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D5.1 – Environmental factors and mapping to pilots

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Type	Report	**Dissemination Level**	*Public*
Version	1.0	**Status**	Pre-release
Description	This deliverable's focus is the identification of significant environmental aspects of port operations and their environmental impacts. Furthermore, this document analyses and discusses existing methods for estimating environmental aspects currently in use. Lastly it identifies the key (environmental) performance indicators (eKPI) related to the most significant environmental aspects needed as inputs for Port Environmental Index (PEI).		
Work Package	WP5		

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Abstract

The main aim of this deliverable is to identify the significant environmental aspects of port operations which will underpin future development related to the Port Environmental Index (PEI). The document reviews the different methods for estimating environmental aspects currently in use and describes environmental aspects of port operation currently published in the scientific and technical literature. The environmental aspects were mapped to PIXEL ports and ranked using a criteria of probability of an environmental aspect occurring as well as the magnitude or severity of its environmental impact. According to the mapping exercise, the most significant environmental aspects identified for the PIXEL pilot ports are emissions to the atmosphere and noise, followed by discharges of wastewater to the marine environment and the production of waste. Other aspects considered in this document, such as light pollution, odor emissions and resource usage were considered of lesser importance. In addition, the document identifies the key (environmental) performance indicators (eKPI) related to the most significant environmental aspects which will be used as inputs to the algorithms behind PEI. The constraints and opportunities for PEI adoption in small and medium-sized ports are also discussed in the document. The main constraints to PEI adoption in ports is data availability considering that the algorithms behind PEI are data intensive needing a considerable number of inputs. In addition, at the moment of writing this deliverable, it is not known whether it will be possible to collect all the input data in an automated fashion using IoT sensors or not.

Statement of originality

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List of acronyms

Acronym	Explanation
ABP	Associated British Ports
AIS	Aquatic Invasive Species
ASPM	Azienda Speziale Porto di Monfalcone
BOD	Biochemical Oxygen Demand
COD	Chemicals Oxygen Demand
ECOSLC	ECO Sustainable Logistics chain
EIAP	Environmental Impact Assessments of Port
eKPI	Environmental Key Performance Indicators
EMAS	Eco-Management and Audit Scheme
EMS	Environmental Management System
ESPO	European Sea Ports Organisation
GHG	GreenHouse Gases
GM	Green Marine
GPMB	Grand Port Maritime de Bordeaux - Port of Bordeaux
INDAPORT	Environmental Indicator System for Ports project
ISO	International Organization for Standardization
KPI	Key Performance Indicator
LNG	Liquefied Natural Gas LNG
MSFD	Marine Strategy Framework Directive
OPS	On-shore Power Supply
PEI	Port Environmental Index
PERSEUS	Policy-oriented marine Environmental Research for the Southern European Seas
PIXEL	Port IoT for Environmental Leverage
PMIS	Port Management Information System
PPA	Piraeus Port Authority SA
RoRo	Roll On-Roll Off
PERS	Port Environmental Review System
SDM	Self-Diagnosis Method
SEA	Significant Environmental Aspect
SWOT	Strengths, Weaknesses, Opportunities, Threats

TEAP	Tool for identification and assessments of environmental aspects in ports
TEU	Twenty foot Equivalent Unit
ThPA	Thessaloniki Port Authority
WP	Work Package

1. About this document

The main focus of this deliverable is to identify environmental aspects, their impacts, and significance, related to port operations. Aside from that, attention is also given to the definition of Key Performance Indicators (KPIs). Those indicators form the basis for the further improvement of the environmental performance of ports, as they are used to evaluate the environmental performance of ports.

In the part of the document that deals with the approach for assessing the significance of various environmental aspects, attention is given both to the current approaches that are used by ports and to the approach adopted for use in the PIXEL project. Assessment of the significant environmental aspects and the definition of KPIs form the foundation on which the development of the PEI would be the subject of D5.2 and D5.3.

1.1. Deliverable context

Keywords	Lead Editor
Objectives	The main objective is the definition of a methodology to evaluate the PEI from the available information in ports and to evaluate the need for new data sources for accuracy and efficiency of the processes.
Exploitable results	The deliverable should result in an efficient methodology that will be used in the assessing of the significance of various environmental aspects of port operations. That methodology will take into account objective (frequency, possible consequences, and legislation) significance criteria, but would also allow for the personal opinion of port environmental managers, in some cases. Also, the deliverable will give the definition of KPIs used for the assessment of the ports' environmental performance. The results of this deliverable are necessary for the continuation of the development of the PEI and will be directly referenced in further deliverables in WP5.
Work plan	The deliverable serves as a summary of the work done during the curse of tasks T5.1 and T5.2. In the later phase of the project, it would significantly contribute to the execution of other tasks of WP5. The WP5 and, consequently, D5.1 are also closely related to the tasks of the WP4 that deals with the modeling of the environmental impact/pollution (T4.1-T4.4).
Milestones	Together with the D3.7, this deliverable forms the basis of the verification for MS4, "Environmental Analysis completed".
Deliverables	The deliverable is the direct prerequisite for the deliverable D5.2 and, consequently, D5.3 and D5.4. The methodology for the assessment of the significance of the environmental aspects and the results of that assessment would be used in the computation of the PEI in D5.2 and D5.3.
Risks	The risks are most closely connected with the part of the deliverable that deals with the methodology for the assessment of the significance of the environmental aspects. While the definition of environmental aspects and KPIs are mostly objective, the assessment of the significant environmental aspects always has at least some human factor involved. Although the subjective influence will be minimized, it is still impossible to tell how much of the influence it will have in the later stages of the project.

1.2. The rationale behind the structure

As mentioned in the previous subsection, the deliverable deals with environmental aspects and KPIs. In order to be as clear as possible, the deliverable is divided into seven sections, not counting introductory and closing sections. Those sections are ordered in sequence that is meant to be as logical as possible. In other words, each section (and their subsections) should be a continuation of the previous one and/or a prerequisite for the following one.

The first section (after the introduction) deals with the definition of the environmental aspects and the impact they have on human health and the environment. It forms the foundation for the understanding of the next section, which contains the description and comparison of the widely used approaches used for the identification of environmental aspects of port operations. Before the next chapter dealing with the environmental aspects (the assessment of significance), two shorter sections required for its understanding are inserted. The first of them contains the description of pilot ports that should give the reader some information about the ports for which the significance assessment would be done and the second consists of the description of the PEI that is needed to give the reader an idea why should the significance assessment be done.

The section that deals with the methodological approaches for the significance assessment builds on all of the previous sections and contains both the review of the current methodologies and proposes a new methodology that should be used during the PIXEL project. The first subsection (existing methodologies) should both shed some light on the issues of the significance assessment and serve as a foundation for the development of the new methodology. The environmental aspects are also the centerpiece for the next section, which deals with the mapping to pilots. The last section before the conclusion serves as an introduction to Key Performance Indicators (KPIs). This section was given the final place in the deliverable as the understanding of the environmental aspects and their significance is necessary for a clear view on the issue of KPIs.

1.3. Methodology

In Figure 1.1 a general methodological approach and workflow for PEI development is presented.

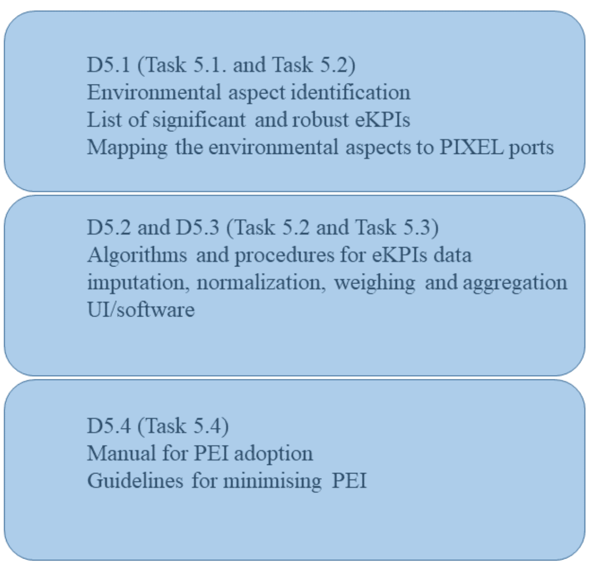

Figure 1.1 Methodological approach for PEI development

In this deliverable the environmental aspects of port operations have been addressed and mapped to the four PIXEL pilot ports. Listing the different environmental aspects and ranking them according to their significance is the first step in the methodology for developing PEI, since PEI will be based on the integration of indicators of the significant environmental aspects (SEA) (Task 5.1). Also, in this document an extensive list of the environmental key performance indicators (eKPI) related to each aspect have been identified and assessed according to their significance, robustness and availability (Task 5.2).

In later iterations on the work on the Port Environmental Index the data will be further deconstructed and analysed using the Analytic Hierarchy Process. The most relevant eKPi will be selected among the ones listed in this deliverable (D5.1), preferably coming to a common list of a standardized set of indicators to be used across different small and medium sized European ports. Following the selection, the eKPIs will be grouped according to the environmental aspect, normalized, weighted and aggregated. The different normalization procedures, weighing as well as aggregation will be explained and described in D5.2 and D5.3 (Task 5.2 and Task 5.3)

Finally, in D5.3 Task 5.3 and Task 5.4 after all the algorithms and procedures will be carefully documented and a user manual for PEI adoption in ports will be developed and the metrics will be given for the port's overall environmental performance in the EU28 countries. In addition, the guidelines for assessing and minimising the port's PEI will be briefly introduced.

2. The rationale behind the deliverable

There are tremendous inconsistencies with respect to the KPIs/environmental indicators which are used for managing ports environmental outcomes. Therefore, one of the main outcomes of PIXEL will be to address this problem and provide an evidence-based, standardized and quantitative methodology which can be deployed to all ports for assessing their environmental impact (ESPO/EcoPorts 2017).

The methodology will result in a composite index called the Port Environmental Index (PEI) which integrates all the relevant environmental metrics (KPIs) into a single, easily understandable, metric

The **Port Environmental Index (PEI)** is a composite environmental index. Composite indexes are mathematical aggregations of a set of indicators.

The PEI combines different environmental indices, the so-called **environmental Key Performance Indicators (eKPIs)**, into a single metric using an underlying mathematical algorithm. Thus, the first step towards constructing the PEI is to identify the KPIs to be modeled.

Based on the above rationale the main aim of this deliverable is to present the methodology to be used for computing the PEI.

The approach includes the following steps:

I. logging the activities performed in the pilot ports,
II. identifying the environmental aspects of each logged port activity,
III. assigning significance to the identified environmental aspects,
IV. building a comprehensive set of the most relevant KPI for each significant environmental aspect
V. calculating the PEI.

The general process for identifying the KPIs is presented in Figure 2.1.

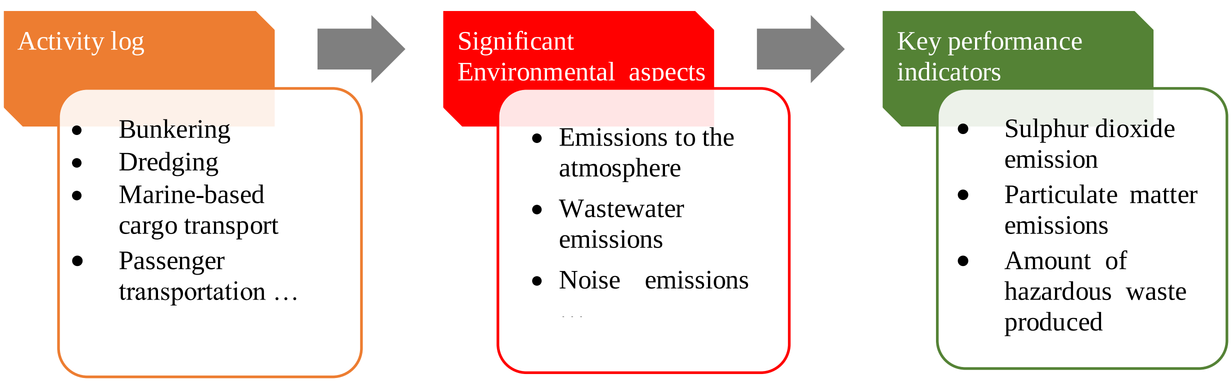

Figure 2.1 The process of identifying the eKPIs for ports activities to be integrated into PEI

3. Environmental aspects and their impact on human health and the natural environment

3.1. Environmental aspects

The relative importance and significance of different environmental aspects depend on the characteristics of each port. The ports differ in terms of their purpose, size, location, type of activities being carried out, type of coastline and underwater, etc. There are also different protection measures implemented in accordance with the requirements of the specific laws of a particular country and/or region. The economic dimension of sustainability refers to all aspects of a company's business and its impact on the economic and other significant well-being of all stakeholders at the local, national and/or global levels.

