, suppliers, local communities, governments, media, NGOs, etc.) (PIANC WG174, 2017). However, depending on the issue, the decision of which groups to include has to be different. Being selective in order to include the relevant stakeholders for each decision is an important practice. The mechanisms for their inclusion also depends on the port context and particular conditions.

b. Sustainability reporting

Stakeholders shall, for instance, be included in the process of developing sustainability reports, which shall be developed periodically by ports for several reasons. Some legislations force them to do it, whereas other ports develop them to show a green image. It is certain that one of the objectives of sustainability reports is to show communities what are the actions taken place in the port in terms of sustainability, to create public awareness and provide transparency, and to improve communication with all stakeholders. However, a good reporting strategy can also allow other high-level goals.

A good sustainability report allows making an assessment of the environmental performance, in order to find weaknesses and set sustainable goals. The evaluation shall be based on the port's mission and on the top green philosophies, and the objectives derived from this reporting process are defined to improve the environmental performance of the port.

The cooperation with stakeholders also contributes to reporting, who are involved in selecting indicators, data collection, evaluation of the trends and suggestions for better performance

(PIANC WG174, 2017). Port users and tenants also have responsibility for the shift into a more sustainable port, as they can identify the key issues to be evaluated and their respective targets.

c. Control systems and monitoring

Monitoring is an essential practice during port operations, not only to verify the compliance of the technical and legal requirements but also to verify if the port green standards and objectives are achieved. Air and water quality, together with noise, dust and emissions levels must be monitored, to take action plans for improvement if the impacts are higher than intended, especially in residential areas. Targets shall be set for a specific year, and if the tendency of improvement checked on a yearly basis will not allow reaching the goal for that time, alternative measures shall be considered to accelerate the process. Monitoring of the specific measures that are taken after the sustainability reporting that contribute towards the set goals of the port shall also be carried out.

A control system of the performance of the terminal operators and clients shall also be implemented, to ensure that the high environmental performance is maintained throughout the years. Sustainability key performance indicators can be used for this purpose, and in the action plan, objectives to improve them shall be set. Examples are energy consumption reduction, emissions reduction, improvement of water quality, etc. After the action plan is completed, the progress shall be evaluated again to verify that the objectives are met.

d. Continuous improvement

The continuous improvement during operations is key for maintaining the high environmental performance of a Green Port. It dos not only refer to reducing the impacts to the environment but also to trying to improve and optimize operations, which in the end will contribute in a positive way in terms of sustainability.

Productivity is, a very important aspect in a port, which is related to sustainability. A higher productivity is linked to a higher environmental performance. For instance, if a gantry crane can lift two containers at the same time, the cycle time is reduced and, therefore, the emissions are reduced. Therefore, a continuous improvement of productivity shall always be sought, not only by introducing new equipment but improving operations, flows of cargo, etc. In other words, sources of inefficiency shall be eliminated, for which a continuous monitoring and assessment of operations is required. A convenient tool for analyzing the inefficiencies of the port and looking for new opportunities for improvement is the SWOT analysis.

e. Stimulation of green technologies and innovation

Circumstances change quickly over the years. The most recent technology can become obsolete in a short period of years. A Green Port is developed with a long-term mentality, and measures to account for future changes of conditions are taken in the planning and design phase of the port. This is not sufficient if the Port Authority is not active and does not stimulate new green or innovative technologies that appear throughout the years. These innovations can include, for instance, the elimination of dust or noise or the contribution to a zero CO_2 emissions port. The port's policy shall be adapted to these new circumstances and knowledge, to continuously set new objectives.

3.9. CONCLUSIONS OF METHODOLOGY

The methodology for developing a Green Port has been divided into the different stages of port developments: planning, design, construction, and operation. However, these stages are closely related, and if a Green Port is aimed, decisions cannot be taken only considering the phase in which the project is in. In earlier phases, it is already important to take decisions and consider measures that relate to further phases. For instance, for the site selection, the design shall already be drafted. As in the case of the port of Ferrol (Appendix A), it is possible that a certain location is favorable, but the conditions do not allow for an integrated design which in the end can lead to higher impacts than selecting another location. Another example relates the hinterland transport. In the design phase, a rail system or inland waterway may show a higher environmental performance than a road system. However, if electric trucks or fuels with no emissions are used for operations, larger benefits are obtained, especially if a non-congested road is already constructed in the area and there is no need for a new transport infrastructure. An analysis on a higher level, considering the whole process instead of the specific conditions of that phase is therefore required.

Furthermore, the methodology focuses on the best practices for a Green Port, for which optimal local conditions (apart from sufficient financial resources) are required. In contrast, all conditions for developing them will probably never be favorable, becoming also a technical or environmental challenge which sometimes may not be resolved. For instance, a certain location might be the only alternative for locating a port due to ecological constraints or land and technical resources availability. It may involve high biodiversity and environmental impacts, but this could be compensated with a high environmental performance during operations. If the benefits are high compared to the impacts have to be addressed somehow, and not only considering the environmental aspects but also social and economic aspects, as the purpose of developing a port is not improving the environmental conditions but benefiting communities by giving them access to products.

Moreover, the proposed methodology is developed with the aim of obtaining a timeless and generic guideline, considering all aspects that may damage the environment instead of focusing exclusively on the current top environmental priorities , which change over the years (Figure 42 in Appendix A) and with the purpose of being able to apply it to any new port development around the world. However, the priorities for each specific case may be different, depending on local conditions. Some ports may focus on some specific objectives and add new criteria to the methodology, while some other criteria may not be relevant for that port.

4. COMPARISON BETWEEN GREEN AND TRADITIONAL PORTS

In section 2.3, a comparison was made between green and traditional ports, based on literature. However, after defining which are the top green philosophies (section 3.2), developing the proposed methodology with specific criteria to be considered towards the Green Port goal and keeping in mind the proposed definition (section 2.1), it can be concluded that the concept and differences between these two type of ports extend further than what was found in the literature. For that reason, a refined comparison between them is made (Table 6). The criteria in **blue** correspond to the differentiative aspects obtained from literature and the current green port practices (which were already identified in section 2.3), while the criteria in **black** correspond with the new differentiating aspects derived by the research and own reflection.

Table 6 Refined comparison of a Green Port and traditional port (blue derived from literature; black derived from the proposed methodology)

SUBJECT	TRADITIONAL PORT	GREEN PORT
Stakeholders	Not meaningful participation of stakeholders or community and normally only during EIA	Co-creation with communities and stakeholders to generate an added value
Economic driver	Benefits/Economy	Green growth/ Economy, social & environment
Relation with nature	Replacing nature	With nature/develop nature along with port
Mentality	Short term (current benefits)	Long-term (future benefits)
Technology	No use of new and innovative technological developments	Involvement of technological and societal developments to enhance transition towards green growth
Port authority role	Re-active landlord	Pro-active landlord in the development of the region and the logistic chain
Energy	Energy obtained from fossil fuels	Energy efficiency from renewable sources
Resources	"Take, make and dispose"	Reuse of resources
Quality of air	No special measures for reducing the quality of air during operation	Improving environmental performance through programmes to reduce emissions to a minimum during operation
Biodiversity	Reduction of negative impact on biodiversity	Enhancement of biodiversity and conservation areas
Cargo	Allowance of any type and origin of cargo	Attract diverse cargo, turnover from non-fossil cargo
Vision of sustainability	Sustainability as a legal obligation	Sustainability as an economic driver
Site location selection	As per land ownership and/or without preliminary studies	As per optimization of material, in harmony with nature, minimum negative biodiversity impact & minimum negative community impacts

Growth approach	Focuses on Gross Domestic Product (GDP) growth	Elimination of sources of inefficiency, promotion of innovation, reboot of new economic opportunities from the emergence of new green markets and activities
Environmental impacts	Compensation of impacts	Avoidance of impacts
Sustainable actions extent	Following actual regulations, EIA	Long-term vision, irrespective of actual regulations
Use of material	No re-use/optimization of material	Use of excess of material, naturally present materials, and land resources efficiently for functional requirements and for an added value
Dealing with future uncertainties	Scenario-based planning for making quantitative forecasts	Adaptive planning, including flexibility in planning and design as a means towards sustainability
Design decisions	Based on the project boundaries	Based on understanding the whole system
End of life cycle	The subject is left to future generations	The subject is treated from the planning phase, reducing restrictions for future urban redevelopment

It can be observed that most of the new criteria for comparison, derived from the proposed methodology of the previous section, are related to the planning and design phase (Table 7), which are not covered by literature nor by the sustainability reports of the current ports, as they are in their operational phase.

Table 7 Correspondence of subjects for comparison to the development phases

SUBJECTS	GENERAL	PLANNING	DESIGN	CONSTRUCTION	OPERATION
Stakeholders		X	X	X	X
Economic driver	X				
Relation with nature		X	X		
Mentality	X				
Technology				X	X
Port authority role	X				
Energy					X
Resources				X	X
Quality of air					X
Biodiversity		X	X		
Cargo					X
Vision of sustainability	X				
Site location selection		X			
Growth approach	X				
Environmental impacts		X	X		

	GENERAL	PLANNING	DESIGN	CONSTRUCTION	OPERATION
Sustainable actions extent	X				
Use of material		X	X	X	
Dealing with future uncertainties	X				
Design decisions			X		
End of life cycle		X	X		

5. FINANCING

The best practice for a Green Port (normally) comes together with a higher cost, making financial feasibility an obstacle towards the optimal solution. Some of the criteria that can be followed to achieve a green goal may not involve higher costs (e.g. a sandy foreshore instead of breakwater as protection), but others are linked with high investments (e.g. onshore power supply). Nevertheless, it may be possible that there is a technical impossibility of following the criteria that reduce costs, leaving only the option of considering the costly measures if a Green Port is the goal.

For a Green Port, the gains towards sustainability are higher, however, this cannot be considered a return on the investment, as it is not an economic gain. Therefore, not only the business case can become more complicated, but also acquiring capital, especially because project financing is traditionally based on a short-term mentality. This becomes significantly relevant for regions under development, where there is a lack of public capital, which increases the difficulty in achieving the Sustainable Development Goals from the United Nations (Figure 6) or the goals from the Paris Agreement, by means of infrastructure development. Some ways to ease the financing of Green Ports are elaborated on below.

5.1. BLENDED FINANCE

In order to give the first step for developing Green Ports (and in general for sustainable development projects) a financial scheme that reduces the difference in costs and valuates externalities is needed. Blended finance is an option, defined as “the strategic use of development finance for the mobilization of additional finance towards sustainable development in developing countries” (OECD, 2018). The objectives of blended finance are to attract private investments which were not going to be destined to development for projects with high social and environmental components and benefits, and to fight against the existing market barriers by investing in projects which are not feasible in the present but have the potential to be in the future. Investments in developing countries involves high risks because the uncertainty in the returns is higher, and by using a financial scheme strategically, the risk-return profile of the investment can be improved, attracting private investors to projects with non-favorable business cases. An illustration of the procedure is shown in Figure 9.

This financial scheme is applicable for projects financed by public organizations, like governments or development banks, which cannot be developed without capital from private investments. Regarding the total investment, the proportion of the private capital is much higher than of the public. Private investors are mainly commercial investors who benefit through the later exploitation of the infrastructure or by means of added value generated in the port for them.

Figure 9 Illustration of how blended finance works (OECD, 2017)

There are several organizations that are already using this financial scheme. The International Finance Corporation (IFC), from the World Bank Group, uses several instruments to implement blended finance, which are risk mitigation/guarantees, concessional debt (senior and mezzanine), equity (direct investments and private equity) and performance-based incentives (IFC, 2017).

5.2. INVESTMENT FROM STAKEHOLDERS

In general, financing from different sources is an advantage for Green Ports, which are generally characterized by high investments or non-favorable business cases, together with high risks, in certain cases. This allows the diversification of both risks and the investment, which reduces the implementation issues, which are mainly financial. A good opportunity for finding investors comes together with the stakeholders' co-creation. Stakeholders such as operators, municipalities or industries may be willing to invest if added value is found and created through the port development. This gives another reason to carry out the co-creation, which directly benefits the Port Authority or private investors.

When a value is created for different stakeholders, obtaining capital from banks is also easier, as the creation of value is an important subject[4] for them.

5.3. GREEN BONDS

Another way for obtaining the necessary capital of investment is by means of Green Bonds, which can be obtained by projects which generate environmental benefits such as renewable energies, energy efficiency, sustainable waste management, circular economy processes, clean transportation, etc. Green Port developments count with this type of projects, and therefore,

[4] The Deutshe Bank includes 'creating value of all stakeholders' as one of the eight points of their strategy

can be eligible for these bonds. Apart from being an attractive financing alternative, project developers can find them as an incentive to invest in sustainable projects and show their sustainable business approach.

Green Bonds have been already issued for a high number of projects of different nature by development banks like the World Bank or the Deutsche Bank. Nevertheless, there are some challenges linked to the issuers. The returns are similar compared to a normal bond, but there are additional costs in these type of projects (for defining green criteria, monitoring, and ensuring the compliance of the green practices, maintaining the processes sustainable or extra transparency). Furthermore, the concept of 'green' project is not global, so different perspectives can complicate the process of assigning these bonds. Some financial institutions joined to develop guidelines for issuing Green Bonds[5], the so-called 'Green Bond Principles', but they are not used worldwide. The evaluation framework in Appendix B provides a set of criteria to define whether a port is Green or falls into the category of traditional ports and could be used as a tool for Green Bonds issuing. It has to be noted that the issuing of these bonds depends on national top priorities. As per the Deutsche Bank, some investors in Scandinavia have started to exit traditional bonds to focus only on investments that involve Green Bonds. If this practice extends, which is possible, given the global importance that is given to sustainable development, Green Ports will benefit significantly.

5.4. ENVIRONMENTAL, SOCIAL, AND GOVERNANCE (ESG) FUNDS

Another option that could benefit Green Ports financing involves the Environmental, Social, and Governance (ESG) funds. The ESG criteria are defined as a "set of standards that investors use to screen potential investments that considers ethical impact and sustainable practices and pursue sustainable growth" (Investopedia, 2017). The environmental criteria look at the performance regarding the natural environment, while the social criteria are about relationships with employees, suppliers, clients, customers, and communities and the governance criteria deal with leadership, audits, internal controls, and shareholder rights.

ESG criteria used by investors are, for instance, a company's impact on climate change or carbon emissions, the degree of communities' development, the water use, energy use, waste, pollution, natural resource conservation, management of environmental risks, etc. When looking for an investor, and in order to be eligible for these funds, it is important to quantify impacts, for which the scoring system of the Green Port methodology may be used. It also has to be cost-effective and low-risk investments, which means that if innovative solutions are included in the design, their efficiency has to be proven. At the same time, the reduction of financial risks is implicit in a Green Port development, in the sense that a long-term mentality is adopted.

[5] Bank of America, Citigroup, Crédit Agricole CIB, JPMorgan Chase, BNP Paribas, Daiwa, Deutsche Bank, Goldman Sachs, HSBC, Mizuho, Morgan Stanley, Rabobank, and SEB.

6. CASE STUDY: AMATIQUE PORT

The proposed methodology for developing a Green Port will be refined based on learning from a case study: Amatique port. It is a greenfield port under development, located in the Atlantic side of Guatemala, in the region of Izabal. The project is not in its initial phase, being currently in the design phase; however, the green opportunities will be analyzed from the initial stage (site selection). The preferred site in terms of the proposed methodology will be selected, and for the following phase, the current design will be evaluated and measures to improve the environmental performance will be given.

As explained in the introduction of this report, there are several reasons for the selection of this project as the case study. First, it is a greenfield port, and it can be developed in a sustainable way from the beginning, so the proposed methodology can be tested in the planning phase, which is discarded by literature. Second, the project site is located on a protected area, and the stakeholders ask for a green approach in order to compensate for the negative environmental impacts on the Nature Reserve, being necessary for their support. Finally, the main product that will be handled in the port are bananas, which require a high energy consumption during transport and storage, as they require to be refrigerated. Developing the port along with a green approach would compensate for this requirement.

The case study section is divided into several subsections. First, a general description of the project is given. Next, the project issues regarding the protected area are explained. Later, the proposed methodology is applied; with the purpose of testing it for the planning stage (site selection and masterplanning). Finally, the encountered issues while applying the methodology to the case study are described and the refinements found to improve the methodology are explained.

6.1. BACKGROUND OF THE PROJECT

Guatemala is reported to have good growth potential, ranking in position 17 in the world of the highest projected annual growth through 2016 (5,46%) (Center for International Development at Harvard University, 2018). This presents business opportunities in the country, also to cope with the required development of infrastructure with the growing demand from the population. Moreover, at present, there is also an unsatisfied demand for modern, efficient port facilities, especially on the Atlantic/Caribbean side of the country.

For those reasons, some private parties are interested in developing a new private terminal in Guatemala in order to be the preferred provider of world-class port facilities for containerized and bulk import/export operations by servicing maritime traffic with optimum efficiency. They own a land of 172 ha in the Amatique Bay, located on the Caribbean coast, where they would like to develop the new port: Amatique port (Figure 10).

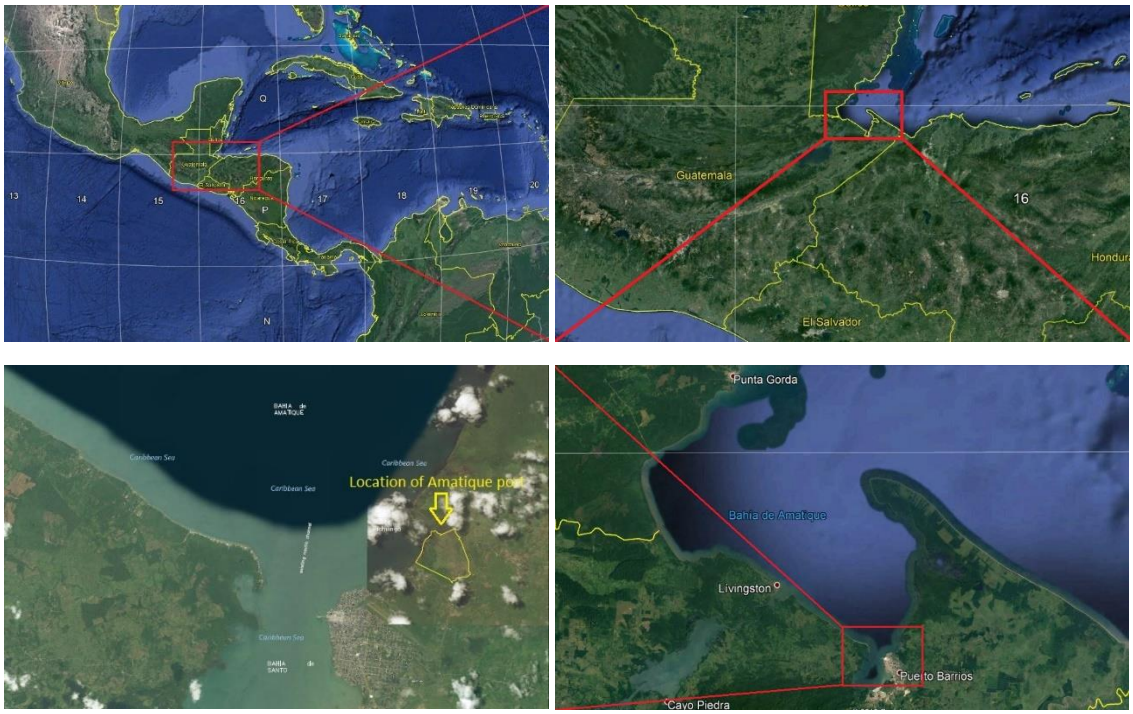

Figure 10 Location of Amatique port (source: Google Earth)

6.2. PROJECT ISSUES

The land owned by the private party counts an environmental issue, which relates to the protected area “Refugio de Vida Silvestre Punta de Manabique”. The peninsula named Punta de Manabique, situated in the northern direction from the property is a protected area of category III of the IUCN Protected Area Management Categories. The protection does not only apply to the land, but also to the marine area that surrounds it. Figure 11 shows the uses of the land. The port is located on the southern edge of this protected area. The onshore part of the port site is located in the “Zona de Amortiguamiento” (land colored in brown) and the access channel will cross the “Zona de Conservación Marítima” (marine area colored in dark blue), as it will connect to the main access channel of Santo Tomás and Puerto Barrios. The boundaries of the protected area together with the port boundaries are shown in Figure 12.

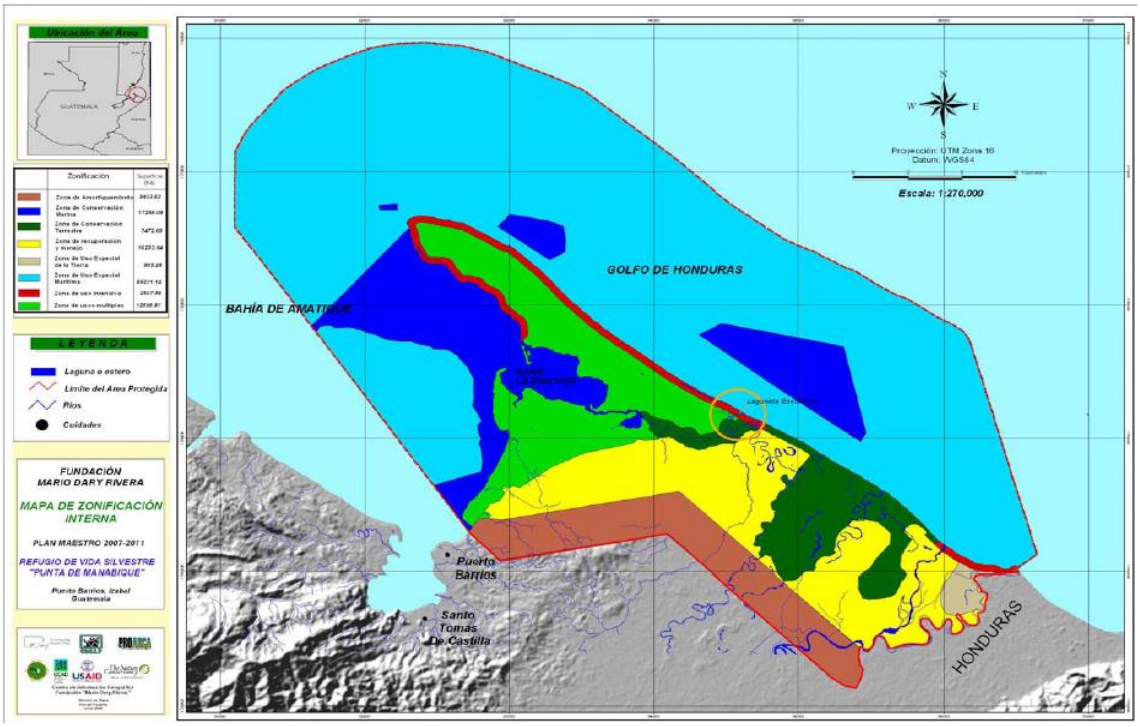

Figure 11 Punta de Manabique land uses (FUNDARY, CONAP, & TNC, 2006)

Figure 12 Boundaries of the protected area and port (source: own elaboration)

The Zona de Conservación Marítima has the highest degree of conservation inside the protected area. It counts with the main marine biodiversity and it includes the area in the Atlantic side of Guatemala where nesting of marine turtles is more frequent. The Zona de Amortiguamiento is the area where most of the communities can be found. Its objective is the conservation and restoration of significant fauna, flora, and natural and cultural interactions.

Because the port will be located inside the boundaries of a protected area, and the access channel will cross an even more important area for conservation, the stakeholders ask for a Green Port development. Sustainable choices made from the planning phase can compensate for the negative impact of locating the port inside the protected area.

6.3. DEVELOPMENT OF AMATIQUE GREEN PORT

The methodology for developing a Green Port will be applied to Amatique Port, and after that, it will be refined. Therefore, the following sections will follow the same structure, analyzing each criterion for each subject of that phase, to later evaluate it with the evaluation framework. The focus will be put on the planning phase (site selection and masterplanning).

6.3.1. Site selection

As stated at the beginning of this chapter, the site for Amatique port is already selected, based on land ownership. However, considering the methodology to develop a Green Port, the better solution will be sought in terms of location, as the current site location involves high negative environmental impacts to local biodiversity. The current site is compared to the identified alternative sites in the evaluation framework, concluding that there is a better site possible which involves less negative impacts.

a. Stakeholders

The relevant stakeholders for the site selection phase have to be identified, as the cooperation and co-creation with them are crucial to obtain a sustainable solution. These are included in Table 8. For the purpose of testing the methodology, some assumptions would be made, as the contact with the stakeholders is not possible.

Table 8 Relevant stakeholders for the site selection

STAKEHOLDERS	TASK	INPUT
Government	National support for the project	-Support and preference for alternatives
Cargo producers	Potential clients	-Area(s) of interest
CONAP (Consejo Nacional de Áreas Protegidas)	Coordination of the protected areas in Guatemala	-Impact on the protected area if the port is located on A4 (biodiversity loss) -Information about maintenance of the integrity of the natural system (relocation, conservation, etc.) -Impact on coastal processes (rough comparison)
FUNDAECO (Fundación para el Ecodesarrollo y la Conservación)	Protection and conservation of protected areas in Guatemala	-Impact on the protected area if the port is located on A4 (biodiversity loss) -Information about maintenance of the integrity of the natural system (relocation, conservation, etc.)
Municipality of Puerto Barrios	Administration of Puerto Barrios and influence on public acceptance	-Concerns of community -Concerns of fishermen -Level of skilled labor
Municipality of Puerto Santo Tomás	Administration of Puerto Santo Tomás and influence on public acceptance	-Concerns of community -Concerns of fishermen -Level of skilled labor

Municipality of Livingston	Administration of Livingston and influence on public acceptance	-Concerns of community -Concerns of fishermen -Level of skilled labor
COMUDE (Consejo Municipal de Desarrollo Urbano y Rural)	Representation of communities	-Future expansion plans of cities for buffer areas
Communities living on the site	To be resettled	-Way of living -Possible benefits
Fishermen associations of Izabal	Protection of fishermen interests	-Loss of fishing grounds (temporal or irreversible)
Affected people on their economic activities	Carrying out their activities on the site (farmers, cattle rangers, etc.)	-Type of activities -Other sources of income

b. Methodology

- Use of existing port facilities

The first step, before starting developing a greenfield port, is to consider if an expansion of the existing ports is possible, involving overall lower environmental impacts. Only the ports of the Atlantic coast will be considered, as the objective of the port is to increase port capacity in that side and will serve the European and East America trade (as per the market study developed for the project). Figure 13 shows the destinations of the Guatemalan banana exports, which are the main cargo of the new terminal.

