Sustainability assessment of Mediterranean container terminals: Piraeus and Livorno case studies

Recommendations for the extension of the Port of the Future Serious Game

Alexia Sotiriadou
4626117

TUDelft

Deltares
Enabling Delta Life

Delft University of Technology

Faculty of Civil Engineering and Geosciences

Department of Hydraulic Engineering

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Name (student number) Alexia Sotiriadou (4626117)

Committee Prof. Dr. Ir. Mark van Koningsveld (TU Delft)

Dr. Ir. Poonam Taneja (TU Delft)

Ass. Prof. Dr. Ir. Jarit de Gijt (TU Delft)

M.A. MSc. Allister Slingenberg (Deltares)

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PREFACE

This document is written in partial fulfilment of the requirements for the degree of the Master of Science in Civil Engineering at Delft University of Technology. The research was carried out in cooperation with the independent institute for applied research in the field of water and subsurface, Deltares, within COREALIS, a Horizon 2020 EU project. COREALIS consists of 9 Working Packages (WPs) and Deltares is leading on WP4 objective, that consists of the governance and decision making in the Port of the Future project. The realization of this objective is proposed from COREALIS to be achieved through "the extension of the Port of the Future Serious Game (PoFSG) in contents and functionality to facilitate stakeholder engagement".

The outcome of the thesis aims to assess the sustainability of Mediterranean container terminals, though the case studies of Piraeus and Livorno and based on the results, develop tools that can serve as an input to the extension of the PoFSG.

This is the public version of my thesis. Information from the COREALIS project that was mainly accessed from meetings and regards the two port case studies has been used. Due to confidentiality reasons, public access is not given as the report contains data that cannot be available to the general public (Port of the Future Serious Game details, Piraeus and Livorno ports' confidential data, COREALIS unpublished data).

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ACKNOWLEDGEMENTS

While this journey comes to an end, I feel satisfied and grateful that I gained valuable knowledge, further developed my critical thinking and was lucky enough to elaborate my thesis in a subject that I enjoyed along all the way, regardless the ups and downs that it encompassed. Through my thesis, I was challenged to confront with the reality during the attempt to gather information about the ports, I attended in focus meetings in the ports, I interacted with stakeholders and I got the opportunity to meet a lot of great people.

I would not have made it without the support of many individuals around me. Therefore, I would like to thank them here.

I would like to start thanking my supervisor in Deltares Allister Slingenberg, who gave me the opportunity to be part of the COREALIS project and kept me involved, including me in meetings, allowing me to travel to the ports of Livorno and Piraeus and being always willing to help me.

I am also thankful for the graduation committee of TU Delft who was guiding me throughout my thesis research: Prof.ir. Mark van Koningsveld, dr.ir. Poonam Taneja and Ass. Prof. ir. Jarit de Gijt. Prof. van Koningsveld who always kept me in the right track and gave me valuable recommendations and dr. de Gijt who also provided significant suggestions and advised me in specific matters. Last but not least, dr. Poonam Taneja who, apart from being my daily supervisor in TU Delft, was always acknowledging my work and giving me the strength to continue. I am also really grateful to Prof. ir. Tiedo Vellinga, for his invaluable help to make this thesis possible.

Furthermore, I would like to thank all the members of the authorities and the terminals that I met in the Focus Meetings and collaborated, for their willingness to be interviewed for this project, answering to my questionnaires and providing me with a large part of the information that I needed. I would also want to thank all the other stakeholders I contacted, for their patience and willingness to fill out the questionnaires. Additionally, I would also like to thank Mr Etmektzoglou for his invaluable guidance and assistance during the Python scripting.

Of course, I really want to thank my family in Greece, my mother and my father, who always supported me, no matter what. I could not find words to describe who grateful I am. Furthermore, I would like to thank my friends from Greece and elsewhere who were always there for me, no matter the distance separating us, and last but not least my friends in the Netherlands, without whom my life here would not have been the same.

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SUMMARY

Nowadays, that ports are among the most important nodal points of the world supply chain, they are considered to have a central role to the efforts of improving the sustainable performance of the supply chain at a local or global scale (United Nations, 2018). The largest part of the European ports are engaged into addressing proactively environmental and societal issues in order to obtain an always more sustainable development (ECOPORTS 2017), however there are several sources that indicate that there are gaps and barriers that impede the Mediterranean container ports' sustainable development (Aurelio Tommasetti, et al 2014,Buiza et al. 2015). More specifically, in the ports of Piraeus and Livorno, the concept of sustainability is not yet well-thought-out in the decision-making process and various problems exist obstructing their sustainable development.

In order to solve the problems that are identified in the ports and are closely related to sustainability, there is an emerging need to assess their current performance.

A framework is developed to assess the sustainable performance of ports and specifically container terminals. Specialized container terminals in modern ports have all the characteristics to be considered independent units of the port and as such a separate approach of the stresses they produce and their sustainability is appropriate in order to assess with objectivity their impacts. The creation of the Port Sustainability Assessment Framework (PSAF) allows the comparison of the current state of terminals with the desired state. The desired state is defined by the author, based on operational objectives/targets related to the factors related to the port activity which are considered to affect significantly People, Planet and Profit, the sustainability themes. Through the comparison of the current and desired state of the ports, their sustainability performance is evaluated as a percentage of achievement of the operational objectives/targets of each People, Planet and Profit category.

Additionally, the sustainability of ports is also assessed based on the perceptions of the stakeholders, by means of a questionnaire. In other words, port sustainability is approached based on the stakeholders' views and insights on sustainability. Furthermore, in the same questionnaire, the priorities of the stakeholders on various sustainability themes are assessed and the importance/weight factors for all the sustainability themes are calculated.

Two container terminal case studies are used to apply the PSAF and assess their sustainable performance, the container terminals of Piraeus and Livorno, two container terminals of different size and challenges but both located in the Mediterranean. It can be concluded that the concept of sustainability in the two case studies has not yet been embedded in their decision making and their operations and subsequently their sustainable performance is relatively low.

Another aspect that this thesis study attempts to confront, is the need to extend the Port of the Future Serious Game (PoFSG) in order to include in a realistic way port-city future developments and impacts on the environment/ society, as well as to facilitate stakeholder engagement (Horizon 2020: COREALIS, 2017). In that sense, several weaknesses of the PoFSG are identified, however; the focus is drawn on mainly two aspects of the game that need improvement: the system based on which the measures' performance to PPP is scored and the inclusion of relevant sustainable measures.

Therefore, a new Sustainable Performance Scoring System (SPSS) is created to score the measures objectively. The strong point of the SPSS is that weight factors are integrated for each sustainability theme so not only the effects of the implementation of measures on the port can be presented but also their contribution to the sustainable development of the port city. In addition, measures related to the most important sustainability themes, based on the stakeholders' views (air quality/carbon emissions and safety levels/climate change adaptation) are proposed and are scored using the SPSS.

The application of the sustainability measures is tested on the two terminals' case studies and the relevancies to the PoFSG are illustrated so that it can be ensured that they are helpful to the PoFSG.

For the rest of the weaknesses of the PoFSG, more generic recommendations are made. This will result in making the game more dedicated to raising awareness based on local conditions and consequently facilitating stakeholder's involvement.

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GLOSSARY OF TERMINOLOGY

In this sub-section, definitions on the key concepts in the manner in which they are used in this research are presented below:

Analytical catalogue: An extensive and descriptive list of the mainflows of substances, energies, materials and other resources that enter or exit the container terminal (CT) domain and the stresses they create (excel format and graphical cause-effect presentation)

Flow: The schematic representation of the course of a pollutant from source to destination medium or receiver

Impact: Direct and indirect effect on a certain element/factor like soil, water, fauna, flora etc.

Measures: Specific sustainable policies that can be implemented to improve their sustainable performance (since those measures have an effect on the three pillars of sustainability, People, Planet and Profit).

Measures in the PoFSG: Policies for port sustainable development divided into several different categories and have a determined effect on the three pillars of sustainability (People, Planet and Profit)

People, Planet, Profit: They describe the triple bottom line and the goals of sustainability.

PSAF: Port Sustainability Assessment Framework

Stresses: Modification of the normal state of a factor due to a natural and/or anthropogenic cause(s). Example of an anthropogenic cause is the pollution generation. Example of a natural cause is the pollution that a volcano eruption can cause. They can result in impacts in PPP.

Sustainability level: Extent to which the port is sustainable according to pre-defined criteria and levels

Sustainability themes: Factors related to the port activity which are considered to affect significantly People, Planet and Profit (in the context of a container terminal).

Triple bottom line: The triple bottom line (known also as TBL or 3BL) is a three-part framework: social, environmental (or ecological) and financial.

ABBREVIATIONS

µg	Microgram
Cd	Cadmium
Cfu	Colony-forming unit
CO	Carbon monoxide
CO2	Carbon dioxide
Cr	Chromium
Cu	Copper
dB	Decibel
Ecoli	Escherichia coli
EIA	Environmental Impact Assessment
Hg	Mercury
hr	Hour
i.e.	In other words
kg	Kilogram
km	Kilometre
kW	Kilowatt
l	Litre
m	Meter
mg	Milligramm
Ni	Nickel
NO2	Nitrogen dioxide
Pb	Lead
PAH	Polycyclic aromatic hydrocarbons
PCT	Piraeus Container Terminal
PM10	Particular matter (diameters that are 10 micrometers and smaller)
PoFSG	Port of the Future Serious Game
PPA	Piraeus Port Authority
PPP	People, Planet, Profit
PSAF	Port Sustainability Assessment Framework
SO2	Sulfur dioxide
SPSS	Sustainable Performance Scoring System
TDT	Terminal Darsena Toscana
TEUs	Twenty-foot equivalent unit
Zn	Zinc

1 INTRODUCTION

1.1 Background

1.1.1 Sustainable ports

In recent years, where the world is challenged to deal with countless threats and challenges, the notion of **sustainability** has been placed under the spotlight, strengthening its link with development. Sustainable is the development that satisfies both our present needs and what we now assume to be the needs of the future generations (WCED, 1987). Today is generally accepted that the sustainability concept encompasses all the multilevel processes, procedures and actions that could lead to the betterment of the conditions of present and future life on Earth (Poonam Taneja, Vellinga, and Ros 2014).

Nowadays, ports are among the most important nodal points of the world supply chain and as such, they have a central role to the efforts of improving the sustainable performance of the supply chain at a local or global scale (United Nations, 2018). **Sustainable ports** follow a new growth concept that encompasses sustainability, using "green" growth as an economic driver. The "green" port strategy is a strategy to maintain the future development of the port in harmony with the surrounding natural and anthropogenic systems (PIANC 2014a). Therefore, port master planning should be part of the wider concept of integrated area planning that would and take also into account connectivity, liveability and the biodiversity of the comprise surrounding area (PIANC 2014a). Nowadays, the largest part of the European ports and harbours are engaged into addressing proactively environmental issues in order to obtain an always more sustainable development (ECOPORTS 2017).

Since the beginnings of containerization in the early '60, the **container terminals** have progressively been developed according to the needs of the global container market, the evolution of the container ships and the modern approach of the "seaport" concept. This last one has been shaped under the weight of the fact that more than 80% by weight and more than 70% by value of the global trade is today handled by seaports (UNCTAD 2016). Nowadays, a container terminal has become a specialized, distinct and important part of the modern port and as such, it can and must be studied, in terms of sustainability, as an independent physical and functional domain.

1.1.2 Corealis and Port of the Future Serious Game

The **H2020 – Port of the Future project 'COREALIS'**, is a project that "*aims to develop a strategic, innovative framework for cargo ports to handle upcoming and future capacity, traffic, efficiency and environmental challenges*". COREALIS consists of 9 Working Packages (WPs) and Deltares is leading on WP4 objective. The objective is governance and decision making in the Port of the Future project.

COREALIS is composed of four high-level objectives. The relevant objective and the motivation for this thesis study would be the Objective O4: "Enable the port to take informed medium-term and long-term strategic decisions and become an innovation hub of the local urban space". There are several means in which this objective could be achieved, however, focus is given to the extension of the **Port of the Future Serious Game** (PoFSG) to facilitate stakeholder engagement.

As explained in the Manual of the Port of the Future Serious Game (Liagkouras et al. 2015):

> "*the game aims at raising awareness for the current policy-making challenges of ports, so as to support the port stakeholders in achieving sustainable development. The game applies a fictional but realistic environment, autonomous scenarios, a set of sustainability policy measures and a qualitative set of indicators that provide information on the effects of society, natural environment and economy. The Port of the Future Serious Game can also facilitate policy-making in ports with respect to socio-economic development, taking into account the impact of sustainable design on balanced growth*".

1.2 Problem statement

The problem that is addressed in this thesis project is two-fold, however, the two aspects are closely related to each other:

The first aspect refers to the problematic of **sustainability that is not yet well-thought-out** or fully integrated in the decision-making process in the ports of the Mediterranean. Gaps and barriers exist that impede the **Mediterranean container ports'** sustainable development (personal communications with various local port stakeholders). Among others, there is a poor adoption of standards, inadequate advancement of the necessary technology, and serious lacks in the waste and air emission management (Buiza et al. 2015).

For example, based on the statement in the Corealis project, the **Piraeus Container Terminal** (PCT) has several problems/weaknesses mainly regarding the operational activities, the energy consumption levels, the air pollution, the traffic congestion (Horizon 2020: COREALIS, 2017). The **container terminal of Livorno**, since its boundary is adjacent to the city needs to improve on efficiency in a sustainable way without the need of upgrading the existing physical infrastructure (Horizon 2020: COREALIS, 2017).

The sustainability assessment is performed for **container terminals** for several reasons. Initially, since the COREALIS project aims to extend the Port of the Future Serious Game (PoFSG) through Living labs in the Piraeus Container terminal and the in the Livorno container terminal (and partly general cargo terminal), it seems logical to consider those specific container terminal case studies. Additionally, even if there are many papers concerning container terminals in general, there are only a few studies that deal with green and/or sustainable container terminals. Furthermore, specialized container terminals in modern ports have all the characteristics to be considered independent units of the port (distinct operations, functions, superstructure and infrastructure) and as such a separate approach of their impacts and sustainability is appropriate in order to assess with objectivity their impacts.

The second aspect regards the need for the extension of the **Port of the Future Serious Game** (PoFSG) to make it more dedicated and realistic and consequently facilitate stakeholder engagement. The game needs to become more realistic and **plausible/acceptable to different stakeholders** (Horizon 2020: COREALIS, 2017). The modified and improved PoFSG will incorporate sustainable aspects for several scenarios of logistics, port design and climate adaptation. (Horizon 2020: COREALIS, 2017). Within the COREALIS project, the functionalities of the game are aim to be extended and implemented it in the **Piraeus** and **Livorno** Living Labs (LLs).

1.3 Objectives of Research

In order to solve the problems that are identified in the ports, which are closely related to their sustainable performance, it is necessary to develop a method to **objectively assess the ports' sustainability**. In that manner, a clear image of the performance of the ports will be gained and it will be easier to identify the gaps that exist in the policies and management strategies used as far as sustainability is concerned.

The need for the extension of the PoFSG has to be approached by identifying the weaknesses that currently exist in the game and proposing concrete solutions to the most crucial ones. Hence, this subject is approached mainly by the introduction of **realistic measures aiming at a sustainable port development**, suitable to the container terminals of Piraeus and Livorno. Additionally, a system is also necessary to **score the sustainability measure's performance** on People, Planet and Profit.

Therefore, the two main Objectives of this thesis project are presented below.

- Assess objectively the sustainability performance of Mediterranean container terminals
- Elaborate proposals and recommendations that could be used to make the PoFSG more suitable for the Mediterranean ports.

It has to be noted that the output of the first objective is expected to be used as an input for the extension of the PoFSG (second objective), though the introduction of relevant and important measures, based on the main sustainability concerns and the identified needs of the container terminals.

1.4 Research Questions

The Objectives presented in the previous sub-chapters can be translated into more detailed Research Questions.

The two Main Research Questions are presented below:

-1- How can the sustainable performance of container terminals' be objectively assessed?

-2- How can the PoFSG become more dedicated and realistic?

To obtain an answer, there are several Research sub-Questions that should be answered:

#1 What research method can be followed to systematically and objectively assess the sustainability of a container terminal?

#2 What is the sustainability level achieved by the container terminals of Piraeus and Livorno?

#3 How can the perceptions of stakeholders be included in the sustainable development of a container terminal?

#4 What method could be used to determine weight factors for the purpose of ranking the sustainability themes?

#5 What aspects of the PoFSG need to be improved and in what way?

#6 What method could be used to score the performance of sustainable measures to People, Planet and Profit?

#7 Which measures could be proposed to contribute to the improvement of the terminals' performance on the two most important themes?

1.5 Steps to answer the Research sub-Questions

In order to answer all the above Research Questions, several steps need to be implemented.

In order to answer the **#1 Research sub-Question** it is necessary to perform the following steps:

- Create a Port Sustainability Assessment Framework (PSAF) (based on the Systematic Frame of Reference, van Koningsveld 2003)
- Define the strategic objectives of the PSAF
- Develop a method to study the terminal processes in order to identify the potential stresses
- Define the main sustainability themes based on the identified potential stresses
- Define the contents of the elements of the PSAF (preliminary operational objectives, indicators, quantitative state concept, thresholds/target values and final operational objectives) for port sustainability
- Test the success of applicability of the PSAF in the two port case studies

In order to answer the **#2 Research Sub-Question** it is necessary to perform the following steps:

- Apply the PSAF to the two container terminal's case studies
- Test the level of achievement of the operational objectives defined in the two port case studies

In order to answer the **#3 Research sub-Question** it is necessary to perform the following steps:

- Chose the suitable method to elicit people's perceptions.
- Create of a Questionnaire to perform stakeholder perception analysis
- Test the effectiveness of the questionnaires through the identification of its strong and weak points
- Conclude which are the most important sustainability themes based on stakeholder's perceptions
- Conclude on what are the views of the average interviewee

In order to answer the **#4 Research sub-Question** it is necessary to perform the following steps:

- Apply and partially modify the Analytical Hierarchy Process (AHP) for the creation of importance weight factors for each sustainable theme
- Use Python scripts to automatically process the data of each questionnaire and derive the results
- Calculate (using the AHP method) the weight factors for each sustainability theme

In order to answer the **#5 Research sub-Question** it is necessary to perform the following steps:

- Explore the weaknesses of the PoFSG
- Develop techniques to improve the disadvantages or the gaps that exist in the PoFSG:
    - Develop a system to assign PPP scores in the measures of the PoFSG
    - Propose measures to make the game more dedicated and relevant to the most crucial sustainability themes
    - Suggest additional modifications

In order to answer the **#6 Research sub-Question** it is necessary to perform the following steps:

- Create an initial scoring system to evaluate the performance of port sustainability measures based on their effects on People, Planet and Profit
- Incorporate into the system the weight factors for each sustainability theme
- Test the applicability of the scoring system on the already existing measures of the PoFSG
- Create a method to quantify the port sustainable development based on a set of selected sustainability measures

In order to answer the **#7 Research sub-Question** it is necessary to perform the following steps:

- Redefine the operational objectives for the two most important themes
- Propose measures that would aim at effecting positively the two most important themes
- Test the applicability of the proposed sustainability measures in the two ports case studies
- Test the applicability of the proposed sustainability measures in the PoFSG
- Score the measures based on the scoring system that was created (SPSS)

1.6 Research methodology

The methodology that was followed in this thesis project, along with the Research sub-questions that are related to each part, is indicated in Figure 1.

In green are indicated the research steps and in blue the actions taken to achieve each research step. The yellow shapes indicate which Research sub-Questions are answered in each part of the thesis.

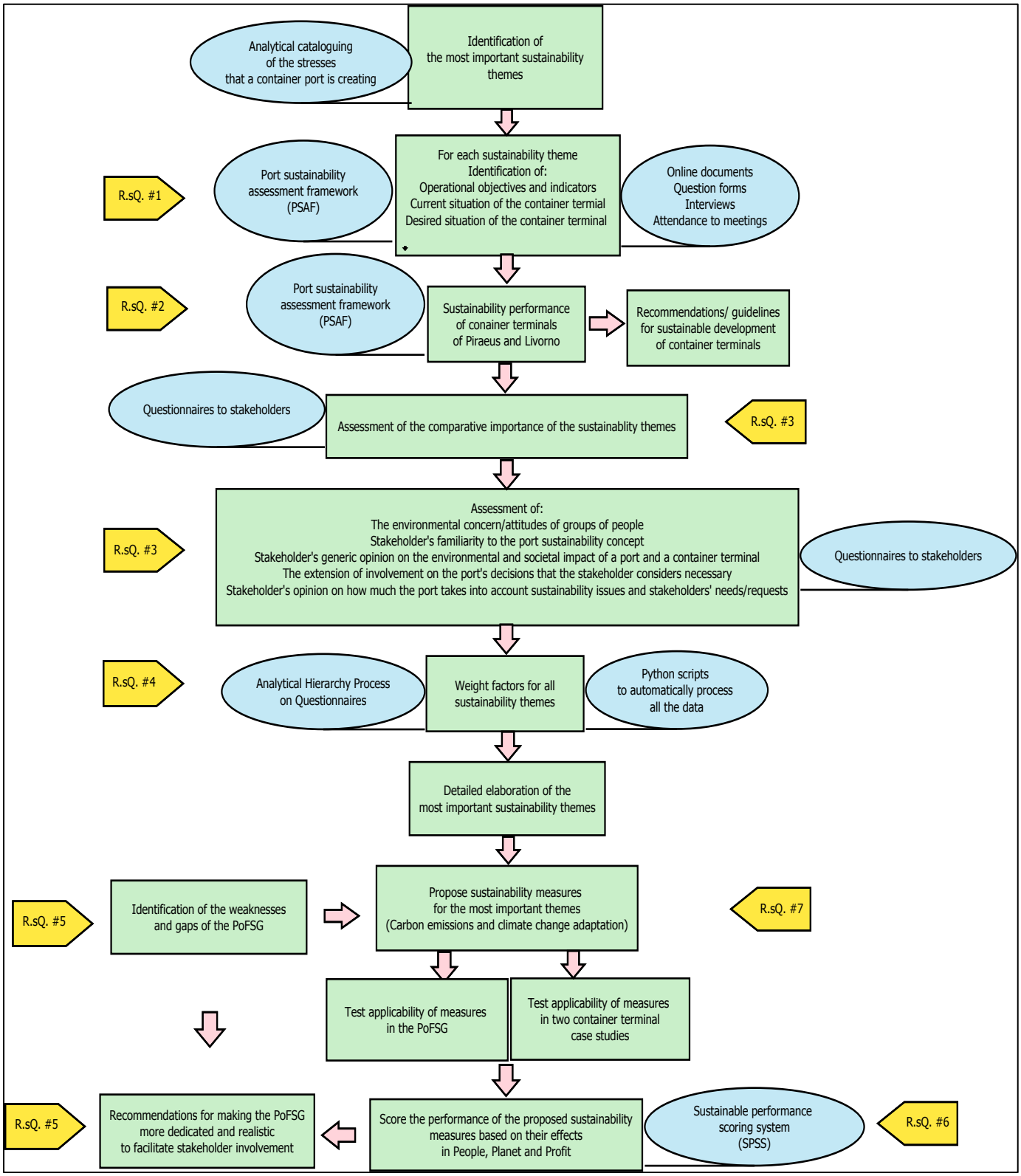


Figure 1: Methodology followed in the present thesis project (Source: Author)

1.7 Report outline and reader's guide

The thesis outline and development is presented in Figure 2 in order to explain the structure of the report and clarify relations between the outcomes of each chapter. Consequently the contents of the Chapters 2-5 are briefly discussed.

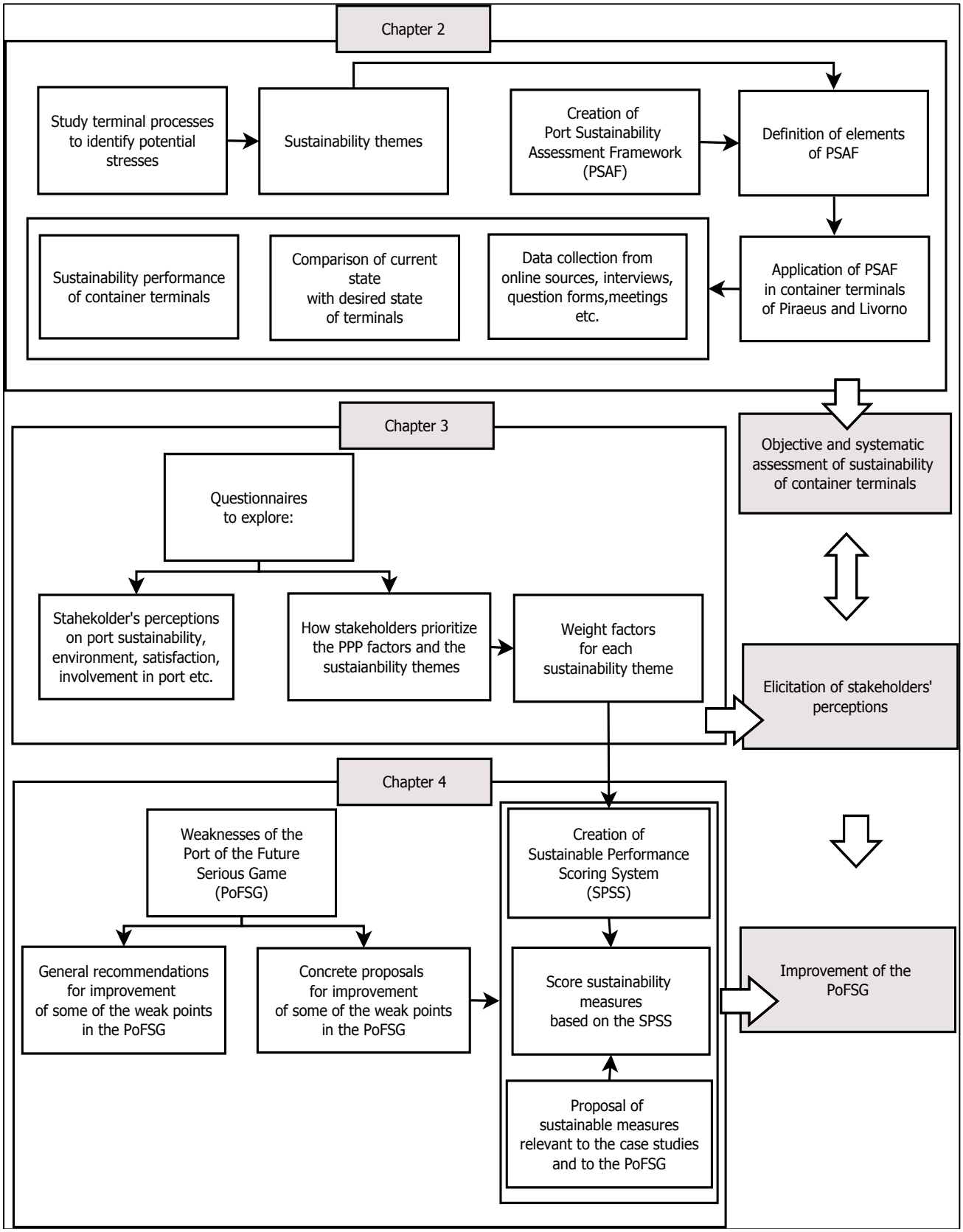


Figure 2: Thesis structure outline

Chapter 2

The container terminal processes are studied in order to identify the potential stresses that they may be causing**.** In that way, the **sustainability themes** can be defined, which constitute factors related to the container terminal's activity and are considered to affect significantly People, Planet and Profit. A framework is then developed for the systematic approach of the sustainability of container terminals, the **Port Sustainability Assessment Framework (PSAF)**, which aims to define the current condition of a terminal and compare it with the desired state. For each sustainability theme, the contents of the elements of the PSAF are defined (**preliminary operational objectives**, **indicators**, **quantitative state concept**, **thresholds/target values and final operational objectives).** The PSAF is applied in the container terminal case studies of Piraeus and Livorno to define the current and historical condition of the ports and compare them with the operational objectives (desired state). The results of the comparison are expressed as a percentage of achievement for each terminal of the operational objectives that are set.

Chapter 3

In this chapter, a questionnaire is developed aiming to elicit stakeholder's perceptions on port sustainability. More specifically, the exploration of the opinions of the stakeholders on the **comparative importance of the sustainability themes** is carried out through questionnaires. Additionally, the perceptions regarding **ecocentricity and anthropocentrism** are accessed, their **knowledge of port sustainable development**, their perception on **ports and container terminals** and their perception on their **involvement** in the decision making. The outcomes of the questionnaire result to a stakeholder perception analysis and to the production of importance weight factors for each sustainable theme, using the Analytical Hierarchy Process (AHP).

Chapter 4

In this chapter, the main weaknesses of the current version of the PoFSG are explored and **modifications** are recommended either in terms of concrete proposals either in the form of more general recommendations. A new **sustainable performance scoring system (SPSS)** is developed to evaluate the performance of port-related strategic and policy measures on People, Planet and Profit (proposed to substitute the current scoring system in the PoFSG). The **weight factors** for each sustainability theme, derived from Chapter 3, are used to calculate the final score of each measure so that sustainability could be objectively assessed. Considering the two sustainability themes which are given the largest priority by stakeholders (Air quality/carbon emissions and Safety levels/ climate change effects) and based on the gaps that exist in the PoFSG and also the weak points identified in the terminal case studies, the PSAF and specifically the **"Intervention"** procedure is further extended. In that manner, **measures** are included that aim to enhance the **sustainable performance** of the ports and at the same time serve as invaluable inputs to the PoFSG. The sustainable performance (effect on People, Planet and Profit) of the proposed measures derives from the application of the SPSS.

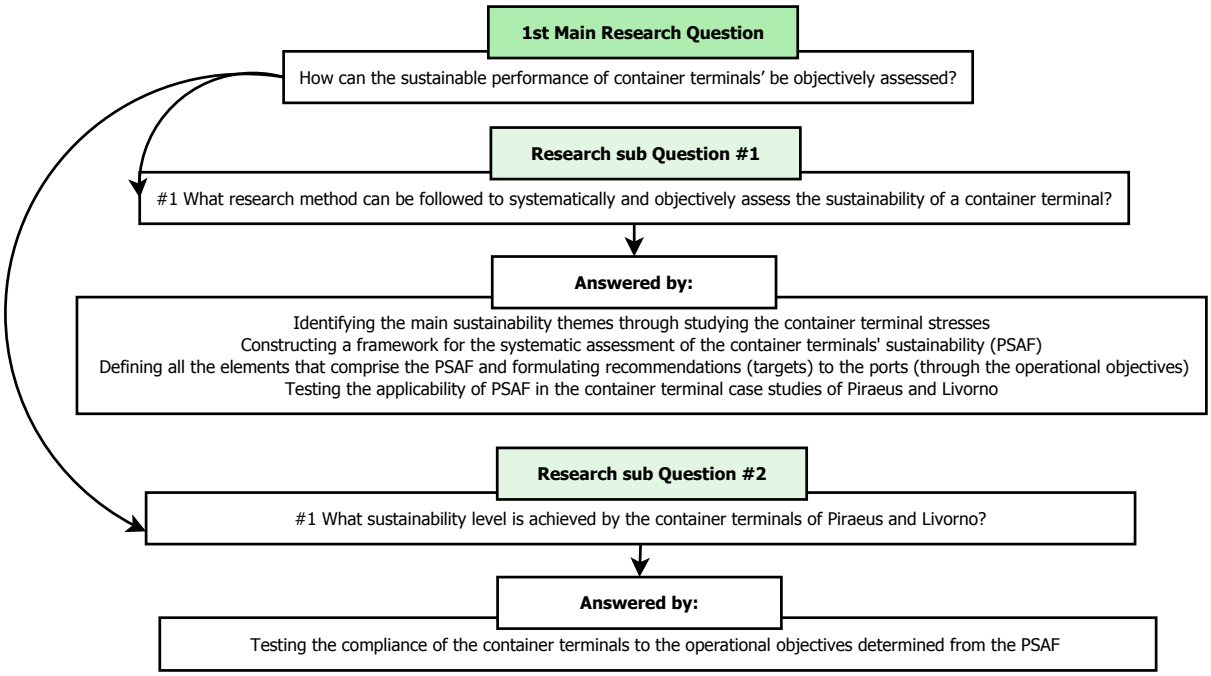
Chapter 5

In this Chapter, the answers given to the Research Questions and Research sub Questions are exposed and consequently the main conclusions of this thesis study are discussed. Furthermore, based on a reflection on the processes, methods used and outcomes, recommendations for future research are proposed.

2 ASSESSMENT OF CONTAINER TERMINALS' SUSTAINABILITY

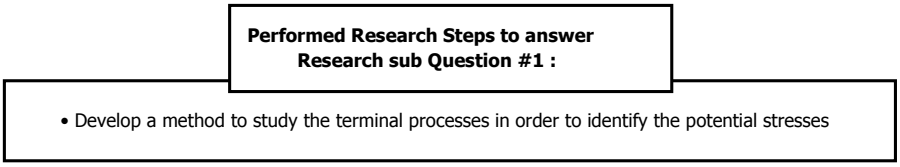
The terminal processes are studied in order to identify the potential stresses that the terminals may be causing**.** In that way, the **sustainability themes** (factors related to the container terminal's activity and are considered to affect significantly People, Planet and Profit) are defined.. A framework is then developed for the systematic approach of the sustainability of container terminals, the **Port Sustainability Assessment Framework (PSAF)**, which aims to define the current condition of a port and compare it with a desired state. For each sustainability theme, the contents of the elements of the PSAF are defined (**preliminary operational objectives**, **indicators**, **quantitative state concept**, **thresholds/target values andfinal operational objectives).** The PSAF is applied in the container terminal case studies of Piraeus and Livorno to define the current and historical condition of the ports and compare them with the operational objectives (desired state). The results of the comparison are expressed as a percentage of achievement for each terminal of the operational objectives that are set.

The research Questions and consequently the Research sub Questions that are answered in the context of this Chapter are presented in the following flowchart.



2.1 Studying terminal processes to identify potential stresses

In this section, the container terminal processes are studied in order to identify the potential stresses that the terminals may be causing**.** This section serves for the definition of the **sustainability themes**. A **catalogue of the stresses** is created for separate terminal domains (physical or logical), divided based on the activities of the terminal. The method followed for the creation of the catalogue is described in detail.



Since the beginnings of containerization in the early '60, the container terminals have progressively been developed according to the needs of the global container market, the evolution of the container ships and the modern approach of the "seaport" concept. This last one has been shaped by the fact that more than 80% by weight and more than 70% by value of the global traded is today handled by seaports (UNCTAD 2016). Nowadays, a container terminal has become a specialized,

distinct and important part of the modern port and as such, it can be studied, in terms of sustainability, as an independent physical and functional domain (system) with defined physical and operational boundaries that exists and functions inside the port.

In order to approach the container terminal's sustainability concept, it is necessary to determine the terminal's stresses. In that way, the sustainability themes can be defined, which constitute the port-related factors that are considered significant for People, Planet, Profit.

It was decided to approach the subject by means, when possible, of direct, homogeneous, physical and quantifiable flows of substances, energies, materials and other resources that enter or exit the container terminal (CT) domain and create an analytical catalogue of all the above flows, specifying, among other, the start and end point of the flow, the flow characteristics, the receiving medium/external system or the entering resource and the direction of the flow. Once the catalogue (an excel table) completed, it would be possible to cross-reference, in multiple ways, producers and receivers of the flows.

In the case of outgoing flows, the producers of the flows were grouped by functional/operational similarity and the flows were repeated for each destination medium (air, water, soil, etc.) or outside domain[1] (system) that received them (ecosystems, social, economic, etc.) For example, all terminal's equipment produce various outgoing flows: a flow of combustion gasses to the atmosphere (medium= air, producer=the part of the CT equipment that use internal combustion engines), a flow of noise (system=acoustic environment, producer= engines, movements, beepers, actuators, etc., of all CT equipment), a flow of oily and other waste (system=port reception facilities, producer=all CT equipment) and a flow of garbage[2](system=port reception facilities, producer=all CT equipment).

The flows that enter the CT domain were similarly described, separating the flows of the external resources provided for each group of internal consumers. Using the aforementioned example, the incoming flows for the CT equipment are: a flow of electrical energy (resource= power supply, consumer=all electric CT equipment), a flow of fuel (resource= various fuel types, consumer= all internal combustion CT equipment) and a flow of various materials needed for maintenance (resource= various materials, consumer= all CT equipment).

The above example is schematized in the figure that follows.

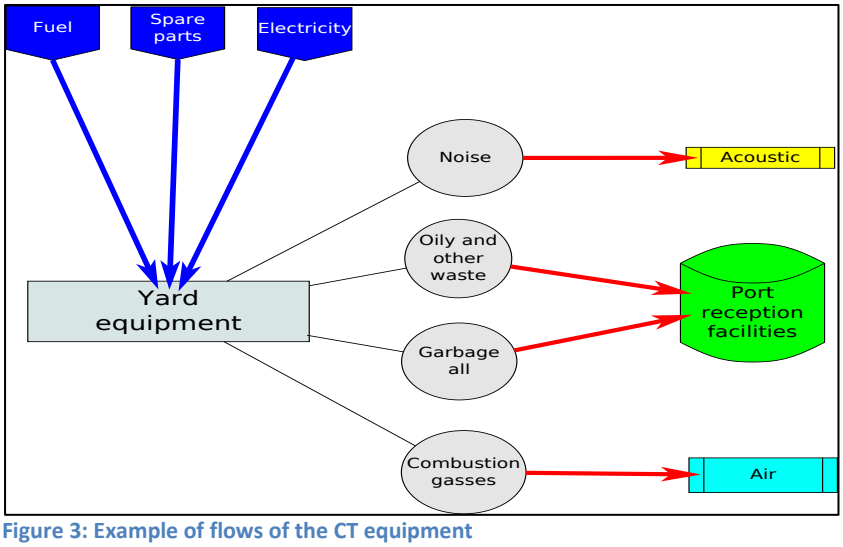


Figure 3: Example of flows of the CT equipment

[1] It was decided to use the concept "domain" and "sub-domain" instead of "system" and "subsystem" in order to avoid the systems theory implications of the emergent properties, properties that are characteristic of the system as a whole and not its component parts or subsystems (Johnson 2006).

[2] The distinction of oily waste, waste and garbage are following the MARPOL 73/78 - Directive 2000/59/EC Annexes

There are other, concrete but less easily quantifiable, flows of the CT equipment of the above example that have been taken into account inside more general categories of producers, for instance, the particulate matter (PM) produced in the CT yard by various movements, normal wear, etc. that ends in the atmosphere (and through the CT yard's runoff in water and soil) was summarized in a flow from a generic category defined as "All moves and wear in the CT yard" to the air medium, and two different flows from the generic category "Yard's runoff", one to the water medium and the other to the soil/sediment medium. Other concrete, but only potential, flows like leaks, spills, gas/fume/vapour escapes, accidents, etc., have been examined separately.

Other systems, that depend on the composition of the mediums or systems directly receiving the port's physical flows, are not taken into account. For example, the emissions of NO_x in the atmosphere have obvious effects on human health, fauna and flora and generally to biodiversity, ecosystems and social/economic systems. Therefore, they are not taken into account because they are indirect. On the contrary, the "emission" of invasive species that can occur during untreated ballast water exchange or the sea reclamation during port expansion or construction have direct effects on the marine ecosystem and they are taken into account.

In the cases where a relation between the CT domain and the outside world do not involve a physical flow, the cause-effect relation was equated to a logical flow, in order to be, in some way, "interfaceable" and compatible to the catalogue of physical flows as was described above. For example, the mere existence of the container terminal and its operations/functions create various logical flows: the flow "influence" that causes attraction of related/complementary/similar activities to the outside (producer=all CT activities, receiving system= socio/economic), the flow "employment", the flow "pressure" that causes deterioration of the surrounding residential environment and progressive change of the land use from residential to commercial/industrial. It is clearly not always possible to express in mathematical terms connections between direct causes and effects when abstract concepts are involved, however, in the present context where the importance lays primarily in cataloguing the main direct effects of the CT on other external systems, the semantics of the cause-effect phraseology is not important at all.

To facilitate this cataloguing task it was decided to separate the terminal domain in various physical or logical sub-domains and catalogue their stresses separately. The sub-domains used were:

A. Container ships and feeders;
B. Port vessels;
C. All terminal activities (yard activities included), equipment and buildings of the container terminal;
D. The physical presence of the CT land infrastructures, the marine infrastructures of the port, the construction phase of all infrastructures and eventual channels, their maintenance and their eventual expansion;
E. The potential risk of leaks, spills, gas escapes and accidents of all the above units.

The main concept discussed is applied throughout a structured framework. In that way, the direct stresses a container terminal is creating can be systematically tracked. The method is presented in Appendix C where which all the steps of the logical procedure followed are displayed. An example of the flowchart used is presented as well in the same Appendix in order to illustrate the procedure.

Based on the literature presented in Appendix C , each reported impact has been "translated" in a flow (or more flows) and then each flow was inserted in the catalogue of the sub-domain(s) it was related to. In the same Appendix, the resulting stresses for each terminal's sub-domain are presented in the form of a table along with a detailed graphic representation of the above.

Using the tables for each receiving/modified medium or system it becomes possible to define the main sustainability themes that , but also the possible indicators that can be used for each theme.

2.2 Port Sustainability Assessment Framework (PSAF)

In this section, a framework is developed for the systematic approach of the sustainability of ports, the **Port Sustainability Assessment Framework (PSAF)**. By the identification of the **strategical objectives**, the **sustainability themes** and consequently, the **operational objectives** along with **indicators** related to port sustainable development, the PSAF aims to define the current and desired state (defined by the operational objectives) of a terminal and compare them. The choice of the **sustainability themes** for the assessment of the port sustainability performance is directly linked to the outcomes of the previous Section. For each sustainability theme, the contents of the rest of the elements of the PSAF are defined. Additionally, the previously defined operational objectives are used as recommendations (targets) for the ports.

Performed Research Steps to answer Research sub Question #1 :

- Create a Port Sustainability Assessment Framework (PSAF) (based on the Systematic Frame of Reference, van Koningsveld 2003)
- Define the strategic objectives of the PSAF
- Define the main sustainability themes based on the identified potential stresses
- Define the contents of the elements of the PSAF for port sustainability

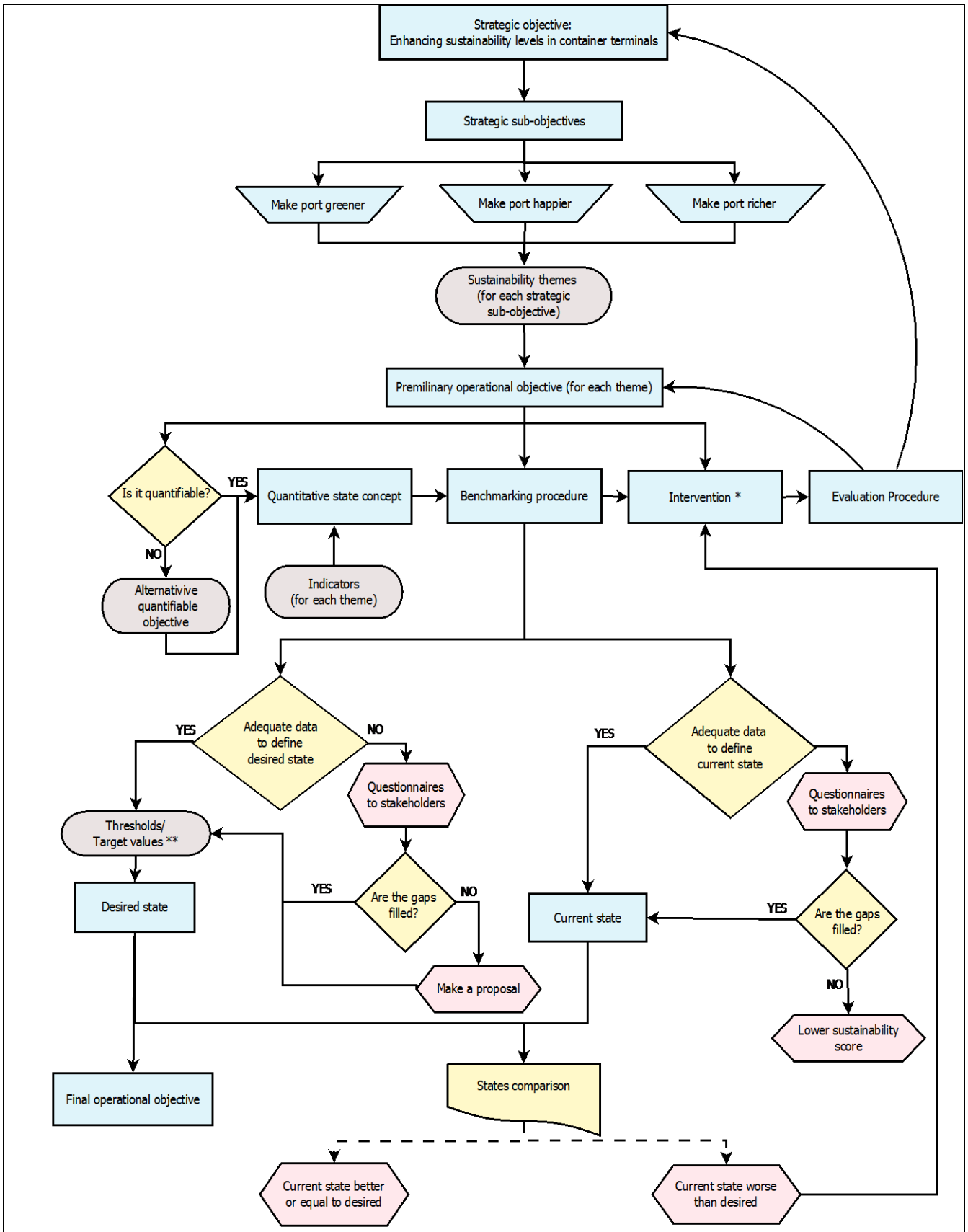
(preliminary operational objectives, indicators, quantitative state concept, thresholds/target values and final operational objectives)

2.2.1 Description of PSAF

A framework is developed for the systematic approach of the sustainability of ports. The Port Sustainability Assessment Framework (PSAF) is a modification of the basic frame of reference for policy development developed by van Koningsveld (van Koningsveld and Mulder 2004). More information regarding the framework developed by van Koningsveld and its main components can be found in Appendix A in the Sub-chapter "Frame of reference for policy development".

The PSAF, by the identification of the strategic and operational objectives related to port sustainable development, aims to define the current condition of a port and compare it with the desired state that is also defined through this framework.

The PSAF is presented in Figure 4.



* The intervention procedure will be further extended in a separate framework presented in the following chapters

** Due to lack of available data, the thresholds/ target values are based on what the author considers an adequate threshold based on the target values that are used by ports that present a high sustainable performance and papers related to port sustainability.

Figure 4: Port Sustainability Assessment Framework (PSAF) (based on the Systematic Frame of Reference, van Koningsveld 2003)

The **strategic objective** is defined as 'Enhancing sustainability levels in ports'. From this rather general objective more specific **sub-objectives** that divide the higher goal into three dimensions follow, and are related to:

- Reduction of ports' environmental footprint (Make the port greener)
- Reduction of ports' societal footprint (Make the port happier)
- Enhancing ports' productivity/economic growth (Make the port richer)

Initially, each sub-strategical objective category (Planet, People and Profit) is described by several **sustainability themes** which derived from the analysis performed in Section 2.1, regarding the cataloguing of the container terminal's direct impacts. The choice rests on the frequency of occurrence of a specific theme in the list that is created, in the severity of the stress and last but not least the authors' personal opinion of what is considered important crosschecking with various literature sources. The sustainability themes serve as a keystone for the preliminary definition of the operational objectives so that the sub-strategic objective can transform into more specific targets.

As it can be observed in Figure 4 the **initial operational objectives** are formulated once the sustainability themes are defined and are expected to reflect on more general targets (since the actual desired state and the thresholds have not been analyzed yet). They outline the direction, in a way that the quantitative concept can be defined.

Through the **quantitative state concept** that accompanies each theme, **indicators** are defined which serve as a tool for evaluating the achievement of the operational objectives and subsequently, the evaluation of the ports' sustainability performance. In the (Preliminary) Sustainability reporting for ports (IAPH-PIANC 2017) the importance of the use of port sustainability indicators is pinpointed. It states that the monitoring of the sustainability indicators must be carried out with appropriate frequency to allow for decision-making and not exclusively for the purpose of creating a Sustainability Report.

For each indicator, **thresholds/target values** are introduced. These thresholds determine the desired (reference) state of each theme. They serve the purpose of making the operational objectives more concrete and relate them to achievable targets. In many cases, a threshold cannot be defined since there is no predefined level of acceptance. For example, the productivity levels cannot be compared with a threshold since there are such significant differences between terminals that are related to their size, operational depth etc. that cannot be directly compared to one single value. Using these thresholds or a more general concept in the case that a threshold does not exist, the desired state can be defined.

It should be emphasized, that the target values defined do not reflect on the thresholds that each port is setting separately, but to what the author considers an adequate threshold based on the target values that are indicated by ports that present a high sustainable performance (for instance Port of Rotterdam, Port of Antwerp, Port of Los Angeles etc.) and papers related to port sustainability. The reason for this modification of the framework is the lack of available data regarding the targets for future development that the two port case studies are setting.

When all the steps of the main body of the framework are realized (**definition of quantitative state concept** and **desired state**) for each theme category, the operational objectives can be translated into more concrete targets, the **final operational objectives**, which can be used to evaluate the sustainable development of container terminals more straightforwardly and contribute to the achievement of the strategical objectives.

For example, one theme that belongs to the Reduction of the Environmental Footprint is Air Quality. The operational objective that is initially outlined is: "The air quality should not exceed levels that can harm the environment or the living conditions". Later, when all the internal steps of the framework were realized, and based on the indicators and thresholds that were defined, the

updated operational objective is: "The Air quality and more specifically, the concentrations of SO2, NO2, CO and PM10 must comply with the standard set by the European Commission".

In the final stage, the sustainability performance of the ports is presented through the comparison of the current state with the desired state. In the case that the desired state is deviating from the actual state then an intervention should be proposed.

2.2.2 Resulting elements of PSAF

Following the procedure that the PSAF outlines, described in the previous section, its elements are determined.

Detailed information on the selection of the elements comprising PSAF is presented in Appendix D . In this Appendix the following method is followed:

- Link of the stresses of the container terminal to the sustainability themes resulting from Section 2.1 and Appendix C , with argumentation as to their selection
- Definition of preliminary operational objectives for each theme
- Definition of the indicators describing the preliminary operational objective
- Determination of the thresholds for each indicator, through literature search (in the case that indicators are quantifiable and thresholds exist)
- Based on the preliminary operational objectives and the thresholds/target values identified, determination of the final operational objectives for each theme

The **final operational objectives** can serve as **guidelines/recommendations** for container terminal's sustainable development. It has to be noted that the operational objectives are more dedicated to container terminals; however, they also include more general aspects that reflect upon the sustainable development of the wider port. Thus, in that sense, the PSAF can be used also for different port terminals.

The concluding sustainability theme for each PPP category is presented below.

The **Planet (environmental)** themes chosen are:

- Air quality
- Water consumption
- Water column quality
- Sediment quality
- Noise
- Energy consumption

The **People (socio-economic)** themes are:

- Employment opportunities
- Safety levels
- Land use charges
- Recreation and aesthetics
- Stakeholders involvement
- Traffic congestion

The above-mentioned sustainability themes reflect upon socio-economic matters, rather than purely social aspects. It is clear, that the interconnection between society and economy is strong. For instance, the sustainability theme "recreation and aesthetics" is related to the satisfaction and well-being of the society but also affects the economy by means of tourism and not only. More details will be found in the following relevant subsection.

The port **Profit (productivity/economic)** themes are:

- Intermodality
- Productivity
- Personnel training
- Terminal potential
- Expandability
- Circular economy

The above-mentioned sustainability themes are reflecting mainly upon the internal profit of the port.

In Appendix E lays a table presenting the set of themes – indicators –operational objectives for each strategic sub-objective.

The concluding operational objectives for each sustainability theme are presented below.

Regarding **air quality**:

- The concentration of air pollutants should be lower than the standards defined by the European Commission.
- Over a period of five years, CO2 emissions must fall by 10%.
- The fuel consumption should be reduced by more than 20% in the next 5 years

Regarding **sediment quality**:

- The heavy metals concentration in the sediment of the port basin should be less than the values that are defined in Annex II to Directive 1999/31/EC.
- The oil concentration in the soil should be less than 40 mg/kg dry

Regarding **water quality**:

- The concentration of Intestinal Enterococci and E.coli should be below the levels indicated by each country's Directive.
- The heavy metals should be lower than what is defined by the European Commission
- The oil concentration should be less than 200 μg/L.
- The water transparency should be good, indicated with 8m of Secchi disk depth.

Regarding **water consumption**:

- The water consumption should be optimized according to the traffic of the container terminal, using the treated grey waters where applicable.

Regarding **noise:**

- The noise levels in the ports should not exceed the limits in areas that are mainly industrial, defined by each country's Decree.

Regarding **energy consumption**:

- The ratio of electricity consumption to TEUs traffic should be optimized.
- The ratio of electricity consumption to fuel consumption should be increasing.
- The ratio of energy from renewable sources to the total energy consumption should be increasing.
- "Optimize pollution reduction while maintaining a commercially-viable operation that does not significantly increase costs and waiting times for their customers".

Regarding **employment opportunities**:

- Value-added services should be introduced both for the terminal's economic benefit and for the introduction of new job positions.
- The expansion of the port should come along with job opportunities in other sectors.

- The working conditions (salaries, holiday leave, allowances etc. should be satisfactory relatively to each countries' local economy.

Regarding **safety levels**:

- The terminal should comply with all the regulations that are put into force regarding the preventions of accidents.
- The personnel of the container terminal should receive regular training regarding the everyday operations of the yard equipment, as well as handling of hazardous cargo.
- Climate change adaptation should play an inseparable role in the development strategies

Regarding **land use changes**:

- A buffer zone should exist in the port-city interface (Noise barriers- vegetation –logistics buildings and include some non-exclusively port-related activities of low intensity)
- The ratio (Residential + commercial uses)/industrial uses should be the maximum possible.

Regarding **recreation and aesthetics**:

- The existence of marine infrastructures damaging the aesthetics: yes/no.
- The ratio of cash flow from recreational activities after and before the construction of the marine infrastructures should not lower than 1.5.

Regarding **stakeholders' engagement**:

- Using the questionnaire that was created for the context of this thesis study, more than 70% of the stakeholders should feel involved in the decision making.
- The information regarding various port performance indicators should be easily accessible.

Regarding **traffic**:

- The hours per working day that the traffic exceeds the carrying capacity of the local road network should be zero.

Regarding **intermodality**:

- The intermodal connectivity of the port should be improved according to the needs of the container terminal and the port (rail and road network).

Regarding **productivity**:

- According to the strategical goal of the port and a market analysis, the goals as to the number of TEUs in the next years should be set by each container terminal.
- A target level of 1,000-1,250 TEU/berth metre/year should be required from medium-sized ports with significant transhipment rates, and about 1,500-1,750 TEU/berth metre/year should be required from large ports.
- The crane utilization should be approximately 100,000-150,000 TEU/gantry crane/year.
- The crane productivity should be approximately 25–40 crane moves per hour.
- The container vessel time spent in the port should be approximately 0.80 days.
- On average, 5.5 cranes during ship working time should be capable to load and/or unload the largest container vessels.
- There should be a yard vehicles tracking system to optimize the average time of activity/inactivity of the yard vehicles and the total number of movements per container unit and empty trips.

Regarding **personnel training**:

- There should be constant training seminars.
- The terminal should be informed about techniques and implement innovations to optimize its efficiency.

Regarding **terminal potential**:

- The terminal capacity should be equal to or higher than the actual container traffic.

Regarding **expandability**:

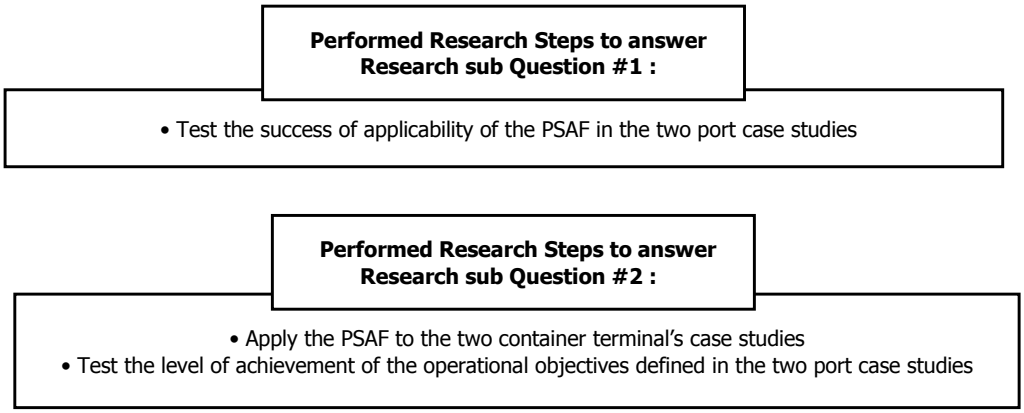
- The Master Plan proposals should comply with the needs of the port and the city and should be amended regularly to include the eventual changes.
- The Master Plans should be designed based on the concept of flexibility and sustainable growth

Regarding **circular economy**:

- The reuse of dredged material inside the port (if non-contaminated), the renewable energy production, the recycling, the use of biofuels and treated greywater should be maximized within the terminals and consequently within the ports.

2.3 Application of PSAF on the two terminal case studies

In this section, the data gathered from the application of the PSAF in the two terminal case studies is presented. In other words, the **current and historical condition** of the two terminal case studies is described. The information deriving from the application of the PSAF to the two terminal case studies are compared with the operational objectives that are set and the results are expressed as a percentage of achievement for each terminal of the operational objectives.



2.3.1 Motivation of selection of case studies

The container terminal case studies that were selected to be assessed as far as sustainability is concerned are the terminals of Piraeus and Livorno. General information on the two case studies are presented in Appendix B

The motivation of selection of the container terminals of Piraeus and Livorno as case studies derive from two necessities.

The first one is expressed by the need of assessing the sustainable performance of Mediterranean ports and proposing ways in which it can be enhanced since the concept of sustainability is not yet well-thought-out and incorporated in the decision making process in most of the Mediterranean ports. From additional literature research, there are several sources that indicate that there are gaps and barriers that impede the Mediterranean container ports' sustainable development (Aurelio Tommasetti, et al 2014, Buiza et al. 2015).

The second motivation derives from the task of the Corealis project to make the PoFSG more dedicated and realistic. This task is meant to extend the functionalities of the game and implement it in the Piraeus and Livorno Living Labs (LLs). Therefore, the choice of the case studies of the ports of Piraeus and Livorno seemed to be the perfect fit to conform to both necessities.

As already mentioned, the choice of assessing the sustainability of container terminals is initially based on the fact that the Corealis project is based on Piraeus Container terminal and on the container terminal of Livorno (and only partly in the general cargo). Additionally, specialized container terminals in modern ports have all the characteristics to be considered independent units of the port (due to their distinct operations, functions, superstructure and infrastructure) and as such a separate approach of their impacts and sustainability is appropriate in order to assess with objectivity their impacts.

However, it should be mentioned that even though the study is based on container terminals, most of the outcomes and recommendations presented in this thesis research could be expanded and be applicable to the wider port entity.

2.3.2 Method for data collection

The approach followed for the collection of the data relevant to the elements of the PSAF is the following:

- **Online research** (articles, papers, published annual reports, environmental reports etc.)
- **Contact the various authorities and responsible parties** (Port Authorities, Terminal Operators, Environmental Organizations that carry out monitoring campaigns, Chamber of commerce and industry etc.)
- Attendance in the **Focus Group meeting in Livorno and Piraeus** (on the 17/07 and 04/09 respectively) that were organized by the Corealis project
- **Question form** (QN1) (drafted in English, Greek and Italian) containing all the data which are required

In the Appendix F it is presented in a detailed way which online literature sources were used, which actions were taken to gather information as well as the contact list of stakeholders and authorities for each port.

The collected data for each terminal case study listed per theme is presented in Appendix H .

After having completed all the previous actions, not all the necessary data could be retrieved and gaps are still remained. The operational objectives for which it was not possible to retrieve information are presented in Appendix I

2.3.3 Sustainability levels of terminals

It has to be taken into account that the main purpose of this thesis project is the creation of a framework for the objective assessment of container ports' sustainability, rather than the direct and detailed quantification of the sustainable performance of the ports. Hence, the sustainability level of the port is estimated based on the comparison of the current and desired state that is expressed by a percentage of achievement of the operational objectives (defined by the author) within the port. In order to illustrate the sustainability level of the port two questions need to be answered:

1. For each sustainability theme, which is the percentage of the operational objectives for which there is available data?
2. Regarding the operational objectives for which there was available data, what percentage of the targets they entail are achieved by the terminals?

The previous steps are also presented as an extension of the PSAF framework that is illustrated in Figure 5.

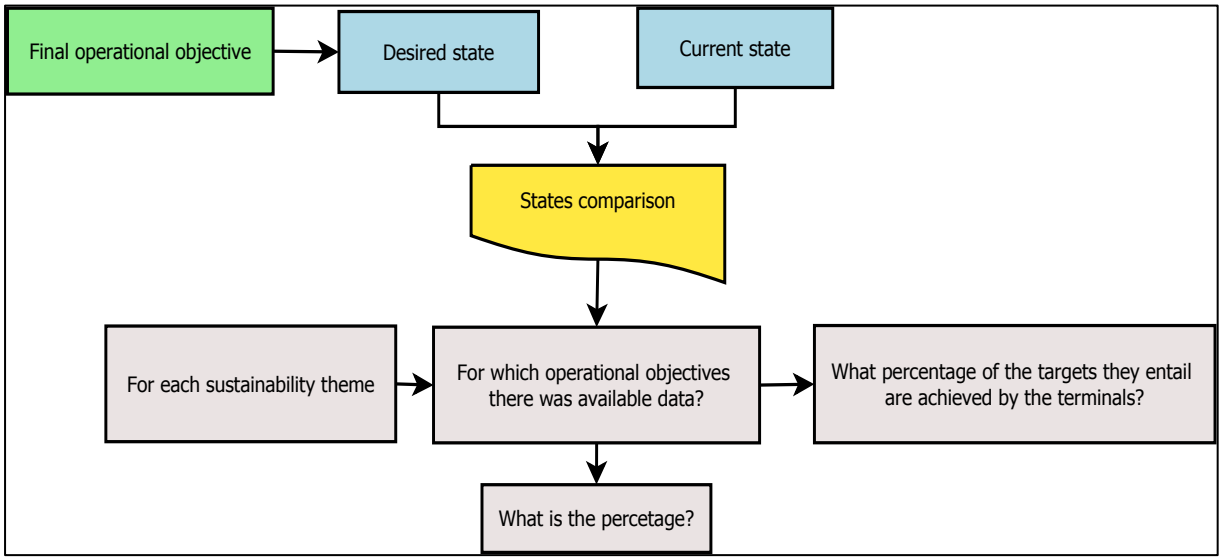


Figure 5: Extension of PSAF - sustainability level

In the tables presented in Appendix I are indicated the non-achieved operational objectives, the achieved ones and the operational objectives for which it was not possible to retrieve information or the available information was not adequate.

In the following figures (Figure 6 and Figure 7) the percentage achievement of the targets defined by the operational objectives for each sustainability theme is presented.

In should be noted that in Figure 6 , the operational objectives for which no adequate data could be retrieved are considered not to be achieved, whereas in Figure 7, the percentages derive only the operational objectives for which sufficient information could be gathered.

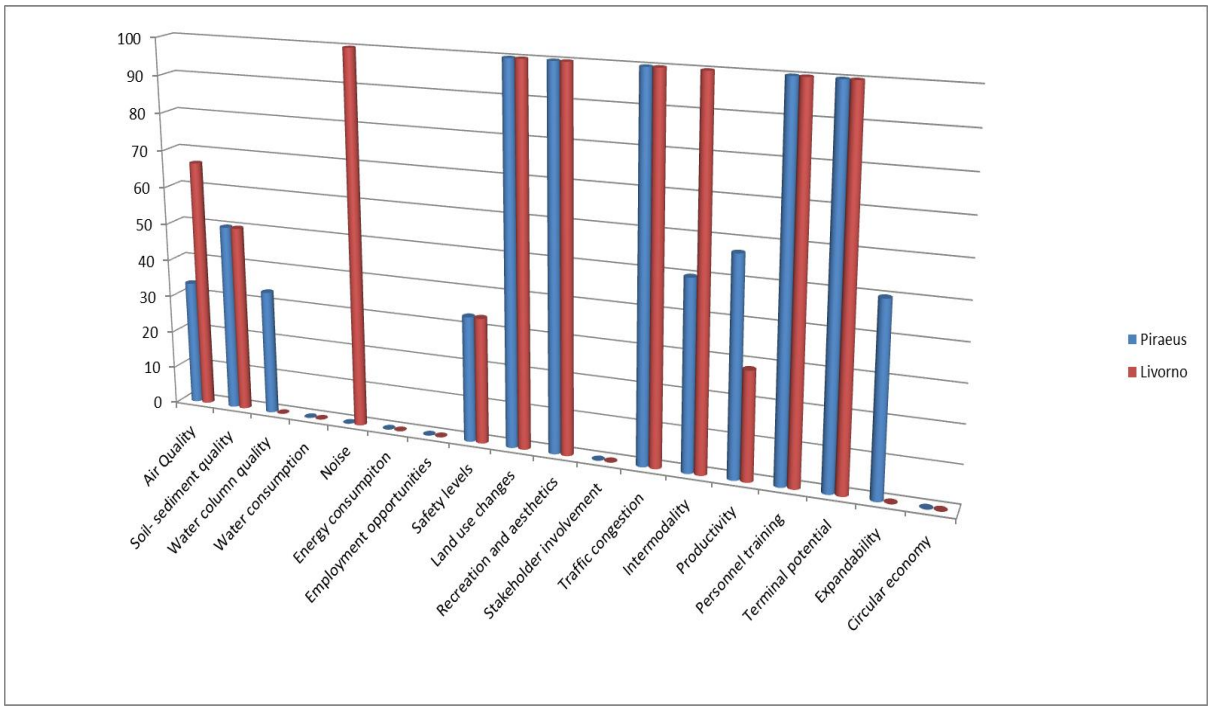


Figure 6: Percentage of achievement of operational objectives in terminals of Piraeus and Livorno (all operational objectives)

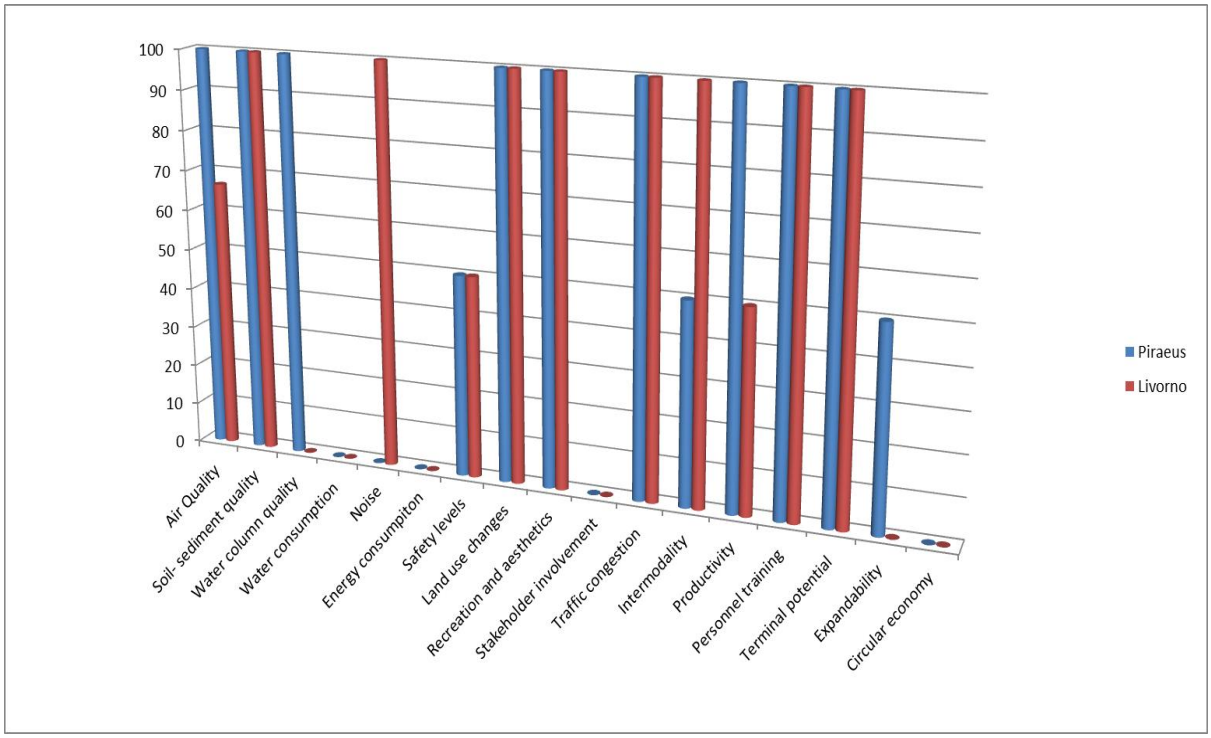


Figure 7: Percentage of achievement of operational objectives in terminals of Piraeus and Livorno (only operational objectives for which there was info available)

It can be concluded that in the Container terminal of Piraeus:

- There is available data for 68% of the operational objectives
- 64% of the operational objectives for which there is available information are achieved by the Piraeus container terminal.