For this reason, each port should ideally asses its own significant aspects of environmental protection to focus its activities on issues and activities that have a high potential for positive environmental impact, providing the greatest guarantee that the environment will be protected and encouraging that the resources are used in a sustainable manner.

Based on the current understanding of the impact of ports and their processes on environmental aspects the generally accepted environmental aspects that are influenced by port processes are:

- emissions to the atmosphere
- emissions of wastewater
- noise emissions
- production of waste,
- light pollution
- odor emissions

The European Parliament and Council of the European Union (2001) gave standards which state that the involved organization, i.e. port, will establish and maintain procedures for determining the environmental aspects of its activities, products or services that can be controlled and expected to have an impact in order to determine those who have or may have a significant impact on the environment[1].

Finally, based on the identified significant environmental aspects, a specific type of emission inventories will be built and will depend on the identification of the significant environmental aspects by the ports. However, the assessment of the significance of environmental aspects can be extremely subjective when a certain individual performs it for a specific organization.

[1] Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment

3.2. Environmental impacts

Owing to the large traffic of various loads and the need for their rapid handling, the ports become increasingly complex systems often located near the local community. Depending on the responsibilities of all stakeholders and their particular interests, ports have a direct impact on economic and environmental aspects, as well as a major impact on human health.

It is evident that there is an impact of the maritime economy and shipping on global, as well as local climate change, especially with regard to local environmental pollution and human health. Basically, all the processes that take place in ports at the terminals have a negative impact on all environmental aspects, they adversely affect the harbor environment, the port ecosystem and human health (Kegalj, 2016). This negative effect is extremely disadvantageous to the aspects of air, water, and soil quality. For this reason, it is necessary, besides other aspects, to properly manage the health issues of both port workers and people living near the ports. Furthermore, the issue of security is raised to protect all aspects of the environment and people for which continuous measurement and control of impact should be carried out in all aspects of risk assessment. Strategic goals of the Port Authority are (should be) aligned with legislation, reducing costs and risks, and protecting the environment and people as a key indicator of business success. These goals contribute to reducing uncertainty, reducing the occurrence of accidents that pose a threat to people, the environment, and port assets. It is known that accidents and dangerous occurrences, environmental incidents, can cause an increase in operating costs and serious disturbance in port services.

This also influences the reputation or image of the port in terms of environmental protection and security management, which in turn affects the decision of the stakeholders on routes and ports of engagement for their ships and cargo.

3.3. Significant environmental aspects

According to ISO 14001, environmental aspects are defined as an element of activities, products or services of a port authority that can interact with the environment. Significant environmental aspect (SEA) is an environmental aspect that has or can have a significant environmental impact. When considering the criteria for selecting a significant aspect of the impact on the environment, several factors need to be considered. The significance of some ecological aspect can derive from legal regulations when it is based on specific legal requirements. Ports often do not have the same obligations to comply with statutory regulations (e.g. when port management does not implement the environmental measures in accordance with regulations for a particular aspect). One of the important factors in the selection of criteria for choosing a significant aspect may be local and/or regional concern if the stakeholders in certain ports point out a certain aspect as significant in relation to another port. One of the criteria for selecting a significant aspect may be its global impact, such as global warming, as opposed to those aspects that primarily have a local significance.

In accordance with the above, it is necessary to establish a methodology for the selection of significant aspects in order to help port authorities establish an environmental management system and increase the awareness of port workers in this field. It is particularly important to stimulate the port management to review and collect relevant regulations affecting each aspect.

Darbra et al. (2005) concluded that significant environmental aspects in seaports are:

- emissions to air (including gases, solid particles, and energy; dust is a significant contribution),
- discharges to water (e.g. waste waters, accidental releases during loading/unloading operations),
- noise (with its potential impact on population and fauna),
- waste generation and dredging disposal,

- odors,
- releases to soil due essentially to industrial activities,
- resource consumption,
- releases to marine sediments and activities affecting the seabed (such as dredging),
- loss/degradation of terrestrial habitats,
- changes in marine ecosystems,
- port development (land and sea occupation)

It is important to keep in mind that each port, depending on its type and its characteristics, will have different types of aspects. Also, it should be noted that the number of significant aspects is not directly related to the environmental performance of the port.

The assessment of the importance of ecological aspects is done by an individual who is an employee of a port, therefore the estimate of significance can be highly subjective, so a more objective approach is required. This approach should be based on a large number of expert opinions by all stakeholders in the process including port management, port operators, other port employees, professionals, scientists, shipping companies, etc. Therefore, it is important to emphasize the need for standard operating procedures for monitoring the environmental impact of ports (Kegalj & Traven, 2018).

Air quality must be in line with the international and European political agenda, through a current revision of the EU air quality policy[2]. The harbor aspect of air quality is recognized as the current major environmental priority in the European port sector as a whole (ESPO/EcoPorts, 2018). This reflects the importance of this aspect because of its direct relationship with the health of people who work or live around the harbor. Air quality is a priority issue independently from the size of the port and of the type of the port.

Energy consumption is a very important issue within the environmental priorities of the port sector. Energy consumption is directly associated with the costs of electricity and fossil fuels. An important reason for considering the aspect of energy consumption is the increased awareness of the impact of burnt gases (i.e. Carbon dioxide, nitrogen, and sulphur oxides) in carrying out load handling. These influences mainly relate to the local community, with the consequence of them being acid rain. Also, the impact is global warming or the exhaustion of non-renewable resources. Improved energy efficiency can also contribute to reducing air emissions and costs. That is why port authorities should attach great importance to saving energy and incorporating it as a goal within its environmental protection program. Energy consumption is also one of the environmental aspects' challenges shared by all sizes of ports and has a significant impact on the relationship with the local community.

Waste management and harbor waste remain an important issue within the environmental priorities of the port sector. Ship waste is a significant item in the recommendations of the Port Reception Facilities Directive and the appropriateness of port reception facilities for the reception of new types of shipwrecks and the increase of volumes[3].

An important environmental aspect to consider is noise. Noise control keeps high priority under the European directive on noise (European Commission, 2002). Operations that can cause noise pollution in the port area are ship and harbor engines, and road and rail traffic. Noise can cause ill effects for the land and marine world, especially for people who work or live around the harbor. The existence of European projects for assessing the impact of noise in the port area, such as NoMePorts (European Commission, 2008), is evidence of the importance of this issue in the port sector and the European Commission (EC).

[2] Air Quality Framework Directive 96/62/EC, 2004/107/EC, 2008/50/EC.

[3] https://ec.europa.eu/transport/modes/maritime/news/2018-01-16-plastic-waste_en

An important environmental aspect is water quality, which affects the biodiversity of the seaport. Likewise, the impact of port activities on environmental aspects related to polluted land and the loss of habitats may be included in the development plans of the port.

Some environmental issues, such as dredging, dust, and port development in general, are also significant environmental aspects that have been a top priority in Europe over the last few years[4].

The issues of environmental protection and the importance of environmental aspects are interrelated so that the quality of air, dust, and noise can be considered significant in terms of relations with the local community. Despite the application of EMAS[5] and ISO 140001, the port authority will select the question that best reflects the imperative of their environmental program objectives.

The environmental aspects of small and medium ports appear consistently within the environmental priorities such as air quality, garbage/port waste, ship waste, water quality, energy consumption, and noise. Undoubtedly, these aspects are also significant and appear in large ports. By contrast, very large ports, apart from the mentioned impacts on the environmental aspects, have concerns about port development issues, both on land and sea, and on the operations and disposal of dredging material.

It is necessary to develop a methodology that will cover a wide range of environmental activities and aspects that exist in ports. Since environmental impacts are largely determined by activities at the port, the interactions between them should be identified.

This methodology, consisting of a multi-criteria analysis, whereby groups of experts, representatives of the four ports (Grand Port Maritime de Bordeaux, Port of Monfalcone, Port of Piraeus and Port of Thessaloniki) fulfilled a list of port activities and assessed their impact on the related environmental aspects. The list of port activities is carried out in accordance with the procedure for identifying those environmental aspects (ISO 14001, 2004, EMAS, 2001). An assessment of the significance of the impact of certain port activities on environmental aspects depends on the type and size of the port.

The procedure is composed of several stages:

1. identification of port operations and activities,
2. assessment of the severity and probability of a negative impact on the environment,
3. verification of legal requirements,
4. identification of the environmental aspects by which each particular port process and activity is affected,
5. a description of how a particular process or activity is interacting with the environmental aspect,
6. a description of the environmental impact of a particular process or activity,
7. evaluation of their level of significance,
8. ranking the overall assessment of significant environmental impacts.

[4]https://www.ecoports.com/assets/files/common/publications/2017_11_08_Sustainability_report_2017_Review_final.pdf

[5] Eco-Management and Audit Scheme

4. Current approaches for identifying environmental aspects of port operations

4.1. The ISO 14000 family of standards and Eco-management and Audit Scheme (EMAS)

The European EMAS regulation (Eco-Management and Audit Scheme) gives a recognized and sustainable legal basis to fulfill administrative as well as social claims. EMAS is the most credible and robust environmental management tool, adding several elements in addition to the requirements of the international standard EN ISO 14001. Since EMAS contains the full text of the ISO 14001 management system, any port authority should be able to make the additional steps and progress towards environmental performance, credibility and transparency (EMAS, 2019).

ISO 14001 brings environmental management into the heart of an organization, complementing business strategy and helping improve environmental performance over time. Incorporating the latest environmental thinking including lifecycle perspective it helps to provide greater protection for the environment. It's a framework which helps focus on the increasing expectations of customers and other stakeholders, as well as regulatory requirements.

ISO 14001 includes an obligation in accordance with the relevant environmental legislation, but not the implementation. "The ISO 14001 certification process does not include a full regulatory compliance audit. In contrast, the EMAS regulation requires EMAS-Organisations to provide evidence of legal compliance with environmental legislation, including permits. Legal compliance will both be checked by the environmental verifier on site and the Competent Body during the registration process".

The European Commission (EC) developed the Eco-Management and Audit Scheme (EMAS) as a voluntary management instrument for the evaluation, reporting, and improvement of environmental performance and communicating environmental achievements (Figure 4.1).

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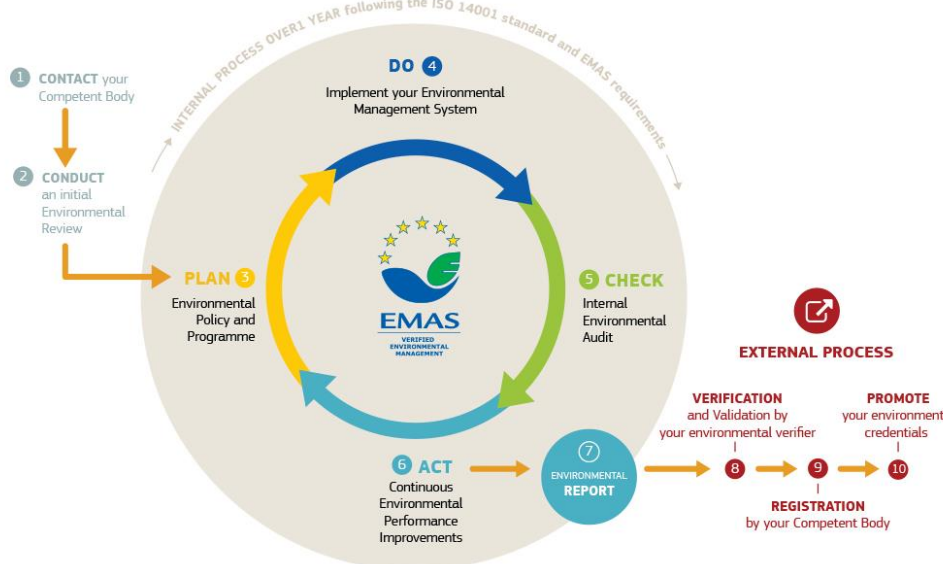

Figure 4.1 EMAS steps (EMAS, 2017)

EMAS was enacted in June 1993 and later revised in 2001, incorporating ISO 14001:1996 (International Standard for Environmental Management Systems) as its environmental management system component (see EMAS Annex II[6]). Besides that, its second revision in 2009 regulated its use by any organization in any country worldwide: Regulation (EC) No 1221/2009 of the European Parliament and of the Council of 25 November 2009. EMAS implies regular annual environmental statements, consisting of a description of the environmental management system and a summary of the data on the environmental performance, which must be validated by an environmental verifier. After registration, it has to be made available to the public and updated on a yearly basis. The purpose of EMAS is to recognize and reward those organizations that go beyond minimum legal compliance and continuously improve their environmental performance. EMAS organizations are required to provide evidence of legal compliance with environmental legislation, including permits, as opposed to the ISO 14001 certification process, which does not include a full regulatory compliance audit. EMAS certification enhances the environmental performance of a company and develops its 'green' image through transparent and validated reporting. It helps an organization to save resources and money and meet environmental requirements.