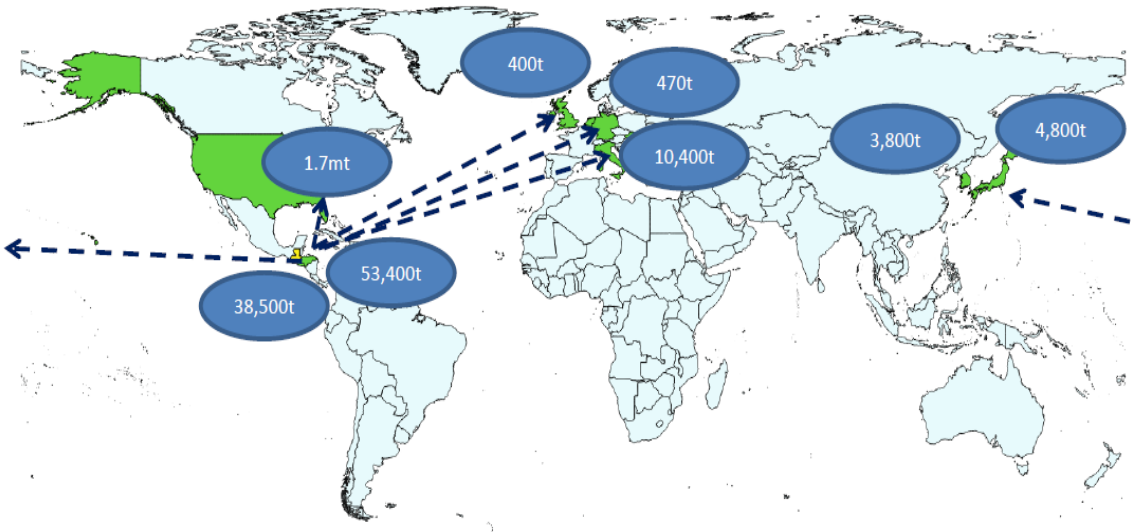

Figure 13 Geographical distribution of the Guatemalan banana exports (source: market study)

The existing Guatemalan ports in the Atlantic side are Puerto Barrios and Puerto Santo Tomás (Figure 14). The two ports are mid-sized ports servicing the American and European market. Puerto Santo Tomás is run by the government, meaning that the government is the Landlord and the terminal operator. Puerto Barrios while government-owned, is run by Chiquita, one of the main banana exporting companies.

Figure 14 Location of competitor ports of Amatique port (source: Google maps)

Both ports are operating beyond their maximum capacity. The Chiquita terminal is operating under a legally questioned contract, as the lease for the facility was granted by an entity not authorized to do so. Additionally, the municipal government would prefer to close the Chiquita terminal, as port traffic now goes through the center of Puerto Barrios, the town, with the consequent damage to city infrastructure. The central and municipal government currently have no alternative as closing the Chiquita operation would inflict great damage to national exports. This has led to clear sympathy and support to develop a new greenfield port which will handle the cargo from this terminal.

To avoid community impacts, the expansion of Puerto Barrios is discarded, limiting the options to extending Puerto de Santo Tomás. Expanding this port will, at first sight, involve significantly lower impacts than the construction of a complete new port. The elements which involve higher environmental and communities' impacts will be avoided, as they are already constructed and in use by the current port. This mainly refers to the navigation channel and the hinterland infrastructure. However, plans to expand the port are already made, and construction is planned to start in 2019. A new liquid bulk and dry bulk terminal will be developed (areas 4 and 5 in Figure 15) and the industrial park behind the terminals will also be expanded. The ideal situation would be to locate Amatique Terminal beside the existing container terminal of Santo Tomás (in areas 4 and 5), as infrastructure may be shared and the draft of the vessels will be very similar. The market study for Amatique Port forecasts the need of four container berths up to 2046, and there is a possibility that there is also a need for one berth for liquid bulk (for palm oil) and breakbulk. The expansion area defined by the Port Authority of Santo Tomás would be sufficient for this purpose. However, to achieve this, the port would have to be privatized, and the Government does not have plans to carry this out.

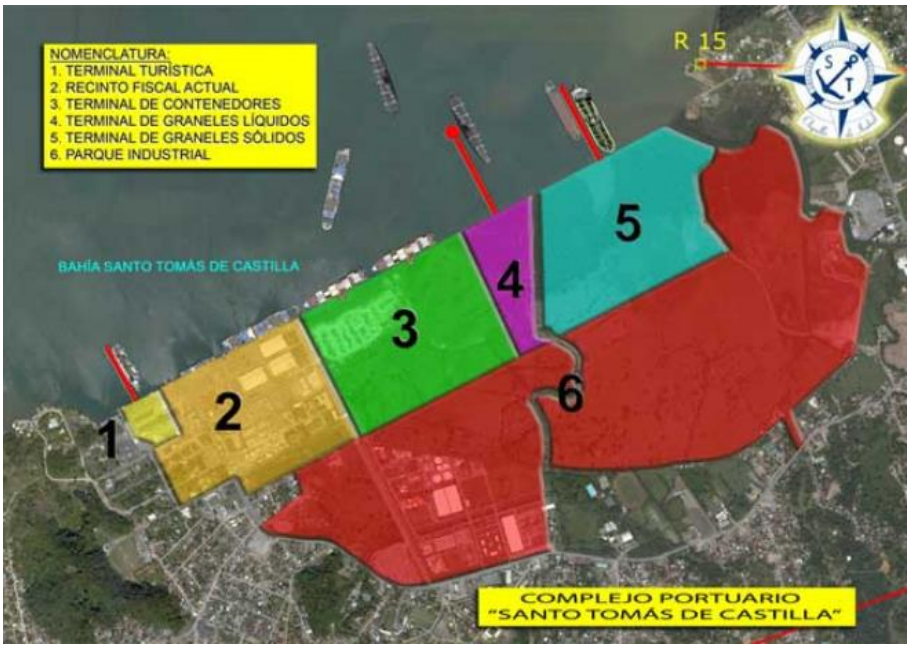

Figure 15 Expansion plans of Puerto Santo Tomás (source: Puerto Santo Tomás de Castilla website)

It has to be noted that if circumstances change and there is a need for extra capacity compared to the forecast, expansion eastward or westward is not possible if the aim is not to impact communities or the environment in a negative way. On the east there is a neighborhood, and, on the west, the area is protected.

In principle, this is the site location with less environmental impacts, hereinafter called "Alternative 3" or "A3". Nevertheless, other alternatives are analyzed both to confirm that it is the optimal solution and, in the case that Santo Tomás Port is not privatized, which is most probable.

- Impact on protected areas

The other alternatives involve developing a greenfield port. For a Green Port, the first step is to identify the protected areas in the region. It has been restricted to the Atlantic side of Guatemala, because of the reasons explained above. Three protected areas are found in the coastal region (Figure 16 and Figure 17).:

- Área de Usos Múltiples, Río Sarstún
- Reserva Protectora de Manantiales, Cerro San Gil
- Refugio de vida Silvestre, Punta de Manabique

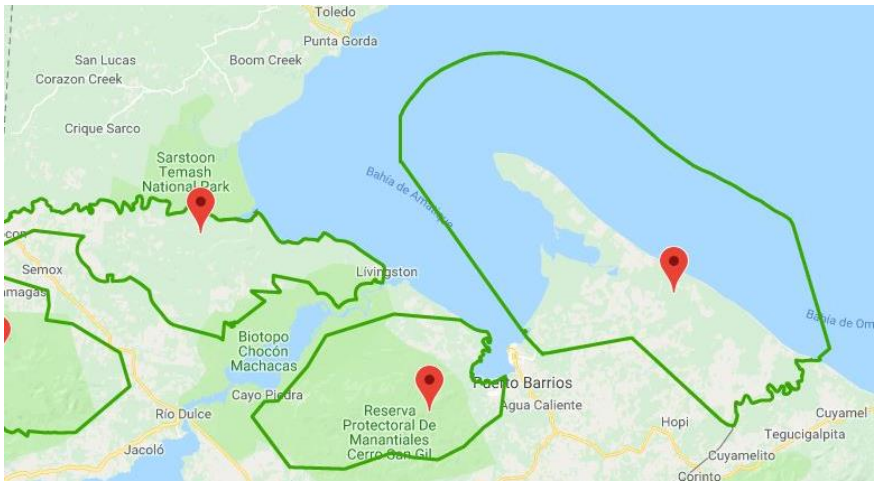

Figure 16 Protected areas on the Atlantic side of Guatemala (source: FUNDAECO website)

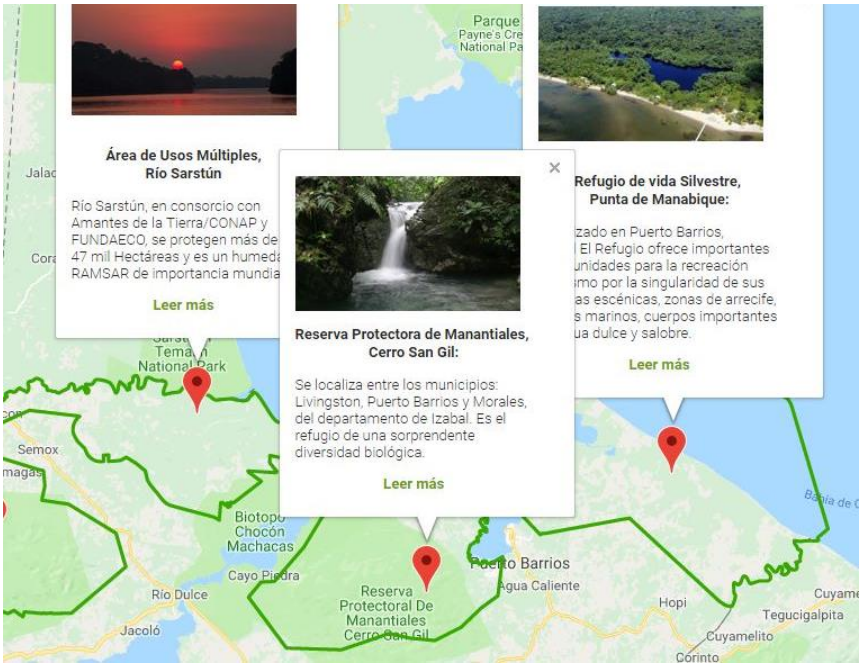

Figure 17 The three protected areas on the Atlantic coast of Guatemala (source: FUNDAECO)

Two coastal regions outside the protected areas remain: the region between Río Sarstún and Cerro San Gil, close to the city of Livingston, and the area around the city of Puerto Barrios (Figure 18). Based on the proposed methodology for developing a Green Port, in which importance is given to avoid protected areas, the port will be located in one of these two regions.

Figure 18 Alternative regions for the port location: near Livingston (left) and around Puerto Barrios (right) (source: FUNDAECO website)

In the region near Livingston, there are several zones outside the boundaries of protected areas. The first one is the city of Livingston, the second one is along the Dulce river (both northern and southern), and the third one is along the coast, on the opposite side of the river from the city. The two first alternatives are discarded. The first one, because there is a lack of space and the port would have to be located very close to communities, having no space for buffer areas, which induces high negative impacts to the city. The second one, because an inland port involves disadvantages (larger volumes of capital and maintenance dredging, sedimentation problems, possible affection to water quality, dependence on water discharge/precipitations, etc.) and because there are marine protected species and the area counts with significant vegetation. The alternative along the coast seems to be a favorable location, as there is enough space and the area is not densely populated. This is called “Alternative 1” or “A1”.

In the area around Puerto Barrios, there are two locations outside protected areas. The first one is the expansion area for Puerto Santo Tomás, and the second one is the area to the north of the city. This is called “Alternative 2” or “A2”. It has to be noted that the ownership of the land in A1 and A2 is not known. These two alternatives are shown in Figure 19, together with A3 and A4, the latter being the current site of the project, based on land ownership. The actual site, since it has similar conditions as A2, will be evaluated by means of the scoring system after the other alternatives are studied in detail.

Figure 19 Alternatives for site selection (source: Google maps)

The area for expansion of Santo Tomás (A3) is also located outside the boundaries of the protected areas.

- Impact on natural habitats:

The degree of vulnerability of the species in the site alternatives can be obtained by means of the tools described in Appendix A. In sites A1, A2, A3, there are several Near Threatened and Vulnerable species (according to the IUCN Categories) that live in the area. However, these species occupy most of the coastal areas of the world or Central America, which means that if a new port is aimed to be developed, these species will be affected with a high probability. Considering the high benefits that a new port brings to communities, in terms of connectivity,

employment, etc., the impact with these species can be acceptable, taking special measures when possible for their conservation. Apart from this globally vulnerable species, the alternatives do not count with other threatened species that make one option more favorable than the other. On the other hand, A4 would be located in an important region for a higher amount of threatened species which are exclusive to the Punta de Manabique.

In terms of forest loss resulting from the new port development, A1 and A3 could be more favorable. The reason is that A2 is located in a forest area, which would involve a higher forest loss than the other alternatives. A1 could be selected along the coast in an area where the loss is not so significant, as there are more areas without forests in that part of the coast. Figure 20 shows the existing forests (in green) and the areas without them in (light green). The complete map can be found in Appendix H. This criterion is considered to be important by the National Council of Protected Areas, the National Institutes of Forests, universities and the Ministry of agriculture, livestock and alimentation, who deliver maps of forest loss periodically and promote their conservation.

Figure 20 Forest coverage in Izabal (source: report of forest coverage 2010)

Moreover, A2 is located in a wetland with forest, corresponding to the blue areas (4.1.4 “Humedal con bosque”) in Figure 21, while A1 is mainly characterized by low shrub vegetation, corresponding to the light green areas (3.3.1 “Vegetación arbustiva baja”). Adjacent to the defined area of A1, broadleaved forests can also be found, and around the center some urban areas exist. These areas will be discarded for the site. Where A3 is located, cultivated grass can be found (2.3.1 “Pasto cultivado”), together with a limited area of broadleaved forests. The complete map, together with the legend can be found in Appendix H. This also gives a reason for selecting A1, which is the preferable option in terms of natural habitats.

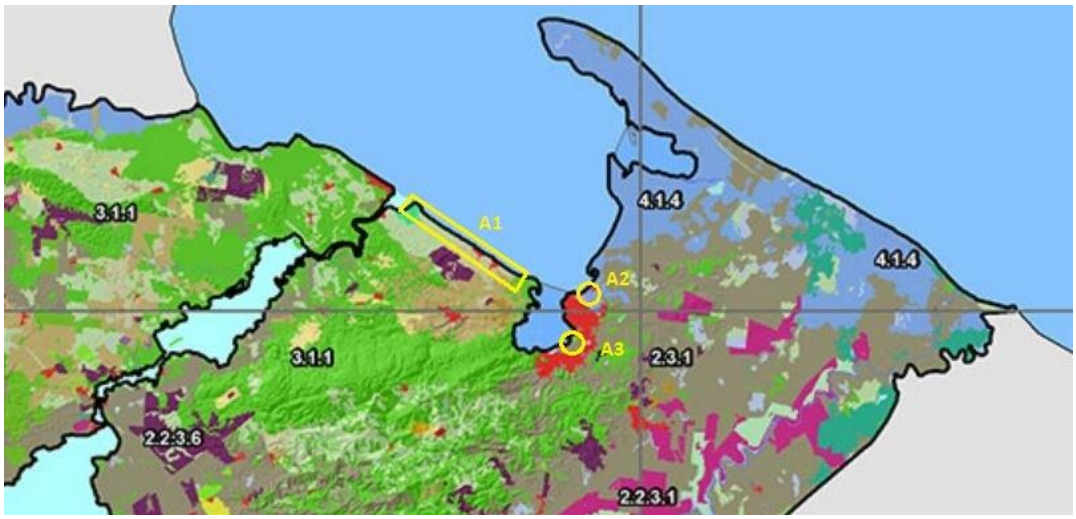

Figure 21 Vegetal coverage and land use of Izabal 2015 (source: Ministry of agriculture, livestock and alimentation (MAGA)

- Use of existing hinterland connection

In terms of using existing hinterland connection, A2 and A3 are more favorable locations. The area is well connected by the main road system of Guatemala (in red in Figure 22), and only an extension to the port would be needed. The railway system also reaches both locations. On the other hand, A1 would require the development of a new road of approximately 30 km to connect to the main system. There are several non-paved roads (Figure 22, in yellow) around this alternative location which could be used for the connection, reducing construction impacts. However, these are located inside the protected area 'Reserva Protectora de Manantiales, Cerro San Gil', except for north-east ones. This means that if the objective is to avoid these special areas for biodiversity, the hinterland connection would have to use the road parallel to the lake 'El Golfete', being the only option to avoid it and restricting the options for the alignment. The presence of this protected area would also make impossible the connection to the existing railway system.

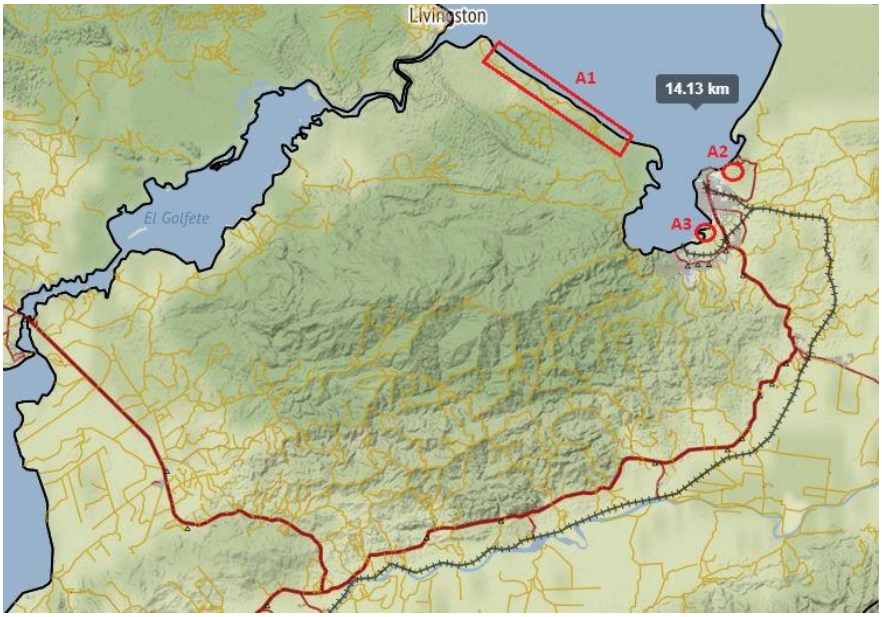

Figure 22 Road system of Guatemala in Izabal (In red, the main network and in yellow the not paved roads) (source: Infraestructura de Datos Espaciales de Guatemala (IDEG))

- Use of natural conditions

A site would be preferable if it has a larger water depth, due to the lower volumes of dredging required. Looking at a nautical chart, it can be concluded that alternatives A1 and A2 are considerably similar in terms of water depths; with A1 being slightly more favorable as per Figure 23. A3 is in a location with smaller depth, but the vessels would make use of the navigation channel that approaches the port of Santo Tomás, being the most preferable option in terms of dredging. The distance of connecting the new channel with the existing channel may also make a difference between A1 and A2, if one of them involves less total dredging.

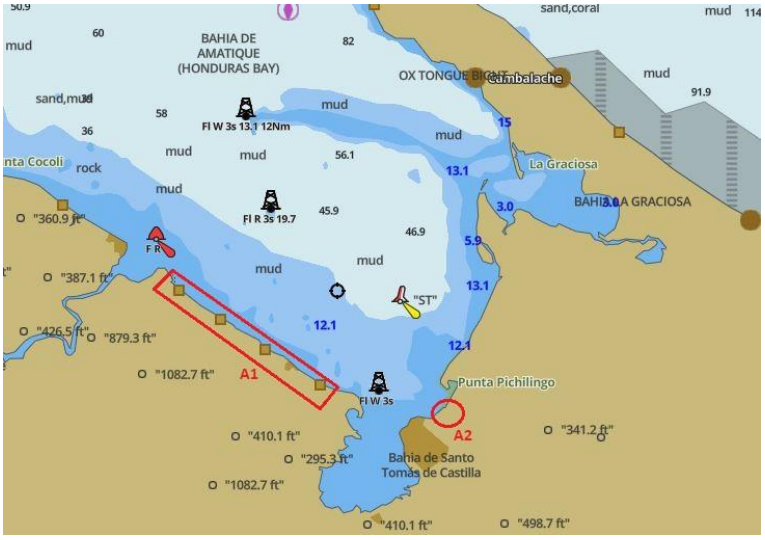

Figure 23 Nautical chart of the region (source: GPS Nautical Charts)

As shown in Figure 24, the distance to the existing navigation channel from A2 is shorter than from A1, especially if the port is located on the eastern side of A1.

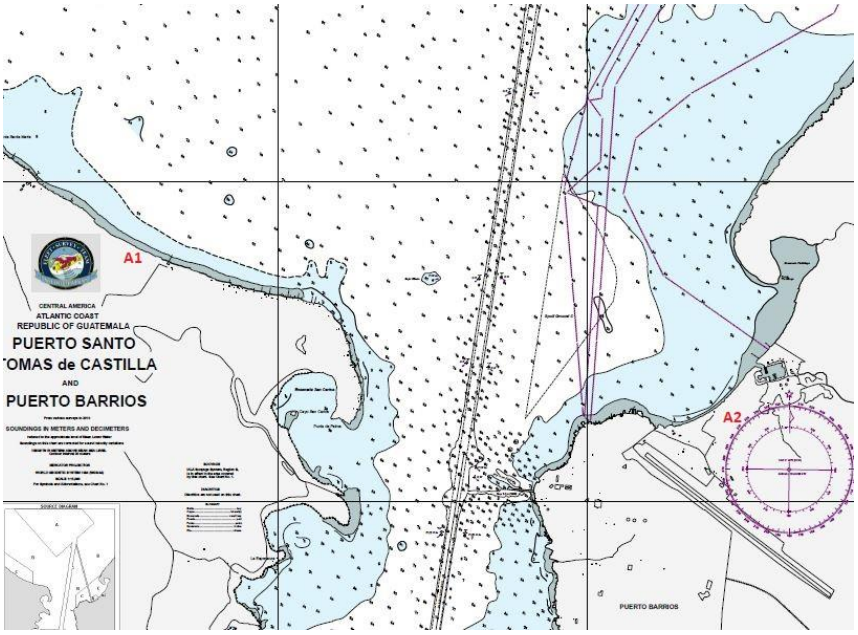

Figure 24 Nautical chart for Puerto Barrios

The use of natural conditions also involves how sheltered the alternatives are, which is beneficial to avoid or reduce impacts derived from breakwaters, which also depends on the hydro-meteo conditions. Looking at the location of the alternatives from a distance (Figure 25), one can see

that all alternatives are in a sheltered position inside Amatique Bay, behind the 'Punta de Manabique'. A2 and A3 would not require breakwaters, as the ports of Santo Tomás and Puerto Barrios are located close to them and they are operative without them. A1 is the most unsheltered location, especially on the left side, but it is still behind the peninsula. However, the bay is characterized by very mild hydro-meteo conditions. The tidal range is less than 0.5m and the currents are weak. An analysis[6] showed the following:

1. Maximum wind speeds during a 6-year period are 10 m/s. The 90% confidence maximum is 6 m/s. The median maximum is 4 m/s.
2. Maximum wave heights during the same 6-year period are 1 m. With a 90 % confidence the maximum is 0.5 m and with a 50 % confidence the maximum is 0.4 m. The median maximum was 0.25 m.

Therefore, given the short fetch to A1 and these conditions, one can conclude that A1 is also in a sheltered position and most probably breakwaters would not be required.

Figure 25 Location of the alternatives in Amatique bay (source: google maps)

- Impact on coastal processes

As a first guess, without developing any hydrodynamic models and based on the similar conditions of both alternatives, none of them will cause a high negative impact in coastal processes, making both alternatives comparable regarding this criterion.

- Impact on water system quality

Both alternatives are not located in an area (or in particular, in a river) where the water system quality could decrease. This criterion is non-applicable for this case.

- Buffer area to local communities

As shown in the land use of Figure 21, there are several populated areas around A2 and A3 and some small populated areas inside A1. The required size of the port, which has been estimated approximately in 1.7 ha, would not allow a buffer area around A2 and A3, to minimize communities impacts (Figure 26 and Figure 27). On the other hand, for A1, a space of 1.7ha can be found with no or minimum impacts to communities (which are small isolated houses, in contrast with alternatives 2 and 3, which are surrounded by cities. A buffer area is, therefore,

[6] By Svašek Hydraulics on the actual site location

possible for A1. A4 differs in this case from A2 because a buffer area to Puerto Barrios would be possible, as it is located on the north of A2, further from the cities.