It can be concluded that in the Container Terminals of Livorno:

- There is available data for 69% of the operational objectives
- 48% of the operational objectives for which there is available information are achieved by the container terminal of Livorno.

However, together with the above results, it should be taken into account that all the necessary data required to define the performance of the port as to the operational objectives that were set, was in the most cases very hard to retrieve. Especially all the environmental information that was not accessible (data from environmental monitoring of air, water column, noise etc.) must be openly shared by law.

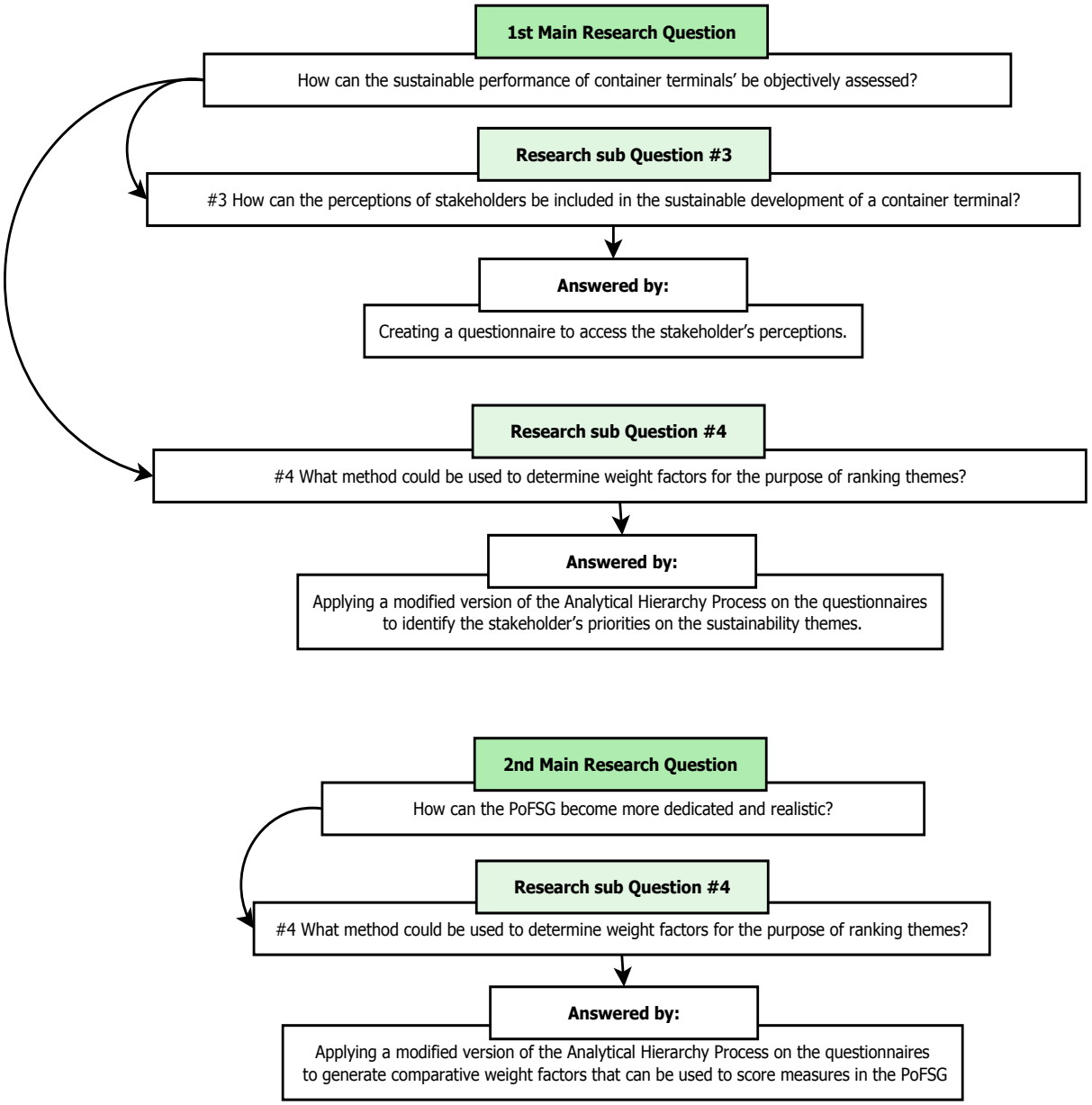
Another aspect that was identified while applying the PSAF to the two terminal case studies was that neither of them performs systematic environmental monitoring of the port area. Thus, even though the results regarding environmental monitoring that were found from campaigns carried out occasionally or in the context of other research projects, were not exceeding the thresholds that were defined, it does not reflect upon a sustainable performance of the port that should be based upon regular and systematic monitoring programs.

All in all, it can be concluded that the applicability of the PFAF in two case studies was successful, since it provided a structured manner to access the information required for comparing the current state of the ports.

3 ELICITATION OF STAKEHOLDER'S PERCEPTIONS ON PORT SUSTAINABILITY

In this chapter, a method is developed aiming to elicit stakeholder's perceptions of port sustainability. More specifically, the exploration of the opinions of the stakeholders on the comparative **importance of the sustainability themes** is carried out through questionnaires. Additionally, the perceptions regarding **ecocentrity and anthropocentrism** are accessed, their **knowledge of port sustainable development**, their perception on **ports and container terminals** and their views of their **involvement** in the decision making. The outcomes of the questionnaire are a stakeholder perception analysis and the production of importance weight factors for each sustainable theme, using the Analytical Hierarchy Process (AHP).

The research Questions and consequently the Research sub Questions that are answered in the context of this Chapter are presented in the following flowchart.



3.1 Method for elicitation of stakeholders' perceptions

Performed Research Steps to answer Research sub Question #3 :

- Chose the suitable method to elicit people's perceptions.

There are various methods to elicit stakeholder's perceptions, for instance, performing face to face interviews, phone interviews or computer-assisted personal interviewing, questionnaires, obtaining past records and studying the stakeholder's reactions on specific matters etc.

Through all the available methods, in the context of this thesis study, the elicitation of stakeholder's perceptions on port sustainability is carried out by means of questionnaires.

This method was considered to be the most suitable for several reasons. Initially, since the desirable number of answers (size of the sample) was relatively large, by means of a questionnaire a large number of perceptions on various aspects of sustainability can be accessed and recorded. Additionally, a questionnaire is considered to be more time efficient from interviews and more precise than attempting to gain some conclusions by studying the reactions of stakeholders from past records.

Furthermore, since sustainability is considered a vague and ambiguous concept, a logical approach would be to define its main components and their relative importance based on what people think. Sustainable port development is an approach that aims to improve the environmental and socio-economic conditions in combination with the increase of the port's profit. In that sense, there does not seem to be a more suitable approach than including the perception of the stakeholders into the design.

A structured questionnaire could assist to the elicitation of the port's stakeholder's views and perceptions on port sustainability as well as setting the base for the formulation of the importance weight factors that would be assigned in each sustainability theme. The last statement is achieved through the inclusion of the Analytical Hierarchy Process method in the structure of the questionnaire. In that manner, the stakeholders can systematically assess the importance of the three pillars of sustainability (PPP) and the sustainability themes comparing them to each other, two at a time. The outcome of this process is the assignment of weights to each PPP and sustainability theme.

In Appendix J are presented detailed info regarding the questionnaire layout, methodology and processing.

3.2 Stakeholder perception analysis and weights of sustainability themes

Performed Research Steps to answer Research sub Question #3 :

- Creation of a Questionnaire to perform stakeholder perception analysis
- Test effectiveness of the questionnaires through the identification of strong and weak points

Performed Research Steps to answer Research sub Question #4 :

- Apply and partially modify the Analytical Hierarchy Process (AHP) for the creation of importance weight factors for each sustainability theme
- Use Python to automatically process the data of each questionnaire and derive results
- Calculate (using the AHP method) the weight factors for each sustainability theme

The questionnaires were sent by email to most of the participants of Corealis Focus Groups held in Piraeus and Livorno. They were also sent to port experts from various countries, but mostly Greek and Dutch, to academics and last but not least to users of the ports that have a background that supports the understanding of those matters. The questionnaires were answered by 43 interviewees of various countries.

In the table that follows the distribution of the stakeholder categories and countries is presented in Table 1.

Table 1: Distribution of interviewees in countries and stakeholder categories

STAKEHOLDERS CATEGORY	
Local community	2
Port user_passenger	8
Port Authority	4
Terminal operator_concessionary	3
Shipping line	1
Ship chandler	1
Port Police	1
Scientific institutions	7
Governement agency	1
Municipallity	1
Port expert	11
Other	3
COUNTRIES/CONTINENTS	
Greece	18
Italy	12
Other EU	10
Non EU	3

The projected deliverables of the questionnaires were the final weights of the PPP themes and the average scoring of the other questions based on the totality of the received questionnaires (a group of all questionnaires). However, it was decided to also process the questionnaires grouped by port experts only, Greek stakeholders, Italian stakeholders and combined Greek and Italian stakeholders (Mediterranean stakeholders) and observe eventual differences among the various groups. The low sample size of any other combination did not permit the examination of more groups. The summarized results are shown in the table that follows and the detailed results for each group are presented in Appendix K .

In the upper part of Table 2, the results of the AHP processing and the resulting weights for PPP and related themes are reported per group. Next, follow the averages of the answers to the last part of the questionnaires, expressed as a percentage (all answer values range from 1 to 5, so they are expressed as value% = -0.25 + value*0.25). In the last part of the table, the main information regarding each group is reported.

Table 2: Summary of results of questionnaires processing per group

	ALL	P. experts	Greece	Italy	GR+IT
PPP weights					
Environment	37.61%	33.51%	36.22%	41.31%	38.30%
Society	34.52%	35.21%	35.86%	27.82%	32.59%
Economy	27.88%	31.28%	27.92%	30.86%	29.12%
AHP final themes weights					
Air quality	8.80%	8.95%	8.52%	8.93%	8.64%
Water quality	7.44%	6.53%	6.90%	7.66%	7.20%
Water consumption	4.96%	2.52%	3.61%	8.02%	5.62%
Soil/sediment quality	6.76%	6.31%	6.49%	7.58%	6.95%
Noise	4.63%	5.95%	4.96%	4.13%	4.54%
Electricity consumption	5.02%	3.26%	5.74%	4.99%	5.35%
Employment opportunities	7.98%	8.77%	8.40%	6.77%	7.76%
Safety levels	9.79%	11.16%	9.35%	5.69%	7.68%
Land use changes	4.47%	4.81%	5.88%	3.77%	4.93%
Recreation and aesthetics	3.62%	3.64%	3.84%	3.51%	3.77%
Stakeholders involvement	3.90%	3.42%	3.18%	4.09%	3.73%
Traffic congestion	4.76%	3.41%	5.22%	4.00%	4.72%
Intermodality	5.68%	5.12%	6.51%	5.29%	5.99%
Productivity	5.21%	5.90%	5.67%	5.98%	5.79%
Personnel training	3.95%	5.30%	4.09%	4.64%	4.32%
Terminal potential	4.63%	3.97%	4.65%	5.78%	5.11%
Expandability	4.30%	6.93%	3.48%	4.87%	4.06%
Circular economy	4.10%	4.06%	3.51%	4.32%	3.85%
NEP	62.05%	58.18%	60.74%	69.72%	64.33%
Port sustainability knowledge	69.77%	73.58%	67.53%	70.31%	68.65%
Stakeholders involved in business strategies	48.26%	47.73%	40.28%	60.42%	48.33%
Stakeholders involved in environmental strategies	66.28%	77.27%	56.94%	72.92%	63.33%
Port serious environmental impacts consern	50.00%	45.45%	48.61%	60.42%	53.33%
Port important societal benefits	69.19%	70.45%	69.44%	64.58%	67.50%
Feeling of involvement	44.77%	56.82%	50.00%	37.50%	45.00%
Port sustainability approach achieved	54.65%	54.55%	52.78%	64.58%	57.50%
N. of Questionnaires	43	11	18	12	30
N. of PPP consistent Questionnaires	35	8	16	11	27
N. of Env consistent Questionnaires	27	6	11	11	22
N. of Soc consistent Questionnaires	25	7	10	8	18
N. of Econ consistent Questionnaires	22	4	10	8	18
STAKEHOLDERS CATEGORY					
Local community	2			2	2
Port user_passenger	8		6	2	8
Port Authority	4		1	2	3
Terminal operator_concessionary	3			3	3
Shipping line	1		1		1
Ship chandler	1		1		1
Port Police	1		1		1
Scientific institutions	7			3	3
Governement agency	1		1		1
Municipallity	1		1		1
Port expert	11	11	4		4
Other	3		2		2
COUNTRIES/CONTINENTS					
Greece	18	4	18		18
Italy	12			12	12
Other EU	10	6			
Non EU	3	1			

3.2.1 PPP priorities

With the exception of the port experts' subgroup, all other groups considered the environment to be the most important factor of PPP. The port expert's subgroup considers the societal factor to have the major priority on PPP. On the other hand, Greek stakeholders consider the environment slightly more important than the societal issues (36.22% against 35.86%) and least important the economy (27.92%), while the Italian stakeholders consider the environment far more important than the society (41.31% against 27.82%) and their second priority is the economic factor (30.86%). The port

experts rate first the society (35.21%), second the environment (33.51%) and last the economy (31.28%).

In the bar chart that follows the PPP factors, together with the NEP% scores are shown for all groups.

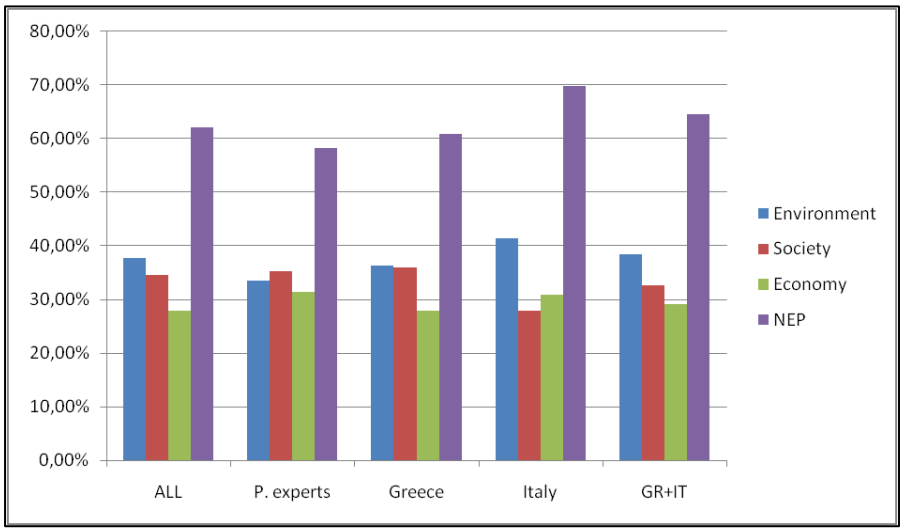


Figure 8: PPP and NEP per group

It can be observed that NEP and environment values seem to be correlated. The hypothesis was tested with the regression analysis, that excel provides, using NEP% as the independent variable and Environment weight% as the dependent (P_{env}%=a+b*NEP%).

The Correlation Coefficient of 0.9762, the Coefficient of Determination of 0.9373 and the Standard Error of 0.0071 confirm the possibility of a valid hypothesis with a=-0.0286 and b= 0.6389 (Figure 9). The above is in line with the NEP general estimation that higher NEP scoring indicates a more pro-environment attitude.

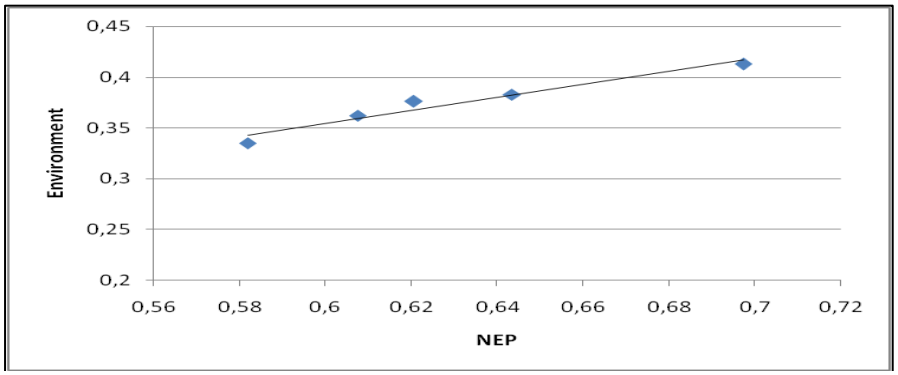


Figure 9: NEP - Environmental priority. Observed data and linear regression

However, the same hypothesis is not valid for the single data of the questionnaires, as there is not a well-defined correlation between P_{env} and NEP.

As explained in Appendix J , in order to test the representativeness of the results of the questionnaires, it was tested if they could likely be part of a normal distribution. In that manner, it can be ensured in some level that the sampling population is representative and the possibility of receiving particular answers from interviewees pursuing a specific aspect can be excluded.

Therefore, in mathematical terms, in order to examine the hypothesis that, at least, the PPP priority data were likely part of a **normal distribution** (null or Ho hypothesis) and keeping in mind that each PPP weight is calculated from pairwise comparisons, it was decided to test the hypothesis that the differences between the averagely most important factor (P_i) with the averagely least important one

(P_j) are likely drawn from a normal distribution. The method in which this test is performed is explained in detail in Appendix J .

The spread between P_{env} and P_{econ} weight (most and least important PPP factor) and the NEP score were tested for normality for each group separately. The results show that for almost all groups and for both hypotheses the possibility that data were drawn from a normal distribution cannot be rejected. Only the group of Greek-Italian stakeholders produced a test p-value inferior to 0.05 (0.0472) and the null hypothesis (the population is normally distributed)should be rejected.

In Table 3, the main characteristics of the normal distribution of each PPP factor and NEP and the results of the Shapiro-Wilk normality test for the group of all questionnaires are shown.

Table 3: Penv-Pecon spread and NEP basic stats and normality test for the all questionnaires group

PLANET-PROFIT DISTRIBUTION	
Average	0.0973
Minimun	-0.6667
Maximum	0.6667
Standard deviation	0.3779
Variance	0.1428
Shapiro-Wilk normality test	**OK**
Test statistic	0.939
p-value	0.053

NEP DISTRIBUTION	
Average	0.6205
Minimun	0.1000
Maximum	0.9000
Standard deviation	0.1482
Variance	0.0219
Shapiro-Wilk normality test	**OK**
Test statistic	0.948
p-value	0.050

In the figures that follow the normal (univariate) distributions of the P_{env}-P_{econ} and NEP is shown for the group of all questionnaires.

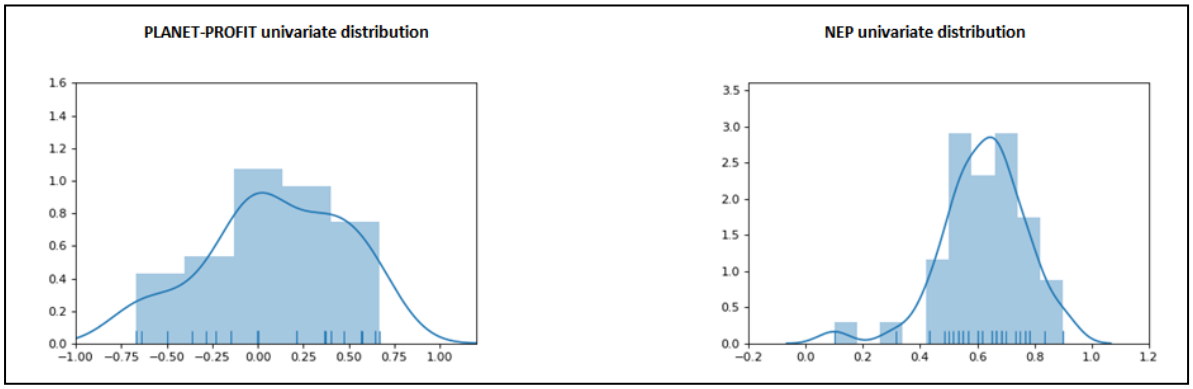


Figure 10: Normal distribution of P_{env}-P_{econ} and NEP (all questionnaires group)

The pairwise relationships among NEP and the 3 PPP factors (for all questionnaires) are presented in the following graph. In the diagonal are represented the univariate kernel density estimation of each factor, in the upper part the pairs scatter plots and in the lower part the pair bivariate densities. The graphs are automatically created in the 3rd Python script, using the module SeaBorn (sns.PairGrid,sns.kdeplot and plt.scatter).

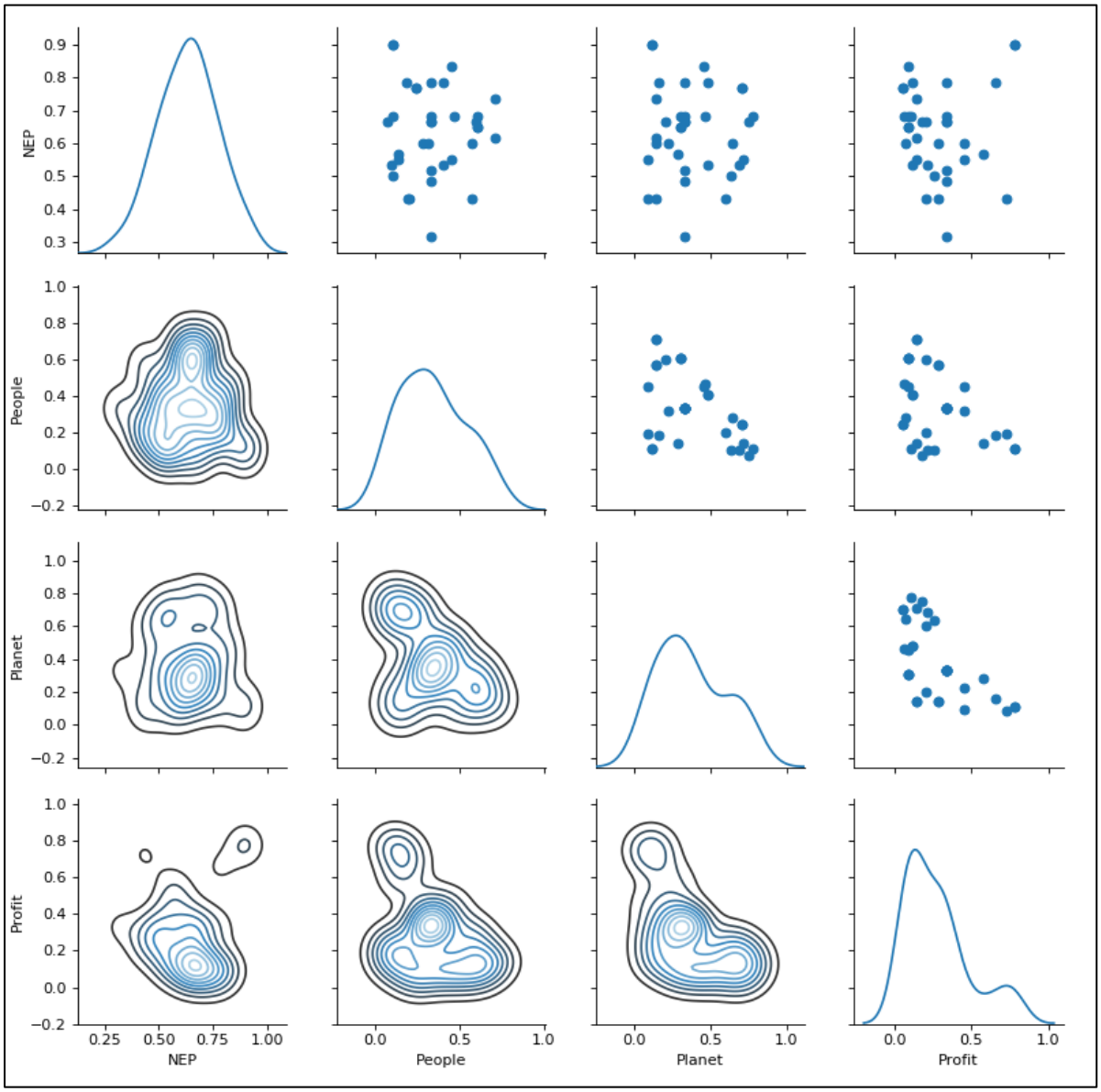


Figure 11: Pairwise relationship among NEP and the 3 PPP factors

All the above are automatically calculated and plotted in the 2nd Python script and exported in the excel workbook that contains the results for each group of questionnaires.

As explained in Appendix J (J1.2 the consistency of the answers that were given has been checked by calculating the consistency ratio (CR≤0.2).

The ratio of the various groups with **acceptable PPP matrix answers** is presented below:

Table 4: Percentage of AHP consistent PPP matrix per group

	ALL	P. experts	Greece	Italy	GR+IT
% of PPP consistent Questionnaires	81.40%	72.73%	88.89%	91.67%	90.00%

The observed low percentage of valid PPP matrices of the port expert group, even if a simple 3x3 matrix is involved, well inside the limits of the "magical number 7 ±2"(Miller 1955), could simply reflect the (unconscious?) unwillingness to fill the questionnaire instead of reflecting a not very clear grasp of the concept of PPP.

3.2.2 Environmental themes' priorities

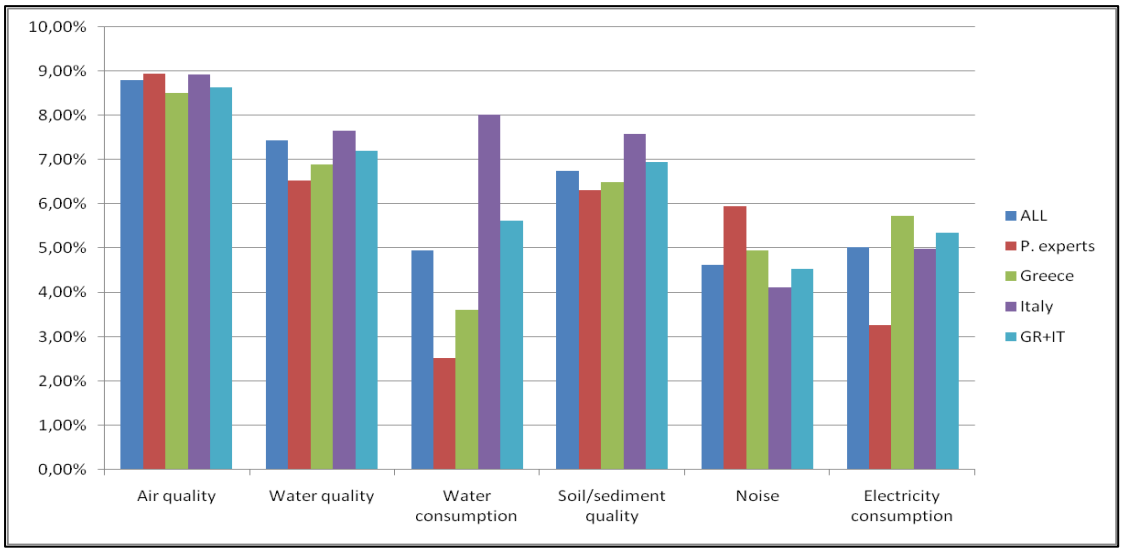


Figure 12: Environmental themes' final weights per group

The theme with the highest priority for all groups is the air quality, which is the overall second most prioritized theme (Figure 12). The Italian stakeholders consider water consumption to be the second most important environmental issue followed by water and soil quality. On the contrary, port experts consider water and electricity consumption to be the least important environmental issues. The final weights of the group of all questionnaires are presented in the table that follows, sorted from largest to smaller.

Table 5: Environmental themes final weights for all questionnaires

Air quality	8.80%
Water quality	7.44%
Soil/sediment quality	6.76%
Electricity consumption	5.02%
Water consumption	4.96%
Noise	4.63%

As explained in Appendix J (J1.2 the consistency of the answers that were given has been checked by calculating the consistency ratio. The ratio of the various groups with acceptable Environmental matrix answers (CR≤0.2) is presented below. The percentage is calculated on the questionnaires with valid PPP consistency.

Table 6: Percentage of AHP consistent Environmental matrix per group

	ALL	P. experts	Greece	Italy	GR+IT
% of Env consistent Questionnaires	77.14%	75.00%	68.75%	100.00%	81.48%

Greek stakeholders have the lowest ratio of consistent Env. matrices. On the contrary, Italian stakeholders have a very clear opinion on the priorities of the six environmental themes. Port experts have a similar error ratio to the one observed for their PPP matrices.

3.2.3 Societal themes' priorities

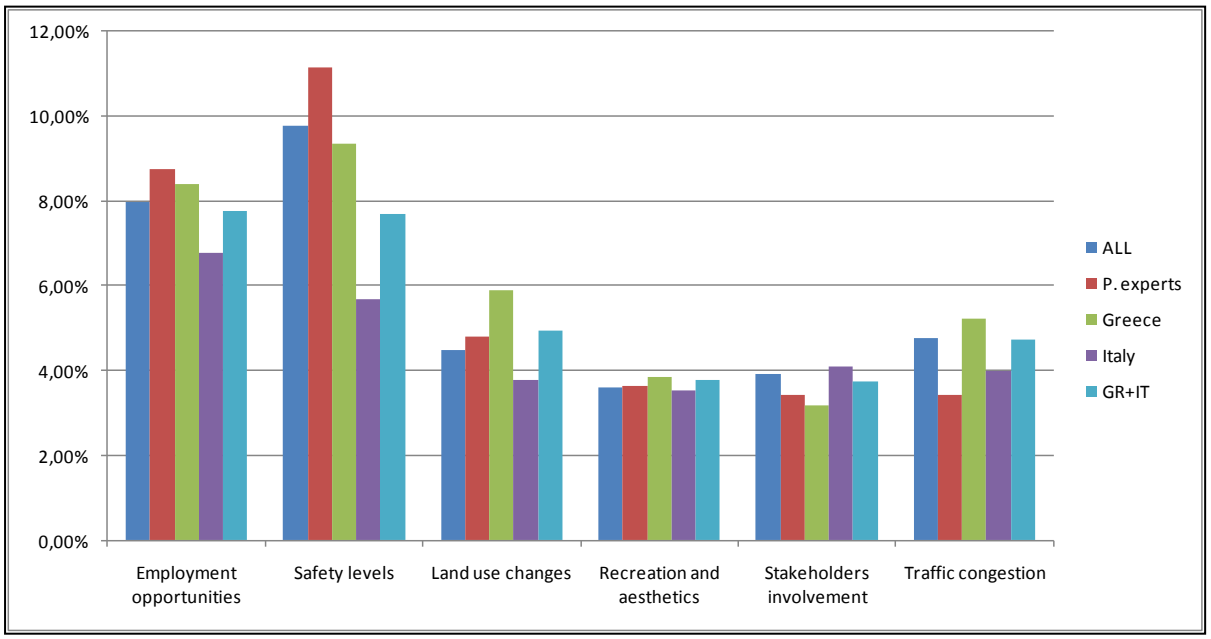


Figure 13: Societal themes' final weights per group

The societal theme with the highest priority is the safety level of the port, which is also the overall most prioritized theme. Only the Italian stakeholders' group considers this theme second after employment opportunities, the second most important theme of all other groups. The remaining 4 themes have a considerably lower priority in all groups. Greek stakeholders show a relatively higher sensitivity to the themes of land use changes and traffic congestion. The final weights of the group of all questionnaires are presented in the table that follows, sorted from largest to smaller.

Table 7: Societal themes final weights for all questionnaires

Safety levels	9.79%
Employment opportunities	7.98%
Traffic congestion	4.76%
Land use changes	4.47%
Stakeholders involvement	3.90%
Recreation and aesthetics	3.62%

As explained in Appendix J (J1.2 the consistency of the answers that were given has been checked by calculating the consistency ratio. The ratio of the various groups with acceptable Societal matrix answers (CR≤0.2) is presented below. The percentage is calculated on the questionnaires with valid PPP consistency.

Table 8: Percentage of AHP consistent Societal matrix per group

	ALL	P. experts	Greece	Italy	GR+IT
% of Soc consistent Questionnaires	71.43%	87.50%	62.50%	72.73%	66.67%

In the Societal matrix, port experts have the highest ratio of consistent matrices. The Greek group still has a lower ratio. The Italian group has also a high rate of inconsistencies, still 10% less than the previous group.

3.2.4 Economic themes' priorities

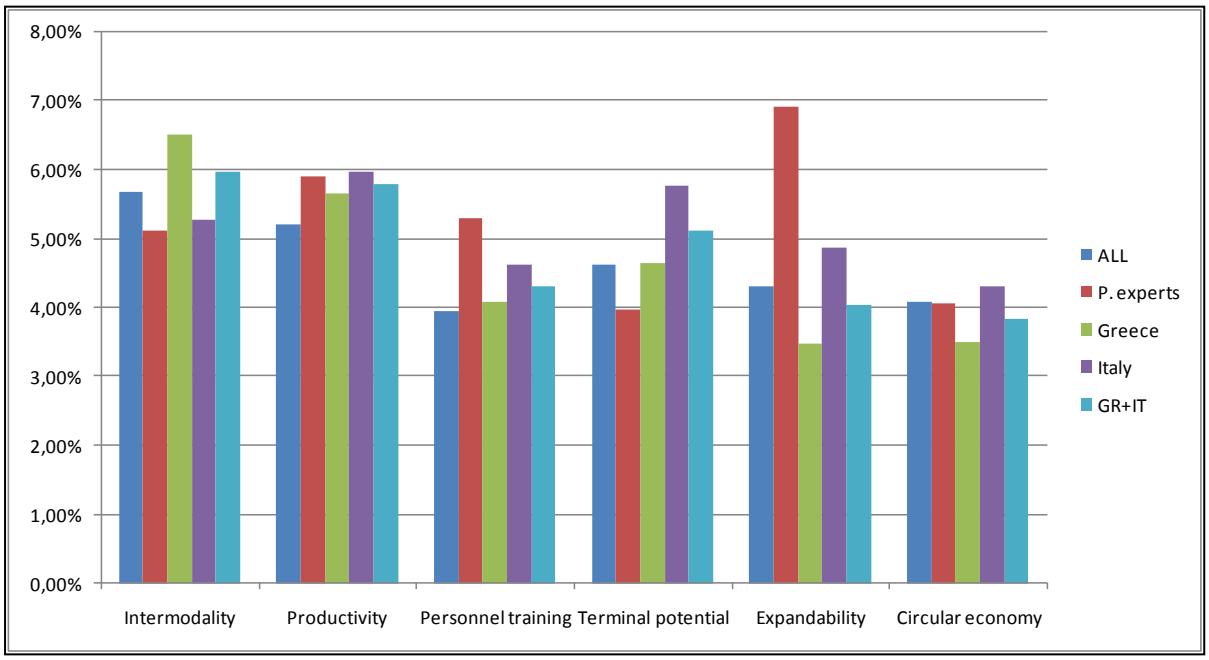


Figure 14: Economic themes' final weights per group

Intermodality and productivity are the most important themes of the economy matrix for the group of all questionnaires. The port experts group gives the highest priority to the expandability theme, followed by productivity and personnel training. The Greek group consider intermodality and productivity to be of the highest priority. The Italian group, instead, prioritize productivity and, secondly, the terminal potential. The final weights of the group of all questionnaires are presented in the table that follows, sorted from largest to smaller.

Table 9: Economic themes final weights for all questionnaires

Intermodality	5.68%
Productivity	5.21%
Terminal potential	4.63%
Expandability	4.30%
Circular economy	4.10%
Personnel training	3.95%

The ratio of the various groups with acceptable Societal matrix answers (CR≤0.2) is presented below. The percentage is calculated on the questionnaires with valid PPP consistency.

Table 10: Percentage of AHP consistent Economic matrix per group

	ALL	P. experts	Greece	Italy	GR+IT
% of Econ consistent Questionnaires	62.86%	50.00%	62.50%	72.73%	66.67%

The economy matrix has the lowest ratio of consistency. This was expected as the questions involve a certain degree of knowledge of the port economy. What was not expected, was the extremely low ratio of consistent matrices of the port experts group. The ratios of consistency for the Greek and the Italian group are identical to the previous matrix.

3.2.5 Stakeholder's perceptions part

In the bar chart that follows a summarized plot of all groups' answers of Part D of the questionnaire is shown.

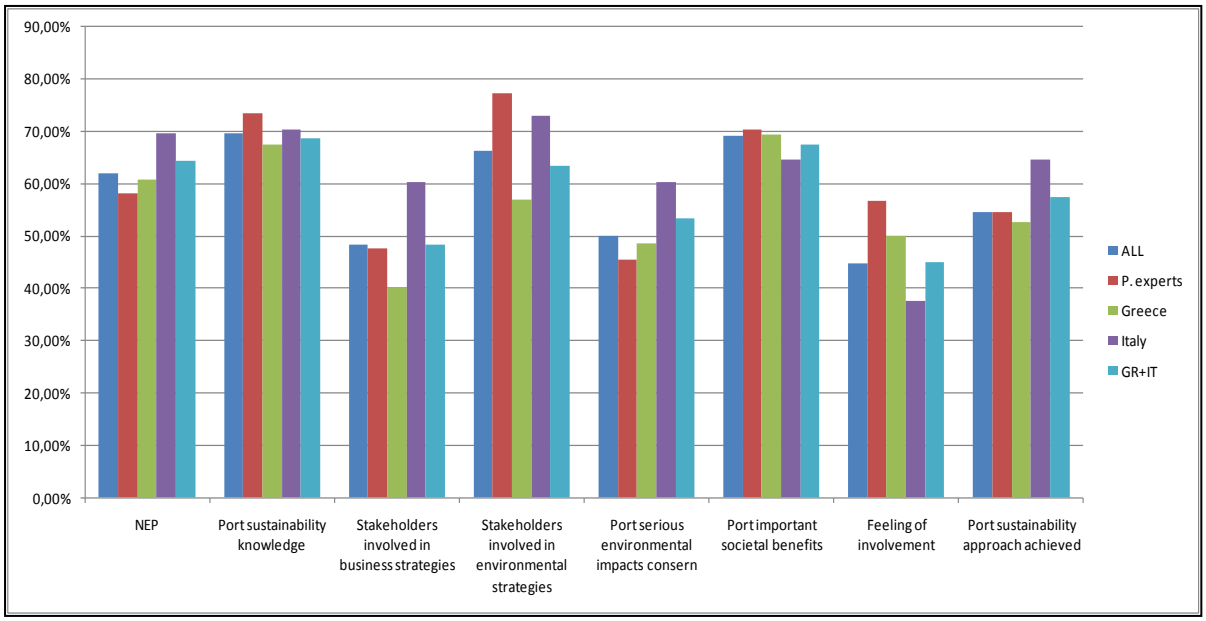


Figure 15: Scoring % of the Part D questions

The first 15 questions produced the NEP scoring, that is here expressed as a percentage. In the unit regarding the PPP weights were shown that NEP and environmental priorities are strongly correlated for all groups. The port experts group has the lowest NEP scoring and the Italian group has the highest.

Regarding the 8 questions that should assess the general knowledge of the concept of port sustainability, even if the group of port experts shows the highest score, 73.58% against 70,31% and 67,53% of the Italian group and Greek group respectively, it seems that they failed to distinctly separate the port expert group from the other ones. This could be due to the fact that: a) all groups have a good grasp of the port sustainability concept, b) the questions could be answered correctly according to a general pro-environment attitude and c) the scientific community generally avoids making statements of almost absolute certainty like the option "strongly agree" of the questionnaire, fact that lowers the score of the answers.

The next single question was about the involvement of all stakeholders in the business strategies of the port. The only group that answered positively this question was the Italian one. All other groups disagreed with the above statement. On the contrary, all groups consider necessary the involvement of all stakeholders in the environmental strategies of the port.

Port experts and Greeks do not feel that the container terminal has serious impacts on the environment. On the contrary, Italians consider that a container terminal could have serious impacts on the environment.

All groups agree that the container terminal can generate important societal benefits.

Regarding the feeling of involvement, port experts, as expected, answer positively to the question. Greek stakeholders are uncertain and Italians feel that they are not part of the decision making processes of the port.

Finally, all groups assess that port authorities have a certain level of positive approach to the sustainability issues of the port.

3.2.6 More themes suggested by interviewees

Few interviewees made suggestions of additional themes for the PPP factors.

The suggested additional environmental themes were: nature, climate, renewable resources, climate change/extreme events, light pollution, biodiversity conservation, the source of energy, existing coastal processes, technological and economic growth to unimaginable yet to us levels, space required.

The additional societal themes were: quality of living environment, resettlements, archaeological/traditional values, security level.

The additional economic themes were: air emissions, added value, throughput.

It can be noted that there is no recurrent theme among the suggestions, and even more, many of the themes are already considered, directly or indirectly, through the research proposed themes. This fact confirms the validity of the 3X6 themes chosen for this study.

3.3 Conclusions and resulting weight factors

Performed Research Steps to answer Research sub Question #3 :

- Test the effectiveness of the questionnaires through the identification of its strong and weak points
- Conclude which are the most important sustainability themes based on stakeholder's perceptions
- Conclude on what are the views of the average interviewee

The total number of questionnaires and the distribution of the countries and stakeholder categories permitted the separate examination of the results for a small number of groups. There are differences among the groups, regarding the priorities of the PPP factors and the priorities of the various PPP themes.

The test for normality of the PPP answers is positive for all groups except the Greek-Italian group, therefore it can be concluded that the population was representative. Even so, the sample is very low to extract valid conclusions for each group separately.

The questionnaire as a whole is efficient and able to identify various differences among the investigated groups. It could be a valid instrument for evaluating priorities and attitudes of port stakeholders if a sufficient number of questionnaires per stakeholder category could be achieved. It could also provide port authorities with valuable info regarding various aspects of their interrelations with various stakeholders' categories and permit them to plan accordingly.

However, the 8 port knowledge questions should be modified in order to achieve a scoring that distinctly separates "port experts" from "non-experts".

The final priorities of the various PPP themes and the average scoring of NEP, port knowledge and the other questions (all calculated over all questionnaires) are respectively presented in Table 11 and Figure 16 respectively.

Table 11: Priorities of the PPP themes

AHP final themes weights sorted	ALL
Safety levels	9.79%
Air quality	8.80%
Employment opportunities	7.98%
Water quality	7.44%
Soil/sediment quality	6.76%
Intermodality	5.68%
Productivity	5.21%
Electricity consumption	5.02%
Water consumption	4.96%
Traffic congestion	4.76%
Noise	4.63%
Terminal potential	4.63%
Land use changes	4.47%
Expandability	4.30%
Circular economy	4.10%
Personnel training	3.95%
Stakeholders involvement	3.90%
Recreation and aesthetics	3.62%

Safety levels and **air quality** are the top priorities of the port's sustainability approach. The themes with least priorities are the stakeholder involvement and the recreation and aesthetics.

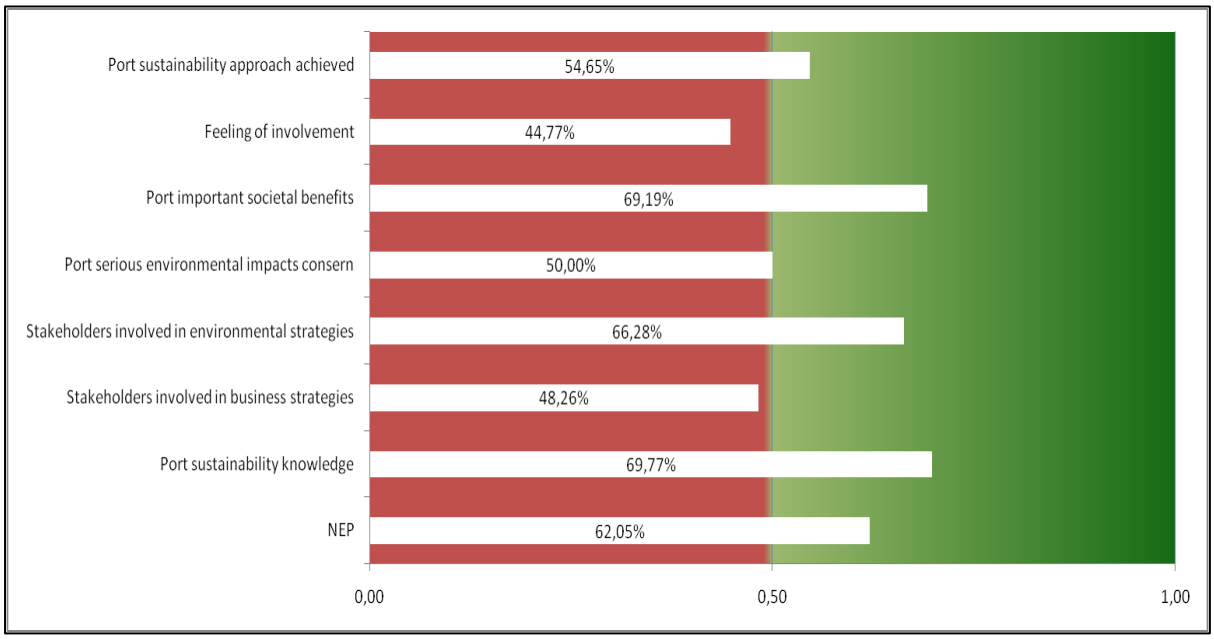


Figure 16: NEP, port knowledge and other answers scoring

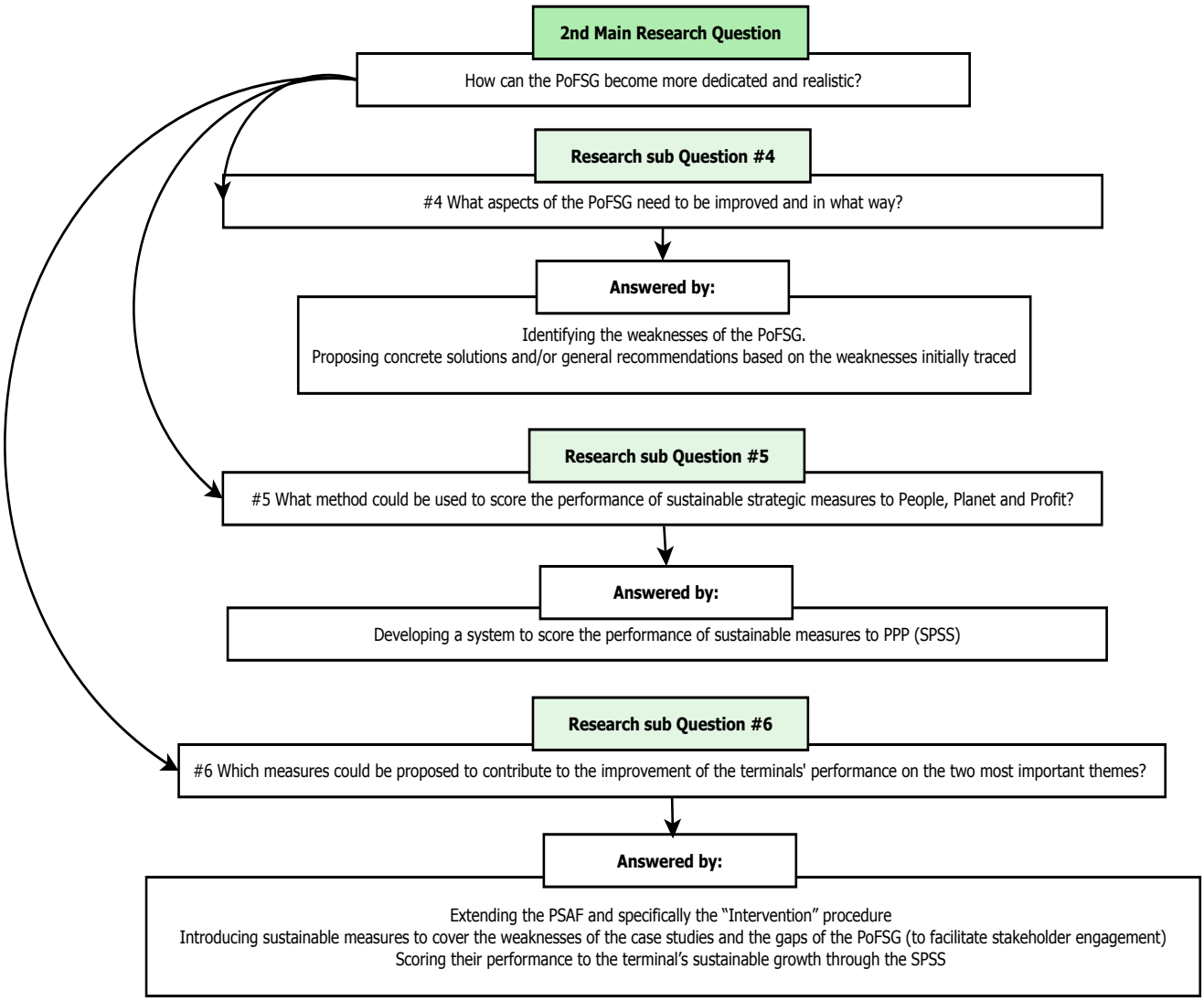
According to the 43 questionnaires, the average interviewee:

- shows a moderately positive pro-ecological aptitude
- has a good grasp of the port sustainability concept
- wants to be involved in the port's environmental strategies
- feels that the port can have important societal benefits
- is weakly positive about the sustainability approach of the port authorities
- is uncertain about serious environmental impacts
- does not feel involved in the decision-making of the port
- does not want to be involved in the port business strategies

4 EXTENSION OF PoFSG

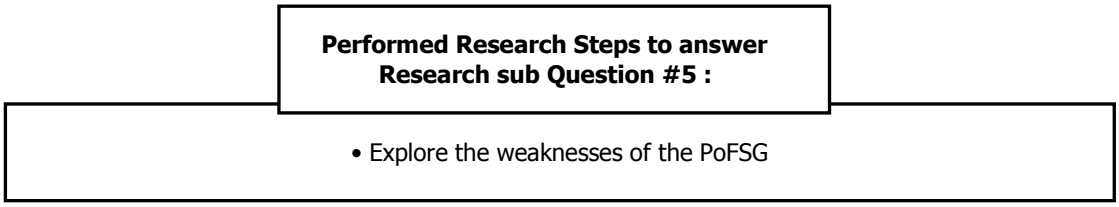
In this chapter, the main weaknesses of the current version of the PoFSG are explored and **modifications** are recommended either in terms of concrete proposals either in the form of more general recommendations. Based on the weaknesses of the game, a new **sustainable performance scoring system (SPSS)** is developed to evaluate the performance of sustainability measures on People, Planet and Profit (proposed to substitute the current scoring system in the PoFSG). The **weight factors** for each sustainability theme, derived from the previous chapter, are used to calculate the final sustainability score of each measure so that sustainability could be objectively assessed. Considering the two sustainability themes with the largest weight factors (Air quality/carbon emissions and Safety levels/ climate change effects) and based on the gaps that exist in the PoFSG and also the weak points of the case studies that were brought into surface, the PSAF and specifically the **"Intervention" procedure** is further extended. In that manner, **measures** are included that aim to **enhance the sustainable performance of the ports** and at the same time serve as invaluable inputs to the PoFSG. Through the extension of the PSAF, the proposed sustainability measures are scored with the **SPSS**. As a result, sustainability measures are proposed for the PoFSG, which include a performance score to PPP.

The research Questions and consequently the Research sub Questions that are answered in the context of this Chapter are presented in the following flowchart.



4.1 Weaknesses of the PoFSG

In this section, the main weaknesses of the current version of the PoFSG will be explored through interviews with experts, recorded feedback and a personal judgment formed while playing the PoFSG.



The general concept of the Port of the Future Serious Game (PoFSG) is explained in Appendix A .

A meeting was held in Deltares, in which employees working in Corealis, as well as employees from different departments, with specialization in ports, sustainability, ecology, serious gaming etc. took part. In this meeting, the PoFSG was presented by Mrs. Vergouwen, member of the Port of the Future project team. The purpose of this meeting was to get acquainted with the PoFSG and identify aspects, essential to be improved. By the end of the meeting, several weaknesses were brought into the surface.

One of the weaknesses that were traced is the logic behind the scores that were designated to some measures as to PPP. Some measures existed for which the scores for People, Planet and Profit could not be logically derived and they did not seem realistic. It was also pointed out, that the logic behind the scoring system that is used for the existent measures is known, but no record exists on the detailed process for the assignment of PPP scores for each measure. Therefore, it was indicated that the **PPP scoring needed to be evaluated.**

While playing the PoFSG it was observed that the “stakeholders” not directly specialized in ports were focusing on a great extent on the scoring values for each PPP that were presented in each card, rather than using this scoring as a supplementary tool to understand the impacts of the measures. In other words, **they neglected the qualitative effect of each measure** and what it represented. In that sense, the second goal of the PoFSG to educate players on combining ecosystem knowledge and sustainable development was not efficiently achieved.

The PoFSG has been played and tested in a lot of countries of the world (Chile, Argentina, Uruguay etc.) where different stakeholders took part. One of the main concerns was that the **list of measures that are involved in the game is too long** and that caused confusion during the selection of the measures.

Another weakness of the PoFSG is that even though the main concept is based on applications of measures to a **fictional port that does not have any specific characteristic**, in order to develop knowledge that could be generally applicable, this seems to obstruct the players to take informed decisions about the port.

In addition, in the context of the Corealis project, there is the need to **include more competitively climate change adaptation strategies**. Currently, climate change adaptation measures are not directly included in the game, however, several measures are proposed in the category "coastal protection" that are considered relevant. During the game various scenarios are played and activate a dialogue among the players during the negotiations of the decision-making process (Liagkouras et al. 2015). One of the scenarios that is introduced is the climate change scenario. The groups of fictional “stakeholders” or actual stakeholders are called to take this situation into account and try to find the best combination of flood defense measures and other measures for improving the performance of PPP. Therefore, the need to make the PoFSG more dedicated to climate change is apparent.

Moreover, the **likelihood of success of the measures** is not included in the game. It would be beneficial if the PoFSG could be used to trigger the stakeholders understanding of the complexity and the uncertainty that is enclosed in decision making, such as the climate change adaptation decision making.

Additionally, the PoFSG does not currently provide any indication of **how much sustainable the port "becomes"** when the players select their measures.

Furthermore, every time that the PoFSG was played, **the results of the game are not recorded**.

Last but not least, Corealis project is dedicated partly to make the PoFSG **more realistic and plausible/acceptable** to different stakeholders in order to make the game even more tailored for stakeholder engagement.

4.2 Sustainable Performance Scoring System (SPSS)

Based on the weaknesses that are identified in the previous section, a new scoring system is developed to evaluate the performance of sustainability measures on People, Planet and Profit that is proposed to substitute the currently existing scoring system in the PoFSG. Through this **sustainable performance scoring system (SPSS)**, **sustainability measures** are scored with respect to the **sustainability themes**.

Performed Research Steps to answer Research sub Question #5 :

- Develop techniques to improve the disadvantages or the gaps that exist in the PoFSG
- Develop a system to assign PPP scores in the measures of the PoFSG

Performed Research Steps to answer Research sub Question #6 :

- Create an initial scoring system to evaluate the performance of port sustainability measures based on their effects on People, Planet and Profit
- Incorporate into the system the weight factors for each sustainability theme
- Test the applicability of the scoring system on the already existing measures of the PoFSG
- Create a method to quantify the port sustainable development based on a set of selected sustainability measures

4.2.1 General

The **sustainability themes** in combination with their respective **weight factors** can be used as a basis to develop a sustainability performance scoring system (SPSS) that could be used from ports to assess the sustainability of policy measures and strategies. T

he **sustainability themes** that were introduced in Section 2.2.2, serve two main purposes. The *first main purpose* has already been presented in the respective chapter and is related to the creation of a framework to assess the sustainability of ports. The *second purpose* concerns the creation of a scoring system to evaluate the performance of policy measures on People, Planet and Profit.

Through the formulation of **weight factors** for each sustainability theme (Chapter 3.3), apart from the *theoretical insight* that can be gained as to which aspect of sustainability that the stakeholders find the most important, the weight factors can be also used for a more *technical purpose*.

The Sustainability Performance Scoring System (SPSS) is inspired from the paper of (Schipper, Vreugdenhil, and de Jong 2017) "A sustainability assessment of ports and port-city plans: Comparing ambitions with achievements". In the specific chapter of "Assessment of sustainability measures in the context of the performance indicators", the effects that implementation of possible measures might have on each of the PPP categories is presented, based on the indicators that are used and that best express the sustainability aspects needed for the of this study. The performance of the measures vary from -5 (very strong negative effect), 0 (no effect), to +5 (very strong positive effect)

for each sustainability sub-indicator. The totals score of each measure is the sum of the partial score assigned to the indicators.

In this thesis study, the above-mentioned method is further extended, integrating the weight factors for each sustainability theme to evaluate more objectively the performance of sustainability measures on People, Planet and Profit. By means of the weight factors, not only the effects of the implementation of measures on the port city can be presented but also their contribution to the sustainable development of the port city.

Therefore, each proposed sustainability measure will be initially scored based on the magnitude of its effect on each sustainability theme (from -5 to +5). This initial score will be then multiplied with the weight factor that corresponds to each sustainability theme. All in all, the sustainability performance score of a sustainability measure for each PPP category is derived by summing the partial final scores of the sustainability themes that are included in each category.

An example of the application of the SPSS to a specific measure is introduced in Table 12.

Table 12: Application of SPSS on a specific policy measure

	Sustainability themes	Replacement of diesel-powered terminal equipment
Planet	Air quality	3
	Sea water quality	0
	Water consumption	0
	Sediment/soil quality	2
	Noise	2
	Energy consumption	3
Planet score		0,64
People	Employment opportunities	1
	Safety levels	2
	Land use changes	0
	Recreation and aesthetics	0
	Stakeholders involvement	0
	Traffic congestion	0
People score		0,27
Profit	Intermodality	0
	Productivity	0
	Personnel training	0
	Terminal potential	0
	Expandability	0
	Circular economy	0
Profit score		0,00

4.2.2 Experts' contribution in SPSS

The initial scores are given by the author based on a literature study, and in the second stage they are tested and fine-tuned by expert knowledge. The experts were given an excel table in which sustainable strategic measures were presented and they were asked to score their performance related to the sustainability themes. The layout of the excel table is presented in Appendix L . The scale that they had to use was raging from -5 (very strong positive effect) to +5 (very strong negative effect).

4.2.3 Sustainability level of port

The level of sustainable development of the port that can be achieved by selecting specific sustainability measures is expressed as a percentage.

Initially, the level that a port can be considered 100% sustainable is set, considering that this is a non-reachable target. The assumption that 0% sustainability is achieved a measure scores negatively (-5) in all sustainability themes and 100% sustainability when all when the measures score positively (+5), is considered extreme and non-realistic. Therefore, a more realistic assumption of what could be considered a fully sustainable set of measures must be defined.

First, it should be clear that a set of measures cannot ensure 100% sustainability. For this reason, 100% sustainability could be achieved when the effect of the measures to two most important sustainability themes from each PPP category would be maximal (+5 score).

In the following Table 13, using the SPSS the sustainability level of a set of measures chosen is presented. It should be noted that the scoring of the measures presented are resulting from Chapter 4.3 and the scores that are given in Table 13 are used as an example and do not represent the final scores that will be generated in the next chapter.

Table 13: Sustainability level of port based on sustainability measures chosen

		Selected sustainability measures			
	Sustainability themes	Replacement of diesel-powered terminal equipment	Adaptation of terminal layout	Enhanced drainage system	Relocation of specific activities within the limits of the existing port
Planet	Air quality	3	3		
	Sea water quality	0	0		
	Water consumption	0	0	2	
	Sediment/soil quality	2	0	2	
	Noise	2	2		
	Energy consumption	3	2	-1	
Planet score		0,64	0,46	0,18	0,00
People	Employment opportunities	1	0		
	Safety levels	2	0	1	3
	Land use changes	0	-1		
	Recreation and aesthetics	0	0		
	Stakeholders involvement	0	0		
	Traffic congestion	0	3		
People score		0,27	0,10	0,10	0,29
Profit	Intermodality	0	0		
	Productivity	0	2	2	-1
	Personnel training	0	0		
	Terminal potential	0	0		-1
	Expandability	0	0		
	Circular economy	0	0	2	
Profit score		0,00	0,10	0,19	-0,09
				Sustainability level %	58

4.2.4 Applicability of SPSS in the PoFSG

Since in the PoFSG there is no detailed description of on how the performances of the measures that are currently used in the PoFSG are derived, the SPSS could replace the current scoring system in order to be able to score the existing and new measures that are introduced in the game.

As an initial step, the SPSS is applied in one already existing measure of the PoFSG to test the results and compare it with the current scoring of the measure. The scoring values are presented in the following tables (in Table 14 current scoring of PoFSG and Table 15 proposed new scoring).

Table 14: Current PPP scoring of measure "Heightening quays"

People			Planet			Profit		
1			0			2		
Safety against flooding	Employment	Well-being	Habitats	Biodiversity	Water quality	Port	Fisheries	Tourism
1	0	0	0	0	0	4	0	1

Table 15: Application of SPSS in the already existing measure of PoFSG

	Sustainability themes	Heightening quays
Planet	Air quality	0,00
	Sea water quality	-0,50
	Water consumption	0,00
	Sediment/soil quality	-1,00
	Noise	0,00
	Energy consumption	-0,50
Planet score		**0,00**
People	Employment opportunities	1,00
	Safety levels	3,50
	Land use changes	1,00
	Recreation and aesthetics	-0,50
	Stakeholders involvement	0,50
	Traffic congestion	-0,50
People score		**0,44**
Profit	Intermodality	1,00
	Productivity	1,25
	Personnel training	0,00
	Terminal potential	1,00
	Expandability	-0,50
	Circular economy	0,00
Profit score		**0,14**

Since the scoring that is used in the SPSS, as explained in the previous section, apart from the scoring that is given by experts (from +5 to -5) includes the contribution of the weight factors, the final scores are easily comparable. For that reason, the initial scores given by the experts for the SPSS will also be presented.

It can be observed that the People category is not affected by the measure of “Heightening quays” in both scoring systems, as expected. Even though in the SPSS the sustainability themes on the People category have a lower score than the Profit category, it can be observed that the final score for “People” is higher and this is attributed to the highest importance weight factors of the sustainability themes on this category. As presented in the current scoring of the PoFSG, “People” received a lower scoring than “Profit”.

Another aspect that has to be taken into account is that the SPPS that the category “Profit” is reflecting mainly upon the internal profit of the port, related to the productivity levels and the capacity of the terminal and the “People” is referring to socio-economic subjects. For that reason, it should be expected that there would be deviations between the two methods.

All in all, it is considered that the SPSS would have **practical use (pros)** on the PoFSG based on the following qualities:

- The sustainability themes for each PPP category are selected by studying the terminal processes to identify the potential stresses. The most important aspects are considered sustainability themes.
- The sustainability themes for the scoring of the measures are six for each category of PPP and this allows a more detailed and objective scoring of the measures.
- The “People” sustainability themes reflect upon socio-economical aspects
- The "Profit" sustainability themes reflect mainly on the internal profit of the port
- By means of the weight factors, not only the effects of the implementation of measures on the port city can be presented but also their contribution to each PPP.
- After selecting a set of sustainability themes, the sustainable development level of the port can be measured, using each measure’s contribution to PPP.

- The scoring of each sustainability measure will not be demonstrated as a number value but as a colour intensity scale so that it will be avoided that players emphasize on the values while neglecting the actual meaning and impact of the port development measures.

The SPSS presents some weaknesses as well:

- A couple of the sustainability themes do not perfectly fit as general scoring criterions for the sustainability measures, but they represent important aspects of the port development. For instance, the themes of intermodality, personnel training and expandability are important aspects of the port development but they do not perfectly fit as general scoring criterions for the policy measures. However, it is decided to include those themes as scoring criterions for the SPSS since they constitute important aspects for the port sustainable development.
- Since the integer numbers that are used by experts to score the effect of the sustainability measures to the sustainability themes are multiplied with the importance weight factors, the resulting scores for PPP are not integer values.
- Since sustainability is not an easily defined concept, the calculation of the sustainability level of the port based on the selected measures cannot be expressed accurately and assumptions are made.

4.3 Sustainability measures

In this Chapter, the currently existing measures of the PoFSG are evaluated as to their applicability to Mediterranean ports. Next, the two sustainability themes with the largest weight factors are further on elaborated. Based on the results**, air quality** and **safety levels** are thought to be the most important among the stakeholders that filled in the questionnaire. The air quality is approached by means of **carbon emissions**, since they are obviously associated with the fuel consumption in the port, as well as, indirectly with the electricity that is consumed in the terminal. The safety levels are approached by means of safety from **climate change impacts**. For these specific subjects, the PSAF and specifically the "Intervention" procedure is further extended to include measures that enhance the sustainable performance of the ports and at the same time serve as invaluable inputs to the PoFSG. The extension of the PSAF is presented in Figure 17 and constitutes a separate framework.

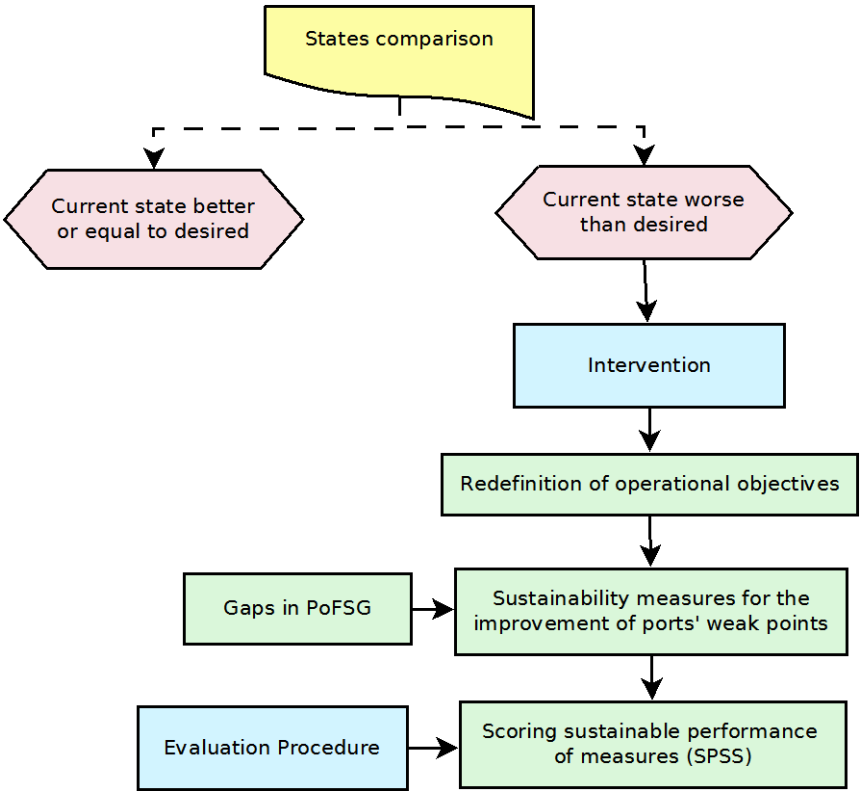


Figure 17: Extension of PSAF – Intervention procedure

The scores will be assigned from the author from literature research and will be fine-tuned using expert knowledge. As a result, sustainability measures will be proposed for the PoFSG, which will include a performance score to PPP.