EMAS checks the compliance of the environmental statement with the requirements of EMAS Annex IV and analyses all the data generated by the environmental management system to ensure it is represented in a fair and balanced way.

ISO 14001 is implemented with the aim of enabling the organization to continuously improve environmental protection in accordance with a provision for legal compliance. It focuses on the management system, while EMAS focuses on the continual improvement of environmental performance. The organization needs to review the already existing environmental programme, the objectives, targets, and measures. The areas and scope covered by ISO 14001 and EMAS may be different. However, implementation of the ISO 14001 does not include a full regulatory compliance audit. Unlike ISO 14001, EMAS regulation requires EMAS organizations to provide evidence of compliance with environmental legislation including permits. Among other things, an important EMAS requirement is the involvement of employees at all levels and their participation in the process of continuous environmental improvement. All organizations which have EMAS must be able to demonstrate that the significant environmental aspects associated with procurement procedures have been identified and are addressed within the EMAS.

[6] http://ec.europa.eu/environment/emas/pdf/factsheets/EMAS_revised_annexes.pdf

4.2. The EcoPorts initiative

EcoPorts was established in 1997 as an initiative of several European ports to raise awareness on environmental protection through intensive cooperation, sharing of knowledge and improvement of environmental management. Since 2011, the program is fully integrated into the European Sea Ports Organisation (ESPO). The ECO Sustainable Logistic Chain Foundation (ECOSLC) allows terminals and ports outside Europe to access the EcoPorts tools (EcoPorts, 2019).

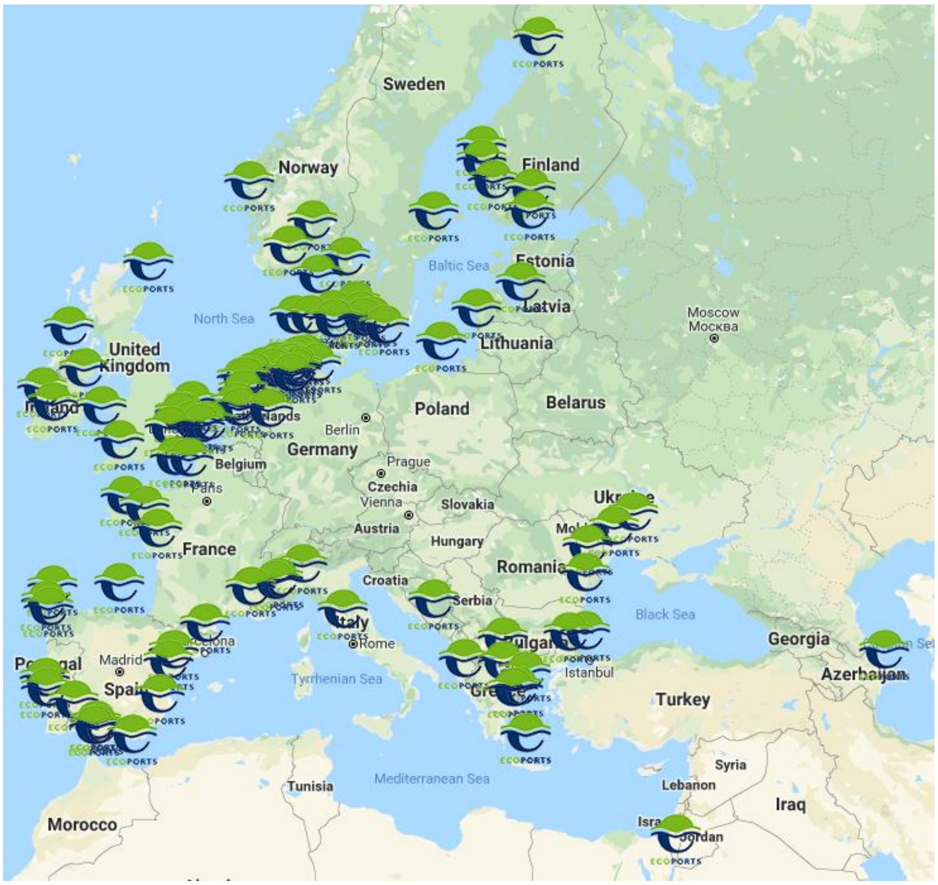

Figure 4.2 PERS, ISO and/or EMAS certified ports in Europe (EcoPorts, 2019)

The EcoPorts Network is steadily growing in number of represented countries and participating ports with the current numbers:

Table 4.1 EcoPorts members (EcoPorts, 2019)

EcoPorts (European Members)	
Participating countries	25
EcoPorts members	115
SDM evaluations	436
Issued PERS certificates	34
Issued ISO certificates	53

The tools for achieving the mentioned objectives are:

1. The Self Diagnosis Method (SDM)
2. The Port Environmental Review System (PERS).

The completion of the SDM list is considered as the “passport” to the EcoPorts network and it also assists ports in identifying the biggest environmental risks. The Port Environmental Review System is an environmental management standard specific to the port sector.

The ESPO Environmental report 2018 states the number of EMS certified member ports as in Figure 4.3.

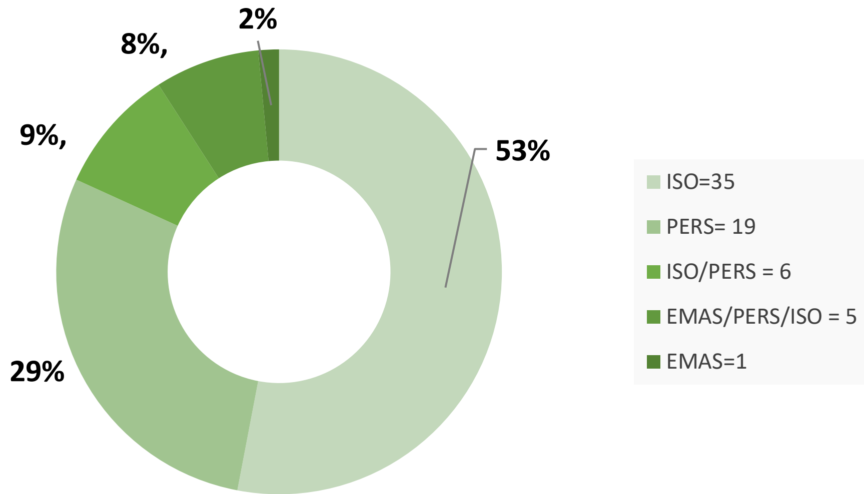

Figure 4.3 EMS certified ports (ESPO/EcoPorts. 2018)

During the compilation of the EcoPorts 2018 annual report, a total of 66 ports out of 90 were EMS certified, 46 were certified under ISO 12001, 6 under EMAS and 30 ports under the Port Environmental Review System (PERS). This is a continuous growth compared to previous reports.

The environmental performance of ports is measured with the help of selected categories of environmental performance indicators (ESPO/EcoPorts, 2018):

1. Environmental management
2. Environmental monitoring
3. Top 10 environmental priorities and
4. Green services to shipping

To know the management efforts that influence the port’s environmental performance, environmental management indicators are needed to provide this information. On the other hand, environmental monitoring indicators provide the percentage of ports and terminals that monitor environmental issues:

Table 4.2 EcoPorts performance indicators (ESPO/EcoPorts, 2018)

Performance indicators			
Environmental management indicators		**Environmental monitoring indicators**	
A.	Existence of a Certified Environmental Management System –EMS (ISO, EMAS, PERS)	**1.**	Waste
B.	Existence of an Environmental Policy	**2.**	Energy consumption
C.	Environmental Policy makes reference to ESPO's guideline documents	**3.**	Water quality
D.	Existence of an inventory of relevant environmental legislation	**4.**	Water consumption
E.	Existence of an inventory of Significant Environmental Aspects (SEA)	**5**	Noise
F.	Definition of objectives and targets for environmental improvement	**6.**	Air quality
G.	Existence of an environmental training programme for port employee	**7.**	Sediment quality
H.	Existence of an environmental monitoring program	**8.**	Carbon footprint
I.	Environmental responsibilities of key personnel are documented	**9.**	Marine ecosystem
J.	Publicly available environmental report	**10.**	Soil quality
		11.	Terrestrial habitats

The EU-funded PORTOPIA[7] project has developed the Environmental Management Index (EMI): The calculation of the index is based on specific weighting of the significances of these management indicators (ESPO/(EcoPorts, 2017):

$$EMI = 1.5 \cdot A + 1.25 \cdot B + 0.75 \cdot C + D + E + F + 0.75 \cdot G + H + I + 0.75 \cdot J \qquad (4.1)$$

The index is calculated by multiplying the weightings of each environmental management indicator to the positive responses to that indicator and then divided with 100 because the responses are expressed in percentages.

Also, very important are the top environmental priorities of the ports. The priorities changed throughout the years, but one can observe the trend of increasing priority of clean air and energy consumption (*Table 4.3*). This reflects the energy transition policies from the Paris Agreement and the increasing awareness about extreme weathers in port areas. The introduction of 0.5 global sulphur cap on fuels (2020) and the IMO NO_x Tier III requirements for vessels made air quality a top priority too. The link between energy consumption and carbon footprint of the ports and climate change made it a growing priority since 2009. In 2004 the importance of noise has grown, and it remains high since 2013, which relates to the relationship with the local community (ESPO/EcoPorts 2017).

[7] PORTOPIA- Ports Observatory for Performance Indicator Analysis

Table 4.3 Top environmental priorities 1996-2018 (ESPO/EcoPorts, 2018)

Top 10 environmental priorities in participating ports							
	1996	**2004**	**2009**	**2013**	**2016**	**2017**	**2018**
1.	Port development (water)	Garbage/ Port waste	Noise	Air quality	Air quality	Air quality	Air quality
2.	Water quality	Dredging operations	Air quality	Garbage/Port waste	Energy consumption	Energy consumption	Energy consumption
3.	Dredging disposal	Dredging disposal	Garbage/ Port waste	Energy consumption	Noise	Noise	Noise
4.	Dredging operations	Dust	Dredging operations	Noise	Relationship with the community	Water quality	Relationship with the community
5.	Dust	Noise	Dredging disposal	Ship waste	Garbage/Port waste	Dredging operations	Ship waste
6.	Port development (land)	Air quality	Relationship with the community	Relationship with the community	Ship waste	Garbage/Port waste	Port development (land)
7.	Contaminated land	Hazardous cargo	Energy consumption	Dredging operations	Port development (land)	Port development (land)	Climate change
8.	Habitat loss/ degradation	Bunkering	Dust	Dust	Water quality		Water quality
9.	Traffic volume	Port development (land)	Port development (water)	Port development (land)	Dust	Ship waste	Dredging operations
10.	Industrial effluent	Ship discharge (bilge)	Port development (land)	Water quality	Dredging operations	Climate change	Garbage/Port waste

Puig et al. (2017) analysed the current trends and status of the environmental performance of 91 European ports, member of EcoPorts. The data is from their 2016 annual report. The sample shows that most of the participants are smaller in size, followed by medium and large ports. Lastly, the least represented are very large ports. The graphical representation is given in Figure 4.4.

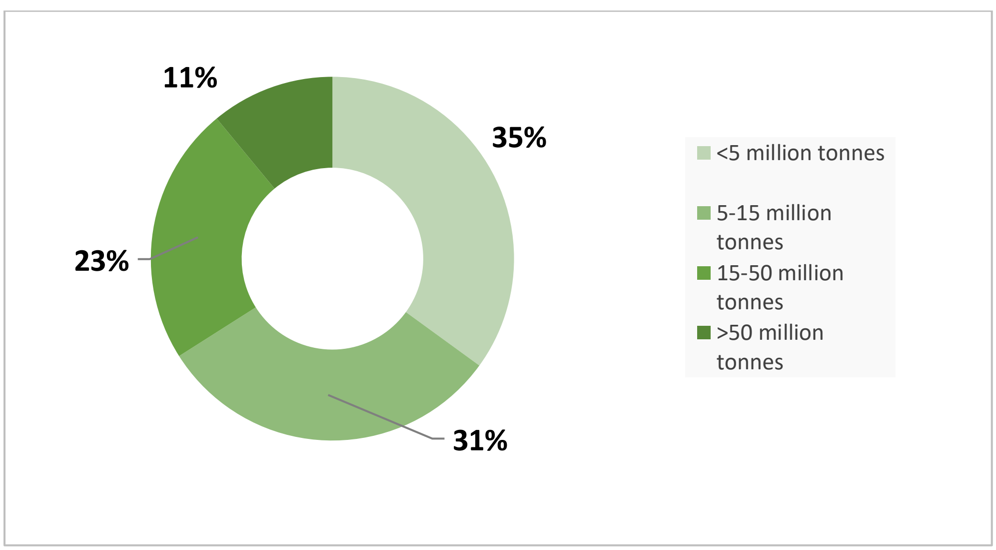

Figure 4.4 Port size distribution (Puig et al., 2017)

Taking into account the data from the SDM Checklist from 2013 one can conclude that air quality, energy consumption and the relationship with the community are common priorities for ports regardless of their size. Smaller ports prioritize ship and port area waste. Furthermore, medium and large ports have most priorities in common, while very large ports mostly focus on port development, as seen in table 4.4 (Puig, 2015).