Figure 26 Approximate area reserved for the port in A2 and A3 (source: Infraestructura de Datos Espaciales de Guatemala (IDEG))

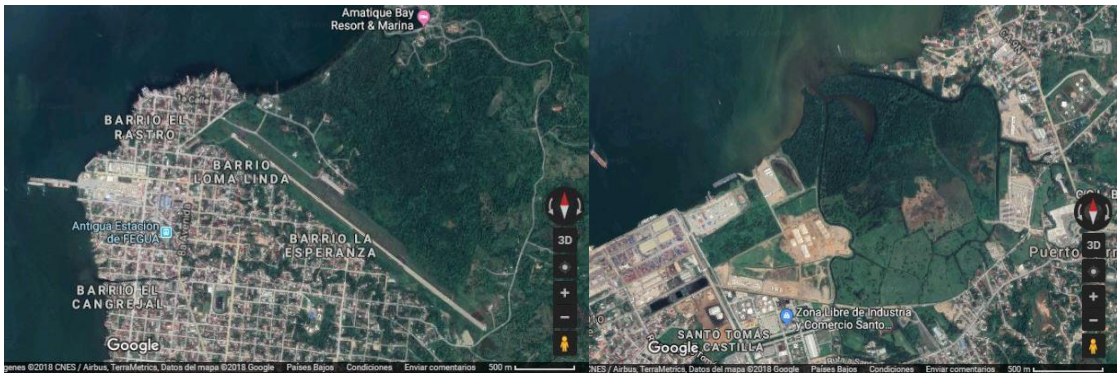

Figure 27 Surrounding communities of A2 (left) and A3 (right) (source: Google maps)

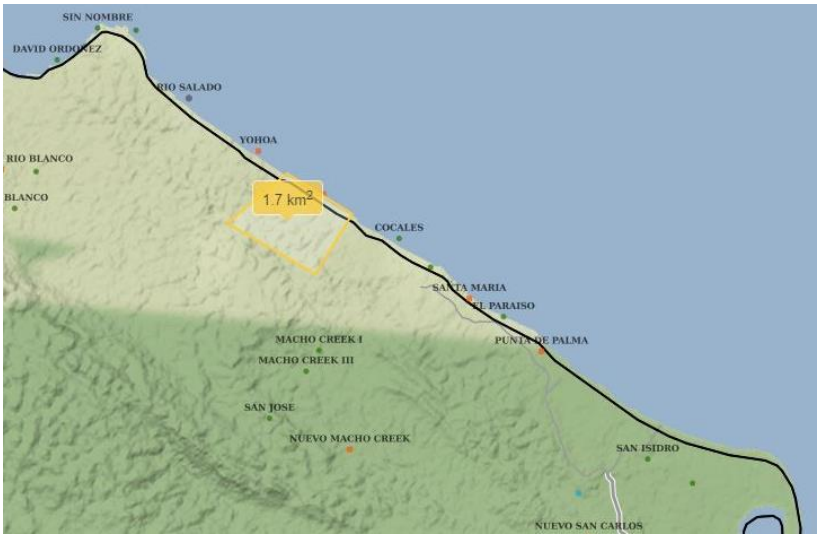

Figure 28 Approximate area reserved for A1 (source: Infraestructura de Datos Espaciales de Guatemala (IDEG))

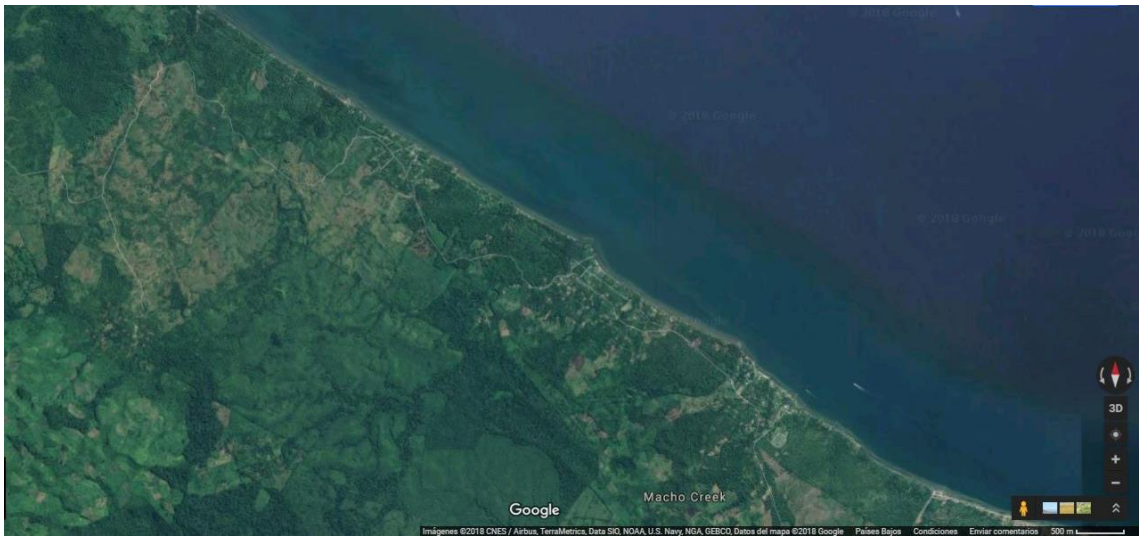

Figure 29 Isolated communities in A1 (source: Google maps)

- Impact on existing recreational areas

After doing research about recreational areas in the region of Izabal, where the alternative locations are situated, one can conclude that there is only one recreational area affected if the port was located on the right side of A1: the beach Punta de Palma (see Figure 30). However, this also coincides with the regions with communities, shown in red in the land use figure (Figure 21), being this area discarded inside A1 to avoid impacts. Therefore, existing recreational areas are not affected, due to locating the port outside protected areas, which are the main touristic attraction of the region (including the marine part, as they count with a rich biodiversity, like coral reefs).

Figure 30 Location of Punta de Palma beach (source: Google maps)

- Necessity of resettlement of communities

All the alternatives are located in low-density areas, as it can be seen from satellite images. However, it would be important to visit the sites in order to understand what time of settlements are there. A resettlement plan is important in case they are found in them, which could be beneficial or harmful for the affected communities. When informal settlements are found, resettlement impacts in a positive way because better living conditions are given to them. However, if communities which live in a traditional way with a high cultural value and who find

difficult to live in another way are probably impacted in a negative way. The information about this is not accessible for the case study and a comparison of the alternatives cannot be made.

- Impact on archaeological cultural values

The significant archaeological sites of the region are not located at any of the alternative locations.

- Employment opportunities to local communities

In terms of employment opportunities, the distance from the alternative locations to regions with skilled workers have to be determined. Alternatives A2 and A3 are located significantly close to the city of Puerto Barrios, giving an advantage for local communities. On the other hand, A1 is located at around an hour distance by car. However, it is more accessible from the city of Livingston. The distance to A1 is not large, but the road system is not functional, with many unpaved roads that must be used to reach the location.

Moreover, not only the distance to communities but the employment rate for these communities would have to be determined. Skilled labor is necessary for this purpose. Guatemala counts with national and regional port training, developed by the National Port Commission[7] which could be useful when there is a lack of skilled labor. To get a fair comparison of the alternatives, the degree of skilled labor would have to be verified by the competent authorities, which could provide with statistics that could be useful for this purpose. For testing the proposed methodology, it is assumed that the port training is sufficient to attract around 70% of the port workers from the nearby cities.

- Impact on fisheries

The location of the fishing grounds has to be analyzed to determine the impact on them when locating the port in one alternative or another. A study of the existing species in Amatique bay was made during 2008 by means of surveys and monitoring (Ixquiac, et al., 2008). After that, they were mapped, dividing it in three groups, according to the relative abundance of the species, which is associated to the type of substrate. The results are presented in Figure 31, Figure 32, and Figure 33. 'Grupo 1' ('Group 1') corresponds with the 14.4% of species in the bay, 'Group 2' with 33.0% and 'Group 3' with 8.2%. It can be concluded from the figures that A2 and A3 (around Puerto Barrios) are better locations in terms of (permanent or reversible) loss of fishing grounds than A1. The existing access channel is marked with a dotted line, to which the new approach channels would connect. It has to be noted that the location with a higher density in A1 is located in front of the beach Punta de Palma and the region with communities, so this side of A1 was discarded as an alternative. The southern part was also not preferable due to the higher forest loss involved. Alternative 1 is, therefore, limited to the half eastern part of A1, and will preferably be located as eastern as possible. For this case, it is assumed that there is a loss in fishing grounds, but it is not significant. However, this would have to be assessed by the fishermen in the area.

[7] As per the National Port Commission website (https://cpn.gob.gt/)

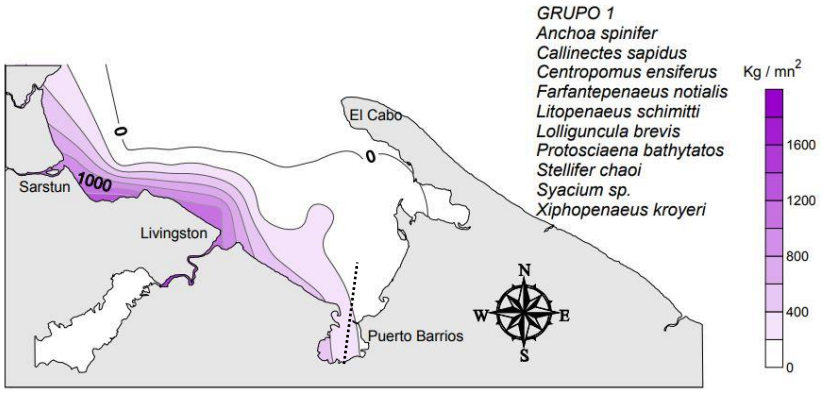

Figure 31 Density of 'Group 1' species (Ixquiac, et al., 2008)

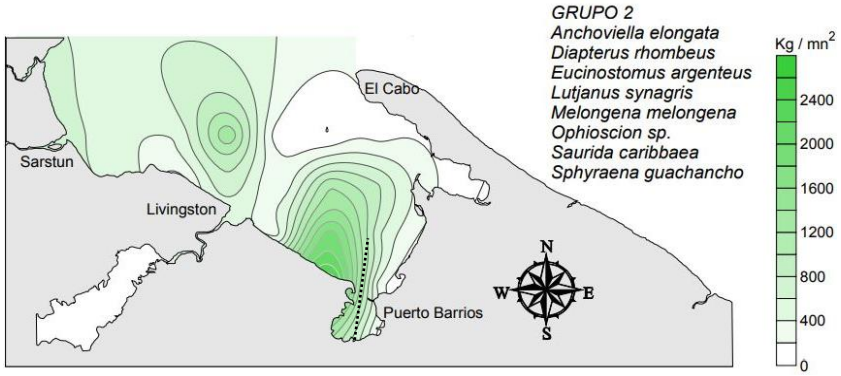

Figure 32 Density of 'Group 2' species (Ixquiac, et al., 2008)

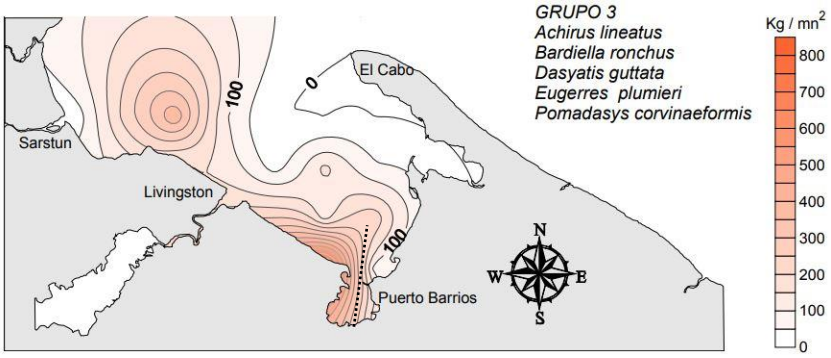

Figure 33 Density of 'Group 3' species (Ixquiac, et al., 2008)

- Impact on existing economic activities

Focusing on the existing economic activities on the land side, the same reasoning will be followed as for the impact on natural habitats, making use of the map of land uses (Figure 21). Since A1 is located on low shrub vegetation, A2 on wetlands with forest and A3 on cultivated grass, one can conclude that the latter is the less preferable alternative in terms of loss of existing economic activities, affecting farming activities.

c. Selection of location in Alternative 1

Alternative 1 was chosen as a strip of land along the coast, in order to find the best solution to avoid or minimize impacts. After considering all green aspects for the site selection, an area of approximately 170 ha (the required area for the port, considering future developments) is chosen (Figure 34). This location has been selected because its environmental performance is the best one compared to the rest of the strip A1 in terms of:

- Minimum forest loss
- Minimum distance to the new hinterland connection along 'El Golfito' lake and the river
- Maximum buffer area to communities
- Minimum impact on fisheries

On the other hand, this location counts with several disadvantages compared to other locations in A1:

- As it is located next to a river, sedimentation problems may occur, requiring higher maintenance dredging
- It is located in the most unsheltered position. The no-need of breakwaters is not certain, due to this aspect and the previous one
- The dredged volumes for the access channel are larger, as the distance to the existing channel is larger than in eastern parts of A1

Figure 34 Three alternative site locations for evaluation (source: Google maps)

d. Evaluation

Once the alternatives are selected and the criteria for developing a Green Port have been assessed, they will be evaluated, following the evaluation framework in Appendix B, in order to select the best location towards the Green Port goal. The current site of the project is also evaluated (A4). Unless stated, the reason for the score of each criterion for this alternative (A4) corresponds to the reason for the score of A2, as they are very similar due to their proximity. The evaluation is shown in Table 9.

Table 9 Score of each alternative per criteria

CRITERIA	DESCRIPTION	A1	A2	A3	A4
Impact on protected areas	A1, A2, A3 are located outside the boundaries of marine and terrestrial protected areas. A4 is located inside and no special measures for conservation are planned to be taken	+	+	+	-
Impact on natural habitats	Except for A4, none of the alternatives count with unique vulnerable species of that area, but A2 involves a higher forest loss	+	0	+	-
Use of existing port facilities	A3 is an expansion of an existing port while A1 and A2 are greenfield ports	-	-	+	-
Use of existing hinterland transport	The new required hinterland infrastructure is shorter than 2 km for A2 and A3, and longer than 3 km for A1	-	+	+	+
Use of natural conditions	A1 is located in a slightly more unsheltered location, also requiring larger dredging volumes than A2 and A3	0	+	+	+
Impact on coastal processes	n.a. (the alternatives are comparable in terms of impact on coastal processes)	0	0	0	0
Impact on water system quality	n.a. (no alternatives in a vulnerable location regarding water quality)	0	0	0	0
Buffer area to local communities	No/limited buffer area is possible for A2 and A3, while for A1 is around 5 km. A buffer area for A4 is also possible	+	-	-	+
Impact on existing recreational areas	No recreational areas are affected in any of the alternatives	+	+	+	+
Necessity of resettlement of communities	The alternatives seem not to impact a high amount of settlements, but there is no sufficient information to compare and assess the possible impacts	0	0	0	0
Impact on archaeological cultural values	Locations with no significant archaeological cultural value	+	+	+	+
Employment opportunities to local communities	A1 is located at 1 hour minimum from Puerto Barrios, while the travel time to A2 and A3 is much lower	0	+	+	+
Impact on fisheries and aquaculture	A2 and A3 impact a lower density of marine species than A1. It is assumed that A1 would not involve a considerable loss of fishing grounds	0	+	+	+
Impact on existing economic activities	A1 and A2 do not impact existing economic activities, while A3 is located on cultivated grass, and it is assumed that there will be a compensation	+	+	0	+
	TOTAL	4+	6+	8+	5+

When assigning a score to each criterion for each alternative, A3 (the expansion of Puerto de Santo Tomás) is the most favorable location, followed by A2 (next to Puerto Barrios), A4 (the current project site) and finally A1 (opposite Livingston). This would be the score without

applying the weighting system in Appendix B, which closely depends on the stakeholders and who are essential for this process. For each criterion, the relevant stakeholders would expose their concerns, provide pertinent information that would facilitate the assessment of the site alternatives and state their preference. To obtain the best solution towards the Green Port goal, the weighting system has to be applied, which can be derived from this stakeholders' cooperation, as it gives importance to the relevant criteria for the project. The stakeholders are not accessible during this research; therefore, the proposed weighting system cannot be applied. However, several scenarios assuming their thoughts and opinions are developed in the following section in order to apply the proposed evaluation framework completely.

e. Stakeholders' scenarios

The relevant stakeholders identified at the beginning of this section could have different views with respect to the port location. Each stakeholder group could have a preference for a particular alternative site, depending on their concerns or priorities. A summary of the possible views that each group could have is included in Table 10.

Table 10 Possible views of the different stakeholders with respect to the alternative sites

STAKEHOLDERS	VIEW A	VIEW B
CONAP COMUDE	The location in A4 would induce high negative environmental impact to the protected area.	It is possible to relocate or conserve the affected species and maintain the integrity of the natural system in A4.
Municipality of Puerto Barrios	A2, being beside the city, will induce negative impacts and reduce the quality of life of the citizens.	A1, located at more than 1 hour by car from the city, is a barrier for applying for a job in the port, reducing the job creation
Municipality of Santo Tomás	A3, being beside the city, will induce negative impacts and reduce the quality of life of the citizens.	A1, located at more than 1 hour by car from the city, is a barrier for applying for a job in the port, reducing the job creation
Municipality of Livingston	The citizens would be less benefited if the port is located on A2, A3 or A4	All alternatives would create job from citizens of Livingston
COMUDE	Future urban expansions are planned for the areas A2 and/or A3	No future urban expansions are predicted for the alternative sites
Communities on site	The affected communities on some alternatives live in a traditional way	The affected communities can be resettled and provided with a higher quality of life
Fishermen	High loss of fishing grounds and their activities would be negatively impacted	Non-irreversible or significant loss in the fishing grounds
Affected people on their economic activities	Loss of land for certain economic activities, with high negative impact	Land with low value and insignificant impact

The combination of any of these views would give a different final score for the alternatives, when the weighting system is applied, because it gives importance to what stakeholders find essential. Depending on their views, the criteria which the stakeholders' groups give importance to and the ones which are not relevant can be deduced. For instance, if the fishermen base their income on certain fishing grounds, the criterion becomes important, because the loss of these

fishing grounds would result in high negative consequences. On the other hand, if the loss would not be significant for this group, the criterion would have a lower weight. Another example relates to the protected area; if the difference between locating the port inside or outside the protected is high because of the related environmental impacts, then the criterion is important. On the other hand, if the integrity of the natural habitat can be maintained, then the criterion has a neutral weight, but this is something that the relevant stakeholders would have to assess.

In order to summarize and group the different views, three scenarios have been determined, which are used to apply the proposed weighting system and to obtain the final score of each alternative site. These scenarios are created by giving priority to certain criteria, assuming that these could be the different conclusions derived from the stakeholders' perspectives.

- Scenario 1: priority is given to minimizing the nuisance on nearby communities

This scenario could occur if it is concluded that the concern of the stakeholders is maintaining the quality of life of the nearby communities. If the priority is given to minimizing negative impacts due to nuisance to the cities close to the alternatives, several aspects are important: establishing a buffer area between the boundaries of the port and the nearby communities, maintaining existing recreational areas and avoiding or minimizing the resettlement of communities. Therefore, three criteria can be assigned with a weight 2 ('important'), which are 'buffer area to local communities', 'impact on existing recreational areas', and 'necessity of resettlement of communities'. It is assumed that the rest of the criteria are considered neutral (weight equal to 1).

- Scenario 2: priority is given to enhancing job opportunities

In this hypothetical case, the importance is given to maintaining the actual sources of income of the citizens while at the same time maximizing the creation of jobs due to the port development in that location. Several criteria are weighted as 2, which are 'employment opportunities to local communities', 'impact on fisheries and aquaculture', and 'impact on existing economic activities'. It is assumed that the rest of the criteria are considered neutral (weight equal to 1).

- Scenario 3: priority is given to protecting the local environment

In this scenario, the protection of the local environment is the first concern, as it a region which is rich in biodiversity, counting with several protected areas along the coast. Therefore, the criteria of 'impact on protected areas', 'impact on natural habitats', and 'use of existing port facilities' gain relevance, to which a weight of 2 would be given. It is assumed that the rest of the criteria are considered neutral (weight equal to 1).

The score of each alternative considering the weights that correspond to each scenario are included in Table 11. The score derived from a combination of the different scenarios is also included. The scores marked in red show the lowest punctuation for that scenario while the score in green shows the highest punctuation and therefore, the preferred site for that scenario.

Table 11 Alternative sites scores for each scenario

SCENARIOS	A1	A2	A3	A4
Score without weighting system	4+	6+	8+	5+
Scenario 1	6+	6+	8+	8+
Scenario 2	5+	9+	10+	8+
Scenario 3	5+	6+	11+	2+
Combined scenario 1,2,3	8+	9+	13+	8+
Combined scenario 1,2	7+	9+	10+	11+
Combined scenario 2,3	6+	9+	13+	5+
Combined scenario 1,3	7+	6+	11+	5+

From the previous table, several conclusions can be derived. In the first place, it can be seen that for all scenarios, except for the combined scenario 1,2, the preferred alternative site is A3. The exception is found when the importance is given to the communities rather than the environment, which is coherent as A3 is located inside the city and A4 (with the highest score) is located at a certain distance, but in the protected area. In the second place, the table shows that the difference between the highest and lowest score varies depending on the scenario. For instance, for scenario 2, there is no significant difference between the scores of the alternatives whereas for scenario 3, there are eight points of difference between the best scored and the least scored alternative. It is a reasonable result because A4, located in a protected area, scores much less than the rest when the priority is given to the local environment. Third, the score of A4 changes from the highest to the lowest depending on the scenario that is being considered. This demonstrates that the stakeholders' cooperation is essential for identifying the preferred alternative in terms of sustainability, because A4 is beneficial for the nearby communities but damaging to the local environment. Nevertheless, the alternative with the highest score was A3 before the application of the weighting system and for the majority of the scenarios this result does not change.

6.3.2. Masterplanning

The preferred site obtained from the proposed scoring system, which is the area for expansion for Puerto de Santo Tomás, is not the area reserved and owned for Amatique project. For the masterplanning phase, the proposed methodology will be tested by assessing the masterplan on the real site, but it has to be noted that this site was not scored as the best solution.

Given the market studies, for the first phase of development, Amatique Terminal would require one container terminal with two berths (where bananas are the main export product which is handled), one break-bulk terminal with one berth and one liquid bulk terminal with one berth (for palm oil). It is expected that the container capacity will be increased with two berths more over the years. However, the palm oil and break-bulk market have not been studied.

a. Stakeholders

The relevant stakeholders for the masterplanning phase have to be identified, as the cooperation with them is crucial to obtain a sustainable solution. The ones that contribute to the Green Port goal are included in Table 8; the stakeholders about technical and legal matters have been ignored. A co-creation with stakeholders has not been done for this project. The stakeholders were identified but they did not closely collaborate during the masterplanning process. The stakeholders' input (included in the table below), would be necessary to optimize the masterplan in order to achieve the Green Port goal.

Table 12 Relevant stakeholders for the masterplanning

STAKEHOLDERS	TASK	INPUT
Cargo producers	Potential clients	-Requirements
Terminal operators	Potential operators	-Requirements -Possible sharing of facilities
Industries	Potential financers or shareholders	-Possible benefits and added value -Possible financing
CONAP (Consejo Nacional de Áreas Protegidas)	Coordination of the protected areas in Guatemala	-Cooperation for conservation areas
FUNDAECO (Fundación para el Ecodesarrollo y la Conservación)	Protection and conservation of protected areas in Guatemala	-Cooperation for conservation areas
Municipality of Puerto Barrios	Administration of Puerto Barrios and influence on public acceptance	-Concerns of community -Information of state of existing hinterland connection and future upgrading plans -Cooperation for recreational areas -Possible financing
Amatique Bay Resort	Located close to the site	-Concerns (impacts, lower occupation)
Community of Creek Negro	Located close to the site	-Way of living -Concerns -Relation with site and use of access road
Land owners in the area of influence	Own the land around the site and for the road	-Concerns -Possible benefits or added value
Universities (San Carlos University)	Give local expertise and do scientific research	-Collaboration on conservation measures -Possible negative impacts and measures

b. Methodology

The layout designed by the port developers is based on the acquired area and, in particular, on the property boundaries. These boundaries are the main reason for the distribution of the terminals and water areas in the final design. The owned property is characterized by an irregular shape, and there is no certainty about the possibility of buying other areas around. Therefore, an attempt has been made to prepare the layout within these boundaries as far as

technically possible. However, this limitation had negative consequences that also become a barrier for certain green goals, which will be described below when testing each criterion of the methodology.

The final design is shown in Figure 35, where the present property boundaries are marked (in red). The break-bulk terminal is located on the north (consisting on one berth), the container terminal on the east (two berths) and the liquid bulk terminal on the south (with a berth on the south part of the basin and a tank farm located inland beside the container yard, on the south)

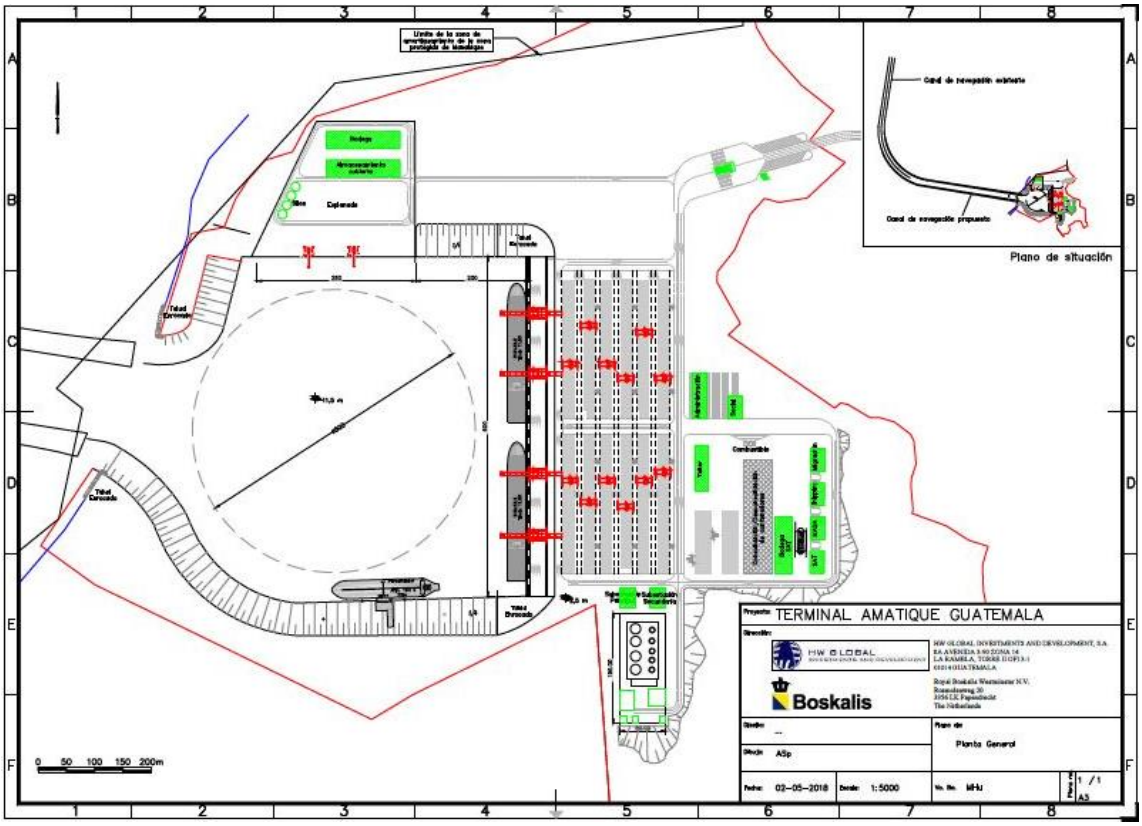

Figure 35 Amatique final layout design (source: masterplan document)

The proposed methodology has been applied to this design. Each criterion is evaluated and improved in terms of sustainability when possible. For several criteria, this improvement is not straightforward, as the cooperation with stakeholders is a requirement. In this case, the contact with stakeholders is not possible and some assumptions will be made where required.