Performed Research Steps to answer Research sub Question #5 :

- Develop techniques to improve the disadvantages or the gaps that exist in the PoFSG
- Propose measures to make the game more dedicated and relevant to the most crucial sustainability themes

Performed Research Steps to answer Research sub Question #7 :

- Redefine the operational objectives for the two most important themes
- Propose measures that would aim at effecting positively the two most important themes
- Test the applicability of the proposed sustainability measures in the two ports case studies
- Test the applicability of the proposed sustainability measures in the PoFSG
- Score the measures based on the scoring system that was created (SPSS)

4.3.1 Current measures in the PoFSG

One of the aims of Corealis project is to make the PoFSG more dedicated and realistic to the ports that are involved. Therefore, a brief presentation of the measures that currently exist in the PoFSG will be conducted, and the measures that are not considered applicable to the two ports case studies and consequently to the Mediterranean will be briefly commented. This will create a general idea of the measures that are included in the game, the gaps and the necessities that exist, which can be used as guidance for the introduction of new measures.

The measures marked in red are not considered applicable and is proposed to be discarded or modified.

Category 1: Port expansion measures (total 5 measures)

- Inland expansion: replacing natural areas
- Inland expansion: replacing urban areas
- Land reclamation: island
- Land expansion: peninsula
- Offshore floating

Category 2: Navigation measures (total 6 measures)

- No breakwater
- Oyster breakwater
- Locks: harbour entrance - Mediterranean Sea countries do not have navigable rivers (except Rhone and Po) (UNECE 2018)
- Locks: inland – Same as previous
- Storm surge barrier: movable – Same as previous
- Dredging

Category 3: Coastal Protection measures (total 7 measures)

- Additional nourishment – Not applicable in many old ports of the Mediterranean since they are naturally sheltered and the sedimentation processes have stabilized
- Reuse dredged material– Same as previous
- Hard structures –same as previous
- Heightening quays
- Artificial reefs

- Artificial saltmarshes - Limited applicability. Not many Med ports are near rivers nor have free land to create saltmarshes
- Artificial mangroves- Not applicable in the Mediterranean, should be considered to substitute mangroves with Posidonia or Cymodocea beds

Category 4: Environmental Measures (total 8 measures)

- Preventing invasive species
- Habitat creation: mangroves– Not applicable in the Mediterranean
- Habitat creation: corals – Not applicable in the Mediterranean
- Habitat creation: seagrass – Applicable. Maybe Posidonia or cymodocea beds
- Eco-connectivity stimulation - Limited applicability. Rarely Mediterranean port separate habitats
- Eco-concrete Structures
- Green Roofs in Buildings
- Wind Energy - Med ports are generally placed in naturally protected areas with low wind potential (Globan Wind Atlas 2018)

Category 5: Governance measures (8 measures)

- Additional Safety rules
- Smaller ships
- Wastewater treatment
- Tax
- Environmental Shipping Index
- Habitat compensation
- Pollution limits
- Attract investors

Category 6: Infrastructure measures (total 7 measures)

- Inland connection: railway
- Inland connection: water – Not many navigable rivers in the Mediterranean
- Inland connection: road
- Resorts
- Nature-based tourism
- Public green infrastructure
- On-shore power supply – Add incentives for ship LNG-powered engines and/or scrubbers. LNG bunkering facilities in ports

Category 7: Urban Measures (total 6 measures)

- Photovoltaics in Roofs – To reduce the number of measures this measure can be clustered with “Green Roofs in buildings”, “Wind energy”, “Solar thermal energy on roofs”.
- Solar thermal energy on roofs – Same as previous
- Sanitation
- Rainwater retention and infiltration ponds
- Urban water square - Generally lack of free land to implement
- Aquifer storage and recovery – Aquifer near the port area in direct contact with sea water

4.3.2 Air quality – Carbon emissions

Based on the results of the questionnaire, the “air quality” sustainability theme was considered to be of the highest importance among the other themes that were presented. Through the study of the various terminal processes to identify the potential stresses, which was elaborated at the beginning of this thesis project, it was concluded that a great number of the activities that are carried out in the terminal affect the air quality.

In the previous relevant chapter, it is emphasized that the CO2 emissions are considered as a separate indicator since it represents the biggest share of the greenhouse gases (GHG). Additionally, the CO2 emissions are evidently associated with the fuel consumption in the port, as well as, indirectly with the electricity that is consumed in the terminal.

Therefore, in this chapter, the focus will be set to sustainable strategic measures for the reduction of the carbon emissions in ports, related to energy consumption besides fuel consumption.

4.3.2.1 Current state of the ports

The information collected through the application of the Port Sustainability Assessment Framework (PSAF) for relevant themes of Air quality and Energy consumption are extensively presented in Appendix H (H1. .

In this subchapter, a brief analysis of the information will be illustrated, contributing, thought the identification of the weaknesses and the strengths of the terminals, to the introduction of measures that would be needed for those specific terminal case studies.

Air quality - Fuel consumption

Piraeus Container Terminal (PCT):

- No adequate info regarding the fuel consumption.
- Diesel is the only fuel type is used in the port

Terminal Darsena Toscana (TDT) in the Port of Livorno

- Calculates the fuel consumption in an organized way, in which the operational and non-operational diesel consumption is calculated separately.
- The diesel consumption in the TDT remains nearly constant during a period of 8 years, as well as the total diesel consumption per yard moves.

Air quality – Carbon emissions

Piraeus Container Terminal (PCT):

- No reference to carbon footprint in the EIA of the port of Piraeus for 2017
- The design of a Solar Park has been implemented to be installed in Neo Ikonio, which is the section of the port that requires the most energy

Terminal Darsena Toscana (TDT) in the Port of Livorno

- The CO2 emissions are calculated and correspond both to the diesel and the electricity consumed.
- CO2 emissions are presenting a decrease during the years of 2015 and 2016 with a slight increase in 2017.
- Targets that should be achieved within a specific time period
- Within the period of the five last years, CO2 emissions have decreased by more than 10%.

Energy consumption

Piraeus Container Terminal (PCT)

- In 2017 35.169.243 KWh were consumed
- Green energy is not produced for the container terminal
- All cranes that the PCT is using are powered by electricity
- The PPA's first solar park producing energy from photovoltaic panels has been operating since July 2016 with capacity of 430 kW.
- No adequate information to draw a conclusion regarding electricity consumption

Terminal DarsenaToscana (TDT) in the Port of Livorno

- Electricity consumption is measures clustering the consumers into separate categories.

- The electricity consumption in the container terminal is remaining constant over the last 8 years with an approximate average value equal to 8.000.000 KWh/ year.
- Targets are set relating to the decrease in the consumption of non-renewable energy sources

Terminal Lorenzini in the port of Livorno

- The yearly electricity consumption of the Lorenzini container terminal was 1.500.000 kWh in 2016
- The electricity consumption is stable but with a relatively high ratio of consumption over a number of container units handled.
- No information regarding energy generation and consumption from renewable sources.
- There is the need to shift more to electricity consumption, while optimizing the total consumption of the terminal.

4.3.2.2 Redefinition of operational objectives

It is crucial to set an initial operational objective, which is related to the monitoring and the calculation of the CO2 emissions that are performed in the port. Through the analysis of the case studies of the Livorno and Piraeus container terminals, it could be concluded that significant efforts still need to be done from the ports to systematically monitor the carbon emissions and most significantly set target values to be achieved in predefined time periods along with plans to achieve them. It is obvious, that the carbon emissions in the port are related to the fuel and electricity consumption, therefore the plans to reduce the emissions could be directly related to the aforementioned themes.

Besides, based on the statement of Professor Jens Froese from the Global Logistics Emission Council (GLEC) “carbon foot-printing of container terminals is not yet mandatory but only recommended”. Additionally, from an article published in the Maritime Executive in 2018, it is explained that there are hardly any examples of ports in which incentive programs have been proven to reduce GHG emissions from shipping and from the results of Section 2, it is concluded that there is a large number of producers of carbon emissions within the port operations and therefore, the need for carbon foot-printing and adopting strategies for the decrease of the carbon emissions in a container terminal is essential.

However, the data that was possible to retrieve for the two terminal case studies are not adequate to define the desirable targets. For that reason, the operational objectives cannot be updated successfully.

Additionally, it could be added that efforts should be stepped up to ensure better monitoring; reporting and verification as a precondition for steering policies towards the most effective outcomes.

4.3.2.3 PoFSG and air quality – suggestions

The Port of the Future Serious Game is explained in Appendix A .

The already existing measures in the PoFSG that relate to the reduction of pollution, an introduction of renewable energy resources etc. are presented below:

- Wind Energy – Environmental measures
- Tax (taxing the high-polluting ships more heavily) – Governance measures
- Environmental Shipping Index– Governance measures
- Pollution limits– Governance measures
- On-shore power supply – Onshore power supply
- Photovoltaics in Roofs – Urban measures
- Solar thermal energy on roofs

The PoFSG has been played and tested in a lot of countries of the world (Chile, Argentina, Uruguay etc.) where different stakeholders took part. One of the main concerns was that the list of measures that are involved in the game is too long and that caused confusion during the selection of the measures.

Therefore, a recommendation would be to cluster some of the measures that belong to the same category. For example, the wind energy, photovoltaics in roofs and the solar thermal energy on roofs could be presented into a single measure named “Renewable energy”.

In addition, the “Tax” measure that refers to taxing the high-polluting ships more heavily could also include incentives for low-emission ships.

4.3.2.4 Measures for the reduction of carbon emissions

The CO2 reduction strategies concern the shipping companies and the terminal operators and above all, cooperation between them to decrease the carbon emissions.

The evaluation of the sustainable (green) performance of container handling equipment following a carbon footprint approach also enables to save energy and decrease CO2 emissions coming from different types of container handling equipment, but also the creation of strategies to realize sustainable and green growth (Yang and Shen 2013).

The first step for the exploration of solutions to reduce of the carbon emissions in ports, is the identification of the main producers.

Based on the study of the terminal processes and the identification of the potential stresses that was performed in Section 2.1, the producers of emissions affecting the air quality can be identified. Therefore, for the calculation of the carbon emissions, the following data is needed:

- The type and number of equipment that is used for container handling – both for fuel and electricity consumption
- Yearly total container throughput of the terminal (TEUs, the yearly number of trucks related to transhipment, the frequency of train departures) –both for fuel and electricity consumption
- The average monthly departure of container and feeder ships and the vessel types
- The total supply for cold-ironing
- The hours that reefer plugs are operational

However, it is clear that the number of vehicles and trucks that are used for terminal operations is not adequate to calculate the carbon emissions. The terminal layout plays an important role since it determines the average distances travelled from vehicles/trucks (Geerlings and van Duin 2011). The energy that is consumed by the equipment within the terminal is related to the distances that are travelled to perform several sub-processes (Geerlings and van Duin 2011).

Through literature research, potential measures for reduction of carbon emissions within the port are explored mainly from the following sources: Geerlings and van Duin 2011, The Maritime Executive, 2018, Flynn, Mcmullen, and Solis 2008, Corealis.

Based on on the performed analysis and the existing gaps in the PoFSG, the following measures are proposed, that are considered to increase the sustainability of ports. They are presented along with the categories that currently exist in the PoFSG in which they could be incorporated. Most of the proposed sustainability measures belong to more than one category, therefore they are catalogued according to the most prominent and important category based on the author. An attempt was made to cluster the measures that involved similar actions into single categories.

Adaptation of the terminal layout (Infrastructure measure)
Through this measure, the terminal layout will be adapted through the optimization of the travel routes and distances inside the terminal. It will become possible to reduce the CO2 emissions of the terminals that do not possess the most optimal layout. (Geerlings and van Duin 2011)

Replacement of (diesel-powered) terminal equipment (Environmental measure)

This measure involves the replacement of diesel-powered terminal equipment to new equipment, electric or hybrid (Geerlings and van Duin 2011).

Energy recovery from gantry cranes (Environmental measure)
The potential energy from a container during a lowering event can be stored in the flywheels (storage of rotational energy) and then reused for the container's subsequent lifting operation. Due to the energy storage from the flywheels, the size of the diesel engine can be reduced and can lead to fuel savings (Flynn, Mcmullen, and Solis 2008).

Blending biofuels (Environmental measure)
This policy is aiming to reduce the emissions by diesel fuel. By blending biofuels with diesel, the CO2 that is emitted per litre of diesel used can be reduced (Geerlings and van Duin 2011).

Vehicle management system (Environmental measure)

The optimization of the vehicle/truck movements in the terminal can reduce the emissions from non-necessary movements. It can also increase the efficiency of the terminal operations (Corealis).

Renewable energy sources (Environmental measure)
This measure entails the production of solar energy, wind energy and energy production from biomass. Specific examples for the reduction of CO2 emissions would be co-firing biomass in power stations, solar energy generation from roof areas of the building (businesses) around the port (Port of Rotterdam).

Green incentives to ships (Governance measure)
This measure involves the expansion of port-based incentives for low-emission ships like carbon pricing schemes, for example, lower pricing policy for scrubbers or LNG engines. Additionally, strict implementation of port state control and linkage of the shipping index to pricing policies (implementation of "the pollutant pays" principle) (The Maritime Executive, 2018).

4.3.2.5 Applicability of the proposed measures to the two ports case studies

Based on the chapter illustrating the information derived from the implementation of the framework to the two ports case studies and the measures that are proposed, it becomes evident that most of the measures presented above are applicable to the two port case studies, and reflect on the achievement of the operational objectives.

Adaptation of the terminal layout:

- There is no available info on if there is a need for adaptation of the terminal layout in PCT. However, since the development and growth/expansion of the PCT is relatively current, the necessity for adaptation is not expected.
- Applicable in the Livorno container terminals - Yard optimization is needed as Mr Barsacchi, from Lorenzini Container Terminal mentioned during the Livorno Focus Group. Currently, there is a distinction between two yards in the terminal of Lorenzini. No specific information is available regarding the TDT container terminal and during the interview that was carried out to the financial operator of TDT, no comments were made regarding the efficiency of the yard operations nor the need of yard optimization, however the distance from the entrance gate to the TDT is relatively large and it seems that there is a margin for further optimization.

Replacement of diesel-powered terminal equipment

- Partly not applicable in PCT - Electrical cranes are already used. Could be applied in all the other kind of equipment (internal vehicles etc.)
- Applicable to the Livorno container terminals – Based on the information gathered, it was concluded that there is the need to reduce the fuel consumption and the cranes that are used are diesel-powered.

Energy recovery from gantry cranes

- Could not be applied easily in PCT since new electric gantry cranes were recently purchased. It can be considered as a measure to increase capacity in the future.
- Applicable in the terminals of Livorno since there is a need to renew the equipment and reduce the fuel consumption.

Blending biofuels:

- Applicable in PCT (diesel is the only type of fuel that they are using)
- Applicable in the Livorno container terminals (diesel is the only type of fuel used)

Vehicle management system

- The only information that is available for PCT is that special attention is given to the road behaviour of the drivers inside the port. Seminars are given to optimize the moves in the port areas, the way they break etc. (Source: Senior IT Engineer in PCT). Based on this information it seems that more structured vehicle management system would be needed in PCT.
- Applicable in the Livorno container terminals: As it was mentioned during the Livorno Focus Group, in Terminal Lorenzini there is not in use any kind of vehicle tracking, and as a consequence, trucks arrive without notice. For that reason, specific time slots that the trucks drivers will be able to book for their arrival during the day. In that way, the waiting time of the trucks will be reduced, and it will become possible to optimize the movements of both the external trucks but also the yard vehicles since their arrival could be anticipated.

Renewable energy sources

- Applicable in PCT (currently no renewable energy sources are used – apart from the planned construction of a Solar Park). The offshore wind park is not applicable for the port of Piraeus due to the combination of inadequate space (the Gulf of Saronikos in which the port is located is very narrow) and lack of high wind velocities. Additionally, the Attica region that the port of Piraeus is located, is not considered a region with high wind potential (Kabouris and Hatziargyriou 2006)
- Applicable in the terminals of Livorno (even though TDT sets targets that involve the decrease of the consumption of non-renewable energy sources, there is no direct plan to shift to alternative energy sources). In Tuscany, there are plans to harness local renewable wind sources due to the hilly and Apennine areas with > 6-8 mt/sec. Additionally, Tuscany's solar average radiation is around 1400-1500 kWh/m2/year.

Green incentives to ships

- Applicable in PCT (no current application of any related policy)
- Applicable in the terminals of Livorno (no current application of any related policy)

4.3.2.6 Application of SPSS to proposed measures

In this subchapter, the proposed measures for the PoFSG for the reduction of the carbon emissions within the port operations will be scored as to their performance in PPP, based on the SPSS that was created in Chapter 4.

4.3.2.6.1 Effects of sustainability measures on sustainability themes

Adaptation of the terminal layout

The adaptation of the terminal layout is considered to have an indirect effect on the air quality since the layout would be optimized and consequently, the unnecessary routes will be reduced or even eliminated. Based on the paper of Geerlings and van Duin, published in 2011, this measure is the most effective for CO2 reduction. Therefore, **air quality** will be affected positively by this measure. Additionally, the **energy consumption** will be also influenced positively in a large extent, especially in the case that the equipment is powered by electricity. The **noise levels** are expected to be slightly reduced since the average distances will be diminished and the routes will be optimized.

The **land uses** will be possibly affected, in the case that the eventual relocation of activities would affect the port-city interface. The **traffic congestion** inside the terminal (and also outside since the ques could decrease) can be minimized in some level since this measure leads to quicker and more effective moves within the terminal.

The effects that this measure entails are significant from the point of view of terminal configurations as well as operational performances (Geerlings and van Duin, 2011). In that sense, the capacity of the container terminal could be affected either positively or negatively compared to the original layout. The **productivity** levels, considering that the adaptation will not be implemented solely for the CO2 emissions reduction, but it will also aim to an optimization of the terminal operations, is mostly expected to grow. However, this measure is a very **costly** option for the reduction of CO2 emissions as explained in by Geerlings and van Duin, 2011.

Replacement of (diesel-powered) terminal equipment

The replacement of diesel-powered terminal equipment to new (more eco-friendly) equipment can reduce the CO2 emissions up to 20 per cent (Geerlings and van Duin 2011) and consequently, **air quality** will be affected positively. The new equipment is expected to lead to significant reductions in fuel and exhaust, and **noise** reduction.

For instance, Kalmar reaches stackers, minimise the noise and the fuel consumption from 17% to 100% compared to the most other RTGs.

Additionally, as mentioned in the Kalmar website “the Kalmar Hybrid RTG combines the latest in Li-ion battery and diesel power-unit technology and requires less maintenance because the power unit’s running hours are considerably reduced since it is not used to give power to the functions of the crane, but only to charge the Li-ion battery”.

Konecranes’ customers make statements of up to 40% fuel savings to as high as 60%. These savings are also realized in both noise and air pollution.

Another example would be the Grid-Powered Electric Transfer Crane, which is estimated to reduce the cost related to energy as well as the CO2 that is emitted by nearly 90% relatively to the conventional RTGs (Obata et al. 2010) as it can be also observed in Figure 18.

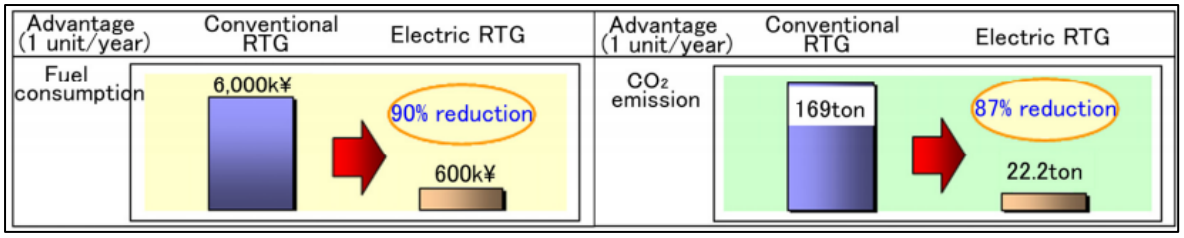


Figure 18: Environmental performance of Grid-Powered Electric Transfer Crane (Obata et al. 2010)

As it can be seen, there are plenty of options regarding the choice of the optimal equipment types for container terminals.

Of course in the case of electrical equipment, the **energy consumption** is expected to rise.

Newer equipment is related to higher **safety levels** in the terminal area. The productivity levels of the terminal are expected to grow with the introduction of new equipment. Comparing the technical specifications (hoisting speed, trolley speed, gantry speed, safe working load etc.) of the earlier versions of RTGs with the new electrical or hybrid versions, it is obvious that the new types have an increased efficiency. In that context, the **productivity** of the terminal will increase.

The **investment cost** of the replacement of the diesel-powered equipment is relatively high, but the reduction of fuel and maintenance costs should be also considered.

Energy recovery from gantry cranes

Based on the research made by (Flynn, Mcmullen, and Solis 2008) regarding the crane operation with flywheels and the preliminary field tests that were made using an engine of reduced size have generated **fuel savings** up to 35% and more. Therefore the emissions output will be decreased and the **air quality** will be improved. Additionally, it was mentioned the "*peak power demand needed from the engine extends the engine's life*"; therefore **less maintenance** will be needed.

Blending biofuels

It has been studied by (Geerlings and van Duin 2011) that "*when 30 per cent of the diesel is composed of blended biofuel, then the CO2 levels by using diesel are also 30 per cent lower per litre of fuel consumed*". The **air quality** will be positively affected.

The use of biodiesel can boost the economy by **creating jobs** in the production procedure.

The concept of **the circular economy** can be introduced through this measure since the biodiesel is a renewable fuel derived from biomass including vegetable oils, animal fats, or waste grease (used cooking oil). However, biodiesel is more expensive than petroleum(Smith and Murray 2014).

Vehicle management system

The optimization of the vehicle/truck movements in the terminal can reduce the emissions from non-necessary movements and improve the **air quality**. This latter described plan refers to the internal vehicles. Vehicle tracking management, through the creation of a clear schedule based on which the truck arrival could be anticipated in specific time slots, could contribute to the improvement of **air quality** and a decrease of **traffic congestion**. The decrease in traffic congestion will reduce the **noise** levels. The **productivity** of the container terminal could increase since the exact operations that need to be carried can be planned in advance and optimised.

Renewable energy sources

A method to reduce CO2 emissions while energy is generated is by co-firing biomass. The co-fired biomass in coal-fired power stations most of the times is made of wood chips, however also other types of materials can also be consisted, for instance materials from the bio-based chemical industry.

The renewable energy sources can improve the **air quality** to a significant extent since the energy produced will replace the use of electrical energy produced in power plants based on coal. Therefore, the energy consumption will decrease. In the case of wind turbines, the **noise** levels will rise in the case that specifically the wind turbines are located close to residential areas within one mile of the blades. This effect will be considered negligible.

The **employment opportunities** will increase, both under the short-term construction phase, but also during the operation period in which new job positions for the operation and the maintenance of the energy sources will be performed. The **land use changes** will be apparent within the construction of a wind farm or a solar park. Additionally, the **aesthetics** of the port can possibly be affected adversely, but this is also dependent on the exact location of the site. The concept of **circular economy** is directly related to the creation and use of renewable sources.

Green incentives to ships

Through the introduction of green incentives to ships, the pollutant emissions related to shipping will be decreased and consequently, the **air quality** will be improved. Additionally, the e**nergy consumption** may rise due to eventual application of cold-ironing.

4.3.2.6.2 Preliminary author's scoring

Based on the discussion on the previous chapter and on the critical knowledge of the author, the proposed sustainability measures regarding the reduction of carbon emissions were scored preliminarily as follows in Figure 19.

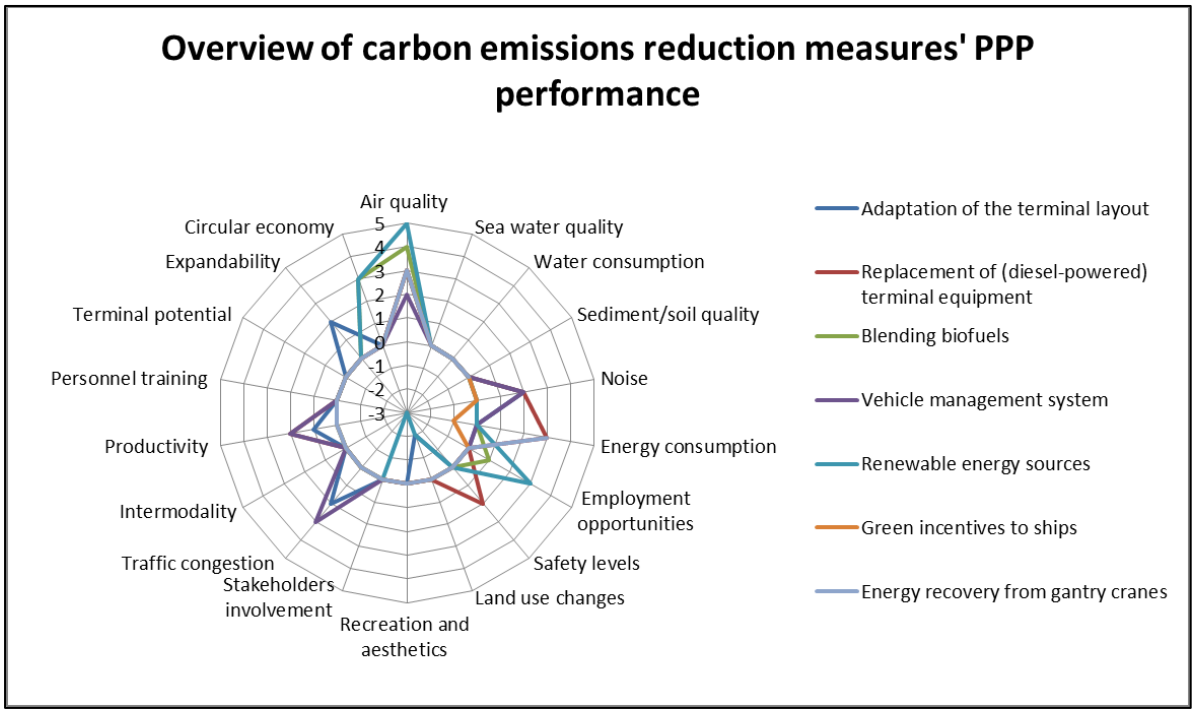


Figure 19: Overview of the sustainability performance of the proposed measures regarding the reduction of carbon emissions

4.3.2.6.3 Final calibrated scores based on expert knowledge

The scores that were assigned by the author could not be considered adequate for the derivation of the scores. Therefore, experts contributed to the formulation of the final scores. The experts filled out in an excel table that is presented in Appendix L . The results of the average scores that were given by the experts, multiplied with the weight factor for each sustainability theme, are presented in the following table (Table 16). By including the weights for each theme in the final score the objective contribution to PPP can be presented.

Table 16: Final scores for the performance of sustainability measures on PPP (carbon emission reduction measures)

		Proposed measures to reduce carbon emissions						
	Sustainability themes	Blending biofuels	Replacement of diesel-powered terminal equipment	Energy recovery from gantry cranes	Vehicle management system	Adaptation of terminal layout	Renewable energy sources	Green incentives to ships
Planet	Air quality	3,50	3,25	2,25	2,50	2,50	4,25	2,75
	Sea water quality	0,25	0,25	0,00	0,00	0,00	0,25	0,50
	Water consumption	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Sediment/soil quality	0,00	0,75	0,00	0,25	0,00	0,00	0,50
	Noise	0,00	1,75	0,00	1,75	1,67	0,00	0,75
	Energy consumption	0,50	1,75	1,75	1,25	1,25	0,75	0,00
Planet score		0,35	0,52	0,29	0,38	0,36	0,43	0,35
People	Employment opportunities	1,50	0,75	0,50	0,50	0,00	2,75	0,25
	Safety levels	0,00	0,75	-0,25	0,75	0,25	0,00	0,25
	Land use changes	-0,25	-0,25	0,00	0,00	-0,25	-2,00	0,00
	Recreation and aesthetics	-0,50	-0,25	0,00	0,00	0,25	-1,75	0,00
	Stakeholders involvement	0,50	0,50	0,00	0,25	0,25	0,50	1,50
	Traffic congestion	0,00	0,00	0,00	3,00	2,25	0,00	0,00
People score		0,11	0,13	0,01	0,27	0,14	0,08	0,10
Profit	Intermodality	0,50	0,00	0,50	0,75	0,75	0,00	0,00
	Productivity	0,50	0,75	0,00	2,00	2,00	-0,25	0,00
	Personnel training	0,00	0,75	0,75	0,50	0,50	0,50	0,75
	Terminal potential	0,00	-0,25	0,25	0,50	0,75	-0,50	-0,25
	Expandability	0,25	0,00	0,25	0,00	1,00	-0,25	0,50
	Circular economy	2,50	0,25	0,50	0,75	0,00	2,25	0,25
Profit score		0,17	0,07	0,10	0,22	0,24	0,07	0,05

4.3.2.6.4 Additional info on the proposed measures

As can be seen in the table presented in Appendix L , the experts were asked to assess the relative **cost** of the proposed sustainability measures, along with the **payback period**. It should be mentioned that this was a rough approach just to have an initial indication of the cost. The cost had to be rated from 0 to +5 and the payback period had the following scale:

- Less than 5 years
- Between 5 and 10 years
- More than 10 years

The results that derived from the answers of 3 experts (Prof. Vellinga from TU Delft, Dr. Taneja from TU Delft and Ir. De Wit from PoR):

Blending biofuels:
Cost: 2
Payback period: most common: Less than 5 years

Replacement of terminal equipment:
Cost: 2
Payback period: most common: Between 5 and 10 years
Likelihood of success: most common: Likely

Energy recovery from gantry cranes:
Cost: 2.5
Payback period: most common: Between 5 and 10 years
Likelihood of success: most common: Likely

Vehicle management system:
Cost: 1.5
Payback period: most common: Less than 5 years
Likelihood of success: most common: About as likely as not

Adaptation of terminal layout:
Cost: 3.5
Payback period: most common: Between 5 and 10 years
Likelihood of success: most common: About as likely as not

Renewable energy sources:
Cost: 2
Payback period: most common: Between 5 and 10 years
Likelihood of success: most common: Likely

Green incentives to ships:
Cost: 1.5
Payback period: most common: Between 5 and 10 years
Likelihood of success: most common: Likely

This method was used to roughly approach the cost of the proposed sustainability measures and is aiming in estimating the initial costs of the measures. The intention is to later on apply it to the PoFSG to interpolate them with the existing costs of the measures.

Based on the resulting sustainability measures and the recommendations for the PoFSG that are illustrated in the next chapter, the new measure cards that are proposed to replace the existing ones are presented in Chapter 4.4.

4.3.3 Safety levels – Climate change protection and adaptation

Based on the results of the questionnaire, the "safety levels" sustainability theme was of the highest importance among the presented themes. By the social sustainability theme "safety levels", the proactive prevention of accidents and other direct human health risks of all port-related activities are included. This term has a wide and general meaning and includes all the possible human health risks that could be expected in a port. "Since ports are exposed to the risk of the impacts of climate variability and change" (UNCTAD, 2017a), it is clear that they should be considered as well.

4.3.3.1 Current state of the ports

The information collected through the application of the Port Sustainability Assessment Framework (PSAF) for relevant themes of Air quality and Energy consumption are extensively presented in the Appendix H (H2.2).

In this subchapter, a brief analysis of the information will be illustrated, contributing, thought the identification of the weaknesses and the strengths of the terminals, to the introduction of measures that would be needed for those specific terminal case studies.

Climate change adaptation strategies are not well-thought out in the ports of Piraeus and Livorno and subsequently, they are not taken into account in the Master Plans of the ports.

4.3.3.2 Redefinition of operational objectives

The operational objective regarding climate change was defined as:

- "Climate change adaptation should play an inseparable role in the development strategies"

This operational objective will be further investigated and more detailed targets will be specified to increase the resilience of ports to a changing climate.

Based on the analysis that was performed and is presented in the Appendix A (A9. , the updated and the more detailed operational objective is presented below:

"Climate change adaptation should initially be approached by the identification of potential vulnerabilities of the port deriving from the constant guidance and control on how climate change will affect the port services. Then, the concept of Adaptive Port Planning should follow, incorporating uncertainty and flexibility considerations in the decision making, design and planning process. Choices should be made among "low-regret" options, "win-win" options, flexible options, the inclusion of ''safety margins'', soft adaptation strategies, reduction of decision time-scales etc. Overall, climate change should be embedded in operational planning, instead of just being incorporated into emergency preparedness."

4.3.3.3 PoFSG and climate change – suggestions

The Port of the Future Serious Game is explained in Appendix A .

Currently, climate change adaptation measures are not directly included in the game, however, several measures are proposed in the category "coastal protection" that are considered relevant.

The measures that can be considered relevant to the climate change impacts are presented below along with the category in which they belong:

- Additional Safety rules – Governance measures
- Oyster breakwater - Navigation measures
- Storm surge barrier: movable – Navigation measures
- Heightening quays – Coastal protection measures
- Hard structures – Coastal protection measures

During the PoFSG different scenarios are introduces to explore the potential impacts and to generate a discussion and negotiation between the stakeholders/players (Liagkouras et al. 2015). One of the scenarios that are introduced is the climate change scenario. The groups of fictional "stakeholders" or actual stakeholders are called to take this situation into account and try to find the best combination of flood defense measures and other measures for improving the performance of PPP.

Suggestions are made regarding the involvement of climate change in the PoFSG. They are presented below.

Climate change adaptation measures/strategies

The study regarding climate change protection and adaptation, in combination with the description of the measures and scenario related to climate change that exist in the PoFSG, give the space for suggestions to increase the game's involvement with climate change adaptation strategies.

Therefore, it is suggested that relevant measures should be considered to make the game more dedicated to climate change. The measures should be distributed in various categories so that the stakeholders would not choose solely from one category called for example "Climate change adaptation", since this would limit the understanding of the actual choice of a specific measure and they might choose a measure just because its relation to climate change is indicated.

The proposed measures are discussed in the next sub-chapter.

Uncertainty

Additionally, the uncertainties and the challenges of the climate change adaptation measures should be considered in the game. As Becker et al. 2013 mentioned, "*at present, it remains unclear what adaptation strategies should be undertaken for different types of ports and on what timeline*". Furthermore, the planners and have not incorporated yet uncertainty in their way of thought and do not apprehend that flexible designs allow the evolution of various paths (P Taneja, Ligteringen, and Walker 2012).

Therefore, it would be beneficial if the PoFSG could be used to trigger the stakeholders understanding of the complexity and the uncertainty that is enclosed in the climate change adaptation decision making. On the other hand, the results of the game should be recorded in order to obtain the statistical results of the choices that have been made among the stakeholders as well as the argumentation, so that the preferences would be revealed between the choice of hard and soft measures.

A likelihood of success will be assigned for each proposed measure. This will be approached in a rough manner, initially, due to limited time, proposing however to be a topic for further study. The uncertainty encompassed in each proposed strategy will be determined by experts.

The probability bins among which the experts would have to choose will be three and are taken from the European Climate Change Adaptation Platform.

- Likely: 66 - 100% probability
- About as likely as not: 33 - 66% probability
- Unlikely: 33% probability

4.3.3.4 Climate change protection and adaptation measures for the PoFSG

The climate change adaptation measures are divided into two main categories: Hard strategies and soft strategies.

The hard interventions entail large investments, while soft interventions are the ones which reduce the uncertainty levels that are encompassed during the decision making, through governance and management strategies (Becker et al. 2013).

Under those two categories, there are three potential strategies: protect, accommodate, and retreat. Based on Mills-Knapp et al., 2011, "*the three protection strategies mentioned above, encompass a broad range of interventions designed to hold back seawater from inundating development, including sea walls, development of manmade topographical features to prevent erosion, and integrated pump systems. Accommodation strategies allow some inundation to occur, but protect infrastructure from damage and continually maintain operations and resiliency of infrastructure. Retreat, often the last resort, entails the managed withdrawal from coastal areas where neither protection nor accommodation is possible*".

The following measures are proposed, that are considered to increase the sustainability of ports. The main literature sources that used are Mills-Knapp et al., 2011, Scott, National Climate Change Adaptation Research Facility (Australia), and RMIT University, 2013, Mol 2017, and A. K. Y. Ng et al. 2013. The measures are presented along with the categories that currently exist in the PoFSG in which they could be incorporated. Most of the proposed sustainability measures belong to more than one category, therefore they are catalogued according to the most prominent and important category based on the author. An attempt was made to cluster the measures that involved similar actions into single categories.

Enhanced drainage system (Urban measure)
This measure is applied to reduce storm-water runoff, and consequently, the collected rainwater could be reused. Sumps and catchment systems are useful in gathering the rainwater that cannot be absorbed. Pumps are used in order to take out the storm water from the above-mentioned systems. On the other hand, the pumps require energy to operate and continuous maintenance (Mills-Knapp et al., 2011).

Enhanced maintenance and upgrading of infrastructures (Coastal protection measure)
This category includes maintenance and boost of the already existent infrastructures that were not originally designed to be resistant to extreme events. It could be achieved by reinforced rock walls that resist stronger and higher surges, enhanced materials to withstand corrosion caused by storm surges and high precipitation(Mills-Knapp et al., 2011).

Cargo handling organizational modifications (Governance measures)
This category of measures includes modifications on cargo handling activities for the enhancement of the functionality of ports under severe weather conditions. Some measures could be: reducing stacking height of containers to decrease the risks of extreme wind speed effects, use of equipment with a high loading efficiency to decrease the 'uptime' needed, use of active mooring systems where wave conditions could be severe(Scott, National Climate Change Adaptation Research Facility (Australia), and RMIT University, 2013) and(Mol 2017).

Relocation of activities(Governance measure)
This measure refers aims to limit the risk of damage in case of flooding of quay walls and increasing the safety levels during terminal operations. The repositioning of infrastructure involves storing the hazardous and dangerous goods to areas protected the potential surge, the subdivision of the various quay areas using safety rings so that the impacts could be limited etc.(A. K. Y. Ng et al. 2013) However, this could impede the efficient exploitation of the terminal area and possibly decrease the available space. (A. K. Y. Ng et al. 2013)

Emergency response plans (Governance measure)
The emergency response plans involve the adoption of risk mitigation plans and evacuation plans in the case of major and extensive accidents. These strategies should be combined with supplementary measures that are selected to mitigate the risks in the first place.

The measure "Dredging" that already exists in the PoFSG, should also be taking into account more constant extreme wave conditions that will change the sedimentation patterns in the port basin.

4.3.3.5 Applicability of the proposed measures to the two ports case studies

Based on the chapter illustrating the information derived from the implementation of the framework to the two ports case studies and the measures that are proposed, it becomes evident that most of the measures presented above could be applicable to the two port case studies, and reflect on the achievement of the operational objectives.

Since no one of the ports case studies is including strategies and considerations regarding climate change adaptation, it can be concluded that all the proposed measures can be considered relevant to the port of Piraeus and Livorno.

4.3.3.6 Application of SPSS on proposed measures

4.3.3.6.1 Effects of the sustainable measures to the sustainability themes

Enhanced drainage system
Through this measure, the **safety levels** are expected to increase since the stormwater runoff will be reduced and the risks of flooding will be decreased. The rainwater captured in the sumps and the catchment systems could be reused for various port operations and this would decrease the **water consumption**. On the other hand, the pumps need additional **energy consumption** to operate (Mills-Knapp et al., 2011). The existence of sumps and catchment systems would decrease the amount of the run-off that will result in the sea water body and in that way the **seawater quality** could be improved. In that, the effect that the extreme precipitation events could have in the operation and **productivity** of the terminal could be increased.

The **costs** for the creation of an enhanced draining system are not very high and a compensation is expected from the damages that will be avoided through the implementation of such a measure. On the other hand, the pumps would require continuous maintenance(Mills-Knapp et al., 2011).

Enhanced maintenance and upgrade of infrastructures
Through this measure, the **safety levels** in the port operations are expected to increase. Since this category of measures includes reinforced rock walls and the use of more resistant materials, it is possible that it could decrease the **aesthetics** of the area and possibly limit the existence of **recreational activities**.

This strategy requires a **low capital investment** and resilience benefits are created directly.(Mills-Knapp et al., 2011). However, those measures do not refer to long-term planning strategies (especially as far as climate change is concerned) (Mills-Knapp et al., 2011).

Cargo handling organizational modifications
Through this category of policy strategies, the **safety levels** in the port operations are expected to increase. The effects of the measures will be the reduction of the impacts that extreme wind speeds could have in port operations, the reduction of the total 'uptime' that is needed in a port for its activities, the reduction of downtime because of flooding of quay walls and the reduction of dwell time in the port. Based on this, it is evident that the **efficiency** of the port operations during extreme events could be increased. On the other hand, decreasing the stacking height of the container terminals implies the need of more space to maintain equal productivity levels so the **terminal potential** is expected to decrease (Scott, National Climate Change Adaptation Research Facility (Australia), and RMIT University, 2013) and(Mol 2017).

This category of policy strategies is expected, with a **relatively low capital investment** to increase the productivity of the port under extreme weather conditions.

Relocation of specific activities

Through this measure, the **safety levels** in the port operations are expected to increase. The relocation of critical infrastructure and the subdivision of quay areas will limit the impacts to a merely local level and the damages will decrease. However, this measure could impede the efficient utilization of the terminal area and possibly decrease its **capacity**(A. K. Y. Ng et al. 2013)

Emergency response plans

Through these policy measures, the **safety levels** will indefinitely increase, since there will be evacuation plans in the case of major accidents (flooding, fire, extreme weather events etc.) and risk mitigation plans (for instance, collaborating with weather stations to be informed in advance regarding extreme weather events). The emergency response plans can only be adopted through **personnel training**.

The capital investment is almost non-existent but it should be clear that these policies should be combined with supplementary measures that are selected to mitigate the risks in the first place.

Dredging

More constant extreme wave events possibly mean change in the sedimentation patterns in the port basin.

4.3.3.6.2 Preliminary author's scoring

Based on the discussion on the previous chapter and on the critical knowledge of the author, the proposed sustainability measures regarding the reduction of carbon emissions were scored preliminarily as follows in the

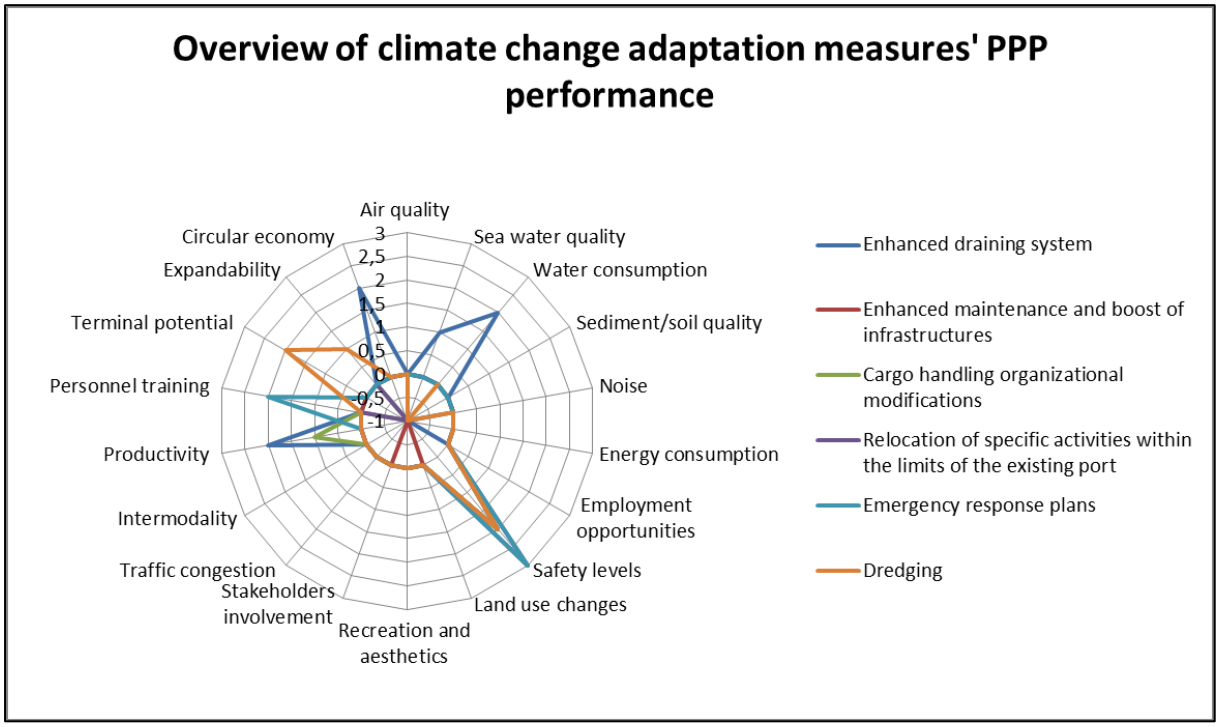


Figure 20: Overview of the sustainability performance of the proposed measures regarding climate change adaptability

4.3.3.6.3 Final calibrated scores based on expert knowledge

The scores that were assigned by the author could not be considered adequate for the derivation of the scores. Therefore, experts contributed to the formulation of the final scores. The experts filled out in an excel table that is presented in Appendix L . The results of the average scores that were

given by the experts are presented in the following table (Table 17). By including the weights for each theme in the final score the objective contribution to PPP can be presented.

Table 17: Final scores for the performance of sustainability measures on PPP (climate change adaptation measures)

	Sustainability themes	Proposed climate change adaptation measures in relation to port safety						
		Enhanced drainage system	Enhanced maintenance and upgrading of infrastructures	Cargo handling organizational modifications	Relocation of specific activities within the limits of the existing port	Emergency response plans	Dredging	Heightening quays
Planet	Air quality	-0,50	0,00	0,00	0,00	0,00	-1,00	0,00
	Sea water quality	0,00	-0,50	0,00	0,00	0,00	-1,00	-0,50
	Water consumption	1,75	0,00	0,00	0,00	0,00	0,00	0,00
	Sediment/soil quality	0,00	-0,50	0,00	-0,50	0,00	-1,25	-1,00
	Noise	0,00	0,00	0,00	-0,50	0,00	-0,50	0,00
	Energy consumption	-1,00	0,00	-0,50	-0,50	0,00	-2,00	-0,50
Planet score		-0,01	0,00	0,00	0,00	0,00	0,00	0,00
People	Employment opportunities	0,00	0,50	1,50	1,00	1,00	1,50	1,00
	Safety levels	1,25	2,50	1,75	3,25	3,25	2,00	3,50
	Land use changes	-0,50	2,00	0,00	-1,50	0,00	-2,00	1,00
	Recreation and aesthetics	0,00	-0,25	0,00	0,00	0,00	-1,00	-0,50
	Stakeholders involvement	0,50	0,50	0,50	0,50	1,50	-1,00	0,50
	Traffic congestion	0,00	0,00	2,00	1,50	0,00	0,00	-0,50
People score		0,12	0,38	0,40	0,42	0,46	0,15	0,44
Profit	Intermodality	0,00	1,00	2,00	1,50	0,00	1,00	1,00
	Productivity	1,25	1,00	1,00	0,33	0,50	1,00	1,25
	Personnel training	0,00	-0,50	2,00	1,00	1,50	2,00	0,00
	Terminal potential	0,00	0,00	-0,25	-1,00	0,00	2,25	1,00
	Expandability	1,50	1,00	0,00	0,00	0,00	1,25	-0,50
	Circular economy	2,00	0,00	0,00	0,00	0,00	0,00	0,00
Profit score		0,21	0,13	0,23	0,10	0,09	0,34	0,14

4.3.3.6.4 Additional info on the proposed measures from experts

As can be seen in the table presented in Appendix L , the experts were asked to assess the relative **cost** of the proposed sustainability measures, along with the **payback period**. It should be mentioned that this was a rough approach just to have an initial indication of the cost. The cost had to be rated from 0 to +5 and the payback period had the following scale:

- Less than 5 years
- Between 5 and 10 years
- More than 10 years

The answers of the 3 experts (Prof. Vellinga from TU Delft, DrTaneja from TU Delft and Ir. De Wit from PoR) are presented below:

Enhanced drainage system:
Cost: 1.5
Payback period: most common: More than 10 years

Enhanced maintenance of infrastructures:
Cost: 2.5
Payback period: most common: Between 5 and 10 years

Cargo handling organizational modifications:
Cost: 2
Payback period: most common: Between 5 and 10 years

Relocation of specific activities:
Cost:4
Payback period: most common: More than 10 years

Emergency response plans:
Cost: 1.5
Payback period: most common: Less than 5 years

Dredging:
Cost: 3.5
Payback period: most common: Between 5 and 10 years

Heightening quays:
Cost: 5
Payback period: most common: More than 10 years

As mentioned before, this method is used to roughly approach the cost of the proposed sustainability measures and is aiming in estimating the initial costs of the measures. The intention is to later on apply it to the PoFSG to interpolate them with the existing costs of the measures.

Additionally, as can be seen in the table presented in Appendix L , the experts were asked to assess the likelihood of success of the proposed sustainability measures. This attempt was made to somehow introduce in the PoFSG the possibility that some measures are encompassed with a level of uncertainty as to if they will provide the desired results.

Until this point, it was possible to retrieve only three answers from experts (Prof. Vellinga from TU Delft, Dr Taneja from TU Delft and Ir. De Wit from PoR) which were asked to rate the **likelihood of success** based on the following scale.

- Likely: 66 - 100% probability
- About as likely as not: 33 - 66% probability
- Unlikely: 33% probability

The answers to the likelihood of success of the climate change adaptation measures are presented:

Enhanced drainage system:	most common: Likely
Enhanced maintenance of infrastructures:	most common: Likely
Cargo handling organizational modifications:	most common: Likely
Relocation of specific activities:	most common: Likely
Emergency response plans:	most common: Likely
Dredging:	most common: about as likely as not
Heightening quays:	most common: Likely

The experts assigned the rate of success of the measures based on the case that the climate impacts do appear. Therefore, it is understood that this approach could not contribute effectively into triggering the stakeholders understanding of the complexity and the uncertainty that is enclosed in the climate change adaptation decision making.

Based on the resulting sustainability measures and the recommendations for the PoFSG that are illustrated in the next chapter, the new measure cards that are proposed to replace the existing ones are presented in Chapter 4.4.

4.4 Recommendations for the PoFSG

In this section, **modifications and alterations** recommended for the PoFSG are presented based on the main aims of the game and its current weaknesses.

Performed Research Steps to answer Research sub Question #5 :

- Develop techniques to improve the disadvantages or the gaps that exist in the PoFSG
- Suggest additional modifications

As explained in Appendix A , the PoFSG's main aim is raising awareness regarding the decision making challenges that exist in ports, and lead the stakeholders to plan based on sustainable development. Additionally, the PoFSG is used as a tool to educate the players regarding sustainable development. Last but not least, the game is meant to facilitate stakeholder involvement and produce fruitful debates among the players (stakeholders).

Therefore, the PoFSG's structure should be facilitating the stakeholder involvement and the range of subjects that it covers (sustainable development, ecosystem knowledge, socio-economic

development etc.) should be expressed adequately and realistically through measures and scenarios. Furthermore, the game should be adaptable to various categories of stakeholders and provide incentives for the creation of debates among them which could contribute to forming and atering their mind-set and notions regarding port sustainable development.

Based on the above-mentioned requirements of the PoFSG and the weaknesses that have been explored in Chapter 4, a list of recommendations for the improvement of the current edition of the PoFSG is presented.

Initially, the weaknesses of the PoFSG that are elaborated in Chapter 4 are presented:

1. PPP scoring is not solid and needs to be evaluated
2. The players neglected the qualitative effect of each measure and focused on the scoring
3. The game needs to become more realistic and plausible/acceptable
4. The list of measures that are involved in the game is too long
5. The port that is developed is fictional and does not have any specific characteristic
6. Climate change adaptation strategies are not actively included
7. The uncertainties/likelihood of success and the challenges of the measures are not included
8. The results of the game are not recorded
9. There is no indication of how sustainable the port "becomes" when the players select a set of measures

The modifications/solutions proposed to improve the gaps that exist and confront those weaknesses are presented below.

1. The **Sustainability Performance Scoring System (SPSS) developed** in this thesis study in Chapter 4 can be used as a new tool for scoring the measures of the PoFSG. Its applicability is tested in the same chapter and it is proven that it is beneficial to the game.

2. In order to urge the players not to neglect the qualitative effect of each measure and to focus less on the quantitative scoring of the measures, it is proposed to modify the method for presentation of the measures' performance in PPP on the measure cards. It is suggested to **present the PPP performance of each measure card with colour intensity scale so that it will be avoided that players emphasize on the values** while neglecting the actual meaning and impact of the port development measures.

3. The need for the game to become more realistic is approached in the context of this thesis study in several manners.

Initially, the **sustainable measures that are proposed to be included in the PoFSG are focusing on the two most crucial sustainable themes**, which were objectively chosen based on the perceptions of the stakeholders. In other words, through the introduction of measures that the stakeholders of the ports find the most important the stakeholder inclusion will be facilitated and the game will become more dedicated. Additionally, through the **application of the PSAF in the two container terminal case studies – Piraeus and Livorno- a thorough understanding is gained as to their sustainable performance.** The results are used to check if the proposed sustainable measures are applicable in the two port case studies. In that manner, it can be ensured that irrelevant and non-realistic measures would not be introduced in the PoFSG.

In addition, the questionnaire created in this thesis and presented in Chapter 3 can be handed in to the stakeholders before visiting a port or a local community in order to play the PoFSG. The aim would be the assessment of the significance weights for each sustainability theme according to the views of the local stakeholders. Therefore, the resulting scores of the measures that exist in the game as well as the final sustainability level of the port that would result from the selection of a set

of measures would be **adapted to their perceptions**. In conclusion, the game could be **tailor-made** for each port-city community.

4. The fact that a large amount of measures exist in the game and create confusion to the players has been taken into account during the selection of the proposed sustainability measures. An attempt is made to **cluster the new measures which had a similar character and served the same purpose.**

5. Another weakness of the PoFSG is that even though the main concept is based on applications of measures to a **fictional port that does not have any specific characteristic**, in order to develop knowledge that could be generally applicable, this seems to obstruct the players to take informed decisions about the port. To counterbalance this weakness and at the same time preserve the general character of the port, it could be attempted to introduce a list of port characteristics that would be changing in each game. For instance it would be useful to provide information on the: existence of natural preservation areas, distance from the city, stakeholder perceptions (perhaps they would be very resistant to changes, or be cooperative, perhaps the majority have a specific interest etc.), intermodal connections, main activities of port, potential growth of cargo etc. In that manner the motivation of selection of the measures would be more solid.

6. As mentioned in Chapter 4 the involvement of climate change adaptation measures is not thorough in the PoFSG. For that reason**, additional climate change adaptation measures have been introduced**. The measures are distributed in various categories so that the stakeholders would not choose solely from one category called for example "Climate change adaptation" since this would limit the understanding of the actual choice of a specific measure and they might choose a measure just because its relation to climate change is indicated. It would be beneficial if the PoFSG could be used to trigger the stakeholders understanding of the complexity and the uncertainty that is enclosed in the climate change adaptation decision making. The sustainability measures aiming to the reduction of carbon emissions are illustrated, described and scored in the Section 4.3.2 and the climate change adaptation measures in the Section 4.3.3.

The sustainability measures are presented below, namely:

<u>Carbon emissions reduction measures:</u>

- Adaptation of the terminal layout (Infrastructure measure)
- Replacement of (diesel-powered) terminal equipment
- Energy recovery from gantry cranes
- Green incentives to ships
- Vehicle management system
- Renewable energy sources
- Blending biofuels

<u>Climate change adaptation measures:</u>

- Enhanced drainage system
- Enhanced maintenance and upgrading of infrastructures
- Cargo handling organizational modifications
- Relocation of activities
- Emergency response plans

7. The uncertainties and the challenges of the measures can be included in the game through a level of likelihood of success that can be assigned to the measures. The uncertainty encompassed in each proposed strategy is determined by experts. The probability bins among which the experts would have to choose will be three and are taken from the European Climate Change Adaptation Platform.

- Likely: 66 - 100% probability
- About as likely as not: 33 - 66% probability

- Unlikely: 33% probability

8. It is also suggested to record the results of the PoFSG. More specifically, the importance of keeping track of the chosen measures is relatively low, compared to the significance of recording the argumentation of the stakeholders' and their way of thought while choosing them. In that manner, the perceptions of the stakeholders will be recorded, something that could be used as a predisposition tool for the inclusion of the stakeholders during the planning and designing phase. Moreover, the efficiency of the game can be tested when keeping track of the results through the comparison of the mind-sets that existed in the first round and in the last. More specifically, for the climate change scenario, it would be beneficial to obtain the statistical results of the choices that have been made as well as the argumentation, so that the preferences would be revealed between the choice of hard and soft measures.

9. It would be important at the end of the game for the stakeholders to visualize how sustainable is the port they are developing or in other words what is the level of sustainability that encompasses their decision-making mentality. The above suggestion can be implemented via the weight factors for each sustainable theme that have been calculated in Chapter 3.3. At the end of the game, when a set of measures is selected, **a percentage of sustainable performance of the specific set** can be presented.

Based on all the recommendations that have been illustrated in the previous paragraphs, the new proposed measure cards for the PoFSG that are meant to replace the existing are presented in the next page (Figure 21). It should be pointed out that the two examples presented demonstrate the two highest related sustainability measures among the two categories of measures (carbon emission reduction and climate change adaptation) introduced in this thesis study.

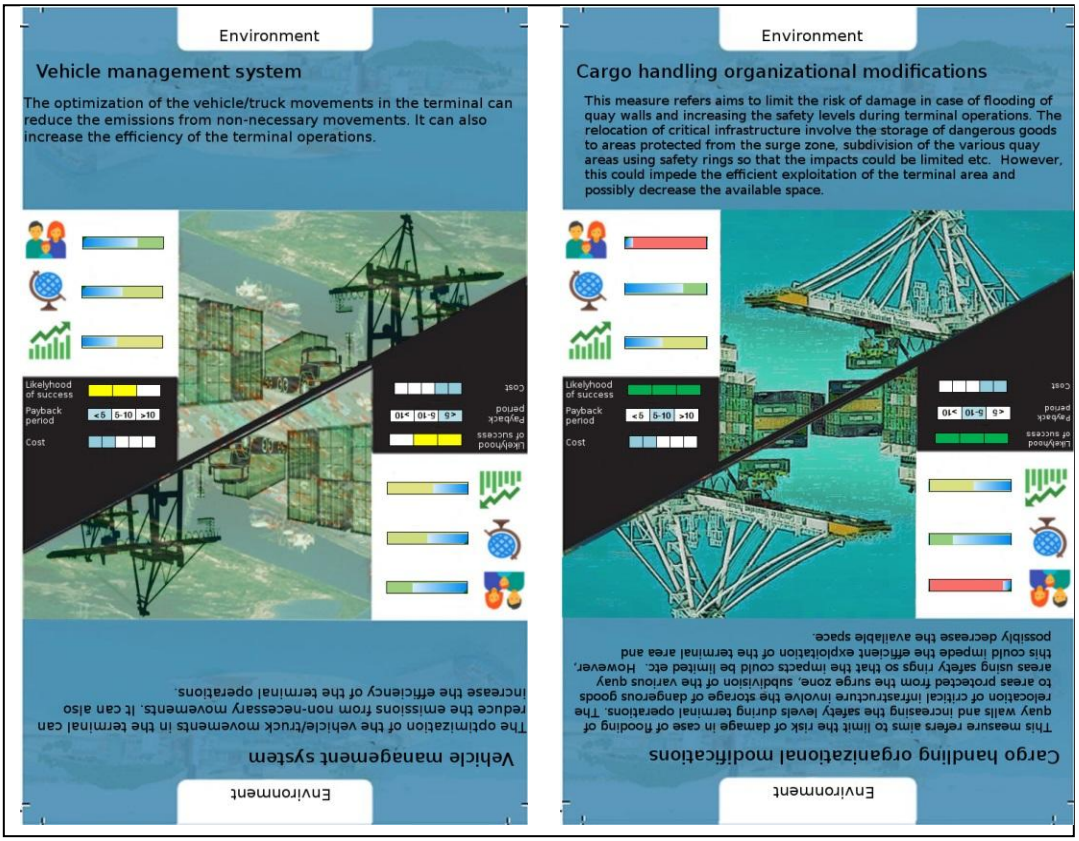


Figure 21: Modified measure cards for the PoFSG

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The two problems that have been addressed in this thesis are the gaps and barriers that impede the Mediterranean container ports' sustainable development and the need to extend the PoFSG in order to include in a representative way port-city future developments and quantified impacts on the environment and society.

In this thesis project, it is proposed to solve these problems through:

- The creation of a framework for the objective assessment of the sustainability container terminals (PSAF);
- Proposing recommendations for the improvement of the PoFSG to make it more dedicated and realistic.

5.2 Answers to Research Questions

The two main Objectives of this thesis project are expressed with two Main Research Questions. To obtain answers to these Main Research Questions, seven Research sub-Questions are also answered and they are briefly presented as follows.

#1 What research method can be followed to systematically and objectively assess the sustainability of a container terminal?

- The **direct answer** to the **#1 Research Sub Question is:** Through the creation of a solid framework based on the Systematic Frame of Reference developed by van Koningsveld 2003, the desired state of a port can be compared with the current state. Consequently the sustainability can be assessed.
- This Research sub question serves in answering the **First Main Research Question**.
- The answer to this Research sub Question is given through **Chapter 2.**
- **The contribution of the #1 Research sub Question to the First Main Research Question is** achieved by the creation of a framework to assess the sustainability levels of container terminals (PSAF).

The answer to the #1 Research Sub Question into more detail:

The selected method to systematically assess the sustainability of container terminals is the **Port Sustainability Assessment Framework (PSAF)**, a framework created by the author based on the Systematic Frame of Reference developed by van Koningsveld 2003 (Section 2.2). Through the PSAF that is explained in detail in Section 2.2.1, the identification of the **strategical and operational objectives** related to port sustainable development permits to define desired state of a port and compare with the current condition. The methodology followed permits:

- The identification of the potential stresses that container terminals create and therefore the identification of the most important sustainability themes (Section 2.1)
- The definition of the elements of the framework (PSAF) (Section 2.2.2)
- The formulation of the operational objectives (desired state) of the ports (Section 2.2.2)
- The definition of the current state of the port
- The comparison of current and desired state

#2 What sustainability level is achieved by the container terminals of Piraeus and Livorno?

- The **direct answer** to the **#2 Research Sub Question is:** Applying the PSAF to the container terminals of Piraeus and Livorno, it is assessed that the sustainability levels of the terminals are relatively low. It can be concluded that the concept of sustainability is not actively incorporated in the decision making.
- This Research Sub question serves in answering the **First Main research Question**.

- The answer to this research sub-question is given through **Chapter 2**
- **The contribution of the #2 Research Sub Question to the First Main Research Question is** accomplished through the application of the PSAF in the container terminals of Piraeus and Livorno so that the sustainability levels of the ports can be assessed and the framework's applicability can be tested.

The answer to the #2 Research Sub Question into more detail:

The PSAF is applied to two container terminals' case studies, Piraeus and Livorno (Section 2.3) and the achievement of the operational objectives from the two container terminals' case studies is tested. In other words, **the current state is compared with the desired state**. The results of the comparison are expressed as a percentage of achievement for each terminal of the operational objectives that are set. The resulting sustainability level of the ports and the main conclusions are presented below:

- More than 30% of the required data for the operational objectives was not possible to be retrieved from online sources, interviews or questionnaires.
- Approximately 50% of the operational objectives for which there was available information were achieved by the container terminals
- Retrieving information from contact with port authorities and terminals was in some cases hard since there was strong unwillingness to share some data, especially the environmental data.
- Almost all terminal operators provided nearly all the information that was requested.
- Real and systematic environmental monitoring is not carried out in any of the ports or the container terminals.

#3 How can the perceptions of stakeholders be included in the sustainable development of a container terminal?

- The **direct answer** to the **#3 Research Sub Question is:** By means of a dedicated questionnaire.
- This Research Sub question serves in answering both the **First** and the **Second Main Research Question**.
- The answer to this research sub-question is given through **Chapter 3.**
- **The contribution of the #3 Research Sub Question to the First Main Research Question is** achieved by the stakeholder's prioritization of each sustainability theme so that the assessment of the ports' sustainability can be carried out objectively.
- **The contribution of the #3 Research Sub Question to the Second Main Research Question is** achieved through stakeholder perception analysis which clarifies the stakeholder's priorities that can be incorporated in the game (in the form of sustainability measures) to make it more dedicated and for facilitation of stakeholder engagement.

The answer to the #3 Research Sub Question into more detail:

The elicitation of the stakeholders' perceptions of the port sustainability has been approached by means of a **questionnaire** which is presented in Section 3.1. Through it, people's perceptions are elicited on the **comparative importance of the various sustainability themes**, on their level of ecocentrism and anthropocentrism, on their views of port sustainable development, on their personal opinions regarding the port and container terminal, on their desire for involvement in the decision making.

The priorities that the stakeholders give to the PPP factors and among the sustainability themes are used to objectively approach the sustainability of the ports so that the stakeholder involvement can be facilitated.

#4 What method could be used to determine weight factors for the purpose of ranking the sustainability themes and which are the most important themes?

- The direct answer to the **#4 Research Sub Question is:** By incorporating the Analytical Hierarchy Process (AHP) to the Questionnaires the weight factors are generated. The resulting most important themes to the stakeholders are "Air Quality" and "Safety levels".
- This Research Sub question serves in answering the **First and Second Main research Question**.
- The answer to this research sub-question is given through **Chapter 3**
- **The contribution of the #4 Research Sub Question to the First Main Research Question is** achieved by the importance weight factors that are assigned for each sustainability theme so that the assessment of the ports' sustainability can be carried out objectively.
- **The contribution of the #4 Research Sub Question to the Second Main Research Question is** achieved through the production of the weight factors that serve as a tool for the development of the sustainable performance scoring system used for scoring PPP performance of the measures in PoFSG.

The answer to the **#4 Research Sub Question** into more detail:

In the context of the questionnaire (made in excel) for the collection of the stakeholder's perceptions, the **Analytical Hierarchy Process (AHP)** was incorporated to calculate the weight factors for the sustainability themes. Through the AHP, the pair-wise comparison was conducted from the stakeholders filling in the questionnaire for the sustainability themes. The weights of the environment class, the societal class and the economy class are calculate as well as the weights of the six sustainability themes for each of the above classes are calculated.

The **most important sustainability themes** based on the stakeholders' views are "Air Quality" and "Safety level" whereas the least priority is given to "Stakeholder involvement" and "Recreation and Aesthetics".

#5 What aspects of the PoFSG need to be improved and in what way?

- The **direct answer** to the **#5 Research Sub Question is:** Several aspects of the PoFSG need to be extended (scoring system, facilitating the stakeholder participation, climate change measures etc.). Concrete proposals are made for the aforementioned weaknesses, while more general recommendations are made for other drawbacks that are identified.
- This Research Sub question serves in answering the **Second Main research Question**.
- The answer to this research sub-question is given through **Chapter 4**.
- **The contribution of the #5 Research Sub Question to the Second Main Research Question is** made through the identification of the weaknesses, the suggestion of general recommendations and concrete proposals in order to extend the PoFSG.

The answer to the **#5 Research Sub Question** into more detail:

In order to improve the PoFSG, the first step is identifying the weaknesses of the game (Section 4.1). The list is presented below:

1. PPP scoring is not solid and needs to be evaluated
2. The players neglected the qualitative effect of each measure and focused on the scoring
3. The game needs to become more realistic and plausible/acceptable
4. The list of measures that are involved in the game is too long
5. Climate change adaptation strategies are not actively included
6. The uncertainties and the challenges of the measures are not included
7. The results of the game are not recorded
8. There is no indication of how sustainable the port "becomes" when the players select a set of measures

The focus of the Second Main Research Question of this thesis is mainly drawn upon two aspects: Improvement of the scoring system of the PoFSG (points 1 and 8 of the above presented list) and the introduction of sustainable strategic measures to make the PoFSG more dedicated and realistic (points 3, 4 and 5 of the above presented list). For these improvements, specific Research sub Questions are formulated, so it will be furtherly discussed in the next paragraphs.

In Section 4.4, recommendations are presented to encounter the rest of the drawbacks that are encompassed within the PoFSG. The solutions for each weakness that has been presented above are illustrated as follow.

1. Introduce new Sustainability Performance Scoring System (SPSS)
2. Represent the PPP performance of each measure card with a colour intensity scale
3. Propose sustainable measures focusing on the two most crucial sustainable themes applicable to the container terminal case studies and to the PoFSG
4. Cluster the new measures which have a similar character and serve the same purpose
5. Introduce additional climate change adaptation measures
6. Introduce a "likelihood of success" indicator assigned to each measure
7. Keep track of argumentations of stakeholders
8. Present percentage of sustainable performance of the measures chosen at the end of the game

#6 What method could be used to score the performance of sustainable strategic measures to People, Planet and Profit?