Table 4.4 Top environmental priorities for different port sizes from the SDM Checklist 2013 (Puig, 2015)

Top 10 environmental priorities in participating ports				
	<5 million tonnes	**5–15 million tonnes**	**15–50 million tonnes**	**>50 million tonnes**
1.	Garbage/port waste	Air quality	Energy consumption	Port development (water)
2.	Ship waste	Noise	Air quality	Dust
3.	Air quality	Ship waste	Noise	Dredging: operations
4.	Energy consumption	Garbage/port waste	Garbage/port waste	Air quality
5.	Relationship with local community	Port development (land)	Ship waste	Energy consumption
6.	Noise	Water quality	Climate change	Port development (land)
7.	Dredging: operations	Energy consumption	Dredging: disposal	Dredging: disposal
8.	Dust	Port development (water)	Port development (land)	Conservation areas
9.	Water quality	Dredging: operations	Relationship with local community	Relationship with local community
10.	Bunkering	Relationship with local community	Water quality	Climate change

As far as the location of the participating ports is concerned, all possible categories are represented. Estuaries and embayment, protected coast and marine inlet are almost equally presented in the sample. After them comes engineered coastline and lastly, ports located by a river are the least represented in the sample (*Figure 4.5*).

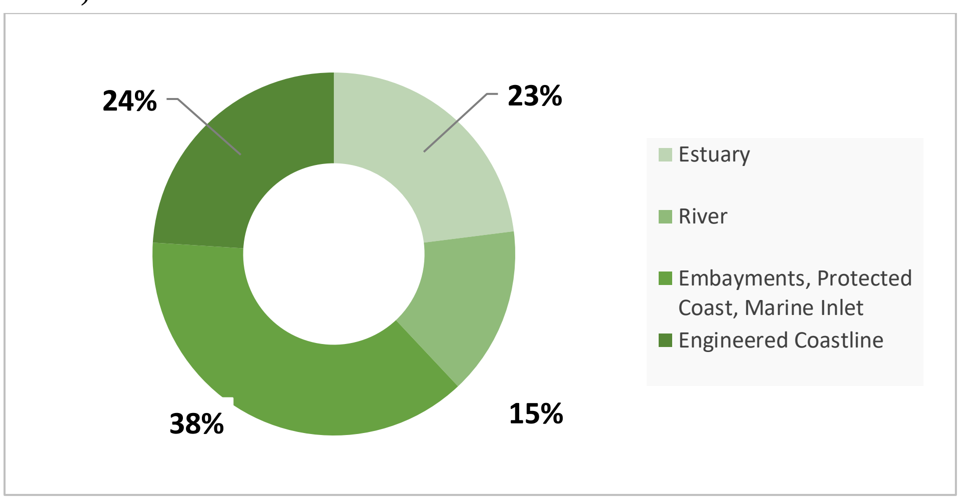

Figure 4.5 Port location distribution (Puig et al., 2017)

Regardless of the location of the port, all have the same top priorities: air quality, energy consumption and noise (Puig et al., 2015), as seen in table 4.5.

Table 4.5 Top environmental priorities for different port locations from the SDM Checklist 2013 (Puig, 2015)

Top 10 environmental priorities in participating ports				
	Estuary	**Engineered coastline**	**River**	**Embayment**
1.	Garbage/port waste	Air quality	Energy consumption	Air quality
2.	Dredging: operations	Noise	Climate change	Ship waste
3.	Dredging: disposal	Energy consumption	Air quality	Garbage/port waste
4.	Energy consumption	Ship waste	Relationship with local community	Noise
5.	Air quality	Garbage/port waste	Noise	Dust
6.	Noise	Relationship with local community	Dust	Dredging operations
7.	Port development (land)	Dust	Port development (land)	Relationship with local community
8.	Conservation areas	Water quality	Water quality	Water quality
9.	Climate change	Port development (land)	Port development (water)	Energy consumption
10.	Sediment contamination	Port development (water)	Odors	Bunkering

The last category is Green service to shipping which includes three indicators for measuring port services which aim to encourage greener shipping (ESPO/EcoPorts, 2018):

1. Onshore Power Supply (shore-side electricity) for ships at berth
2. Liquefied Natural Gas (LNG) bunkering facilities
3. A reward program for greener vessel visiting the port

In 2015, the SDM checklist was updated so it can collect data in these areas. Sample of the collected data is shown in table 4.6.

Table 4.6 Green service port indicators (ESPO/EcoPorts, 2018)

Port services indicator	**2016(%)**	**2017(%)**	**2018(%)**
Is On-shore Power Supply (OPS) available at one or more of the berths?	53	48	51
• If YES, high voltage?	20	19	24
• If YES, low voltage?	47	40	42
Does the port offer differentiate dues for "Greener" vessels?	62	51	54
Is Liquefied Natural Gas (LNG) bunkering available in the port today?	22	22	30
Are there currently ongoing LNG bunkering infrastructure projects in the port?	N/A	N/A	24

It should be noted that the sample size in 2016 was 61 participating ports, in 2017 it was 91 and in 2018 it was 90 responding ports. Regarding the percentage, it falsely appears as a decrease because the sample became wider. The number of ports offering ON-shore Power Supply grew from 32 in 2016 to 44 in 2017. Also, it is shown that a reward for greener vessels is becoming an established practice in half of the participating ports (54%) (ESPO/EcoPorts 2017, 2018).

4.2.1. Self-Diagnosis Method (SDM)

"a concise checklist against which port managers can self-assess the environmental management programme of the port in relation to the performance of both the sector and international standards"

(EcoPorts, 2018.)

The Self Diagnosis Method (SDM) is a tool designed to support and help port authorities and managers in their effort to review and improve their environmental management performance. In 2003 the European Sea Port Organisation (ESPO) recommended this approach to establish a baseline performance in order to be used for annual comparisons of the port's environmental improvement (EcoPorts, 2019).

The Self-Diagnosis Method consists of three main parts:

1. SDM checklist – Filling in the SDM checklist
2. SDM Comparison – Comparison of the SDM score with the European average
3. SDM Review – Expert analysis

Steps for using the Self Diagnosis Method are different for European and non-European countries (*Table 4.7*).

Table 4.7 SDM steps (EcoPorts, 2019)

Self-Diagnosis Method			
European ports		**Non-European ports**	
1.	Registration	**1.**	Registration
2.	Port profile completion	**2.**	Port profile completion
3.	SDM questionnaire completion	**3**	Applying for SDM comparison review/ paying a 1295 € fee
4.	Applying for SDM comparison/ Paying a 100 € fee	**4.**	SDM questionnaire completion
5.	Projection of the port's score against the European benchmark	**5**	Projection of the port's score against the EcoPorts' Port Network benchmark
6.	Applying for SDM Review/ Paying a 500 € fee	**6.**	Receiving SDM Review
7.	Receiving SDM Review		

After registration, ports complete the Self-Diagnosis Method (SDM) checklist, which is then considered as their passport to the EcoPorts network. It allows them to identify and reflect on their environmental risks. The questionnaire is mostly intended to review the management procedures and activities regarding the environment and how the port authorities deal with significant environmental aspects. The SDM version from 2015 is a checklist with 253 qualitative YES/NO questions divided into 9 SECTIONS (Puig et al., 2017), as seen in table 4.8.

Table 4.8 Questions categories from the SDM Checklist (Puig, 2017)

Category		Number of questions
1.	Environmental policy	93
2.	Management organisation & personnel	12
3.	Environmental awareness and training	7
4.	Communication	18
5.	Operational management	21
6.	Emergency planning	19
7.	Environmental issues and monitoring	23
8.	Review and audit	21
9.	Services to shipping	39

After completing the list, ports can compare their results with the environmental performance benchmark built by aggregated and anonymised data from other EcoPorts members. The last part of the SDM is submitting it for an analytic review. An expert analyses the port's environmental management and advises according to their top five priorities. The SDM review also includes a Gap[8] and SWOT[9]analysis. Registering and becoming a member is entirely free (for European ports), the SDM comparison and SDM Review are optional tools and come with a certain fee as seen in table 4.9 (EcoPorts, 2019).

Table 4.9 SDM fee (EcoPorts, 2019)

Pricing	
SDM comparison	100 €
SDM review (with prior SDM comparison)	500 €
SDM review (without prior SDM comparison)	600 €
SDM access and review for non-European ports	995 €

Furthermore, SDM can be used to recognize the most important activities and operations carried out in ports in order to determine the related significant environmental aspects such as shown in table 4.10 (EcoPorts Foundation 2004, Puig et al., 2015).

[8] Gap analysis compares actual performance with desired or potential performance
[9] A SWOT analysis helps to identify a person's/organization's strengths, weaknesses, opportunities and threats.

Table 4.10 Most likely activities and operations carried out in ports (Puig et al. 2015)

Port activities	
Administrative services	**Cargo handling and/or storage of:**
Bunkering	• Containers
Marine-based cargo transport (Shipping)	• Oil, gas and petroleum products
Mooring	• Dry bulk
Towing	• Hazardous cargo- non-oil
Land-based cargo transport (train, truck, car, etc.)	• Liquid bulk - non-oil
Passengers transportation (ferry & cruise ships)	• Ro/Ro
Dredging	• Vehicles/Trade cars
Disposal of dredged material	• Perishable Goods
Shipbuilding, repair, and maintenance	**Port-based industry:**
Maintenance of port vehicle and equipment	• Chemical & pharmaceutical plants
Port development	• Aggregate industry
Pilotage	• Agro-food Industries
Water sports	• Metal ore processing and refining
Marinas and yacht clubs	• Steelworks
Fishing & Aquaculture activities	• Power stations
Maintenance of port installations and infrastructure	• Oil refineries
Ship Waste Management	• Fish processing and market
Port Waste Management	

Port activities and associated environmental aspects are important for the identification and description of environmental impacts which make the basis for calculating the Port Environmental Index (PEI): In Chapter 7, a methodology for the identification of significant environmental aspects is described in more detail.

4.2.2. Port Environmental Review System (PERS)

The Port Environmental Review System (PERS) certificate is issued by EcoPorts which incorporates the general requirements of environmental management standards like ISO 14001. It also, takes into consideration port specific requirements and priorities. After the SDM checklist analytical review, a port gets an EcoPorts Port status and it can continue with the introduction to PERS and apply for certification (EcoPorts, 2019).

Figure 4.6 PERS certified ports in Europe (EcoPorts, 2019)

The application process for European and non-European ports is different for PERS (*Table 4.11*).

Table 4.11 Procedure for obtaining the PERS certificate (EcoPorts, 2019)

Port Environmental Review System (PERS)			
European ports		**Non-European ports**	
1.	Login on website	**1.**	Login on website
2.	Download PERS guidelines and documentation	**2.**	Applying for PERS/ Paying a fee
3.	PERS implementation-	**3**	Download PERS guidelines and documentation
4.	Applying for PERS/ Paying a fee	**4.**	PERS implementation
5.	Collect and submit all necessary documents	**5.**	Collect and submit all necessary documents
6.	Application evaluation by Lloyd’s register	**6.**	Application evaluation by Lloyd’s register
7.	Receiving a Certificate of Verification and feedback	**7.**	Receiving a Certificate of Verification and feedback

European Ports can obtain PERS documentation and guidelines from the website and start the PERS implementation by following these guidelines. Only after the guidelines are implemented participants pay the fee for the review and certification process. Non-European ports first need to pay the fee and then they receieve the guidelines and can start implementing them. The evaluation and review of the application by Lloyd’s register takes roughly four weeks. There is also an option for a preparation workshop which helps and assists ports in the implementation of PERS for a certain fee as seen in table 4.12 (ECOSLC, 2018).