- Productivity

The smaller the size of the port, the lower the negative environmental impacts are on the local surroundings, natural habitats and biodiversity. By distributing the port areas in an efficient way, the required area can be minimized. For Amatique port, this was clearly achieved due to the restriction of locating the port inside the property boundaries. The irregular size and limited dimensions of this area also limit the port area.

- Distribution of port terminals considering communities

The site is located at a certain distance from the main cities in the area and other communities. The direct impacts from the port (light, noise, visual impact) would only be noticed by the Amatique Bay Resort, located south from the site (Figure 36). There are also other isolated

communities around the site (Community of Creek Negro), but it is unknown where they are exactly located.

The possible negative impacts would not be noticeable by a large number of inhabitants. Even so, the terminal which could induce a higher negative impact, which is the break-bulk terminal (because it could also handle dry bulk cargo) is located further from the resort. The palm-oil terminal is the closest terminal, but it does not involve dust and the produced noise is lower than for break-bulk and container terminals. However, the height of the tanks could form a visual barrier. Wind studies or 3D visualizations have not been carried out, so the impact cannot be properly assessed.

Figure 36 Site location and Amatique Bay Resort (source: Google maps)

- Use of land given type of soil, volumes, and quality

A topographic survey showed the results of Figure 37. Most of the area consists of a flat land, at a level close to Mean Sea Level (MSL). On the south-east side, there is a hilly area with levels up to 25-30m above MSL, and the layout was designed to avoid the excavation of this part, by locating the terminals and water areas to the north. The quality of the soil is poor and similar in all flat locations of the site and therefore, there would not be a significant difference in terms of optimization of soil given its quality or type if the distribution terminal or water areas are changed.

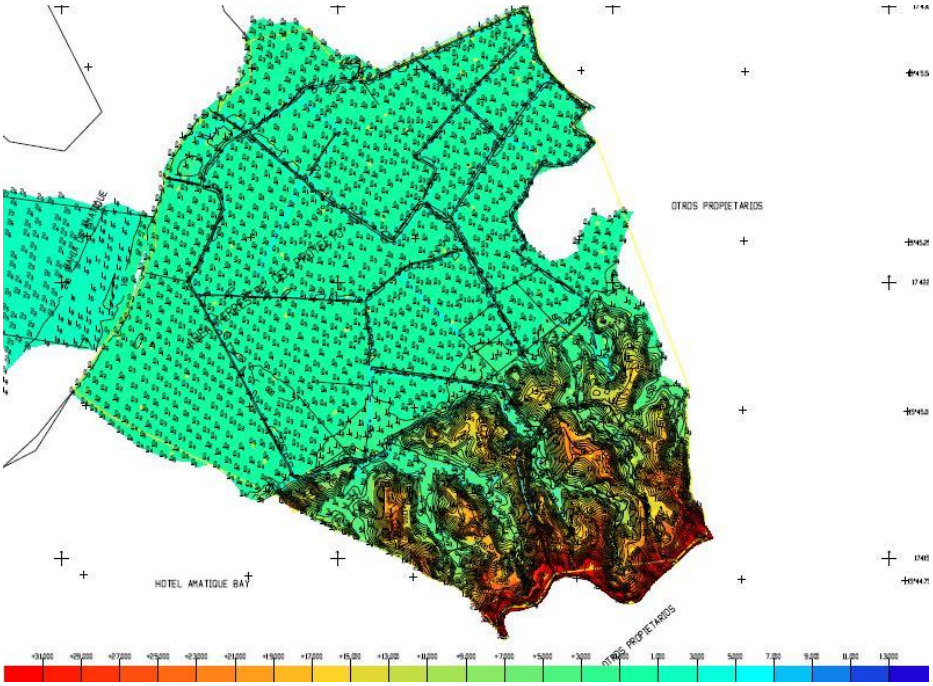

Figure 37 Results of a topographic survey

- Flexible layout and adaptive planning

The designed layout, based on present property boundaries, is not based on flexibility. The uncertainty about the acquisition of extra land which forces the design to remain inside the boundaries is the main barrier to obtain a flexible solution. Expansion possibilities are restricted, especially on the south side, both because of this boundary and due to the location of the tank farms from the liquid bulk terminal beside the container terminal (this location was chosen to stay within the boundaries). Moreover, a detailed container forecast has been carried out, which indicates the requirement of a third container berth for 2027 and a fourth for 2034. The capacity of the container terminal cannot be increased only after 15 years of operation if the forecast reflects what actually happens, due to the limitation described above.

In addition, no detailed market studies have been made for the palm oil and break bulk, and the decision to include dedicated terminals from the first phase is made on assumptions. The only available forecast shows that a palm oil berth would be needed for 2024. For the case of the break bulk terminal, a lack of flexibility can be appreciated due to the quay length. The reason is that, given the lack of a forecast, and in order to account for uncertainties, the dimensions of this terminal could be designed to be adequate for containers, so that it could be transformed if necessary due to a change of requirements. The break bulk quay length is 280 m, whereas the minimum required quay length for the container terminals is 300 m. Twenty meters of additional quay length could make a difference in the future and a large amount of negative impacts could be avoided, if the terminal could be transformed instead of constructing a new one. This quay length was reduced compared to the preliminary design because the container quay wall orientation was rotated around 30º to place it in N-S direction with the purpose of avoiding the hilly area of the south.

In order to improve the environmental score, it would be preferable if the tank farm of the palm oil terminal was located behind the liquid bulk berth (on the south or southwest of the port), instead of beside the container yard (on the southeast) (Figure 38). This would not restrict the possible expansion plans to the south. Moreover, it is also advisable that the quay length of the

break bulk terminal is extended up to 300 m, obtaining a solution which can be used by different types of cargo in case there is a difference with the forecasted volumes. The container terminal would have to be shifted 20 m to the east or rotated in order to maintain a safety distance between these two terminals for a future basin that would give access to a third container berth located at the north (Figure 38).

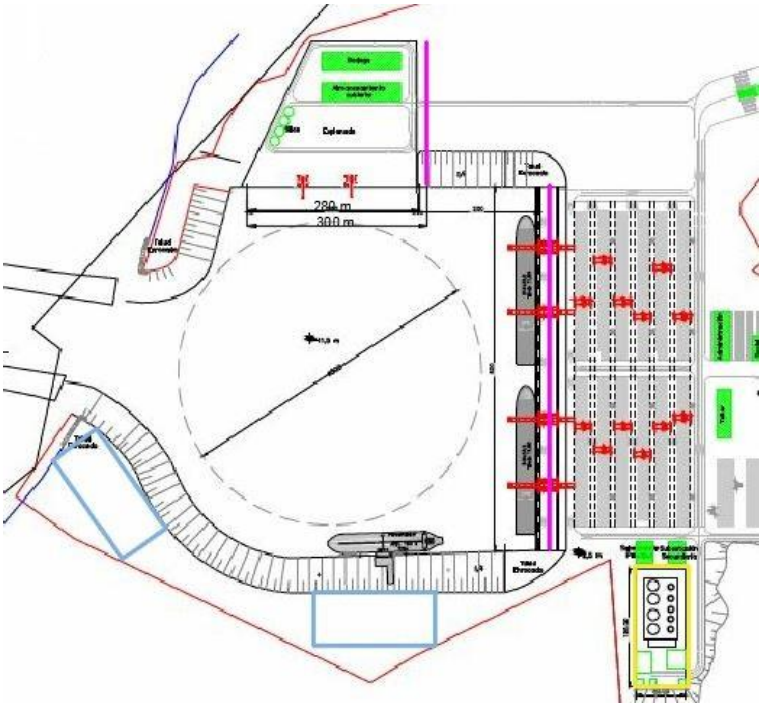

Figure 38 Possibilities for increasing flexibility: different locations for the tank farm (in blue, compared to the current location in yellow) and expansion of the break-bulk quay length with the required shift of container quay (in pink)

- Compensation measures

In order to compensate for locating the port inside a protected area, a compensation measure is planned by the port developers: the construction of a bird island. The purpose is to enhance biodiversity and use the dredged material efficiently, in a nearby location compared to the location of the disposal area, which induces also a reduction in the emissions, possible spills, fuel use and time. However, this measure does not compensate for the location of the port in a protected area, since its size and benefits to biodiversity are much lesser than the losses. To have a complete assessment of the negative impacts, the organizations in charge of the conservation of this areas and other local nature-interest groups could be engaged, to arrive at measures that would induce a high positive impact, such as conservation sites.

- Use of common infrastructure and facilities

In the final layout design, three separate terminals are designed for the first development phase, although the development of the volumes of palm oil and break bulk have not been studied and forecasted. This lack of information would give a reason for the sharing of facilities during the first years of the development, given that it is possible that in future, after these terminals are constructed, the throughput volumes are reduced, and they are not necessary.

Several alternatives for the first development phase are possible, given the market study information for the containers sector. Figure 39 includes a timeline from the start of operations (2020) up to 2046. Its purpose it is to show the possible future expansions of the terminals over the years, depending on different alternatives for the first development phase. It shows in which

years an additional terminal or berth is required, given the forecast (marked with an arrow and a sketch of the additional berth in the date of required start of operations). 'Alternative A' is the selected option while options 'B,C,D' are other possible alternatives, with a higher flexibility due to the sharing of facilities and lower initial investments. These are elaborated on below.

A. Alternative A includes three separate terminals (two container berths, one break-bulk berth and one liquid bulk berth). It is forecasted that a third and a fourth container berth would be required in 2027 and 2034, respectively. It is unknown whether additional break-bulk or liquid-bulk berths would be required in the future.
B. Alternative B has the purpose of minimizing CAPEX by sharing facilities in one terminal with two container berths, but which involves the construction of additional berths in a shorter time. It is predicted that an additional berth would be needed in 2024, either a palm oil berth or a container berth. In the first case (B1) the construction of a third container berth would be required by 2027 and another one by 2034. In the second case a fourth container berth would be needed by 2032. Future expansions could be a palm oil berth and/or break-bulk berth (B2) or a container berth, where all these products would be handled (B3).
C. Alternative C includes a container terminal (two berths) and a palm oil terminal (one berth). This option is between alternatives A and B1, in terms of investment, and the break-bulk volumes would be handled in one container berth, leaving a separate berth for liquid bulk volumes.
D. Alternative D would involve a container terminal and a multipurpose terminal where the handling of break-bulk and palm oil volumes would be shared.

In terms of a Green Port approach, alternatives C and D may be preferable, as there would be a lower disruption to the environment if one of the three terminals is not constructed and the facilities is shared, especially because it is not certain if the volumes would increase considerably. They are also preferred options compared to alternative B, which would require the mobilization of all equipment to contruct an additional berth to be operative only four years after the start of operations, leading to higher negative environmental impacts than constructing both terminals in the first phase.

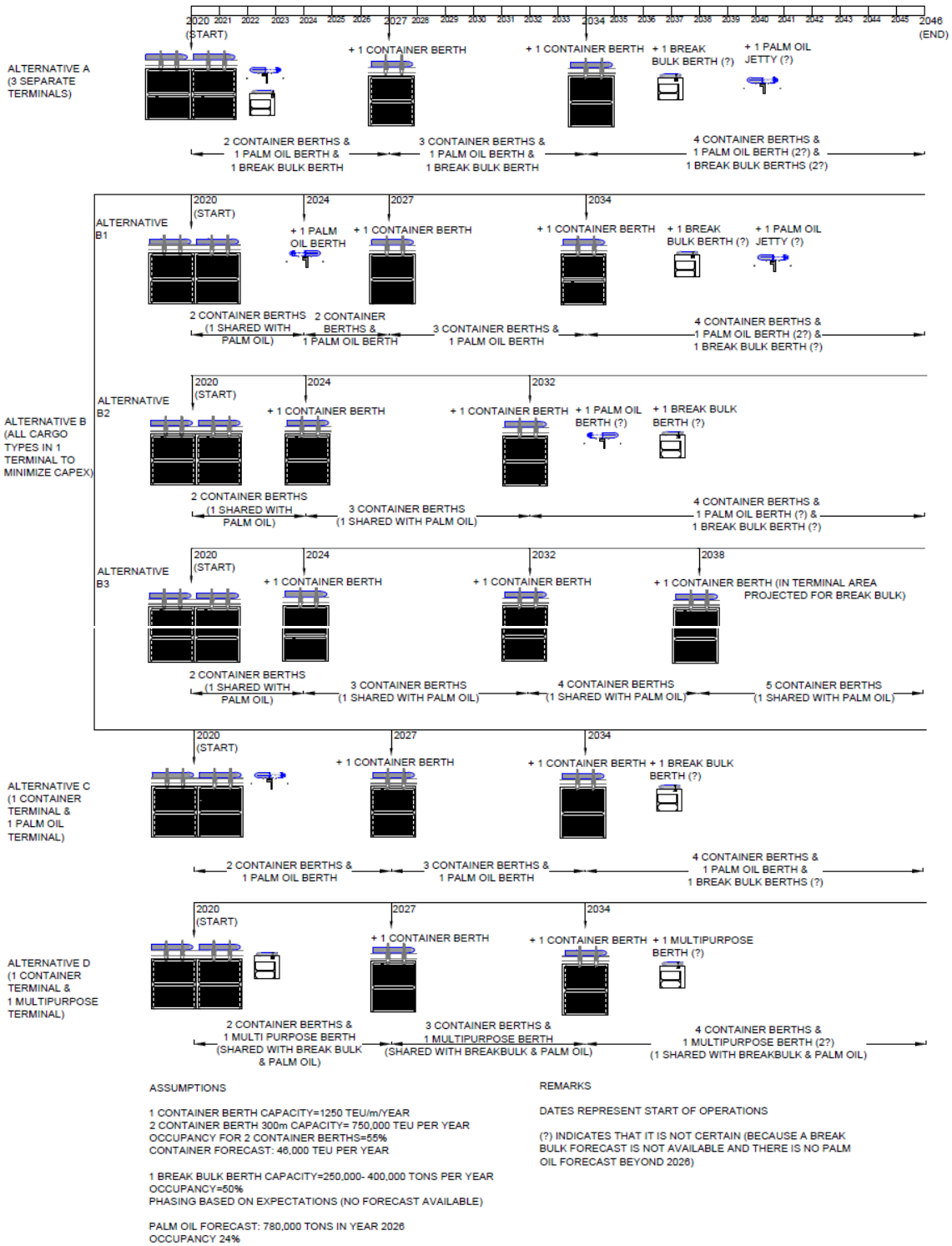

Figure 39 Alternatives for first development phase for Amatique (source: own elaboration)

- Use of waterfront and water depths

The turning circle occupies most of the harbor (except for the berth pockets of the three terminals) which will be used by all vessels, including those with the largest draught. Therefore, locating the terminals in other positions would not reduce the dredged volumes. The liquid bulk tanks located in the terminal do not require water access and they are located inland (see Figure 38), which is an approach towards the green goal. It also gives the option of expanding the

terminal with another berth; however, this restricts expansion possibility of the container terminal.

- Use of environmentally friendly transport solutions

A road will be developed to connect the port with the existing highway, with the alignment shown in Figure 40. This type of hinterland connection involves the highest negative environmental impacts, unless some measures are taken such as constructing an electric overhead so that trucks resemble to trains (which emit less) or using electric trucks during operations. The other possible alternative is to use the existing railway system (Figure 22) and extending it to the port boundaries.

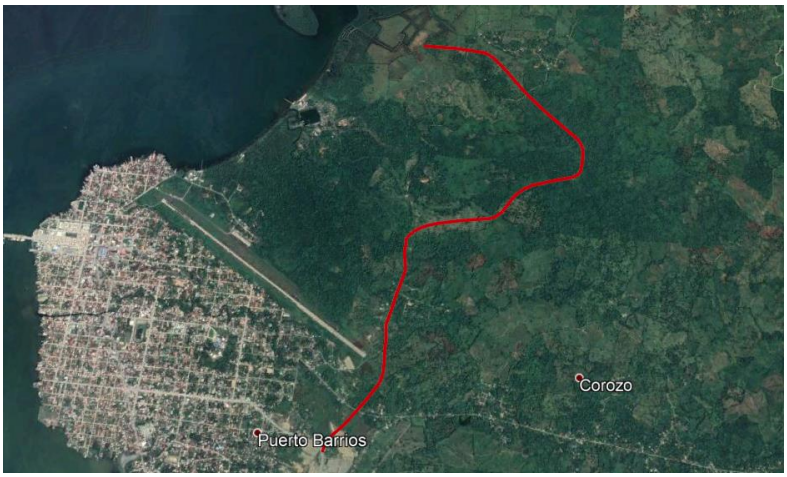

Figure 40 Road alignment

- Integration of the port into the urban or natural environment

By avoiding the hilly area located on the southern part of the port, it is being integrated into the natural environment. Apart from being a measure to maintain the existing environment, it forms a natural visual barrier, which is beneficial for nearby communities and it is one of the measures that contribute to the Green Port goal.

Other aspects that contribute to this integration are the lack of breakwaters, and the use of natural slopes inside the basin (except for the entrance of the port where a revetment that provides more protection is needed).

If the port was not located on a protected area, the option of dredging the turning circle in open sea would be advisable in terms of integration into the natural environment; nevertheless, it is not allowed due to the protection of these coastal waters. The construction of infrastructure is not allowed because only right of way is given. For the dig-in option, the disruptive effects on the marine environment and the impacts on fisheries would be reduced.

- Connectivity

The port does not disrupt the transport flow of communities and it is assumed that the flow of species is also not disrupted, given the location and configuration of the port. Moreover, as studied in the feasibility stage, the capacity of the highway to which the road will connect will not be surpassed due to the traffic from the port, as there are expansion plans to upgrade and expand this main city road. Therefore, the existing connectivity to the city would not be at stake.

- Conservation areas

No conservation areas are planned to be developed in or around the port. Nature related stakeholders could be engaged in order to find locations where conservation is valuable, which is especially relevant in this case due to the site location in the protected area.

- Recreational areas

No recreational areas are planned to be developed. A cooperation with nearby municipalities could benefit the communities and could also profit the port. This could be carried out on the southern part of the port, where there is a margin from the harbor or palm oil berth to the property line, and because no expansions are expected on that side.

- Inclusion of economic and social aspects

No added value is created to stakeholders beyond communities, meaning that communities are benefited by means of employment opportunities or the integration of the port into the environment; however, other stakeholders have not been considered in the masterplanning phase in order to create value for them. This means that, for instance, industries or terminal operators were not engaged for this process to search for a value which could not only benefit themselves but also the port (they can become shareholders or financers).

c. Evaluation

After the evaluation of each criterion, the total score of the masterplan by means of the proposed evaluation framework is included in Table 13. A descriptive summary of the reason for that score is also included.

Table 13 Score of the masterplan per criteria

CRITERIA	DESCRIPTION	A4
Productivity	The port areas are distributed efficiently, and the required area is minimized	+
Distribution of port terminals considering communities	The terminals with higher impacts are located further from the resort, but no detailed studies have been carried out	0
Use of land given type of soil, volumes, and quality	n.a. (the area is flat, and the type and quality of the soil is similar all around the site)	0
Flexible layout and adaptive planning	The designed layout is not a flexible solution, that accounts for uncertainties and future developments, due to the avoidance of the hilly area and the restriction related to the property boundaries and the location of the tank farm	-
Compensation measures	The bird island serves as a compensation measure; however, the size is not comparable to the degraded areas inside the protected area	0
Use of common infrastructure and facilities	Three separate terminals are designed separately, while there would be options for sharing facilities	-
Use of waterfront and water depths	The waterfront and water depths are used in an efficient way	+
Use of environmentally friendly transport solutions	A road system is developed instead of an alternative environmentally friendly transport solution	-

Integration of the port into the urban or natural environment	The port is integrated into the surrounding natural environment	+
Connectivity	The existing flow and connectivity is guaranteed	+
Conservation areas	No conservation areas will be developed	-
Recreational areas	No recreational areas will be developed	-
Inclusion of economic and social aspects	No added value is created to stakeholders beyond communities	-
	TOTAL	2-

The current masterplan obtains a score of 2- when evaluated with the proposed framework. It has to be noted that the majority of the negative scores are obtained because no added value is given to the local environment and other stakeholders, as the masterplan is designed without stakeholders' co-creation. Moreover, this score is determined without applying the scoring system, which gives importance to the criteria that stakeholders find valuable. In order to apply the weighting system, similar scenarios as for the site selection process have been assumed, which are elaborated on in the following section:

d. Stakeholders' scenarios

- Scenario 1: priority is given to maintaining the quality of life of nearby communities

If the main priority derived from the stakeholders' engagement is the wish of maintaining the quality of life of the communities, several criteria would be weighted as 'important' (weight 2). These are 'distribution of port terminals considering communities' (in order to reduce nuisance), 'use of environmentally friendly transport solutions' (to avoid high levels of contamination in the cities), 'integration of the port into the urban or natural environment' (to maintain the beauty of the area), and 'connectivity' (to ensure that the current flow is not at stake). It is assumed that the rest of the criteria are considered neutral (weight equal to 1).

- Scenario 2: priority is given to minimizing the negative impacts to the local environment

For this case, if the stakeholders' groups find it as relevant, the priority is given to minimizing the negative impacts on the local environment. This means that every measure that contributes to maintaining the current state of the area would be given a weight 2. This includes the minimization of the required area, the optimization of the volumes, compensation for damages to the environment and integration of the port into the surroundings. Therefore, the criteria weighted as important are 'productivity', 'use of land given type of soil, volumes, and quality', 'compensation measures', and 'integration of the port into the urban or natural environment'. It is assumed that the rest of the criteria are considered neutral (weight equal to 1).

- Scenario 3: priority is given to adding value to the region

In this scenario, the priority is given to adding value to the region (to the local environment, the nearby communities, industries, etc.), rather than on minimizing the negative impacts related to the port development. The relevant criteria for this scenario are 'conservation areas', 'recreational areas', and 'inclusion of social and economic aspects'. It is assumed that the rest of the criteria are considered neutral (weight equal to 1).

The score of the masterplan considering the weights that correspond to each scenario are included in Table 14. The score derived from a combination of the different scenarios is also included. The score marked in red shows the scenario for which the masterplan design obtains a lower score, while the score marked in green shows the opposite.

Table 14 Masterplan score for each scenario

SCENARIOS	A1
Score without weighting system	2-
Scenario 1	1-
Scenario 2	0
Scenario 3	5-
Combined scenario 1,2,3	2-
Combined scenario 1,2	1+
Combined scenario 2,3	3-
Combined scenario 1,3	4-

Several conclusions can be derived from the scores of each scenario. In the first place, it can be concluded that if the stakeholders find the creation of added value valuable (scenario 3), the masterplan obtains the lowest score. The reason is that the masterplan is based on minimizing impacts rather than creating added value, which is the traditional approach of port developments. The same reasoning justifies the highest score for the combined scenario 1,2, which is based on minimizing impacts to local communities (or maintaining their quality of life) and to the local environment. Moreover, it can be seen that from the original score without applying the weighting system and the updated one, the score varies up to three points (higher or lower), which is lower than in the case of the site selection, as in the site selection the restrictions are limited, while for the masterplan the location is already selected, and the degree of freedom is not so high.

e. Optimization of masterplan

To optimize the current masterplan, the cooperation with the stakeholders is the first step. Via this cooperation, conservation or recreational areas could be derived if it is found that they could be good opportunities for enhancing certain species in the area or for promoting tourism by means of recreation around the port. The same applies to the compensation areas, because different opportunities could be identified and the most beneficial could be selected. These measures that create added value could also improve financing if the nearby municipalities or the nearby resort find it interesting and are willing to invest. The contact with local industries could also benefit them if dedicated facilities for their operations are planned, which could also contribute to the financing of the project. In addition, the contact with possible clients and terminal operators could give information on whether a sharing of facilities is possible, which could indicate that some terminals are not necessary, reducing the negative impacts. The scores of the criteria ‘compensation measures’, ‘use of common infrastructure and facilities’, ‘conservation areas’, ‘recreational areas’, and ‘inclusion of economic and social aspects’ could be improved, leading to a greener solution.

Secondly, there are other criteria for which the score can be improved, and which are related to the layout of the port and distribution of terminals. The use of common infrastructure is one of

them, because as explained in the previous section, opting for a share of facilities in the container terminal or the break-bulk terminal (alternatives C or D in Figure 39) seems to be a preferable solution given the forecast. In the optimized layout, only two terminals would be included; however, the possible clients or terminal operators are not contacted, and the input is relevant for this measure. Moreover, the port developers decided to develop three separate terminals, and for that reason, this is not changed in the optimized masterplan (but would improve the score if after the stakeholders' contact it is found that there are not restrictions in handling the different commodities in the same terminal).