- The **direct answer** to the **#6 Research Sub Question is:** Each proposed sustainability measure is initially scored based on the magnitude of its effect on each sustainability theme (from -5 to +5) and then multiplied with the weight factor that corresponds to each sustainability theme.
- This Research Sub question serves in answering the **Second Main research Question**.
- The answer to this research sub-question is given through **Chapter 4** and more specifically through Section 4.2.
- **The contribution of the #6 Research Sub Question to the Second Main Research Question is** achieved by the development of the Sustainable Performance Scoring System that can also be used in the game, replacing the existing one and though the identification of the sustainability level of the port in the end of the PoFSG when the players have selected a specific set of measures.

The answer to the **#6 Research Sub Question** into more detail:

A Sustainable Performance Scoring System (SPSS) is created to score the sustainable performance (effects to PPP) of the measures that are introduced in the PoFSG. Through this scoring system, each proposed sustainability measure will be initially scored based on the magnitude of its effect on each sustainability theme (from -5 to +5). These scores are previously given by port experts. The initial score is consequently multiplied with the weight factor that corresponds to each sustainability theme. All in all, the sustainability performance score of a policy measure for each PPP category derives from summing the partial final scores of the sustainability themes that are included in each category. The level of sustainable development of the port that is achieved by selecting specific sustainability measures can be expressed by means of a percentage of sustainability.

#7 Which measures could be proposed to contribute to the improvement of the terminals' performance on the two most important themes?

- The **direct answer** to the **#7 Research Sub Question is:** Measures related to the improvement of the air quality/ reduction of carbon emissions and measures for the increase of the safety levels of a port/ climate change adaptation.
- This Research Sub question serves in answering the **Second Main research Question**.
- The answer to this research sub-question is given through **Chapter 4** and more specifically through Section 4.3.
- **The contribution of the #7 Research Sub Question to the Second Main Research Question is** achieved by the introduction of sustainable measures (related to the two most important themes based on stakeholders' perceptions) along with their sustainable performance scoring derived from the application of the SPSS.

The answer to the **#7 Research Sub Question** into more detail:

The proposed sustainability measures contributing to the improvement of the PoFSG focus on the two highest rated sustainability theme (air quality and safety levels). They are suitable both to the PoFSG and the container terminal case studies. The proposed measures' sustainability derives from their SPSS scoring.

The air quality is approached by sustainable strategic measures for the reduction of carbon emissions in ports. The above-mentioned measures are **climate change mitigation measures**. The list of measures is presented below:

- Adaptation of the terminal layout
- Replacement of (diesel-powered) terminal equipment
- Energy recovery from gantry cranes
- Blending biofuels
- Vehicle management system
- Renewable energy sources
- Green incentives to ships

The safety levels are approached by means of **climate change adaptation measures**. The list of measures is presented below:

- Enhanced drainage system
- Enhanced maintenance and upgrading of infrastructures
- Cargo handling organizational modifications
- Relocation of activities
- Emergency response plans
- Dredging

5.3 Conclusions

Several conclusions result from this research and they can be summarized as follows:

- The sustainability performance of container terminals can be assessed by a framework (PSAF) and the sustainability levels of the ports can be illustrated as a percentage of the achievement of the operational objectives of each People, Planet and Profit category.
- The results of the application of the PSAF in the Piraeus container terminal and in Livorno container terminal demonstrates that the sustainability level of the terminals is relatively low. Additionally, very limited amount of the requested data was available online. Retrieving information by contacting port authorities was hard since there was strong unwillingness to share data, especially the environmental data. On the other hand, terminal operators provided almost all the information that was requested. Also, it is concluded that systematic environmental monitoring is not carried out in any of the ports or the container terminals.

All in all, the container terminals of Piraeus and Livorno need to incorporate the concept of sustainability in the planning and operational phase as well as in their decision making since they seem to be far from the goal of a sustainable/green port. It is recommended for the ports and consequently the terminals to follow the guidelines that derive from the operational objectives defined from the PSAF.

- The elicitation of the stakeholders' perceptions on port sustainable development can be assessed successfully by means of a dedicated questionnaire. In the current questionnaire, safety levels and air quality were the top priorities of stakeholders (higher weight factors). The themes with least priorities are the stakeholder involvement and the recreation and aesthetics. According to the 43 questionnaires, the average stakeholder shows a moderately positive pro-ecological aptitude, wants to be involved in the port's environmental strategies, is weakly positive about the sustainability approach of the port authorities, does not feel involved in the decision-making of the port but does not want to be involved in the port business strategies.
- There is a list of drawbacks in the PoFSG that need to be improved to allow the game to be more dedicated and realistic and facilitate stakeholder involvement. Those weaknesses lay in different sectors of the game and therefore, it is not easy to study them all into detail. Two of the most important that have been studied in more detail are: a) the current PPP scoring in the game that is not solid and needs to be evaluated and b) that the game needs to become more dedicated and acceptable from stakeholders.
- In the PoFSG, the performance of strategic and policy measures to sustainability can be assessed by means of a scoring system (SPSS). Through the integration of weight factors for each sustainability theme, a more objective and quantitative evaluation of the performance of sustainability measures on People, Planet and Profit can be achieved. In that manner, not only the effects of the implementation of measures on the port can be presented but also their contribution to the sustainable development of the system port/city.
- For air quality and safety levels, considered the most important among the stakeholders, new sustainability measures are proposed in the PoFSG based on the gaps that exist in the current version. The air quality is approached by sustainable strategic measures for the reduction of carbon emissions in ports. The safety levels are approached by climate change adaptation measures. The proposed sustainability measures aim to make the game more dedicated to local conditions. From the proposed measures, “Adaptation of the terminal layout” and “Vehicle management system” were considered the most sustainable among the proposed Carbon emission reduction measures. From the category of the climate change adaptation measures, the “Cargo organizational modifications” and the “Heightening the quays” were considered to score higher on sustainability.
- The new scoring system (SPSS) and the proposed sustainability measures contribute into making the PoFSG more dedicated and adapted to the local reality.

5.4 Reflections

In this chapter, the reflections on this thesis are presented. The reflections are divided into three categories: reflections on the process that is followed, the methods that are used and on the outcomes. In that way, the results of the thesis can be objectively interpreted.

5.4.1 Reflections on the process

The general approach that has been followed during this thesis study was based on the necessity to assess the sustainability of Mediterranean ports and specifically container terminals and to the need of the the PoFSG to show in a realistic way port-city future developments and quantified impacts on the environment/society and with which level of sustainability (Horizon 2020: COREALIS, 2017). These two aspects were easily combined since the outcomes of the first assessment could be used as an input to the second part that involves the improvement and extension of the PoFSG.

The process that was followed was adequately focusing on the first Research Question "How can the sustainable performance of container terminals' be objectively assessed?" through the several steps followed to build a framework that serves that purpose and through the application of this framework to two case studies (Piraeus and Livorno) to test the applicability of the framework and conclude on the sustainable performance of the two ports.

The process that was followed to reflect on the Second Research Question "How can the PoFSG become more dedicated and realistic?" is considered adequate. Based on the request of the Corealis project, to improve the PoFSG to show in a realistic way port-city future developments and quantified impacts on the environment/society and with which level of sustainability, the focus was mainly set in the proposal of improvement of two aspects of the game (sustainability scoring system and introduction of realistic sustainability measures). In that sense, the rest of the identified weaknesses were approached by means of general recommendations that could constitute material for future research.

The assumption that was initially made (based on literature sources), regarding the fact that in the majority of Mediterranean ports the concept of sustainability is not well thought out, was proven to be correct for the two Mediterranean port case studies that were examined (Piraeus and Livorno).

5.4.2 Reflections on the methods used

The methods that were used to approach the several aspects encompassed in this thesis study are manifold. A brief analysis is made below, along with comments on the success of applicability of those methods.

Studying terminal processes to identify potential stresses of container terminals

The direct stresses that a container terminal is creating are systematically tracked using a method defined by the author. It was decided to approach the subject by means, when possible, of direct, homogeneous, physical and quantifiable flows of substances, energies, materials and other resources that enter or exit the container terminal (CT) domain and create an analytical catalogue of all the above flows. Through this method, the flows are identified from the literature and after a few reports; it was simply a question of double-checking the existence of the flow in the various sub-domains. In that way, it was ensured that a complete list of flow would be generated.

Port Sustainability Assessment Framework (PSAF)

The Port Sustainability Assessment Framework was created to objectively assess the sustainability levels of container terminals. Through the application of the PSAF to the two port case studies (Piraeus and Livorno), its efficiency could be tested. The applicability of the PFAF in two case studies was successful, since it provided a structured manner to access the information required for comparing the current state of the ports, and in other words checking their compliance with the operational objectives. As expected, a relatively large amount of data could not be found, however, this is not attributed to the efficiency of the PSAF but to the unwillingness of the authorities to share their data.

Questionnaires to access the stakeholder's perceptions

The questionnaire as a whole was efficient and was able to identify various differences among the investigated groups. It could be a valid instrument for evaluating priorities and attitudes of port stakeholders if a sufficient number of questionnaires per stakeholder category could be achieved.

The 8 port knowledge questions should be modified in order to achieve a scoring that distinctly separates "port experts" from "non-experts".

The NEP questions have been universally used for decades to assess the pro-ecological attitude of groups.

The rest of the Part D answers could provide port authorities with valuable info regarding various aspects of their interrelations with various stakeholders' categories and permit them to plan accordingly.

Questionnaires to produce significance weight factors for sustainability themes
The total number of questionnaires and the distribution of the countries and stakeholder categories permitted the separate examination of the results for a small number of groups. There are observed differences among the groups, regarding the priorities of the PPP factors and the priorities of the various PPP themes.

In order to test the representativeness of the results of the questionnaires, it was tested if they could likely be part of a normal distribution so that the possibility of receiving particular answers from interviewees pursuing a specific aspect can be excluded. The test for normality of the PPP answers was positive for all groups except the Greek-Italian group. Even so, the sample is very low to extract valid conclusions for each group separately.

Analytical Hierarchy Process (AHP) to generate the weight factors for sustainability themes
The AHP method was efficient in generating weight factors for the sustainability themes through a pair comparison method. The consistency of the resulting weights was checked by calculating the consistency ratio (CR). If the ratio was CR ≤ 0,1 the results were accepted, otherwise, they were discarded and not taken into account in the calculation of the weight factors.

Python scripts to process the answers of the questionnaires
Python was used for the data grabbing from the excel files and their processing. Two scripts were written, with the invaluable assistance of Mr Etmektzoglou who also controlled (and debugged) the rest of the code that was inserted. The two main scripts efficiently processed the data and gave the expected results, in a time-efficient manner.

Sustainable Performance Scoring System (SPSS)
The SPSS that was created in the context of this study was successful in several aspects, mainly due to the introduction of the sustainability themes based on which the performance of sustainability measures could be scored, due to the weight factors that allowed the presentation of not only the effects of the implementation of measures on the port city but also their contribution to each PPP and the fact that after selecting a set of sustainability themes, the sustainable development level of the port can be measured, using each measure's contribution to PPP.

However, the SPSS presents some weaknesses as well:

- A couple of the sustainability themes do not perfectly fit as general scoring criterions for the sustainability measures, but they represent important aspects of the port development
- Since the integer numbers that are used by experts to score the effect of the sustainability measures to the sustainability themes are multiplied with the importance weight factors, the resulting scores for PPP are not integer values.
- Since sustainability is not an easily defined concept, the calculation of the sustainability level of the port based on the selected measures cannot be expressed accurately and assumptions are made.

5.4.3 Reflections on the outcomes

Each of the methods described in the previous section produce specific outcomes. As mentioned in the Introduction of the current Chapter, the main outcomes of this thesis project are two: A framework for the objective assessment of the sustainability container terminals (PSAF) and the recommendations for the extension of the PoFSG to make it more dedicated. A brief analysis of the outcomes is to be made below, mainly to assess the reliability of the results.

In order to achieve the ***first main outcome*** the following were necessary:

Definition of sustainability themes

The main sustainability themes related to container terminal's sustainable growth are identified through the identification of the potential stresses that container terminals create. Since the method used is efficient and valid the results are trustworthy as well. The six most important themes for each PPP category are considered representative subjects that can describe the port's sustainable development. A check of the validity of the sustainability themes was made through the questionnaires in which the interviewees were asked to add more sustainability themes that they thought they would be important. Most of the themes they proposed were already included as a sub-category of the sustainability themes presented, therefore, the completeness of the themes was confirmed.

Definition of the elements of the framework (PSAF)

The elements of the PSAF were defined in a systematic manner, based on which for each of the sustainability themes initial operational objectives were defined (which did not include any threshold but just a general idea of what is the target), then the indicators to describe them, afterwards the thresholds and last but not least the operational objectives initially set were redefined. Following this structured method, the elements of the PSAF are considered properly defined.

Formulation of the operational objectives (desired state)

The operational objectives defined for each sustainability theme were adequate for the purposes of this thesis study; however, they could be more detailed since they are also used as guidelines/recommendations to the ports. Within the time limits of this thesis study, it was not possible to elaborate more all the operational objectives.

Definition of the current state

The definition of the current state of the port was achieved through the application of the PSAF to the two container terminal case studies. The collection of data was based on the framework and was efficiently collected; identifying the points where there was an unwillingness of information sharing and where there was no available information. The sources through which the information could be gathered have been thoroughly analysed, and mostly through the attendance to the meetings that took place in Piraeus and Livorno a great amount of information was retrieved. Additionally, it is worth mentioning that the data is presented in an impartial way, without the influence of the personal opinion of the author.

Comparison of the current state with the desired state

The comparison of the current state with the desired state concluded in the assessment of the sustainability levels of the terminals. A high-level check of the compliance with the operational objectives that were defined by the author was performed. This check is expressed by a percentage of compliance of each terminal with the operational objectives of each People, Planet and Profit category. Since the purposes of this thesis study are the creation of a framework for the objective assessment of container ports' sustainability, the direct and detailed quantification of the sustainable performance of the ports is not performed. For this reason, the sustainability levels of the ports are high level.

Stakeholder perception analysis

Through the questionnaires, the identification of the perceptions of the stakeholders was attempted. The validity of the outcomes was proven by several points. Initially, the fact that NEP (high ecocentricity) and environmental priorities are strongly correlated for all groups shows that the answers given by the interviewees were not random. In some questions, all the groups answered the same, for instance, all groups consider necessary the involvement of all stakeholders in the

environmental strategies of the port and all groups agree that the container terminal can generate important societal benefits. The persistence of the answers could be interpreted as a validity check.

The Italian group, however, answered positively in the question that referred to the involvement of all stakeholders in the business strategies of the port and in the questions that stated that a container terminal could have serious impacts on the environment. In those two questions, the other groups answered negatively.

Regarding the questions that assess the general knowledge of the concept of port sustainability, it seems that they failed to distinctly separate the port expert group from the other ones. This could be due to the fact that: a) all groups have a good grasp of the port sustainability concept, b) the questions could be answered correctly according to a general pro-environment attitude and c) the scientific community generally avoids making statements of almost absolute certainty like the option "strongly agree" of the questionnaire, fact that lowers the score of the answers.

In order to generate the ***second main outcome*** the following were necessary:

Weight factors for sustainability themes

The weight factors for the sustainability themes are calculated by the AHP method that is taking into account the inconsistencies in the answers and discards the ones that do not comply in the consistency check. Additionally, 43 questionnaires were filled that is considered a sufficient number to derive valid results. Therefore, it can be concluded that the weight factors that have been generated can be considered reliable for the purposes of this thesis.

Weaknesses of the PoFSG

The identification of the weaknesses of the PoFSG was made through discussions with experts and personal experience playing the game, where opinions from the participants were shared regarding downsides of the game. This method is considered adequate for the context of this thesis, but it should be noted, that these are not the only downsides of the game and other aspects of the game should be further investigated.

Sustainability measures for the PoFSG

The sustainability measures for the PoFSG that are proposed in this thesis study are related to the two most important sustainability themes. Additionally, the measures' applicability in the two port's case studies (to check if they are realistic) and their applicability in the PoFSG (based on the gaps and the current measures that exist) were tested. The resulting sustainability measures comply with both of the checks and therefore, they can be considered useful.

Sustainability performance of proposed sustainability measures

The sustainability performance of the proposed measures was assessed using the scoring system that was created (SPSS). The scoring system involved the use of expert knowledge to assign the initial scores. However, within the time limits of this thesis study, it was not possible to use the knowledge of a large number experts and only 3 contributed to the scoring system, Therefore, the sustainability performance scoring of the proposed measures cannot be considered of great reliability. However, with the addition of other contribution of experts in the scoring, the results could be considered reliable.

Recommendations for the PoFSG

The proposals that are made for the improvement PoFSG, apart from the introduction of the scoring system and the sustainability measures, are less thoroughly analysed and this is clearly defined in the context of the thesis.

5.5 Future research/ recommendations

Based on what is exposed in the previous section, topics that would be beneficial to be further on elaborated in the future are revealed.

Initially, the operational objectives of the PSAF that define the desired state of the ports could be further on elaborated in order to become more detailed. Additionally, it would be beneficial to generalize the operational objectives so that they could be directly applied not only to container terminals but to the other port's terminals as well.

Furthermore, the lack of accessible information regarding the current state of the ports rendered the quantification of their sustainable performance unattainable. Therefore, it is suggested to apply the framework created within this thesis (PSAF) to collect more detailed data regarding ports and/or container terminals. Consequently, it is proposed to use the weight factors for each sustainability theme (derived from the questionnaires) to show how sustainable the port is performing. In other words, the effect of achieving or not the operational objectives included in a specific sustainability theme would have a different effect to the total sustainability of the port, depending on the weight that is assigned to it and this depends on the perceptions of the stakeholders.

It is also suggested to use the questionnaire created in the context of this thesis as a tool for the assessment of more stakeholders' perceptions so that more answers from different stakeholder categories could be taken in to account. In that way, the perception analysis could be made in terms of each stakeholder category.

Another recommendation would be the input to base the scoring of the sustainability measures on the input of more experts. In that way, more solid scores could be assigned.

Last but not least, there might be several more aspects that would need improvement in the PoFSG. A wide range of weaknesses have been discussed in this thesis study, however, it is suggested to investigate further other aspects that could potentially be extended. Additionally, the general recommendations that have been suggested for PoFSG can serve as a baseline for future research.

Appendix A *Literature Review*

A1. Port sustainability – Green Port strategies

The definition of a sustainable port as defined from the WG (PIANC 2014a) is the following:

"A sustainable port is 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."

A1.1 Indicators

Green port assessment requires the combination of various parameters. These parameters, expressed as indexes, should be comprehensive, quantitative or qualitative. KPIs should be developed so that they could be easily tweaked/modified in order to keep up with future technological advancements and market evolution (Chris Park and Robert Whittier 2012). They should also be able to reflect future changes and to adapt progressively to the changing societal needs, but still be able to assess a green port in every timeframe (Wan et al. 2017). In an world where resources and energy have always more importance, KPIs could play a crucial role in tracking financial success but also in comprehending environmental and societal risks, issues that become crucial to the organizations survival (Chris Park and Robert Whittier 2012).

The list of the sources used to comprehend the importance and utility of the performance indicators, as well as the challenges that they entail is presented in Appendix A , along with the main concepts that were adopted from each specific source.

Table 18: Port Key Performance Indicators literature list

Key Performance Indicators (KPIs)	
Literature list	**Contents used**
Port performance indicators (United Nations 1976)	The first attempt to base the operation and development of the port on indicators
UNSTAD	Has developed acceptable and feasible Key Port Performance Indicators to measure the impact of the European Port System on society, environment and economy. The result is the First European Port Performance Dashboard.
PPRISM (EPSO) 2010	Establishing a culture of performance measurement in European ports.The Dashboard contains well defined indicators, that are accepted by stakeholders and measure performance trends in the European port sector
PORTOPIA 2017	It presents combined or ratio-based indicators within the group of indicators on market trends and structure, and a link of these indicators with different categories of indicators.
Linking Performance Indicators to Strategic Objectives (United Nations 2017)	Developments in port management worldwide and across the networks of the Port Management Programme clearly reflect an increasing demand for performance assessment.
The Sustainability reporting for ports (IAPH-PIANC 2017)	Presents the nature of the KPIs including the weaknesses that should be considered in their use. Each port has its own and different needs and has to be considered and treated as a separate entity, even if there is a global green policy approach that is used as a guideline

A2. Stakeholder inclusion/ management

The importance of the stakeholder involvement is pinpointed in the Report of (IAPH-PIANC 2017). Stakeholder inclusion processes should always be designed with the culture, values and institutional set-up of a specific port cluster context in mind.

The importance of the balance between the impact on and perception of the stakeholders is presented in Figure 22.

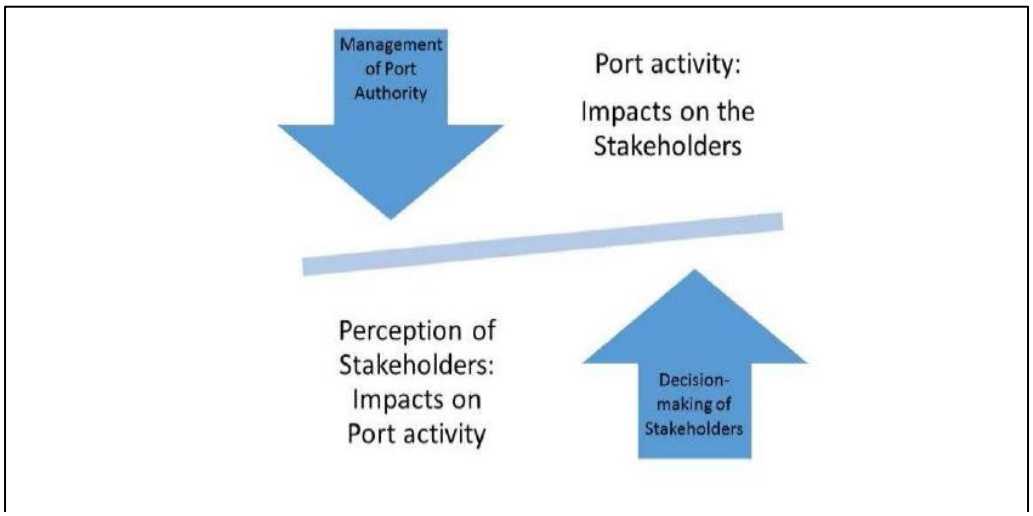


Figure 22: A balance between the impact on and perception of stakeholders (Source: IAPH-PIANC 2017)

Based on (IAPH-PIANC 2017) the stakeholders involved in corporate social responsibility initiatives are presented in Figure 23.

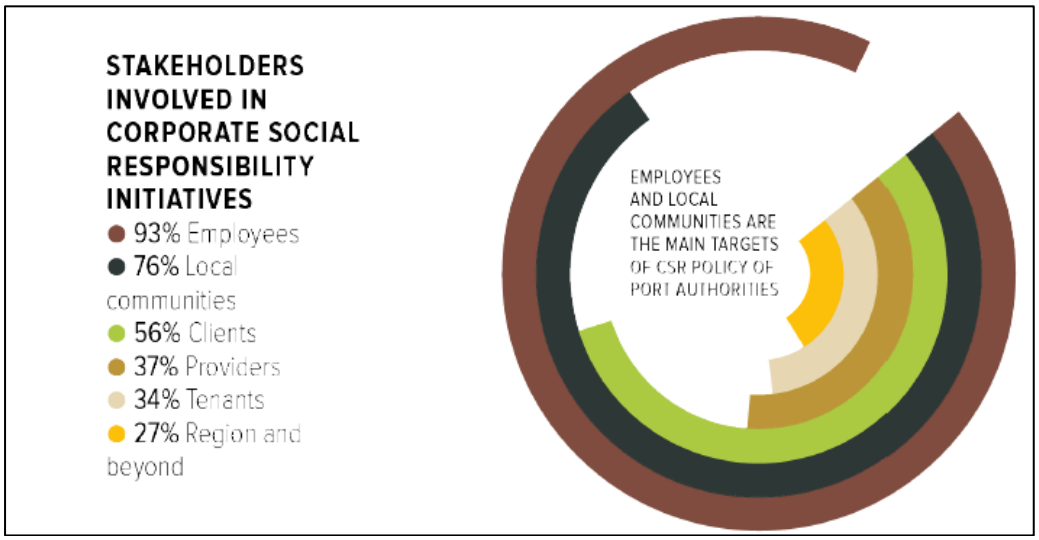


Figure 23: Stakeholders involved in corporate social responsibility initiatives (source: PORTOPIA, 2017)

A3. Lack of application of sustainable port strategies from Mediterranean ports

Based on personal knowledge of the local conditions in various Mediterranean countries, the statement that a great number of the South European/ Mediterranean ports are lagging behind on the adoption of sustainable and green port strategies was formulated; however, it is necessary to verify it using concrete literature sources.

According to the European Port Industry Sustainability Report (PORTOPIA 2017): *"the Mediterranean ports are experiencing the fierce competition of newcomers located in North Africa, which find their competitive advantage".*

It is vital to integrate the sustainability concept in port strategies, because it constitutes an, always more important, factor of their competitiveness (Med Maritime Integrated Projects - Mermaid 2015). Although, worldwide, progress has been made, an averagely slower rate of adaptation is observed in the Mediterranean (with the exception of the Adriatic area) (PORTOPIA 2017).

The challenges of the Mediterranean container ports were mentioned in the Med Maritime Integrated Projects - Mermaid website, within an article published on 2015 in which it was indicated that in order to adequately define the actions to gain competitiveness and sustainability, it is important to monitor closely all port activities.

In the paper of Buiza et al., published in 2015, the current situation of the Mediterranean container ports is examined focusing mainly on their operational, energy and environment issues.

The study (Buiza et al. 2015) concludes that the existing gaps and barriers exist impede the Mediterranean container ports' sustainable development. Among others, there is a poor adoption of standards, inadequate advancement of the necessary technology, and serious lacks in the waste and air emission management. From the review of the available resources of data, there is no reference regarding the energy consumption level of the majority of the Mediterranean ports, nor about the energy related costs and expenditures.

Due to the relatively low available literature describing the current sustainable status of the ports in Europe and specifically the Mediterranean ports and the fact that the European ports and harbours should be engaged into addressing proactively environmental issues in order to obtain an always more sustainable development (ECOPORTS 2017), it would necessary to assess the sustainability levels of Mediterranean ports.

Moreover, since the focus of the paper (Buiza et al. 2015) was set on three specific areas of activities: the operational, energy and environment ones, it was decided to extend this identification process and elaborate upon the selection of sustainability performance indicators and the documentation of the current sustainable levels of the ports based on the indicators.

A4. Horizon 2020: COREALIS project

The H2020 – Port of the Future project 'COREALIS', is a project that "aims to develop a strategic, innovative frameworkfor cargo ports to handle upcoming and future capacity, traffic, efficiency and environmental challenges". Through COREALIS, ports will minimize their environmental footprint to the city, they will decrease disturbance to the local population through a significant reduction in the congestion around the port(European Commission,2017). A brief description of the project is presented below. All the literature is extracted from the Horizon 2020: COREALIS proposal.

"COREALIS comprises a palette of port-driven technological and societal innovations, tailored to realise the objectives that are visualised in Figure 24. The innovations will be implemented and tested in real operating conditions in 5 Living Lab environments, associated with the 5 COREALIS ports, Piraeus, Valencia, Antwerp, Livorno and Haminakotka Living Labs (LLs).

Figure 24: The COREALIS palette of innovations for Port of the Future

COREALIS consists of 9 Working Packages (WPs) and Deltares is leading on WP4 which objective is the governance and decision making in the Port of the Future and has the leadership of Task 4.1 concerning PoFSG for improved decision making. This task is meant to extend the functionalities of the game and implement it in the Piraeus and Livorno Living Labs (LLs).

One of the most important objectives of the project is enabling the port to take informed medium-term and long-term strategic decisions and become an innovation hub of the local urban space. This, among others, will be achieved through the extension of the Port of the Future Serious Game (PoFSG), in technical contents and functionality to facilitate stakeholder engagement.

By using the game, port managers will explore and analyse the possible development trajectories, highlight port dynamics, take green port policy decisions while ensuring optimal port operations, and evaluate impacts of potential development and policy pathways. The game is intended to raise awareness for the port-city challenges and support stakeholders to achieve development with a positive environmental impact. Because the game will include practical measures and realistic descriptions of outcomes and (technical, system) implications, it will raise awareness among policymakers, port designers and urban planners about climatic and environmental sustainability via a balanced approach. Usability and impacts of different options can be compared with operational needs and the objectives of sustainable port development to better align decision making with key port-city sustainable policies.

The modified and improved PoFSG will incorporate sustainable aspects for several scenarios of logistics, port design and climate adaptation. It will incorporate uncertainties for future operations and address cost savings challenges for mid- and long-term.

PoFSG will try to (based on the objectives of the project):

- Identify the real-time indicators to improve quality of services
- Create an emissions database is included in PoFSG KPIs.

• Promote the smart urban development of port-cities, enabling port managers make informed decisions towards sustainable policies with city stakeholders."

A5. Port of the Future Serious Game

The Port of the Future Serious Game (PoFSG) has been developed by Deltares with the scope of raising awareness of the current policy-making problematic of the ports, in order to support the port stakeholders into taking informed decisions towards the port's sustainable development (webpage: Deltares)

As is stated in the PoFSG manual(Liagkouras et al. 2015):

> "*The game applies a fictional but realistic environment, autonomous scenarios, a set of measures and a qualitative set of indicators that provide information on the effects for society, natural environment and economy. By introducing real-world challenges associated with port development and going through a decision making process for selecting sustainable measures, the stakeholders can experience aspects of sustainable port development first hand through the serious game.*
>
> *The Port of the Future Serious Game can also facilitate policy-making in ports with respect to socio-economic development, taking into account the natural requirements and the impact of sustainable design on balanced growth. For these reasons, the game can be played by a wide range of players including port authorities, planners, managers, policymakers, private companies, NGOs, scientists, nature developers, scientist, students and citizens.*
>
> *The procedure of the game can be summarized as follows. The aim is to move away from the traditional port and to reach the "Port of the Future" vision. To achieve that, a team of up to five players choose appropriate policy measures in four rounds.*
>
> *The measures are grouped in seven fundamental categories according to their nature, namely 1) port layout principles, 2) navigation, 3) coastal protection, 4) environmental measures, 5) governance, 6) infrastructure and 7) urban measures.*
>
> *The game can serve two main goals, as well as other indirect goals. The first is to assist policymakers of the port sector in developing master plans with the ultimate goal of improving the performance of the port under the three pillars of sustainability, namely people, planet and profit. The second goal is to educate players on combining ecosystem knowledge and sustainable development, subject to the allocation of financial resources among the investment and maintenance costs of policy measures. The players can explore the possible range of short term and long term impacts of their different policy options in a safe environment, as the future situation of the port will then develop as a result of the policy measures that have been implemented.*
>
> *In addition to these two direct goals, the game indirectly intends to raise awareness and facilitate stakeholder involvement and debate among stakeholders in complex political governmental processes. This is achieved by using a simulation model which includes a number of important aspects that are associated with real-life policy-making, such as uncertainty and risk. What is more, different scenarios will be played to investigate the wide range of possible impacts and to trigger the debate among the players by creating constructive conflicts between them during the negotiation and decision-making process.*
>
> *This is expected to demonstrate that successful policy-making in ports can only be achieved when the stakeholders work in close collaboration with each other.*
>
> *Ultimately, the game aims to highlight the fact that the "Port of the Future" vision should be pursued and can be realistically achieved, as it entails economic, environmental and social benefits for a wide range of port-related stakeholders*."

The procedure of the game can be visualized in the following Figure 25.

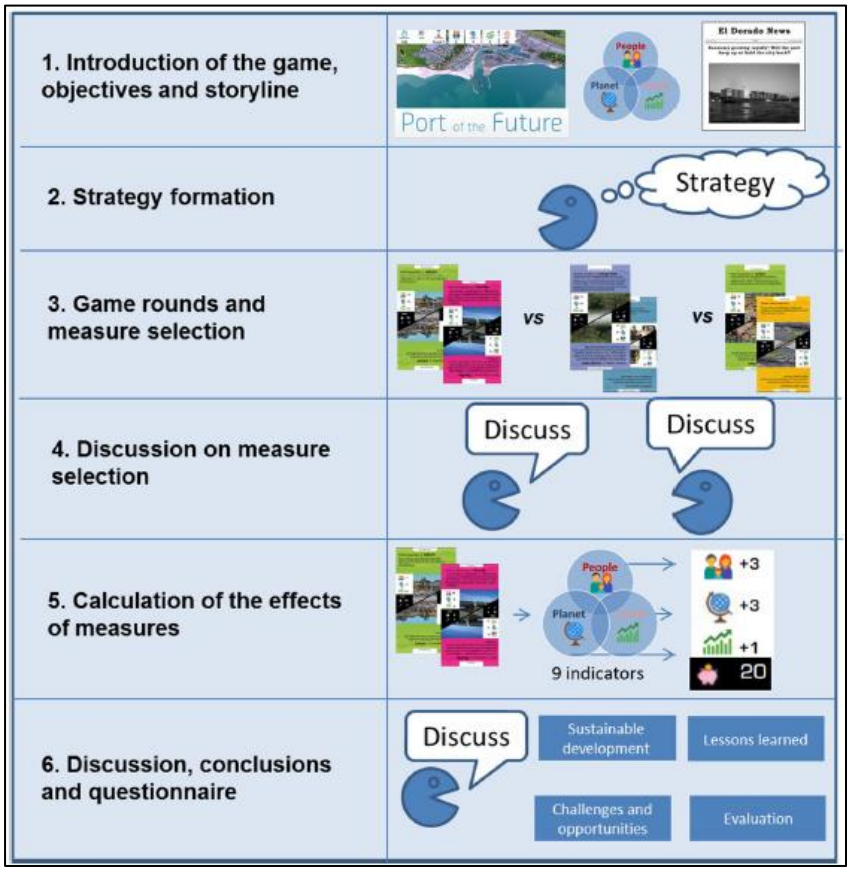


Figure 25: Visualization of the game procedure Port of the future Serious Game (Source: Deltares website)

A6. Frame of reference for policy development

A framework is developed for the systematic approach of the historical and the current condition of the ports and the comparison with the desired state. The framework is mainly based on the basic frame of

The frame of reference for policy development developed by van Koningsveld (van Koningsveld and Mulder 2004), was used with some modifications, for the systematic approach of the historical and the current condition of the ports and the comparison with the desired state.

The elements of the frame of reference for policy development are presented in the following figure.

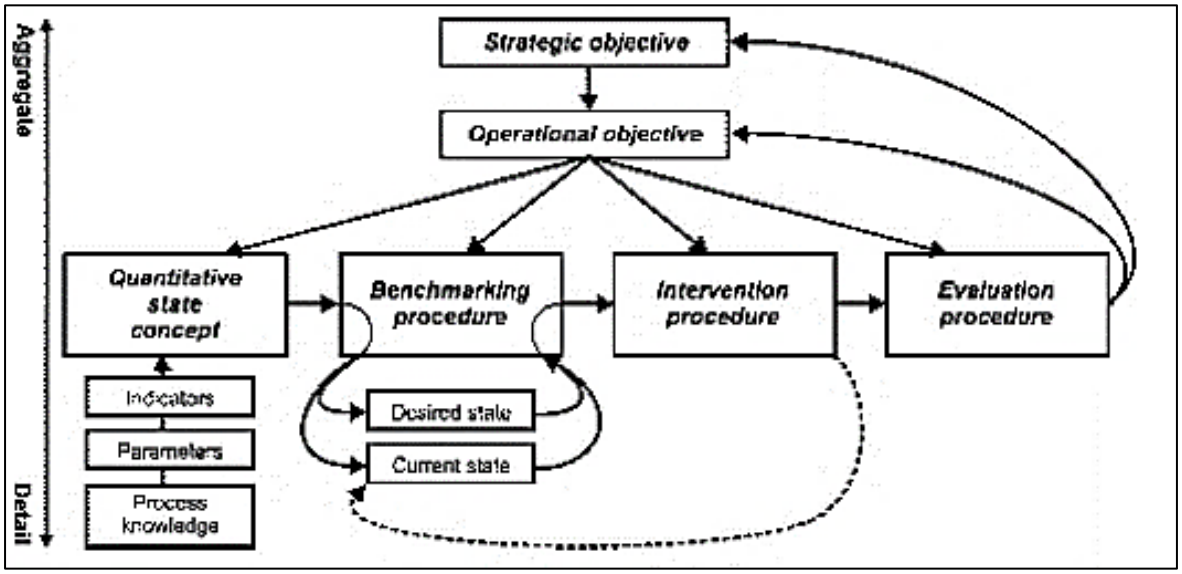


Figure 26: A frame of reference for policy development (source: van Koningsveld 2003)

The identification of the strategical objective and the operational objectives is the first step of the framework. The operational objective shapes the strategic objective into a more specific target. The strategic and operational objectives, together with the decision recipe, represent what the authors call the basic operational 'frame of reference'.

The decision recipe includes:

(1) quantitative concept of the system's current state;
(2) procedures for objective benchmarking;
(3) procedures for preferred interventions and
(4) procedures for evaluation.

After a study of the journal article "Sustainable Coastal Policy Developments in The Netherlands -A systematic Approach Revealed" by van Koningsveld and Mulder on 2004, the following conclusions were made regarding the various levels of the framework and their application:

- The first element would be an objective assessment of the state of the system. The quantitative state concept includes a set of indicators and to assess the current state as well as identify the reference state of the system.
- A benchmarking procedure must be developed to objectively assess the problem/situation defined. The procedure necessitates of the definition of a predefined reference state to be used for the comparison to the observed (or predicted) system state. The intervention procedure describes a procedure or a set of procedures to improve or alter the current condition. Periodic evaluation of policy effectiveness is recommended.
- After the evaluation, conclusions can be drawn in regards to the policy that is currently or proposed to be followed. This policy can be reviewed and modified according to the levels that need to be reached. So a new strategic objective and operational objective can be defined, now that the system of policy and science on the subject matter has become clearer.

The frame of reference requires the decomposition of each strategic objective to one or more operational objectives (Figure 27) expressed in terms of quantitative state concepts.

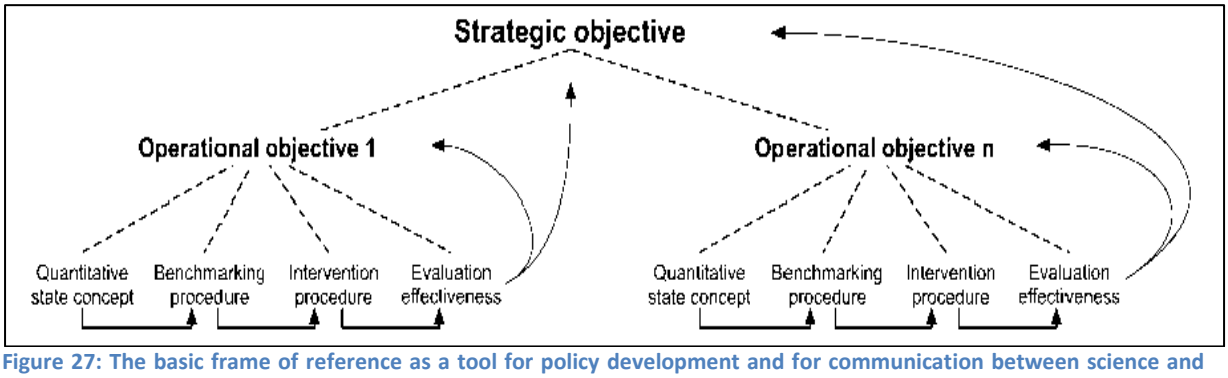


Figure 27: The basic frame of reference as a tool for policy development and for communication between science and coastal management (source: van Koningsveld 2004)

A7. Analytical Hierarchy Process (AHP)

The calculation of the weight factors of the sustainability themes in this thesis project will be accomplished through the Analytical Hierarchy Process (AHP).

The Analytic Hierarchy Process (AHP) pair comparison method is a multiple criterion decision-makingmethod originally developed by Saaty in 1977 (Saaty 2008; Pandian 2013a; C. Y. Ng and Chuah 2014; Bunruamkaew 2012; Mu and Pereyra-Rojas 2017). In the Analytical Hierarchy Process, the decision-maker/ expert has to express his opinion about the value of one single pairwise comparison at a time. Usually, the decision-maker has to rate his answer among choices (Pandian in 2013).

Very often qualitative data cannot be expressed in the form of absolute values. For this reason, many decision-making methods aim to determine the relative importance of each parameter involved in the problem (Triantaphyllou and Mann, 1995).

Based the paper published by Pandian in 2013 a three-stage methodology is proposed to estimate weights for the identified dimensions of sustainability using AHP based pairwise comparison method.

The first stage estimates the relative importance of three major concerns of economic, social and socio-economic performances with respect to sustainability through a pair-wise comparison made between them and provides their respective weights We, Ws and Wse,.

In the second stage, pair-wise comparison is made individually between the identified key performance dimensions 'i' for each sustainable concerns of economy Wie (i = 1 to4), social Wis (i = 5 to 8) and Wise (i = 9 to 12) and the weights of them in their category are found.

In the third stage, the weights for each dimension to estimate the sustainable composite index is found by multiplying the, Wie ,Wis and Wise with their respective We, Ws and Wse.

i.e. Wi = We * Wie (i = 1 to 4)
Wi = Ws * Wis (i = 5 to 8)
Wi = Wse * Wise (i = 9 to 12)

The intensity of importance (Average) obtained through personal interviews with experts working in the industries and the general public, normalized weights and the average of normalized weights. The normalized values are obtained by dividing by its corresponding column sum.

It is difficult to get quantitative figures for the dimensions of the industries. The performance of each dimension is collected through qualitative statements from the responsible respondents. The statements are coined such a way that they are chosen based, and the respondent is able to choose and provide instant answers to all the dimensions. Five choices are picked for each dimension to indicate the performance level of the industry with respect to that dimension (Poor, below average, average, above average, excellent).

A8. New Ecological Paradigm (NEP)

The New Ecological Paradigm is used in the Questionnaires to assess the level of eco-centricity or anthropocentricity of groups of persons.

The New Ecological Paradigm scale is a measure of endorsement of a "pro-ecological" worldview, initially developed in 1978 (Dunlap 2000; Anderson 2012; Dunlap and Van Liere 2008). It is used extensively in environmental education, outdoor recreation, and other realms where differences in behaviour or attitudes are believed to be explained by underlying values, a worldview, or a paradigm. The scale is constructed from individual responses to fifteen statements that measure agreement or disagreement.

The revised NEP has fifteen statements, called items. Eight of the items, if agreed to by a respondent, are meant to reflect the endorsement of the new ecological paradigm (NEP), while the agreement with the other seven items represents the endorsement of the dominant social paradigm (DSP). Using a Likert scale, a commonly used rating scale, respondents are asked to indicate their strength of agreement with each statement (strongly agree, agree, unsure, disagree, and strongly disagree).

The authors emphasized that the revised NEP questions had several strengths, making it a more reliable and valid tool for measuring a population’s environmental view of the world. In particular, they stated that the new scale was internally consistent, that is, people who responded to some items in one pattern tended to respond to other items in a consistent manner, and that it represented a measure of a single scale (it has unidimensionality).

A9. Climate change impacts in seaports

The impacts related to climate change, refer to sea level rise, storm surges and waves that can create dangerous conditions for the navigation and berthing of ships (UNCTAD 2017a), owing to, for example, invasion of waves (long period) (Rossouw and Theron, 2012). Flooding from extreme rainfall events, as well as other extreme events for example landslides, will create problems in the hinterland transportation (road/rail). In that way, the access to ports is affected (UNCTAD 2017a). The extreme winds have been predicted to be more frequent and they are considered to be more catastrophic (Coumou and Rahmstorf 2012). They can cause overtopping of coastal defences, failure of infrastructures and disruptions of operations and services (United Nations, 2015). As Vogel et al. stated in their publication of 2017, heat waves might limit the port operations and cause pavement/track damages.

The summary of the major climate variability and change impacts on ports are presented in Table 19.

Table 19: Summary of major climate variability and change impacts on ports (Source: UNCTAD 2017a)

Climatic Factor	Impacts on open sea, estuarine and inland waterway ports
Sea level (mean and extreme)	
(i) mean sea level changes; (ii) increased destructiveness of storm surges/waves; (iii) changes in the wave energy and direction	Damages in port infrastructure/cargo from incremental and/or catastrophic inundation and wave regime changes; higher port construction/maintenance costs; potential modulation of tides causing sedimentation/dredging in port/navigation channels and operational time table changes; effects on key transit points; increased risks for coastal road/railway links; relocation of people/businesses; insurance issues
Temperature	
Higher mean temperatures; (ii) heat waves and droughts (iii) increased spatio-temporal variability in temperature extremes	Damage to infrastructure/equipment/cargo and asset lifetime reduction; increases in the staff health risk; higher energy consumption for cooling terminals and cargo; restrictions for inland navigation that may affect estuarine port competitiveness (e.g. port of Rotterdam); reductions in snow/ice removal costs; extension of the construction season; changes in transport demand
In arctic areas, permafrost degradation and reduced arctic ice coverage	Major damages in infrastructure; coastal erosion affecting road and rail links to ports Longer shipping seasons-NSR; new shorter shipping routes-NWP/less fuel costs, but higher support service costs
Precipitation and Fog	
Changes in the mean and the intensity and frequency of extremes (floods and droughts)	Land infrastructure inundation; damage to cargo/equipment; navigation restrictions in inland waterways; network inundation and vital node damage (e.g. bridges); problems in port equipment operations (e.g. cranes); changes in demand
Increases in fog intensity/duration	Impact on ship and terminal operations (reduced visibility)
Wind	
Extreme harbour winds	Problems in seaport navigation and berthing; operational disruptions due to inability to load/unload

A9.1 Climate change in the Mediterranean

"*Extreme coastal sea levels constitute a most significant hazard for coastal activities and infrastructure*" (UNCTAD 2017a). Recent research that has been made regarding the European coast has mentioned that the future storm surge levels are expected to increase in the Atlantic, North Sea and Baltic coasts, while the Mediterranean is expected to have minor changes (Vousdoukas et al. 2016).

Consequently, in the Mediterranean, the impacts of climate change are not expected to be the same as in the North Sea, the Atlantic etc. taking into account that the tidal range in the Mediterranean basin is relatively low, the sea level extremes that could be expected are mostly associated merely to storm surges (Marcos, Tsimplis, and Shaw 2009). Additionally, the Mediterranean Sea is a semi-closed basin with relatively large depth and its only inflow and outflow of water is the Atlantic Ocean (Gibraltar Strait). Last but not least, it is expected an increase in salinity in the Mediterranean Sea

that will counterbalance sea level rise attributed to thermal expansion from warming (European Environment Agency, 2017).

The predicted variation in relative sea level rise in the years of 2018-2100 to the years 1986-2005 considering the average emission scenario (RCP4.5 based on an ensemble of CMIP5 climate models), presented from the European Environment Agency for the Mediterranean Sea basin is 0.3-0.5 meters.

It should be noted in this point that “taking regional projections for relatively small isolated and semi-closed ocean basins, such as the Mediterranean or the Baltic, is even more difficult than for the open ocean” (European Environment Agency, 2017) and for that reason, the results may present even more uncertainties.

Therefore, even if the value of sea level rise in the Mediterranean Sea basin is not expected to reach the highest levels that are predicted for several other areas, it is still crucial to incorporate climate change policies in the port planning and development in order to respond effectively to climate change challenges.

A9.2 Climate change and uncertainty

Climate change adds up a level of uncertainty in decision-making. Uncertainty can be generated from the limited scientific understanding of the climatic system (even though in the last decades the scientific knowledge on climate change and variability has upgraded) and of the manner in which the greenhouse emissions’ trend will be modified in the future (Willows et al. 2003) Additional uncertainty is added regarding the impact that climate change has on society, environment and economy since the understanding of the impacts is mainly related to events that have been experienced in the past (Willows et al. 2003).

Various approaches have been established confront with uncertainty in design and planning based on the European Climate Change Adaptation Platform and are presented below.

Adaptive management

This management system includes the exploration of strategies that are relatively easily modified in the case new comprehensions derived from research are inserted. Adaptive strategies are most applicable under the circumstances that the decision timescales allow gradual adaptation and decisions can be modified and updated as soon as new information and knowledge becomes available.

Scenario Planning

Taking into consideration deep uncertainty, decision-making should be performed taking into account several different outcomes. Then, alternative policy decisions are analysed based on their performance under diverse future scenarios.

Robust or Resilient Strategies

Through this approach, the possible future circumstances that could be confronted are detected, and the strategies that could be applied successfully across the whole range of future conditions are identified. The definition of a robust strategy is a strategy thathas a good performanceamong a wide variety of different futures.

The European Climate Change Adaptation Platform also presents the different types of adaptation options that can be adopted and are presented below:

- Selection of a "low-regret" (or ‘‘no-regret'') option: there are benefits even in the case of nonappearance of climate change and the cost for implementation are relatively low;
- Selection of "win-win (-win)" option: benefits in the climate change risks minimization and additional creation of benefits in the society, the environment and/or economic benefits.

- Preference in flexible options: making possible future modifications;
- The inclusion of ‘‘safety margins'' to new plans and investments: to guarantee that they are resilient to a variety of possible (predicted) climate change impacts;
- Promotion of soft adaptation strategies: in order to create adaptive capacity
- Reduction of decision time-scales
- Postpone of action: without neglecting the future. This might be applicable in the contexts of a long-term adaptation strategy that explores the significance of the benefit of a particular action and concludes that there is no added value for the time being.

A9.3 Climate change adaptability in ports

“*The ability of the system to change in response to developments within the system boundary is referred to as adaptability*” (P Taneja, Ligteringen, and Walker 2012).

In addition to the previous definition:

> *“adaptation to climate change is a process of continuous social and institutional learning, adjustment and transformation” and “understanding adaptation as an ongoing process of learning is relevant for local and regional scale decision-making*” (Fünfgeld and McEvoy 2011)

The first approach to climate change adaptability strategies is to comprehend the port's vulnerabilities. The decrease of the vulnerability of ports necessitates a precise determination of possible risks and potential impacts (Becker et al. 2013). In this point, it should be noted that in that context, each port is different and requires a tailor-made approach. However, the theory that forms the basis remains the same. The identification of the vulnerabilities of a port could be based on the vulnerability based approach developed by (Fünfgeld and Darryn McEvoy 2013).

The second step would choose the "appropriate" climate change policies. This presupposes an enhanced understanding of the concept of working under uncertainty in combination with the fact that even though the climate change impacts might not be placed within the time boundaries for which the port planning has been performed, but it is necessary to include them in the time being (Scott, National Climate Change Adaptation Research Facility (Australia), and RMIT University, 2013). As mentioned in the previous section, decision making under uncertainty is a rather difficult task. "*The certainty that the payoff will justify the investment decreases, while the importance of acquiring a strategic advantage over the competition becomes increasingly important*" as was mentioned from P Taneja, Ligteringen, and Walker in 2012.

In that sense, it becomes obvious that an “appropriate” climate change port strategy does not exist nor a clear pattern that can be followed during decision making.

For that reason, it is necessary that port managers receive guidance regarding the impacts that climate change will generate on their activities and operations. Additionally, training sessions should be performed to port authorities and managers involved to port planning to keep them updated regarding the sensitivities of the port operations over the climate change impacts. Different institutional methodologies are needed to develop the long-term concept in the decision-making process regarding port resilience (Becker et al., 2013). Another important aspect is constantly updating and keeping current the analysis and evaluation material that can be used in the decision making process (Scott, National Climate Change Adaptation Research Facility (Australia), and RMIT University, 2013).

Flexibility and Adaptive Port Planning

The climate change adaptation policies could be approached with the introduction of the concept of the "Flexible Port" that was firstly defined by Bellis in 1990 and involved a rather specific concept that concerns mainly the accommodation of ships. The concept of flexibility in port planning and design was re-examined by Dr Taneja.

In that context, “the port with the capability to change so as to be functional under new, different, or changing requirements (with minimal extra investment, and without appreciable loss in overall service quality, in terms of efficiency and reliability), can be said to be a flexible port “ (P Taneja, Ligteringen, and Walker 2012).

“Adaptive Port Planning (APP) is an approach that bridges the gaps in the traditional practices of port planning by incorporating uncertainty and flexibility considerations” (P Taneja, Ligteringen, and Walker 2012). Features like port adaptable and flexible planning can ensure that a port can be dynamic under changing requirements, enabling its operation under uncertainty, extending its economic lifetime, and therefore promising payback on investments (P Taneja, Ligteringen, and Walker 2012).

Some of the features of APP are listed in the Flexibility of Port Planning and design report by (P Taneja, Ligteringen, and Walker 2012). The most relevant features are presented below:

- Considers a variety of possible futures;
- Considers proactive actions for the confrontation of both forseen and unforeseen changes that might happen throughout the project design or after
- Methodically observe the external environment for potential developments and also the consequences of the actions that were carried out in order to reduce the probability that an impact occurs
- Presents the cost-benefit of the risk management
- Makes the decision-makers to be more precise regarding the assumptions in which they base their plans
- Systematically explores assumptions based on new knowledge and understanding from the strategic environment.

Based on those main features, it can be concluded that the APP approach could be easily linked to climate change adaptability design and planning. APP could assist in the identification of the most relevant strategies to be encompassed within climate change adaptation.

Appendix B *Container terminal case studies – Piraeus and Livorno*

B1. Port of Piraeus

B1.1 General information about the container terminals

- In **1930** was established the Piraeus Port Authority (PPA).
- In **1992** Pier II of the Container Terminal (CT) became operative.
- In **2008** followed the Pier II and (to be) Pier III concession to Piraeus Container Terminal SA (PCT SA - a subsidiary of COSCO Group) ratified with L.3755/2009- GG 52A/2009 and later amended with L.4072/2012- GG86A/2015 and L.4315/2014-GG269A/2014).
- PCT SA installation on Pier II was achieved in **2009**.
- In **2010** Pier I became operational.
- In **2016** the majority shareholding of PPA SA (67%) was sold to COSCO Group (ratified with L.4404/2016- GG 126 A/2016) (sources: PPA SA website, National Printing House of Greece website).

A general description of each Pier of the container terminal follows.

CT Pier I

According to the PPA website (http://www.olp.gr/en/) Pier I became operative in 2010. East quayside of Pier I has a length of 500m and depth of 18m, while west quayside is 320m long and has a depth of 12m. The annual capacity of Pier I is 1.000.000 TEUs. There are present 4 Over Super Post Panamax and 3 Panamax cranes.

CT PIER II

The Pier II is operative from 1992. The terminal operator is PCT SA from 2009. The east quayside is 780 m long, with an operational depth of 14.5m, while west quayside is 700 m long, with an operational depth of 16,5m. It covers a total area of 373.365m^2. The annual capacity of Pier II is 3.200.000 TEUs.

The Pier specifications are:

- 18 QCs
- 760 reefer plugs for 1.090 reefer TEUs
- 16 Electric Rubber Tired Gantry Cranes (E-RTGs)
- 16 semi-automated RMGs

CT Pier III

The east side of Pier III has 600m quay length. The west side of the Pier III has an operational quay length of approximately 390m.

The Pier specifications are:

- 10 Super Super Post Panamax (SSPP) QC's
- 6 RMGs
- 18 ERTGs
- 360 reefer plugs

The throughput of the Pier III is now 2.300.000 TEUs.

The layout of Pier II and III is presented in Figure 28.

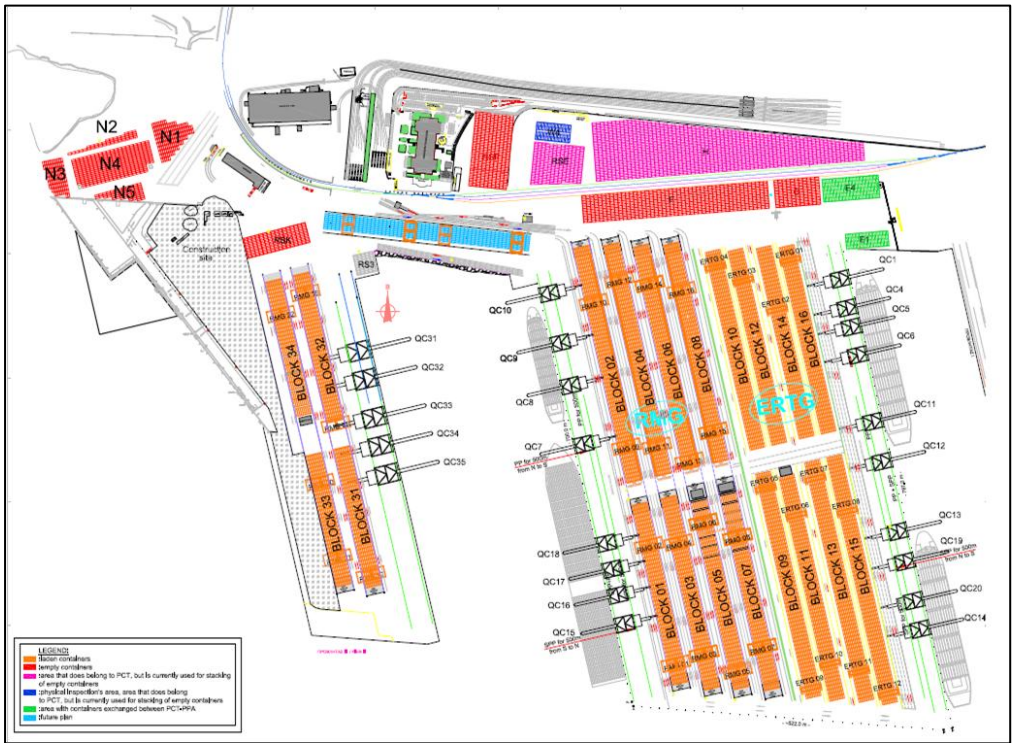


Figure 28: Layout of Pier II and III

The evolution of the container terminals through the years is presented in Figure 29.

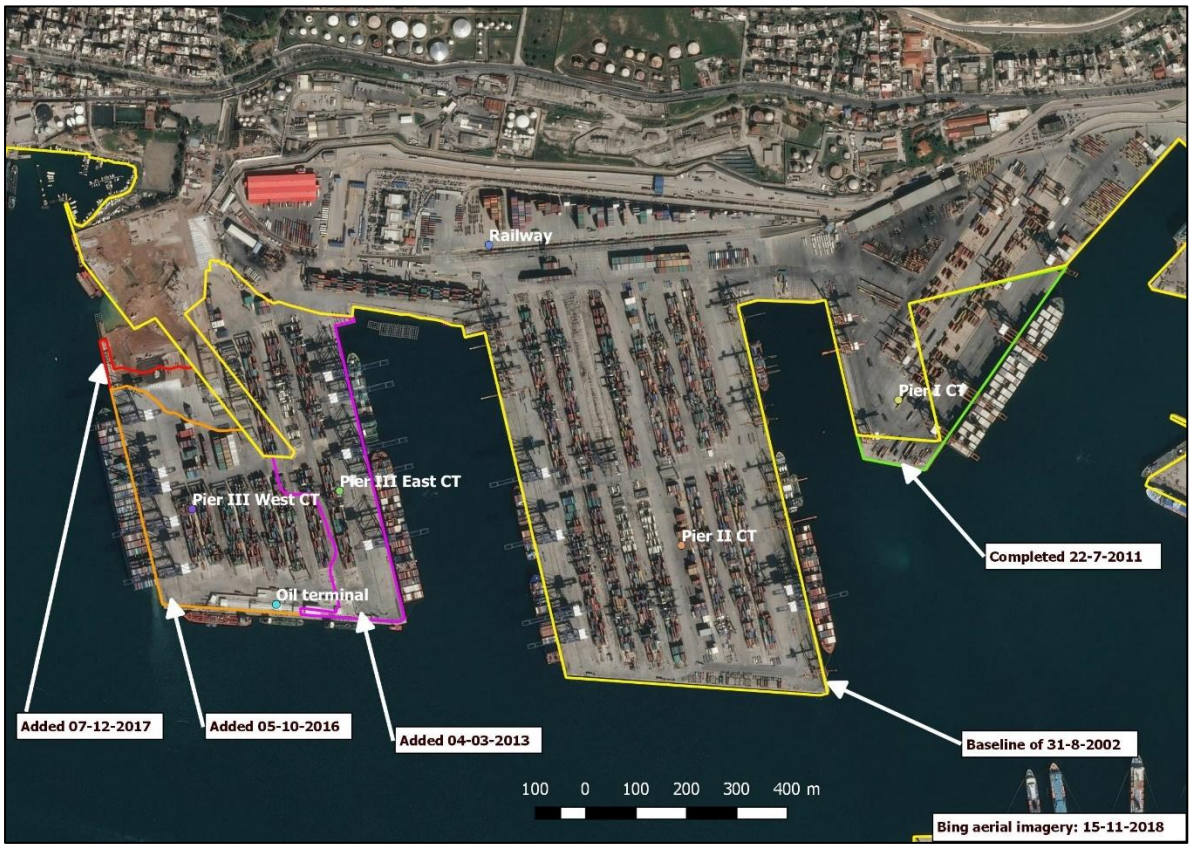


Figure 29: Evolution of Piraeus container terminals over the years (2002-2018)

B2. Port of Livorno

B2.1 General information about the container terminals

In the port of Livorno are operating two container terminals. The Lorenzini container terminal is located in the eastern part of the commercial port and the Terminal Darsena Toscana is located on the western part of the commercial port. The first is smaller than the second both in terms of area and cargo. A brief presentation of the terminals is presented below:

Terminal Lorenzini&C:

From the website of Lorenzini&C the following information was retrieved:

"The areas at Lorenzini's disposal have increased from 1,000 square metres of 1985 to over 90,000 square metres today, and its vehicle fleet is in continuous expansion. Over the last two years, amongst several other purchases, one may count 4 RTG cranes and a new self-propelled Gottwald HMK7608 crane. The terminal is equipped with an internal railroad track of approximately 400 metres.

The Lorenzini Terminal is a concessionary company in accordance with art. 18 of Law 84/94, and namely the owner of a maritime State allotment of areas and wharves/docks within the port for the direct performance of port operations; it is also authorized as per art. 16 to the carrying out of port services. Within the public properties and following the measures connected with the Industrial Plan, Lorenzini Terminal has at its disposal the following areas and structures:

- A total concession area of more than 90.000 m^2
- Annual terminal capacity of 180.000 TEUs
- A 400-metre railway track
- A building destined to Border Inspection Post (BIP)
- A roofing covering a total of 2.000 m^2
- 342 Reefer Plugs
- A platform balance for various goods and containers, with a 60-ton capacity"

Terminal Darsena Toscana (TDT):

The Darsena Toscana terminal is the major container terminal in the Port of Livorno. Established in 1997, TDT has been an integral part of Gruppo Investimenti Portuali (GIP) since 2012. It is the major container terminal in the Port of Livorno, with an operating capacity of 900.000 TEUs. The terminal area is 384.000 m^2, the quay length 1.430 m and the quay depth 13 m.

TDT is the leading Italian terminal by volume for reefer cargo and its high structures organisation has been in place since 2003. TDT provides 863 reefer plugs (80 of them in the inspection area) and reefer racks for safe temperature monitoring.

Logistically speaking, TDT is 9 km from top-tier logistics platform A. Vespucci.

The evolution of the container terminals through the years is presented in Figure 30.

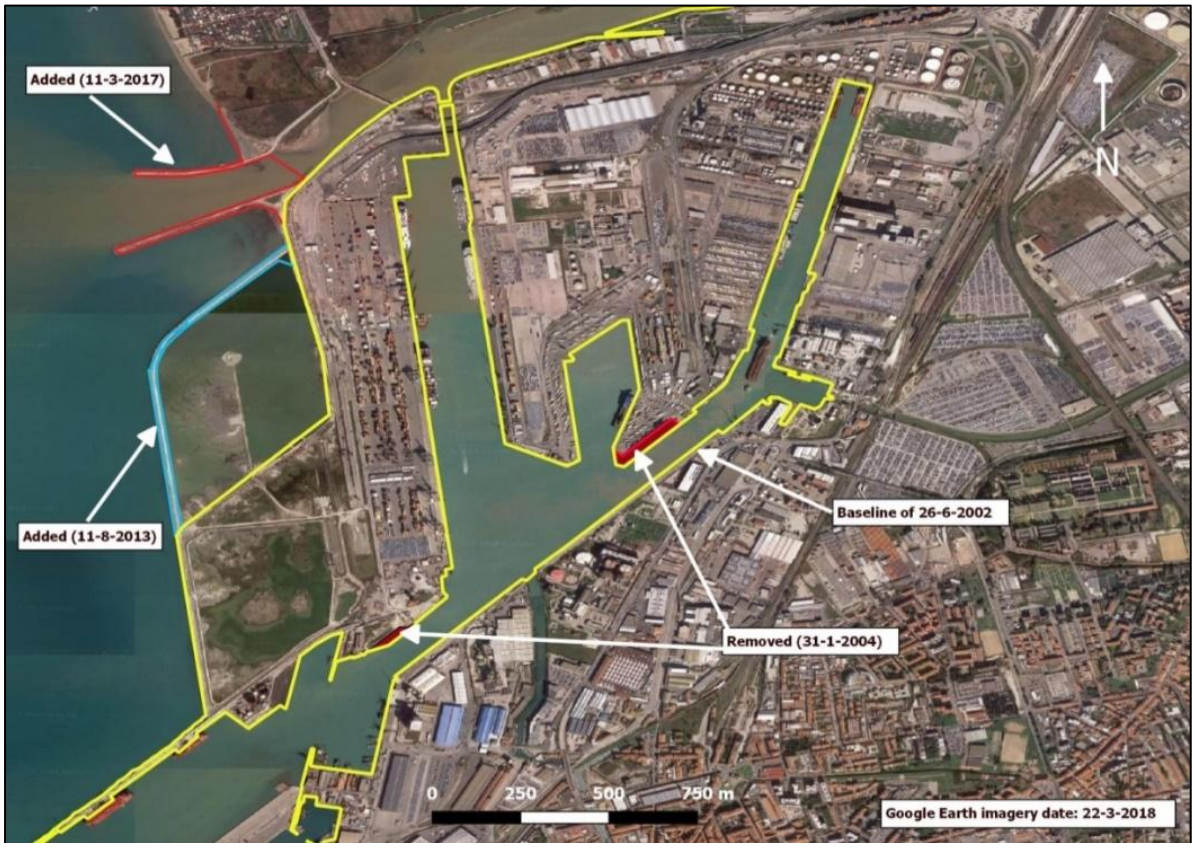


Figure 30: Evolution of Livorno container terminals over the years (2002-2018)

Appendix C *Stresses of container terminal*

C1. Framework used to explore the potential stresses of container terminals

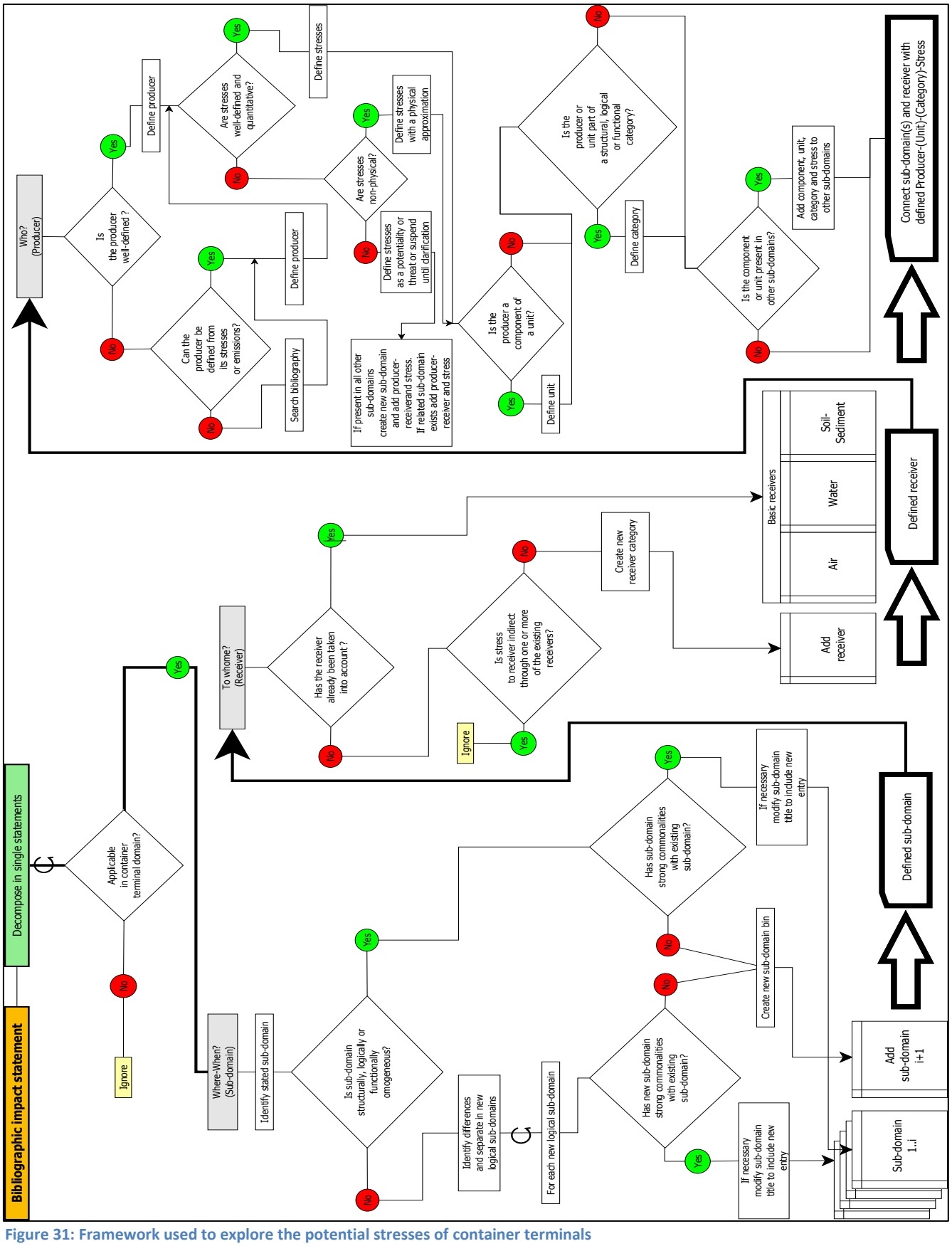


Figure 31: Framework used to explore the potential stresses of container terminals

Pubblication

United Nations. 1992. "Assessment of the Environmental Impacts of Port Development." https://www.unescap.org/sites/default/files/pub_1234_fulltext.pdf

Statement

Air quality consists of two main elements: (a) soot and dust, measured by suspended particulate matter (SPM), which originate from dry bulk cargo handling and storage, construction work on land, and road traffic; and (b) concentration of sulfur dioxide (S02)' nitrogen dioxide (N02), carbon monoxide (CO), and hydrocarbons (HC) emitted from ships, vehicles and various equipment used for port activities. Harmful substances and odour are also elements to be considered in this category.. (p. 6-7)

Decompose

Air quality consists soot and dust, measured by suspended particulate matter (SPM), which originate from dry bulk cargo handling and storage

Not applicable, Ignore

Air quality consists of soot and dust, measured by suspended particulate matter (SPM), which originate from construction work on land

PRODUCTION - RECEPTION AREA	CATEGORY	PRODUCER-RECEIVER	FLOW TYPE	FLOW DIRECTION	MAIN COMPONENTS OF FLOW	RELATION TO PORT	DESTINATION or MODIFIED MEDIUM/SYSTEM
CONSTRUCTION SITE	All activities	Various	Dust - loose materials	OUT	Particulate matter	In port	Air

Air quality consists of soot and dust, measured by suspended particulate matter (SPM), which originate from road traffic

Road traffic: Inside port area (direct) and outside port area (indirect).
Stress: Particulate matter
Cause: port activities (very generic - needs definition)
Producer: movement of vehicles
Logical extension: movement of all moving equipment
Sub-domain: Container terminal activities

Cause: search bibliography

Gustafsson et al
Factors influencing PM10 emissions from road pavement wear
2009

PRODUCTION - RECEPTION AREA	CATEGORY	PRODUCER-RECEIVER	FLOW TYPE	FLOW DIRECTION	MAIN COMPONENTS OF FLOW	RELATION TO PORT	DESTINATION or MODIFIED MEDIUM/SYSTEM	RESOURCES
LAND AREA OPS	All moves in yard	Yard pavement	Dust	OUT	Particulate matter	In port	Air	

Air quality consists of concentration of sulfur dioxide (S02)' nitrogen dioxide (N02), carbon monoxide (CO), and hydrocarbons (HC) emitted from ships

Sub-domains:
separate ships logically: ships that operate only in port and ships visiting the port

Stress: combustion gasses
Combustion emissions producer: engines
Unit: Moving units with egnines
Ships have main and auxiliary engines (separate flows)
Extend stress to all sub-domains that have equipment with engines

PRODUCTION - RECEPTION AREA	CATEGORY	PRODUCER-RECEIVER	FLOW TYPE	FLOW DIRECTION	MAIN COMPONENTS OF FLOW	RELATION TO PORT	DESTINATION or MODIFIED MEDIUM/SYSTEM
SHIP	Propulsion - Energy production	Main engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	Near port	Air
SHIP	Energy production	Aux engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	In port	Air
PORT VESSEL	Propulsion - Energy production	Main engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	Near port	Air
PORT VESSEL	Energy production	Aux engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	In port	Air
CONSTRUCTION SITE	All equipment	Engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	In port	Air
LAND AREA OPS	Yard equipment	Engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	In port	Air
LAND AREA OPS	Yard building	Temperature control equipment	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	In port	Air
LAND AREA OPS	Yard truck	Engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	In port	Air
LAND AREA OPS	Yard cars	Engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	In port	Air
LAND AREA OPS	Commute/Visit	Engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	Outside port	Air
LAND AREA OPS	Intermodality trucks	Engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	Outside port	Air
LAND AREA OPS	Intermodality trains	Engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	Outside port	Air

Air quality consists of concentration of sulfur dioxide (S02)' nitrogen dioxide (N02), carbon monoxide (CO), and hydrocarbons (HC) emitted from various equipment used for port activities.