Table 4.12 Pricing differentiation for obtaining the PERS certificate (ECOSLC, 2018)

Pricing (ECOSLC)	
Ports with a valid ISO 14001 certificate.	
• Ports handling up to 25 million tons of cargo per year	2975 €
• Ports handling over 25 million tons of cargo per year	3995 €
Ports without valid ISO 14001 certificate	
• Ports handling up to 25 million tons of cargo per year	4675 €
• Ports handling over 25 million tons of cargo yearly	6370 €

A SWOT (Figure 4.7) analysis concludes all given information in subchapter 4.2. One of the main strengths of EcoPorts is that they are the leading environmental initiative in the European port sector. The main weakness is the qualitative approach:

Figure 4.7 EcoPorts SWOT analysis

4.3. The Green Marine environmental program

"detailed framework for maritime companies to first establish and then reduce their environmental footprint"

(Green Marine, 2018.).

Green Marine represents an environmental certification program for the marine industry in the North American territory with the main objective of reducing the environmental footprint of maritime/port companies. The program is led by the Green Marine Management Corporation, which is a not-for-profit organization. Members of the corporation are from the marine industry in Canada (voting members) and the United States (non-voting members).

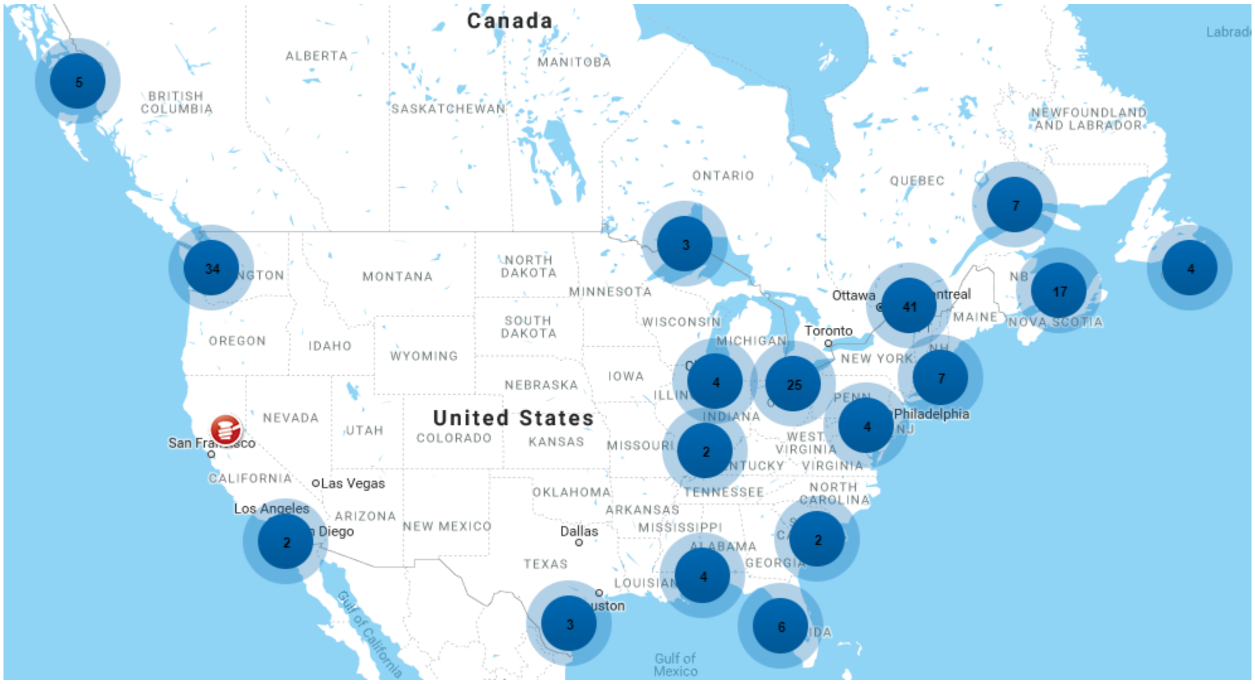

Figure 4.8 Green Marine member map (Green Marine, 2019)

Participants include different kinds of ships like container ships, tankers bulk carries, etc. Also ferries, barges, and tugs. On land, terminal facilities and port authorities of different sizes and activities (stevedoring companies, container, and bulk cargo terminals, etc.) also participate in the environmental program (*Figure 4.8 and Table 4.13*).

Table 4.13 Green Marine participants (Green Marine, 2019)

Green Marine Participants	
Shipowners	34
Ports	43
Seaway	2
Terminals	86
Shipyards	6

Green Marine has an advisory committee which consists of industry stakeholders, environmental groups and legislators. This unique group provides advice in different areas of the program and they give shape to the criteria, for each environmental performance indicator. These indicators are tailored to the marine transportation sector. The 12 performance indicators for key environmental issues are shown in table 4.14 with the corresponding organisational entities (Green Marine, 2019).

Table 4.14 Performance indicator for addressing environmental issues (Green Marine, 2019)

Performance indicators		Shipowners	Ports and Seaway	Terminals and shipyards
1.	**Aquatic invasive species**	●		
2.	**Cargo residues**	●		
3.	**Community impacts**		●	●
4.	**Dry bulk handling and storage**		●	●
5.	**Environmental leadership**		●	●
6.	**Garbage and waste management**	●	●	●
7.	**Greenhouse gas emission**	●	●	●
8.	**Oily water**	●		
9.	**Pollutant air emission NO_x**	●		
10.	**Pollutant air emission SO_x and PM**	●		
11.	**Prevention of spills and leakages**		●	●
12.	**Underwater noise**	●	●	

1. Aquatic invasive species (AIS)

For safe navigation and ship stability, ballast water operations are of great importance. For maritime shipping, it is very difficult to come to safe ballast water management solutions which at the same time minimize ecosystem impacts of introducing AIS. One of the main objectives for Green Marine is the risk reduction of propagating and introducing AIS. International and domestic ship-owners are encouraged to adopt tested and recognized best practices (e.g. research and development participation on new treatment systems, maintain annual ballast water inventories, etc.). Some of the Green Marine requirements are: keeping an antifouling management plan, cleaning of hulls to remove antifoulants and research and development on new antifouling systems (Walker, 2015).

2. Cargo residues

Cargo residues refer to ship-owners. They are generated during loading and unloading solid bulk cargo from ship holds. During cargo change, holds are rinsed to avoid possible contamination, which is often discharged in offshore waters for non-toxic cargoes. Nevertheless, accumulated cargo deposit can impact sensitive habitats. Green Marine aims to reduce cargo residue by implementing best management practices (Walker, 2015).

3. Community impacts

Noise, odor, sand, and dust are generated during port operations. Light is also perceived as a negative port activity by-product. Implementing tangible measures to reduce the impacts of port activities are encouraged. Adopting new technologies and changing operating practices can minimize societal impacts and improve performance (Walker, 2015).

4. Dry bulk handling and storage

Handling and storage of dry bulk refer to terminals, which can produce fugitive dust that causes nuisance emission to local communities. Just like with cargo residues, Green Marine aims to reduce dust production by implementing best management practices.

5. Environmental leadership

This indicator applies to port authorities and their users and tenants (e.g. stevedoring companies, terminal operators). Tenants and users are encouraged to continuously improve their environmental performance. This can be achieved by including environmental clauses in leases and contracts, promoting voluntary environmental programs, etc.

6. Garbage and waste management

Ships' solid waste production (e.g. operational, organic and domestic) needs to be properly treated and regulated to reduce their environmental footprint and health risks for the crew. The produced waste must be recycled or disposed on shore according to the area's waste management systems. Participants are required to provide adequate reception facilities for the produced waste.

7. Greenhouse gas emission

Among the main contributors to global climate change are fuel combustion and increased economic activity by generating greenhouse gas (GHG) emissions. Participants are encouraged to adopt energy performance plans and maintain annual GHG emission inventories. Each one of them is responsible for defining their own emission strategies and they must show ongoing GHG emission reductions to reach Levels 4 and 5 (Figure 4.10).

8. Oily water

During maintenance operations, water, fuel or oil on board ship often mix. To avoid pollution, contaminated water accumulated in holds must be properly treated before discharging at sea. Green Marine aims to minimize bilge water discharges. To do this, ship-owners need to implement control and maintenance measures modernize oily water treatment and implement best practices.

9. Pollutant air emission NO_x

One of the greatest challenges for the marine industry is nitrogen oxide (NO_x), sulphur oxide (SO_x) and particulate matter (PM) and emissions. Consequences from these pollutants include negative impacts on health, and poor air quality (e.g., acid rain and smog). Green Marine participants need to implement a systematic control policy to document fuel and work toward the reduction of NO_x emissions.

10. Pollutant air emission SO_x and PM

Diesel engines working with inexpensive heavy fuel oil (HFO) have high sulfoxide (SO_x) and particulate matter (PM) emissions and make the maritime industry a big contributor to the occurrence of respiratory disease and acid rain. Starting January 2020, The International Maritime Organization (IMO) will enforce a new 0.5% global sulphur cap, lowering it from the present 3.5% limit.

.11. Prevention of spills and leakages

Through maintenance operations and accidental spills during cargo handling activities ports can contaminate water, soil, and sediments. Green Marine encourages participants to install effective stormwater management systems.

12. Underwater noise

In recent years underwater noise pollution is getting more recognized as a major threat to underwater life. In 2017, Green Marine certified ports and maritime companies have voluntarily accepted to adopt new evaluation criteria regarding underwater noise. These indicators encourage the maritime sector to collaborate with the scientific community to collect noise emission data the development of noise reduction strategies (Green Marine, 2019).

Participants need to adopt certain technologies and practices which are evaluated on a scale from 1 to 5:

1. Self-evaluation process
2. External verification
3. Publication of results
4. Continual improvement
5. Certification

Figure 4.9 Green Marine certification process (Green Marine, 2019)

1. Self-evaluation process

Participants qualify for a certificate by benchmarking their annual environmental performance through self-evaluating guides provided by the Green Marine environmental program. The progress is measured with a scale from 1 to 5 using the performance indicators defined in the self-evaluation guides. After self-evaluating the participant must submit an annual report (Green Marine, 2019):

Figure 4.10 Progress measuring scale (Green Marine, 2019)

2. External verification

The results are verified by a third-party evaluator. These accredited Green Marine verifiers must meet certain conditions as:

- having sector experience
- experience with vessel operations
- accreditation and experience in verification
- environmental work and/or academic experience.

Participants pay the verification fee and the certificates are valid for two years.

3. Publication of results

The Green Marine participants agree to the publication of their accomplishment and results with certification in the program's website and annual report.

4. Continual improvement

Each participant must achieve level 2 (Best practices) during the first year of participation for at least one environmental performance indicator. Also, after the first year, participants must yearly level up in at least one performance indicator until all indicators are on level 2 or higher.

5. Certification

Successful participants receive the certification logo for the completion of the environmental program's certification process during the programs annual conference. Green Marine hosts the annual Greentech Environmental conference in July, where participants receive their certificate and various presentations and workshops about maritime transportation, innovations and best practices are held (Green Marine, 2019).

Although the approaches include an independent third-party evaluation in order to ensure that the results are credible and transparent, the methodological approach is based on self-evaluation procedures which can bias significantly the outcomes (*Figure 4.11*).

HAS THE PARTICIPANT FULFILLED THE FOLLOWING CRITERIA?	STATUS	PROOF / JUSTIFICATION
1a.2.5 Periodically inspect vessels' hulls including niche areas, such as: sea chests, propeller thrusters, keels, rudders, and dry dock support strips. *Note: Refer to 2011 IMO Biofouling Guidelines Sections 1.4, 7.2, 7.3, and 7.4. A copy can be found in the Members section of the Green Marine website.*	○ YES ○ NO ○ N.A.	
1a.2.6 If needed, remove biofouling organisms from the hull, propellers, stern tube, sea chests, and other wetted portions of a vessel. *Note: Cleaning is suggested if biofouling covers over 15% of the wetted surfaces. At 15% coverage, the vessel is considered extensively fouled. Diagrams to help estimate percent coverage can be found in the Members section of the Green Marine website.*	○ YES ○ NO ○ N.A.	

Figure 4.11 Example questions for ship owners (Green Marine-Ship Owners, 2018)

To become a member a potential participant must pay a certain fee, which may vary according to their operations and activities, as seen in table 4.15.