The other criterion to be improved by means of changes in the layout is 'flexible layout and adaptive planning'. As explained in the previous section, the current layout is not flexible due to three reasons:

- The property boundaries, which limit future expansions and in which the distribution of the terminals is based on
- The break-bulk terminal quay length, which does not allow containers to berth in case of change in requirements
- The location of the tank farm, which does not allow for future expansion of the container terminal

An optimized layout is proposed to improve the flexibility and possibilities for expansion (Figure 41), in which the property boundaries are not considered as a barrier, which would be the ideal situation, but which is not followed because the investor is private, who are in general characterized by a short-term mentality (minimum investments and maximum benefits in the short-term). The optimized layout includes:

- The expansion of the break-bulk quay length up to 300m, the required quay length for the container berths.
- A rotation of the alignment of the container terminal, parallel to the coast, to favor future developments and because with this alignment the expansion to the south would involve less disruption to the environment as the hilly area would be less affected overall.
- The relocation of the palm oil berth to the east, and the tank farm behind it, to leave space for another possible future berth between this berth and the container terminal and not to disrupt a possible (and probable, given the forecast) expansion of the container terminal to the south.

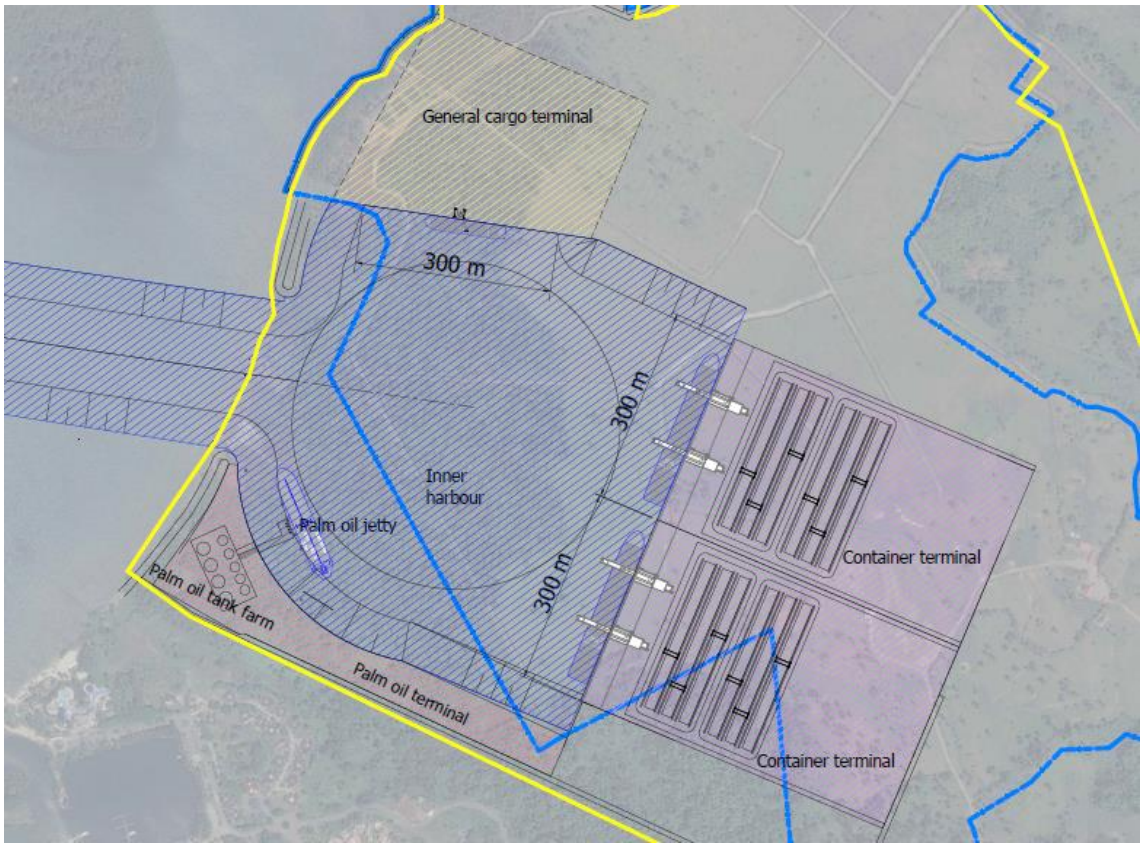

Figure 41 Optimized layout in terms of the proposed framework (source: own elaboration)

For this layout, the score would change from 2- to 0, as the score of the criterion 'flexible layout and adaptive planning' would become a +. If the commodities were handled in one or two terminals rather than 3, the overall score would become 2+. Moreover, if the stakeholders were engaged, opportunities for recreation, conservation or other economic or social activities could be developed, improving the score up to 8+, which would depend on how valuable they find this added value.

6.4. ISSUES IN APPLICATION OF METHODOLOGY AND REFINEMENT

The proposed methodology and evaluation framework for a Green Port has been tested with the case study. This leads to the identification of several issues when it is applied to Amatique port, allowing to make a refinement of the proposed framework, in order to make it practical and applicable to other similar port projects around the world. The identified issues during application and how the framework has been refined is elaborated on in this section.

6.4.1. Site selection

Regarding the implementation issues during the site selection process, the attention is given to those which are directly related to the proposed methodology, omitting the general issues related to the lack of information in the first development phase of a port project. This phase is normally based on a desk study and the required information may only be available from open sources. This information may come along with issues related to the accuracy of the obtained data, the consistency of the data between different sources, the degree of reliability and update

of information, etc. These aspects have been considered during the analysis and they have been left aside in this section.

The first issue is both related to the accessibility of data and the involvement of stakeholders. Some information which is essential in the process of developing a Green Port may only be provided by stakeholders because there is no available information that can be obtained from open sources during a desk study. Moreover, the cooperation with stakeholders is necessary for the green development. The impact on existing fishing grounds, aquaculture activities or other economic activities may only be assessed when talking to the different stakeholders. The possibility of a compensation or necessity of relocation can be derived from this cooperation. The same applies to the availability of skilled labor, which can only be assessed after involving suitable institutions from the Government or the municipalities. Another limitation of the desk study is the obtention of information such as the possibility of relocation and conservation of species to ensure the integrity of the natural system, for which expertise would be needed (i.e. CONAP, FUNDAECO, etc.). With all this information, the score of the criteria in the evaluation framework may change, in particular for A4, which could lead to the result of another site as the best alternative when considering the proposed methodology.

Another issue is that some impacts of selecting a site cannot be assessed until a detailed study is made, which are only confirmed after construction. Therefore, some criteria such as 'impact on coastal processes' and 'impact on water system quality' can only be assessed roughly and will only have an impact on the best solution when the alternative sites are considerably different and if one of them clearly shows that the impact would be larger.

The ideal situation during the site selection process would be going to the site, in order to fully understand what there is, what the losses could be and what can be gained in each alternative site and to involve the relevant stakeholders. However, this involves costs and time spent, which is not favorable for the business case.

The scoring system of one of the criteria in the site selection phase was refined: 'Impact on natural habitats', as it may not be possible to guarantee the conservation of species from the first stage of development and because this conservation is also included in other criteria. The modified version is found in the Appendix (B) and the original version before testing the evaluation framework was the following:

Impact on natural habitats	+	The location does not count with an important natural habitat and a smooth relocation and conservation of the affected species can be guaranteed
	0	The location does not count with an important natural habitat; conservation of affected species is possible but cannot be guaranteed
	-	The location disrupts an important natural habitat and/or the relocation and port activities will probably lead to loss of species

6.4.2. Masterplanning

When testing the masterplanning phase with the case study, the main difficulties that arise relate to the interpretation of the criteria. Evaluating what the meaning of several words are when applied to a masterplan is not a simple task (i.e. 'integration', 'disruption', 'significant', etc.). This has to be kept in mind when scoring the criteria for each particular case and shall be treated with common sense, in order to be applicable to other projects.

In addition, the measures to be followed towards the green goals are not as straightforward as the measures for the site selection, which mainly referred to the characteristics on the site instead of what could be carried out in them. In this phase, there is not one single solution and optimizations are always possible with extra surveys or studies and may not be straightforward. For instance, when referred to 'maximum productivity' and 'minimum required total area', it has to be done as a rough guess, because the idea is to increase productivity and reduce the required total area as much as possible, instead of developing mathematical models from the first development phase to check it.

Two criteria from this phase have been refined after proving with the case study. The reason is to account for sites with homogeneous soil where a different location of the terminals would not reduce the excavated or disposed soil volumes and to avoid words such as 'full integration' due to its vague meaning. The original criteria before the case study refinements are the following:

Use of land given type of soil, volumes, and quality	+	The horizontal layout and land use is based on the type, quality and optimization of soil volumes
	0	The horizontal layout and land use is based on the type and quality of the soil or on optimization of soil volumes
	-	The horizontal layout and land use is not based on the soil type and volumes
Integration of the port into the urban or natural environment	+	The port is developed through Building with Nature and it is fully integrated into its surroundings
	0	Some Building with Nature measures are taken
	-	The impact on the surroundings is high, and/or the system is disturbed or disrupted due to the port development

6.4.3. General conclusions

Several conclusions can be derived from the case study, which are also applicable to other similar port projects with similar conditions.

First of all, while testing the proposed methodology, it can be concluded that the institutional setting in Guatemala does not work efficiently, limiting the possible Green Port developments. Instead of following a landlord system, many ports are owned and run by the Government, such as the port of Santo Tomás. This can lead to some negative consequences in terms of sustainability, as it was proved during the case study analysis. The best site in terms of the proposed scoring system is the area for expansion of the port of Santo Tomás. Nevertheless, as being run by the Government, which does not have an interest in privatizing it, the option shall be discarded by private investors, who must look for another alternative site to develop a greenfield port, with its consequent higher negative environmental impacts. Whereas if the institutional setting changed and the port was privatized, it would be more efficient, and the volumes could be handled using part of the existing infrastructure, reducing the associated impacts, which may be even larger when a greenfield port is developed by a private investor. The reason is that they look for a high efficiency and the ports are developed with a short-term mentality, looking for short-term revenues rather than adopting a long-term mentality which is the basis for the success of Green Port developments. Therefore, for the prosperity of Green Ports, attention should be put on the Governments, since they can make a direct contribution if they are involved, by making them aware of the importance of these type of developments and of the means to achieve them.

Another conclusion derived from the case study is that it is simple to obtain a high positive score for the site selection phase, which is mainly based on avoiding future negative impacts (the four alternative sites obtained a positive score). However, it is the opposite situation for the masterplanning phase, as special measures have to be taken to obtain a high sustainable performance, which involve additional costs or studies, because the option of 'doing nothing' towards the green goals gets a negative score. It is important to bear this in mind to maximize the environmental performance in this first phase, with the purpose of obtaining a total positive score in the planning phase, in order to apply for Green Bonds or ESG funds. To be eligible for the first, the environmental and social measures need to be shown by explaining which sustainable goals are related with them (circular economy, energy efficiency, clean transportation, etc.); while for the latter, the impacts need to be quantified. For applying for the ESG funds it could be beneficial if the amount of avoided impacts for the site selection and masterplanning is quantified, giving a clear idea on how the green approach benefits the environment and society, which could lead to the financing through this model. For the case study, however, with a negative score for the masterplan, financing through the models of section 5 would be difficult, as they are destined to projects which can show a high environmental performance or benefits to the environment. However, financing by means of investment from stakeholders (industries, companies, municipalities, etc.) is still an option if willingness to invest for added value is found. It is essential to include stakeholders in the planning phase because it is possible that they are interested only in certain sites, and if they are engaged during the masterplan process, when the degree of freedom is lower, some opportunities for financing could be lost.

7. IMPLEMENTATION RELATED ISSUES AND POSSIBLE SOLUTIONS

7.1. IMPLEMENTATION RELATED ISSUES

The theory of what a Green Port is and how to develop it has been made clear throughout this document. On the other hand, putting it into practice in a real project comes along with several issues; otherwise, every greenfield port or port expansion around the world would be developed along the principles of the Green Port, which produces economic, social and environmental benefits instead of exclusively economic benefits.

7.1.1. Economic feasibility

The first implementation issue of Green Ports is economic feasibility. The development of a port project (and in general, any project or investment) is based on a business case, which has to show that an economic benefit is obtained or else the project is not carried out. Every port development is unique and counts with its own conditions, which determine if a green measure is feasible or not. However, generally, many of the green measures come together with an added cost (during construction and/or operation), especially when they relate to innovative solutions (Wiegmans & Geerlings, 2010), which also involve uncertainties which are traditionally translated as risks, being negative for the business case and for the Green Port goal. Without financial incentives, developing a port in a sustainable way rather than following the traditional approach does not (usually) benefit the port developers. However, there are several ways for financing these green developments (section 5), which are useful for these cases and from which the port developers could take advantage from.

7.1.2. Competition among ports

The second implementation issue relates to the competition among ports. A Green Port may involve a loss of competitiveness during operation, both regarding maritime transport and terminal operators. The green measures that affect vessels may contribute to their call at another port, especially due to the measures regarding the higher port dues for unsustainable vessels and even more if the port follows the measure of not accepting vessels with an ESI score lower than a certain limit. Therefore, it is important to search for a cooperation between ports in order not to compete in terms of sustainability[8]. For terminal operators, operating in a Green Port involves higher costs if extra measures have to be taken for minimization of waste, reuse of waste and material, and to function in a sustainable way by means of efficient and environmentally friendly yard equipment, which becomes a relevant problem when the Port Authority does not give economic incentives. Involving a larger cost, it is also not convenient for port developers.

[8] One initiative is the World Ports Sustainability Program

7.1.3. Lack of legislation

The lack of policies and legislative drivers that requires the inclusion of measures as the ones described in the proposed methodology is another barrier for implementation. Some directives that are related to the port activities already exist, for instance, regarding vessels' discharge, reception facilities or vessels' emission levels[9]; however, they mainly focus on the vessels performance instead of on the ports' activities. It can be concluded that the reason is that the vessels performance can be more easily quantified compared to the port configuration and activities from planning to construction. In other words, it is more straightforward to quantify what Green vessels are (which mainly depends on emission levels and waste production and discharge) than what Green Ports are (for which a high number of criteria needs to be considered), due to the complexity of their development and operations.

Moreover, although the existing directives are created with the purpose of harmonizing the national legislation between the different countries, the concepts included in them can be interpreted differently, which happened when applying older versions of the Directive of the European Parliament and of the Council on port reception facilities for the delivery of waste from ships. It is also mentioned that "enforcement is often insufficient and there is a lack of incentives to deliver the waste onshore" (European Parliament, 2018). The same would apply to future directives that regulate ports, together with an added difficulty due to their larger complexity compared to maritime shipping, as mentioned before. This obstacle also relates to the degree of freedom that also needs to be included to be applicable to every port, and independent on their size, traffic, type of cargo, local conditions, etc.

7.1.4. Lack of financial incentives

Since economic feasibility one of the main obstacles for Green Port developments, it can be derived that the lack of financial incentives is the main cause. Due to the complexity of defining what Green Ports are, financial incentives are not common for Green Port developments. Whereas the degree of sustainability is clear for other projects (e.g. developing a solar power), quantifying if a port is sustainable or not is not trivial. This was the main reason for doing a research on this topic: to define them and evaluate them depending on the green measures that are taken in order to start inserting the concept in society and decision-makers, to create awareness about the problem and give a specific methodology and scoring system, which could lead to the promotion for the elaboration of international guidelines that in the end contribute to give incentives for their development. These financial incentives are essential for the achievement of Green Ports, due to the added costs that they involve and because regulations would probably not cover all beneficial aspects that could be included in their development, so additional incentives apart from complying with current legislations are beneficial to cover all sustainable aspects.

7.2. POSSIBLE SOLUTIONS

The most straight-forward solution to diminish or eliminate the implementation issues of Green Ports is out of the scope of port developers, which has to do with the lack of a specific legislation

[9] Derived from the MARPOL convention (The International Convention for the Prevention of Pollution from Ships)

and incentives of these sustainable projects. But there are also other drivers that could reduce these issues and make port developers opt for the sustainable solution.

7.2.1. Port legislations towards sustainability

Green Ports require specific legislation from international or intergovernmental organizations, especially for greenfield ports or expansions, in order to avoid negative impacts from the first stages and enforce them to follow a sustainable approach. National policies could contribute; however, the issue regarding the loss of competitiveness would not be solved in this case. Therefore, the ideal situation is that these legislations come from international or intergovernmental organizations. Health, climate change, quality of life, protection of the environment, etc. are all topics which can be improved, and which have a global scope; therefore, they shall be promoted at the world level. Ports are a source of high negative environmental and social impacts, but decision-makers do not give sufficient attention to this problem and to its mitigation. Only after construction, when the impacts are visible, ways to reduce them are considered (corresponding to the traditional approach).

The scoring system as the one proposed can also be helpful to define whether a port is green or not and could be used to give rewards or fines or even to prohibit the development of new ports if a positive score is not obtained. For this purpose, it is important to arrive at harmonized and clearly defined concepts, together with a common definition and evaluation framework.

7.2.2. Green Port financial incentives

Apart from specific Green Port legislations, their success also requires their promotion and incentives provided by international or intergovernmental organizations, at a higher level. This could lead to financial incentives which are the main solution and driver. All the proposed criteria that can contribute to a greener solution cannot be quantified and included in a regulation because they depend on the specific conditions of the project, which does not mean that their importance is lower. Moreover, some criteria do not relate to the current environmental priorities, in which legislations are based, but a high negative impact or high benefit can be produced when following a measure or not. For that reason, port developers shall be able to show that the port has been developed in a sustainable way, complying not only with the regulations but going further to obtain a greener solution. The proposed methodology and evaluation framework can serve for this purpose, which does not focus on reducing impacts but on avoiding them while maximizing environmental and social benefits, increasing public acceptance and decision-makers or other organizations awareness and financial contribution. Financial incentives by decision-makers can also contribute to issuing Green Bonds or financing of these type of green projects, for which setting sustainable criteria is essential. The importance of sustainable development is clear; however, something has to be done to promote it in the port's sector, rather than just setting targets without cooperating to achieve the objectives and to facilitate the transition to sustainable port developments.

7.2.3. Development as a means of anticipation for future changes

Another possible incentive for sustainable port development is the inclusion of sustainable measures as a means of anticipation for when ecosystem and social valuation are incorporated in policies and regulations. The actual regulations focus on the current environmental priorities, which have changed over time (Figure 42 in Appendix A), and they will probably change in the following years. The proposed methodology for developing a Green Port is made trying to include all of them, in order to make it timeless and complete, from the initial development phases. Making sustainable decisions at the beginning, when the degree of freedom is higher, can result in high savings in the future, in the case that there is a need for modernization, upgrade or demolishment because future environmental standards are not met.

7.2.4. Green approach for the business case

Being a means for anticipation also leads to solutions regarding economic feasibility. In the business case and cost-benefit analysis (CBA), adoption of a Green Port is linked to a future-proof solution, reducing the risks. The benefits which are not direct (such as gains of ecosystem services) are also to be included, which also contribute to show the benefits and make them understandable for decision-makers. With their inclusion, a project may become cost-effective, which already happened in other cases which were apparently not feasible[10]. Moreover, it is important to understand the willingness to pay for ecosystem services and other added value such as recreation, protection, seafood, nature, housing, etc. in order to valuate them, for which the cooperation with stakeholders is essential, which can also contribute to the cost-effectiveness of the project. The losses or consequences if a green measure is not taken are to be included in the CBA as well.

7.2.5. Shift in mentality

In general, a shift in mindset is required. It is clear that Green Port solutions give wider benefits than traditional solutions (environment and society, in short and long-term). Port developers shall also obtain a higher benefit so that everybody is benefited, but in this case, it relates to the economic gains. This means that there shall be a transition in terms of financing, for which criteria on sustainability shall be defined to enhance the investments on this type of projects, which would lead to a shift towards sustainability in the ports sector. Some investors are already focusing on financing green projects, which is the start of this shift in mentality (Kim & Chiang, 2014). With the promotion of these solutions, the concept may be embedded in the society, which may enable investment, engagement, and research, and finally reach international organizations, decision-makers, and investors, which are the entities that can contribute in monetary terms to the success of these sustainable developments[11].

[10] E.g. the project 'Room for the River', in the Netherlands
[11] As per the World Ports Sustainability Program

8. CONCLUSIONS AND RECOMMENDATIONS

8.1. INTRODUCTION

Negative environmental impacts induced from the climate change are increasing the awareness for the importance of sustainable development. The concept of sustainability is being applied to a larger number of processes over time, both on daily and industrial processes. The application to ports is still in its early stage, due to the complexity of port developments and operations.

Existing guidelines focus on measures to be taken during operation, in order to be applicable to existing ports around the world. However, for greenfield ports, which could avoid negative impacts from the beginning and maximize benefits to all stakeholders, these guidelines are not applicable and useful. There is a lack of a detailed methodology to develop a Green Port from the planning stage, when the degree of freedom is larger and when knowing how to develop in a sustainable way would be valuable. The site location selection, for instance, is not included in the existing frameworks, while a large number of negative impacts can be avoided if the site is selected in a sustainable way.

For this reason, the outcome of this research is a detailed methodology for all phases of a port development with measures to follow that contribute to the achievement of a Green Port. It was necessary to define in advance, what a Green Port is, compared to traditional ports, to set a clear goal. The planning stage of the methodology was refined by means of a case study, with which was also possible to identify several issues with the implementation.

8.2. ANSWERS TO THE RESEARCH QUESTIONS

The Green Port is commonly considered as an abstract idea due to the lack of a definition and a detailed and specific framework to implement it. This was defined as the objective of this research, which would answer the main research question:

How can we design and implement a Green Port?

To obtain an answer, there are several sub-questions that shall be answered:

 # 1 What is a Green Port and what are the differences with a traditional port?

 # 2 What opportunities can be identified in each phase of a port project for the development towards sustainability?

 # 3 What green goals can be set for each opportunity for sustainable development?

#4 What are the issues regarding the implementation of Green Ports?

After this research, answers to these sub-questions can be given, and they are elaborated on below.

 # 1 What is a Green Port and what are the differences with a traditional port?

After the literature study, several definitions of Green Port were found. The key concepts of each of them were combined in a new definition, together with other relevant concepts derived from the best environmental practices of several ports around the world. The proposed definition of a Green Port, as included in section 2.4, is: one which is designed, constructed and

operated integrating an environmental, social, and economic philosophy, balancing between the port's benefit and future generations' needs. A Green Port also follows a long-term mentality, stimulating green technologies, innovation, and energy and resources efficiency, minimizing (negative) impacts and maximizing benefits by creating added value for the environment and society through a stakeholders' co-creation".

The difference with traditional ports is closely related to this definition and it is also found by analyzing the 'greenest' ports in the world, as they are claimed to be, due to their measures to achieve a higher environmental performance compared to other ports. However, this is not sufficient to get a fair comparison, and it was refined after a detailed methodology to develop a Green Port was created. During this process, additional differences were found, through personal reflection and from other sustainable measures that can be taken during the planning and design phases, which were not followed by the analyzed ports as they have been operating for a longer period, when sustainability was not a topic commonly related with ports.

The difference between Green Ports and traditional ports refer to several aspects (section 4): cooperation with stakeholders, the economic driver, the relation with nature, the scope of mentality, the use of technology, the role of the Port Authority, the source and consumption of energy and resources, the quality of air, the biodiversity conservation, the type of cargo, the vision of sustainability, the site location, the growth approach, the way of minimizing environmental impacts, the extent of sustainable actions extent, the management of future uncertainties, the design decisions and the mentality towards the end of the life cycle.

 # 2 What opportunities can be identified in each phase of a port project for the development towards sustainability?

The phases of a port development in this report have been defined as planning, design, construction, and operation (which includes maintenance and management). The green opportunities that are identified for each of them during this research, are defined as general opportunities, as it is considered that in order to achieve the Green goal, it is important to first identify the subjects which would contribute to accomplishing it, especially in complex processes such as port developments and operations.

The main opportunities to which sustainable measures can be taken were defined after a literature study based on a personal reflection, and they are as follows. For the planning phase, importance shall be given to the port's mission, site selection, and masterplanning. For the design phase, numerous green opportunities can be found in the infrastructure design, materials, and energy procurement. During construction, attention shall be given to the maritime works and the earthworks, to take measures to minimize negative impacts. Finally, in the operation phase, a sustainable approach can be followed for the port in general, the terminals, the vessels and by means of an environmental management system.

 # 3 What green goals can be set for each opportunity for sustainable development?

For each identified opportunity towards sustainable development, several green goals can be defined, and which can be achieved by considering different criteria which form part of the proposed methodology for Green Port developments (section 1). For each opportunity/aspect, the green goals are as follows:

1. Port's mission
    a. Green Port purpose

    b. Green strategy
    c. Green standards and behavior
    d. Green values
2. Site selection
    a. Biodiversity conservation
    b. Minimum negative environmental impact
    c. Minimum negative social impact
3. Masterplanning
    a. Efficient port layout
    b. Integration into the surroundings
    c. Added value
4. Infrastructure
    a. Minimum negative environmental impact
    b. Future proof
    c. Added value
5. Materials
    a. Efficient use of material
    b. Materials selection based on sustainability
    c. Efficient waste management
6. Energy
    a. Energy efficiency
7. Maritime works
    a. Environmentally friendly construction methods
    b. Equipment selection based on sustainability
8. Earthworks
    a. Environmentally friendly construction methods
    b. Equipment selection based on sustainability
9. Port (general)
    a. Pro-active port Authority role
    b. Sustainable hinterland transport
    c. Energy and resources efficiency
10. Terminals
    a. Hazardous material management
    b. Sustainable yard equipment
    c. Efficient waste management
11. Vessels
    a. Emissions reduction
    b. Ballast water management
12. Environmental management system
    a. Continuous cooperation with stakeholders
    b. Sustainability reporting
    c. Control systems and monitoring
    d. Continuous improvement
    e. Stimulation of green technologies and innovation

There are several steps to achieve the previous green goals, on which the proposed methodology for developing a Green Port are based and which were tested by the case study in order to assess their applicability.

#4 What are the issues regarding the implementation of Green Ports?