Already covered, Ignore

Harmful substances and odour are also elements to be considered in this category

Suspend until clarification

From other reference of the same pubblication

Emissions of dust from bulk cargo handling and gasses from cargo handling equipment can be sources of air pollution. Liquid cargo handling may result in the release of vapour during the cleaning of storage tanks and by the breather system for ambient temperature changes. Accidental leakage of gasses may cause problems such as toxic material emission,explosions, fumes, odours and hazardous airborne emissions. Waterfront industries may release various kinds of gasses and can be major sources of air pollution and odour. (p. 17)

PRODUCTION - RECEPTION AREA	CATEGORY	PRODUCER-RECEIVER	FLOW TYPE	FLOW DIRECTION	MAIN COMPONENTS OF FLOW	RELATION TO PORT	DESTINATION or MODIFIED MEDIUM/SYSTEM
ALL	L-S-E-A-C	Various	Gasses	OUT	Various harmful/hazardous gasses		Air
ALL	L-S-E-A-C	Various	Gasses	OUT	Flamable gasses		Air
ALL	L-S-E-A-C	Various	Gasses	OUT	Odours		Air

Figure 32: Example of the application of framework to explore the potential stresses of container termin

C2. Main literature sources

The main bibliographic sources regarding the port stresses were:

PORTOPIA - The European Port Industry Sustainability Report 2016 (PORTOPIA 2016); Ecoports, Sustainability Report 2017(ECOPORTS 2017); World Bank, Technical Paper n. 126, Environmental Considerations for Port and Harbour Developments (Davis, MacKnight, and IMO Stuff 2000); United Nations, Assessment of the environmental stresses of port development (United Nations 1992);(Trozzi and Vaccaro 2000); Port of Antwerp, Sustainability Report 2017 (Port of Antwerp 2017); Port of Rotterdam Environmental Review System (PERS) report 2015 (Port of Rotterdam 2015a); various Port of Livorno EnvironmentalStatements(Autorita' Portuale di Livorno 2016), (Autorita' di Sistema portuale del Mar Tirreno Settentrionale 2018); Port of Livorno Strategic EnvironmentalAssessment (VAS), 2013 (Autorita' Portuale di Livorno 2017, 2013); Port of Piraeus PERS Environmental Statement 2016 (Piraeus Port Authority 2016);and many other EIA studies of ports worldwide.

Additionally, for various port-city related issues the bibliographic sources were:(Urbanyi-Popiołek and Klopott 2016), (Trachtenberg School of Public Policy and Public Administration, George Washington University et al. 2018), (Bottasso et al. 2013), (Rodrigue, Comtois, and Slack 2013),(Kelty and Bliven 2003), (Longcore and Rich 2004), (Cicerali, Kaya Cicerali, and Saldamlı 2017).

For the ships' stresses the main bibliographic sources were: Environmental Effects of Marine Transportation (Walker et al. 2018); EMSA/OP/02/2016, The Management of Ship-Generated Waste On-board Ships, (CE Delft 2017); MARPOL 73/78 with updated annexes, regulations and MEPC resolutions ("Pollution Prevention" n.d.); AFS Convention, 2001("International Convention on the Control of Harmful Anti-Fouling Systems on Ships (AFS)" n.d.); Bio-fouling, IMO ("Biofouling" n.d.); Ballast Water Management Convention (BWM)("Ballast Water Management" n.d.); Air emissions of ships, (Guerrero 2015) and (Scarbrough, Wakeling, and Tsagatakis 2018); ship noise: IMO ("Noise" n.d.), (Danish Environmental Protection Agency 2010) and (Badino et al. 2012); ship strikes (Australian Marine Mammal Centre n.d.)and (NOAA Fisheries 2018); Port State Control: Directive 2009/16/EC "Port State Control" implementing the (1982) Paris Memorandum of Understanding on Port State Control (Paris MoU); Port reception facilities: Directive 2000/59/EC Council on port reception facilities for the delivery of waste from ships; Proposal for a Directive of the European Parliament and of the Council on port reception facilities for the delivery of waste from ships, repealing Directive 2000/59/EC and amending Directive 2009/16/EC, 2018, Commission Staff Working Document, Strasbourg, 16.1.2018SWD(2018) 21 final; (Port of Tallinn 2017), (Port of Rotterdam 2015b).

For the construction phase, apart from all the aforementioned EIAs (Environmental Impact Statements) that also comprised the construction phase stresses, the USEPA, Measuring Construction Industry Environmental Performance, 2007(US EPA 2007), the OSPAR Guidelines for the Management of Dredged Material at Sea, 2014 (OSPAR commission 2014) and the website www.european-dredging.info("EuDA - Home" n.d.) were also consulted.

C3. Cataloguing the container terminal's direct impacts

Container Ship's and port vessel's Impacts

PRODUCTION - RECEPTION AREA	CATEGORY	PRODUCER-RECEIVER	FLOW TYPE	FLOW DIRECTION	MAIN COMPONENTS OF FLOW	RELATION TO PORT	DESTINATION or MODIFIED MEDIUM/SYSTEM
SHIP	Ship equipment	Various sources	Various oil containing lquids and solids	OUT	Oily waste Marpol 73/78 Annex I: A. Ship-generated: Fuel oil residues/sludge; Used engine oil; Bilge water; Ballast water oil contamination. B. Cargo residue: Wash water oil	In port	Reception Facilities
SHIP	Incinerator	Ship Incinerator	Incineration gasses	OUT	Incinerator gasses: Various gasses. LIMITS: CO < 200 mg/MJ; soot number< Bacharach 3 or Ringelman 1 (20% opacity); Unburned components in ash residues maximum 10% by weight	Open sea	Air
SHIP	Ship operations	Various sources	Various	OUT	Garbage various Marpol 73/78 Annex V: Domestic waste; Small dangerous waste; plastic; glass; metal; food waste; cargo related waste; other waste	In port	Reception Facilities
SHIP	Ship operations	Various sources	Various	OUT	Ozone depleting substances, Scrubber waste Marpol 73/78, Annex VI	In port	Reception Facilities
SHIP	Ship drainage system	Toilets; latrines; washing machines; other	Sewage	OUT	Sewage Marpol 73/78 Annex IV: Black and grey waters Pathogens - other	In port	Port/City Treatment Facilities
SHIP	Ship drainage system	Toilets; latrines; washing machines; other	Sewage	OUT	Sewage Marpol 73/78 Annex IV: Black and grey waters Minimum pathogens - other	Open sea	Water
SHIP	Ship hull	Ship hull	Anti-fouling	OUT	Antifouling paint components	Near port	Water
SHIP	Ship hull	Ship hull	Anti-fouling	OUT	Antifouling paint components	Near port	Soil-Sediments
SHIP	Ship hull	Hull fouling organisms	Hull	OUT	Alien/invasive species	Near port	Ecosystems
SHIP	Ballast tanks	Ship ballast	Ballast tanks	OUT	Ballast water treated - BWMS approved (BWM - 2017) Minimum presence of species	Open sea	Water
SHIP	Ballast tanks	Ship ballast	Ballast tanks	OUT	Ballast water (BWM - 2017) Alien/invasive species	In port	Reception Facilities
SHIP	Ballast tanks	Ship ballast	Ballast tanks	OUT	Ballast water sediments (BWM - 2017) Various pollutants and species	In port	Reception Facilities
SHIP	Ballast tanks	Ship ballast	Ballast tanks	OUT	Ballast water if no compliance with BWM convention Alien/invasive species	Near port	Ecosystems
SHIP	Propulsion - Energy production	Main engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	Near port	Air
SHIP	Energy production	Aux engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	In port	Air
SHIP	Propulsion - Energy production	Engines, fans. Other equipment	Noise	OUT	Sound waves	Near port	Acoustic
SHIP	Propulsion - Energy production	Propellers, engines, other equipment	Underwater noise	OUT	Sound waves - vibrations propagated underwater	Open sea	Acoustic (underwater)
SHIP	Ship navigation	Propellers - hull	Physical impact	OUT	Marine fauna strikes	Open sea	Ecosystems
SHIP	Ship general	Ship operations	Spills-Accidents-Collisions	OUT	VIEW ACCIDENTS-SPILLS-COLLISIONS TABLE	Potential	Water/Soil/Air/Societal/Economic

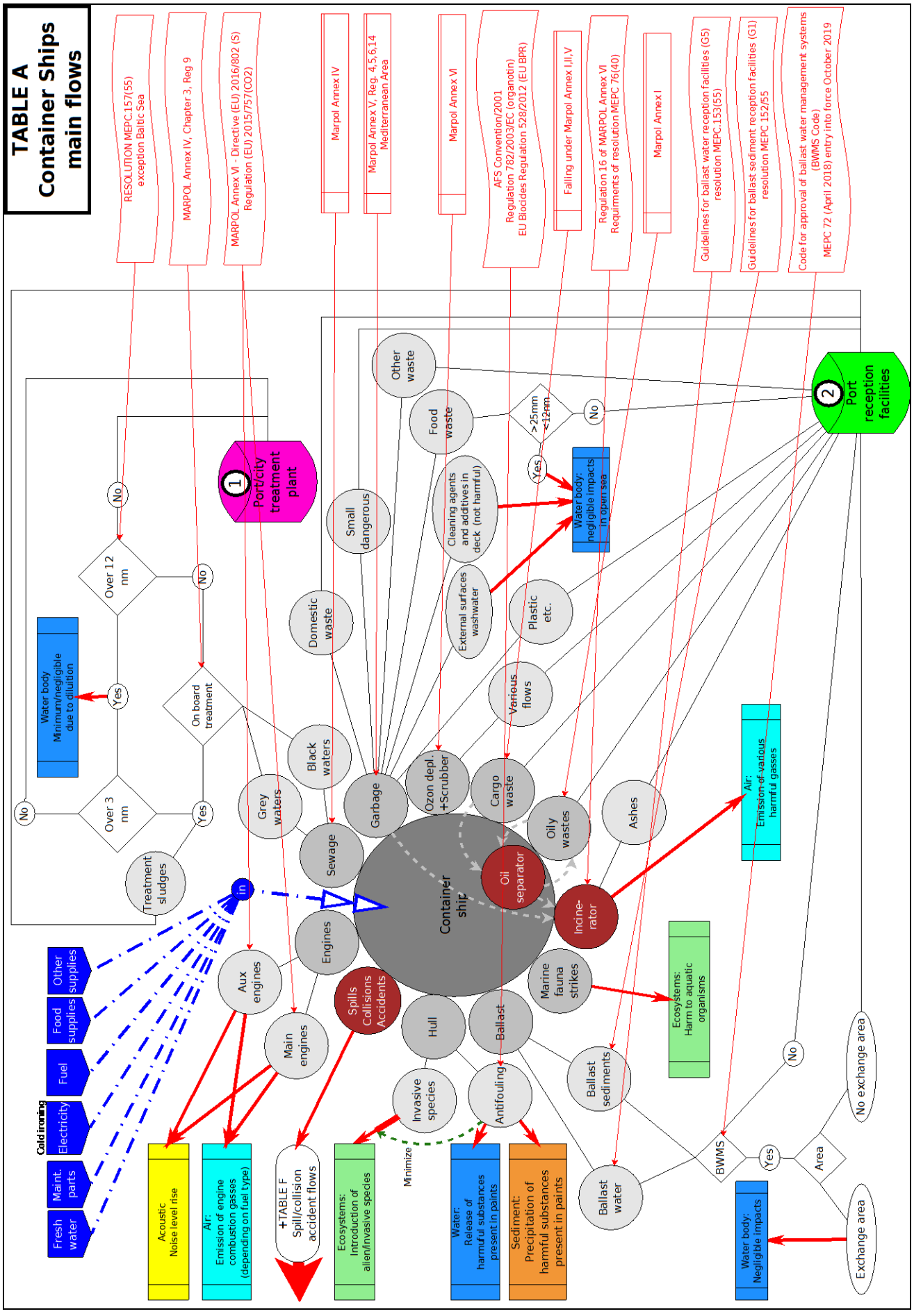


TABLE A
Container Ships
main flows
RESOLUTION MEPC.157(55) exception Baltic Sea
MARPOL Annex IV, Chapter 3, Reg 9
MARPOL Annex VI - Directive (EU) 2016/802 (S) Regulation (EU) 2015/757(CO2)
Marpol Annex IV
Marpol Annex V, Reg. 4,5,6,14 Mediterranean Area
Marpol Annex VI
AFS Convention/2001 Regulation 782/2003/EC (organotin) EU Biocides Regulation 528/2012 (EU BPR)
Falling under Marpol Annex I,II,V
Regulation 16 of MARPOL Annex VI Requirments of resolution MEPC 76(40)
Marpol Annex I
Guidelines for ballast water reception facilities (G5) resolution MEPC.153(55)
Guidelines for ballast sediment reception facilities (G1) resolution MEPC 152/55
Code for approval of ballast water management systems (BWMS Code) MEPC 72 (April 2018) entry into force October 2019
1 Port/city treatment plant
2 Port reception facilities
Container ship
Over 12 nm
Over 3 nm
On board treatment
Water body Minimum/negligible due to dilution
Water body: negligible impacts in open sea
Treatment sludges
Grey waters
Black waters
Sewage
Garbage
Domestic waste
Small dangerous
Other waste
Food waste
>25mm <12mm
Cleaning agents and additives in deck (not harmful)
External surfaces washwater
Plastic etc.
Various flows
Ozon depl. +Scrubber
Cargo waste
Oily wastes
Ashes
Oil separator
Incine-rator
Air: Emission of various harmful gasses
Engines
Aux engines
Main engines
Spills Collisions Accidents
Hull
Ballast
Marine fauna strikes
Ecosystems: Harm to aquatic organisms
Invasive species
Antifouling
Ballast sediments
Ballast water
BWMS
Area
No exchange area
Exchange area
Water body: Negligible impacts
Other supplies
Food supplies
Fuel
Electricity
Maint. parts
Fresh water
Cold ironing
Acoustic Noise level rise
Air: Emission of engine combustion gasses (depending on fuel type)
+TABLE F Spill/collision accident flows
Ecosystems: Introduction of alien/invasive species
Minimize
Water: Release of harmful substances present in paints
Sediment: Precipitation of harmful substances present in paints
in
Yes
No

PRODUCTION - RECEPTION AREA	CATEGORY	PRODUCER-RECEIVER	FLOW TYPE	FLOW DIRECTION	MAIN COMPONENTS OF FLOW	RELATION TO PORT	DESTINATION or MODIFIED MEDIUM/SYSTEM
CONSTRUCTION SITE	All equipment	Engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	In port	Air
CONSTRUCTION SITE	All activities	Various	Dust - loose materials	OUT	Particulate matter	In port	Air
CONSTRUCTION SITE	All activities	Various	Dust - loose materials	OUT	Particulate matter - other materials	In port	Water
CONSTRUCTION SITE	All activities	Various	Dust - loose materials	OUT	Particulate matter - other materials	In port	Soil-Sediments
CONSTRUCTION SITE	All activities	Various	Dust - loose materials/light	OUT	Particulate matter - other materials/photons	In port	Light
CONSTRUCTION SITE	All activities	Engines; movements; beepers; other	Noise	OUT	Sound waves	In port	Acoustic
CONSTRUCTION SITE	All equipment	Engines; hydraylic systems; other	Oily waste	OUT	Oily materials	In port	Reception Facilities
CONSTRUCTION SITE	All activities	Various	Garbage	OUT	Various - Separated flows	In port	Reception Facilities
CONSTRUCTION SITE	All activities	Various	Other waste	OUT	Various - Separated flows	In port	Reception Facilities
CONSTRUCTION SITE	All activities	Engines	Fuel	IN	Petrol; diesel; LNG; other	In port	
CONSTRUCTION SITE	All equipment	Various	Maintenance material/spare parts	IN	Various	In port	
CONSTRUCTION SITE	All activities	Various	Construction materials	IN	Various	In port	
CONSTRUCTION SITE	All activities	Various	Hazardous demolition materials	OUT	Various	In port	Appropriate management facilities
CONSTRUCTION SITE	All activities	Various	Non-hazardous demolition materials	OUT	Various	In port	Alternative management facilities-Reusage
CONSTRUCTION SITE	All activities	Various	Filling materials	IN	Various	In port	
CONSTRUCTION SITE	All equipment	Various	Electrical supply	IN	Electricity	In port	
CONSTRUCTION SITE	Construction facilities	Sinks; other	Sewage	OUT	Grey water	In port	Port/City treatment facilities
CONSTRUCTION SITE	Construction facilities	Latrines; toilets	Sewage	OUT	Black water	In port	Port/City treatment facilities
CONSTRUCTION SITE	Employment	Constr. operations	Work demand	IN	Personnel	Near port	Socio-economic
CONSTRUCTION SITE	Marine activities	Various	Sediment resuspension and transport	OUT	Various sediment components	Near port	Water
CONSTRUCTION SITE	Marine activities	Various	Sediment resuspension and transport	OUT	Various sediment components/photons	Near port	Light
PORT INFRASTRUCTURE	Land/sea reclamation	Port infrastructure	Sea volume/land area occupation	OUT	Piers; breakwaters;yards; other marine infrastructures	Near port	Ecosystems
PORT INFRASTRUCTURE	Land/sea reclamation	Port infrastructure	Damage	OUT	Filling/covering - Occupying	Near port	Socio-economic
PORT INFRASTRUCTURE	Upland run-offs	Port basin	Liquids	IN	Pathogens; various liqids - disolved solids	In port	Water
PORT INFRASTRUCTURE	Upland run-offs	Port basin	Solids	IN	Various solids	In port	Soil-Sediments
PORT INFRASTRUCTURE	Waterfront obsruction	Port infrastructure	Pressure-damage	OUT	Physical presence	Near port	Socio-economic
PORT INFRASTRUCTURE	Breakwaters	Breakwaters	Modification-obstruction	OUT	Basin's water circulation	In port	Water
PORT INFRASTRUCTURE	Marine infrastructure	Breakwaters-Sea reclamations	Coastal processes	OUT	Waves- Currents - Sediment transport	Near port	Ecosystems
PORT INFRASTRUCTURE	Marine infrastructure	Breakwaters-Sea reclamations	Coastal processes	OUT	Waves- Currents - Sediment transport	Near port	Socio-economic
PORT INFRASTRUCTURE	Marine infrastructure	Breakwaters-Sea reclamations	Coastal processes	OUT	Waves- Currents - Sediment transport	Near port	Soil-Sediments
PORT INFRASTRUCTURE	Infrastructures	All infrastructures	Sea barrier	OUT	Physical presence	Near port	Socio-economic
PORT INFRASTRUCTURE	Infrastructures	All infrastructures	Upland run-off barrier	OUT	Physical presence	Near port	Socio-economic
PORT INFRASTRUCTURE	Dredging	Port basin	Dredging operations	OUT	Physical damage	Near port	Ecosystems
PORT INFRASTRUCTURE	Dredging	Port basin	Dredging operations	OUT	Resuspension of sediments	Near port	Water
PORT INFRASTRUCTURE	Dredging	Port basin	Dredged material disposal	OUT	Hazardous material	In port	Appropriate management facilities
PORT INFRASTRUCTURE	Dredging	Port basin	Dredged material disposal	OUT	Non hazardous material	In port	Alternative management facilities-Reusage
PORT INFRASTRUCTURE	Dredging	Port basin	Dredged material open sea dumping	OUT	Non hazardous material	Outside port	Ecosystems
PORT INFRASTRUCTURE	Dredging	Port basin	Dredged material open sea dumping	OUT	Non hazardous material	Outside port	Soil-Sediments
CONSTRUCTION SITE	All activities	All activities	VARIOUS	OUT	VIEW ACCIDENTS-SPILLS-COLLISIONS TABLE	In port	Water/Soil/Air/Societal/Economic

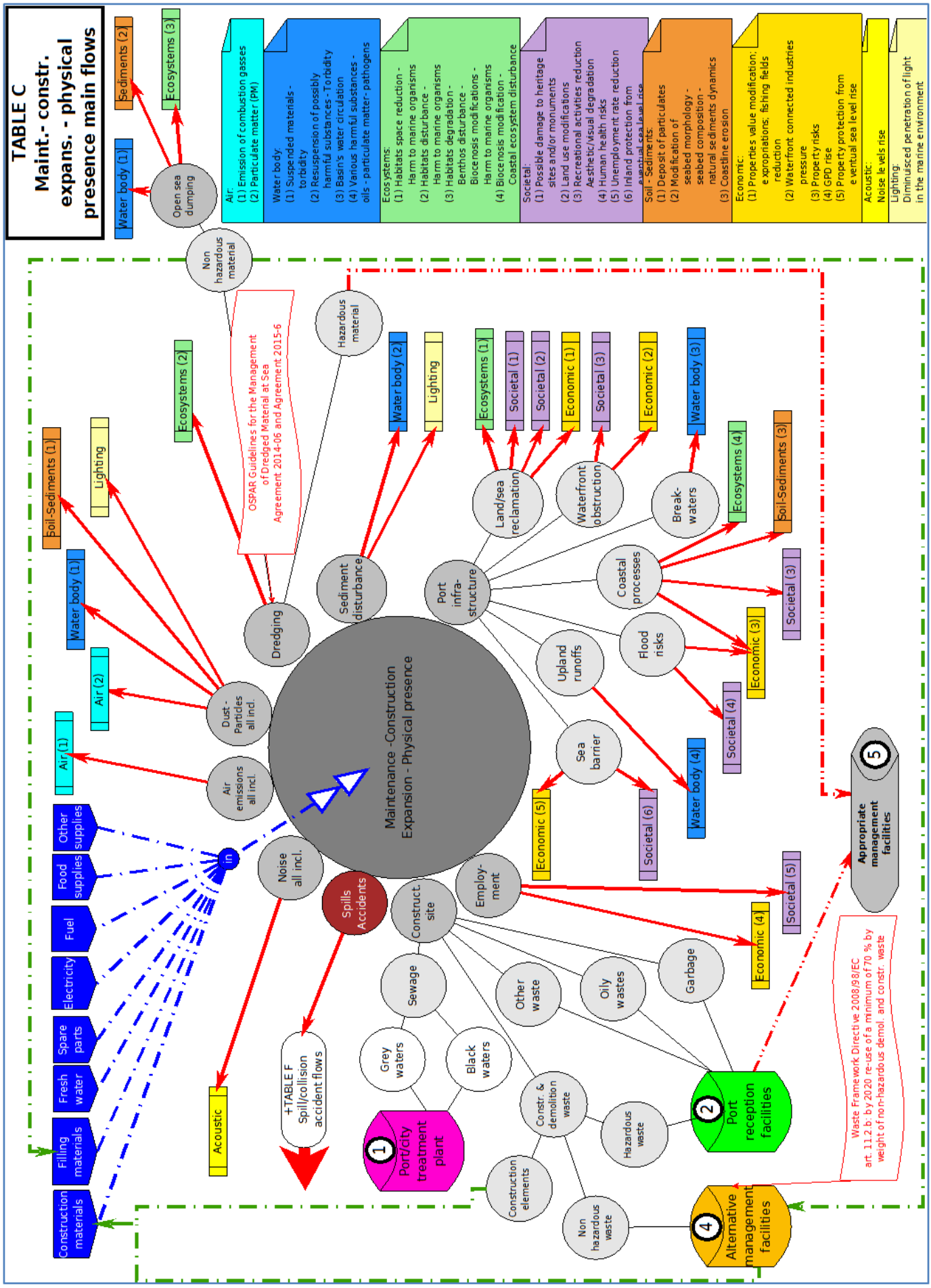


TABLE C
Maint.- constr. expans. - physical presence main flows
Air:
(1) Emission of combustion gasses
(2) Particulate matter (PM)
Water body:
(1) Suspended materials - torbidity
(2) Resuspension of possibly harmful substances - Torbidity
(3) Basin's water circulation
(4) Various harmful substances - oils - particulate matter- pathogens
Ecosystems:
(1) Habitats space reduction - Harm to marine organisms
(2) Habitats disturbance - Harm to marine organisms
(3) Habitats degradation - Benthos disturbance - Biocenosis modifications - Harm to marine organisms
(4) Biocenosis modification - Coastal ecosystem disturbance
Societal:
(1) Possible damage to heritage sites and/or monuments
(2) Land use modifications
(3) Recreational activities reduction Aesthetic/visual degradation
(4) Human health risks
(5) Unemployment rate reduction
(6) Inland protection from eventual sea level rise
Soil - Sediments:
(1) Deposit of particulates
(2) Modification of seabed morphology - seabed composition - natural sediments dynamics
(3) Coastline erosion
Economic:
(1) Properties value modification: expropriations: fishing fields reduction
(2) Waterfront connected industries pressure
(3) Property risks
(4) GPD rise
(5) Property protection from eventual sea level rise
Acoustic:
Noise levels rise
Lighting:
Diminusced penetration of light in the marine environment
Sediments (2)
Ecosystems (3)
Water body (1)
Open sea dumping
Non hazardous material
Hazardous material
OSPAR Guidelines for the Management of Dredged Material at Sea
Agreement 2014-06 and Agreement 2015-6
Ecosystems (2)
Water body (2)
Lighting
Ecosystems (1)
Societal (1)
Societal (2)
Economic (1)
Societal (3)
Economic (2)
Water body (3)
Soil-Sediments (1)
Lighting
Water body (1)
Air (2)
Air (1)
Dust - Particles all incl.
Air emissions all incl.
Dredging
Sediment disturbance
Land/sea reclamation
Waterfront obstruction
Break-waters
Ecosystems (4)
Soil-Sediments (3)
Port infra-structure
Coastal processes
Societal (3)
Upland runoffs
Flood risks
Economic (3)
Societal (4)
Sea barrier
Water body (4)
Economic (5)
Societal (6)
Maintenance -Construction
Expansion - Physical presence
In
Other supplies
Food supplies
Fuel
Electricity
Spare parts
Fresh water
Filling materials
Construction materials
Noise all incl.
Spills Accidents
Construct. site
Employ-ment
Societal (5)
Economic (4)
Appropriate management facilities
5
Sewage
Other waste
Oily wastes
Garbage
Grey waters
Black waters
Constr. & demolition waste
Hazardous waste
Construction elements
Non hazardous waste
Acoustic
+TABLE F
Spill/collision accident flows
1
Port/city treatment plant
2
Port reception facilities
4
Alternative management facilities
Waste Framework Directive 2008/98/EC
art. 11.2 b: by 2020 re-use of a minimum of 70 % by weight of non-hazardous demol. and constr. waste

Terminal area activity Impacts

PRODUCTION - RECEPTION AREA	CATEGORY	PRODUCER-RECEIVER	FLOW TYPE	FLOW DIRECTION	MAIN COMPONENTS OF FLOW	RELATION TO PORT	DESTINATION or MODIFIED MEDIUM/SYSTEM
LAND AREA OPS	Yard equipment	Engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	In port	Air
LAND AREA OPS	Yard equipment	Motors; actuators; beepers; movement; other	Electrical supply	IN	Electricity		
LAND AREA OPS	Yard equipment	Various	Oily and other Waste	OUT	Various - Separated flows	In port	Reception Facilities
LAND AREA OPS	Yard equipment	Various	Garbage	OUT	Various - Separated flows	In port	Reception Facilities
LAND AREA OPS	Yard equipment	Various	Fuel	IN	Petrol; diesel; LNG; other		
LAND AREA OPS	Yard equipment	Various	Maintenance material/spare parts	IN	Various		
LAND AREA OPS	Yard equipment	Engines; movements; beepers; other	Noise	OUT	Sound waves	In port	Acoustic
LAND AREA OPS	Yard reefer plugs	Operation	Electrical supply	IN		In port	
LAND AREA OPS	Yard building	Kitchen sinks; bathroom sinks; other	Sewage	OUT	Grey water	In port	Port/City treatment facilities
LAND AREA OPS	Yard building	Latrines; toilets	Sewage	OUT	Black water	In port	Port/City treatment facilities
LAND AREA OPS	Yard building	Operations	Garbage	OUT	Various - Separated flows	In port	Reception Facilities
LAND AREA OPS	Yard building	Operations	Waste	OUT	Various - Separated flows	In port	Reception Facilities
LAND AREA OPS	Yard building	Temperature control equipment	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	In port	Air
LAND AREA OPS	Yard building	Temperature control equipment	Electrical supply	IN	Electricity	In port	
LAND AREA OPS	Yard building	Various building equipment	Noise	OUT	Sound waves	In port	Acoustic
LAND AREA OPS	Yard building	Water outlets	Water supply	IN	Fresh water	In port	
LAND AREA OPS	Yard building	Operations	Food supplies	IN	Various		
LAND AREA OPS	Yard building	Operations	Other supplies	IN	Various		
LAND AREA OPS	Yard building	Operations	Maintenance material/spare parts	IN	Various		
LAND AREA OPS	Yard truck	Engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	In port	Air
LAND AREA OPS	Yard truck	Engines; movements; beepers; other	Noise	OUT	Sound waves	In port	Acoustic
LAND AREA OPS	Yard truck	Operations	Oily and other Waste	OUT	Various - Separated flows	In port	Reception Facilities
LAND AREA OPS	Yard truck	Operations	Garbage	OUT	Various - Separated flows	In port	Reception Facilities
LAND AREA OPS	Yard truck	Operations	Electrical supply	IN	Electricity		
LAND AREA OPS	Yard truck	Operations	Maintenance material/spare parts	IN	Various		
LAND AREA OPS	Yard truck	Operations	Fuel	IN	Petrol; diesel; LNG; other	In port	
LAND AREA OPS	Yard cars	Engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	In port	Air
LAND AREA OPS	Yard cars	Engines; movements; beepers; other	Noise	OUT	Sound waves	In port	Acoustic
LAND AREA OPS	Yard cars	Operations	Oily and other Waste	OUT	Various - Separated flows	In port	Reception Facilities
LAND AREA OPS	Yard cars	Operations	Garbage	OUT	Various - Separated flows	In port	Reception Facilities
LAND AREA OPS	Yard cars	Operations	Maintenance material/spare parts	IN	Various	In port	Reception Facilities
LAND AREA OPS	Yard cars	Engines	Fuel	IN	Petrol; diesel; LNG; other		
LAND AREA OPS	Yard cars	Motors	Electrical supply	IN	Electricity		
LAND AREA OPS	Commute/Visit	Engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	Outside port	Air
LAND AREA OPS	Commute/Visit	Engines; movements; beepers; other	Noise	OUT	Sound waves	Outside port	Acoustic
LAND AREA OPS	Commute/Visit	Vehicles	Traffic	OUT	Vehicles in road network	Outside port	Socio-economic

LAND AREA OPS	Intermodality trucks	Engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	Outside port	Air
LAND AREA OPS	Intermodality trucks	Engines; movements; beepers; other	Noise	OUT	Sound waves	Outside port	Acoustic
LAND AREA OPS	Intermodality trucks	Vehicles	Traffic	OUT	Vehicles in road network	Outside port	Socio-economic
LAND AREA OPS	Port vessels		VARIOUS	OUT	VIEW PORT VESSEL TABLE		Water/Soil/Air/Societal/Economic
LAND AREA OPS	Intermodality feeders/ships		VARIOUS	OUT	VIEW CONTAINER SHIP TABLE	Near port	Water/Soil/Air/Societal/Economic
LAND AREA OPS	Intermodality trains	Engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	Outside port	Air
LAND AREA OPS	Intermodality trains	Engines; movements; beepers; other	Noise	OUT	Sound waves	Outside port	Acoustic
LAND AREA OPS	Intermodality trains	Trains	Traffic	OUT	Trains in rail network	Outside port	Socio-economic
LAND AREA OPS	Intermodality trains	Motors; other equipment	Electricity supply	IN	Electricity		
LAND AREA OPS	Yard lights all	Lighting equipment	Luminescense	OUT	Photons	Near port	Light
LAND AREA OPS	All moves in yard	Yard pavement	Dust	OUT	Particulate matter	In port	Air
LAND AREA OPS	Yard run-offs	Yard pavement	Liquids	OUT	Various liquids - disolved solids	In port	Water
LAND AREA OPS	Yard run-offs	Yard pavement	Solids	OUT	Various solids	In port	Soil-Sediments
LAND AREA OPS	Vegetation	Flora	Irrigation	IN	Fresh water	In port	
LAND AREA OPS	Vegetation	Flora	Noise reduction	OUT	Noise reduction	Near port	Acoustic
LAND AREA OPS	Employment	Land operations	Work demand	IN	Personnel	Near port	Socio-economic
LAND AREA OPS	Renewable energy	Wind mills; solar panels; breakwaters energy; cranes energy; other	Energy production	INTERNAL	Electricity	In port	
LAND AREA OPS	Cold-ironing	Ship berths	Electrical supply	IN	Electricity	In port	
LAND AREA OPS	Bunkering	Refueling facilities	Fuel	IN	Various fuel types	In port	
LAND AREA OPS	Accidents-Spills	All activities	VARIOUS	OUT	VIEW ACCIDENTS-SPILLS-COLLISIONS TABLE	In port	Water/Soil/Air/Societal/Economic
LAND AREA OPS	Construction	All activities	VARIOUS	OUT	VIEW CONSTUCTION-MAINTENANCE-PHYSICAL PRESENCE TABLE	Near port	Water/Soil/Air/Societal/Economic
LAND AREA OPS	Maintenance	All activities	VARIOUS	OUT	VIEW CONSTUCTION-MAINTENANCE-PHYSICAL PRESENCE TABLE	Near port	Water/Soil/Air/Societal/Economic
LAND AREA OPS	Expansion	All activities	VARIOUS	OUT	VIEW CONSTUCTION-MAINTENANCE-PHYSICAL PRESENCE TABLE	Near port	Water/Soil/Air/Societal/Economic
LAND AREA OPS	Physical presence	All activities	VARIOUS	OUT	VIEW CONSTUCTION-MAINTENANCE-PHYSICAL PRESENCE TABLE	Near port	Water/Soil/Air/Societal/Economic
LAND AREA OPS	Land use	Port land use	Pressure	OUT	All envirnmental flows	Near port	Socio-economic
LAND AREA OPS	Port activities	All port activities	Influence	OUT	All port activities	Near port	Socio-economic
LAND AREA OPS	Port activities	Main function	Exchange	IN-OUT	Comodities		Socio-economic
LAND AREA OPS	Port activities	Main function	Creation	IN-OUT	Value added services	Near port	Socio-economic

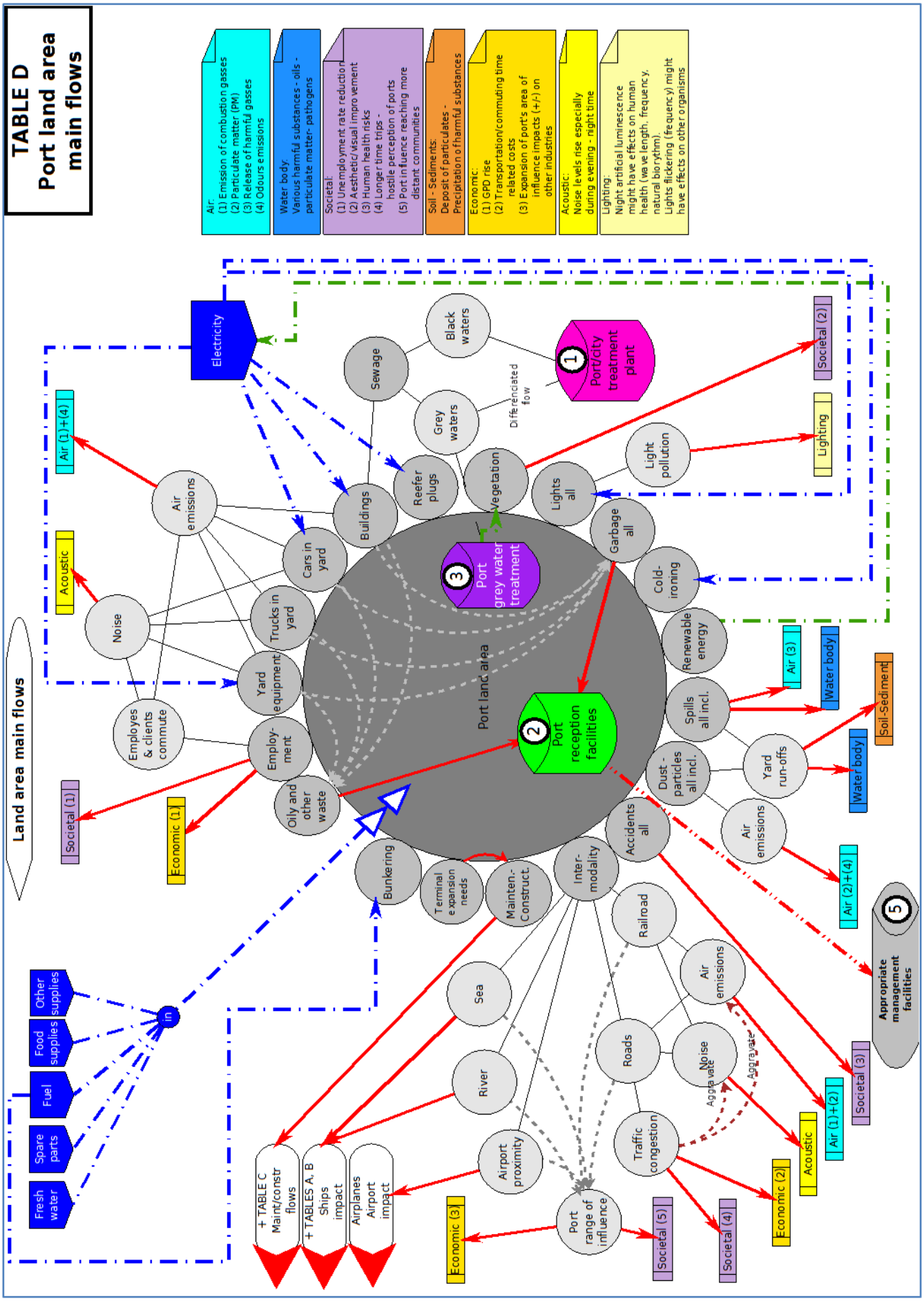


TABLE D
Port land area
main flows
Air:
(1) Emission of combustion gasses
(2) Particulate matter (PM)
(3) Release of harmful gasses
(4) Odours emissions
Water body:
Various harmful substances - oils - particulate matter- pathogens
Societal:
(1) Unemployment rate reduction
(2) Aesthetic/visual improvement
(3) Human health risks
(4) Longer time trips - hostile perception of ports
(5) Port influence reaching more distant communities
Soil - Sediments:
Deposit of particulates - Precipitation of harmful substances
Economic:
(1) GPD rise
(2) Transportation/commuting time related costs
(3) Expansion of port's area of influence impacts (+/-) on other industries
Acoustic:
Noise levels rise especially during evening - night time
Lighting:
Night artificial luminescence might have effects on human health (wave length, frequency, natural biorythm)
Lights flickering (frequency) might have effects on other organisms
Land area main flows
Port land area
Electricity
Black waters
Sewage
Grey waters
Differenciated flow
1 Port/city treatment plant
Societal (2)
Lighting
Light pollution
Air (1)+(4)
Air emissions
Acoustic
Noise
Buildings
Reefer plugs
Vegetation
Lights all
Garbage all
Cars in yard
Trucks in yard
Yard equipment
3 Port grey water treatment
Cold-ironing
Renewable energy
Employes & clients commute
Employ-ment
Societal (1)
Economic (1)
Oily and other waste
2 Port reception facilities
Spills all incl.
Air (3)
Water body
Soil-Sediment
Dust - particles all incl.
Yard run-offs
Water body
Air emissions
Air (2)+(4)
Accidents all
Bunkering
Terminal expansion needs
Mainten.-Construct.
Inter-modality
Railroad
5 Appropriate management facilities
Sea
River
Roads
Air emissions
Noise
Aggravate
Aggravate
Traffic congestion
Airport proximity
Port range of influence
Societal (3)
Air (1)+(2)
Acoustic
Economic (2)
Societal (4)
Societal (5)
Economic (3)
+ TABLE C Maint/constr flows
+ TABLES A, B Ships impact
Airplanes Airport impact
in
Other supplies
Food supplies
Fuel
Spare parts
Fresh water

Spills – Leaks- Accidents – Collisions Impacts

PRODUCTION - RECEPTION AREA	CATEGORY	PRODUCER-RECEIVER	FLOW TYPE	FLOW DIRECTION	MAIN COMPONENTS OF FLOW	RELATION TO PORT	DESTINATION or MODIFIED MEDIUM/SYSTEM
ALL	L-S-E-A-C	Various	Gasses	OUT	Various harmful/hazardous gasses		Air
ALL	L-S-E-A-C	Various	Gasses	OUT	Flamable gasses		Air
ALL	L-S-E-A-C	Various	Gasses	OUT	Odours		Air
ALL	L-S-E-A-C	Various	Dust - loose materials	OUT	Particulate matter (PM)		Air
ALL	L-S-E-A-C	Various	Various	OUT	Various harmful/hazardous substances		Water
ALL	L-S-E-A-C	Various	Various	OUT	Oils - fuels		Water
ALL	L-S-E-A-C	Various	Various	OUT	Oily wastes		Water
ALL	L-S-E-A-C	Various	Various	OUT	Pathogens		Water
ALL	L-S-E-A-C	Various	Various	OUT	Habitat space reduction		Ecosystems
ALL	L-S-E-A-C	Various	Various	OUT	Habitat degradation		Ecosystems
ALL	L-S-E-A-C	Various	Various	OUT	Biocenosis alteration		Ecosystems
ALL	L-S-E-A-C	Various	Various	OUT	Harm to organisms		Ecosystems
ALL	L-S-E-A-C	Various	Various	OUT	Alien/invasive species		Ecosystems
ALL	L-S-E-A-C	Various	Various	OUT	Various harmful/hazardous deposits		Soil-Sediments
ALL	L-S-E-A-C	Various	Various	OUT	Human health risks		Socio-economic
ALL	L-S-E-A-C	Various	Various	OUT	Aesthetic/visual degradation		Socio-economic
ALL	L-S-E-A-C	Various	Various	OUT	Affected area devaluation		Socio-economic
ALL	L-S-E-A-C	Various	Various	OUT	Effects on other industries		Socio-economic
SHIP/VESSEL	L-S-E-A-C	Various	Various	OUT	Recovery cost		Socio-economic
ALL	L-S-E-A-C	Various	Various	OUT	Fines		Economic
ALL	L-S-E-A-C	Various	Various	OUT	Environmental remedy cost		Socio-economic
ALL	L-S-E-A-C	Various	Various	OUT	Clean-up and decontamination costs		Socio-economic
ALL	L-S-E-A-C	Various	Various	OUT	Insurance costs		Economic
ALL	L-S-E-A-C	Various	Various	OUT	Uninsured costs		Economic

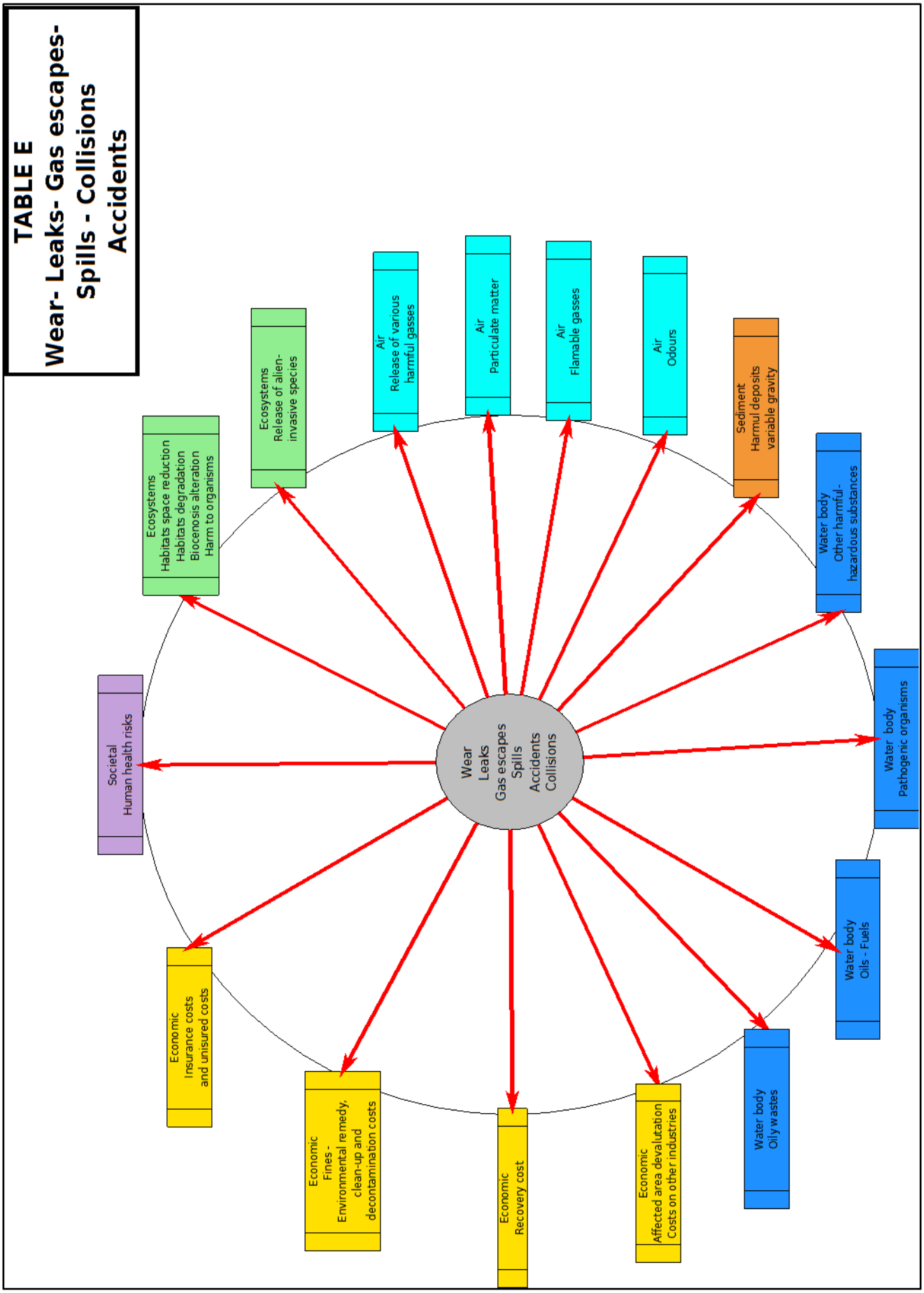


TABLE E
Wear- Leaks- Gas escapes- Spills - Collisions Accidents
Wear
Leaks
Gas escapes
Spills
Accidents
Collisions
Ecosystems
Habitats space reduction
Habitats degradation
Biocenosis alteration
Harm to organisms
Ecosystems
Release of alien-invasive species
Air
Release of various harmful gasses
Air
Particulate matter
Air
Flamable gasses
Air
Odours
Sediment
Harmul deposits variable gravity
Water body
Other harmful-hazardous substances
Water body
Pathogenic organisms
Water body
Oils - Fuels
Water body
Oily wastes
Economic
Affected area devalutation
Costs on other industries
Economic
Recovery cost
Economic
Fines -
Environmental remedy, clean-up and decontamination costs
Economic
Insurance costs and unisured costs
Societal
Human health risks

Appendix D *Definition of elements of PSAF*

D1. Planet elements

From the latest PORTOPIA report (The European Port Industry Sustainability Report 2017), the top 10 environmental priorities of the European port authorities have been examined and comply with all the Planet themes that are presented below.

The Planet (environmental) themes chosen are:

- Air quality
- Water consumption
- Water column quality
- Sediment quality
- Noise
- Energy consumption

In the following sections will follow a description of each of those themes along with the definition of the preliminary operational objectives and the indicators linked to them. Subsequently, the quantitative state concept will be defined and as a consequence, the final operational objectives will be determined.

D1.1 Air quality

Filtering the medium column of the worksheet 'Total flows', the various activities that are affecting the air quality are presented (Table 20).

Table 20: Sources that produce emissions to the air medium

PRODUCTION - RECEPTION AREA	CATEGORY	PRODUCER-RECEIVER	FLOW TYPE	FLOW DIRECTION	MAIN COMPONENTS OF FLOW	RELATION TO PORT	DESTINATION
SHIP	Incinerator	Ship Incinerator	Incineration gasses	OUT	Incinerator gasses: Various gasses. LIMITS: CO < 200 mg/MJ; soot number< Bacharach 3 or Ringelman 1 (20% opacity); Unburned components in ash residues maximum 10% by weight	Open sea	Air
SHIP	Propulsion - Energy production	Main engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	Near port	Air
SHIP	Energy production	Aux engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	In port	Air
PORT VESSEL	Propulsion - Energy production	Main engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	Near port	Air
PORT VESSEL	Energy production	Aux engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	In port	Air
CONSTRUCTION SITE	All equipment	Engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	In port	Air
CONSTRUCTION SITE	All activities	Various	Dust - loose materials	OUT	Particulate matter	In port	Air
LAND AREA OPS	Yard equipment	Engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	In port	Air
LAND AREA OPS	Yard building	Temperature control equipment	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	In port	Air
LAND AREA OPS	Yard truck	Engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	In port	Air
LAND AREA OPS	Yard cars	Engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	In port	Air
LAND AREA OPS	Commute/Visit	Engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	Outside port	Air
LAND AREA OPS	Intermodality trucks	Engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	Outside port	Air
LAND AREA OPS	Intermodality trains	Engines	Combustion gasses	OUT	NOx, SOx, CO, CO2, PM, VOC, HC, odours; other	Outside port	Air
LAND AREA OPS	All moves in yard	Yard pavement	Dust	OUT	Particulate matter	In port	Air
ALL	L-S-E-A-C	Various	Gasses	OUT	Various harmful/hazardous gasses		Air
ALL	L-S-E-A-C	Various	Gasses	OUT	Flamable gasses		Air
ALL	L-S-E-A-C	Various	Gasses	OUT	Odours		Air
ALL	L-S-E-A-C	Various	Dust - loose materials	OUT	Particulate matter (PM)		Air

From Table 20 it can be concluded that the combustion gasses from the auxiliary engines of container ships and feeder vessels, the emissions from equipment during eventual construction, maintenance activities, combustion gasses from the engines of the yard equipment, the yard and intermodal trucks, as well as the intermodal train, produce emissions affecting the air medium. Additionally, suspended dust from the yard pavement is also taken into account.

Additionally, even though this would be considered an indirect effect to the air quality, it would be worth observing the flows of fuel entering the container terminal domain to be used by ships, various activities during construction, yard equipment, trucks and cars used in the yard as well as bunkering (Table 21). With the exception of bunkering and container/feeder ship fuel supply (that are the same), the rest of the flows of fuel corresponding to combustions inside the port area.

Table 21: Flows of fuel that enter the Container Terminal domain

PRODUCTION - RECEPTION AREA	CATEGORY	PRODUCER-RECEIVER	FLOW TYPE	FLOW DIRECTION	MAIN COMPONENTS OF FLOW
SHIP	Bunkering	Ship operations	Fuel supply	IN	Various types of fuel
PORT VESSEL	Bunkering	Ship operations	Fuel supply	IN	Various types of fuel
CONSTRUCTION SITE	All activities	Engines	Fuel supply	IN	Petrol; diesel; LNG; other
LAND AREA OPS	Yard equipment	Various	Fuel supply	IN	Petrol; diesel; LNG; other
LAND AREA OPS	Yard truck	Operations	Fuel supply	IN	Petrol; diesel; LNG; other
LAND AREA OPS	Yard cars	Engines	Fuel supply	IN	Petrol; diesel; LNG; other
LAND AREA OPS	Bunkering	Refueling facilities	Fuel	IN	Various fuel types

D1.1.1 Preliminary operational objective

- The concentration of harmful components in the air medium should not exceed levels that can harm the environment or the living conditions.
- The fuel consumption of the container terminal should be lowered.

D1.1.2 Indicators

The indicators chosen to express in detail the theme of air quality and to monitor the achievement of the operational objective are presented below:

- Air quality standards (NO2, CO, SO2, PM10)
- CO2 footprint
- Fuel consumption (and the ratio of fuel consumption over the total container units traffic)

Those indicators are defined using Table 20 and Table 21. The combustion gasses that are the main outflow in the medium of air are comprised of the air quality standards that are mentioned in the above list.

The **CO2 emissions** are decided to be considered as a separate indicator since it represents the biggest share of the greenhouse gases (GHG). "Carbon footprinting of container terminals is not yet mandatory but recommended", writes Professor Jens Froese from the Global Logistics Emission Council (GLEC).

The **fuel consumption**, even if indirectly, can be used to reflect upon the air quality level of the container terminal entity.

D1.1.3 Thresholds/ Target values

Air quality standards (NO2, CO, SO2, PM10):
From the "Standards - Air Quality - Environment - European Commission" The standards are found.

- **SO2: 350 µg/m3 1 hour - 125 µg/m 24 hours**
- **NO2: 200µg/m3 1hour - 40 µg/m3 1 year**
- **CO: 10 mg/m3 maximum daily 8-hour mean**
- **PM10: 50 µg/m3 24 hours - 40 µg/m3 1 year**

Carbon footprint

Over a period of five years, CO2 emissions must fall by 10% (this target was achieved from the Port of Rotterdam from 2012 until 2017).

In the European Union, a strong variability exists on several techno-economic parameters, for instance, the composition of the electrical mix. This is evident especially regarding policies promoting electric vehicles: the GHG savings that derive from the use of electric instead of internal combustion vehicles may vary for each Member State, and it depends on the average carbon footprint of the electricity mix which is produced nationally or regionally (Moro and Lonza, 2017). Therefore, the threshold that was defined above referring to a percentage cannot be translated into the same volume of CO2 emissions for each country.

Fuel consumption

In the Recommendations Manual for terminals by Froese, Töter, and Erdogan 2014, it is indicated that through the use of hybrid technology (diesel-electric) and energy recuperation it was proved that the total operations' energy consumption can be reduced up to 45%. Furthermore, there are other existing measures that can be also adopted, for example, the use of start-stop engines technology to all diesel equipment, which could permit a further reduction of fuel consumption between 10 – 15%; the use of alternative fuels and power sources like fuel cells, hydrogen fuel and LNG.

Based on the aforementioned Manual, the fuel consumption should be reduced by more than 20% in the next 5 years.

D1.1.4 Final operational objectives

Considering the information given by the quantitative state concept, the operational objectives that were set in the previous steps are amended to:

- The concentration of air pollutants should be lower than the standards defined by the European Commission.
- Over a period of five years, CO2 emissions must fall by 10%.
- The fuel consumption should be reduced by more than 20% in the next 5 years.

D1.2 Soil- sediment quality and quantity

Filtering the medium column of the worksheet 'Total flows', the various activities that are affecting the sediment quality and the coastal morphology are presented (Table 22).

Table 22: Sources that produce flows that cause stresses in the soil and the sediment

PRODUCTION - RECEPTION AREA	CATEGORY	PRODUCER-RECEIVER	FLOW TYPE	FLOW DIRECTION	MAIN COMPONENTS OF FLOW	RELATION TO PORT	DESTINATION or MODIFIED MEDIUM/SYSTEM
SHIP	Ship hull	Ship hull	Anti-fouling	OUT	Antifouling paint components	Near port	Soil-Sediments
PORT VESSEL	Ship hull	Ship hull	Anti-fouling	OUT	Antifouling paint components	Near port	Soil-Sediments
CONSTRUCTION SITE	All activities	Various	Dust - loose materials	OUT	Particulate matter - other materials	In port	Soil-Sediments
PORT INFRASTRUCTURE	Upland run-offs	Port basin	Solids	IN	Various solids	In port	Soil-Sediments
PORT INFRASTRUCTURE	Marine infrastructure	Breakwaters-Sea reclamations	Coastal processes	OUT	Waves- Currents - Sediment transport	Near port	Soil-Sediments
PORT INFRASTRUCTURE	Dredging	Port basin	ged material open sea dun	OUT	Non hazardous material	Outside port	Soil-Sediments
LAND AREA OPS	Yard run-offs	Yard pavement	Solids	OUT	Various solids	In port	Soil-Sediments
ALL	L-S-E-A-C	Various	Various	OUT	Various harmful/hazardous deposits		Soil-Sediments

The container ships' and feeder vessels' anti-fouling components can affect the sediment quality. During the eventual construction activities, dust-loose materials from the construction site could be

suspended, resulting in the water body and consequently in the soil. The upland run-offs, as well as the yard run-offs, can carry solids that will end up in the soil, causing deteriorations of the quality. Last but not least, the category of Spills-Leaks-Accidents and Collisions is also affecting the sediment quality via eventual deposit (harmful or hazardous).

D1.2.1 Preliminary operational objectives

The concentration of harmful components in the sediments should not exceed levels that can affect ecosystems.

D1.2.2 Indicators

- Presence of heavy metals
- Oil concentration

For the definition of the indicators, the most important elements of the general components mentioned in Table 24 were traced from the Work Package 2.2: Environmental Monitoring Systems in European Ports from the Med Maritime Integrated Projects - Mermaid, 2015, which specifically refers to the port of Piraeus and Livorno.

As far as the definition of the heavy metals, it is stated in the OSPAR Guidelines for the Management of Dredged Material at Sea (OSPAR COMMISSION 2014) the following trace metals should be determined in all cases: Cadmium (Cd), Copper (Cu), Mercury (Hg), Zinc (Zn), Chromium (Cr), Lead (Pb), Nickel (Ni).

D1.2.3 Thresholds/ Target values

Heavy metals

As also refers the ECOPORT 8 2012, the most apt European legislative instrument that deals with soil contamination prevention and management (until the Soil Framework Directive implementation) is the Landfill Directive (Council Directive 1999/31/EC).

The limit values for non-hazardous waste are presented in the Official Journal of the European Communities 2002b'Establishing criteria and procedures for the acceptance of waste at landfills pursuant to Annex II to Directive 1999/31/EC'. The limit values refer to:

> "*granular non-hazardous waste recognized in the same cell as stable, non-reactive hazardous waste, calculated at L/S = 2 and 10 l/kg for total release and directly expressed in mg/l for C0 (in the first eluate of percolation test at L/S = 0,1 l/kg). The granular wastes contain all wastes which are not considered monolithic. Member States should define which the corresponding limit values they will use*".

Source: (Annex II to Directive 1999/31/EC)

Calculated at L/S= 2 l/kg for total release

- Cadmium (Cd): 0.6 mg/l
- Copper (Cu): 25 mg/l
- Mercury (Hg): 0.05 mg/l
- Zinc (Zn): 25 mg/l
- Chromium (Cr): 4 mg/l
- Lead (Pb): 5 mg/l
- Nickel (Ni): 5 mg/l

Oil concentration

As stated in the (Ministerie van Volkshuisvesting Ruimtelijke Ordeningen Milieu 2000): Dutch targets and intervention values. These values, for the soil, are presented in mg/kg dry matter and they are widely used. The threshold for PAHs is 40 mg/kg dry (Table 23)

Table 23: Polycyclic aromatic hydrocarbons (PAH)

IV Polycyclic aromatic hydrocarbons (PAH)				
PAH (sum 10) [4.14]	1	40	-	-
naphthalene			0.01	70
anthracene			0.0007*	5
phenatrene			0.003*	5
fluoranthene			0.003	1
benzo(a)anthracene			0.0001*	0.5
chrysene			0.003*	0.2
benzo(a)pyrene			0.0005*	0.05
benzo(ghi)perylene			0.0003	0.05
benzo(k)fluoranthene			0.0004*	0.05
indeno(1,2,3-cd)pyrene			0.0004*	0.05

D1.2.4 Final operational objectives

Considering the information given by the quantitative state concept, the operational objectives that were set in the previous steps are amended to:

- The heavy metals concentration in the sediment of the port basin should be less than the values that are defined in Annex II to Directive 1999/31/EC.
- The oil concentration in the soil should be less than 40 mg/kg dry.

D1.3 Water quality

Filtering the medium column of the worksheet 'Total flows', the various activities that are affecting the water quality are presented (Table 24).

Table 24: Sources that produce flows to the water medium

PRODUCTION - RECEPTION AREA	CATEGORY	PRODUCER-RECEIVER	FLOW TYPE	FLOW DIRECT	MAIN COMPONENTS OF FLOW	RELATION TO PORT	DESTINATION or MODIFIE
SHIP	Ship drainage system	Toilets; latrines; washing machines; other	Sewage	OUT	Sewage Marpol 73/78 Annex IV: Black and grey waters Minimum pathogens - other	Open sea	Water
SHIP	Ship hull	Ship hull	Anti-fouling	OUT	Antifouling paint components	Near port	Water
SHIP	Ballast tanks	Ship ballast	Ballast tanks	OUT	Ballast water treated - BWMS approved (BWM - 2017) Minimum presence of species	Open sea	Water
PORT VESSEL	Ship hull	Ship hull	Anti-fouling	OUT	Antifouling paint components	Near port	Water
CONSTRUCTION SITE	All activities	Various	Dust - loose materials	OUT	Particulate matter - other materials	In port	Water
CONSTRUCTION SITE	Marine activities	Various	ıent resuspension and trar	OUT	Various sediment components	Near port	Water
PORT INFRASTRUCTURE	Upland run-offs	Port basin	Liquids	IN	Pathogens; various liqids - disolved solids	In port	Water
PORT INFRASTRUCTURE	Breakwaters	Breakwaters	Modification-obstruction	OUT	Basin's water circulation	In port	Water
PORT INFRASTRUCTURE	Dredging	Port basin	Dredging operations	OUT	Resuspension of sediments	Near port	Water
LAND AREA OPS	Yard run-offs	Yard pavement	Liquids	OUT	Various liquids - disolved solids	In port	Water
ALL	L-S-E-A-C	Various	Various	OUT	Various harmful/hazardous substances		Water
ALL	L-S-E-A-C	Various	Various	OUT	Oils - fuels		Water
ALL	L-S-E-A-C	Various	Various	OUT	Oily wastes		Water
ALL	L-S-E-A-C	Various	Various	OUT	Pathogens		Water

The container ships' and feeder vessels' produce flows to the water medium through sewage, anti-fouling and ballast tanks. During the eventual construction activities, dust-loose materials from the construction site could be suspended and result in the water body. The quality of the sea water column can be affected as well from upland run-offs in the port basin (inflow) as well as yard run-

offs. Additionally, dredging activities cause suspension of sediment and the existence of breakwaters also affects the circulation of water and the sediment transport in the port basin. Last but not least, the category of Spills-Leaks-Accidents and Collisions is also affecting the water quality via the eventual liquid flow of substances (harmful or not), oils-fuels and pathogens.

D1.3.1 Preliminary operational objective

The concentration of harmful components in the sea water body should not exceed levels that can harm the ecosystems.

D1.3.2 Indicators

- Ecoli / Intestinal enterococci
- Heavy metals
- Transparency-turbidity
- Oil concentration

For the definition of the indicators, the elements that are monitored as far as water quality were traced from the Work Package 2.2: Environmental Monitoring Systems in European Ports from the Med Maritime Integrated Projects - Mermaid, 2015, which specifically refers to the port of Piraeus and Livorno.

D1.3.3 Thresholds/ Target values

Intestinal enterococci and E.coli

Based on Annex I to Directive 2006/7 in Greece the threshold for excellent quality of waters is 500 cfu/100 ml and 200 cfu/100ml for the Intestinal enterococci and E.coli respectively.