Table 4.15 Green Marine membership fee 2019 (Green Marine 2019)

Pricing		
Ship-owners		
• Bulk carriers & Container ships		$561/ship $5,602 min.
• Tugs, ferries and other small ships		$393/ship $3,924 min.
• Annual max:		$16,807
Port authorities		
Revenues ($M)):		
0 - 8.9		$3,924
9 - 14.9		$5,602
15 - 19.9		$6,723
20 - 24.9		$7,843
25 -49.9		$8,963
50+		$10,083
Seaway corporations		
• Annual fee		$8,963
Terminals		
• Revenue	• Tons	
< $100m	< 3.0m	$2,772
$100 to $200m	3.0 to 5.0m	$3,892
> $200m	> 5.0	$5012
Shipyards		
• 0-99 Employees (fee per facility)		$3,200
• 100+ Employees (fee per facility)		$5,333

The Green Marine program shown through a SWOT analyses (Figure 4.12) :

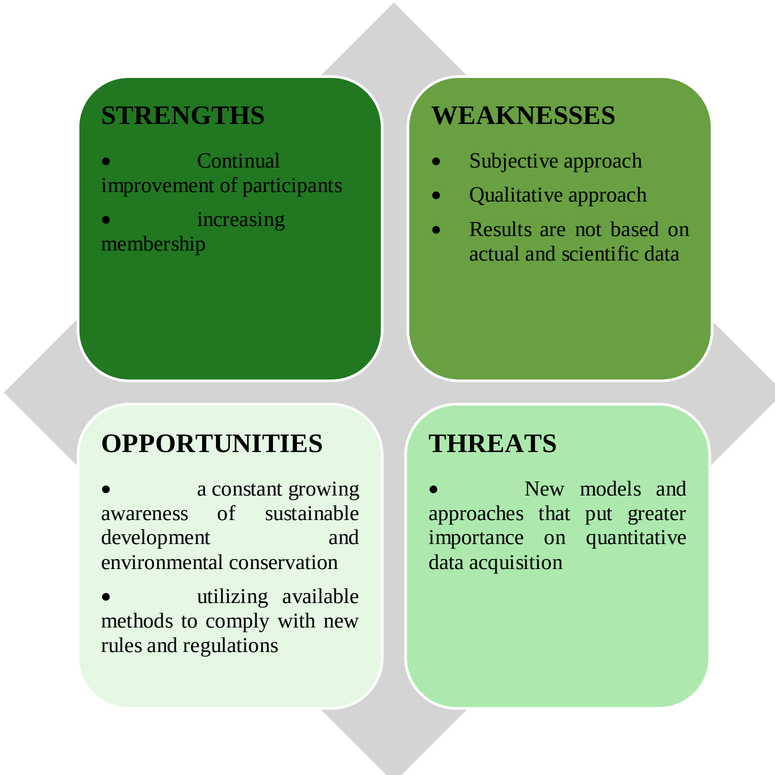

Figure 4.12 Green Marine SWOT analyses

Both the EcoPorts initiative and the Green Marine programme use a qualitative approach, focusing on the processes in place rather to their actual output, which severely limits the assessment of the true environmental performance of a port.

Example: In the Green Marine programme, the ports obtain points for having implemented eco-friendly procedures. If the port has completed an annual report on GHG emissions it is considered to be operating on the third level of environmental performance regarding the emissions of greenhouse gasses and air pollutants (the baseline level is 1 and it entails that the port is compliant with the environmental regulations) However, two ports can have vastly different emission quotas, but if both would have completed an annual reports on the emissions of GHG and air pollutants they performance would be graded as equal.

5. Description of pilots

5.1. Grand Port Maritime de Bordeaux (GPMB)

GPMB is a core port of the TEN-T (Trans-European Network of Transport) is located on the Atlantic coast, just outside of Bordeaux, Region Nouvelle-Aquitaine and belongs to the Atlantic Corridor. GPMB is the focal point of a dense network of communication by different means of transport (inland waters, sea, air, rail and road).
The Port of Bordeaux is made up of seven specialized terminals distributed throughout the Gironde estuary. Brassens is the main bulk import-export pole and allows to transit by the maritime way a multitude of goods within a radius of 200 to 300 km (depending on the products). Due to its multi-zone characteristics and its proximity to Bordeaux, the Bassens terminal appears as an ideal test area for PIXEL, easily duplicable to other European terminals. The Bassens terminal is a major logistics center, around a vast industrial-port area. Spread over more than 3 km of wharves, the activities of the site are varied: recycling traffic, cereals, oilseeds, industrial bulk, forest products, heavy packages, containers, liquid chemicals, quartz, aggregates, etc. It centralizes more than a third of the port traffic (more than 3.2 million tons per year) and has road and rail network facilitating prepost shipments.
It realizes 2% of French maritime traffic, i.e. 8 to 9 Mt/year, which puts GPMB ranks 7th of French ports. It is significant that its GPMB energy consumption reaches 11% of that of Bordeaux Metropolis. Given that GPMB owns several old warehouses whose rooftops reach about 30000 m², it could produce enough photovoltaic power for the port.
Due to the increase in traffic to the largest ships, the 120 km long extension and deepening of the Gironde Estuary is needed. For this purpose, GPMB has invested in building an innovative water-injection LNG propelled dredge, the Ostréa. The design of Ostréa should bring enhanced dredging efficiency while reducing sediments movements in the Estuary. In accordance with Bordeaux Metropolis "high quality of life" plan, because this dredge will be mainly used in Bordeaux Metropolis, GPMB has anticipated the most severe regulations about the air quality (NOx and SOx emissions).
The specificity of the port operations management GPMB is that various dedicated solutions such as gauge stations network, vessel traffic systems and radars have been developed and a specific device to control and secure the Pont de Pierre crossing by river barges.

5.2. Port of Monfalcone (ASPM)

The port of Monfalcone is located at the intersection of two strategic European routes, the Mediterranean Corridor and the Adriatic-Baltic Corridor that pass through the area. The Friuli Venezia Giulia Region, where the port of Malfalcone is located, is at the crossroads between the countries facing the Adriatic Sea, those of Central and Eastern Europe and the route connecting the Far East and Europe via the Suez Canal. Regia Friuli Venezia Giulia as the easternmost region of Italy is one of the preferred doors for commodities coming from Eastern Europe, especially raw materials, wood, and chemical products, by rail and road. It is also significant for export flows.
The Port of Monfalcone has an operating area of 750.000 sqm, 66.000 sqm of warehouses and sheds and 480.000 sqm of open customs storage areas. The port's access canal, with a length of 4,500 mt, has a depth of 11.7 mt. The commercial wharf is 1,500 mt long, a maximum draft of 10.9 mt and 9 berths. There are two private quays, the first serving a power station and the second for grain silos. The Port of Monfalcone has an optical and magnetic sensor to read the tickets and badges used to access to the Port, fully equipped with a monitoring system that allows to identify vehicles and persons and check their permits to enter the port (badge reader, barcode reader, cameras with a licence plate number detector).
The Port of Monfalcone is specialized in general and dry bulk cargo. The main routes of the ships calling upon the Port of Monfalcone touch the principal ports of the Mediterranean and the Black Sea, Canada,

Chile, and Brazil, as well as other ports in the Atlantic and Pacific Oceans. The port area is reached by train as well as by road. The railway line (Tarvisio - Trieste, and Venice - Trieste) is directly connected to the Port of Monfalcone through a dedicated junction. Furthermore, the A4 (Venezia-Trieste) and A23 (Austria-Trieste) motorways pass just 1,5 km from the Port and permit direct access to the industrial area through a dedicated road system thus avoiding the urban road system.

5.3. Port of Piraeus (PPA)

The Pireus is the natural port of Athens just 10 km away from the Athens' Center. Because of its strategic location and its infrastructure, the port makes it a hub for international trade and a focal link between the Greek islands and the mainland as well as a cruise center. Because of all this, the port of Piraeus is the main sea gateway of Greece and one of the busiest ports in the Mediterranean. Piraeus is the country's main import and export gateway. It is the first European westbound port after crossing Suez Canal with the suitable infrastructure to serve international trade and landside transportation. The PPA functions as a development lever for the local and national economy and plays a significant role in the development of the shipping, tourism and international trade clusters. The Port of Piraeus is confronted with accessibility and connection problems, both between the port area and the greater Athens and Piraeus cities.

PPA provides high quality, efficient and safe port services and contributes to local and national economy by achieving sustainable growth. It provides the link between the Greek islands and the mainland and with its ongoing investment plan aims to be established as the most important HUB, Logistics, Cruise, Container and RoRo center in the East Mediterranean.

"Piraeus Port Authority S.A." ("PPA S.A." or "Company") was established in 1930 as Civil Law Legal Corporation (C.L.L.C.), the Company is a subsidiary of COSCO SHIPPING (Hong Kong) Limited which controls 51,00% of the voting rights. PPA applies an Integrated Quality & Environmental Management System in compliance with the requirements of the ISO 9001:2015 and ISO 14001:2015 standards and is fully committed to meet its customers' needs and expectations, prevent pollution and mitigate any adverse impact the port operations may have on the environment, fulfill its compliance obligations and enhance the effectiveness of the applied Integrated Quality & Environmental System. As a member of EcoPorts/ESPO, PPA obtained another environmental standard of EcoPorts – PERS, which increases the transparency of environmental reporting, enables effective monitoring of environmental challenges and improves environmental management.

The PPA ICT system consists of the Port Management Information System (PMIS). The information system currently supporting the functions of the terminal, both on an administrative-economic level and on an operational level, is the system SPARCS N4 of the company Navis. The PMIS functions cover ship traffic management, shipyard and freight station planning operations, administrative and financial management, handling and control of handling activities, cargo/storage consolidation services, an inspection of entry and maintenance of equipment. The cruise terminal provides an excellent example of the integration of the various Information Systems and Control Engineering applications in an overall Port Information System (PMIS) architecture that incorporates the vessel traffic management, the sea yard and freight station planning operations, the administrative and financial management, the management and control of the handling activities, the cargo consolidation/warehouse services, the gate inspections and the equipment maintenance. PPA has achieved an ''EcoPorts port'' status and has joined the Ecoports network (www.ecoports.com). The Environmental Management Standard that PPA implements has been certified since 2004, according to the European Environmental Management System PERS (Port Environmental Review System) of ESPO.

5.4. Port of Thessaloniki (ThPA)

Thessaloniki is located on an advantageous position, lined to the maritime transportation network of the Balkans and Black Sea countries but also in the cross-European and national land transportation network. It is the major port for northern Greece and is also the transit gateway for the southern Balkans and it is part of the Trans-European Core Transport Network. It is located on the inner part of the Bay of Thermaicos, on the northern section of the Eastern Mediterranean Sea, to the west of the centre of the city of Thessaloniki. The port enjoys a privileged position being located at the crossroad of land transportation networks.

The terrestrial port zone of ThPA S.A. covers an area of 1.55 million sq. m. and extends along 3.5 km. The infrastructure includes 6 piers spreading on 6,200 meters of quays and berth depth up to 12 meters.

As consequence building a number of luxury hotels and new business centers, they face the problem of dust and noise due to their proximity to the port, although the port is offering a great view to their customers and employees. The industrial area of Thessaloniki, the main bus station and logistic centers are all located at the west side of the city it is an area already environmentally burdened. The main truck gate of the Port is on its west side and imposes a significant amount of traffic during the peak hours.

6. The Port Environmental Index

The Port Environmental Index (PEI) is a quantitative composite indicator of the overall environmental performance of a port.

The core idea behind PEI is to devise a comprehensive, standardized and transparent methodology to be used as an integrator of all the significant environmental aspects of ports and the related impacts into a single metric.

The maritime industry should strive for strategies to improve the development of ports, without increasing the port's negative impact on the environment. Various stakeholders participating in port processes do not have the same view of environment protection considering their own interests in the business process, therefore the interest in certain indicators differs. The differences between ports are reflected in their geographical characteristics and profile of activities, as well as their legal status.

There are various advantages in introducing the PEI (Port Environmental Index) into the port management. PEI may clearly show how an organization operates in environmental terms and provide a sound basis for setting future goals and improvements. The PEI takes into consideration the fact that every port is unique in the sense of its geographical position, the profile of activities and social-economic position, and still, the environmental issues remain ubiquitous although they may influence with various intensity and impact. There is a wide range of port types in the EU in the sense of their statutory requirements, management, operation, activities, and responsibilities. The PEI should reflect the fact that there is a wide range of responsibilities, so the interests of port authorities may vary from berth to the port area, from city to regional considerations depending on their constitution, area of impact and stakeholder orientation. It is precise because of that that the PEI is suitable for inland ports, small ports, large international ports and may be relevant for their operators and contractors, which speaks in favor of introducing the PEI in port management.

Furthermore, the calculated PEI values can be applied in determining, i.e. evaluating the impact of a certain port terminal on the environment within a designated time period and predicting the expected impact of the processes on the environment considering the planned business goals.

The PEI integrates all significant indicators of port processes impact on the environment in a value which enables the evaluation of that impact, as well as the interpretation of port operation and its environmental sustainability. The PEI can be used as an indicator for predicting future trend developments can be used as an indicator of development trends in the terminal business, i.e. work organization and in that sense optimization of sea terminal services (loading/unloading activities, warehousing, depot and accompanying services). Furthermore, the PEI offers information for the decision-making process which will define the program of environmental monitoring, responsibilities, and procedures in case of recorded excessive values of negative impact on the environment. PEI calculation may help in communicating the actual impacts of terminal operations on the environment and serve as correcting measure for directing the basic operation of port terminals towards sustainability. In any port, the PEI may serve for demonstrating the progress in port terminal operation in the sense of reducing the port environment pollution, and thus it should become a part of annual sustainability reports.