While developing the proposed methodology for Green Ports, several issues for implementation could already be predicted. One of them deals with the ambiguity of the methodology and the necessity of an evaluation framework to assess 'how green' the port would be when certain measures are taken or not. For that reason, it was developed, including a scoring and weighting system, with which the implementation becomes more straightforward because it clarifies if certain actions are considered to contribute to the Green Port goal or not.

Apart from this matter, in order to successfully answer this sub-question, the learnings from the case study application shall be used. Some of the encountered implementation issues are specific for this case study, in which a cooperation with the stakeholders was not possible, leading to a lack of accessibility of data and difficulties to assess the impacts and make decisions on possible benefits. The issues regarding the general implementation of the methodology for Green Port developments mainly relate to the interpretation of the criteria, which could be assessed differently depending on the project due to general concepts that are included in them, given the complexity of ports.

In general, the issues for the implementation of Green Ports can be summarized in the lack of legislative and financial incentives, which becomes especially relevant because of the higher costs that involve these green developments. For that reason, economic feasibility becomes the main implementation issue and the lack of global regulations could also lead to the loss of competitiveness between ports reducing the willingness to develop a port with a green approach. However, green port developments also require a shift in mentality and a green approach for the business case, which could indicate that the solution is preferable because of the reason of developing Green Ports with a long-term mentality, as a means of anticipation of future changes, reducing future costs and risks.

8.3. LESSONS LEARNT

Several conclusions can be derived from this research, which contributed to learning various lessons. These can be summarized as follows:

1. It is not straightforward to define what a Green Port is and to apply the definition to existing ports or ports under development. A port does not fall either into the category of Green Port or into the category of traditional ports, due to the complexity in development and activities. There are different degrees between these two types of ports and it is even difficult to analyze if a port is 'greener' than another, unless a specific scoring system is applied to both. The measures that contribute to a more sustainable port have been detailed along this research, and they can clarify whether a port has been developed and/or is operating following a sustainable approach. For that reason, the proposed scoring system is based on measures to be taken. Nevertheless, the definition of this scoring system also involves difficulties, as it has to be general enough to be applicable to different cases and specific enough so that the measure to be taken is straightforward instead of vague.
2. A Green Port cannot be achieved if the philosophy behind does not focus on enhancing sustainability in all phases of development. The purpose to develop a Green Port needs to be included in the port mission of a port, from the first phase, in which all development decisions are based on. It shall also be one of the bases of the

management during operations. A checklist of green measures as a tool for achieving a sustainable solution is not sufficient if the philosophy behind is not based on a long-term mentality and a continuous improvement by means such as stimulating green technologies or innovation, continuous search for stakeholders' benefits, and added value, constant efforts for minimization of negative impacts, etc.

3. The environmental priorities change over time, and the existing guidelines are based on the current concerns. The proposed methodology is based on all the identified environmental issues linked to port projects, with the purpose of making it timeless and complete. However, if new environmental issues or new available green technologies arise over time, they shall also be considered by including additional criteria in the evaluation framework that contributes to improvement. It is also based on making it applicable to different cases around the world, but it may be possible that certain important criteria (towards sustainability) for that case is not covered by any criterion. The addition of criteria when they are relevant for specific cases shall be done for a fair evaluation.
4. There are a large number of measures that can be taken in the planning phase of a port project (site selection and masterplanning) that does not involve additional costs but contributes significantly to the Green Port goal. The fact that existing guidelines for sustainable ports focus on measures during the operation phase does not imply that these are the only measures to be taken for that purpose. A Green Port is not only characterized by including sustainable measures during operations, but during all phases. By following a green approach from the first stages of development, many future negative impacts and high investments can be avoided, leading to high future benefits in terms of economy, society, and the environment. This contrasts with the traditional port approach, as the focus is put on reducing the negative impacts once the port is constructed and in operation, rather than avoiding them from the start.
5. A stakeholders' co-creation is necessary to achieve the Green Port goal. In this research, it has been identified as one of the 'top green philosophies' in which the proposed methodology is based on; however, it is not part of the scoring system but only included as the so-called 'process criteria', to which a score is not assigned. This co-creation is, nevertheless, crucial for the search for common benefits and added value, and to appropriately apply and assess other criteria that benefit society, economy or the environment. This was proved during the case study, in which several criteria could not appropriately be assessed due to the lack of this cooperation with the stakeholders. Opportunities to obtain a high score in terms of sustainability were also lost because added value was not created, only focusing on reducing the negative impacts that the port development would generate.
6. For the successful implementation of Green Ports, it is important to promote the concept, together with specific guidelines or methodologies, in order to help financing. Only after the concept is clear and embedded in society, specific financial or legislative drivers may arise, which is important to overcome the main identified issues that are related to the implementation: economic feasibility and competition among ports. Global organizations have an important role for this purpose, in order to promote the concept and the measures that provide local and global benefits.

8.4. FUTURE RESEARCH

Some recommendations for future research can be derived from the pending items of this research, which mainly refer to a refinement of the complete methodology. The scope of this research included a test of the planning stage of the proposed methodology with a case study, after which it was refined. However, the methodology includes a procedure for all phases of development, which were not tested, as the importance was given to the first phase because of the lack of guidelines that were found in literature that focus on it. Therefore, future research could be based on testing and refining it with a case study for every development phase, for which a depth involvement into a project would be recommended, in order to have all information available, contact with stakeholders and with the project managers, etc. This could also result in additional implementation issues of Green Ports and possible solutions. The application of different case studies, with different conditions and contexts, is also valuable for the refinement and application to other cases around the world, for which additional criteria for evaluation might be included.

Moreover, possible future research could focus on developing a framework for a green approach to the business case and cost-benefit analysis. Economic feasibility is one of the main barriers to the success of Green Ports, and one of the reasons is that traditional business cases are used to evaluate their feasibility. Nevertheless, for the case of ports which have been developed with a sustainable approach, several parameters could be included. For instance, the gains in ecosystem services form part of the benefits, the losses or consequences if a green measure is not followed could also be included (benefiting the business case if they are considered in the design), the risk could be reduced because of the long-term mentality of these type of developments, and the willingness to pay for recreation, seafood or housing could be addressed to understand and evaluate additional indirect benefits.

Furthermore, in order to facilitate financing, methods for quantifying the avoided negative impacts during the first development phases would be useful. It is simple to quantify these effects during operation; however, the prediction of the impacts if a measure is followed or not is not so straightforward. The ideal situation would be if these could be quantified and the proposed evaluation framework could then be optimized. This would probably enhance the financial incentives because it can be proven if the project contributes towards sustainability or not, and it could also lead to regulations for a sustainable approach from the planning phase (which cannot be based on qualitative ideas, but they must be quantified).

Another recommendation is to optimize the scoring system of the evaluation framework with other views and expertise. It is currently based on a personal reflection after the literature study and research, but different experts or researchers could develop it in a different way. Finding a common solution with which everybody agrees is nearly impossible, but it can always be improved with an objective mentality. The possible engaged experts, apart from port experts, could have an ecology, governance or research background.

In general, it is recommended that further research into sustainable ports continues. A port development is a complex process, and many measures to be taken cannot be defined as ‘sustainable or not sustainable’, as the options to follow are wide. It is also a challenge to quantify how sustainable a measure is, being case dependent and because measures taken inside the port boundaries have consequences that extend further, and their identification may not be straightforward or predicted. In addition, circumstances change over time, and updated

research on this topic is important, to go in hand with technological innovations and future situations.

8.5. IN CONCLUSION

The concept of sustainability in relation to ports it is still relatively new. Some measures towards sustainability have already been taken in ports around the world; however, the concept of Green Port is not yet embedded in decision-makers, port developers, and, in general, society. Port processes are complex and include many different processes, and that is where the difficulty in labeling a port as green or non-green arises. However, sustainable port development is likely to become more relevant with time, just as with other processes that are making a shift towards sustainability, since it is a concept that is closely linked with the future, and about not disrupting the needs of other generations. For this reason, the promotion of the Green Port is essential. This, in time, would lead to financial incentives for their development, which is vital for their success.

The shift from the traditional approach to the green approach does not refer to including some environmentally friendly measures during design or operation. It involves a shift in mentality from the conception to the end of the lifetime of the port, for which a sustainable philosophy that adapts to the changing circumstances over time is required. Examples from around the world are necessary for this shift and to boost their development; for which port authorities and decision-makers play a crucial role in innovating and investing in green projects.

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APPENDICES

A. LITERATURE STUDY

1. OVERVIEW OF LITERATURE STUDY

The literature study is summarized in Table 15, grouping the literature in different subjects that are relevant for the choice of the research topic. Some comments to prove the lack of a detailed and complete definition and methodology for Green Ports are also included.

Table 15 Literature study

SUBJECT	AUTHORS	COMMENTS
Definition of Green Port	PIANC, 2014a	General, with wide and undefined terms and no concrete actions
	Green Energy Ports Conference, 2013	No mention of stakeholders' participation and long-term vision
	Zheng, 2015	No mention of stakeholders' participation, long-term vision and concrete actions
Green Port criteria	Abood, 2007 Bailey & Solomon 2004 Chiu, Lin and Ting 2014 Darbra *et al*., 2005 Hiranandani, 2014 Lirn, Wu and Chen 2013 PIANC, 2014a Wakeman, 1996 Yang & Chang, 2013 ESPO, 2013 Klopott, 2013	They give an incomplete list of green measures. They focus on operation: energy efficiency, air quality, water quality & conservation, indoor environmental quality, materials & resources conservation, dredging and disposal of dredge materials, storage, transport and management of hazardous substances, ballast water control dredging, and habitat preservation & restoration
Sustainability reports/ green practices	Algeciras Bay Port Authority, 2016 Sustainable Port of Antwerp, n.d. Bremen Ports, 2015 Busan Port Authority, 2014 Port of Long Beach. The Green Port, n.d. Maritime and Port Authority of Singapore, 2016 Port of Amsterdam, 2017 Port of Rotterdam, n.d. Port of Vancouver, 2016 Puerto de Vigo, 2016 Port de Barcelona. 2017	Ports include their green practices in an annual sustainability report. They do not mention green measures to apply for greenfield ports, as they only focus on the sustainable actions their port is following during operation. Attention is given on improving quality of air and water by reducing the negative impact during port activities, searching for alternative green energies, efficient use of natural resources, waste management solutions, and measures for the switch towards sustainable transport both maritime and inland
Green Port frameworks	PIANC, 2014a Zheng, 2015 Boer, 2016 Vrolijk, 2015	They do not give an overall methodology to follow. Focus is put on the main environmental issues, but a complete picture is not given

2. GREEN PORT CRITERIA

In order to develop a Green Port, there are several green criteria that can be implemented. These are discussed by different authors (Abood, 2007; Bailey & Solomon 2004; Chiu, Lin and Ting 2014; Darbra *et al*., 2005; Hiranandani, 2014; Lirn, Wu & Chen 2013; PIANC, 2014; Wakeman, 1996; Yang & Chang, 2013) and they focus on the following:

1. Energy efficiency
2. Air quality
3. Water quality & conservation
4. Indoor Environmental Quality
5. Materials & Resources conservation
6. Dredging and disposal of dredged materials
7. Storage, transport and management of hazardous substances
8. Ballast water control
9. Dredging
10. Habitat preservation & restoration
11. Land & water areas

However, all these criteria focus on operation and vessels performance, and not on planning, design or construction, which are also relevant in order to obtain a Green Port, as negative impacts can be avoided from the first stage of the port development, instead of having to mitigate or compensate them in the future. Moreover, none of the authors include all criteria in their reports, being proved by Canbulat (2014) after comprising all the green criteria mentioned in literature (Table 16).

	Criteria / Writers	(Chiu, Lin and Ting, 2014)	(Hiranandani, 2014)	(ESPO, 2013)	(Klopott, 2013)	(PIANC, 2013)	(Yang *et al.*, 2013)	(Lirn, Wu and Chen, 2013)	(Yang and Lin, 2013)	(Yang and Chang, 2013a)	(Park and Yeo 2012)	(Cannon, 2008)	(Darbra *et al.*, 2005)	(Peris-Mora *et al.*, 2005)	(Bailey and Solomon, 2004)	(Saxe and Larsen, 2004)	(Wakeman, 1996)	(Frankel, 1987)	TOTAL
1	Solid and hazardous waste handling and generation	X	X	X	X	X	X	X			X	X	X	X	X		X		13
2	Air pollution and air quality	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			15
3	Water pollution and water quality	X	X	X	X	X	X				X		X	X	X				10
4	Port greenery	X																	2
5	Environmental protection training and Marine habitat quality preservation	X	X		X	X		X					X				X	X	8
6	Dust pollutants		X	X	X	X		X										X	6

7	Ballast water		X	X	X	X		X										5
8	Noise and vibration pollution	X	X	X	X	X	X	X		X	X	X	X	X	X			X	13
9	Energy consumption	X		X	X	X	X		X	X		X	X	X			X		11
10	Solid waste dumping management and Soil contamination		X	X		X	X	X					X	X	X				8
11	Electrically powered equipment usage, energy-saving device usage		X		X	X		X	X	X	X	X							8
12	Fuel spilling contingency plan					X		X						X				X	4
13	Recyclable resources usage		X			X		X			X						X		4
14	Light pollution					X						X			X				3
15	Reducing vessel speed and emission after landfall		X			X		X									X		4
16	Dredging, Marine sediment and coastal erosion	X	X	X	X	X	X	X			X		X	X			X	X	12
17	Low-sulphur fuel usage		X	X				X				X				X	X		6
18	Sewage and Wastewater treatment		X			X	X	X							X				5
19	Sustainable energy usage		X			X		X				X							4
20	Loss or degradation of wetlands														X				1
21	Destruction of fisheries and endangered species		X												X			X	3
22	Risk of severe accidents						X											X	2
23	Severe traffic congestion		X	X	X														3
24	Loss of cultural resources														X				1
25	Construction or renovation of the port facility													X				X	2
26	Smell odour pollution (Toxic gas might not only have an offensive smell)						X	X					X						3
27	Port development			X	X								X						3
28	Relation with local community			X	X													X	3
29	Hinterland and water areas uses					X													1

Table 16 Green Port Criteria from literature (Canbulat, 2014)

In addition, the different papers in literature focus especially on the current green priorities based on the main environmental issues. However, these priorities change over time (ESPO, 2017) as it is reflected in Figure 42. The colored ones indicate the green criteria that are repeated from one year to another.

	1996	2004	2009	2013	2016	2017
1	Port Development (water)	Garbage / Port waste	Noise	Air quality	Air quality	Air Quality
2	Water quality	Dredging: operations	Air quality	Garbage/ Port waste	Energy Consumption	Energy Consumption
3	Dredging disposal	Dredging disposal	Garbage / Port waste	Energy Consumption	Noise	Noise
4	Dredging: operations	Dust	Dredging: operations	Noise	Relationship with local community	Water quality
5	Dust	Noise	Dredging: disposal	Ship waste	Garbage/ Port waste	Dredging: operations
6	Port Development (land)	Air quality	Relationship with local community	Relationship with local community	Ship waste	Garbage/ Port waste
7	Contaminated land	Hazardous cargo	Energy consumption	Dredging: operations	Port development (land related)	Port development (land related)
8	Habitat loss / degradation	Bunkering	Dust	Dust	Water quality	Relationship with local community
9	Traffic volume	Port Development (land)	Port Development (water)	Port development (land)	Dust	Ship waste
10	Industrial effluent	Ship discharge (bilge)	Port Development (land)	Water quality	Dredging: operations	Climate change

Figure 42 Top 10 environmental priorities of the European port sector over time (ESPO, 2017)

3. CONCLUSIONS

After doing the literature review, it has been established that sustainability is one of the most important key drivers for development. It is especially relevant for transport infrastructures, which have a considerable negative impact on the environment, where ports are nodal points in the network. However, it has been established that there is a lack of a detailed, complete, and timeless methodology for green port developments to be followed by decision-makers to directly implement into port systems. For that reason, the objective of the research is to cover this gap in literature by developing an improved methodology for Green Ports.

B. EVALUATION FRAMEWORK

1. SCORING SYSTEM

Table 17 Scoring system for a Green Port based on the proposed methodology

PHASE	SUBJECT	GREEN GOAL	CRITERIA	SCORE	EXPLANATION
PLANNING	SITE SELECTION	Biodiversity conservation	Impact on protected areas	+	Location outside the boundaries of protected areas (marine and terrestrial)
				0	Location inside the boundaries of protected areas but ensuring the integrity of the natural system
				-	Location inside the boundaries of protected areas without taking special measures for conservation
			Impact on natural habitats	+	The location does not count with an important natural habitat; which refers to vulnerability of species and loss of vegetation
				0	The location would affect species with a certain degree of vulnerability and/or the vegetation loss is relatively high
				-	The location disrupts an important natural habitat
		Environmental impact	Use of existing port facilities	+	An existing port will be used after adaptation or expansion
				0	An existing port will be expanded but less than 50% of the existing facilities will be used
				-	A new port will be developed
			Use of existing hinterland connection	+	Existing hinterland infrastructure will be adapted and used to connect the port, and/or the required new infrastructure is no longer than 2 km
				0	Existing hinterland infrastructure will be used, and/or the length of the required new infrastructure is between 2 and 10 km
				-	A complete new hinterland connection will be needed. The length to an existing infrastructure or city is more than 10 km
			Use of natural conditions	+	Sheltered location and/or with larger depths to minimize dredging
				0	n.a. (no alternatives in a sheltered location or with relatively different depths compared to the others)
				-	Unsheltered location and with lower depths which require much dredging

			Impact on coastal processes	+	The location will induce a low impact on existing coastal processes
				0	n.a. (no location alternatives with significant impact to coastal processes)
				-	The location will induce a high impact on existing coastal processes
			Impact on water system quality	+	The location does not affect the water system quality
				0	n.a. (no alternatives in a vulnerable location regarding water quality)
				-	The location which may affect the quality of the overall water system (if much dredging is required in a river)
		Social impact	Buffer area to local communities	+	The distance between the port boundaries and local communities is higher than 5 km
				0	The distance between the port boundaries and local communities is between 1 and 5 km
				-	The distance between the port boundaries and local communities is lower than 1 km
			Impact on existing recreational areas	+	No existing recreational areas are affected in that location
				0	An existing recreational area will be eliminated/significantly affected to construct the port, but a new recreational area with the same nature and similar characteristics is developed to compensate
				-	An existing recreational area will be eliminated/significantly affected to construct the port
			Necessity of resettlement of communities	+	No individuals will need to be resettled in that location or the resettlement brings benefits to the communities
				0	The resettlement does not benefit the affected communities but does not harm them
				-	The resettlement impacts the affected communities in a negative way
			Impact on archaeological cultural values	+	Location with no significant archaeological cultural value
				0	Location with archaeological cultural value, unknown during the site selection process and discovered after the beginning of construction
				-	Location with significant archaeological cultural value

			Employment opportunities to local communities	+	Location at a maximum travel time of 1 hour with accessible means of transport in the region to communities with skilled workers
				0	Location at a travel time between 1 and 2 hours with accessible means of transport in the region to communities with skilled workers
				-	Location at a minimum travel time of 2 hours with accessible means of transport in the region from communities with skilled workers
			Impact on fisheries and aquaculture	+	Location with no losses of fishing grounds, stock or aquaculture areas
				0	Temporary and reversible loss of fishing grounds during marine works/loss of an area below 10% and compensation to fishermen for loss of fishing grounds
				-	Location in a significant area for fisheries or aquaculture and/or no compensation to fishermen for loss of fishing grounds
			Impact on existing economic activities	+	Location which does not impact existing economic activities
				0	The port is located on land dedicated to existing economic activities, with a loss of 10% of the total area used for the activity, and there is a compensation
				-	Location in a significant area for existing economic activities and/or no compensation for loss valuable land
	MASTERPLANNING	Layout	Productivity	+	Efficient distribution of port areas and uses to maximize productivity and minimize the required total area
				0	n.a.
				-	Maximization of productivity is not considered in the layout design to minimize the required total area
			Distribution of port terminals considering communities	+	The location of the terminals is based on minimizing the impacts and risks on communities, using results of wind studies and 3D visualizations or there are no nearby communities that would be affected
				0	Terminals with higher impacts and most visible are located furthest from communities
				-	The distribution of terminals is only based on functional requirements
			Use of land given type of soil, volumes, and quality	+	The horizontal layout and land use is based on the type, quality and optimization of soil volumes
				0	The horizontal layout and land use is based on the type and quality of the soil or on optimization of soil volumes or the site is flat and counts with the same type of soil
				-	The horizontal layout and land use is not based on the soil type and volumes

			Flexible layout and adaptive planning	+	A flexible and adaptable solution is designed, to ensure present and future functionality
				0	Flexibility is included in the design by not disrupting future possible expansions
				-	Future uncertainties are not considered in the layout by opting for flexible solutions
			Compensation measures	+	Compensation measures are taken in a smart way, using resources and materials efficiently, with a size comparable to the degraded areas
				0	Compensation measures are taken, involving a high amount of extra resources and/or of a significantly lower size than the degraded areas
				-	No compensation measures are taken
			Use of common infrastructure & facilities	+	Some infrastructures and facilities are shared between different terminals
				0	n.a. (the nature of the terminals does not allow a sharing of facilities)
				-	Each terminal has its unique infrastructure and facilities
			Use of waterfront and water depths	+	Terminals which require larger water depths are located close to the port entrance and facilities which do not require water access are located further from the basin
				0	Terminals which require larger water depths are located far from the port entrance or facilities which do not require water access have a quay wall
				-	Terminals which require larger water depths are located at the end of the basin and/or a quay wall is given to facilities which do not require water access
			Use of environmentally friendly transport solutions	+	An environmentally friendly solution is developed for the hinterland connection
				0	An environmentally friendly solution is developed for the hinterland connection, but its construction will involve high environmental impacts
				-	The hinterland connection is a traditional road system
		Integration into the surroundings	*Integration of the port into the urban or natural environment*	+	The port is developed through BwN measures and it is integrated into its surroundings
				0	The port is integrated into its surroundings but no BwN measures are followed
				-	The impact on the surroundings is high, and/or the system is disturbed or disrupted due to the port development

			Connectivity	+	The existing flow and connectivity of species and communities is guaranteed, taking measures to avoid congestion due to the port transport
				0	There is a disruption in the species flow, but the communities flow and connectivity are ensured
				-	Use will be made of an existing congested road network to minimize construction costs and there is a disruption in the species flow
		Added value	Conservation areas	+	New nature conservation areas are developed in and/or around the port in land areas with a low value for communities, with a size above 10% of the port land area
				0	New nature conservation areas are developed in and/or around the port, in land areas with a low value for communities, with a size below 10% of the port land area
				-	No nature conservation areas are developed, or they are located in a valuable land area for communities
			Recreational areas	+	New recreational areas are developed in and/or around the port in land areas with a low value for communities, with a size above 10% of the total port land area
				0	New recreational areas are developed in and/or around the port in land areas with a low value for communities, with a size below to 10% of the total port land area
				-	No recreational areas are developed, or they are located in a valuable land area for communities
			Inclusion of economic and social aspects	+	Added value is created to stakeholders beyond communities given their priorities, identified during the co-creation process
				0	Some added value is created but no significant attention is given to it
				-	The masterplanning does not create added value to stakeholders beyond communities
DESIGN	INFRASTRUCTURE	Environmental impact	Use of Onshore Power Supply technology	+	Onshore power will be supplied to vessels while being berthed
				0	No provisions for using OPS are made because it would involve high negative environmental impacts to the local environment during construction
				-	No provisions for using OPS are made
			Measures for mitigation of environmental accidents risks	+	The design is based on mitigating the risk of environmental accidents
				0	n.a. (the nature of the terminals and cargo do not involve environmental risks)
				-	No safety measures for environmental accidents are considered in the design

			Impacts on communities	+	Air, noise, light, visual, odor, vibrations and dust impacts are not noticeable to nearby communities due to design elements
				0	n.a. (there are no impacts to communities due to the nature of the port terminals or distance to the city)
				-	Impacts on nearby communities are not eliminated
			Impacts on coastal processes	+	The design minimizes the changes in current coastal processes
				0	n.a. (coastal processes in that location are not significant)
				-	The design impacts significantly the current coastal processes
			Use of carbon capture technology	+	Carbon capture technology is used, and other measures to reduce emissions are also considered in the design phase
				0	Carbon capture technology is the only measure to reduce emissions considered in the design phase
				-	Neither carbon capture technology nor other measures to reduce emissions are included in the design
		Future proof	Flexible and adaptable design	+	A flexible and adaptable solution is designed, to ensure present and future functionality
				0	Flexibility is partly included in the design, only in a few elements of the nautical or onshore infrastructure
				-	Future uncertainties are not considered in the design by opting for flexible solutions
		Added value	Inclusion of ecological enhancement measures	+	Ecology is enhanced throughout the whole design
				0	Some ecological enhancement measures are included in the infrastructure design
				-	No measures for enhancing ecology are taken in the design
	MATERIALS	Use of material	Use of resources	+	Efficient use of material, reuse allows not requiring extra volumes of soil
				0	Reuse of material is sought, but extra volumes of soil are required
				-	The efficient use of resources is not a criterion of the design
			Reuse of material	+	The reuse of material is used both for functional requirements and to create added value
				0	Some material is reused for functional requirements or to create added value
				-	Reuse of material is not considered in the design

		Materials selection	Nature of materials	+	Environmentally friendly, biodegradable or recyclable material, from renewable sources are used in the design when functional requirements can be satisfied
				0	Environmentally friendly materials are not adequate to satisfy the functional requirements
				-	Environmentally friendly materials are not selected for the design
			Performance characteristics of materials	+	Materials are selected considering quality, durability and energy conservation criteria
				0	Materials are not selected considering quality, durability and energy conservation criteria
				-	Selected materials will require high maintenance
			Source of materials	+	Materials are supplied from nearby sources and from suppliers with certified environmentally friendly supply chains
				0	Materials are supplied from nearby sources or from suppliers with certified environmentally friendly supply chains
				-	Materials are supplied from faraway sources, from suppliers which do not count with certified environmentally friendly supply chains
		Waste materials	Waste management	+	The design is based on minimizing the amount of waste and the disposal is made in an adequate site at a short distance from the site after separating and recycling waste
				0	The design is not based on minimizing the amount of waste, but the disposal is made in an adequate site at a short distance from the site after separating and recycling waste
				-	The design is not based on minimizing the amount of waste and it is not separated and recycled or the disposal site is not adequate
			Handling of hazardous waste	+	Measures for safe handling and disposal of hazardous waste are taken during design
				0	The port will not handle hazardous materials or waste
				-	No special measures to ensure safety while handling and disposing of hazardous waste are considered in the design
	ENERGY	Energy efficiency	Energy consumption	+	An effective design to minimize energy consumption is developed
				0	Measures to reduce energy consumption are planned to be taken in the operational phase
				-	No measures to reduce energy consumption are planned