Heavy metals

Based on Annex II of the amended Directives 2000/60/EC and 2008/105/EC (31.1.2012) from the European Commission the limits of the heavy metals in the seawater are defined as:

Mercury (Hg) < 0,07 μg/l
Nickel (Ni) < 34 μg/l
Cadmium (Cd) (depending on water hardness classes)

- ≤ 0,45 μg/l (Class 1)
- 0,45 μg/l (Class 2)
- 0,6 μg/l (Class 3)
- 0,9 μg/l (Class 4)
- 1,5 μg/l (Class 5)

Lead (Pb) < 14 μg/l

Oil concentration

The maximum concentration should be 200 μg/L (Source: Neff 1979)

Transparency/turbidity

From the study of Giuseppe Magazu, 1978: Methods of study of the plankton and of the marine production a depth of 8m of Secchi disk depth approximately is considered adequate.

D1.3.4 Final operational objectives

Considering the information given by the quantitative state concept, the operational objectives that were set in the previous steps are amended to:

- The concentration of Intestinal Enterococci and E.coli should be below the levels indicated by each country's Directive.
- The heavy metals should be lower than what is defined by the European Commission
- The oil concentration should be less than 200 μg/L.
- The water transparency should be good, indicated with 8m of Secchi disk depth.

D1.4 Water consumption

Filtering the medium column of the worksheet 'Total flows', the activities and operations that are requiring a supply of water are presented (Table 25).

Table 25: Water supply that is required in the Container Terminal domain

PRODUCTION - RECEPTION AREA	CATEGORY	PRODUCER-RECEIVER	FLOW TYPE	FLOW DIRECTION
SHIP	Ship general	Ship operations	Fresh water supply	IN
PORT VESSEL	Ship general	Ship operations	Fresh water supply	IN
LAND AREA OPS	Yard building	Water outlets	Water supply	IN
LAND AREA OPS	Vegetation	Flora	Irrigation	IN

Freshwater supply is needed for the various ships operations as well as for the terminal buildings. Regarding the eventual vegetation that may exist in the terminal area, the water for irrigation could derive from the treated grey waters that are produced from the various port operations.

D1.4.1 Preliminary operational objectives

The water consumption should be optimized according to the traffic of the container terminal, using the treated grey waters where applicable.

D1.4.2 Indicators

- The volume of fresh water consumed from terminal building and operations (possibly divided by the port calls and the number of employees)
- The ratio of the volume of reuse of treated greywater and total required volume of water.

The above-mentioned indicators will contribute to the monitoring of the target set by the operational objective, through the optimization of the freshwater consumption and increase of reuse of the treated grey water.

D1.4.3 Thresholds/ Target values

There is no specific threshold for the indicators that were specified in the previous subchapter. There should be a continuous effort from the container terminal to reduce water consumption.

D1.4.4 Final operational objective

The quantitative state concept did not contribute on the amendment of the preliminary operational objective. Therefore, the preliminary operational objective will be maintained:

- The water consumption should be optimized according to the traffic of the container terminal, using the treated grey waters where applicable.

D1.5 Noise

Filtering the medium column of the worksheet 'Total flows', the various activities that are affecting the sediment quality are presented in Table 26.

Table 26: Sources that produce noise that cause stresses in the acoustic environment

PRODUCTION - RECEPTION AREA	CATEGORY	PRODUCER-RECEIVER	FLOW TYPE	FLOW DIRECTION	MAIN COMPONENTS OF FLOW	RELATION TO PORT	DESTINATION or MODIFIED MEDIUM/SYSTEM
SHIP	Propulsion - Energy production	Engines, fans. Other equipment	Noise	OUT	Sound waves	Near port	Acoustic
PORT VESSEL	Propulsion - Energy production	Engines, fans. Other equipment	Noise	OUT	Sound waves	Near port	Acoustic
CONSTRUCTION SITE	All activities	Engines; movements; beepers; other	Noise	OUT	Sound waves	In port	Acoustic
LAND AREA OPS	Yard equipment	Engines; movements; beepers; other	Noise	OUT	Sound waves	In port	Acoustic
LAND AREA OPS	Yard building	Various building equipment	Noise	OUT	Sound waves	In port	Acoustic
LAND AREA OPS	Yard truck	Engines; movements; beepers; other	Noise	OUT	Sound waves	In port	Acoustic
LAND AREA OPS	Yard cars	Engines; movements; beepers; other	Noise	OUT	Sound waves	In port	Acoustic
LAND AREA OPS	Commute/Visit	Engines; movements; beepers; other	Noise	OUT	Sound waves	Outside port	Acoustic
LAND AREA OPS	Intermodality trucks	Engines; movements; beepers; other	Noise	OUT	Sound waves	Outside port	Acoustic
LAND AREA OPS	Intermodality trains	Engines; movements; beepers; other	Noise	OUT	Sound waves	Outside port	Acoustic
LAND AREA OPS	Vegetation	Flora	Noise reduction	OUT	Noise reduction	Near port	Acoustic

The container ships and the feeder vessels cause stresses in the acoustic environment through their engines, fans and other types of equipment. During construction, the acoustic medium is affected by the engines, the movements, the beepers and other equipment. The yard operations increase the noise levels in a container terminal due to the yard equipment (Gantry Container Cranes etc.), the yard and intermodal trucks and trains and the yard cars that are creating traffic in the terminal.

D1.5.1 Preliminary operational objective

The levels noise levels in the ports should not constitute excessive noise exposure towards the city residential area and the staff of the terminal.

D1.5.2 Indicators

The Lden (Day Evening Night Sound Level) will be used as an indicator for the noise levels. Lden is the average sound level over a 24 hour period, with a penalty of 5 dB added for the evening hours, from 19:00 to 22:00, and 10 dB added for the night time hours, from 22:00 to 07:00.

D1.5.3 Thresholds/ Target values

In the Greek Government Gazette 293/A/6-10-1981 Article 2 Paragraph 5 it is indicated that the noise limit in an area that is exclusively industrial is 70 dB(A). In areas that are mainly industrial, the threshold is 65 dB (A) and in those that prevails both the industrial and the urban element the limit is 55 dB (A).

The transport noise limit values in Greece, which are set out in the Ministerial Decision 211773/2012 (Official Gazette 367/B'/27.4.2012) are set at 2 metres from the building façade and correspond to Lden(24 hr) equal to 70 dB (A).

In the Italian Decree of the President of the Council of Ministers (DPCM) 14/11/97 it is indicated that the noise threshold in exclusively industrial areas is 70 dB (A), in mainly industrial areas 70 dB (A) and in those that prevails both the industrial and the urban element the limit is 65 dB (A).

D1.5.4 Final operational objective

Considering the information given by the quantitative state concept, the operational objectives that were set in the previous steps are amended to:

- The noise levels in the ports should not exceed the limits in areas that are mainly industrial, defined by each country's Decree.

D1.6 Energy consumption

Filtering the flow type column of the worksheet 'Total flows', the various activities that are requiring electricity inflow are presented in.

Table 27: Flows of electrical energy that enter the Container Terminal domain

PRODUCTION - RECEPTION AREA	CATEGORY	PRODUCER-RECEIVER	FLOW TYPE	FLOW DIRECTION
SHIP	Cold ironning	Ship operations	Electrical supply	IN
PORT VESSEL	Ship general	Cold ironning	Electrical supply	IN
CONSTRUCTION SITE	All equipment	Various	Electrical supply	IN
LAND AREA OPS	Yard equipment	Motors; actuators; beepers; movement;	Electrical supply	IN
LAND AREA OPS	Yard reefer plugs	Operation	Electrical supply	IN
LAND AREA OPS	Yard building	Temperature control equipment	Electrical supply	IN
LAND AREA OPS	Yard truck	Operations	Electrical supply	OUT
LAND AREA OPS	Yard cars	Motors	Electrical supply	IN
LAND AREA OPS	Intermodality trains	Motors; other equipment	Electricity supply	IN
LAND AREA OPS	Renewable energy	Wind mills; solar panels; breakwaters	Energy production	INTERNAL
LAND AREA OPS	Cold-ironing	Ship berths	Electrical supply	IN

On the one hand, high electricity consumption in a container terminal might entail that the fossil fuel consumptions are lower due to switching to electrical cranes and equipment, on the other hand, excessive electricity consumption has an indirect impact to the wider environment and not exclusively inside the container terminal domain.

Based on the Table presented above, electricity is consumed by the container ships' and the feeder vessels' various operations, the equipment used in the construction site, the various yard equipment (cranes etc.), the yard reefer plugs, the yard building temperature control equipment, eventually the yard cars and trucks in the case they are electrical, the intermodal trains and last but not least the cold ironing are considered consumers of electricity.

D1.6.1 Preliminary operational objective

The ratio of electricity consumption to TEUs traffic should be optimized.

The ratio of electricity consumption to fuel consumption should be increasing.

The ratio of energy from renewable sources to the total energy consumption should be increasing.

D1.6.2 Indicators

- Ratio electricity consumption/TEU
- Ratio electricity consumption/fuel consumption
- Ratio energy from renewable sources/total energy consumption

The indicators chosen are closely related to the preliminary objectives that are defined.

D1.6.3 Thresholds/ Target values

Considering the results of the thesis study of Heij in 2015, he described that a 50% decrease in the peaks of the electricity demand would be beneficial for the optimization of the terminal's operations in respect to the cost and the handling capacity. This reduction should be intersected with the eventual increase of the electrical consumption (switching from diesel) and the cost in which this shift would be translated to. Therefore, it can be understood that it would not make sense to define a threshold for this multi-parameter problem and instead a more general operational target will be set.

D1.6.4 Final operational objectives

The quantitative state concept did not contribute through the introduction of threshold on the amendment of the preliminary operational objective. Therefore, the preliminary operational objective will be maintained:

- The ratio of electricity consumption to TEUs traffic should be optimized.
- The ratio of electricity consumption to fuel consumption should be increasing.
- The ratio of energy from renewable sources to the total energy consumption should be increasing.

Additionally, the following more generalized operational objective is set:

- “Optimize pollution reduction while maintaining a commercially-viable operation that does not significantly increase costs and waiting times for their customers”.

D2. People elements

The People (socio-economic) themes are:

- Employment opportunities
- Safety levels
- Land use charges
- Recreation and aesthetics
- Stakeholders involvement
- Traffic congestion

The above-mentioned sustainability themes reflect upon **socio-economic** matters, rather than purely social aspects. It is clear, that the interconnection between society and economy is strong. For instance, the sustainability theme “recreation and aesthetics” is related to the satisfaction and well-being of the society but also affects the economy by means of tourism and not only. More details will be found in the following relevant subsection.

In the following subchapters will follow a description of each of those themes along with the definition of the preliminary operational objectives and the indicators linked to them. Subsequently, the quantitative state concept will be defined and as a consequence, the final operational objectives will be determined.

The societal quantitative state concept will be defined only partially since the social elements reflect on qualitative concepts, however, an attempt will be made to transform them into a more quantitative concept.

D2.1 Employment opportunities

Filtering the Category column of the worksheet 'Total flows', the activities that are contributing in the employment opportunities are presented in Table 28.

Table 28: Activities that create employment opportunities in the Container Terminal

PRODUCTION - RECEPTION AREA	CATEGORY	PRODUCER-RECEIVER	FLOW TYPE	FLOW DIRECTION	MAIN COMPONENTS OF FLOW	RELATION TO PORT	DESTINATION or MODIFIED MEDIUM/SYSTEM
CONSTRUCTION SITE	Employment	Constr. operations	Work demand	IN	Personnel	Near port	Socio-economic
LAND AREA OPS	Employment	Land operations	Work demand	IN	Personnel	Near port	Socio-economic
LAND AREA OPS	Port activities	Main function	Creation	IN-OUT	Value added services	Near port	Socio-economic

The various operations that are contributing in the employment opportunities are involved with the construction site and the land operations but also with the industries that are indirectly related to the port. In that sense, possible expansions of the yard area, growth of terminal capacity, upgrade of the rail network and other relevant activities can create additional job positions. The value-added services can also lead to the creation of employment opportunities. On the other hand, the automatization of the container terminal can trigger a decrease in employment opportunities in the container terminal domain.

The creation of employment opportunities is related to the working conditions as well (salary, right for holiday leave, days off etc.).

Economically, the creation of employment opportunities is related to the GDP rise.

D1.1.1 Preliminary operational objective

The staff of the container terminal should feel satisfied with the working conditions based on the local economy.

Along with the possible expansion or growth of the port, employment opportunities should be created not necessarily in the terminal domain, but also in the related industries.

D1.1.2 Indicators

- Staff satisfaction
- Estimation of the workforce directly and indirectly related to the container terminal's operation
- New job positions through the expansion or introduction of industries that are indirectly related to the terminal

D1.1.3 Thresholds/ Target values

A threshold cannot be designated in this specific theme.

D1.1.4 Final operational objectives

The quantitative state concept did not contribute on the amendment of the preliminary operational objective. Therefore, the preliminary operational objectives will be maintained but they will be more closely defined:

- Value-added services should be introduced both for the terminal's economic benefit and for the introduction of new job positions.
- The expansion of the port should come along with job opportunities in other sectors.
- The working conditions (salaries, holiday leave, allowances etc. should be satisfactory relatively to each countries' local economy.

D2.2 Safety levels

Safety in a container terminal is a subject that is related to eventual accidents/leaks/collisions etc. as well as to everyday operations of container handling. Eventual climate variability and change impacts to the ports are included in the category of accidents since can be considered to affect the safety levels of a port.

D1.2.1 Preliminary operational objective

The terminal should comply with all the regulations regarding the preventions of accidents.

The personnel of the container terminal should receive regular training regarding the everyday operations of the yard equipment, as well as handling of hazardous cargo.

The terminal should incorporate climate change adaptability in their policies.

D1.2.2 Indicators

- Yearly mean accidents at work (container terminal) with sick leave
- Frequency of personnel training
- Level of container terminals' compliance with safety regulations
- Inclusion of climate change adaptation policies in the development measures of the ports

The indicators mentioned are connected to the preliminary operational objectives. Frequent and updated training sessions and following safety regulations would have an effect in the safety levels achieved in the container terminal.

D1.2.3 Thresholds/ Target values

A threshold could not be assigned on the frequency of the personnel training, but there should be a proof that there are constant training, every time that new machinery is pursued, or a different system is implemented so that the personnel could operate safely.

D1.2.4 Final operational objectives

The quantitative state concept did not contribute on the amendment of the preliminary operational objective. Therefore, the preliminary operational objectives will be maintained:

- The terminal should comply with all the regulations that are put into force regarding the preventions of accidents.
- The personnel of the container terminal should receive regular training regarding the everyday operations of the yard equipment, as well as handling of hazardous cargo.
- Climate change adaptation should play an inseparable role in the development strategies.

D2.3 Land use changes

This theme refers to all changes to the land use of the surrounding urban fabric that directly and indirectly depend on or are influenced by the port existence and activities.

D1.3.1 Preliminary operational objective

The city should be protected from port intensive activities.

D1.3.2 Indicators

- Existence of a buffer zone in the port-city interface for noise and intense port activities
- Ratio of the sum of residential and commercial uses over industrial uses confining with the port.

D1.3.3 Thresholds/ Target values

A specific threshold cannot be defined for the ratio (Residential + commercial uses)/industrial but the larger it is, the more optimal it becomes.

D1.3.4 Final operational objectives

Considering the information given by the quantitative state concept, operational objectives that were set in the previous steps are amended to:

- A buffer zone should exist in the port-city interface (Noise barriers- vegetation –logistics buildings and include some non-exclusively port-related activities of low intensity)
- The ratio (Residential + commercial uses)/industrial uses should be the maximum possible.

D2.4 Recreation and aesthetics

Filtering the flow type and the destination columns of the worksheet 'Total flows', the effects of the various sub-domains that are affecting the recreational activities and the aesthetics of the container terminal are presented in Table 28.

Table 29: Effects of a Container Terminal to the recreational activities and aesthetics

PRODUCTION - RECEPTION AREA	CATEGORY	PRODUCER-RECEIVER	FLOW TYPE	FLOW DIRECTION	MAIN COMPONENTS OF FLOW	RELATION TO PORT	DESTINATION or MODIFIED MEDIUM/SYSTEM
PORT INFRASTRUCTURE	Land/sea reclamation	Port infrastructure	Damage	OUT	Filling/covering - Occupying	Near port	Socio-economic
PORT INFRASTRUCTURE	Waterfront obstruction	Port infrastructure	Pressure-damage	OUT	Physical presence	Near port	Socio-economic
PORT INFRASTRUCTURE	Marine infrastructure	Breakwaters-Sea reclamations	Coastal processes	OUT	Waves- Currents - Sediment transport	Near port	Socio-economic
PORT INFRASTRUCTURE	Infrastructures	All infrastructures	Sea barrier	OUT	Physical presence	Near port	Socio-economic
PORT INFRASTRUCTURE	Infrastructures	All infrastructures	Upland run-off barrier	OUT	Physical presence	Near port	Socio-economic
LAND AREA OPS	Land use	Port land use	Pressure	OUT	All envirnmental flows	Near port	Socio-economic
ALL	L-S-E-A-C	Various	Various	OUT	Aesthetic/visual degradation		Socio-economic

The land/sea reclamation could lead to possible damage to heritage sites and/r monuments, to land use modifications, property value modifications, propriety expropriations, fishing fields reduction etc. The waterfront obstruction with port infrastructure and the construction of breakwaters may cause pressure to the surrounding environment, reducing the recreational activities, creating a degradation of the aesthetic/visual environment and pressuring the waterfront connected industries. The various port activities may attract other related and similar activities, that are expected to enhance the financial benefit of the port and the local economy, but it will contribute in the aforementioned deterioration of the residential environment if any. It should be considered, that the development of tourism is strongly related to the aesthetics of the area.

D1.4.1 Preliminary operational objectives

The port infrastructures should not be pressuring and/or damaging the environment of the residential area.

D1.4.2 Indicators

- Distance from a residential area
- Existence of marine infrastructures that are damaging the aesthetics
- Ratio of cash flow from recreational activities before and after the construction of marine infrastructures

D1.4.3 Thresholds/ Target values

Relevant factors that could affect the existence of flora used as a noise barrier as well as a view barrier, the location of the port (for example if the location is perpendicular to the residential area towards the sea it is expected to pressure more than if it was located in the same distance but away from the boundaries of the city).

D1.4.4 Final operational objective

Considering the information given by the quantitative state concept, the operational objectives that were set in the previous steps are amended to:

- The existence of marine infrastructures damaging the aesthetics: yes/no.
- The ratio of cash flow from recreational activities after and before the construction of the marine infrastructures should not lower than 1.5.

D2.5 Stakeholder's involvement

The importance of the stakeholder involvement was delineated from the (IAPH-PIANC 2017) which stresses that "*co-operation with all stakeholders is essential in any port development and operations*". It also states that the first set-up of a sustainability report is based on making a stakeholder map and in each consecutive step there is stakeholder involvement.

D1.5.1 Preliminary operational objectives

Stakeholder involvement should be given special focus during the decision making, while at the same time, for each subject matter, infiltrating the weight of each stakeholder's category opinions contribution.

Stakeholders should have access to information on various port-related performance indicators

D1.5.2 Indicators

- Stakeholder satisfaction
- Opinion of each category of stakeholders as to the level of involvement in matters that involve the environment
- Opinion of each category of stakeholders to the level of involvement in matters that involve business strategies
- Level of access on various port-related performance indicators

D1.5.3 Thresholds/ Target values

The stakeholder's satisfaction and their level of involvement will be assessed in a relatively rough manner through questionnaires.

The level of access on various port-related performance indicators will be assessed during this thesis research, through the web search, the contact with the responsible parties of port authorities and terminals.

D1.5.4 Final operational objectives

Considering the information given by the quantitative state concept, the operational objectives that were set in the previous steps are amended to:

- Using the questionnaire that was created for the context of this thesis study, more than 70% of the stakeholders should feel involved in the decision making.
- The information regarding various port performance indicators should be easily accessible.

D2.6 Traffic congestion

Filtering the flow type column of the worksheet 'Total flows', the activities that cause stresses in the traffic congestion outside the port are presented in Table 28.

Table 30: Effects of Container Terminal activities to traffic congestion outside the port

PRODUCTION - RECEPTION AREA	CATEGORY	PRODUCER-RECEIVER	FLOW TYPE	FLOW DIRECTION	MAIN COMPONENTS OF FLOW	RELATION TO PORT	DESTINATION or MODIFIED MEDIUM/SYSTEM
LAND AREA OPS	Commute/Visit	Vehicles	Traffic	OUT	Vehicles in road network	Outside port	Socio-economic
LAND AREA OPS	Intermodality trucks	Vehicles	Traffic	OUT	Vehicles in road network	Outside port	Socio-economic
LAND AREA OPS	Intermodality trains	Trains	Traffic	OUT	Trains in rail network	Outside port	Socio-economic

The vehicles used for commute visits as well as intermodal trucks add to the traffic congestion of the city that is possibly adjacent to the terminal. Intermodal trains could cause overloading of the rail network. On the other hand, it could be considered that if the train leads to eventual decongestion

of the road network. When the traffic exceeds road capacity longer time trips are expected as well as a hostile perception of the port.

Environmentally, traffic congestion also aggravates the emissions of combustion gasses and noise of normal traffic.

Economically, a rise of transportation-commuting time-related costs is expected in the case that the traffic exceeds the road capacity.

D1.6.1 Preliminary operational objectives

The city should not be affected by the traffic that is created by the container terminal, so the traffic on the local road network should not exceed the carrying capacity of the road.

D1.6.2 Indicators

- Hours per working day that the traffic exceeds the carrying capacity of the local road network.

D1.6.3 Thresholds/ Target values

The capacity of the road network should be never exceeded.

D1.6.4 Final operational objective

Considering the information given by the quantitative state concept, the operational objectives that were set in the previous steps are amended to:

- The hours per working day that the traffic exceeds the carrying capacity of the local road network should be zero.

D3. Profit elements

The port Profit (productivity/economic) themes are:

- Intermodality
- Productivity
- Personnel training
- Terminal potential
- Expandability
- Circular economy

The above-mentioned sustainability themes are reflecting mainly upon the internal profit of the port.

In the following subchapters will follow a description of each of those themes along with the definition of the preliminary operational objectives and the indicators linked to them. Subsequently, the quantitative state concept will be defined and as a consequence, the final operational objectives will be determined.

D3.1 Intermodality

By intermodality, it is implied the facility of access to international road networks, connections to the rail network, distance from airports, transhipments etc.

Through the intermodal connections, the port influence can reach a wider area and have impacts on other industries as well. The improvement of the intermodal connection of a port most likely results in growth of its competitiveness.

D1.1.1 Preliminary operational objectives

The intermodal connectivity of the port should be improved according to the needs of the container terminal and the port (rail and road network).

In this theme, there is no specific operational objective, since the reasonable intermodal levels that a container terminal has to reach differ according to the geographical position of the port, the volume of the containers and the forecast of the future traffic and potentials connected to the market.

D1.1.2 Indicators

- Number of lanes in the port entrance
- Rail connection capacity
- Distance from the closest airport
- Transhipment volumes

As mentioned before, the indicators for that theme are only used to describe the current situation and not to set to accomplish operational targets, since they may differ significantly among different ports.

D1.1.3 Thresholds/ Target values

Neither of the indicators mentioned in the previous subchapter can be related to thresholds since they are only describing the current situation and not to set to accomplish operational targets, since they may differ significantly among different ports. Additionally as already mentioned, the reasonable intermodal levels that a container terminal has to reach differ according to the geographical position of the port, the volume of the containers and the forecast of the future traffic and potentials connected to the market.

D1.1.4 Final operational objective

The quantitative state concept did not contribute on the amendment of the preliminary operational objective. Therefore, the preliminary operational objectives will be maintained:

- The intermodal connectivity of the port should be improved according to the needs of the container terminal and the port (rail and road network).

D3.2 Productivity

The productivity and the efficiency of the various container terminal operations (container loading and unloading, logistics of the yard and intermodal truck movements and operations, storage system etc.), is closely related to the profit of the terminal.

D1.2.1 Preliminary operational objectives

The terminal efficiency should be increased in the cases that there is a growing trend of container traffic.

D1.2.2 Indicators

- TEUs traffic over the last years
- Vessel time spent in port
- TEUs/hour/crane
- Moves/crane/hour
- Measure of moves per berth meter
- Number of simultaneous cranes per vessel type
- Truck time spent in the terminal area

The indicators above are reflecting upon the productivity of the container terminal operations.

The first indicator can show the change of the container traffic over the years which could be used as an indication eventual growth of container traffic over the last years would imply that the productivity levels should be increased.

Efficient cargo handling operations as measured by crane productivity and contributes significantly to cargo being able to rapidly leave the port. Vessel time in port includes the time prior to berthing,

time spent at berth (dwell and working times) and time spent undocking and transiting beyond port limits (UNCTAD 2017b).

Based on a study made by Penfold, Ocean Shipping Consultants, and FCS 2015, the crane moves per hour calculations are not very reliable without further analysis, as they depend also on shift patterns, recording practices and various personnel breaks. For that reason, the authors propose the introduction of the indicator of moves per berth meter that would describe the operations more efficiently.

D1.2.3 Thresholds/ Target values

Measure of moves per berth meter

As already stated previously, the study of A. Penfold, Ocean Shipping Consultants, and FCS 2015 suggests that the measure of moves per berth metre would be one of the most efficient indicators of productivity. The authors state:

"A target level of 1,000-1,250 TEU/berth metre/year is achievable for medium-sized ports with a high transhipment component, with some 1,500-1,750 TEU/berth metre/year is more appropriate for large ports and about 400-500 TEU/berth metre/year for those smaller ports and terminals at the other end of the scale".

TEUs/crane/year (Crane Utilization)

Based also on the aforementioned study:

> "*a level of 100,000-150,000 TEU/gantry crane/year is a reasonable target for these markets, on the assumption that one gantry crane is required for every 86-115m of quay, (depending on the LOA of the post-Panamax vessel type in question*".

Taking into account that a minimum berth length of 700 m is required to berth two fifth-generation post-Panamax vessels, according to the authors, 3 or 4 gantry cranes will be required in order to reach the maximum levels of productivity.

Moves/crane/hour (Crane productivity)

Based on PORTOPIA, 2015 container terminals at the ports of Los Angeles and Long Beach operate with approximately 28 to 35 moves per crane per hour. Maximum rates of 40 moves per hour can be attained in specific cases. The above statement is further on verified by (OECD, 2013) that indicate that:

“average performance levels in a large port can reach 110,000 TEUs per year per crane, 25–40 crane moves per hour, a dwell time of 5–7 days for imported boxes and 3–5 days for exported boxes”.

It is obvious that the numbers presented above are related to the capacity of the vessels that a terminal is serving, apart from the available equipment and its productivity. For that reason, specific targets are impossible to set, but only a general target defining the acceptable range of expected waiting time.

Vessel time spent in port

Based on the statistics published by Marine Traffic in 2017, the average time in the port for container vessels is around 0.87 days (the average time in port is equivalent to the average of median per world ports). More specifically, in the Netherlands, container vessels spend an average of 1.14 days in the ports, while in Spain 0.51 days (Average time in port is equivalent to the average of median per port per each country).

Number of simultaneous cranes per vessel type

Based on (Martin, Martin, and Pettit 2015) no detailed or recent research has been published on this subject and the area. However, research-based in interviews with terminal operators has recognized

that for ships in which 12 quay cranes could operate, 5.5 cranes (average) are used during ship working time.

Regarding the truck time spent in the terminal area, there is no specific threshold since it is a multi-parameter problem.

D1.2.4 Final operational objective

Considering the information given by the quantitative state concept, the operational objectives that were set in the previous steps are amended to:

- According to the strategical goal of the port and a market analysis, the goals as to the number of TEUs in the next years should be set by each container terminal.
- A target level of 1,000-1,250 TEU/berth metre/year should be required from medium-sized ports with significant transhipment rates, and about 1,500-1,750 TEU/berth metre/year should be required from large ports.
- The crane utilization should be approximately 100,000-150,000 TEU/gantry crane/year.
- The crane productivity should be approximately 25–40 crane moves per hour.
- The container vessel time spent in the port should be approximately 0.80 days.
- On average, 5.5 cranes during ship working time should be capable to load and/or unload the largest container vessels.
- There should be a yard vehicles tracking system to optimize the average time of activity/inactivity of the yard vehicles and the total number of movements per container unit and empty trips.

It should be pointed out, that the abovementioned operational objectives are not absolute for each port and they depend on a great extent to each ports operations, available equipment, size, current traffic, forecasted traffic etc.

D3.3 Personnel training

The productivity of the container terminal is also related to the efficiency of the personnel. This involves the training on the use of the machinery and equipment as well as other operations that concern the management and the logistic of the terminal operations. Eventual new entries of software used for the optimization of the terminal services would imply that the personnel would have to become acquainted with it through training sessions.

D1.3.1 Preliminary definition of the operational objective

The personnel of the container terminal should receive training sessions to improve the efficiency of the container terminal operations.

D1.3.2 Indicators

- Frequency of personnel training and/or hours per year that the personnel receives training sessions.

The indicators mentioned are connected to the preliminary operational objectives. Frequent and updated training sessions of the personnel would contribute on the productivity of the terminal.

D1.3.3 Thresholds/ Target values

A threshold could not be assigned on the frequency of the personnel training, but there should be proof that there are constant training, improving the efficiency of the operations and the staff. Innovations should be introduced in the terminal on a regular basis to optimize the operations quality and time and the personnel efficiency.

D1.3.4 Final operational objective

Considering the information given by the quantitative state concept, the operational objectives that were set in the previous steps are modified to:

- There should be constant training seminars.
- The terminal should be informed about techniques and implement innovations to optimize its efficiency.

D3.4 Terminal potential

This theme is presented to describe the capacity of the port.

D1.4.1 Preliminary operational objective

The terminal capacity should be equal to or higher than the actual container traffic.

D1.4.2 Indicators

- Maximum TEUs capacity
- Total quay length
- Operational Depth
- Total yard area
- Equipment

D1.4.3 Thresholds/ Target values

Neither of the indicators mentioned in the previous subchapter can be related to thresholds since they are only describing the current situation and not set to accomplish operational targets.

D1.4.4 Final operational objective

The quantitative state concept did not contribute on the amendment of the preliminary operational objective. Therefore, the preliminary operational objectives will be maintained:

- The terminal capacity should be equal to or higher than the actual container traffic.

D3.5 Expandability

This theme refers to the possibility of expansion of land and/or sea infrastructures and achievement of suitable depths for super Post Panamax.

The eventual land/sea expansions that on the one hand are connected to container traffic growth and creation of new employment opportunities (GDP rise), on the other hand, means properties value modification, expropriations and fishing field's reduction. The sea reclamation could also be considered responsible for changes in the coastal processes that can cause risks of losing properties (through erosion).

D1.5.1 Preliminary operational objective

The Master Plan proposals should comply with the needs of the port and the city and should be amended regularly to include the eventual changes.

The Master Plans should be designed based on the concept of flexibility and sustainable growth.

D1.5.2 Indicators

- Master Plan proposals
- Per cent of expansion of land area
- Per cent of expansion of quay length
- Suitable depth of post Panamax

D1.5.3 Thresholds/ Target values

Neither of the indicators mentioned in the previous subchapter can be related to thresholds since they are only describing the current situation and not set to accomplish operational targets.

D1.5.4 Final operational objective

The quantitative state concept did not contribute on the amendment of the preliminary operational objective. Therefore, the preliminary operational objectives will be maintained:

- The Master Plan proposals should comply with the needs of the port and the city and should be amended regularly to include the eventual changes.
- The Master Plans should be designed based on the concept of flexibility and sustainable growth

D3.6 Circular economy

Filtering the flow type column of the worksheet 'Destination of Modified Medium', the activities that produce flows that can be reused are presented in Table 31.

Table 31: Alternative management in the port basin operations

PRODUCTION - RECEPTION AREA	CATEGORY	PRODUCER-RECEIVER	FLOW TYPE	FLOW DIRECTI	MAIN COMPONENTS OF FLOW	RELATION TO PORT	DESTINATION or MODIFIED MEDIUM/SYSTEM
CONSTRUCTION SITE	All activities	Various	Non-hazardous demolition materials	OUT	Various	In port	Alternative management facilities-Reusage
PORT INFRASTRUCTURE	Dredging	Port basin	Dredged material disposal	OUT	Non hazardous material	In port	Alternative management facilities-Reusage
LAND AREA OPS	Yard building	Kitchen sinks; bathroom sinks;	Sewage	OUT	Grey water	In port	Port/City treatment facilities
LAND AREA OPS	Renewable energy	Wind mills; solar panels; breakwaters	Energy production	INTERNAL	Electricity	In port	

The port area presents a fertile ground, as the existence of industrial clusters located there and the sea connections among in ports facilitates the sustainable use of resources and waste because they present the advantage of the development of synergies between the various industries. One of the main principles of the circular economy is to use renewables, study a feedback loop to optimize production and maximize the usage value of products (Ballini and Song 2017).

Some examples of moving towards a more circular economy include the reduction of use of energy and materials in production and use phases, reduction of the use of materials that are hazardous or difficult to recycle(European Comission 2014). Additionally, the reduction of energy consumption and the introduction of renewable energy would be pillars for the development of the concept of the circular economy. Last but not least, the reduction of the water consumption through reuse of the treated grey waters for several operations is important as well.

D1.6.1 Preliminary operational objective

The terminal should get familiarized and adopt the concept of the circular economy.

D1.6.2 Indicators

- Use of dredged material for port expansion projects and other actions.
- Renewable energy production
- Use of biofuels
- Reuse of treated grey water
- Recycling

The indicators presented above are based on the European Federation of Inland Ports, that in 2016 issued the report "The Circular Economy and Inland Ports" that lists a number of challenges and requirements.

D1.6.3 Thresholds/ Target values

There is not a specific standard/target that can be set for the above-mentioned indicators.

D1.6.4 Final operational objective

The reuse of dredged material inside the port (if non-contaminated), the renewable energy production, the recycling, the use of biofuels and treated greywater should be maximized within the terminals and consequently within the ports.

Appendix E *Table of elements of PSAF*

The set of themes – indicators –operational objectives are presented for each strategic sub-objective.

Strategic sub-objective	Themes	Operational objectives	Indicators
Make the port greener	**Air quality**	• The concentration of air pollutants should be lower than the standards defined by the European Commission. • Over a period of five years, CO_2 emissions must fall by 10%. • The fuel consumption should be reduced more than 20% in the next 5 years.	Air quality standards (NO_2, CO, SO_2, PM_{10})
			Carbon footprint
			Fuel consumption (and ratio of fuel consumption over the total container units traffic)
			Control of the emission certificates of the ships approaching
	Soil- sediment quality and state	• The heavy metals concentration in the sediment of the port basin should be less that the values that are defined in the Annex II to Directive 1999/31/EC. • The oil concentration in the soil should be less than 40 mg/kg dry.	Presence of heavy metals
			Oil concentration
	Water column quality	• The concentration of Intestinal Enterococci and E.coli should be below the levels indicated from each country's Directive. • The concentration of heavy metals in the surface waters should be lower than the maximum acceptaple concetrations defined by the European Comission. • The oil concentration should be less than 200 ng/L. • The water transparency should be good, indicated with 8m of secchi disk depth.	Ecoli / Intestinalenterococci
			Heavy metals
			Transparency-turbidity
			Oil concentration
	Water consumption	The water consumption should be optimized according to the traffic of the container terminal, using the treated grey waters where applicable	Volume of fresh water consumed from terminal building and operations (possibly divided by the port calls and the number of employees)
			Ratio of volume of reuse of treated grey water and total required volume of water.
	Noise	The levels noise levels in the ports should not exceed the limits in areas that are mainly industrial defined by each country's Decree.	Lden (Day Evening Night Sound Level)
	Energy consumption	• The ratio of electricity consumption to TEUs traffic should be optimized. • The ratio of electricity consumption to fuel consumption should be increasing. • The ratio of energy from renewable sources to the total energy consumption should be increasing. Additionally the following more generalized operational objective is set: • Optimize pollution reduction while maintaining a commercially-viable operation that does not	Ratio electricity consumption/TEU (or moves)
			Ratio electricity consumption/fuel consumption

Strategic sub-objective	Themes	Operational objectives
Make the port happier	**Employment opportunities**	• Value added services should be introduced both for the terminal's economic benefit and for the introduction of new job positions. • The expansion of the port should come along with job opportunities in other sectors. • The working conditions (salaries, holiday leave, allowances etc. should be satisfactory relatively to each countries' local economy.
	Safety levels	• The terminal should comply with all the regulations that are put into force regarding the preventions of accidents. • The personnel of the container terminal should receive regular training regarding the everyday operations of the yard equipment, as well as handling of hazardous cargo. • Inclusion of climate change adaptation policies in the development measures of the ports
	Land use changes	• A buffer zone should exist in the port-city interface (Noise barriers- vegetation –logistics buildings and include some non-exclusively port related activities of low intensity) • The ratio (Residential + commercial uses)/industrial uses should be the maximum possible.
	Recreation and aesthetics	• The existence of marine infrastructures damaging the aesthetics: yes/no. • The ratio of cash flow from recreational activities after and before the construction of the marine infrastructures should not be lowers than 1.5.
	Stakeholder involvement	• Using the questionnaire that was created for the context of this thesis study, the questions related to the satisfaction and the level of involvement of stakeholders should be more than 3. • The information regarding various port performance indicators should be easily accessible.
	Traffic congestion	• The hours per working day that the traffic exceeds the carrying capacity of the local road network

Strategic sub-objective	Themes	Operational objectives	Indicators
Make the port wealthier	Intermodality	• The intermodal connectivity of the port should be improved according to the needs of the container terminal and the port (rail and road network).	Number of lanes in the port entrance
			Rail connection capacity
			Distance from the closest airport
	Productivity	• According to the strategical goal of the port and a market analysis, the goals as to the number of TEUs in the next years should be set by each container terminal. • A target level of 1,000-1,250 TEU/berth metre/year should be achieved for medium sized ports with a high transhipment component, with some 1,500-1,750 TEU/berth metre/year. • The crane utilization should approximately 100,000-150,000 TEU/gantry crane/year. • The crane productivity should be approximately 25–40 crane moves per hour. • The container vessel time spent in the port should be approximately 0.80 days. • On average, 5.5 cranes during ship working time should be capable to load and/or unload the largest container vessels. • There should be a yard vehicles tracking system to optimize the average time of activity/inactivity of the yard vehicles and the total number of movements per container unit and empty trips.	TEUs traffic over the last years
			Transshipment volumes
			Vessel time spent in port
			TEUs/hour/crane
			Moves/crane/hour
			Measure of moves per berth meter
			Number of simultaneous cranes per vessel type
			Truck time spent in the terminal area
	Personnel training	• There should be constant training seminars. • The terminal should be informed about techniques and implement innovations to optimize its efficiency.	Frequency of personnel training and/or hours per year that the personnel receives training sessions.
	Terminal potential	• The terminal capacity should be equal or higher than the actual container traffic.	Maximum TEUs capacity
			Total quay length
			Operational depth
			Total yard area
			Equipment
	Expandability	• The Master Plan proposals should comply with the needs of the port and the city and should be amended regularly to include the eventual changes. • The Master Plans should be designed based on the concept of flexibility and sustainable growth	Master Plan proposals
			Percent of expansion of land area
			Percent of expansion of quay length
			Suitable depth of post Panamax
	Circular economy	The reuse of dredged material inside the port (if non-contaminated), the renewable energy production, the recycling, the use of biofuels and treated grey water should be maximized within the terminals and consequently within the ports.	Use of dredged material for port expansion projects and other actions.
			Renewable energy production
			Use of biofuels
			Reuse of treated grey water
			Recycling

Appendix F *Info gathering actions for two port case studies*

F1.1 Port of Livorno

Main sources of information

For the Port of Livorno the following key information regarding Master Planning and Environment has been retrieved:

1. Livorno Port Authority, Environmental Statement 2012-2015, 30-June-2012
2. Livorno Port Authority, Environmental Statement 2015-2018, 30-June-2015
3. Livorno Port Authority, 2016 Update of Environmental Statement 2015-2018, 30-June-2016
4. North Tyrrhenian Sea Port System Authority[3], 2017 Update of Environmental Statement 2015-2018, 30-June-2017
5. North Tyrrhenian Sea Port System Authority, 2018 Update of Environmental Statement 2015-2018, 30-June-2018
6. Port of Livorno Master Plan (2012): http://www.porto.li.it/it-it/homepage/strumentidiprogrammazione/pianoregolatore/pianoregolatore2015/relazioni.aspx (30 documents)
7. Strategic Environmental Assessment (VAS) 2013, that contains the documents of the Strategic Environmental Assessment of the Master Plan of 2012: http://www.porto.li.it/it-it/homepage/strumentidiprogrammazione/pianoregolatore/pianoregolatore2015/proceduravas/rapportoambientale.aspx (3 documents)

Also from the website of the Port of Livorno Authority (http://www.porto.li.it/) and the website of the North Tyrrhenian Sea Port System Authority, statistical data, info on port land concessions, port infrastructure, etc. have been retrieved.

The Master Plan of 2012 was approved with the decision n.36-25/3/2015 of the Regional Council of Tuscany (documents of point 5).

The first 4 documents provide general information about the environmental impact of the port as a whole but also include some specific info regarding the container terminal. There is a reference to various environmental themes (air-water quality, noise, water-electricity consumption, etc). In the last update of the Environmental Statement (2017), it is stated that the air quality, noise and marine monitoring programs will be put in an act by 2018. Furthermore, the Port of Livorno has participated to the TEN-T «GreenCranes» project (2012-2014), where electrical, fuel consumption and carbon footprint of the Livorno's container terminal (Darsena Toscana) have been reported for 2011.

Some documents regarding the «GreenCranes» project have been accessed through the websites of the North Tyrrhenian Sea Port System Authority (https://www.portialtotirreno.it/studi-e-sviluppo/progetti-conclusi/greencranes/) and the GreenCranes Project (http://www.greencranes.eu/)

Although most of the abovementioned documents do not provide precise details on metrics' results and values and some of them are at least 6 to 8 years old, it clearly shows that (possibly/probably) the data exist and the port authorities should be able to provide them.

Actions and contacts

A Living Lab in Livorno was held on the 17/07/2018. Several participants attended the meeting mainly from Research instituted related to the Corealis project (CNIT, ERICSSON, VTT and Deltares), however, stakeholders from the Port Authority and the Container Terminal Lorenzini operator were also present. During the meeting, all the parties were informed that they would receive a question

[3] In 2016 the new Port Authority has been instituted with the Presidential Decree n. 169, 4/8/2016 (Annex A, 3rd case)

form (QN1) reflecting on the information gaps that were traced during the data collection, in the context of this thesis study. The question form can be found in Appendix G .

Contacts have been also made with:

- The operator of Terminal Darsena Toscana (TDT) that was not taking part in the Corealis project;
- The Environmental Protection Agency for the Region of Tuscany, ARPAT, (Agenzia Regionale per la Protezione Ambientale della Toscana);
- Port Authority of Livorno;

The important and relevant information that was collected during the above-mentioned meetings, discussions and emails, as well as the ''filled'' question forms, are presented in the following subchapters with the relative source reference. The question form (QN1) is presented separately as well in Appendix G .

F1.2 Port of Piraeus

Main sources of information

The Port of Piraeus has an environmental permit issued in 2006. The website of the Port of Piraeus Authority (PPA) (http://www.olp.gr/en/nature-protection/nature-quality) has not published all the measurements resulting from the environmental monitoring, (according to the terms and conditions of their Environmental Permit of 2006 should have been published in their site), however it is stated that they implement environmental monitoring programs holding partnership with universities and other external experts, regarding Seawater quality, Noise quality, Air quality, Landscape and Energy and Waste management.

A new EIA has been known to be submitted to the competent authorities (Directorate of Environmental Permits of the Ministry of Environment) before the end of 2017 but it isn't yet at the phase of the public consultation, so it is not yet accessible. However, unofficially from a source that asked to stay anonymous, it has been possible to have access to the chapter regarding the current state of the environment (EIA Port of Piraeus, edition 3, March 2017, Chapter 8, Current state of the environment) where there are included the historical data of the results of the monitoring program.

In the Environmental Report of 2016 of Piraeus Port Authority S.A. (accessible at http://www.olp.gr/images/GR_PDF/slops/PERS_REPORT_2016.pdf) it is stated that there is an implementation of a regular programme of publicity campaigns on a variety of environmental issues related to port activities, communication of the environmental policy to the public (employees, tenants and contractors) and publication, every two years, of an Environmental Performance Report, available to the personnel, the public and other interested parties. However, the above-mentioned statement does not seem to conform to the reality since all the environmental monitoring data are not provided in the website of the PPA.

Actions – contacts

A Living Lab in the offices of the Piraeus Container Terminal (PCT) was held on the 04/09/2018. A large number of participants attended the meeting, such as the members of the research institutes taking part in the Corealis project, representatives from the Municipality, the Port Authority of Piraeus (PPA), the Container Terminal, the Customs, the ferry companies, the business development sector and several other stakeholders. Like in the Port of Livorno Living Lab, all parties were informed that they would receive a question form (QN1) reflecting on the information gaps that were traced during the data collection, in the context of this thesis study. The question form can be found in Appendix G . Contacts have been also made with the environmental department of PPA but with no result regarding the data requested.

Appendix G *Question form (QN1) to responsible parties (filling the gaps)*

QUESTIONNAIRE - QUESTIONARIO

Please provide data for as many years as possible

Per favore fornire i dati per il maggior numero di anni possibile

Is there an environmental monitoring program for the port ? **'E in atto un programma di monitoraggio ambientale del porto ?** If yes, please provide the yearly reports regarding air quality, noise, water column quality and sediment quality. **Se sì, per favore fornire i rapporti annuali riguardanti la qualità dell'aria, il rumore, la qualità della colonna d'acqua e la qualità dei sedimenti.**
Yearly water consumption of the container terminal. **Consumo annuale acqua del container terminal.**
Yearly electricity consumption of the container terminal. Include the recharging of eventual electric/hybrid vehicles. **Consumo annuale energia elettrica del container terminal. Da includere la ricarica di veicoli elettrici-ibridi.**
Yearly green energy produced for the container terminal. **Energia elettrica da fonti rinnovabili prodotta per il container terminal annualmente.**
Yearly fuel consumption of the container terminal divided per fuel type (LNG-diesel-petrol-etc). **Consumo annuale di carburante, diviso per tipologia (LPG, LNG, diesel, benzina, ecc).**
Total number of employees\workers that normally work in the container terminal area, inclusive of subcontractors (yearly average). **Numero totale di impiegati\lavoratori che normalmente lavorano nell' area del container terminal, inclusi subappaltatori (media annuale)**
Please provide an estimation of the workforce directly and indirectly related to the container terminal's operation. **Per favore fornire una stima dei posti di lavoro che sono direttamente o indirettamente collegati con il complessivo funzionamento del container terminal.**
Averagysalary per employee-category **Salario medio dei dipendenti per categoria**
Payroll expenses and subcontracting expenses **Spese per il personale e subappalti**
Yearly mean accidents at work (container terminal). **Media annuale degli incidenti del lavoro (container terminal).**
Hours of occupational health & safety seminars per year. **Ore di seminari sulla salute e sicurezza sul lavoro per anno.**
Averageshipwaiting time **Tempo medio di attesa per le navi container**
TEUs throughput/year
TEUs transshipment/year

Trucks entering the terminal (per year)
Automezzi pesanti che entrano nel terminal (per anno)

Vessel calls/year/vesselscapacity
Arrivi annuali navi contenitore/capacità navi (classe)

TEUs exiting/entering by rail
TEUs spediti/arrivati per treno

How many TEUs/hour per crane type
TEUs/ora per tipologia gru

Average time the trucks remain in the terminal area
Tempo medio degli automezzi pesanti nel terminal

Safety and health training program (hours per year)
Corsi sicurezza sul lavoro (ore per anno)

Work productivity training program (hours per year)
Corsi formazione professionale dei lavoratori (ore per anno)

Container moves per berth meter per year(TEUs/berth meter/ year)
Movimenti contenitori per metro banchina per anno (TEUs/metro banchina/anno)

CONTAINER TERMINAL GENERAL INFO
(Quaylength**) Lunghezza totale banchine**
(Depth) **Profondità**
(Cranes by type) **Gru per tipologia**
(Land area) **Superficie totale piazzali**

Please state in brief the organization's strategic goals.
Per favore descrivere in breve gli obiettivi strategici dell' ente/ditta.

Please state eventual performance indicators your organization uses (environmental, societal and economic) and provide the available time-series for each of them.
Per favore descrivere eventuali indicatori di prestazione usati (ambientali, sociali, economici) e fornire le diaponibili serie temporali per ognuno di essi.

Appendix H *Current state of two container terminal case studies*

H1. Planet

H1.1 General information about environmental monitoring

Port of Piraeus

Currently, there is no environmental monitoring programme implemented by the Piraeus Container Terminal (Source: Answer to question form from Operational manager of PCT); however, the container terminal area (sea/land) is incorporated in the general environmental monitoring programme of the Port of Piraeus Authority.

Port of Livorno

In the New Master Plan of the Port of Livorno – Articulation of the temporal interventions (Autorità di Sistema Portuale del Mar Tirreno Settentrionale 2017) it is indicated that a platform (MoniCA) is designed and should be concluded in 2018 that will allow to integrate measuring stations of environmental variables (e.g. nitrite concentrations, PMx, COx, etc.) and to store the trend of the variables measured on the platform.

Terminal Darsena Toscana:
Figure 33 shows the overall performance based on the indicators that the terminal has chosen.

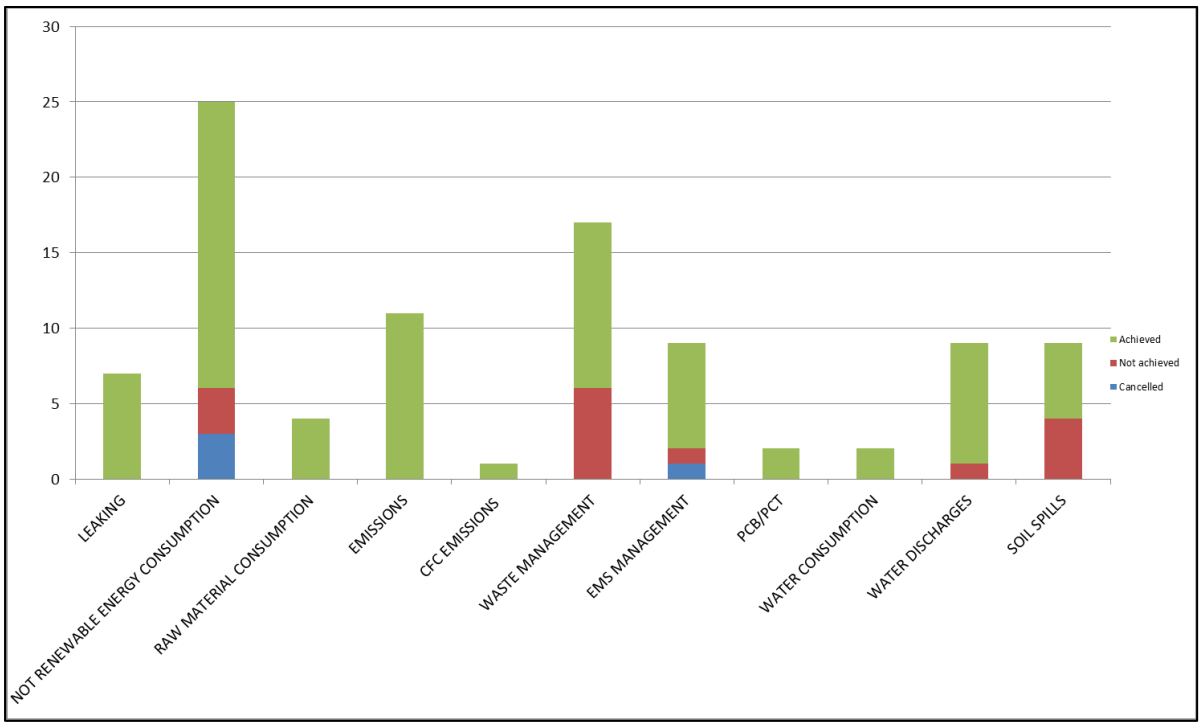


Figure 33: Environmental performance of TDT in the period 2008-2015 (Source: TDT)

Terminal Lorenzini:
There is a monitoring programme for the port of Livorno and the Container Terminals but Port Authority is in charge of it, not the container terminal (Source: Answer to question form from Terminal Lorenzini).

H1.2 Air quality

H1.2.1 Air quality standards (NO2, CO, SO2, PM10)

Piraeus

Among the terms and conditions that are set by the Decision of Approval of the Environmental Terms and Conditions of the Port of Piraeus (Greek Common Ministerial Decision No. 104050/2006), a programme of monitoring the air pollution should be set up in the N-NW part of the central port area. This program will include measurements of pollutant gas accumulation (CO, NOx, PM10) that will be recorded in a census sheet, which will be forwarded once a month to the directorate.

In Environmental Report of Piraeus port, (Piraeus Port Authority S.A. 2016) it is indicated that there is a permanent monitoring station that has been installed on the west area of the central port of Piraeus in cooperation with the National Technical University of Athens and records the following parameters: Nitrogen oxides NOX), Xylenes, Sulfur dioxide (SO2), Ethylbenzene, Carbon monoxide (CO), Ozone (O3), Toluene (C7H8), Benzene (C6H6), Particulate matter PM10.

PM10 concentrations

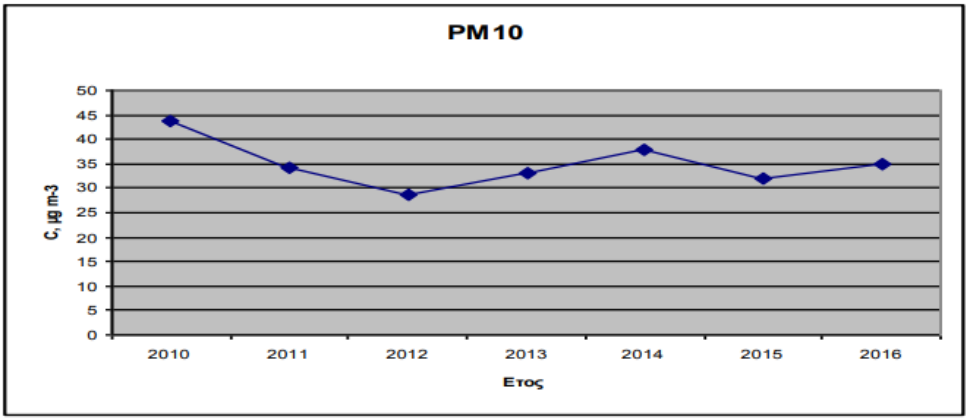


Figure 34: PM10 yearly concentrations range during 2010-2016 (source: Piraeus Port Authority S.A. 2016)

Figure 34 shows the PM10 yearly concentrations range during 2010-2016. In 2014-2016 the annual mean value was 35 μg/m3, under the limit of 40 μg/m^3 specified by Directive 2008/50/EC. The mean daily values of PM10 may exceed the limit value locally and for a very short while, during ships high traffic periods.

In the same report it was indicated that NO2, SO2 and CO concentrations during 2010-2016 presented no exceeding of the legislative limits of the mean hourly and mean 8hr values, however, there are no graphs presented for those substances. In the most recent Annual Report of the Air Quality of Athens area of the Ministry of Environment and Energy (ΥΠΟΥΡΓΕΙΟ ΠΕΡΙΒΑΛΛΟΝΤΟΣ ΚΑΙ ΕΝΕΡΓΕΙΑΣ, 2017) it is indicated that the station Number 9 is the closest to the Port of Piraeus. The exact contribution of the Port of Piraeus and specifically the container terminal is not possible to be extrapolated from these values. However, they will be provided to obtain a general image as regards to the air quality level of the area around the Port of Piraeus.

Figure 35: Atmospheric pollution measuring stations in the Attica region operated by the Atmospheric Quality Department (Source: Greek Ministry of Environment and Energy)

NO2 – yearly change

The limit value (200µg /m^3, not to exceed 18 hours per year) was not exceeded at any measuring location. The value of 40 µg/m3 averaging in 1 year was exceeded in the years that are indicated in red in the following table.

Table 32: Evolution of average annual concentration values of NO2 in measuring station of Piraeus from 2005 – 2016 (Source: Greek Ministry of Environment and Energy)

Station Piraeus 1 #9												
Years	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Average annual values of NO2 (µg/m3)	66	66	72	60	71	46	44	41	36	33	52	64

SO2, CO and NO2 - hourly and daily average values

From the tables presented below (ΥΠΟΥΡΓΕΙΟ ΠΕΡΙΒΑΛΛΟΝΤΟΣ ΚΑΙ ΕΝΕΡΓΕΙΑΣ, 2017) it can be observed that the Air Quality Standards set by the European Committee, 2017 are not exceeded for the Piraeus measurement station that is located close to the port of Piraeus.

Table 33: Averaging 24 hours and averaging 1-hour concentration values of SO2 for the measuring station of Piraeus in the year of 2016

Station Piraeus 1 #9 - SO2 (µg/m3) 2016			
	Max value	Median value	Number of daily values > 125 µg/m3
Averaging 24 hours values	25	7	0
	Max value	Median value	Number of daily values > 350 µg/m3
Averaging 1 hour values	90	6	0

Table 34: Averaging 1-hour concentration values of NO2 for the measuring station of Piraeus in the year of 2016

Station Piraeus 1 #9 - NO2 (µg/m3) 2016			
	Max value	Median value	Number of daily values > 200 µg/m3
Averaging 1 hour values	188	62	0

Table 35: Averaging 8 hours of concentration values of CO for the measuring station of Piraeus in the year of 2016

Station Piraeus 1 #9 - CO (µg/m3) 2016		
	Max value	Number of daily values > 10 mg/m3
Averaging 8 hour values	5,5	0

Operational objective check:

The concentration of air pollutants is lower than the standards defined by the European Commission.

Livorno

ARPAT, the Environmental Protection Agency of the Tuscany Region, has an air quality measuring station (LI-LAPIRA), part of the regional air quality network, at about 2.1km east-northeast of the container terminal (Figure 36) that started functioning in 2015. Another station of the network is positioned at about 5.6km south-southeast of the container terminal (LI-CAPPIELLO) and started functioning in 2014. Historical, real-time data and yearly reports for all stations of the network can be retrieved from the ARPAT website.

PM10 concentration

In the report published by ARPAT in March 2017, regarding the PM10, for both stations there no is exceeding of the day average of 50µg/m^3 (Legislative Decree 155/2010, Annex XI) and the annual average is 18µg/m^3 for LI-CAPPIELLO and 19µg/m^3 for LI-LAPIRA (Figure 36). In 2014 the daily

average was 17µg/m^3 for LI-CAPPIELLO and in 2015 it was 18µg/m^3 for LI-CAPPIELLO and 21µg/m^3 for LI-LAPIRA, all value much lower than the 40µg/m^3 set by the LD 155/2010 as day average limit.

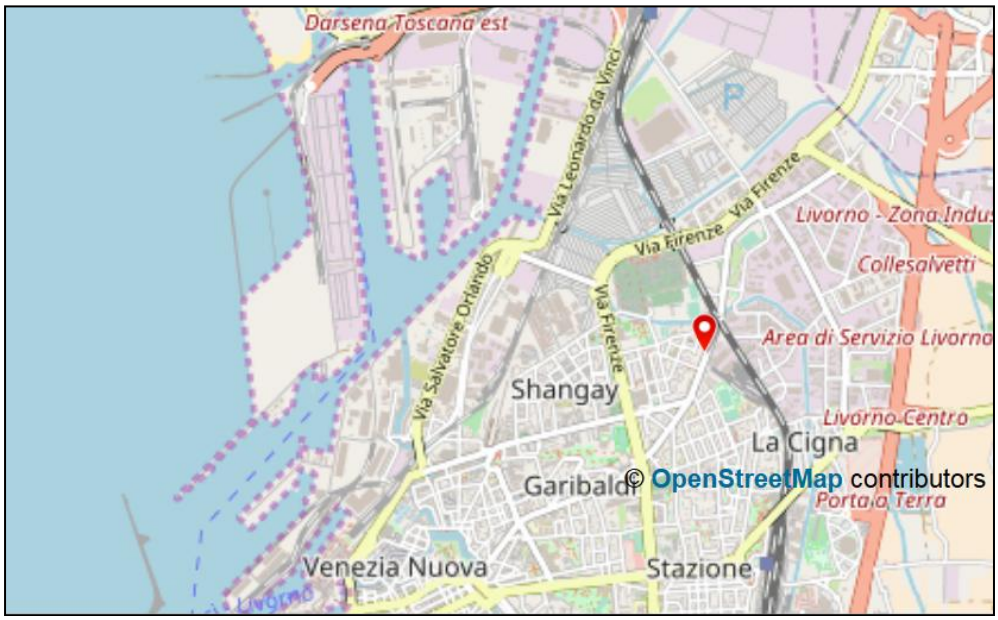


Figure 36: Air quality station Li-LAPIRA (source: ARPAT website)

NO2, CO and SO2 concentrations

Regarding NO2, the hourly limit is 200µg/m3 and the average year limit is 40µg/m3. The LI-LAPIRA station never exceeded the hourly limit and the average year values were 23 and 21 µg/m3 in 2015 and 2016 respectively. The more remote station LI-CAPPIELLO registered 19 and 16 µg/m3 in 2015 and 2016 respectively and no daily exceeding.

Operational objective check:

The concentration of air pollutants is lower than the standards defined by the European Commission.

H1.2.2 Fuel consumption

Piraeus

The data from the following Table 36 are retrieved from PCT.

Table 36: Fuel consumption of the Container Terminal Pier II & III (Source: PCT)

2016	3.859.092,00	Diesel in lt
2017	4.224.866,00	Diesel in lt

In 2017 the ratio of fuel consumption over a number of container units approximately 1,4.

Operational objective check:

The historical evolution of fuel consumption cannot be reproduced based on a two year period. For that reason, no conclusion can be made regarding the operational objective.

Livorno

Terminal Darsena Toscana:

From Figure 37, it can be concluded that the total diesel consumption remains almost constant in the period of 2005-2017. The ratio of total diesel consumption per yard moves performed is also remaining constant.

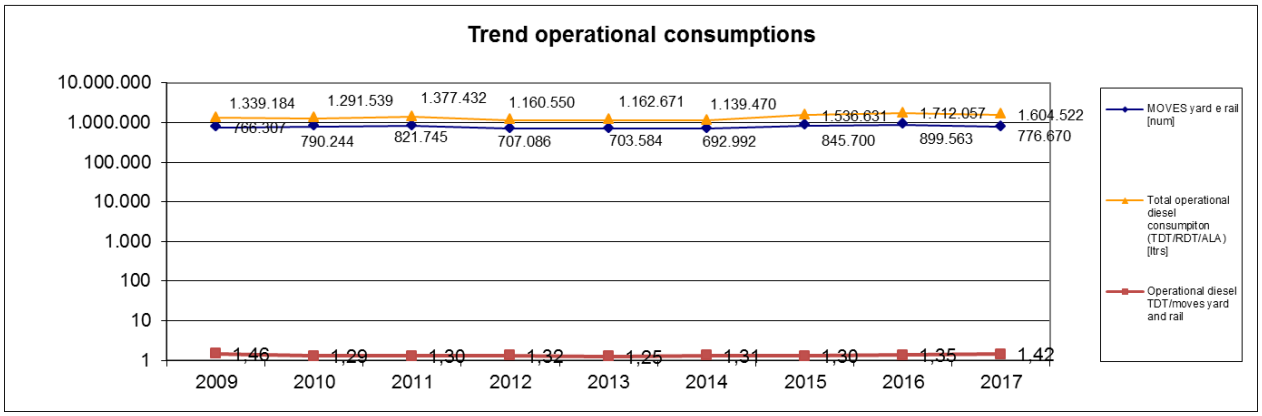


Figure 37: Trend of the operational diesel consumption of TDT/RDT/ALA (source: TDT)

In Livorno, in 2017 the container traffic was equivalent to 515.792 TEUs in the TDT only, so that gives a ratio of fuel consumption over a number of container units approximately 2.25.

Operational objective check
Since the diesel consumption remains nearly constant during a period of 8 years, as well as the total diesel consumption per yard moves, and it is indicated that the ratio of consumption per TEUs handled is higher than Piraeus, there should be measures taken for the optimization and decrease of the fuel consumption within the port operations.

H1.2.3 Carbon footprint

According to Covenant of Mayors for Climate and Energy: Default emission factors for local emission inventories, the energy mix of Greece has a conversion factor for 2013 of 0.757 tCO2/MWh, while the energy mix of Italy (2013) has a conversion factor of 0.343 tCO2/MWh.

Piraeus

There is no reference to carbon footprint in the EIA of 2017.

However in the Environmental Report (Piraeus Port Authority S.A. 2016) found on the website of the Port Authority it is stated then there is implementation of a monitoring programme on air quality and CO2 footprint estimation.

Additionally it is mentioned that a Solar Park has been implemented and installed in Neo Ikonio. The installation will provide 635,000 'green' kWh per year to the electricity grid, corresponding to 635 tonnes of CO2 emissions that are avoided.

Operational target check:
Not enough available information.

Livorno

Terminal Darsena Toscana:
The CO2 emissions normalized by the number of units per year in the TDT are presented in Figure 38 as well as the emissions originated from the electric consumption (excluding the consumption of the reefer's fridge).

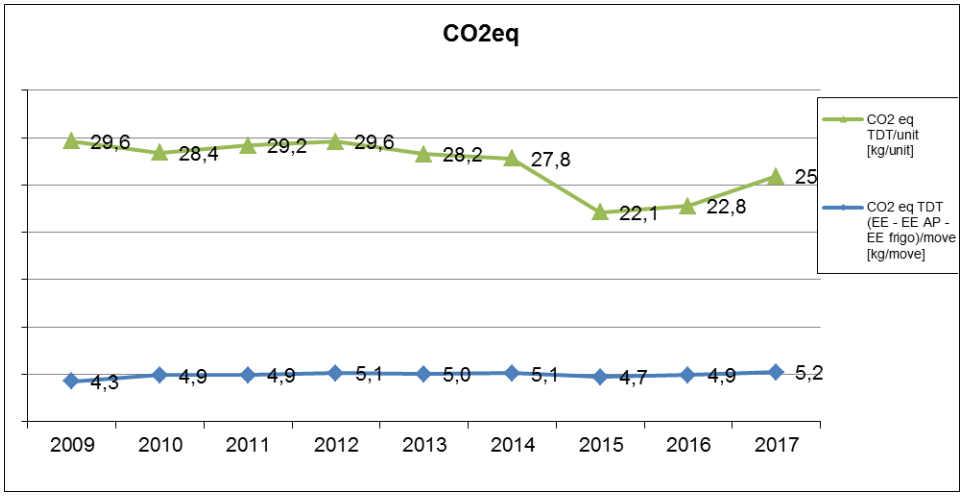


Figure 38: CO2 eq calculated in TDT normalized by the units (Source: TDT)

As can be observed from Figure 38 the CO2 emissions in TDT are presenting a decrease during the years of 2015 and 2016 with a slight increase in 2017. Even though the number value of the CO2 emissions in this year is nearly the same with all the previous years, the number of vessel moves is relatively higher.

Operational target check:
Over the period of the five last years, CO2 emissions have decreased by more than 10%.

H1.3 Sediment quality

Piraeus

From the EIA regarding the disposal of dredged material and slugs (Electric Arc Furnace), 2015:

Date of sampling: 30/03/2015

Sample origin: Neo Ikonio Peramatos (area west from Pier III).

Table 37: Samples were taken in the area west from Pier III (Source: Electric Arc Furnace, 2015)

Component	Threshold non dangerous (mg/kg)	1	2	3	4	5	6	7
Cd	0,6	0,01	0,02	0,02	0,02	<0,01	0,01	0,02
Cu	25	0,59	0,57	0,59	0,64	0,44	0,59	0,42
Hg	0,05	<0,002	<0,002	<0,002	<0,002	<0,002	<0,002	<0,002
Zn	25	0,1	0,12	0,09	0,08	0,07	0,08	0,01
Cr	4	<0,02	<0,02	<0,02	<0,02	<0,02	<0,02	<0,02
Pb	5	0,17	0,14	0,13	0,16	0,14	0,17	0,18
Ni	5	0,15	0,12	0,18	0,18	0,13	0,16	0,12

Operational objective check:
The leachability of the samples tested, as deduced from the table presented above, is not exceeding the limits set by both standards for the classification of inert materials at their disposal.

Livorno

(Livorno Port Authority 2013), Environmental Report 2013:

According to the results of a single sampling campaign (not specified when it took place) the degree of major contamination, both as an extension of the area concerned and as levels of concentration, was found in the layers between 1 and 2 m deep, while in the layer relative to the first 50 cm the detected contamination was lower than the underlying layers. The contamination found was mainly due to heavy metals (such as Cd, Hg, Pb and Zn) and organotin compounds, and secondarily to polycyclic aromatic hydrocarbons (PAHs). Below two meters of depth, contamination was present in a point-like manner and mainly related to Cd and As.