Also, the introduction of PEI in the port management enables the port to plan the reduction of negative impact on the environment by applying a technological solution to a port process, e.g. introduce a newer and/or more efficient means of work into the process, using renewable energy sources and other improvements. By introducing the PEI, the port may establish and quantify how a certain measure would influence on the reduction or increase of environmental impact. Thus, it is possible to track changes in accordance with the planned and previously established values, calculated by means of the PEI model.

Possible constraints of introducing the PEI may be found in the fact that certain ports in their efforts to become environmentally efficient, for which they spend certain resources, consider these confidential and a part of the competitive port business plan. However, the use of the PEI as a measure of the commercial impact may be a sensitive issue. This should be further discussed as there are a potential overlap and differences in the interpretation of the possible so-called environmental, social-economic, logistic, operative and market impact. Owing to that, the discussions with port authorities show that it is important to justify the purpose of PEI on the EU level in order to stimulate all parties, i.e. stakeholders to participate.

Furthermore, another possible disadvantage of introducing PEI refers to the need for continuous measurement and analysis of indicators for obtaining precise information about the impact of port processes on the environment. All ports do not have the same technological level of equipment for measuring indicators or the same environment protection regulations, so it is more difficult to obtain and observe the same parameters. Possible shortcomings of PEI calculation may be in weighing the indicators that reflect the hierarchy and/or priorities according to the opinion of scientists and experts, and thus may be considered subjective.

7. A methodological approach for identifying significant environmental aspects in pilot ports

According to Puig (2016), 89% of the European ports have identified significant environmental aspects, representing an increase from 84% in 2013. In order to make an assessment of the aspects, a valid methodological approach must be used. In the past, several methodological approaches for identifying environmental aspects in ports were developed. Some of them are listed in the first section of this chapter, with the more detailed description being given for each of them after that. It should be noted that various approaches for identifying environmental aspects in other fields of human activity exist, but they are not listed here. The methodology developed during the course of the PIXEL project is described in the second section.

7.1. Existing methodological approaches for identifying significant environmental aspects

The approaches that deal with the environmental aspects in ports are:

- The ABP method – developed by Associated British Ports Research and Consultancy Ltd. in 1997 (Darbra et al. 2005; Williams and Micallef 2009)
- ECO-information Strategic Analysis Questionnaire for the Environmental Port Manager ("Self-Diagnosis Methodology 1998" or "SDM 98") (Darbra et al. 2005)
- ECOPORT method – developed within the framework of the ECOPORT project (Darbra et al. 2005; Puig 2016; Puig et al. 2015)
- ECOPORT II method (Valenciaport 2007)
- EcoPorts method - developed by Darbra et al. (2005), within a framework of ECOPORTS project
- INDAPORT method (Peris-Mora et al. 2015)
- TEAP (Puig et al. 2015)

Several ports have developed their own methodologies (Puig 2016):

- A Coruña Port (Puerto de A Coruña 2013)
- Algeciras Port (Autoridad Portuaria de la Bahía de Algeciras 2014; Autoridad Portuaria de la Bahía de Algeciras 2017)
- Cartagena Port Authority (Puerto de Cartagena 2014)
- Livorno Port Authority (Autorità Portuale di Livorno 2012)
- Roses Port (Ajuntament de Roses 2012; Ajuntament de Roses 2018)
- Valencia Port Authority (Valenciaport 2013)
- Vigo Port Authority (Puerto de Vigo 2016)

7.1.1. The ABP method

Although there isn't any information on environmental aspects assessment methods developed on a European level before the next year, Associated British Ports Research and Consultancy Ltd. developed their own method for the identification of environmental aspects that appear during the development of coastal areas in 1997. In Darbra et al. (2005), it is described as "a method that allows identification of aspects and their ranking based on the risk that they entail and, as a consequence, of its significance". It should be noted that this method wasn't developed for impacts that ports have on the environment apart from the one that they have during their development or expansion. However, it forms the prototype for all the later methods.

The ABP method is implemented through an online software package that consists of eight steps that are required to define the probability that something will happen and the magnitude that it will have on the environment. Based on the probability and magnitude levels, aspects can be assigned a score for their risk and significance and, based on those scores, a user can determine which aspects are considered to be significant and which aspects can be neglected in future work (Darbra et al. 2005; Williams and Micallef 2009).

The main goals of the ABP method are the following (Williams and Micallef 2009):

- To formalize and document the assessment process for any proposed development
- To allow judgments to be made on a case-by-case basis
- To enable that those judgments are carried out by quantifying impacts as much as it is possible
- To provide a basis on which decisions can be made in determining significant project efforts.

The eight steps of the method are the following:

1. Description of a project or plan – it should contain the information about the situation before the port development project, what kind and magnitude of development is planned, about operations that are required for the development and changes to operations after the development
2. Identification of possible impacts – it should consider which features of the development can cause which environmental effect (for example, water, soil and/or air pollution)
3. Identification of consequences – it is a continuation of the previous step, for each of the impacts listed in step 2, consequences that are likely to occur should be listed here
4. Estimation of the magnitude of consequences – there are four self-explanatory levels of magnitude (severe, high, mild and negligible). In order to make the level assessment more trustworthy, an explanation should be given for each of the assigned magnitude values. It is good to note that the monetary value can be added for some of the consequences.
5. Estimation of the probability of consequences – this step is analogous to the previous one, only the level of probability is given instead of the level of magnitude. The levels are the same as they are for magnitudes
6. The relevance of consequences – the user should decide whether a consequence has a significant impact on the environment (such as habitats in the port area)
7. Assessment of risk – the risk should be assessed on the foundation of the magnitude and probability values assigned in the 4th and 5th steps. The levels of those two are not numerical, so a matrix should be used. A slightly simplified matrix for risk assessment is shown in table 7.1. It is important to say that the levels of probability and magnitude are more complex than those described here, but for the sake of understanding the methodology, it is unnecessary to go into more details

8. Overall assessment – at the end of the method application, two matrices should be produced, one which has the summary of the estimated magnitude and probability values for each of the consequences (*Table 7.1)* and one which should identify a subset of relevant consequences.

Table 7.1 Matrix for risk assessment, ABP method (Williams and Micallef 2009)

	Consequences			
	Severe	**High**	**Mild**	**Negligible**
Probability				
High	High	High	Medium/Low	Near zero
Medium	High	High/Medium	Low	Near zero
Low	High/Medium	Medium/Low	Low	Near zero
Negligible	High/Medium/Low	Medium/Low	Low	Near zero

At the end of the review of the ABP method, several points can be observed. The first is the most obvious one – that this method was developed only for a small segment of the total impact that a port can have on the environment, nevertheless its basic methodology could be applied to a broader context. The second one is the relationship between magnitude and risk that is in places very similar to the methodology to be used by MEDRI in the Pixel project. The downside of the ABP method of assessing magnitude and probability is that it uses descriptive terms (high, medium, etc.) instead of numerical values, so it is impossible to have some numerical cut-off values and risk should be determined using matrices.

7.1.2. ECO-information Strategic Analysis Questionnaire for the Environmental Port Manager ("Self-Diagnosis Methodology 1998" or "SDM 98") (1998)

Although it is sometimes hard to determine which of the relevant methodologies identified was the first one developed, from the study of all the relevant literature, it seems that the first method developed specifically for the assessment of environmental aspects in ports on a European level is the "Strategic Analysis Questionnaire for the Environmental Port Manager", developed by ESPO in 1998 (Darbra et al. 2005). It should be noted that the first European environmental code for ports was the "ESPO Environmental Code of Practice", from 1994 (Puig 2016). The updated version of this method was already described in section 4.2.1., and in this section, the focus would be on the identification of the significant environmental aspects using this method.

The ECO-information questionnaire lists 10 port environmental issues, while a set of 18 questions is repeated for each of the aspects (Darbra et al. 2005). The questionnaire was designed in order to support port managers in regularly reviewing the environmental situation in their ports. During its inception, the goal was to have an environmental management tool that can lead both to comparison with the previous year (considering environmental performance) and to assess the effects of various investments. The other main goal was to compare ports throughout Europe in terms of their environmental performances (Paipai 1999).

The goals of SDM98 can be given in more details, citing Paipai (1999) "The method was aimed to:

- Be specific to the ports industry
- Be confidential
- Be both easy to use and logically structured

- Explain and inform about environmental management
- Enable the collection or collation of baseline date
- Enable inventory of potential environmental effects
- Enable inventory of key legislation and compliance
- Form the basis of an environmental report
- Support continual improvement
- Compare environmental performance with international standards
- Compare environmental performance between ports”

It is easy to see that those form pretty much universal purpose of all the methodologies used in assessing environmental aspects and/or impact in ports. All those goals also apply for all the other methodologies listed in this section and they wouldn’t be repeated in each of them unless some difference is explicitly stated in the source material.

The SDM consists of several elements (Paipai 1999):

- Description of the site
- Examination of present management practices
- Inventory of port activities
- Inventory of potential environmental effects
- Selection of key issues
- Key issue characteristics

The method was developed to embody the principles of SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis. It was planned that it should both identify potential problems and concerns and prioritise areas that might require management attention. The first version of SDM98 focused on the strategic aspects of environmental issues. The results were displayed as a list of attention points that can be used to detail the port’s environmental strategy. Flow chart of SDM98 is displayed in Figure 7.1, while the scanned part of the questionnaire with the overview of the main environmental issues is given in Figure 7.2. More details about the method can be found in (Paipai 1999).

The rest of the questionnaire deals with issues such as emergency planning, inventories, environmental training, etc. The questionnaire considers some relation between port activities and their influence on the environment in “Section M5: Inventories”. However, based on the available data, there doesn’t seem to be any kind of quantitative rating of various influences on the environment, apart from “Y” (yes), “P” (partially) and “N” (no). Also, there is no distinction between various factors that might influence the final rating of various pollutants (such as probability and severity).

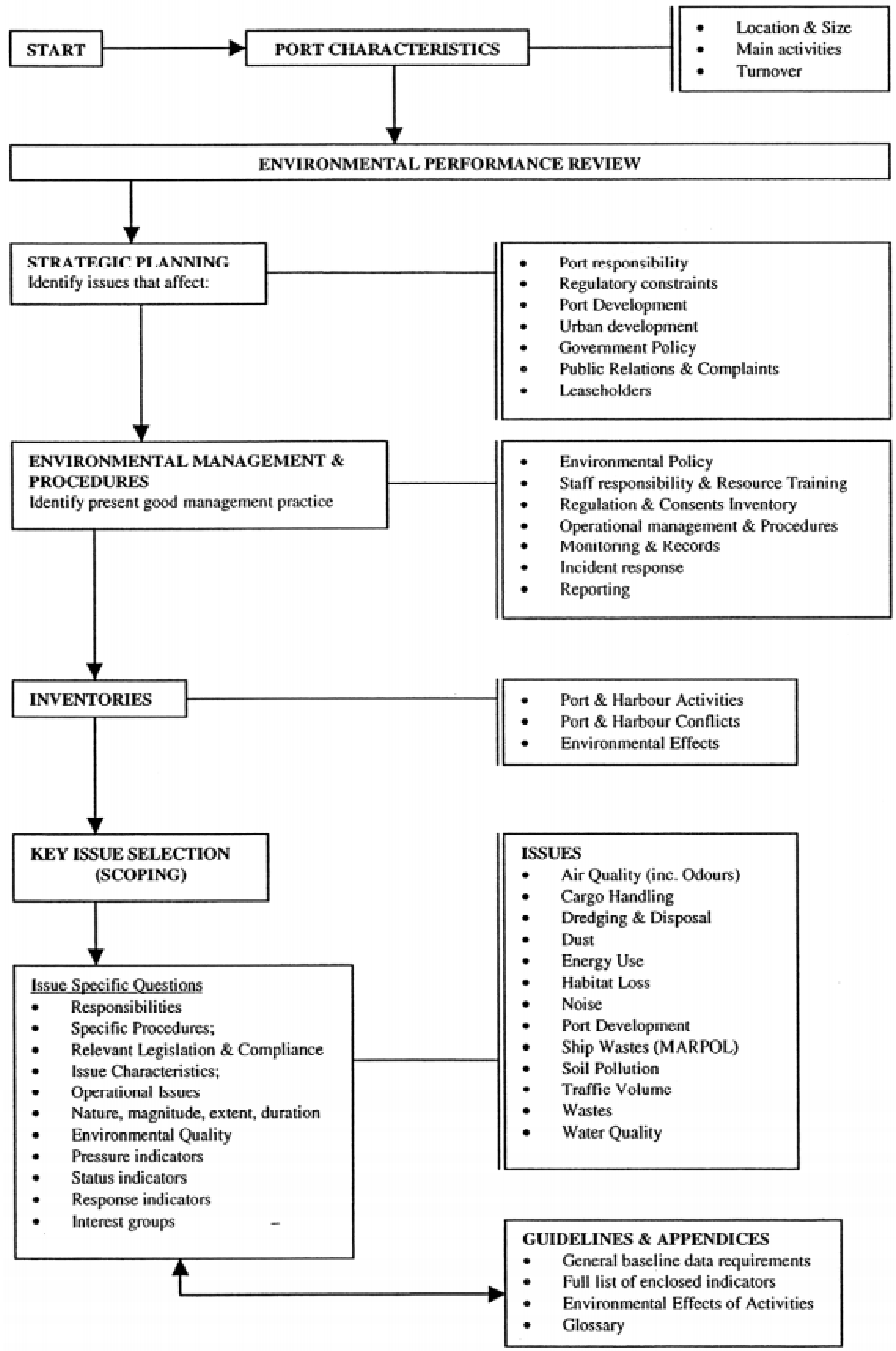

Figure 7.1 Flow chart of SDM98 (Paipai 1999)