			Use of renewable energies	+	Most of the energy required in the port will be obtained from renewable sources
				0	The physical conditions are not adequate for the use of renewable energies or only part of the energy required in the port is obtained from renewable sources
				-	Renewable sources are not considered for the obtention of energy
CONSTRUCTION	MARITIME WORKS	Construction methods	Processing of contaminated material	+	A survey of contaminated bottom sediments is executed before dredging, and if found, they are cleaned or placed in a safe and suitable location without spills during transport or placement
				0	A survey of contaminated bottom sediments is not executed
				-	Contaminated material is not cleaned, placed in a safe location or spills occur while transport or placement
			Impacts assessment	+	The method of construction is chosen and designed to minimize the physical changes and impacts assessed before construction
				0	An impact assessment is carried out but no significant changes in the construction method are made
				-	The method of construction is only based on minimizing costs
			Increase of turbidity	+	The increase of turbidity compared to the situation before construction is acceptable considering the underwater organisms and their sensibility to fluctuations in turbidity.
				0	The sensibility of underwater organisms to fluctuations in turbidity is not identified, but there are no losses of ecosystems
				-	The sensibility of underwater organisms to fluctuations in turbidity is not identified and the dredging is carried out without special measures, leading to the loss of ecosystems
			Use of overflow	+	Overflow is not allowed when there are nearby vulnerable ecosystems
				0	Overflow is allowed close to ecosystems with a lower degree of vulnerability
				-	Overflow is allowed when there are nearby vulnerable ecosystems
			Disposal of material	+	The disposal of material is done in a controlled way and distributed it evenly over the area in an area without environmental significance
				0	Measures to reduce energy consumption are planned for the operational phase
				-	No measures to reduce energy consumption are planned

			Impacts to communities	+	Measures for reducing noise and dust pollution and vibrations are taken when there are nearby communities
				0	n.a. (there are no nearby communities)
				-	No measures for reducing noise and dust pollution and vibrations are taken, and nearby communities are affected
		Equipment selection	Environmental performance of equipment	+	The equipment is selected to maximize the performance given boundary conditions and to minimize the physical changes and impacts assessed before construction
				0	The equipment is selected to maximize the performance given boundary conditions or to minimize the physical changes and impacts assessed before construction
				-	The equipment is selected only based on minimizing costs
	EARTHWORKS	Construction methods	Construction plan	+	Efficient construction plan to minimize construction period and equipment traffic flows
				0	The construction plan allows to minimize the construction period or to minimize equipment traffic flows
				-	The construction plan does not have the purpose of minimizing construction period and equipment traffic flows
			Impacts on communities	+	Measures to reduce impacts to communities during construction are taken
				0	n.a. (no communities are affected by the construction works)
				-	No measures are taken to reduce impacts to communities during construction
			Impacts on the local environment	+	Measures to reduce impacts to communities during construction are taken
				0	n.a. (no communities are affected by the construction works)
				-	No measures are taken to reduce impacts to communities during construction
		Equipment selection	Environmental performance of equipment	+	Equipment with no emissions is selected
				0	Measures to reduce energy consumption are planned to be taken in the operational phase
				-	No measures to reduce energy consumption are planned

OPERATION, MAINTENANCE AND MANAGEMENT	PORT (GENERAL)	Port Authority role	Acceptance of terminal operators or companies	+	Only companies and terminal operators which operate with a high environmental performance and which contribute with employment opportunities to nearby communities (if any) are allowed in the port
				0	Companies or terminal operators in the port operate with a high environmental performance or contribute with employment opportunities to nearby communities
				-	The environmental performance or the employment opportunities are not criteria for the acceptance of companies in the port
			Acceptance of cargo	+	Companies in the port follow a sustainable business approach, handling 'green' products
				0	The port does not handle fossil fuels, but the cargo cannot be considered 'green'
				-	The port handles fossil fuels
			Cooperation between companies	+	Companies inside the port cooperate to improve their sustainability performance
				0	n.a. (there is only one company in the port or they cannot benefit from others)
				-	Companies inside the port do not cooperate to improve their sustainability performance
		Hinterland transport	Use of electric trucks	+	Electric trucks are used for the transport of cargo to the hinterland
				0	Another mean of transport is used for the hinterland transport
				-	Traditional trucks are used for the transport of cargo to the hinterland
			Implementation of an environmental zoning	+	Only trucks with no emissions are allowed to be used or access certain areas in the port
				0	Only trucks with newer/cleaner engines compared to traditional trucks are allowed to be used or access certain areas in the port or another means of transport is used or n.a. (if no trucks access the port)
				-	There are no restrictions for trucks to enter the port
		Energy and resources efficiency	Lighting system	+	Most of the lighting in the port is obtained from photovoltaic panels, consists of LED bulbs and includes control systems for energy savings
				0	Some of the light in the port is obtained from photovoltaic panels/the physical conditions are not adequate, LED bulbs are used or control systems for energy savings are included
				-	The lighting in the port is not obtained from photovoltaic panels, does not consist of LED bulbs and does not include control systems for energy savings

			Reuse of resources	+	Rainwater is stored and reused
				0	n.a. (the location does not count with a significant amount of precipitations)
				-	Rainwater is not stored and reused
			Operational efficiency	+	Minimum waiting times and maximum productivity are achieved to minimize emissions
				0	Other measures for operational efficiency are taken
				-	No measures are taken to maximize operational efficiency for minimum emissions
	TERMINALS	Hazardous material management	Environmental accidents prevention	+	Safety measures and processes are followed to prevent environmental accidents are followed, including training personnel, regular inspections and the necessary mitigation equipment all over the port
				0	n.a. (hazardous material is not handled in the port)
				-	No special safety measures are taken to prevent environmental accidents
			Emergency response plan	+	An emergency response plan to act rapidly and coordinated in case of environmental accidents and natural disasters is developed
				0	The emergency response plan developed focuses on environmental accidents or on natural disasters
				-	An emergency response plan in case of environmental accidents is not developed
		Yard equipment	Environmental performance of equipment	+	Equipment with no emissions is selected
				0	Equipment with reduced emissions compared to traditional equipment is selected
				-	The equipment not selected based on the environmental performance
		Waste management	Amount of waste	+	No cargo residues are generated in the port
				0	More than 50% of cargo residues are reused as raw material in or outside the port
				-	Less than 50% of cargo residues are reused as raw material in or outside the port
			Waste processing and disposal	+	Waste is reused, recycled or energy is recovered during the waste processing, and when disposed, the quality of soil or groundwater is not disrupted
				0	Waste is not reused, but the disposal is done carefully not to disrupt the quality of soil or groundwater is not disrupted
				-	The disposal of waste disrupts the quality of soil or groundwater

	VESSELS	Emissions	Acceptance of vessels	+	Only vessels with an ESI score higher than 50 are allowed to enter the port
				0	Only vessels with an ESI score higher than 25 are allowed to enter the port
				-	All type of vessels, regardless of their environmental performance, are allowed to enter the port
			Port dues and rewards	+	Shipping companies with high environmental performance are incentivized via lower port dues or rewards, while low environmental performance and high levels of noise involves fines
				0	High environmental performance is incentivized but fines are not given to shipping companies with low environmental performance or high levels of noise
				-	Port dues are equal regardless of the environmental performance and no rewards or fines are applied
			Measures for emissions reductions	+	The port marine service vessels count with a higher environmental performance than traditional vessels and the velocity in the port and navigation channel is restricted to minimize emissions and noise
				0	The velocity in the port and navigation channel is restricted to minimize emissions and noise, but traditional marine vessels are used
				-	The Port Authority uses traditional marine service vessels and there are no restrictions for the vessels velocity
		Ballast water management	Ballast Water and Sediments Management Plan	+	A Ballast Water and Sediments Management Plan is developed, guaranteeing the compliance with the BWM Convention
				0	n.a.
				-	No measures to guarantee the compliance with the BWM Convention are taken

The scoring system from the criteria marked in *italics* was refined after the case study (planning phase). The criteria before testing the evaluation framework are including in section 6.4.

Process criteria

Two subjects from the methodology have not been included in the scoring system table from last section. These are the 'port mission' (planning phase) and the 'environmental management system' (operation phase). The reason is that they have been separated to derive 'process criteria' from them because one cannot derive green goals from them, but actions or measures that contribute to reach a green goal (which are the ones defined before and which are given

the criteria with which they can be reached). For instance, sustainability reporting is not a green goal in itself, but a measure that contributes to improving the environmental performance. The same happens with the stakeholders' co-creation, and for that reason some process criteria will also be defined for it. These process criteria also differ from the criteria of in terms of the scoring system, being a checklist instead of a +/0/- scoring. These are defined in Table 18.

Table 18 Process criteria

PHASE	SUBJECT	PROCESS CRITERIA	CHECKLIST
PLANNING	PORT'S MISSION	Green Port purpose	Definition of objective (sustainability) and subobjectives (future-proof, minimization of impacts, and maximization of benefits and added value)
		Green strategy	Definition of a strategy with action plans to achieve the defined objectives based on resources and top green philosophies
		Green standards and behaviors	Definition of a policy with targets based on sustainable standards
		Green values	Definition of values as drivers for development based on the Green Port goal
OPERATION, MAINTENANCE AND MANAGEMENT	ENVIRONMENTAL MANAGEMENT SYSTEM	Continuous cooperation with stakeholders	Inclusion of internal and external stakeholders to contribute with ongoing efforts to improve performance and increase benefits to all of them
		Sustainability reporting	Development of sustainability reports as a strategy for improvement of the environmental performance by setting green goals
		Control systems and monitoring	Setting of a monitoring program to verify compliance with green objectives and targets and definition of action plans when the tendency of the measured value will not allow the achievement of the goal
		Continuous improvement	Searching and taking measures for improvement and optimization of operations, maximizing productivity, and eliminating sources of inefficiency
		Stimulation of green technologies and innovation	Looking for opportunities for implementation of green technologies or innovative solutions that contribute to the Green Port goal, forming part of the adaptive planning also to remain functional
STAKEHOLDERS' CO-CREATION	PORT MISSION	Involvement of stakeholders before project conception	Identification and involvement of stakeholders to define the port mission (objectives, strategy, etc.) based on the raised issues and to maximize their benefit
	SITE SELECTION	Site selection as per stakeholders' opinion	The stakeholders' co-creation shall provide with sufficient information to focus on the relevant criteria to select the best site

	MASTERPLANNING	Creation of added value to stakeholders (incl. communities)	Creating added value not only to communities but other stakeholders during the masterplanning process
	DESIGN	Creation of added value to the environment and port users	Contribution of stakeholders to create added value to the environment and between port operators and users
	CONSTRUCTION	Cooperation with stakeholders to minimize impacts	Cooperation with stakeholders about local ecological matters and to minimize communities impacts
	OPERATION	Continuous cooperation with stakeholders	(Defined before in operation, maintenance, and management phase)

2. WEIGHTING SYSTEM

Each criterion of the evaluation framework is given a score depending on the measure which is taken. Nevertheless, all criteria may not have the same importance. The degree of importance is, however, case dependent, to which stakeholders also contribute. Depending on what is valuable for the stakeholders of the specific project, the criterion may be of high importance or irrelevant. In Table 19 a guideline to be used in order to select the weight for each criterion is given. It is possible that, given the specific conditions of the project, some criteria may fall into the description of different weights. If this is the case, as a general rule, the higher weight shall be chosen, unless the characteristics of the project make a lower weight more convenient.

Table 19 Weighting system for criteria of evaluation framework

WEIGHT	IMPORTANCE	DESCRIPTION
2	Important	-The criterion is highly valued by the relevant stakeholders -The negative impact would be high if the + score is not followed -The benefits would be high if the + score is followed -Maintenance dredging would be significantly high if the + score is not followed -The criterion involves safety matters -The criterion minimizes the risk of negative environmental impacts -The criterion contributes to emissions' reductions
1	Neutral	-The negative impact would not be high if the + score is not followed -The benefits would not be high if the + score is followed -The criterion is not important not irrelevant
0	Irrelevant	-For site selection criteria: there are no alternatives in the region which would get a + score -The relevant stakeholders give no importance to the criterion -Technical impossibility to get a + score given project conditions -The criterion is not relevant/applicable given project conditions

C. PROTECTED AREAS AND IMPORTANT NATURAL HABITATS

1. IUCN CATEGORIES

Table 20 IUCN Protected Area Management Categories (Dudley, N., 2008)

IUCN CATEGORY		DESCRIPTION
IA	Strict Nature Reserve	Strictly protected areas set aside to protect biodiversity and also possibly geological/geomorphologic features, where human visitation, use and impacts are strictly controlled and limited to ensure the protection of conservation values. Such protected areas can serve as indispensable reference areas for scientific research and monitoring.
IB	Wilderness Area	Usually large unmodified or slightly modified areas, retaining their natural character and influence without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition.
II	National Park	Large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible, spiritual, scientific, educational, recreational, and visitor opportunities.
III	Natural Monument or Feature	Protected areas set aside to protect a specific natural monument, which can be a landform, sea mount, submarine cavern, geological features such as a cave, or even a living feature such as an ancient grove. They are generally quite small protected areas and often have high visitor value.
IV	Habitat/Species Management Area	Protected areas aiming to protect particular species or habitats, their management reflects this priority. Many Category IV protected areas will need regular, active interventions to address the requirements of particular species or to maintain habitats, but this is not a requirement of the category.
V	Protected Landscape/Seascape	A protected area where the interaction of people and nature over time has produced an area of distinct character with significant, ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values.
VI	Protected area with sustainable use of natural resources	Protected areas that conserve ecosystems and habitats together with associated cultural values and traditional natural resource management systems. They are generally large, with most of the area in a natural condition, where a proportion is under sustainable natural resource management and where the low-level non-industrial use of natural resources compatible with nature conservation is seen as one of the main aims of the area.

2. IDENTIFICATION OF PROTECTED SPECIES AND IMPORTANT NATURAL HABITAT SITES

Convenient tools that could be used for identifying important natural habitat sites for birds, which are significantly affected by port developments because of their proximity to the coast or because of altering their migrating routes are, for instance, the BirdLife International networks. An e-Atlas of Marine Important Bird (BirdLife International, 2012) was created for this purpose, covering 3000 Important Bird and Biodiversity Areas (IBAs) in coastal and deep water around the world. It focuses on seabirds, which are the most threatened group of birds, especially affected by artificial light, which is one of their major threats (GHD, 2013). The IBAs are recognized in several countries in their national legislation (BirdLife International, 2018), but even if the project site is not inside the boundaries of these legislations, they shall be considered to properly assess what actions to follow to conserve biodiversity in the area to ultimately achieve the Green Port goal.

Another of their tools is the Data Zone (BirdLife International, 2018), with nearly 12000 (IBAs) also for inland territories. It gives information about the different bird species and their status via the IUCN Red List Categories (Figure 43) the threats to the key biodiversity, protected areas and habitat and land use. This information is accessible both for the whole country and for specific regions in it, which is useful to assess a particular area where the port project may be located.

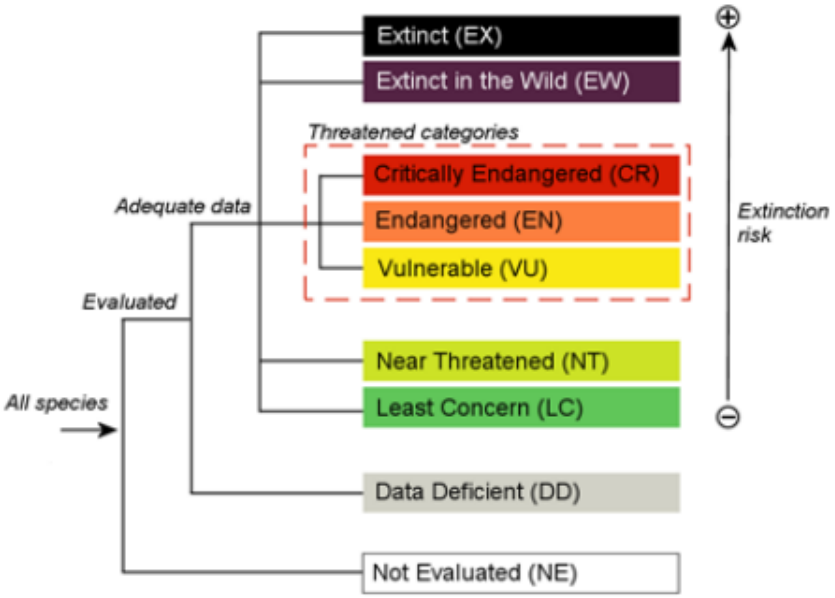


Figure 43 IUCN Red List Categories (IUCN Species Survival Commission, 2000)

D. ECOLOGY ENHANCEMENT MEASURES IN DESIGN

It is essential to understand the system and consider the surrounding area to optimize the design. Some measures to enhance ecology include shifting from hard solutions to soft solutions, giving texture to the structures surface (using rough materials), maximizing void spaces in rock rubble groynes, using a mix of materials in the design, incorporating habitat niches in vertical walls, creating pools to retain water at low tide or positioning structures lower in the tidal frame (Naylor, Venn, Coombes, Jackson, & Thompson, 2011). These measures are very closely related to the Building with Nature approach, characteristic of Green Port developments, which may not only create an added value to the environment but also for society. For instance, if a sandy foreshore is designed as a coast protection instead of using rubble mount, a recreational area is developed, which benefits society and nature. Local vegetation can also serve as port protection or water purification, like mangroves, seagrass, salt marshes, etc., so attention shall be put on the local conditions to enhance species, and therefore the local environment, also for functional reasons. For this purpose, it is essential to understand the local ecology and at the same time analyzing which ecosystem services are provided if they are enhanced, to select the best alternative.

The Environmental Design of Low Crested Structures (DELOS) project (Burcharth, S.J.Hawkins, B.Zanuttigh, & A.Lamberti, 2007) shows how different design characteristics can influence ecology in hard coastal structures, regarding the position within the tidal frame, distance from the shore, porosity, frequency of maintenance works, proportion of submerged versus emerged elements, length of the structure, spatial arrangement, type of material, etc.

For instance, sustainable decisions can be made regarding the design of the quay walls. Different materials can give a higher or lower carbon footprint of the quay wall structure (Heel, Maas, Gijt, & Said, 2011). A texture can also be given on its surface, to allow different species to settle in it. The possibility of letting species grow on structures could also contribute to gaining public support and creating value. It also leads to the enhancement of ecosystem services, foodstuffs provision, cultural enhancement, habitats creation for other species or the regulation of the sea conditions (by for instance, dissipating waves).

The selection of the material may also lead to ecological enhancement. When concrete is required, due to technical reasons, the consideration of concrete that enhances the ecological value shall be considered. This type of material is already developed (e.g. by ECOncrete) which involves a lower ecological footprint than standard concrete and enhances natural habitats. It is already in use for applications like seawalls, armor units, quay walls, piles, revetments and anchoring, enhancing the colonization of marine species, due to the shape of the units or surface of the structure. However, for its application, it is necessary to understand the local conditions and decide which species are aimed to boost in order to use different components.

In general, given the extent to which ecological values are considered, the port design can belong to one of the categories defined by the 'Estuary Edges' project (Biodiversity by Design Ltd, Salix River and Wetlands Services Ltd, Beckett Rankine Ltd and EcoSchemes Ltd., 2009), which focuses in designs in estuarine environments (Table 21).

Table 21 Categories for designing estuary edges (Biodiversity by Design Ltd, Salix River and Wetlands Services Ltd, Beckett Rankine Ltd and EcoSchemes Ltd., 2009)

	DESCRIPTION	ECOLOGICAL VALUE
Bioengineered designs	Plants are used for long-term protection from erosion, and aim to mimic natural systems, but may be inappropriate in all situations.	The ecological value of such designs is closest to that of a natural tidal bank.
Biotechnically engineered designs	Plants contribute significantly to the design, but harder engineering elements are also used for stability.	The ecological value of such designs can approach that of a natural bank
Structurally engineered designs	These designs are mainly artificial, with ecological elements added on.	The ecological value of such designs varies widely but can be high.
Hard engineering	These designs are used when there is too much water energy for ecology, other than seaweed and exposure-tolerant invertebrates.	The ecological value of such designs is generally negligible

In order for a port to be green, its design shall resemble the maximum degree possible to the idea behind the bioengineered design, applying the concept not only to estuarine environment but to other types of environments where the port is located. The hard engineering design, with a negligible ecological value, shall be avoided. The challenge for its implementation lies on balancing between ecology enhancement and technical requirements and on the specific local variables (loads, quality of soil, available space, design lifetime, etc.), which may require the selection of one or another type of design. 'Green-grey' solutions may, therefore, be the preferable alternative in many situations, when wave energies are high or space availability low, resembling an option between soft and hard solutions. They are based on 'grey' structures in which the ecological value is improved, obtaining a 'nature enriched solution'.

E. RENEWABLE ENERGIES

1. WIND ENERGY

If the port is located in a region where wind levels are significant, wind turbines can be installed either inside its boundaries or offshore, to obtain the power to (partly) operate and even provide electricity to households. Connection to the grid shall also be made if the wind levels are not sufficient, and for specific periods of the year. However, the location shall be selected carefully, so that nature and communities are not affected negatively. Communities shall not be affected by the noise, the reflection of the sun or the shadow flicker, which is an inconvenience encountered in certain residential areas at a specific time of the day, due to the flickering effect when the blades rotate in front of the sun. Therefore, detailed analyses shall be carried out in case there are nearby communities. And it shall also count with the social acceptance because of visual quality. Biodiversity is another aspect to consider, especially if the port is situated in a migratory flow. Nevertheless, if there are limited options for their location, the option of disconnecting the wind turbines in certain periods of the year shall be considered, however, it is not the optimal solution.

2. SOLAR POWER

A Green Port shall count with solar panels in its buildings roofs with the objective of supplying the port and maybe nearby households. Other port elements such as buoys, dolphins and waterways markings can also be powered by their own solar panel (as in the Port of Rotterdam). Back-up or storage technologies are needed because of the fluctuating power production. This renewable energy alternative has the advantage of not impacting biodiversity or communities in a negative way.

3. BIOMASS

Biomass is considered a renewable energy option because the energy is generated in a closed carbon cycle with zero net emissions, as the offset of carbon dioxide during the burning process comes from actual plants rather than from fossil fuels (and its corresponding CO_2) locked underground for millions of years. So, the emissions will be again absorbed my vegetation through the photosynthesis and released again during the combustion process (Figure 44).

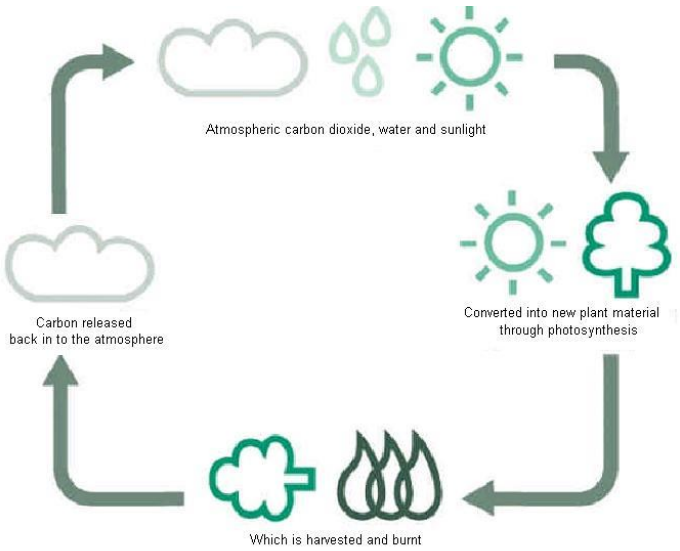


Figure 44 Closed carbon cycle (source: University of Strathclyde)

This option can be considered if a sufficient supply of sustainable biomass is guaranteed, together with sufficient capabilities for transport and storage of biomass feedstock. The required infrastructure to carry out the combustion process is also a requirement.

4. GEOTHERMAL ENERGY

Exploitation of geothermal energy is another renewable energy alternative with no emissions. However, the restrictions for its use, given the heat source, are limited, because a suitable geological formation is required. The risk of seismic incidents due to the deep drilling activities and the legal issues shall also be analyzed in advance.

5. OCEAN ENERGY

Ocean energy can also be used as a sustainable way of energy generation, including both tidal and wave energy. For this purpose, underwater turbines are required, for which a suitable location shall be found to avoid disturbances with shipping, not to affect marine ecosystems and where the changes in sedimentation processes are not prejudicial. The advantage of tidal energy usage is that the energy production is predictable, and the social acceptance is probably higher compared to other renewable energies (considering that, following the green port approach, the port is not located close to relevant or protected marine ecosystems). On the other hand, the costs are high, and it considerably depends on the site location, being necessary a high tidal range and flow velocities to be efficient.

6. HYDROPOWER ENERGY

The possibilities for hydropower energy shall also be considered when designing a Green Port, being a source of energy that does not harm the environment. This option is relevant given certain characteristics of the site, when the difference in the terrain levels is high, to produce high flow velocities. It can be utilized not only in cases where there are rivers flowing towards the area, but also if there is a possibility of storing water in higher levels and obtaining energy when necessary.

7. OTHER SOURCES OF ENERGY

Energy efficiency could also be obtained from other sources of energy, which are not commonly named as “renewable” but they are based on the principle of Circular Economy. The waste of certain business inside the port may form the source of energy for others or to supply local communities. This analysis is an important step in a Green Port development and shall be carried out from the first stages. A possible option is the use of the excess of steam from waste.