In the marine area of the container terminal, the contamination was limited, mainly in the superficial layer (0-50cm) and didn't exceed the limits of certain eco-toxic risk which would make necessary priority interventions.

Operational objective check:
Due to the observed contamination, mainly due to heavy metals (such as Cd, Hg, Pb and Zn) in the layers between 1 and 2 m deep, the operational objective is not achieved.

H1.4 Water column quality

Piraeus

In the EIA of 2017 is stated that PPA SA implements a Marine Environment Quality Monitoring Program on an annual basis, in cooperation with the University of Piraeus. The sampling stations near the CT are shown in the figure that follows:

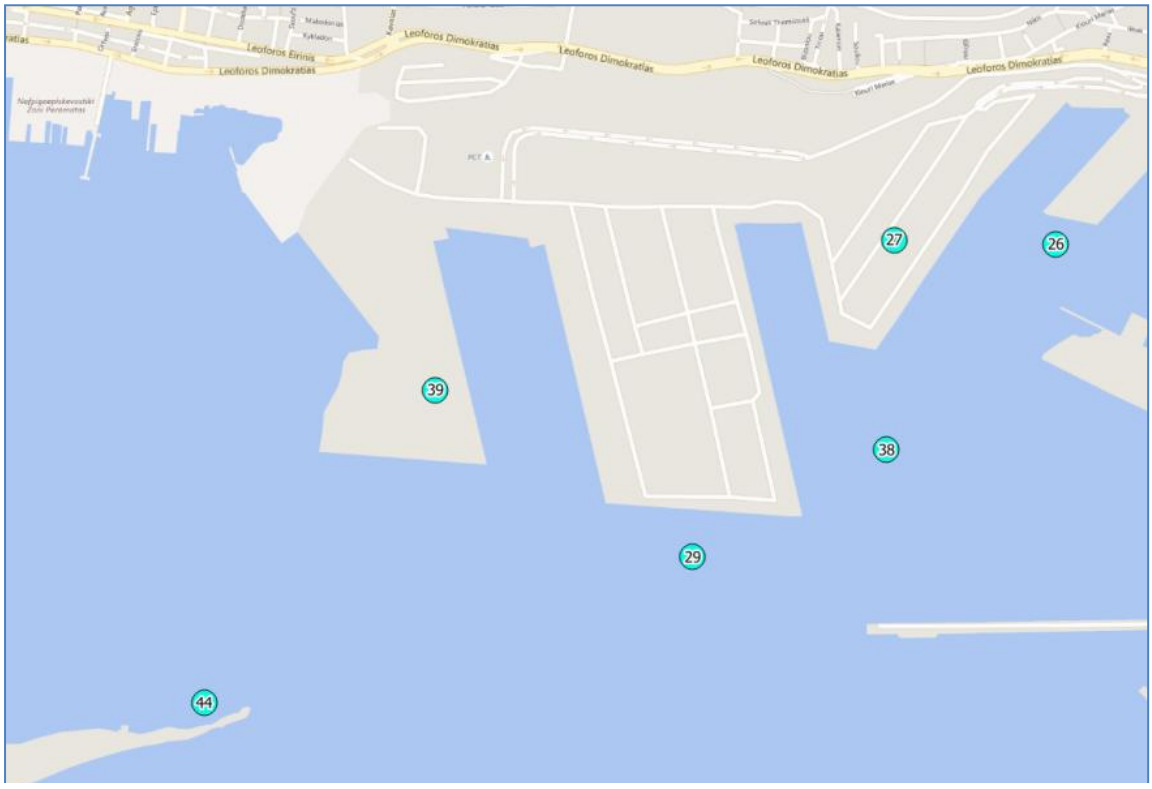


Figure 39: Water sampling stations. Stations 27 and 39 were used before the pier expansions. Own realization based on EIA Port of Piraeus, edition 3, March 2017, Chapter 8.

In the following tables the historical data of the water column sampling are presented.

Table 38: Total coliforms MPN Coli/100ml

Station	Apr-08	Nov-08	Apr-09	Apr-10	Apr-11	May-12	May-13	Nov-13	Jun-14
26	158	50	249	224	169	294	74	809	10
27	148	130	74	10	108	552	63	602	10
29	122	10	63	<10	41	<1	<1	235	<1
38	31	71	1	<10	97	10	20	324	10
39	<10	<10	1	10	426	<1	<1	226	<1
44	146	<10	1	<10	10	10	<1	63	<1

Table39: Enteroccci MPN Entero/100ml

Station	Apr-08	Nov-08	Apr-09	Apr-10	Apr-11	May-12	May-13	Nov-13	Jun-14
26	<10	20	20	<10	30	<1	<1	211	<1
27	<10	30	1	<10	0	20	1	173	<1
29	<10	<10	1	<10	10	<1	<1	226	<1
38	10	20	1	<10	10	<1	<1	145	20
39	<10	<10	1	<10	74	<1	<1	95	<1
44	<10	<10	1	<10	31	<1	<1	20	<1

Table 40: Heavy metals in water column

Station	Cr ppb					Cu ppb				
	Apr-10	Apr-11	May-12	May-13	Jun-14	Apr-10	Apr-11	May-12	May-13	Jun-14
26	3,7	2,2	1,2	0,4	1,5	1,61	1,3	0,7	1	1,7
27	7,1	1,9	-	-		1,35	0,5	0,4	-	-
29	0,3	-	-	-		2,32	-	0,3	-	-
38	3,3	0,8	0,3	0,3	2,4	0,44	0,7	1	1,5	1,9
39	2,2	0,6	0,3	-		0,75	0,3	0,7	-	-
44	-	0.2	-	-		1.51	0.5	0.2	-	-
Station	Fe ppb					Ni ppb				
	Apr-10	Apr-11	May-12	May-13	Jun-14	Apr-10	Apr-11	May-12	May-13	Jun-14
26	76	20,2	271,4	341,6	542 ,2		0,1	0,5	0,9	1,5
27	57,3	105,9	133,8	-		0,16	0,1	0,7	-	
29	22,1	98,3	255,8	-			0,3	0,7	-	
38	89,2	125,5	188,6	289,1	422 ,1	0,1	0,2	0,3	0,7	1,1
39	44,8	89,5	300	-		0,1	0,3	0,2	-	
44	70,6	103,6	208,4	-		0,45	1,4	0,65	-	
Station	Pb ppb					Zn ppb				
	Apr-10	Apr-11	May-12	May-13	Jun-14	Apr-10	Apr-11	May-12	May-13	Jun-14
26	1.9	0.4	0.3	0.5	0.9	12.1	5	7.1	5.2	5
27	1.2	0.32	0.8	-		4.1	7.2	5.5	-	
29	0.08	0.2	0.6	-		0.4	4.2	5.9	-	
38	2.4	3.5	1.3	1.1	2.9	0.2	2.7	3.6	4.9	5.4
39	0.7	2.5	1.4	-		0.5	2.8	3.7	-	
44	-	0.3	0.2	-		0.3	1.1	3	-	

In the Environmental Report of the Piraeus Port Authority S.A., the following data has been summarized and can be used as an **Operational objective check**:

- The values of the physicochemical parameters of 0C, pH, TDS, Conductivity, Salinity, Turbidity, Dissolved Oxygen do not vary notably during the years and show a good sea-water quality.
- The values of the heavy metals inside the water column (at the surface, -1m and - 3m) do not vary notably during the years and their concentrations range within the normal limits presented in a seawater column.
- The concentrations of oil hydrocarbons in 2015-2016 are smaller than the previous years and within the normal limits presented in a seawater column.

Livorno

Port Authority of Livorno, Environmental Report 2013 (needed for the procedure of Strategic Environmental Evaluation):

During 2010-2012 took place a monitoring program regarding the water quality inside the port of Livorno (Relazione sulle attività di monitoraggio delle acque marine, a cura dell'Autorità Portuale di Livorno, ottobre 2012). The Environmental Report 2013 states only that:

- nickel, which in the first monitoring was higher than the quality standard in most of the monitored points, it is lower than this standard already starting from second monitoring;
- cadmium is lower than the instrumental quantification limit for all points monitored;
- lead is lower than the quality standard in all monitored points, made an exception at the sampling point n.4 carried out in 2012;
- total chrome undergoes a slight worsening in all the analyzed samples that result in all higher than the quality standard taken as a reference;
- arsenic values are close to the standard value taken as reference and they result sometimes higher;
- the values relating to zinc undergo a deterioration in all the samples analyzed;
- rare anomalous values are found with regard to the aluminum parameter.

There is no reporting of the actual data of the monitoring.

Operational objective check:
Not adequate information for a conclusion

H1.5 Water consumption

Piraeus

There is no reference to water consumption in the EIA of 2017.

In 2017, 65.770 lt were consumed in the Piraeus Container Terminal (Source: Answer to question form from Operational manager PCT).

Operational objective check:
The information provided is not adequate to draw a conclusion.

Livorno

Terminal Darsena Toscana:
In Table 41 it is illustrated that the water consumption seems to have increased in the terminal Darsena Toscana over the last years, even though there has not been a great increase in the container traffic. It should be noted that the presented water consumption values refer to the water consumed for firefighting and for other office related uses.

Table 41: Water consumption in TDT (Source: TDT)

		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	1st quarter 2018	2nd quarter 2018
Total Water Consumption TDT	[mc]	7.268	6.963	10.802	10.625	10.374	10.253	8.755	9.085	5.662	5.376	2.512	11.054	13.343	2.585	5.306

Terminal Lorenzini:
The water consumption in Terminal Lorenzini in the year 2016 was 1.350 MC (Source: Answer to question form from Project manager of Terminal Lorenzini).

Operational objective check:
Since the water consumption increase is also related to the number of the staff and there is no available information on this subject, it is not possible to test that the operational objective is achieved.

H1.6 Noise

Piraeus

In the Environmental Report (Piraeus Port Authority S.A. 2016) it is mentioned that the noise monitoring programme consists of 17 spots covered all the port area, commercial & passenger. Each set of measurements is repeated every six months (winter and summer period), however the results of the monitoring are not presented in the report.

According to the EIA of 2017, the noise monitoring program of PPA SA has a number of noise monitoring stations in and near the Container terminal area:

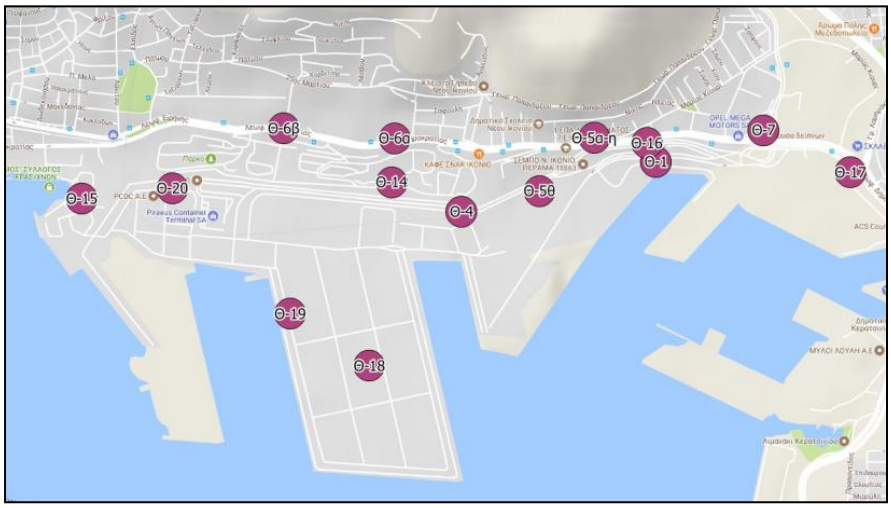


Figure 40: Noise monitoring stations near the container terminals. Own realization based on EIA Port of Piraeus, edition 3, March 2017, Chapter 8.

In the table that follows, the results of the noise monitoring data of the above stations are presented.

Table 42: Noise levels in Leq per station

Station	2007	2011	2013	2015	2016
Θ-1			72.1	70.6	68.9
Θ-4	75.6	67.8	75	67.9	72.5
Θ-5α	79	69.8	76.3	71.5	76.2
Θ-5β	68.8	62.5	68	60.7	60
Θ-5γ		50	52.5	44.3	42.5
Θ-5δ	65.5	68.2	68.5	66.3	64.5
Θ-5ε	70.3	66.7	69.5	64.1	68.1
Θ-5ζ	72.8	73.3	72.7	71.2	70.9
Θ-5η		51.5	49.5	45.6	43.5
Θ-5θ		69.4	78.3	69.1	78.4
Θ-6α	78.5	69.2	78.4	74.2	70
Θ-6β	78.4	75.3	75.3	72.6	74.6
Θ-7	75.4	73.9	76.1	73	74.6

Θ-8	58.3	41.9	56.2	41.5	50.7
Θ-14	68.9	68.4	74.6	59.9	65.4
Θ-15		63	57.2	56.6	55.4
Θ-16		75.4	71.4	71.7	71.8
Θ-17				56.6	57.3
Θ-18					69.9
Θ-19					71.6
Θ-20					68.7

Operational objective check:
In the Greek Government Gazette 293/A/6-10-1981 Article 2 Paragraph 5, it is indicated that the noise limit in areas that are mainly industrial is 65 dB(A). This limit is exceeded for most of the stations every year indicated.

Livorno

The Lden and Lnight noise maps of the port are shown in the figures that follow (source: Port Authority of Livorno, Environmental Report 2013). The software used for the noise modelling took into account only the traffic generated by the port activities.

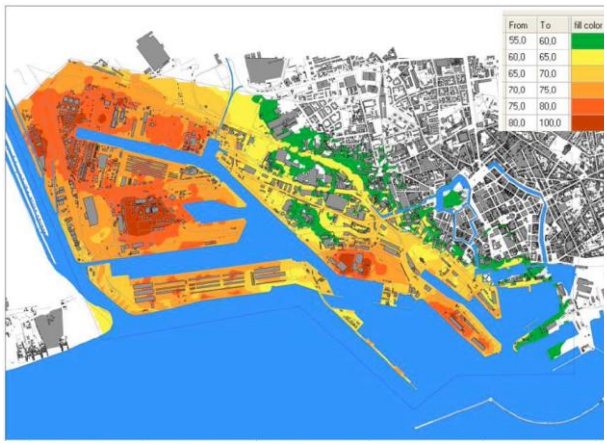


Figure 41: Lden map of the port of Livorno

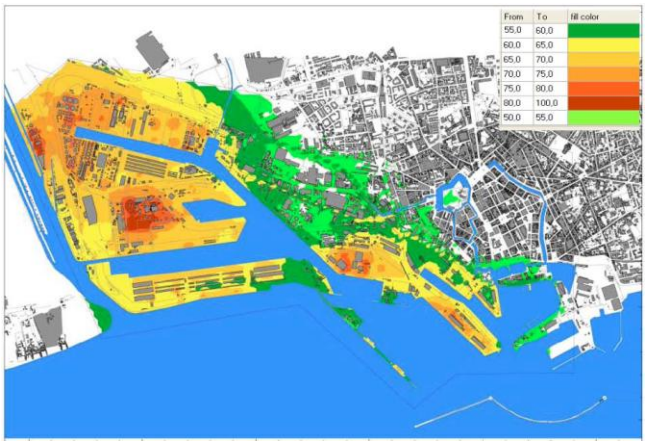


Figure 42: Lnight map of the port of Livorno

Operational objective check:
It can be noted that the acoustic environment of the container terminal, especially regarding the Lnight parameter, does not exceed 70dBA.

H1.7 Energy consumption

According to Covenant of Mayors for Climate and Energy: Default emission factors for local emission inventories, the energy mix of Greece has a conversion factor for 2013 of 0.757 tCO2/MWh, while the energy mix of Italy (2013) has a conversion factor of 0.343 tCO2/MWh.

Piraeus

PCT in using mainly electric equipment (9 all-electric rubber-tyred gantries (RTG) cranes from Kalmar, 9 E-RTGs, 15 electric rubber-tyred gantry cranes).

Based on the Environmental Report (Piraeus Port Authority S.A. 2016) there is a reference in renewable energy sources. In the frames of PPA's Investment Plan 2011-2016, The PPA's first solar park generating energy using photovoltaic panels has been put into operation in July 2016, generating up to 430 kWp.

In 2017 35.169.243 KWh were consumed (Source: Answer to question form from Operational manager in PCT).

Additionally, green energy is not produced for the container terminal (Source: Answer to question form from Operational manager in PCT).

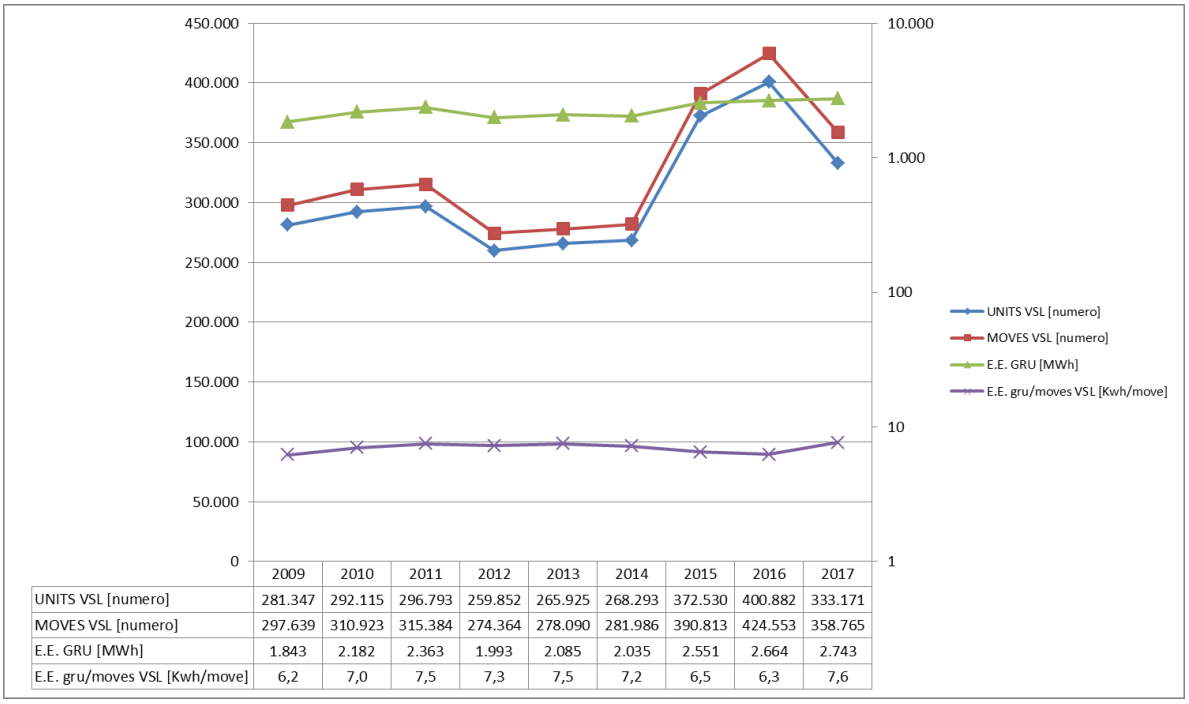
Operational objective check:
Not adequate information for a conclusion regarding electricity consumption.

The operational objective regarding the energy produced from renewable sources is not realized and consequently, green energy should be introduced in the terminal.

Livorno

Terminal Darsena Toscana:

The electricity consumed by cranes is presented in Figure 43 and it is normalized by the number of vessel moves.



	2009	2010	2011	2012	2013	2014	2015	2016	2017
UNITS VSL [numero]	281.347	292.115	296.793	259.852	265.925	268.293	372.530	400.882	333.171
MOVES VSL [numero]	297.639	310.923	315.384	274.364	278.090	281.986	390.813	424.553	358.765
E.E. GRU [MWh]	1.843	2.182	2.363	1.993	2.085	2.035	2.551	2.664	2.743
E.E. gru/moves VSL [Kwh/move]	6,2	7,0	7,5	7,3	7,5	7,2	6,5	6,3	7,6

Figure 43: Electricity consumption in the TDT and GIP (Source: TDT)

It can be observed that the electricity consumption in the container terminal is remaining constant over the last 8 years. More specifically, the cranes' electricity consumption is maintained in the same levels, being proportionate to the number of vessel moves that are performed.

Terminal Lorenzini:

The yearly electricity consumption of the Lorenzini container terminal was 1.500.000 kWh in 2016 (Source: Answer to question form from Project manager of Terminal Lorenzini).

Operational objective check:

The electricity consumption is stable and the fuel consumption, as it can be seen in a previous sub-chapter is remaining almost stable as well, but with a relatively high ratio of consumption over a number of containers, units handled. Therefore, it will be probably needed to shift more to electricity consumption, while optimizing the total consumption of the terminal. No information regarding energy generation and consumption from renewable sources.

H2. People

H2.1 Employment opportunities

Piraeus

The total number of employees\workers that normally work in the container terminal area, inclusive of subcontractors (averages yearly) is approximately 800 per shift (Source: Answer to question form from Operational manager in PCT).

An estimation of the workforce directly and indirectly related to the container terminal's operation would be approximately 3.000 (Source: Answer to question form from Operational manager in PCT).

Livorno

Terminal Lorenzini:
An estimation of the workforce directly and indirectly related to the container terminal's operation would be over 70 directly dependent and over 100 indirectly (Source: Answer to question form from Project manager of Terminal Lorenzini)

H2.2 Safety levels

Piraeus

Yearly mean accidents at work (container terminal) with sick leave are zero (Source: Answer to question form from Operational manager in PCT).

8 Health and Safety Training Programs were planned in total comprising from 128 training hours (Source: Answer to question form from Operational manager in PCT).

The most current Master Plan (2018) of the port of Piraeus, analyses the strategic plans within a horizon of 15 years, however, climate change adaptation strategies are not elaborated.

Livorno

In the terminal Lorenzini there are safety and health training of 980 hours in the year of 2017 (First aid, generic and specific risks, work-related stress etc.) (Source: Answer to question form from Project manager of Terminal Lorenzini).

H2.3 Land use changes

The information that is presented in the present sub-section is formed by the author during the site visits of the port of Piraeus and Livorno.

It should be emphasized as a general fact for both ports, that the ancient Mediterranean ports have slowly reached equilibrium with the urban tissue that surrounds them.

Piraeus

An actual buffer zone (noise barriers- vegetation) does not exist in the port-city interface in the port of Piraeus. The commercial land use surrounding the port acts as a buffer zone.

Livorno

An actual buffer zone (noise barriers- vegetation) does not exist in the port-city interface in the port of Livorno. The commercial land use surrounding the port acts as a buffer zone.

H2.4 Recreation and aesthetics

The information that is presented in the present sub-section is formed by the author during the site visits of the port of Piraeus and Livorno.

The port of Livorno, similarly with the port of Piraeus, is a historical port and its layout has been almost the same for decades. The ports can be considered as a barrier to the seafront in some parts; however, their areas for development of recreational activities exist. A breakwater is constructed along the port, but it cannot be considered to cause any aesthetical obstructions.

Specifically for the container terminals, the cranes and possibly the stacked and stored containers could cause pressure in the aesthetics.

No information is available regarding the cash flow of recreational activities after and before the construction of the marine infrastructures since the port of Piraeus is a historic port and the layout was essentially set from decades.

H2.5 Involvement of stakeholders

From the results from the questionnaires presented in Chapter 3, the following graph was created (Figure 44).

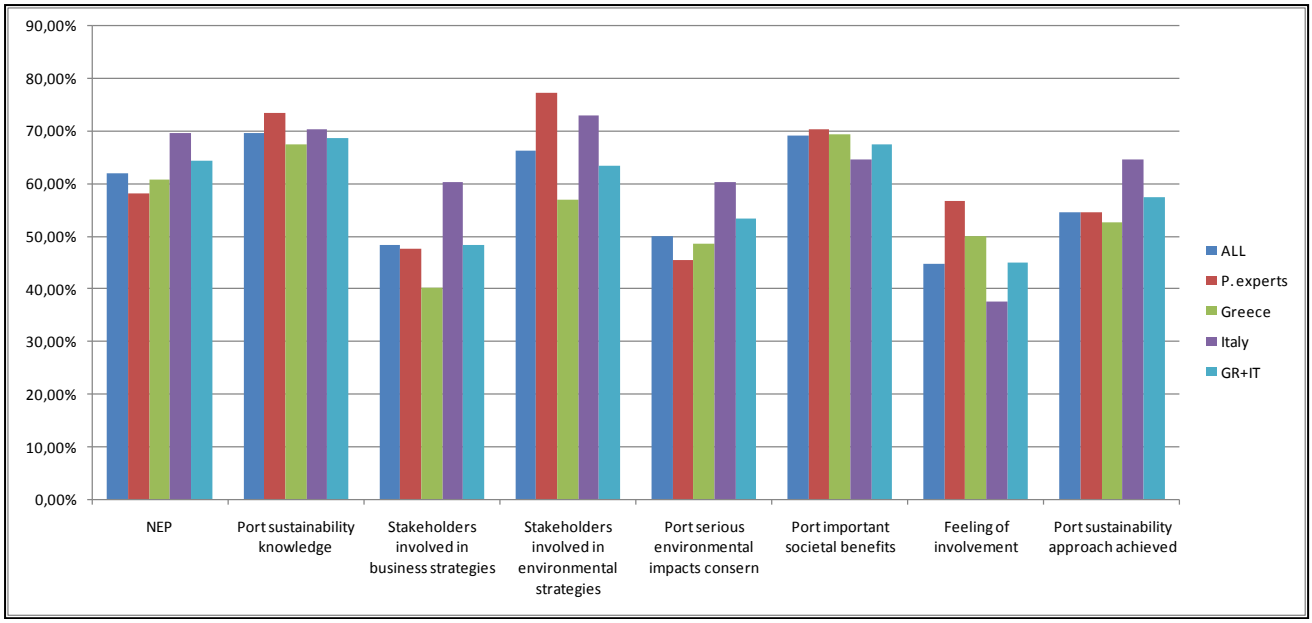


Figure 44: Scoring % of the Part D questions

Piraeus

Since it was not easy to access the feeling of involvement of the stakeholders of the port of Piraeus, a rough approach will be followed, based on the feeling of involvement in the decision making of the stakeholders that answered in the questionnaire (Figure 44)

It can be concluded that only 50% of the Greek stakeholders feel involved in the port decision making, which cannot be considered a satisfying number.

Additionally, the data regarding the port of Piraeus was not easily retrieved. Therefore it can be concluded that the level of access to information was not high and stakeholder inclusion is not facilitated in that sense.

Livorno

Since it was not easy to access the feeling of involvement of the stakeholders of the port of Piraeus, a rough approach will be followed, based on the feeling of involvement in the decision making of the stakeholders that answered in the questionnaire (Figure 44)

It can be concluded that less than 50% of the Greek stakeholders feel involved in the port decision making, which cannot be considered a satisfying number.

Additionally, the data regarding the port of Piraeus was not easily retrieved. Therefore it can be concluded that the level of access to information was not high and stakeholder inclusion is not facilitated in that sense.

H2.6 Traffic congestion

Since the association of the traffic with the road capacity is a complex procedure, it was decided to approach this theme with the Google Maps tool.

Vaibhav Taneja explained that "when Smartphone users turn on their Google Maps app with GPS location enabled, the phone sends back bits of data, anonymously, to Google that let the company know how fast their cars are moving. Google Maps continuously combines the data coming in from all the cars on the road and sends it back by way of those coloured lines on the traffic layers."

Piraeus

For the traffic congestion near the container terminals, the Google Maps "typical traffic layer" was used to examine each week day's average traffic from 6 AM to 22 PM. In all cases, the roads were shown with the green colour that corresponds to fast traffic. An example is presented in Figure 45.

Figure 45: Typical traffic Piraeus Container terminals (Source: Google maps)

Livorno

For the traffic congestion near the container terminals, the Google Maps "typical traffic layer" was used to examine each week day's average traffic from 6 AM to 22 PM. In all cases, the roads were shown with the green colour that corresponds to fast traffic. An example is presented in Figure 46.

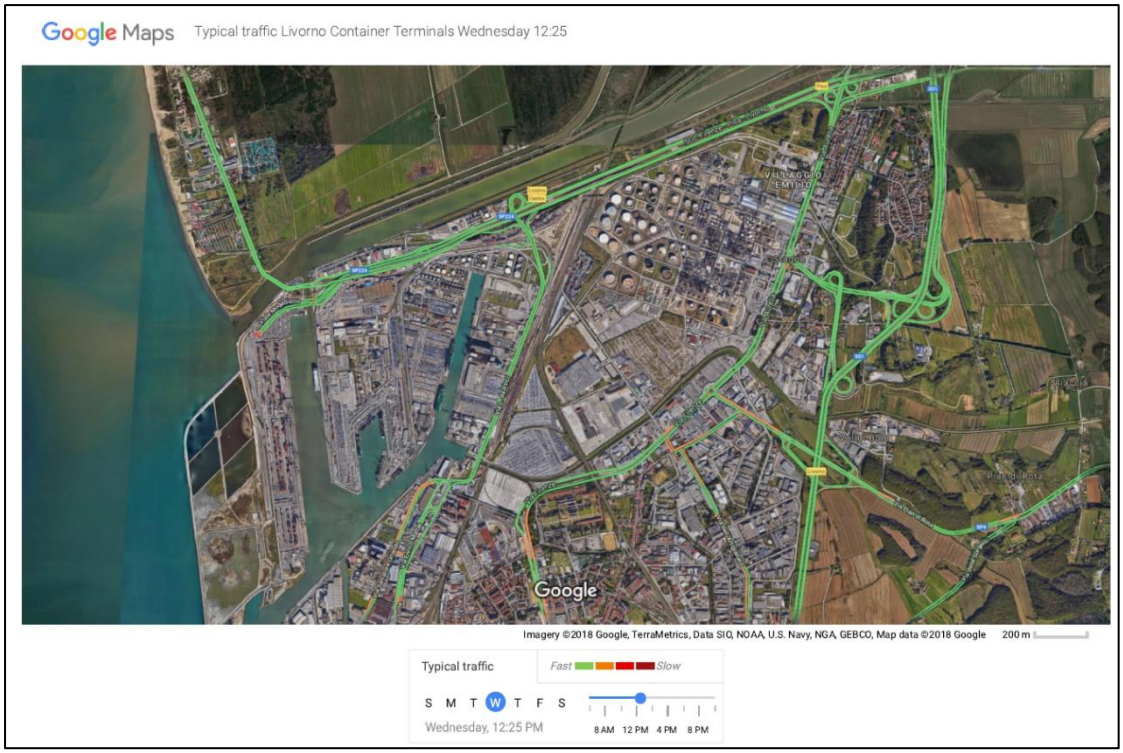


Figure 46: Typical traffic Livorno Container terminals (Source: Google maps)

H3. Profit

H3.1 Intermodality

Piraeus

In the next figure the intermodality of Piraeus container terminals is shown:

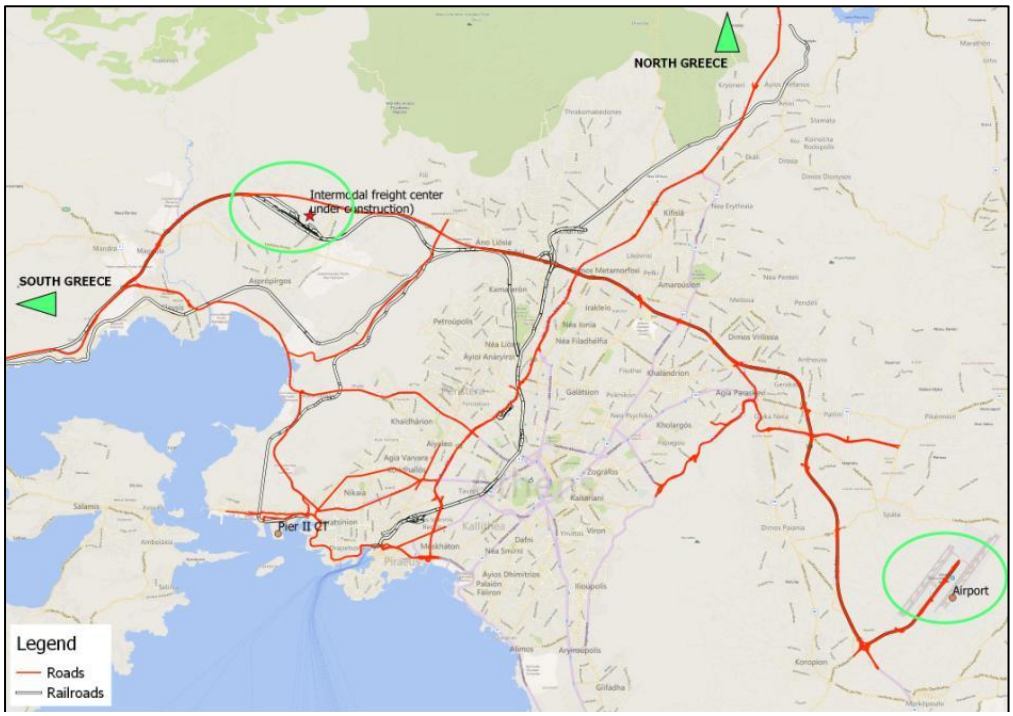


Figure 47: Piraeus container terminal intermodality (own realization)

Rail connection

The railroad connection is functional from 2013 when it was reconnected to the national rail system and the under-construction intermodal freight centre of OSE SA in Attica. The area extends for 85.000m2, to the north of Pier II and III. Rail tracks 4 x 680m.

As it was mentioned in the Piraeus Focus Group, there is an urgent need for an upgrade of the rail network connection to the container terminal.

There is no specific information regarding the exact number of TEUs entering/exiting by rail but they are not expected to be over 5.000 TEUs.

Distance from airport

50-60 km (depending on the route selected)

Livorno

All the text below (A. Penfold, Ocean Shipping Consultants, and FCS 2015):

The main access to the Port of Livorno is the A12 “Genova-Livorno-Rosignano". Along with its route there are numerous and important connection nodes with other motorways such as A11 Firenze-Mare (in turn connected to A1 Milano-Napoli), A15 Parma-La Spezia, A10 Genova- Ventimiglia and A7 Genova-Milano.

Rail connection

From the website of Livorno Port Authority:

Terminal area rail 49.500 m2.
Rail Tracks 3 x 450 m.

Figure 48: Port of Livorno intermodality. Source: Trail Liguria

After the meeting/interview held in TDT with Dr Valerio Liperini, Head of Operational Management of Terminal Darsena Toscana, the following statistics (Table 48) regarding the yearly TEUS imported/exported by train.

Table 43: TEUs imported/ exported by train in TDT

	2010	2011	2012	2013	2014	2015	2016	2017
TEUs inported/exported by train	74.211	61.352	62.693	61.913	57.317	70.844	69.033	72.497

Comparing with the total throughput in the terminal Darsena Toscana it can be calculated that each year the import/export of the TEUs ranges around 15%.

Distance from airport:
20-30 km (depending on the route selected)

H3.2 Productivity

H1.2.1 TEUs traffic per year

Piraeus

In Table 44, the throughput of Piraeus over the years is presented derived from various sources. There were not a complete time-series over the last 20 years, for this reason, it was chosen to retrieve data from different sources, compare them and create a full timeline. It is noticed that the values from the different sources present some differences, however, they are relatively low.

It should be noted that the data from ELSTAT (Hellenic Statistical Authority) and EUROSTAT are provided in tons, whereas all the other values are representing TEUs.

Table 44: Container traffic port of Piraeus (Sources are indicated in the table)

	Container Traffic Piraeus								
Sources:	ELSTAT	EUROSTAT	Containerisation International	UNCTAD	AAPA-ports	PPA		UNCTAD	IAHP
Refering to:	PIRAEUS all	PIRAEUS all	PIRAEUS all	PIRAEUS all	PIRAEUS all	Piraeus (partly)	Explanation of PPA data	*GREECE*	Piraeus All
Years	Tonnes	Tonnes	TEUs	TEUs	TEUs	TEUs		TEUs	TEUs
2000			1.161.000						
2001			1.166.000						
2002			1.404.939						
2003			1.605.135						
2004			1.541.563						
2005			1.394.512						
2006			1.403.408						
2007			1.373.138			1.373.138			
2008		2.998.000	433.582			433.582			
2009		5.071.000	664.895			664.895			
2010		7.888.000	850.000			513.319	From June only Pier I	1.089.607	
2011		18.676.000	1.681.000			490.904	Pier I	1.976.003	
2012		30.326.000	2.734.004			625.914	Pier I	3.051.755	2.734.000
2013		34.946.000	3.199.000			644.055	Pier I	3.486.310	3.164.000
2014	36.341.606	36.342.000	3.493.000					3.934.713	3.585.000
2015	33.288.557	33.289.000	3.360.000	3.287.000	3.360.000			3.679.000	3.330.000
2016	35.461.919	35.462.000		3.750.000	3.735.805			4.026.000	3.737.000
2017	38.813.456								

In the Master Plan, PPA S.A., 2018 it is stated that the traffic at the container station marked a significant reduction due to the continuation of the transhipment of MSC, the main client of Pier I, at its terminal in Turkey (ASIA PORT). More specifically, despite a significant increase of 26% in domestic cargo (from 49,275 to 61,980 TEU's), the total transit cargo commodity of the terminal decreased from about 255,581 TEU's in 2015 to 203,658 TEU's in 2016.

The average ship calls per year are 2.477 in PCT but the vessel capacity data is not available (Source: Answer to question form from Operational manager in PCT).

Livorno

The traffic in TEUs in the container terminals of Livorno are indicated in Table 46, Table 46 and Table 47.

Table 45: Container Traffic in the port of Livorno 2000 - 2008 (Source: Port Authority of Livorno, 2008)

	Container Traffic
Year	TEUs (transshipment included)
2000	531.759
2001	531.814
2002	546.882
2003	592.778
2004	638.586
2005	658.506
2006	657.592
2007	745.557
2008	778.864

Table 47: Container traffic in the port of Livorno 2012-2016 (Source: Dichiarazine ambientale 2015-2018(Sig Franco Fagioli 2015 and 2017)

	Container Traffic
Year	TEUs (transshipment included)
2012	549.047
2013	559.180
2014	577.471
2015	780.784
2016	800.475

Table 46: Livorno Port volumes from 2008 – 2014 (Source: Livorno Port Authority / Ocean Shipping Consultants)

'000 TEUs

	2008	2009	2010	2011	2012	2013	2014
Import	339.36	263.11	278.26	288.64	259.83	263.03	263.90
Export	356.56	273.10	299.97	305.01	262.71	264.32	255.60
Transshipment	82.94	55.85	50.26	44.16	26.51	31.83	57.97
Total	**778.86**	**592.05**	**628.49**	**637.80**	**549.05**	**559.18**	**577.47**
% Transshipment	*10.65%*	*9.43%*	*8.00%*	*6.92%*	*4.83%*	*5.69%*	*10.04%*
Full - Local	524.32	405.04	441.57	461.35	400.33	401.05	392.79
Empty - Local	171.60	131.17	136.66	132.29	122.22	126.30	126.71
Total	**695.92**	**536.20**	**578.23**	**593.64**	**522.54**	**527.35**	**519.50**

Source: Livorno Port Authority / Ocean Shipping Consultants

Terminal Darsena Toscana:

The yearly TEUs handled in their terminal are presented in Table 48.

Table 48: Yearly throughput TDT during the period 2007 – 2017 (Source: TDT)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	al 30/06/2018
Units	**319.925**	**368.731**	**281.347**	**292.115**	**296.793**	**259.863**	**265.925**	**268.293**	**372.530**	**400.882**	**333.171**	**153.545**
Full	217.823	256.597	201.671	214.368	223.383	191.087	189.741	175.487	177.762	187.009	175.931	89.774
Empties	67.787	71.517	52.965	56.070	53.084	56.243	59.117	60.071	74.080	76.002	71.662	25.787
Trashpment	34.315	40.617	26.711	21.677	20.326	12.533	17.067	32.735	120.688	137.871	85.578	37.984
Teus	**501.394**	**588.778**	**451.921**	**467.600**	**471.188**	**406.829**	**417.088**	**426.337**	**588.472**	**640.854**	**515.792**	**243.109**
Turnover	**95,0**	**96,0**	**96,2**	**98,3**	**97,8**	**102,0**	**104,2**	**107,3**	**101,5**	**98,4**	**96,3**	**93,3**

Comparing the throughput statistics for the years 2008 - 2014 that are available for both for the whole port of Livorno as well as individually for the Terminal Darsena Toscana, it can be observed that every year the TDT takes over approximately the 75% of the total container traffic in the port.

In Table 49 the total number of container ships that arrive in the port each year.

Table 49: Container ships calls/ year TDT for the period 2010-2017 (Source: TDT)

	2010	2011	2012	2013	2014	2015	2016	2017
Container ship calls/ year	546	652	565	542	580	791	827	749

Terminal Lorenzini:

In the year of 2017, the container traffic in the Lorenzini container terminal was 170.000 TEUs (Source: Answer to question form from Project manager of Terminal Lorenzini). Even though the information is not adequate to draw a conclusion about the evolution of the terminal, the traffic that is handled is approximately 1/3 of the traffic in the Terminal Darsena Toscana.

The average ship calls per year are over 200 and their capacity is raging between 7.000 and 9.000 TEUs (Source: Answer to question form from Project manager of Terminal Lorenzini).

H1.2.2 Transhipment

Piraeus

It was not possible to gather data regarding transhipment in PCT.

Livorno

The transshipment in the container terminal of Livorno is presented in Table 50 from (A. Penfold, Ocean Shipping Consultants, and FCS 2015).

Table 50: Port of Livorno Regional Transshipment Market (Source: A. Penfold, Ocean Shipping Consultants, and FCS 2015)

	Livorno Regional Container Transshipment Market	Per cent share
Year	TEUs	%
2000	17.800	0,3
2001	29.900	0,4
2002	27.100	0,3
2003	52.200	0,6
2004	59.300	0,6
2005	57.100	0,5
2006	61.300	0,5
2007	74.700	0,5
2008	82.900	0,6
2009	55.800	0,4
2010	50.300	0,3
2011	44.200	0,3
2012	26.500	0,2
2013	31.800	0,2
2014	58.000	0,4

In Table 51 the yearly TEUS (related to transshipment) handled in their terminal are presented.

Table 51: Transhipment volumes TDT for the period 2007-2017 (Source: TDT)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	al 30/06/2018
Trashpment	34.315	40.617	26.711	21.677	20.326	12.533	17.067	32.735	120.688	137.871	85.578	37.984
Teus	**501.394**	**588.778**	**451.921**	**467.600**	**471.188**	**406.829**	**417.088**	**426.337**	**588.472**	**640.854**	**515.792**	**243.109**

In the above table, it can be observed that the transhipment volumes are rather low, they reflect a percentage of 6% in the first years, while after 2105 it increases to 20% approximately.

Comparing with the statistics regarding transhipment of containers for the whole port of Livorno it can be observed that approximately 50% of the container transhipment of the port is taken over from Terminal Darsena Toscana.

H1.2.3 Vessel time spent in the port

Piraeus

The average vessel time spent in the port for 2016 and 2017 are presented in the following table:

Table 52: vessel time spent in the port (Source: PCT)

	Feeder Vessels	Mother Vessels
2016	19,82h	22,33h
2017	20,72h	22,67h

Operational objective check:
The container vessel time spent in the port should be approximately 0.80 days. For mother vessels, the average time is approximately 0.9 days which is higher than the average vessel waiting time in the world.

Livorno

It was not possible to retrieve information regarding the vessel time spent in the container terminals of Livorno.

H1.2.4 TEUs/crane/year (Crane Utilization)

Piraeus

It was not possible to retrieve information regarding the crane utilization in the PCT.

Livorno

In the following table Table 53, it is presented the crane utilization in the port of Livorno.

Table 53: Annual productivity – TEUs per STS Gantry Cranes (A. Penfold, Ocean Shipping Consultants, and FCS 2015)

Year	TEUs
2010	78,560
2011	63,780
2012	54,900
2013	62,130
2014	64,160

Operational objective check:
Although there is not more recent information about the annual crane productivity, it can be concluded that considering that the crane utilization should approximately 100,000-150,000 TEU/gantry crane/year, Livorno is placed a bit lower than the limit.

H1.2.5 Moves/crane/hour (Crane productivity)

Piraeus

27 movements per hour per crane are performed in PCT (TEU data is not available) (Source: Answer to question form from Operational manager of PCT)

Operational objective check:
The crane productivity should be approximately 25–40 crane moves per hour. The crane productivity of Piraeus Container Terminal is within the limit that was set.

Livorno

The statistics regarding the TEUs that are handled per hour per crane type for each year are presented in Table 54.

Table 54: TEUs/hour/crane in TDT for period 2010-2017

	2010	2011	2012	2013	2014	2015	2016	2017
TEUs/hour/crane type	24,74	24,42	25,05	25,83	27,22	28,06	24,79	23,05

Operational objective check:
The crane productivity should be approximately 25–40 crane moves per hour. The crane productivity of terminal Darsena Toscana especially in the last years is smaller than the lowest limit that was set.

H1.2.6 Measure of moves per berth meter

Piraeus

A total of 1.487,20 container moves per berth meter per year(TEUs/berth meter/ year) are realized in PCT in 2017 (Source: Answer to question form from Operational manager of PCT).

Operational objective check:
The number of moves per berth meter of the PCT is very close to the target that was set large ports (1,500-1,750 TEU/berth metre/year).

Livorno

The annual Productivity TEUs per berth length for the port of Livorno is presented in Table 55.

Table 55: Annual Productivity TEUs per Berth Length (Source: A. Penfold, Ocean Shipping Consultants, and FCS 2015)

Year	TEUs
2010	439,5
2011	446,01
2012	385,95
2013	391,03
2014	403,83

Terminal Darsena Toscana:
In Table 56 are presented the number of container moves performed in each meter for each year.

Table 56: Container moves/ berth meter/year TDT for period 2010-2017 (Source: TDT)

	2010	2011	2012	2013	2014	2015	2016	2017
Container moves per meter per years (TEUs/meter/year)	334	337	291	298	305	420	458	368

Operational objective check:
A target level 400-500 TEU/berth metre/year for smaller ports and terminals is achieved from the port of Livorno.

H1.2.7 Number of simultaneous cranes per vessel type

Piraeus

No information regarding the simultaneous cranes working per vessel was retrieved from PCT.

Livorno

No information regarding the simultaneous cranes working per vessel was retrieved from the container terminals of Livorno.

H1.2.8 Truck time spent in the terminal area

Piraeus

The Average time the trucks remain in the terminal area is 17 minutes (Source: Answer to question form from Operational manager of PCT).

Livorno

No information regarding truck time spent in terminal area.

H3.3 Personnel training

Piraeus

A total of 28 productivity training programmes are taken in Piraeus Container Terminal that consist of 941 training hours (Source: Answer to question form from Operational manager of PCT).

Livorno

In the Lorenzini container terminal in 2017, 1.400 hours of work productivity trainingprogrammes were held (Source: Answer to question form from Project manager of Terminal Lorenzini).

H3.4 Terminal potential

It indirectly depends on the type and number of cranes and available land area.

Piraeus

- Capacity Pier I: f 1 million TEUs
- Capacity Pier II: 3.2 million TEUs
- Capacity Pier III: 2.3 million TEUs

Livorno

From the website of Livorno Port Authority: Capacity 900.000 TEUS approx.

H3.5 Quay length

Piraeus

- Total Operational Quayside for PIER II: 1.480 meters
- Total Operational Quayside for PIER III: 1.000 meters

Livorno

- Quay length Darsena Toscana: 1.430 m.
- Berth Length Darsena Toscana: 526 m

Specifically for Lorenzini Container terminal: Quay length is 480m (Source: Answer to question form from Project manager of Terminal Lorenzini).

H3.6 Operational Depth

Piraeus

Quay depth varies between 14,5 – 19,5 m (Source: Answer to question form from Operational manager of PCT).

Livorno

Quay depth: 13, m.

Specifically for the Lorenzini container terminal, the operational depth equals to 11.5 m (Source: Answer to question form from Project manager of Terminal Lorenzini).

H3.7 Total yard area

Piraeus

The total yard area of the PCT is approximately 1,8 square kilometres.

Livorno

Specifically for Lorenzini Container Terminal, the total yard area is over 90.000 m^2(Source: Answer to question form from Project manager of Terminal Lorenzini)

H3.8 Equipment

Piraeus

- 13 Super Super Post Panamax,
- Super Post Panamax
- 12 Post Panamax
- 22 Rail-Mounted Gantry Cranes (RMGs)
- 40 Electrified Rubber Gantry Cranes (ERTGs)

Livorno

From the website of Livorno Port Authority:

- 8 Quay cranes
- 14 RTGs
- 20 Reach Stackers
- 38 Lighting Towers

Table 57: Total number of STS Gantry Cranes (A. Penfold, Ocean Shipping Consultants, and FCS 2015)

Year	#
2010	8
2011	10
2012	10
2013	9
2014	9

Based on the Answer to question form from Project manager of Terminal Lorenzini, specifically for the Lorenzini container terminal the crane types that are operated are:

- N. 2 Gottwald HMK 7608 tons 150
- N. 1 Gottwald HMK 7408 tons 100
- N. 2 Gru mobile Gottwald HMK 300 tons 100
- N. 1 Gru mobile Fantuzzi Reggiane MHC 115 tons 75
- N. 4 RTG Noell Fantuzzi 5+1 AC.

H3.9 Expandability

H1.9.1 Master plans proposals

Piraeus

According to the latest concession amendment (L.4315/2014-GG269A/2014, Figure 49) the final phase of Pier III will comprise the east dock (204.940m^2 - 600m quay), the west dock (135.590m^2 - 770m quay) and the oil terminal (12.802m^2 - 250m quay) at the south quayside. The total annual capacity of Pier III will be 3.000.000 TEUs.

In addition to Piers II and III, the concession to PCT SA comprises a land area of 174.590m^2. The railways terminal extends in an area of 85.000m^2 to the north of Pier II.

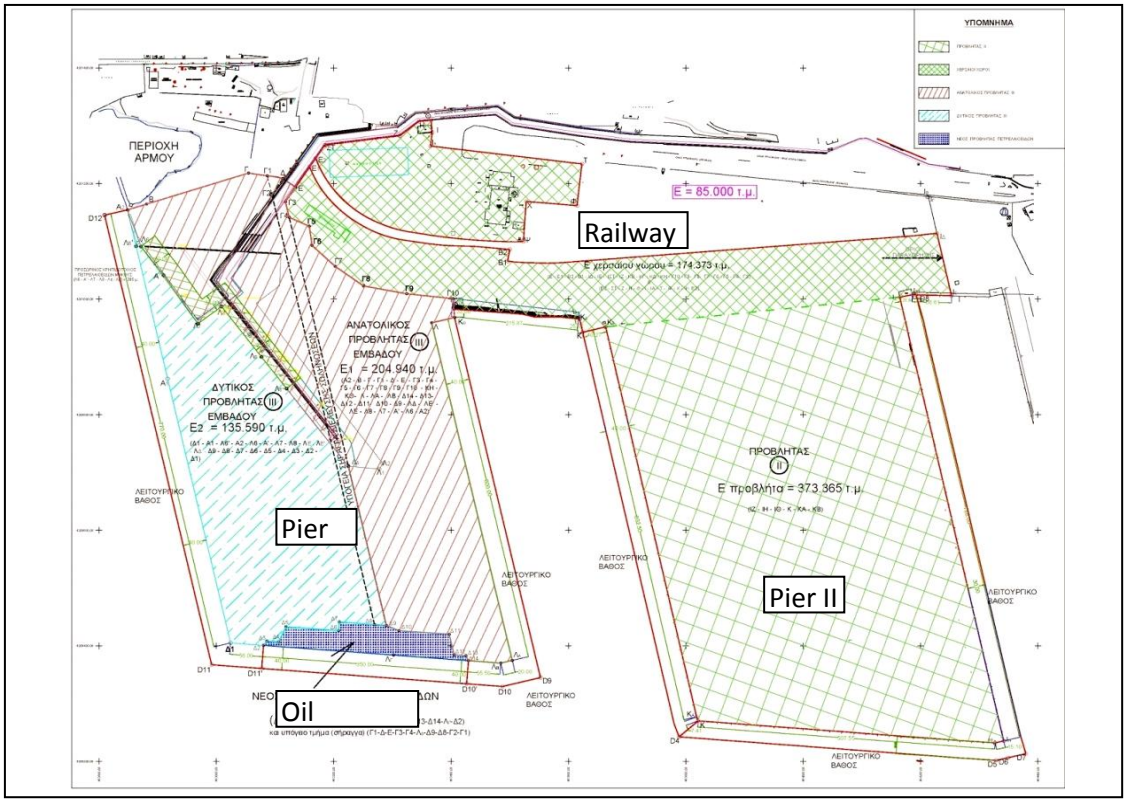


Figure 49 Plan of the final phase of Pier III and Pier II (source: L.4315/2014-GG269A/2014)

In the Master Plan, PPA S.A., it is mentioned that an Investment Plan was approved in October by decision of the Board of Directors the implementation, amounting to € 137.5 million only for 2017, as an integral part of PPA's total mandatory investment plan but also of the voluntary investment plan planned by COSCO SHIPPING (Hong Kong) Limited to make Piraeus port a further commercial hub and an international cruise and ship repair center. The investments involve, among others, the improvement of the port infrastructures as well as repair works for the Container Terminal I.

Livorno

The new Port Authority has been instituted with the Italian Presidential Decree n. 169, 4/8/2016.

The Europa Platform is planned to be built. A financial Engineering Plan for the development of the Logistic node of Livorno through the Implementation of the First Phase of the Platform Europe Is conducted.

It will have an operational depth of 16 m to increase the competitiveness of the terminal. In that way, it could be ''future proofed'' for any eventual increase of vessel size in the future (A. Penfold, Ocean Shipping Consultants, and FCS 2015). It is also noted that this operational depth would correspond to a maximum capacity of 12.500 TEUs.

The following plans regarding the various phases of the planned port expansion are extracted from the New Master Plan of the Port of Livorno – Articulation of the temporal interventions (Autorità di Sistema Portuale del Mar Tirreno Settentrionale 2017).

First phase

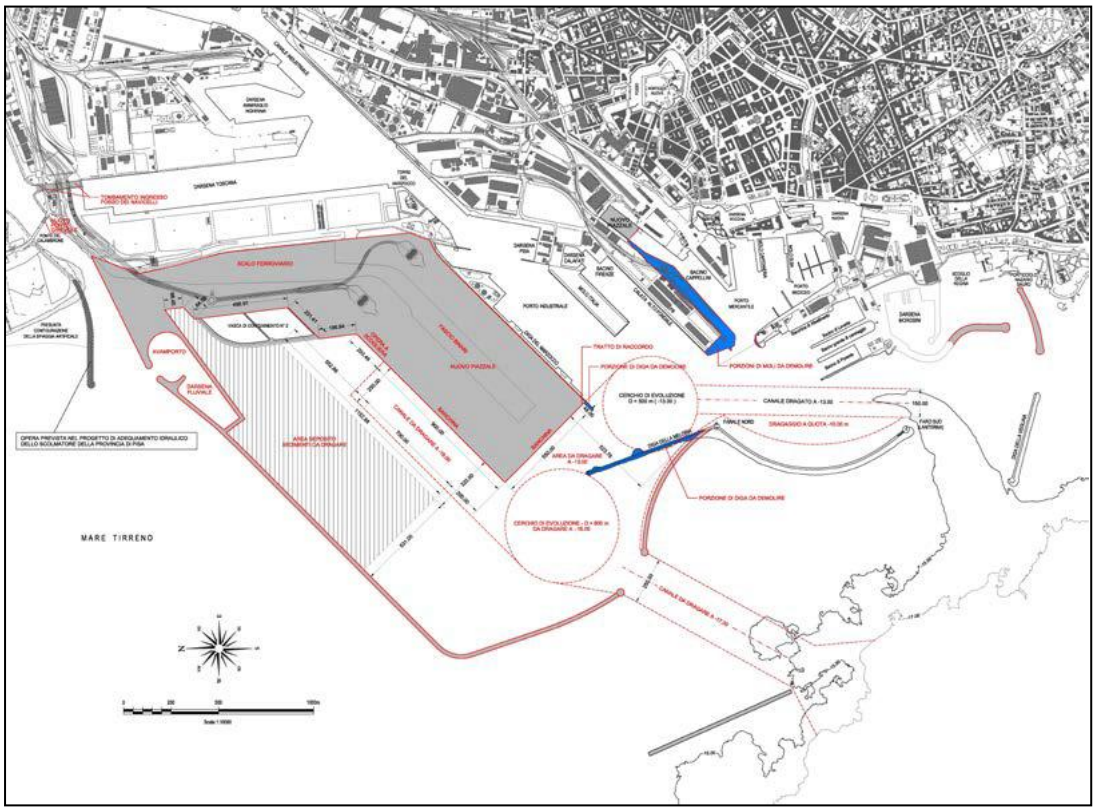


Figure 50: First phase plans of the planned port expansion from the New Master Plan of the Port of Livorno

Second phase

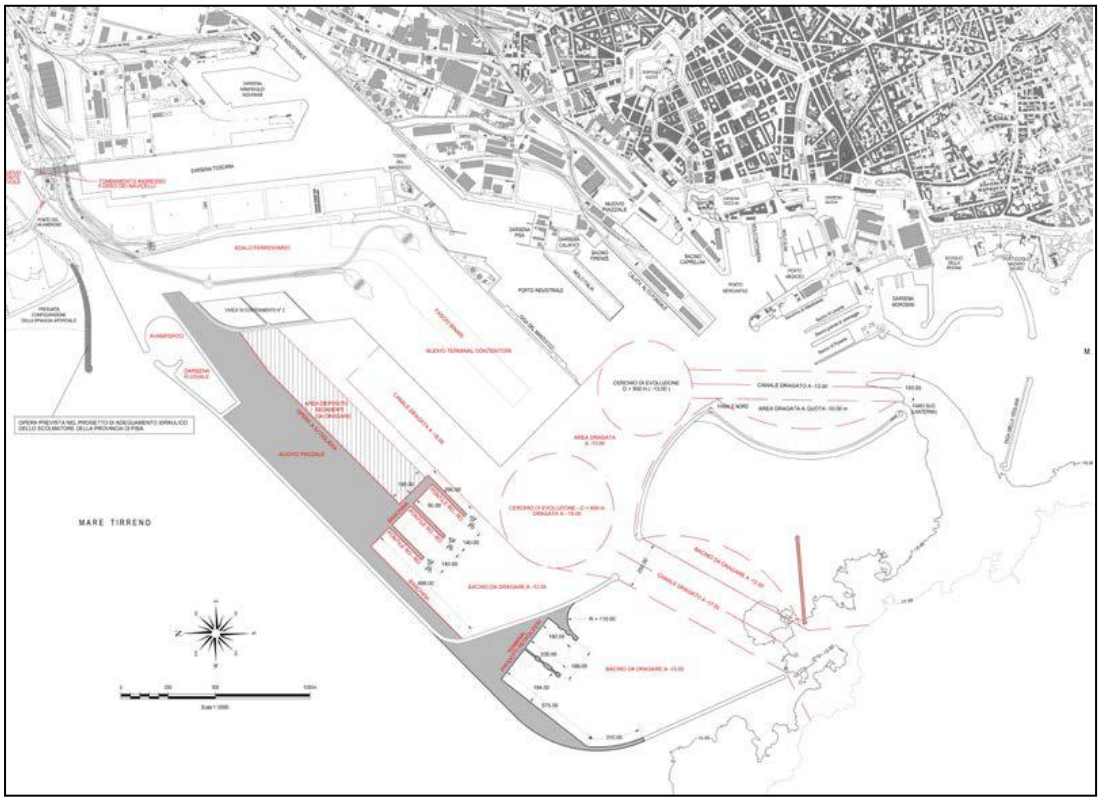


Figure 51: Second phase plans of the planned port expansion from the New Master Plan of the Port of Livorno

Third phase

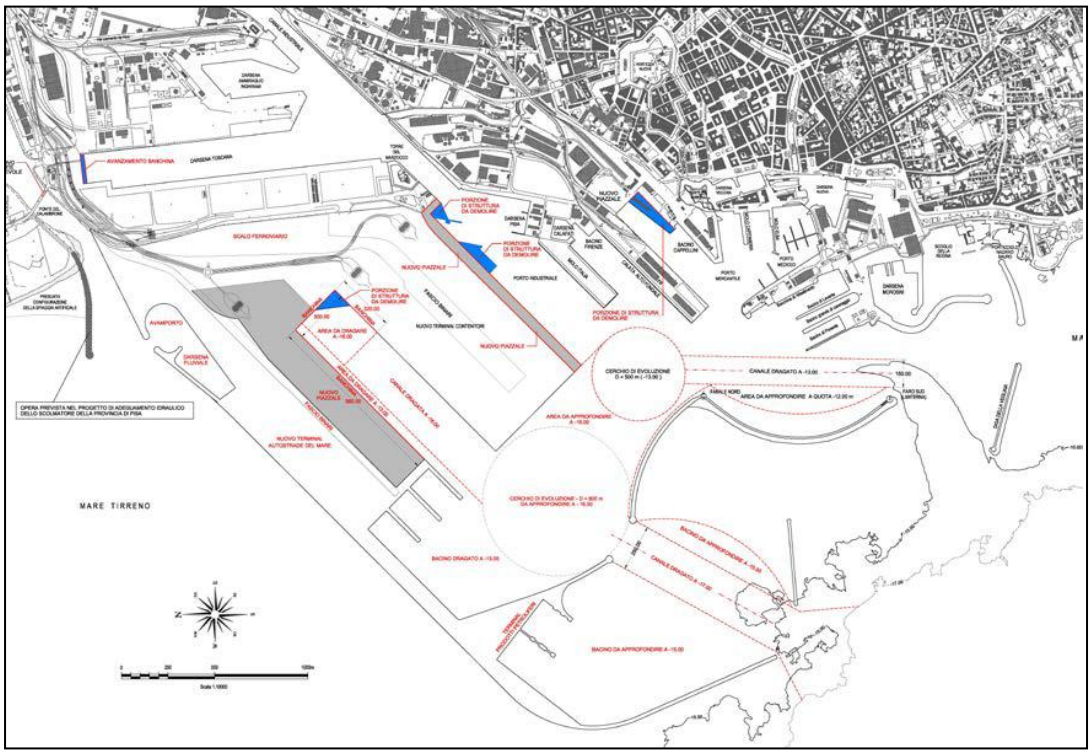


Figure 52: Third phase plans of the planned port expansion from the New Master Plan of the Port of Livorno

Appendix I *Results of application of PSAF in case studies*

Marked with red are the non-achieved operational objectives, with green the achieved ones, with orange the operational objectives for which it was not possible to retrieve information or the information was not adequate and lastly with black the ones that were not explored by the author due to complexity or non-relevancy with the case studies.

Table 58: Port of Piraeus container terminal: compliance with the operational objectives - Planet

Strategic sub-objective	Themes	Operational objectives
Make the port greener	Air quality	• The concentration of air pollutants should be lower than the standards defined by the European Commission. • Over a period of five years, CO2 emissions must fall by 10%. • The fuel consumption should be reduced more than 20% in the next 5 years.
	Soil- sediment quality and state	• The heavy metals concentration in the sediment of the port basin should be less that the values that are defined in the Annex II to Directive 1999/31/EC. • The oil concentration in the soil should be less than 40 mg/kg dry.
	Water column quality	• The concentration of Intestinal Enterococci and E.coli should be below the levels indicated from each country's Directive. The concentration of heavy metals in the surface waters should be lower than the maximum acceptaple concetrations defined by the European Comission. • The oil concentration should be less than 200 ng/L. • The water transparency should be good, indicated with 8m of secchi disk depth.
	Water consumption	The water consumption should be optimized according to the traffic of the container terminal, using the treated grey waters where applicable
	Noise	The levels noise levels in the ports should not exceed the limits in areas that are mainly industrial defined by each country's Decree.
	Energy consumption	• The ratio of electricity consumption to TEUs traffic should be optimized. • The ratio of electricity consumption to fuel consumption should be increasing. • The ratio of energy from renewable sources to the total energy consumption should be increasing. Additionally the following more generalized operational objective is set: • Optimize pollution reduction while maintaining a commercially-viable operation that does not significantly increase costs and waiting times for their customers.

Table 59: Port of Piraeus container terminal: compliance with the operational objectives - People

Make the port happier	Employment opportunities	• Value added services should be introduced both for the terminal's economic benefit and for the introduction of new job positions. • The expansion of the port should come along with job opportunities in other sectors. • The working conditions (salaries, holiday leave, allowances etc. should be satisfactory relatively to each countries' local economy.
	Safety levels	• The terminal should comply with all the regulations that are put into force regarding the preventions of accidents. • The personnel of the container terminal should receive regular training regarding the everyday operations of the yard equipment, as well as handling of hazardous cargo. • Inclusion of climate change adaptation policies in the development measures of the ports
	Land use changes	• A buffer zone should exist in the port-city interface (Noise barriers- vegetation –logistics buildings and include some non-exclusively port related activities of low intensity) • The ratio (Residential + commercial uses)/industrial uses should be the maximum possible.
	Recreation and aesthetics	• The existence of marine infrastructures damaging the aesthetics: yes/no. • The ratio of cash flow from recreational activities after and before the construction of the marine infrastructures should not be lowers than 1.5.
	Stakeholder involvement	• Using the questionnaire that was created for the context of this thesis study, more than 70% of the stakeholders should feel involved in the decision making. • The information regarding various port performance indicators should be easily accessible.
	Traffic congestion	• The traffic should not exceed the carrying capacity of the road

Table 60: Port of Piraeus container terminal: compliance with the operational objectives - Profit

Make the port richer	Intermodality	• The intermodal connectivity of the port should be improved according to the needs of the container terminal and the port (rail and road network).
	Productivity	• According to the strategical goal of the port and a market analysis, the goals as to the number of TEUs in the next years should be set by each container terminal. • A target level of 1,000-1,250 TEU/berth metre/year should be achieved for medium sized ports with a high transhipment component, with some 1,500-1,750 TEU/berth metre/year. • The crane utilization should approximately 100,000-150,000 TEU/gantry crane/year. • The crane productivity should be approximately 25–40 crane moves per hour. • The container vessel time spent in the port should be approximately 0.80 days. • On average, 5.5 cranes during ship working time should be capable to load and/or unload the largest container vessels. • There should be a yard vehicles tracking system to optimize the average time of activity/inactivity of the yard vehicles and the total number of movements per container unit and empty trips.
	Personnel training	• There should be constant training seminars. • The terminal should be informed about techniques and implement innovations to optimize its efficiency.
	Terminal potential	• The terminal capacity should be equal or higher than the actual container traffic.
	Expandability	• The Master Plan proposals should comply with the needs of the port and the city and should be amended regularly *to* include the eventual changes. • The Master Plans should be designed based on the concept of flexibility and sustainable growth
	Circular economy	The reuse of dredged material inside the port (if non-contaminated), the renewable energy production, the recycling, the use of biofuels and treated grey water should be maximized within the terminals and consequently within the ports.

Table 61: Port of Livorno container terminals: compliance with the operational objectives - Planet

Strategic sub-objective	Themes	Operational objectives
Make the port greener	Air quality	• The concentration of air pollutants should be lower than the standards defined by the European Commission. • Over a period of five years, CO2 emissions must fall by 10%. • The fuel consumption should be reduced more than 20% in the next 5 years.
	Soil- sediment quality and state	• The heavy metals concentration in the sediment of the port basin should be less that the values that are defined in the Annex II to Directive 1999/31/EC. • The oil concentration in the soil should be less than 40 mg/kg dry.
	Water column quality	• The concentration of Intestinal Enterococci and E.coli should be below the levels indicated from each country's Directive. • The concentration of heavy metals in the surface waters should be lower than the maximum acceptaple concetrations defined by the European Comission. • The oil concentration should be less than 200 ng/L. • The water transparency should be good, indicated with 8m of secchi disk depth.
	Water consumption	The water consumption should be optimized according to the traffic of the container terminal, using the treated grey waters where applicable
	Noise	The levels noise levels in the ports should not exceed the limits in areas that are mainly industrial defined by each country's Decree.
	Energy consumption	• The ratio of electricity consumption to TEUs traffic should be optimized. • The ratio of electricity consumption to fuel consumption should be increasing. • The ratio of energy from renewable sources to the total energy consumption should be increasing.

Table 62: Port of Livorno container terminals: compliance with the operational objectives - People

Make the port happier	Employment opportunities	• Value added services should be introduced both for the terminal's economic benefit and for the introduction of new job positions. • The expansion of the port should come along with job opportunities in other sectors. • The working conditions (salaries, holiday leave, allowances etc. should be satisfactory relatively to each countries' local economy.
	Safety levels	• The terminal should comply with all the regulations that are put into force regarding the preventions of accidents. • The personnel of the container terminal should receive regular training regarding the everyday operations of the yard equipment, as well as handling of hazardous cargo. • Inclusion of climate change adaptation policies in the development measures of the ports
	Land use changes	• A buffer zone should exist in the port-city interface (Noise barriers- vegetation –logistics buildings and include some non-exclusively port related activities of low intensity) • The ratio (Residential + commercial uses)/industrial uses should be the maximum possible.
	Recreation and aesthet	• The existence of marine infrastructures damaging the aesthetics: yes/no. • The ratio of cash flow from recreational activities after and before the construction of the marine infrastructures should not be lowers than 1.5.
	Stakeholder involvement	• Using the questionnaire that was created for the context of this thesis study, more than 70% of the stakeholders should feel involved in the decision making. • The information regarding various port performance indicators should be easily accessible.
	Traffic congestion	• The traffic should not exceed the carrying capacity of the road

Table 63: Port of Livorno container terminals: compliance with the operational objectives - Profit

Make the port richer	Intermodality	• The intermodal connectivity of the port should be improved according to the needs of the container terminal and the port (rail and road network).
	Productivity	• According to the strategical goal of the port and a market analysis, the goals as to the number of TEUs in the next years should be set by each container terminal. • A target level of 1,000-1,250 TEU/berth metre/year should be achieved for medium sized ports with a high transhipment component, with some 1,500-1,750 TEU/berth metre/year. • The crane utilization should approximately 100,000-150,000 TEU/gantry crane/year. • The crane productivity should be approximately 25–40 crane moves per hour. • The container vessel time spent in the port should be approximately 0.80 days. • On average, 5.5 cranes during ship working time should be capable to load and/or unload the largest container vessels. • There should be a yard vehicles tracking system to optimize the average time of activity/inactivity of the yard vehicles and the total number of movements per container unit and empty trips.
	Personnel training	• There should be constant training seminars. • The terminal should be informed about techniques and implement innovations to optimize its efficiency.
	Terminal potential	• The terminal capacity should be equal or higher than the actual container traffic.
	Expandability	• The Master Plan proposals should comply with the needs of the port and the city and should be amended regularly *to* include the eventual changes. • The Master Plans should be designed based on the concept of flexibility and sustainable growth
	Circular economy	The reuse of dredged material inside the port (if non-contaminated), the renewable energy production, the recycling, the use of biofuels and treated grey water should be maximized within the terminals and consequently within the ports.

Appendix J *Questionnaire layout, methodology and data processing*

J1.1 Questionnaire layout

The questionnaire has been prepared as an excel workbook. It was prepared first in English and then translated into Italian and Greek. It contains two worksheets: the info-help (with a green tab) and the questionnaire itself (with a red tab).

The info-help worksheet contains a short presentation the author, a generic and short definition of my MSc thesis within which the questionnaire has been prepared, a declaration that there will be no processing of the information of the senders' emails in order to protect the complete anonymity of the interviewees, instructions regarding the answering of the various parts of the questionnaire and a brief explanation of the various themes.

The questionnaire worksheet contains only the questionnaire which is divided into 4 parts.

There is a visible part that contains the questions and a hidden part that contains the numeric coding of the answers and a first preprocessing of the data. As it will be explained later, a dedicated python script grabs all data from this hidden part of the questionnaires and processes the answers.

In Part A (generic info regarding the interviewees), the interviewees must select from a drop-down list their relation to a port (stakeholder category). If an interviewee has more than one relations to a port (for example, if one lives near a port, works in a Port Authority and is a port expert) it is explained that the selection should be made according to the relationship that has more strongly influenced his/her opinion. The interviewees must also select from a drop-down list the country or continent where they currently live and work.

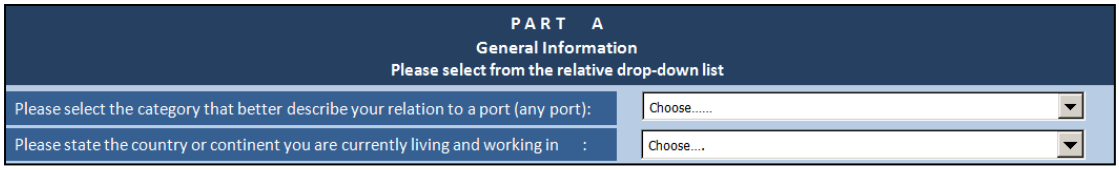


Figure 53: Part A of the questionnaire

The various stakeholder categories were principally based on the stakeholders of the PIANC Report n° 150 - 2014(PIANC 2014b). The stakeholder categories list is the following:

Table 64: Stakeholder categories

I live near a port	Ship chandler
Port user/passenger	Fuel supplier
Port Authority	Community group
Terminal operator/concessionary	Environmental NGO
Stevedoring company	Port Police
Transport company	Fire brigade
Shipping line	Customs
Shipping agency	Press/media
Other port labour	Scientific institutions
Logistics company	Government agency
Warehousing company	Region/Prefecture agency
Importer/exporter	Municipality
Customs broker	Port expert
Towage and pilotage	Local commercial/industrial activity
Waste reception	Other

The countries/continents list is the following:

Table 65: Countries/continents

Greece
Italy
Other EU
Africa
Asia
N. America
Oceania
S. America

In Part B (general opinion on the comparative importance among the 3 PPP classes), the interviewees are asked to compare, by pairs, the relative importance (according to their personal beliefs and opinion) of the environment, the society and the economy, that is, they must compare the importance of a good state of the natural environment, a society of high humanitarian values and economic wealth, in general and not regarding a specific activity or economic sector.

The possible degrees of importance for each pair comparison are:

- Less important,
- Equally important,
- Weakly more important,
- Fairly more important,
- Strongly more important,
- Absolutely more important.

The interviewee must move the slider toward the theme considered more important.

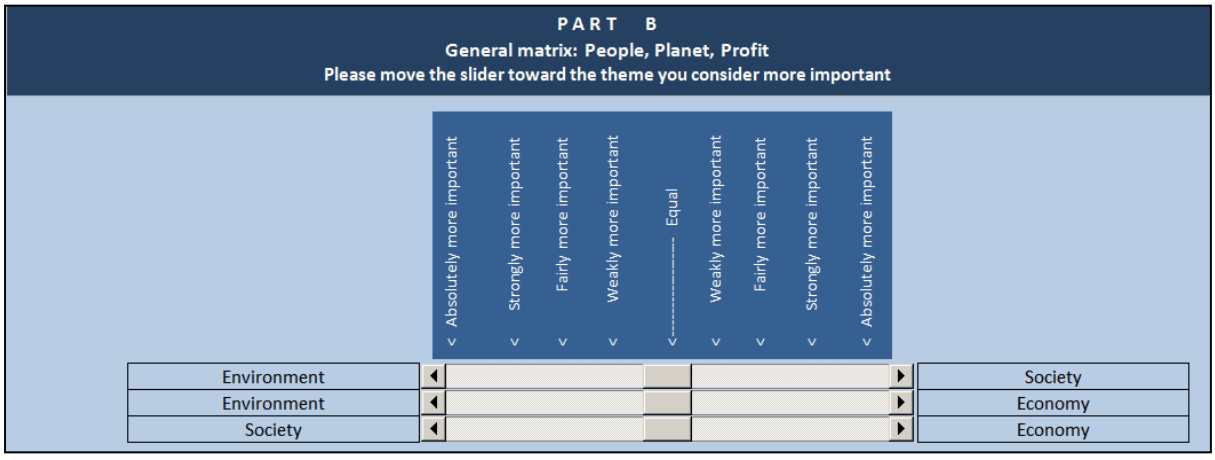


Figure 54: Part B of the questionnaire

In Part C, three different tables must be completed, with the same logic as in Part B. All tables regard specifically the port and its activities.

The first table (Planet) regards the main environmental direct themes that are connected to a port:

- Air quality (all emissions to the air of port-related activities)
- Seawater quality (all discharges to the sea of port-related activities)
- Water consumption (related to all port activities and structures)
- Sediment/soil quality (all substances that end in soil/sediments due to port-related activities)

- Noise (noise pollution due to all port activities)
- Energy consumption (of all port activities and structures)

Other environmental themes that depend mainly/exclusively on the aforementioned themes, like the carbon footprint (emissions to air and energy consumption), biodiversity, fauna, flora, human health (air-water-soil/sediment-noise), etc, are not taken into account directly as they can be (more or less quantitatively) extrapolated from the main themes.

At the end of the table, there are 3 green-coloured cells, where the interviewee can add up to 3 more basic themes.

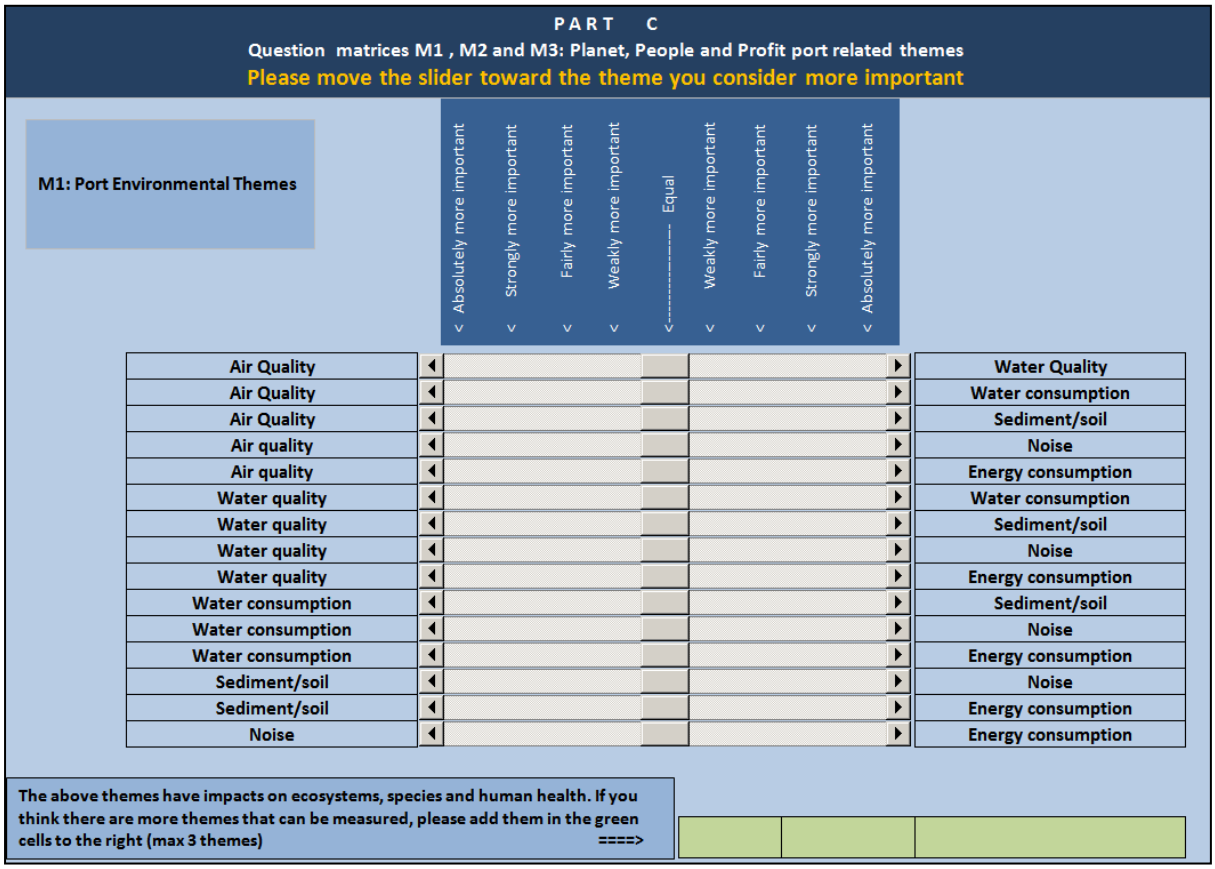


Figure 55: Part C - first matrix of the questionnaire

The second table (People) regards the main societal themes that are connected to a port:

- Employment opportunities (jobs connected directly and indirectly to all port activities)
- Safety levels (active prevention of accidents and other direct human health risks of all port-related activities)
- Land use changes (all changes to land use of the surrounding urban fabric that directly and indirectly depend on or are influenced by the port existence and activities)
- Recreation and aesthetics (recreational activities reduction and/or aesthetic/visual degradation of the surrounding area and/or pressures on waterfront connected industries)
- Stakeholders involvement (stakeholders involvement and participation in various decisions regarding the port, stakeholders access to information on various port-related performance indicators)
- Traffic congestion (impacts on local road network of port-related road traffic, when the local road capacity is exceeded it causes longer time trips, rise of transportation-commuting time-related costs. Environmentally, it also aggravates the emissions of combustion gasses and noise of normal traffic.

At the end of the table, there are 3 green-coloured cells where the interviewee can add up to 3 more basic themes.

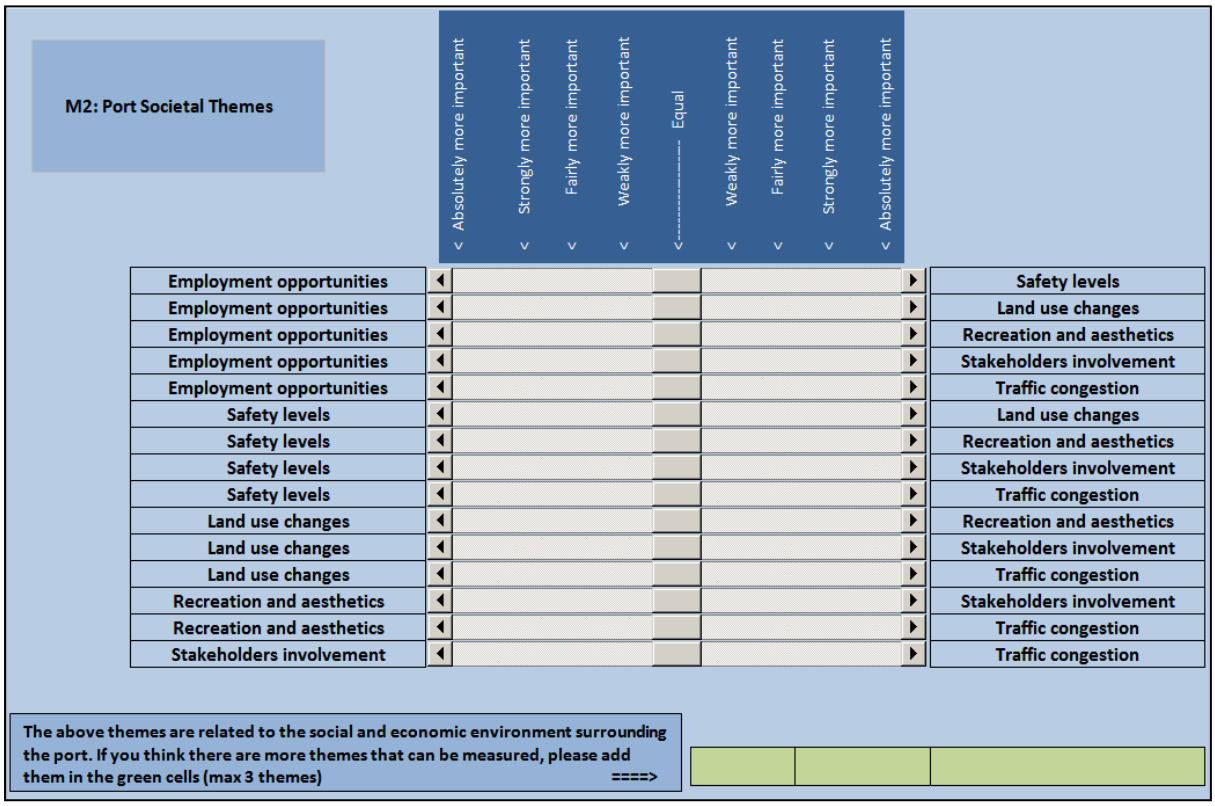


Figure 56: Part C - Second matrix of questionnaire

The third table (Profit) regards the main economic themes of the internal environment of a container terminal:

- Intermodality (access to main trunks of the road network, connections to the rail network, distance from airports, transshipments)
- Productivity(Productivity and efficiency of the various container terminal operations)
- Personnel training
- Terminal potential (maximum TEUs capacity, total quay length, operational depth, equipment)
- Expandability (possibility of expansion of land and/or sea infrastructures and achievement of suitable depths for super Post Panamax)
- Circular economy (repairing, reusing, refurbishing, recycling, upcycling, etc)

At the end of the table, there are 3 green-coloured cells where the interviewee can add up to 3 more basic themes.

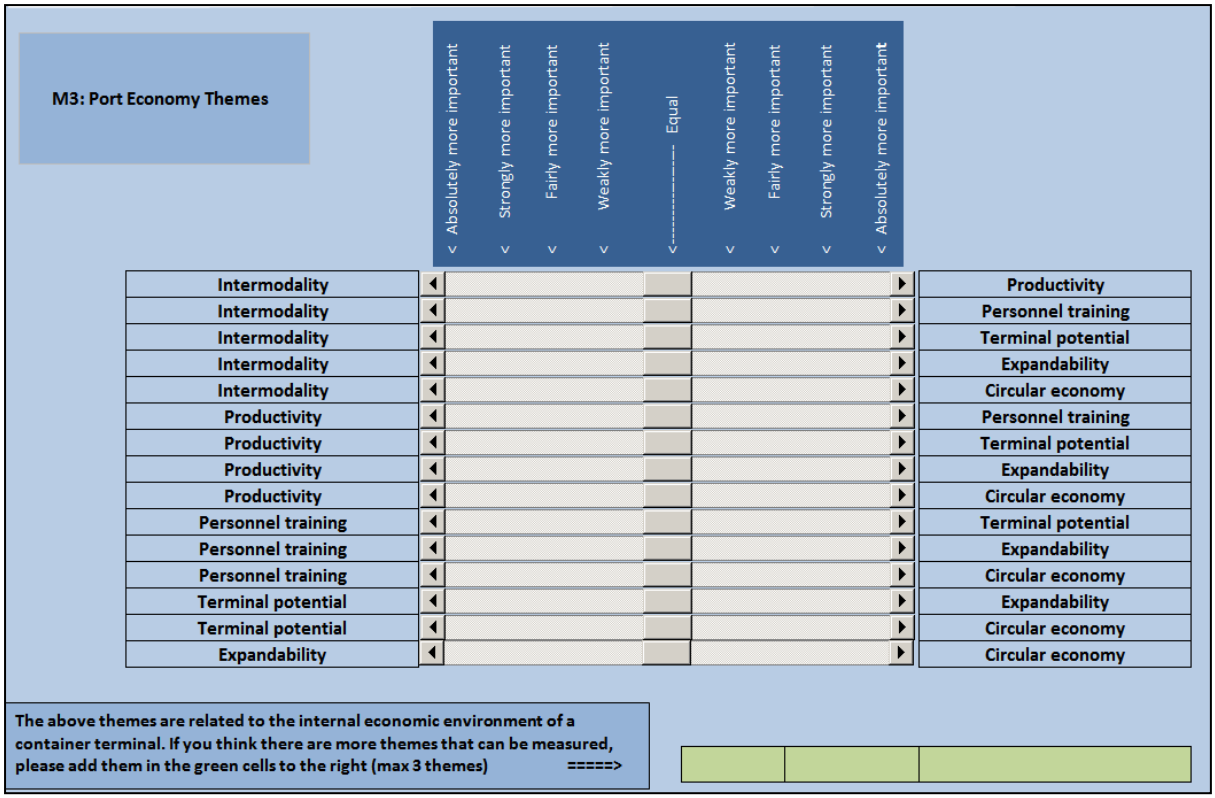


Figure 57: Part C - Third matrix of the questionnaire

In Part D, a series of 29 statements are presented and the interviewees must select a degree of agreement or disagreement to the statement from a drop-down list. The available levels are (typical five-level Likert scale):

- Strongly disagree
- Disagree
- Unsure
- Agree
- Strongly agree

The first 15 statements are those of the revised New Ecological Paradigm (NEP-R) scale test (Dunlap et al, 2000) and assess the level of eccentricity or anthropocentricity of groups of persons.

PART D: Questions 1-29 For each statement, please select your level of agreement from the drop-down list on the right			
1	We are approaching the limit of the number of people the Earth can support	Choose	0
2	Humans have the right to modify the natural environment to suit their needs	Choose	0
3	When humans interfere with nature it often produces disastrous consequences	Choose	0
4	Human ingenuity will insure that we do not make the Earth unlivable	Choose	0
5	Humans are seriously abusing the environment	Choose	0
6	The Earth has plenty of natural resources if we just learn how to develop them	Choose	0
7	Plants and animals have as much right as humans to exist	Choose	0
8	The balance of nature is strong enough to cope with the impacts of modern industrial nations	Choose	0
9	Despite our special abilities, humans are still subject to the laws of nature	Choose	0
10	The so-called "ecological crisis" facing humankind has been greatly exaggerated	Choose	0
11	The Earth is like a spaceship with very limited room and resources	Choose	0
12	Humans were meant to rule over the rest of nature	Choose	0
13	The balance of nature is very delicate and easily upset	Choose	0
14	Humans will eventually learn enough about how nature works to be able to control it	Choose	0
15	If things continue on their present course, we will soon experience a major ecological catastrophe	Choose	0

Figure 58: Part D questionnaire- Questions from 1 - 15

Questions from n.16 to n.22 and n.25 regard various port sustainability, well documented and accepted statements:

- 16. Green growth is based on a proactive long-term vision (PIANC 2014)
- 17. Sustainability growth will be better ensured by closely monitoring KPI´s defined from a long-term perspective (IAPH-PIANC 2017)
- 18. Tailor-made approaches for sustainable solutions in each port (PIANC 2014)
- 19. Efficiency and sustainability should be considered as complementary drivers (PIANC 2014)
- 20. The financial healthiness of the port companies is an indication for the long term stability and economic sustainability of the port (PORTOPIA 2017)
- 21. Circular economy to create linkages between the ports and the city local economy (https://www.docksthefuture.eu/circular-economy-as-a-tool-to-facilitate-the-transition-of-the-european-port-cities-to-the-sustainable-low-carbon-economy/)
- 22. Stakeholder involvement and participation (PIANC 2014)
- 25. The size of the port, in accordance with specialization conditions, and overall traffic emissions have a direct relationship with the level of sustainability of ports (Laxe et al., 2016)

Finally, statements 23,24, and 26 to 29 are used to understand the interviewee's personal opinion on the port and container terminal.

- Statement 23 assesses the level of desired involvement of a stakeholder in the business strategies of a port, and statement 24 the level of desired involvement in the environmental strategies of the port.
- Statement 26 and 27 assess a general opinion on the environmental and socioeconomic impacts of a port.
- Statement 28 assesses the feeling of involvement/participation in various port-related decisions.
- Statement 29 assesses the opinion on the port's approach toward sustainability.

16	Port's green growth is based on a proactive long-term vision	Choose.....	0
17	Sustainability growth will be better insured by closely monitoring KPI´s (Key Performance Indicators) defined from a long term perspective	Choose.....	0
18	For each port are necessary tailor made approaches for sustainable solutions	Choose.....	0
19	Port's efficiency and sustainability should be considered as complementary drivers	Choose.....	0
20	The financial healthiness of the port companies is an indication for the longer term stability and economic sustainability of the port	Choose.....	0
21	Circular economy can create linkages between the ports and the city local economy	Choose.....	0
22	Stakeholders involvement and participation are important for the port's sustainable growth	Choose.....	0
23	All stakeholders should be involved in the port's business strategies	Choose.....	0
24	All stakeholders should be involved in the port's environmental strategies	Choose.....	0
25	The size of the port, in accordance with specialisation conditions, and overall traffic emissions have a direct relationship with the level of sustainability of ports	Choose.....	0
26	A container terminal has serious negative impacts on the natural environment	Choose.....	0
27	A container terminal has important positive effects on the socio-economic environment of a city	Choose.....	0
28	My opinion is important for the decision-makers of the container terminal and the port in general	Choose.....	0
29	The reduction of the container terminal's environmental footprint, the Corporate Social Responsibility and/or the Triple Bottom Line (PPP) are among the major strategic objectives of Port Authorities and Container Terminal Operators	Choose.....	0

Figure 59: Part D questionnaire - Questions from 16 - 29

J1.2 Questionnaire methodology

Part A

Part A permits to divide the interviews into country groups and stakeholder categories. This fact permits potentially the multidimensional examination of the various results of the questionnaire by various combinations of country and stakeholder categories.

Parts B and C

Parts B and C have been designed according to the Analytic Hierarchy Process (AHP) pair comparison method, a multiple criteria decision-making method originally developed by Saaty in 1977 (Saaty 2008; Pandian 2013a; C. Y. Ng and Chuah 2014; Bunruamkaew 2012; Mu and Pereyra-Rojas 2017). More information regarding the AHP can be found in Appendix A .

From the matrix in Part B, the weights of the environment class W_e, the societal class W_s and the economy class W_{ec} are calculated. From the 3 matrices of Part C, the weights of the six themes for each of the above classes are calculated ($6xW_{e,i}$, $6xW_{s,j}$ and $6xW_{ec,k}$, where i,j,k are the environmental, societal and economic themes respectively). The resulting adjusted weight for each theme i, j and k is calculated as $W_e*W_{e,i}$, $W_s*W_{s,j}$ and $W_{ec}*W_{ec,k}$ respectively.

In Part B, a pairwise comparison matrix (3X3) has being created for the 3 sustainability classes (environment, social, economic). A nine-point scale has been used for the comparison answers as follow:

- Equally important= 1
- Weakly more important= 3
- Fairly more important= 5
- Strongly more important= 7
- Absolutely more important= 9
- Less important = NILL

The excel table of the matrix requires from the user to compare simultaneously the pair and reverse pair with a slider that must be positioned toward the most important element of each pair. In the hidden part of the workbook the answers are coded automatically.

From the answers array, a new array of normalized values was created (dividing the cell value by the sum of its column values) and the mean value of each row of the new array corresponds to the user's weight (or overall priority) for each of the 3 PPP classes as indicated in the following tables (Table 66, Table 67 and Table 68)

Table 66: Answers array (A1)

Factor	C1	C2	C3
C1	1.00	7.00	3.00
C2	0.14	1.00	0.20
C3	0.33	5.00	1.00
Total	1.48	13.00	4.20

Table 67: Normalized array (A2)

Factor	C1 normaliz	C2 normaliz	C3 normaliz
C1	0.68	0.54	0.71
C2	0.10	0.08	0.05
C3	0.23	0.38	0.24

Table 68: Resulting weight for each factor

Factor	C1 normaliz	C2 normaliz	C3 normaliz	Average weight
C1	0.68	0.54	0.71	0.64
C2	0.10	0.08	0.05	0.07
C3	0.23	0.38	0.24	0.28

The consistency of the resulting weights was checked by calculating the consistency ratio (CR): For each row of the A2 array the consistency measure was calculated (the matrix multiplication of the average weight column of A2 per the corresponding row of A1 divided by the A2 row's average weight).

Table 69: Consistency measure

Factor	C1	C2	C3
C1	1.00	7.00	3.00
C2	0.14	1.00	0.20
C3	0.33	5.00	1.00
Total	1.48	13.00	4.20

Factor	C1 normaliz	C2 normaliz	C3 normaliz	Average weight	Consistency measure
C1	0.68	0.54	0.71	0.64	3.12145699
C2	0.10	0.08	0.05	0.07	3.01269163
C3	0.23	0.38	0.24	0.28	3.06238685

The λmax is the average of the column of the consistency measures. The consistency index of the array A2, CI = (λmax – *n*)/(*n* – 1) (n = the order of the matrix).

The consistency ratio (CR) of the answers is calculated by dividing the consistency index CI by the random index RI, CR = CI/RI. The random index for 3rd order matrices is 0.58 and for 6th order matrices are 1.24 (Saaty and Tran 2007).

Table 70: Final step to calculate the consistency ratio

Factor	C1 normaliz	C2 normaliz	C3 normaliz	Average weight	Consistency measure
C1	0.68	0.54	0.71	0.64	3.12145699
C2	0.10	0.08	0.05	0.07	3.01269163
C3	0.23	0.38	0.24	0.28	3.06238685

CI	0.03
RI	0.58
C.Ratio	0.06

If the ratio was CR ≤ 0,1 the results were accepted, else the user's PART B and C were discarded (but recorded in a separate array).

The 3 (6x6) matrices of Part C have been processed using the same method described above (this time for 6th order square matrices), and using the resulting weights of Parts B and C, the final weight of each theme have been calculated.

Part D

The initial thought for Part D was that of using it to roughly assess:

a. the interviewee's familiarity with the port sustainability concept (putting in doubt some well-accepted statements)
b. the interviewee's generic opinion on the environmental and societal impact of a port and a container terminal
c. the extension of involvement on the port's decisions that the interviewee considers necessary (as part of a stakeholder category)
d. the interviewee's opinion on how much the port takes into account sustainability issues and stakeholders' needs/requests.

It was decided, however, to include the aforementioned revised New Ecological Paradigm (NEP-R) scale test initially developed in 1978 (Dunlap 2000; Anderson 2012; Dunlap and Van Liere 2008) that is worldwide used to measure the environmental concern/attitudes of groups of people. It is not in the intentions of this thesis to examine deeply and in details the NEP results of the questionnaires. For each grouping of the questionnaire results, the NEP scores will be simply stated (as the average of the 15 answers).

The NEP scoring is based on a separate scale for the odd and the even question numbers. For the odd number questions (pro-ecological) the score is:

- Strongly disagree=1
- Disagree=2
- Unsure=3
- Agree=4
- Strongly agree=5

For the even number questions (pro-societal) the score is:

- Strongly disagree=5
- Disagree=4
- Unsure=3
- Agree=2
- Strongly agree=1

Results above 3 indicate the degree of pro-ecological attitude, while below 3 the degree of pro-societal attitude.

It could be the objective of a follow-up research to evaluate eventual patterns that connect NEP scores to the rest of the questionnaire results and study/explore the multifaceted implications that might arise.

Questions from n.16 to n.22, plus question n.25 (used to assess the familiarity of the interviewee to the concept of port sustainability) score as follows:

- Strongly disagree=1
- Disagree=2
- Unsure=3
- Agree=4
- Strongly agree=5

The average of these answers score should roughly reflect the degree of the interviewee's (intuitive or scientific) knowledge on port sustainability issues (1=poor to 5=strong).

With the same scoring system, each of the remaining answers was assessed.

J1.3 Questionnaire data processing

The questionnaire excel file that was sent to the interviewees had the questionnaire worksheet locked with a password. Only the drop-down lists and the slider controls were unlocked together with the columns where lists and sliders had cells linked or referenced to them. For example, the drop-down list for the stakeholder category was linked to cells M35: M42 that contained 30 stakeholders' categories and cell O35 was referenced as an index of the drop-down stakeholder list selection. In order to avoid accidental changes of all the cells that contained formulas or references and could not be locked (because the user's input should indirectly change the values in these cells), the columns after the questionnaire questions were hidden.

It was desired to process all questionnaires data automatically, so both initial and modified questionnaires had exactly the same structure in the (hidden) results' tables and cells. After searching on the Internet and talking to Mr Etmektzoglou, a physicist with two MScs in software system development, it was decided to use Python for the data grabbing from the excel files and their processing. Two skeleton scripts were written, with the invaluable assistance of Mr Etmektzoglou, who also controlled (and debugged) the rest of the code that the author has inserted.

The **first script** reads the necessary data from all the excel files that are included in a subdirectory (where all questionnaires are saved) and creates various 2D or 3D numpy arrays that are subsequently processed. For all arrays, the first index points to the questionnaire number (for example, if the questionnaires were to be 50, the numpy array containing the answers of the PPP matrix would be 50x3x3). The PPP factor weights, the 3 themes factors' initial weights, the final theme factors weights, the NEP score and all the other scoring were saved as separate files.

The **second script** permits to define the stakeholder category to be processed (all or for one of the various categories) and the country (all or one of the various categories of countries or continents) and processes only the questionnaires that are true for these defined conditions. The script uses the initial matrices for PPP, Environmental themes, Societal Themes and Economy themes of the filtered questionnaires and after averaging for each matrix their cell values, performs the AHP calculations for the various weights. However, the calculated consistency ratio was extremely high for all the matrices (as expected) so it was decided to use the average weights of the single questionnaires that had a valid consistency ratio (CR). In the example shown below (with 27 questionnaires and no filtering of stakeholders or country) the ones that had consistent PPP matrix were 21 and the PPP weights were calculated as the average value of them. The 6 questionnaires with high CR were discarded completely from the rest of the processing of AHP (but not of the other answers like NEP, port knowledge, etc.). The remaining 21 questionnaires were controlled for the Consistency Ratio (CR) of the other 3 matrices and for each matrix the averages of the various theme weights were calculated from the valid questionnaires. In the example below, other 5 questionnaires had inconsistent Environment matrix, 7 had an inconsistent Societal matrix and 6 had an inconsistent Economy matrix.

Additionally, in order to test the representativeness of the results of the questionnaires, it was tested if they could likely be part of a normal distribution. In that manner, it can be ensured in some level that the sampling population is representative and the possibility of receiving particular answers from interviewees pursuing a specific aspect can be excluded.

In order to examine the hypothesis that, at least, the PPP priority data were likely part of a **normal distribution** (null or Ho hypothesis) and keeping in mind that each PPP weight is calculated from pairwise comparisons, it was decided to test the hypothesis that the differences between the averagely most important factor (P_i) with the averagely least important one (P_j) are likely drawn from a normal distribution.

Using the scipy.stats.shapiro Python module the above hypothesis was tested with the Shapiro-Wilk normality test(Shapiro and Wilk 1965; Ghasemi and Zahediasl 2012; Razali and Wah 2011), together with the hypothesis the NEP values were part of a normal distribution. The Shapiro module returns the test statistic of the distribution (W) and the p-value for the hypothesis test. If this p-value[4] is higher than the predefined significance level[5] alpha (normally 0.05, a 5% probability of rejecting a true hypothesis, a confidence level of 95%) then the null hypothesis cannot be rejected and the data are probably drawn from a normal distribution. With the help of the SeaBorn Python module, the univariate distributions of the P_i-P_j spread and the NEP were also plotted.

At the end of the 2nd script, the module Seaborn (https://seaborn.pydata.org/) can also be used to show the graphics of pairwise relationships among various parameters. The lines are inserted as comments. They can be modified and used for various parameter comparisons. It is beyond the purposes of the present thesis the various deeper analyses of the data of the questionnaire.

After the data processing, the results are loaded into the 2 worksheets of an appositely prepared excel template (with various charts, gauges and formulas) and saved as a new excel file that contains the results and the summary of the questionnaires (survey identity). In the following pages the resulting excel file from the final 43 questionnaires that were received are presented:

[4] probability of obtaining the sample data when the null hypothesis is true (type II error)
[5] probability of rejecting the null hypothesis when the null hypothesis is true (type I error)

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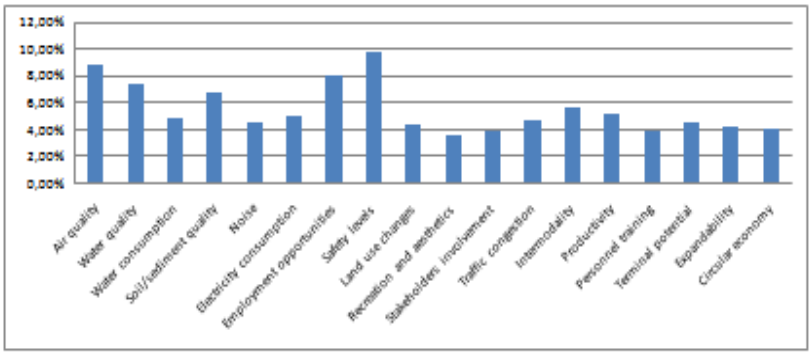
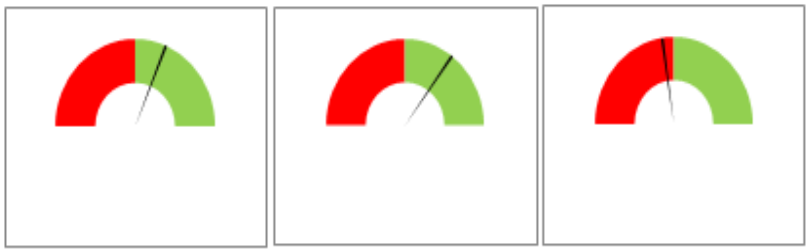
Total Questionnaires	43
Stakeholder type	All
Country/continent	All

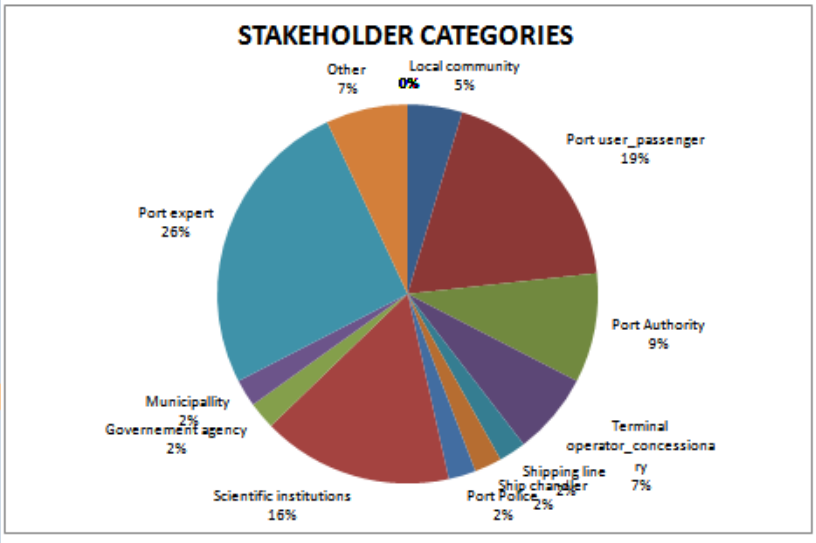
PPP weights	
Environment	37.61%
Society	34.52%
Economy	27.88%

AHP final themes weights	
Air quality	8.80%
Water quality	7.44%
Water consumption	4.96%
Soil/sediment quality	6.76%
Noise	4.63%
Electricity consumption	5.02%
Employment opportunities	7.98%
Safety levels	9.79%
Land use changes	4.47%
Recreation and aesthetics	3.62%
Stakeholders involvement	3.90%
Traffic congestion	4.76%
Intermodality	5.68%
Productivity	5.21%
Personnel training	3.95%
Terminal potential	4.63%
Expandability	4.30%
Circular economy	4.10%





	← DSP — NEP →	
NEP		3.48
	← POOR — GOOD →	
Port sustainability knowledge		3.79
	← NO — YES →	
Stakeholders involved in business strategies		2.93
Stakeholders involved in environmental strategies		3.65
Port serious environmental impacts concern		3.00
Port important societal benefits		3.77
Feeling of involvement		2.79
Port sustainability approach concerns		3.19



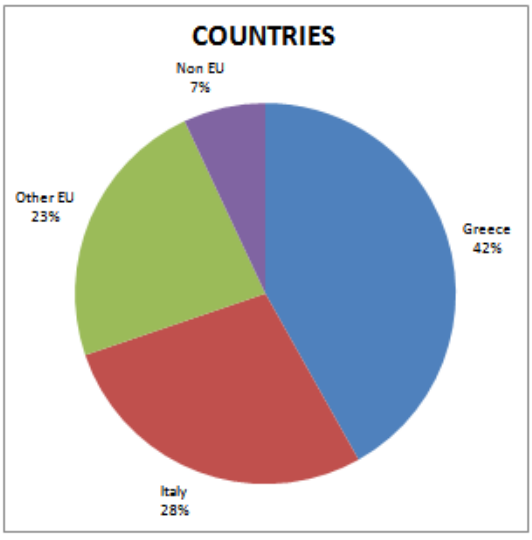
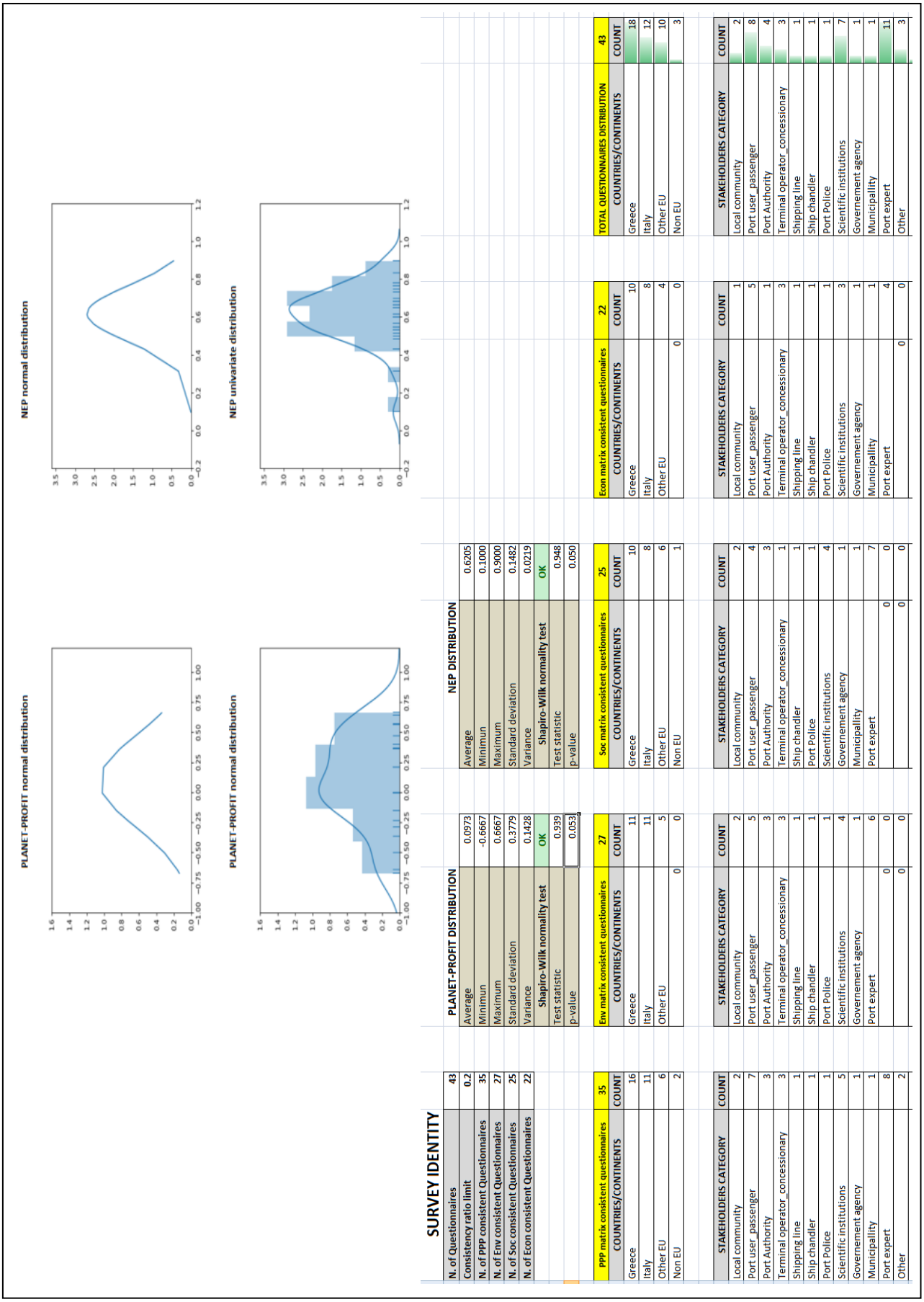


Figure 60: Excel file with results (Sheet1)



SURVEY IDENTITY

N. of Questionnaires	43
Consistency ratio limit	0.2
N. of PPP consistent Questionnaires	35
N. of Env consistent Questionnaires	27
N. of Soc consistent Questionnaires	25
N. of Econ consistent Questionnaires	22

PLANET-PROFIT DISTRIBUTION

Average	0.0973
Minimun	-0.6667
Maximum	0.6667
Standard deviation	0.3779
Variance	0.1428
Shapiro-Wilk normality test	OK
Test statistic	0.939
p-value	0.053

NEP DISTRIBUTION

Average	0.6205
Minimun	0.1000
Maximum	0.9000
Standard deviation	0.1482
Variance	0.0219
Shapiro-Wilk normality test	OK
Test statistic	0.948
p-value	0.050

PPP matrix consistent questionnaires	35
COUNTRIES/CONTINENTS	COUNT
Greece	16
Italy	11
Other EU	6
Non EU	2

Env matrix consistent questionnaires	27
COUNTRIES/CONTINENTS	COUNT
Greece	11
Italy	11
Other EU	5
Non EU	0

Soc matrix consistent questionnaires	25
COUNTRIES/CONTINENTS	COUNT
Greece	10
Italy	8
Other EU	6
Non EU	1

Econ matrix consistent questionnaires	22
COUNTRIES/CONTINENTS	COUNT
Greece	10
Italy	8
Other EU	4
Non EU	0

TOTAL QUESTIONNAIRES DISTRIBUTION	43
COUNTRIES/CONTINENTS	COUNT
Greece	18
Italy	12
Other EU	10
Non EU	3

STAKEHOLDERS CATEGORY	COUNT
Local community	2
Port user_passenger	7
Port Authority	3
Terminal operator_concessionary	3
Shipping line	1
Ship chandler	1
Port Police	1
Scientific institutions	5
Governement agency	1
Municipallity	1
Port expert	8
Other	2

STAKEHOLDERS CATEGORY	COUNT
Local community	2
Port user_passenger	5
Port Authority	3
Terminal operator_concessionary	3
Ship chandler	1
Port Police	1
Scientific institutions	4
Governement agency	1
Municipallity	7
Port expert	0
	0

STAKEHOLDERS CATEGORY	COUNT
Local community	2
Port user_passenger	4
Port Authority	3
Terminal operator_concessionary	1
Ship chandler	1
Port Police	1
Scientific institutions	1
Governement agency	1
Municipallity	7
Port expert	0
	0

STAKEHOLDERS CATEGORY	COUNT
Local community	1
Port user_passenger	5
Port Authority	1
Terminal operator_concessionary	3
Shipping line	1
Ship chandler	1
Port Police	1
Scientific institutions	3
Governement agency	1
Municipallity	1
Port expert	4
	0

STAKEHOLDERS CATEGORY	COUNT
Local community	2
Port user_passenger	8
Port Authority	4
Terminal operator_concessionary	3
Shipping line	1
Ship chandler	1
Port Police	1
Scientific institutions	7
Governement agency	1
Municipallity	1
Port expert	11
Other	3

Figure 61: Excel file with results (Sheet 2)

The logic of the Python scripts is summarized in the following flowchart.

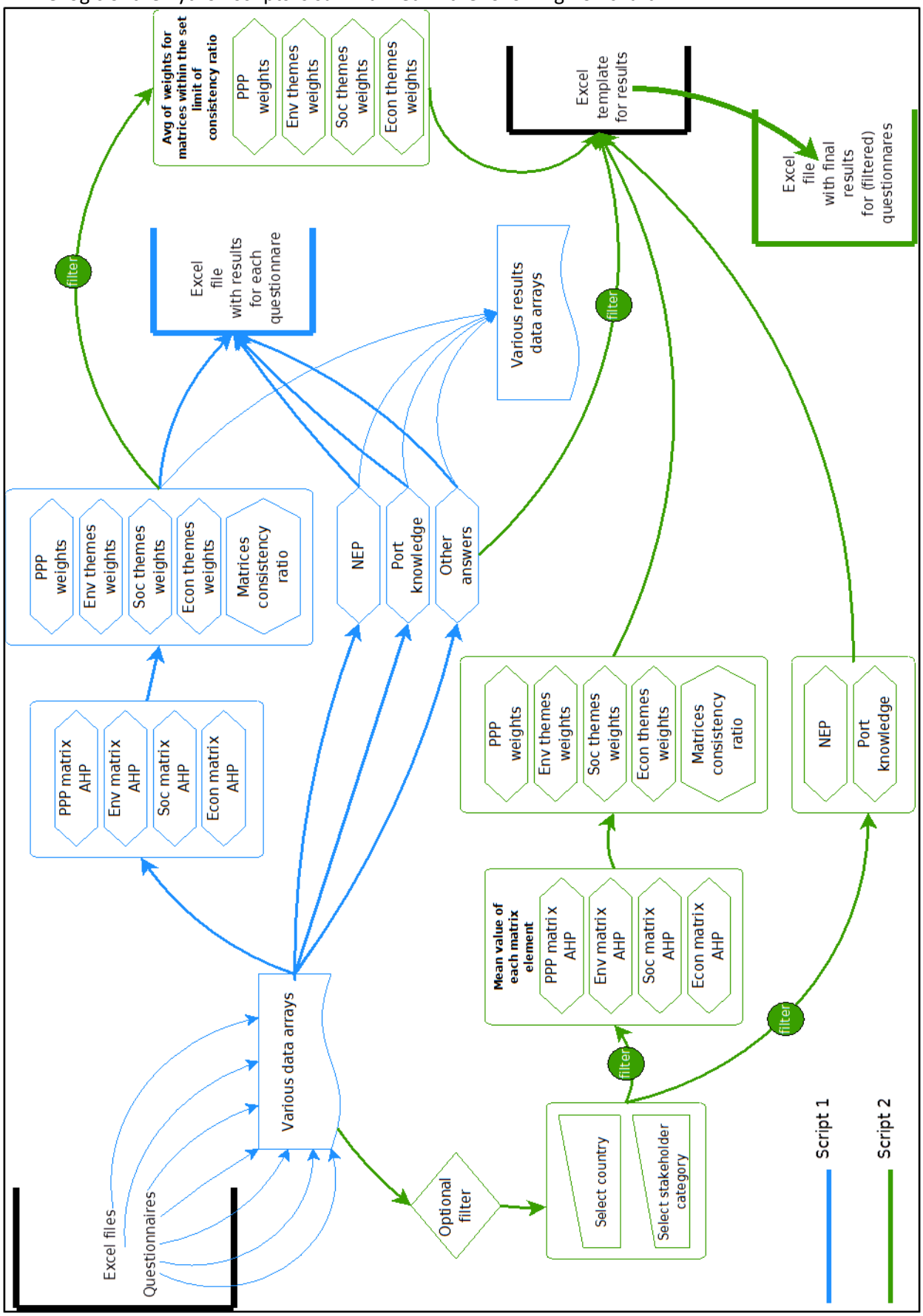
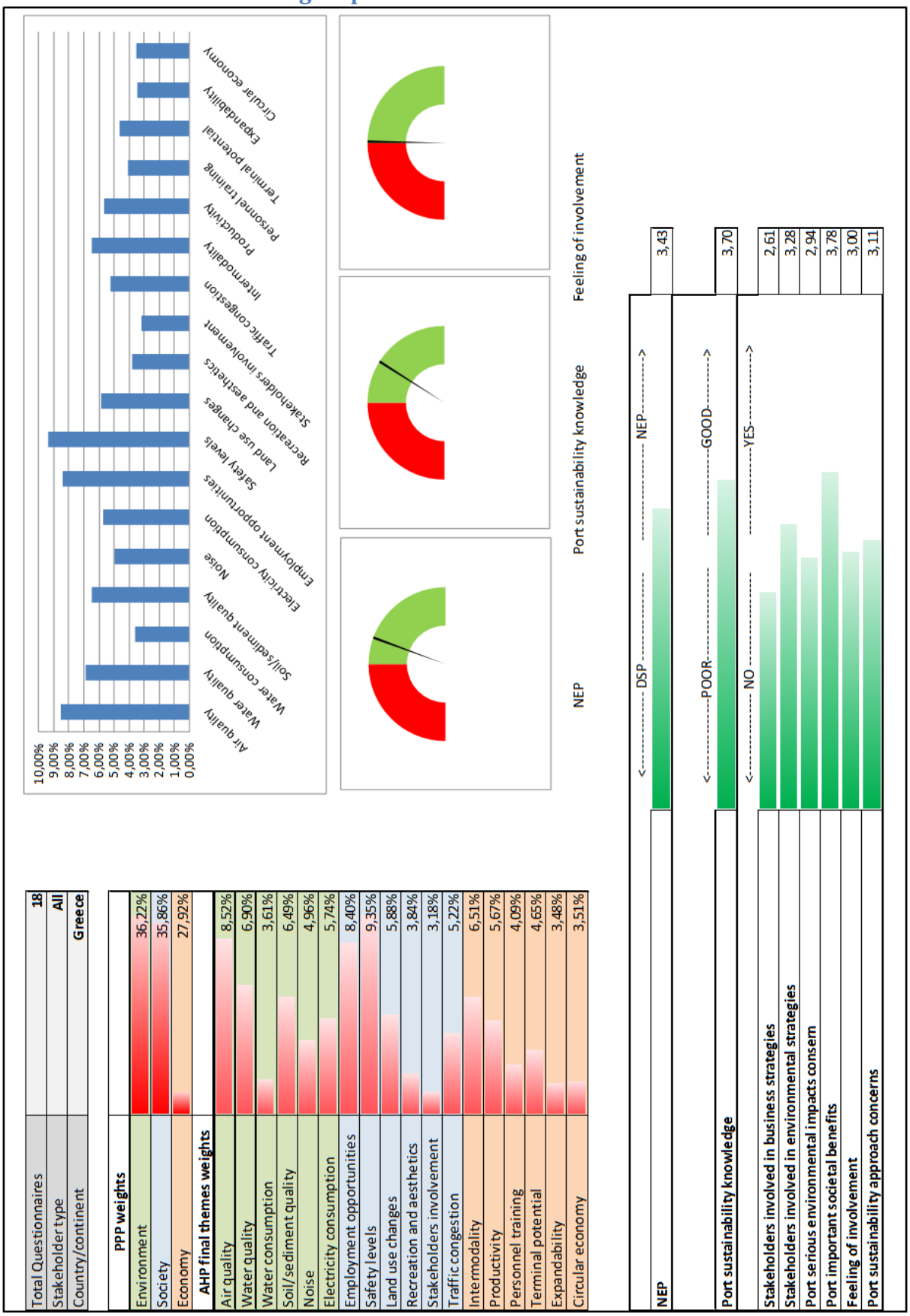


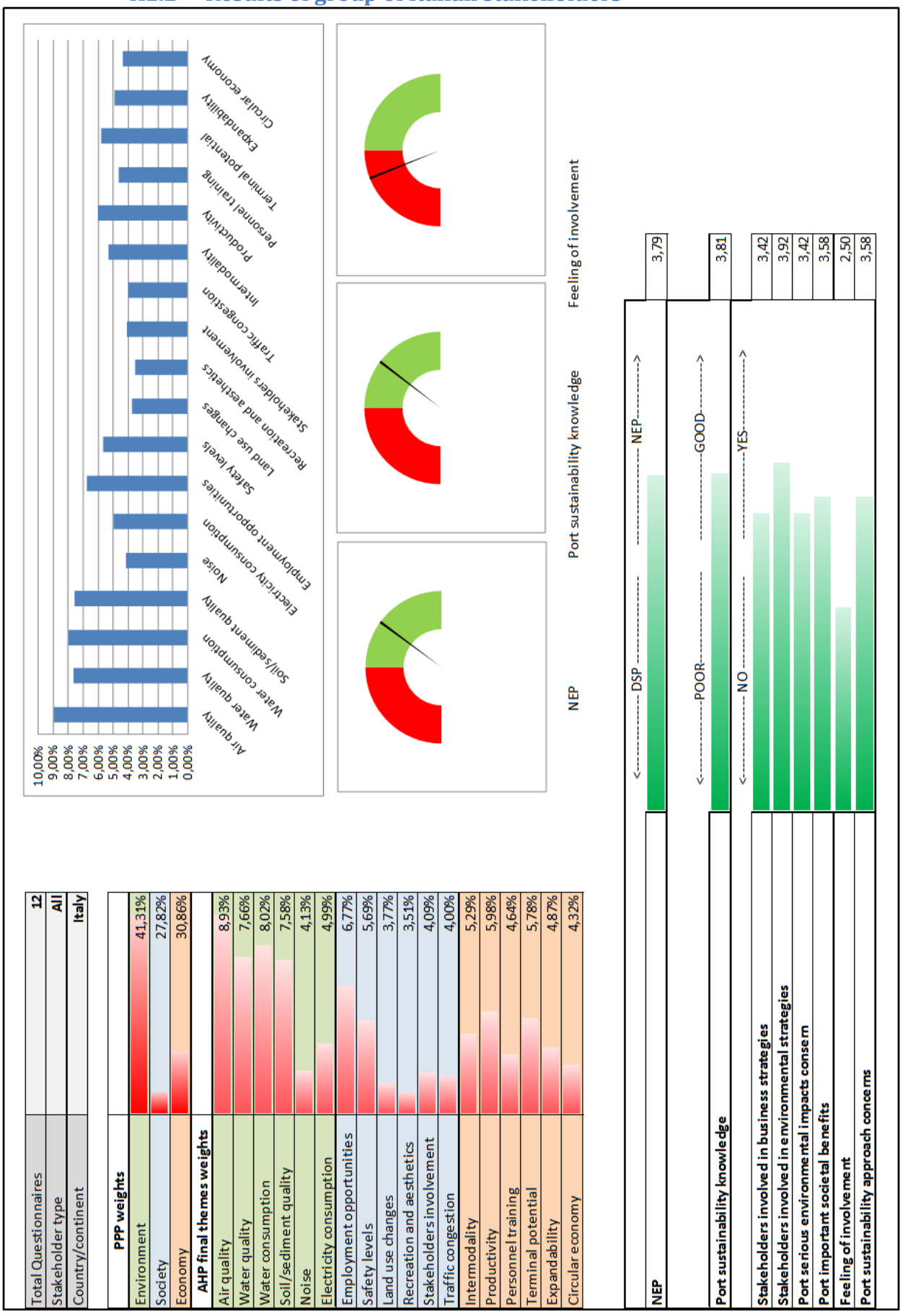
Figure 62: Python scripts flowchart

Appendix K *Summarized results of questionnaires for each group*

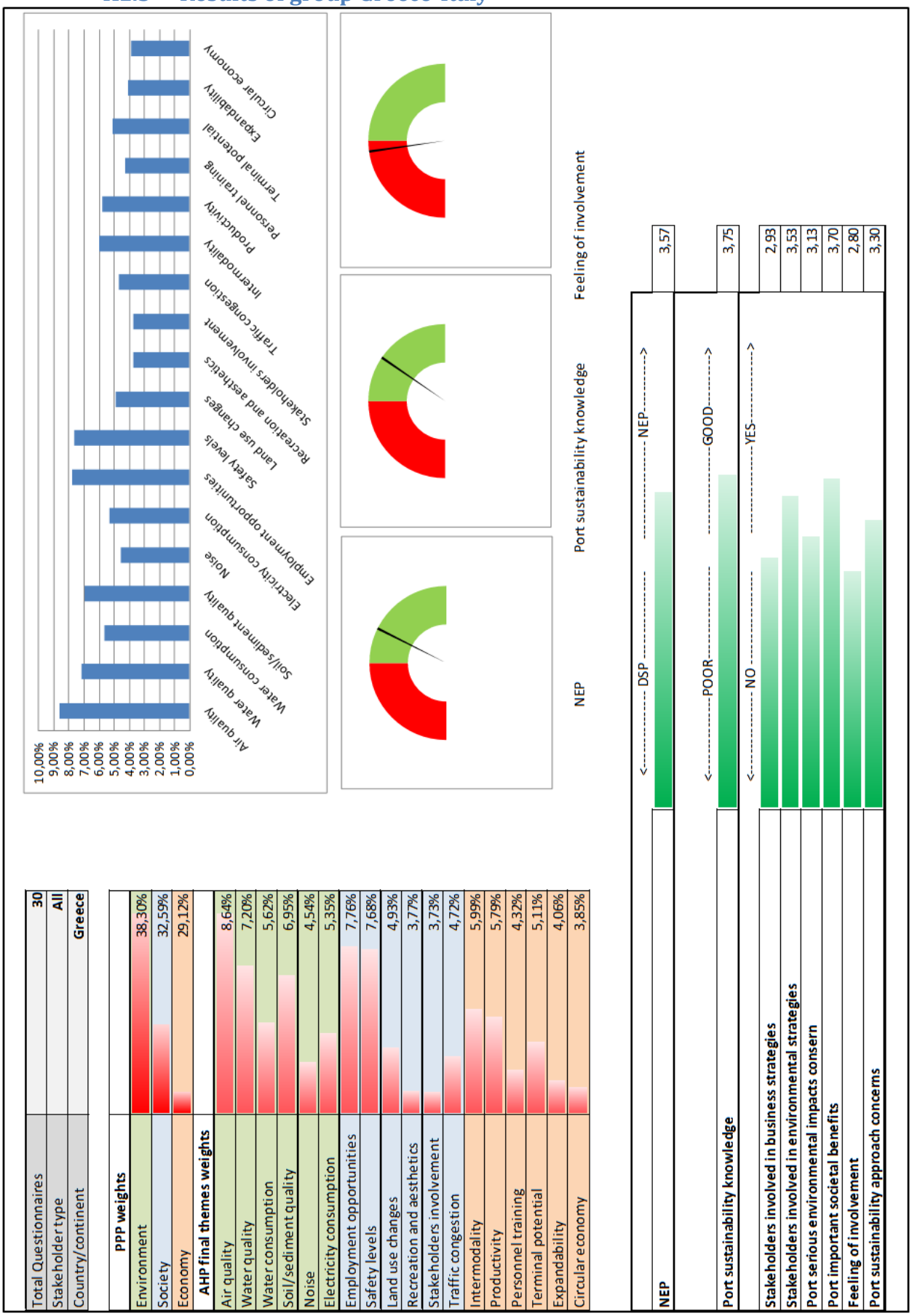
K1.1 Results of group of Greek stakeholders



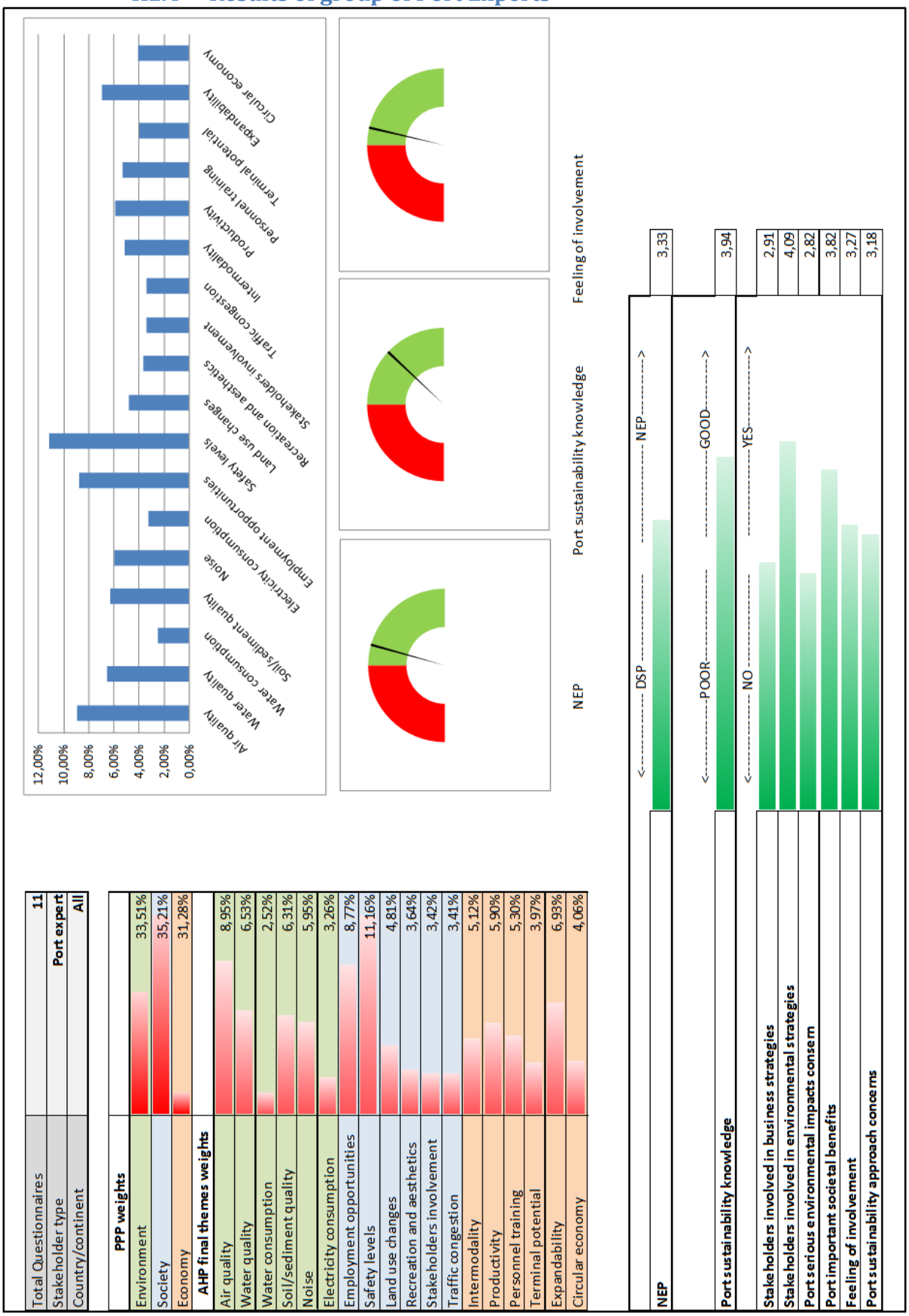
K1.2 Results of group of Italian stakeholders



K1.3 Results of group Greece-Italy



K1.4 Results of group of Port Experts



Appendix L *Table for experts to score the performance of sustainability measures to PPP*

Scroring the performance ofsustainability measures through their effects on People, Planet and Profit

The following scoring scale will be used for the evaluation of the effect of the proposed measures on each sustainability theme (ST). Estimation of cost, payback period and uncertainty of success (orange cells) have a different scoring system.

SCORE	EFFECT	SCORE	EFFECT
0	No effect		
1	Very small positive effect	**-1**	Very small negative effect
2	Small positive effect	**-2**	Small negative effect
3	Moderate positive effect	**-3**	Moderate negative effect
4	Strong positive effect	**-4**	Strong negative effect
5	Very strong positive effect	**-5**	Very strong negative effect

For your convenience, the lightly highlighted cells indicate the sustainability themes (ST) that are most likely affected by each measure. Of course, other themes (ST) that are not marked can be influenced as well, so take also the unmarked themes into account.

Each sustainability theme and proposed measure is further explained with comments. Place the mouse pointer on the cells to read the explanation.

	Sustainability themes (ST)	Proposed carbon emissions reduction measures (climate change mitigation measures) in relation to air quality						
		Blending biofuels	Replacement of diesel-powered terminal equipment	Energy recovery from gantry cranes	Vehicle management system	Adaptation of terminal layout	Renewable energy sources	Green incentives to ships
Planet	Air quality							
	Sea water quality							
	Water consumption							
	Sediment/soil quality							
	Noise							
	Energy consumption							
People	Employment opportunities							
	Safety levels							
	Land use changes							
	Recreation and aesthetics							
	Stakeholders involvement							
	Traffic congestion							
Profit	Intermodality							
	Productivity							
	Personnel training							
	Terminal potential							
	Expandability							
	Circular economy							
	Cost (score from 0 to 5)!							
	Payback period	Choose...	Choose...	Choose...	Choose...	Choose...	Choose...	Choose...
	Likelihood of success of measure	Choose....	Choose....	Choose....	Choose....	Choose....	Choose....	Choose....

	Sustainability themes	Proposed climate change adaptation measures in relation to port safety						
		Enhanced drainage system	Enhanced maintenance and upgrade of infrastructures	Cargo handling organizational modifications	Relocation of specific activities within the limits of the existing port	Emergency response plans	Dredging	Heightening quays
Planet	Air quality							
	Sea water quality							
	Water consumption							
	Sediment/soil quality							
	Noise							
	Energy consumption							
People	Employment opportunities							
	Safety levels							
	Land use changes							
	Recreation and aesthetics							
	Stakeholders involvement							
	Traffic congestion							
Profit	Intermodality							
	Productivity							
	Personnel training							
	Terminal potential							
	Expandability							
	Circular economy							
	Cost (score from 0 to 5)!							
	Payback period	Choose...	Choose...	Choose...	Choose...	Choose...	Choose...	Choose...
	Likelihood of success of measure	Choose....	Choose....	Choose....	Choose....	Choose....	Choose....	Choose....

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