F. DREDGING IMPACTS

The deepening of the navigation channel can involve impacts on a higher scale, like increase in wave action with consequent acceleration of erosion or increase in the salt intrusion form the sea, changing the regime of rivers and shoreline wetlands. Other impacts could include the excavation of habitats for flora or fauna, spills, turbidity or increased concentration of suspended and dissolved material, reduction of water quality, reduction of light penetration which could lead to reduced growth of bottom vegetation, loss of seabed ecosystem, etc.

In particular, for each dredging phase, the main environmental aspects are different (Bray, 2008). In the excavation phase, attention shall be given to the removal of soil, increase of suspended sediments, mixing of soil layers or dilution (in case of hydraulic dredging). In the process of raising the material, focus shall be put on the release of suspended sediments, density of the material, loose and mobile spill layers and overflow. During the horizontal transport, the main environmental aspects are safety, dilution, spillage, and sound and air pollution. And during the placement, the occupation of space and surface, dispersion of the deposited material, sound and air pollution, and groundwater quality. All these variables must be monitored during the process, to act accordingly if the impacts are larger than predicted.

G. EXAMPLES

1. COMPENSATION MEASURES

The Port of Bremen serves as a good example because of having developed nature protection areas of around 1400 ha especially relevant for migratory fish, waterfowl and waders, grassland birds, reed bed birds, and salt marshes as a compensation measure (Bremen Ports, 2015). They are characterized by a tidal lower course of a river, tidal inlets and brackish flats, reed beds, wet fallows, salt marsh with flooding in winter, seasonally flooded grassland, ditches, ponds, and shrubs.

2. NON-INTEGRATION INTO THE SURROUNDINGS

An example of a port which is not integrated into the surroundings is the external port of Ferrol, in Spain (Figure 45). A significant area of the mountains in the peninsula was excavated in order to locate the port in that area, leading to a solution 'built in nature' instead of 'built with nature', which is in contrast with the Green Port principles. The advantage of constructing the port in that location is that it is kept at a certain distance of the city, minimizing communities' impacts, which is positive (Figure 46). Nevertheless, the negative environmental impact is high given the design of the port, and it is also possible that the marine species are also affected, because of the long breakwater.

Figure 45 Port of Ferrol (Autoridad Portuaria de Ferrol-San Cibrao, 2018)

Figure 46 Location of the Port of Ferrol (red) and the city of Ferrol (yellow) (source: Google maps)

3. TERMINAL OPERATORS WITH HIGH ENVIRONEMTNAL PERFORMANCE

The "Go Green" environmental initiative derived from the collaboration between the world's leading container port operators (DP World, Hutchison Ports, PSA International and Shanghai International Port Group) together with the Port of Rotterdam Authority (IHS Markit, 2017), serves as an example to other terminal operators because of their environmental performance

and initiatives to involve communities. The initiative has been completed across 78 terminals in 40 countries, involving 7500 employees.

4. SPILLS RESPONSE PLAN

A spill response flowchart is necessary to be included in a spills response plan, with the actions to follow. The Port of Vancouver uses the one in Figure 47 and can be applied to other port complexes.

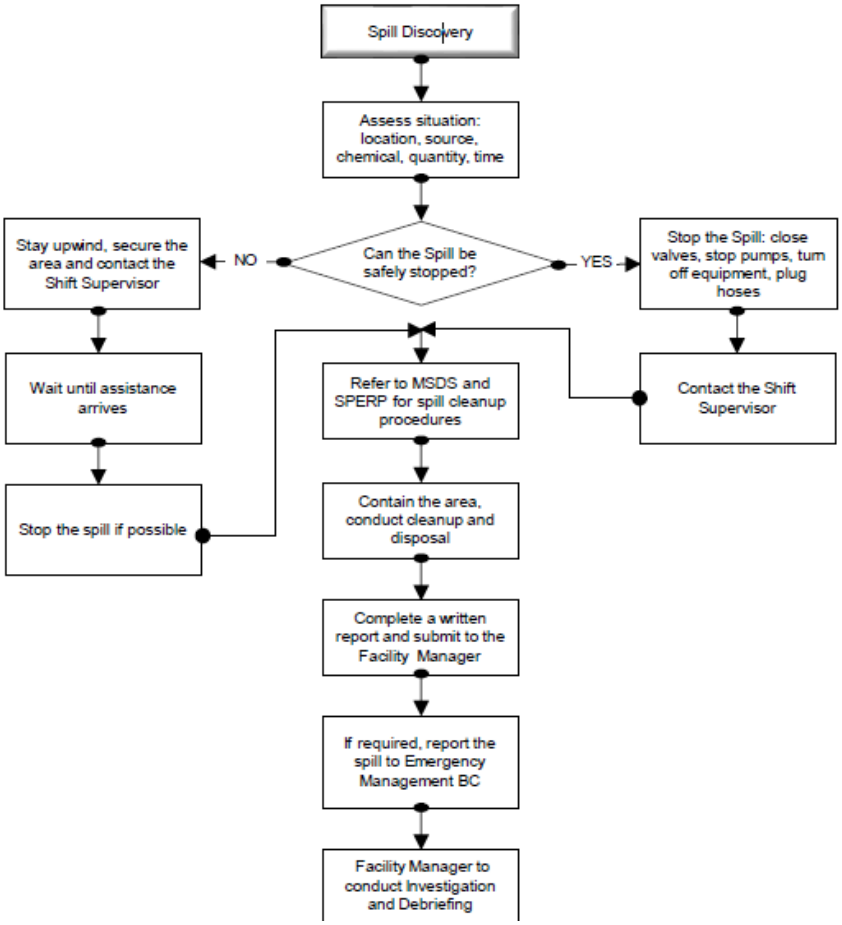


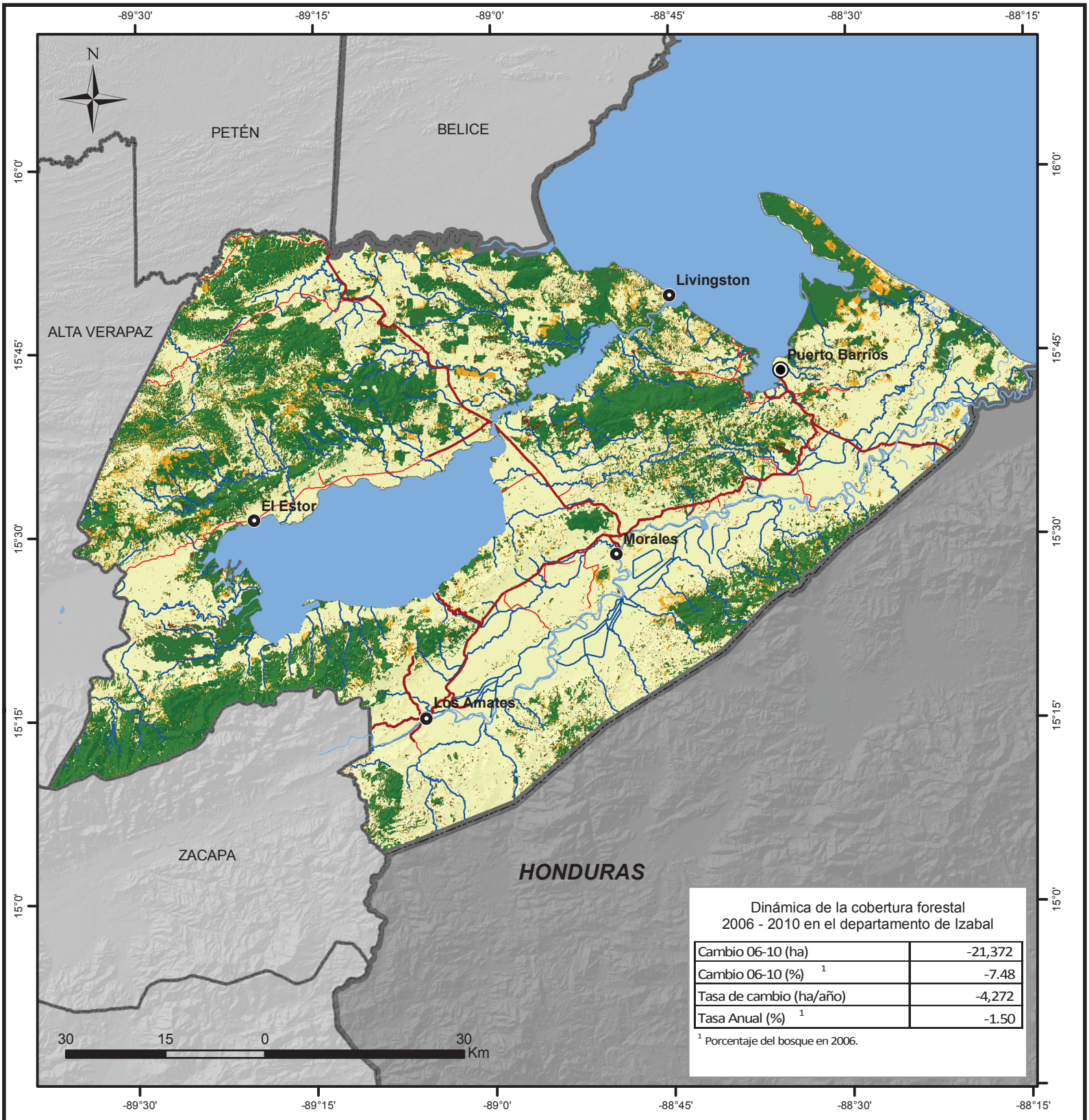
Figure 47 Spill response flowchart for the Port of Vancouver (Hemmera Envirochem Inc. & CMC Engineering and Management Ltd., 2017)

5. TERMINAL EQUIPMENT EFFICIENCY

An example of terminal equipment efficiency is given by the Ports of Auckland. Efficient cranes will be placed in late 2018 (Ports of Auckland, 2017), which are able to carry up to four containers at once, cutting ship loading/unloading times and help increase capacity. They also count with energy reduction features, LED floodlights and 26kW solar power system to offset mains power consumption.

H. CASE STUDY DOCUMENTS

1. MAP FOREST COVERAGE IN IZABAL 2010 (“Dinámica de la cobertura forestal 2006 - 2010 en Izabal”)
2. MAP VEGETAL COVERAGE AND LAND USE IN GUATEMALA 2010 (“Mapa de cobertura vegetal y uso de la tierra República de Guatemala, Año 2010”)



Dinámica de la cobertura forestal
2006 - 2010 en el departamento de Izabal

Cambio 06-10 (ha)	-21,372
Cambio 06-10 (%) [1]	-7.48
Tasa de cambio (ha/año)	-4,272
Tasa Anual (%) [1]	-1.50

[1] Porcentaje del bosque en 2006.

Referencias

- Límite Departamental*
- Cabecera departamental
- Cabecera municipal
- Asfaltado
- No asfaltado
- Ríos principales

Dinámica de la cobertura forestal 2006 - 2010

- Área de bosque
- Área sin bosque
- Ganancia de bosque
- Perdida de bosque
- Sin información
- Agua

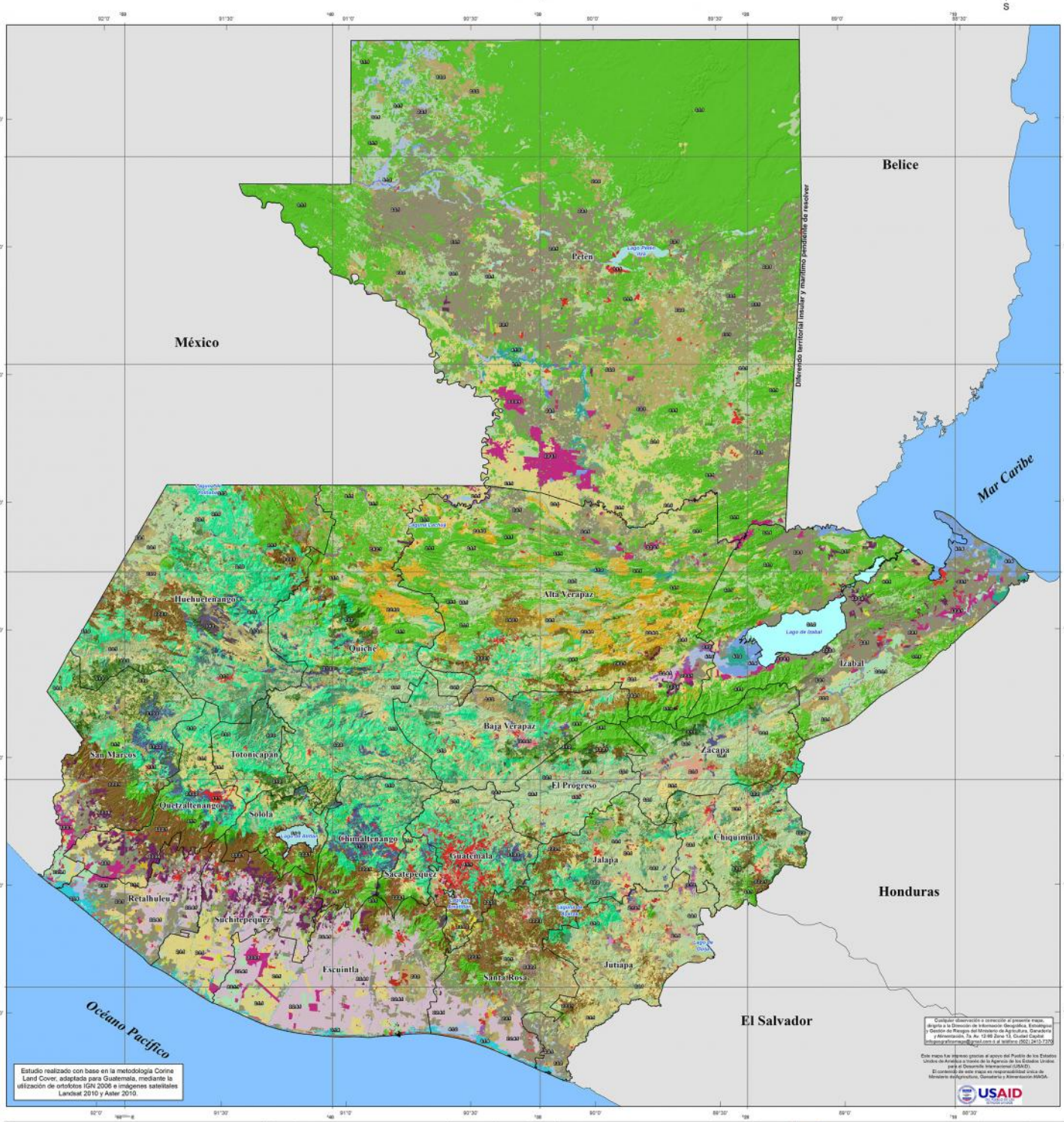
*Los Limites administrativos no son autoritativos

Dinámica de la cobertura forestal 2006 - 2010 en Izabal

Elaborado por:
Instituto Nacional de Bosques -INAB-
Consejo Nacional de Areas Protegidas -CONAP-
Universidad del Valle de Guatemala -UVG-
Universidad Rafael Landivar -URL-

Escala del estudio : 1:50,000
Sistema de Coordenadas Geográficas WGS 1984
Fuente adicional: Base de Datos Digital IGN/SUNIL escala 1:250,000
Guatemala, marzo de 2012

Mapa de cobertura vegetal y uso de la tierra
República de Guatemala
Año 2,010



1. Territorios artificializados		Área (ha)	Área (%)
	1.1. Zonas Urbanizadas	**119,457.29**	**1.0971**
111	1.1.1. Tejido urbano continuo	106,742.93	0.9803
112	1.1.2. Lotificaciones	12,714.35	0.1168
	1.2. Zonas industriales o comerciales y redes de comunicación	**16,207.98**	**0.1488**
	1.2.1. Zonas industriales	**10,352.71**	**0.0949**
1211	1.2.1.1. Agroindustria	2,565.96	0.0236
1212	1.2.1.2. Beneficios	429.91	0.0039
1213	1.2.1.3. Producción hidrobiológica (camaroneras, pisciculas)	2,625.71	0.0241
1214	1.2.1.4. Salinas	2,220.03	0.0204
1215	1.2.1.5. Complejo industrial	2,491.10	0.0229
	1.2.2. Comercios y servicios	**3,714.45**	**0.0341**
1221	1.2.2.1. Centro comercial	85.43	0.0008
1222	1.2.2.2. Hospital	101.24	0.0009
1223	1.2.2.3. Base militar	834.85	0.0077
1224	1.2.2.4. Instalación educativa	245.33	0.0023
1225	1.2.2.5. Prisión	172.25	0.0016
1226	1.2.2.6. Cementerio	1,665.54	0.0153
1227	1.2.2.7. Hidroeléctrica	28.03	0.0003
1228	1.2.2.8. Otros Comercios y servicios	581.77	0.0053
123	**1.2.3. Zonas portuarias**	**53.53**	**0.0005**
	1.2.4. Aeropuertos	**1,371.61**	**0.0126**
1241	1.2.4.1. Aeropuerto internacional	179.78	0.0017
1242	1.2.4.2. Pista de aterrizaje	1,191.83	0.0109
125	**1.2.5. Áreas turísticas, arqueológicas**	**735.69**	**0.0068**
	1.3. Minas, escombreras y zonas en construcción	**3,388.07**	**0.0311**
131	1.3.1. Zonas de extracción minera (canteras)	3,248.63	0.0298
132	1.3.2. Escombreras, vertederos o rellenos sanitarios y plantas de tratamiento	139.44	0.0013

	1.4. Zonas verdes artificiales, no agrícolas	**4,133.06**	**0.0380**
1411	1.4.1. Zoológicos	58.57	0.0005
142	1.4.2. Instalación deportiva y recreativa	4,074.49	0.0374
2. Territorios agrícolas		Área (ha)	Área (%)
	2.1. Cultivos anuales	**1,388,165.95**	**12.7484**
211	2.1.1. Granos básicos (maíz y frijol)	1,217,745.13	11.1834
212	2.1.2. Arroz	17,060.16	0.1567
	2.1.3. Hortalizas	**133,409.09**	**1.2252**
2131	2.1.3.1. Tomate	13,292.24	0.1221
2132	2.1.3.2. Otras hortalizas (papa, cebolla, repollo, zanahoria, lechuga y otros)	120,116.85	1.1031
214	2.1.4 Sandía	1,869.77	0.0172
215	2.1.5 Melón	13,117.65	0.1205
216	2.1.6 Pashte	3,277.96	0.0301
217	2.1.7 Maníi	390.25	0.0036
218	2.1.8 Tabaco	1,295.94	0.0119
	2.2. Cultivos permanentes	**1,331,523.70**	**12.2283**
	2.2.1. Cultivos permanentes herbáceos	**67,860.94**	**0.6232**
2211	2.2.1.1. Banano-Plátano	55,744.38	0.5119
2212	2.2.1.2. Piña	5,728.70	0.0526
2213	2.2.1.3. Fresa	347.99	0.0032
2214	2.2.1.4. Flores y follajes	2,412.01	0.0222
2215	2.2.1.5. Mashán	734.58	0.0067
2216	2.2.1.6. Loroco	384.30	0.0035
2217	2.2.1.7. Sábila	86.56	0.0008
2218	2.2.1.8. Papaya	2,422.42	0.0222
	2.2.2. Cultivos permanentes arbustivos	**492,280.94**	**4.5209**
2221	2.2.2.1. Café	491,965.41	4.5180
2222	2.2.2.2. Té	135.52	0.0012
2223	2.2.2.3. Mora	180.01	0.0017

	2.2.3. Cultivos permanentes arbóreos	**249,012.15**	**2.2868**
2231	2.2.3.1. Palma africana	111,946.11	1.0281
2232	2.2.3.2. Pejíbaye	644.67	0.0059
2233	2.2.3.3. Coco	757.62	0.0070
2234	2.2.3.4. Frutales deciduos	4,600.19	0.0422
2235	2.2.3.5. Cacao	1,237.58	0.0114
2236	2.2.3.6. Hule	94,215.99	0.8652
2237	2.2.3.7. Aguacate	1,797.96	0.0165
2238	2.2.3.8. Mango	12,649.96	0.1162
2239	2.2.3.9. Cítricos	7,988.21	0.0734
22310	2.2.3.10. Macadamia	3,568.29	0.0328
22311	2.2.3.11. Rambután	229.02	0.0021
22312	2.2.3.12. Jocote	400.89	0.0037
22313	2.2.3.13. Otros cultivos permanentes	8,975.65	0.0824
	2.2.4. Cultivos permanentes de plantas o tallos	**522,369.67**	**4.7973**
2241	2.2.4.1. Caña de azúcar	360,300.61	3.3089
2242	2.2.4.2. Cardamomo	162,069.06	1.4884
	2.3. Pastos	**1,846,671.19**	**16.9592**
231	2.3.1. Pasto cultivado	1,145,527.37	10.5201
232	2.3.2. Pasto natural	701,143.81	6.4391
	2.4. Zonas agrícolas heterogéneas	**91,124.23**	**0.8369**
241	2.4.1. Mosaico de cultivos	2,461.39	0.0226
	2.4.2. Sistemas agroforestales	**73,986.08**	**0.6795**
2421	2.4.2.1. Café y cardamomo	64,240.10	0.5900
2422	2.4.2.2. Café y banano	9,441.55	0.0867
2423	2.4.2.3. Café y macadamia	304.43	0.0028
243	2.4.3. Huerto	14,508.65	0.1332
244	2.4.4. Vivero	168.11	0.0015
3. Bosques y medios seminaturales		Área (ha)	Área (%)
	3.1. Bosques	**3,680,538.37**	**33.8008**
311	3.1.1. Bosque latifoliado	2,767,352.62	25.4144
312	3.1.2. Bosque de coníferas	195,615.40	1.7965
313	3.1.3. Bosque mixto	693,732.67	6.3710
314	3.1.4. Bosque manglar	23,837.68	0.2189
	3.2. Otras tierras forestales	**235,083.49**	**2.1589**
	3.2.1. Plantaciones forestales	**71,196.97**	**0.6538**
3211	3.2.1.1. Plantación de conífera	49,773.07	0.4571
3212	3.2.1.2. Plantación de latifoliada	21,423.90	0.1967
322	3.2.2. Árboles dispersos	163,886.52	1.5051
	3.3. Medios con vegetación arbustiva y/o herbácea	**1,786,984.37**	**16.4111**
331	3.3.1. Vegetación arbustiva baja (matorral y/o guamil)	1,786,984.37	16.4111
	3.4. Espacios abiertos, sin o con poca vegetación	**51,292.91**	**0.4711**
341	3.4.1. Playas, dunas o arenales	25,458.01	0.2338
342	3.4.2. Rocoso o lavas	21,816.12	0.2004
343	3.4.3. Espacio con vegetación escasa (tierras desnudas y degradadas)	3,126.67	0.0287
344	3.4.4. Zona quemada	892.11	0.0082
4. Zonas húmedas		Área (ha)	Área (%)
	4.1. Zonas húmedas interiores	**174,003.58**	**1.5980**
411	4.1.1. Pradera pantanosa	10,679.37	0.0981
412	4.1.2. Zonas Inundables	86,678.13	0.7960
413	4.1.3. Humedal con vegetación	29,643.50	0.2722
414	4.1.4. Humedal con bosque	47,002.59	0.4317
5. Cuerpos de agua		Área (ha)	Área (%)
	5.1. Aguas continentales	**157,006.19**	**1.4419**
511	5.1.1. Río	37,058.80	0.3403
512	5.1.2. Lago, laguna o lagunetа	119,947.39	1.1016
	5.2. Aguas marítimas	**3,319.63**	**0.0305**
521	5.2.1. Estero	1,194.05	0.0110
522	5.2.2. Mar y/u océano	2,125.58	0.0195
Total		10,888,900.00	97.8411

* Los datos de la categoría "Bosques" fueron obtenidos en forma conjunta con el Grupo Interinstitucional de Monitoreo Forestal de Guatemala (INAB, MARN, CONAP, IGN, FAUSAC, IARNA-URL, UVG y MAGA), en el año 2,013.

Ministerio de Agricultura, Ganadería y Alimentación (MAGA)
Dirección de Información Geográfica, Estratégica y Gestión de Riesgos (DIGEGR)
Guatemala, junio 2,015

Escala: 1 : 800,000
50 25 0 50 100 Kilómetros

Proyección del Mapa Transversal de Mercator -TM-
Cuadrícula del Mapa Guatemala Transversal de Mercator -GTM-
NOTA: La representación de límites no debe considerarse autoritativa.

Fuente:
Estudio elaborado a escala 1:50,000 por la Dirección de Información Geográfica, Estratégica y Gestión de Riesgos del Ministerio de Agricultura, Ganadería y Alimentación con colaboración de la Asociación Nacional del Café; Centro de Evaluación y Monitoreo - Consejo Nacional de Áreas Protegidas; Proyecto Red de Sistemas de Alerta Temprana contra la Hambruna; Fundación para el Ecodesarrollo y la Conservación; Instituto de Agricultura, Recursos Naturales y Ambiente - Universidad Rafael Landivar; Instituto Privado de Investigación sobre el Cambio Climático; Instituto Geográfico Nacional "Alfredo Obiols"; Instituto Nacional de Bosques; Programa para la Erradicación de la Mosca del Mediterráneo y Universidad del Valle de Guatemala. Este mapa ha sido elaborado sobre la base cartográfica escala 1:50,000, propiedad del Instituto Geográfico Nacional

Gobierno de Guatemala
Ministerio de Agricultura Ganadería y Alimentación

Puede circular según resolución No. 305-2014, INSTITUTO GEOGRÁFICO NACIONAL "Ing. Alfredo Obiols Gómez", exclusivamente para este fin del año 2014.
Este mapa fue elaborado por la Dirección de Información Geográfica, Estratégica y Gestión de Riesgos -DIGEGR- MAGA, con información de Base Cartográfica del INSTITUTO GEOGRÁFICO NACIONAL "Ing. Alfredo Obiols Gómez". Guatemala, agosto de 2014