	Air Quality	Dredging	Dust	Energy use	Habitat Loss	Health & Safety	Noise	Soil Contamination	Waste	Water Quality
Regulation										
• International conventions / legislation										
• European legislation										
• National legislation										
Policy										
• Own port environmental policy										
• European / international policy										
• National / local policy										
Public and Employee Health										
• Public health										
• Employee health & safety										
Port Image and Public Relations										
• Port image (general)										
• Marketing of the port										
Complaints from External Parties										
• Local communities										
• Action groups										
• Port users										
• Governmental organisations										
Financial										
• Financial costs										
• Financial benefits										
• Investments										
• New business opportunities (e.g. recycling)										
Port Development										
• Short term (1-2 years)										
• Long term (3-10 years)										
Natural Environment										
• Nature conservation / protected areas										
• Landscape										
Tourism & Recreational Use										
• Tourism										
• Recreational use										
Others (please specify:)										
Importance of Issue on a scale of 1 to 10*										

* Assess for your Port the importance of each issue, independent from other environmental issues, on a scale of 1 to 10 (e.g. air quality: 5, dredging: 5, dust: 8, etc.):

not important	1	2	3	4	5	6	7	8	9	10	very important

Figure 7.2 Questionnaire example for SDM98 (Paipai 1999)

7.1.3. ECOPORT method

Chronologically, the next significant method for identifying significant environmental aspects is the ECOPORT method, developed during the course of the ECOPORT project, in the early 2000s. It is described as being based on a matrix of activities vs aspects, where the significance can be assessed "by cross-gauging four parameters: aspect nature, fate, environmental applicable requirements and quantity of substance" (Darbra et al. 2005). An example of the questionnaire is given in table 7.2. The matrix in an example is filled simply by filling in "yes" or "no" in each of the boxes. There is no risk assessment or similar ratings in this step of the method.

Table 7.2 An example of the questionnaire for ECOPORT method (Puig et al. 2015)

	Activity, Product or Service				
Environmental aspects					
	Normal	**Cleaning**	**Maintenance**	**Incidents**	**Emergencies**
Air emissions					
Combustion Gases					
Volatile products					
Refrigerating gases					
Welding Gases					
Deposits to water					
Waste generation					
Hazardous					
Inert					
Urban					
Spills and escapes					
Escape from underground deposits					
Spills and escapes from piping and superficial deposits					
Use of resources					
Water					
Electric energy					
Fuel					
Paper / Cardboard					
Plastics					
Hazardous products					
Noise					

After this first step is finished and activities and aspects are related, the assessment of the significance of the aspects should be made. The significance is determined based on the three criteria (Puig 2016):

- Frequency or probability (C_1)
- Control of the impact (C_2)
- Severity (risk and/or quantity) (C_3)

The significance (S) is determined by multiplying the abovementioned factors (Equation 7.1)

$$S = C_1 \cdot C_2 \cdot C_3 \quad (7.1)$$

Values of the factors are given in tables 7.3 (frequency), 7.4 (control) and 7.5 (severity).

Table 7.3 Frequency or probability - scoring system for the ECOPORT method (Puig 2016)

	Frequency	Probability	Value
Very low	Less than once a year	Less than once a year	1
Low	A few times a year	From 2 to 12 times a year	2
Average	A few times a month	From 12 to 47 times a year	3
High	A few times a week	From 48 to 200 times a year	4
Very high	Daily or continually	Over 200 times a year	5

Table 7.4 Control of the impact - scoring system for the ECOPORT method (Puig 2016)

Control	Description	Value
Low	When the aspect is produced, the potential impact also occurs and nothing can be done to avoid it. (E.g.: emissions to air, wastewater deposits, resource consumption without applying good practices or good environmental purchasing criteria)	4
Average	When the aspect is produced but the impact can be reduced. (E.g.: noise, controlled filtered air emissions, waste removed to a dump, resource consumption in accordance with good practices and environmental purchasing criteria)	2
High	Although the aspect is produced, the impact does not occur. (E.g.: waste is recycled, resource consumption in accordance with good practices and purchasing criteria)	1

Table 7.5 Severity - scoring system for the ECOPORT method (Puig 2016)

Quantity	Risk		
	High	Average	Low
High	Very high (16)	High (8)	Average (4)
Average	High (8)	Average (4)	Moderate (2)
Low	Average (4)	Moderate (2)	Low (1)

The cut-off value is proposed in a way that an aspect is considered to be significant if it has obtained a score within the top 20% of the values. Those aspects are then listed in table 7.6, which represents an inventory of significant environmental aspects.

Table 7.6 Table for the list of SEA in ECOPORT method (Puig 2016)

Significant Environmental Aspect		Generation sites	Significance	Indicator
Code	Description			

It is recommended that the inventory of significant environmental aspects should be updated annually, to reflect changes in port activities and new legislations.

7.1.4. ECOPORT II method

In 2007, several changes were introduced to the ECOPORT method described in detail in the previous section. The changes were introduced during the project that was a follow-up project to ECOPORT and was named ECOPORT II. One of the most significant changes was the introduction of two scoring systems, one that should be used for normal conditions and one that should be used for abnormal conditions.

The scoring for normal conditions consists of four different criteria (Valenciaport 2007):

- Nature of the impact (toxicity/danger) generated by the activity or sub-activity (A_1)
- Receptor medium/destination (A_2)
- Applicable environmental requirements (A_3)
- Quantity (depending on the effect, it is given in absolute or relative numbers or concentrations (A_4)

The scoring is the same for all three criteria and has three possible scores (1, 10 and 20). More detailed scoring system can be seen in Valenciaport (2007).

The result is a simple sum of the abovementioned criteria:

$$S = A_1 + A_2 + A_3 + A_4 \quad (7.2)$$

If the significance (S) is over 50% of the maximum score, it is considered to be significant. The other criterion of the significance is the law regulation of the aspect.

In the case of abnormal situations, different scoring criteria are used:

- Frequency (F)
- Consequence (C)
- Probability (P)

There are different scoring criteria and scoring tables for unusual situations and emergency situations (both can be found in Valenciaport (2007), but the significance (S) is always scored with the following formula

$$S = F \cdot C \cdot P \quad (7.3)$$

To conclude, this approach has the advantage of having different criteria that should give better results based on which kind of situation is in question. The negative side is, like all similar approaches, the difference in comparing the significance of aspects in various situations/working conditions.

7.1.5. EcoPorts method

Like the above described ECOPORT method, EcoPorts method was also developed during the course of a project (ECOPORT, 2002-2005). Due to the similarities in their names, one should give a clear explanation of their origins. ECOPORTS project was started by the EcoPorts foundation, that has its origins in research programme ECO-information (1997-1999), which has produced a methodology described in 7.1.2. and was established as the EcoPorts Foundation in 1999 (Wooldridge 2017). ECOPORT and ECOPORT II methodologies are two unrelated methodologies developed during separate projects and only share a similar name with the EcoPorts method and the ECOPORT project.

It was published in Darbra et al. (2005) and was also among the methods described in Puig et al. (2015), where three of the authors also participated, and in Puig (2016). Although mostly referred to as "ECOPORTS method", its official name is "Strategic Overview of Significant Environmental Aspects (SOSEA)". The main objective was helping port managers in the identification of significant environmental aspects and also in the reinforcement of the awareness about them while working in environmental management. It was based on ISO 14001 vocabulary. Special interest was also given to the identification of reasons why some aspect is significant or not.

The methodology is divided into three parts (Darbra et al. 2005):

1. Environmental Activities and Aspects Matrix
2. Significant Environmental Aspects Questions
3. Strategic Perspective of Environmental Aspects

The matrix of environmental activities and aspects is done using a modification of the Leopold matrix[10], in order to make the approach as objective as possible. The matrix should represent all interdependencies between a set of activities and each environmental aspect that are possible. It is different from the matrix in the ECOPORT method in a way that it combines environmental aspects with the port activities and not with operating conditions. The matrix should be filled using only two answers – "A" (applicable) or "NA" (not applicable). It is seen that several empty rows are given in order to enter some aspects possibly overlooked by the authors of the method.

After the aspects are chosen, the port should choose the aspects considered to be significant for each of the activities in a checklist similar to that shown in figure 7.3. There are several criteria for significance assessment:

- Legal regulations
- Local-scale concern
- Global scale concern
- Other (possibilities of having an influence on environmental risks, like economic reasons)

[10] In Darbra et al. (2005), Leopold matrix is defined as "…a very useful method for the environmental impact assessment of several civil engineering works (e.g. roads, airports, railways). Rows represent environmental issues whereas columns stand for the activities liable to cause an environmental impact. For each interaction a ranking value (magnitude/importance) is determined".

Activity 1: Bunkering	(A☐ / NA☐)
Aspects:	
Emissions to air	☐
Discharges to water	☐
Emissions to soil	☐
Emissions to sediments	☐
Waste production	☐
Resource consumption	☐
Others (specify):	

Activity 2: Dredging	(A☐ / NA☐)
Aspects:	
Discharges to water	☐
Emissions to soil	☐
Emissions to sediments	☐
Changes in marine ecosystems	☐
Resource consumption	☐
Others (specify):	

Figure 7.3 An example of the checklist for the ECOPORTS method (Darbra et al. 2005)

After the checklist is filled-in, it is possible to fill in a matrix like in Figure 7.4.

		ACTIVITIES																			RESULTS
		Port Authority							Port Area												
									Tenants							Other Agencies					
		Port Engineering	Dredging	Marine engineering	Administrative and Planning Activities	Shipping and Navigation	Emergency Plans	....	Cargo handling operations	Cargo storage	Port based industry	Fisheries & Aquaculture	Ship building and repair	Stakeholders activities	....	Waste Management	Port installations maintenance	Land traffic	Recreation and tourism	Bunkering	
ASPECTS	Emissions to air					×	×											×			3
	Discharges to water	×	×	×		×	×		×			×		×					×	×	10
	Emissions to soil								×	×				×							3
	Emissions to sediments		×								×									×	3
	Noise													×				×			2
	Waste production				×				×		×	×	×				×		×	×	8
	Changes in terrestrial habitats	×		×																	2
	Changes in marine ecosystems	×	×	×		×						×	×							×	7
	Odour																				0
	Resource consumption					×				×	×		×			×		×		×	7
	Port development (land)	×		×							×							×			4
	Port development (sea)	×																	×		2
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Figure 7.4 An example of the filled matrix for the ECOPORTS method (Darbra et al. 2005)

The significant environmental aspects are determined based on two criteria:

1. All those aspects that have "result" of at least half of the maximum value (in an example, the maximum value is 10, and the cut-off value is 5)
2. All aspects regulated by law

This approach is significantly different from, for example, the ECOPORT method, in a way that it doesn't assign a rating score for each of the aspects based on its probability or severity. That means the aspect that is present in most of the activities is considered to be the most significant. The negative side of that approach is that some aspect can have only a few source activities and yet have a very severe influence on the environment. Using this method, similar aspects would be rated as non-significant.

7.1.6. INDAPORT method

This method, described in Peris-Mora et al. (2005), was developed during the research on INDAPORT project in the mid-2000s. The main goal of the article in which it was presented was, as the title of the article states, "the development of a system of indicators for sustainable port management". Having that in mind, it should be stated that this methodology is not strictly a methodology for the assessment of the significance of various environmental aspects, but also has different uses. However, a part of it is interesting for research on identifying significant environmental aspects and some details on it are given in this section.

The method was developed for the "case study" of the Port in Valencia but was planned to be widely used in other European ports. The first step consisted of identifying activities carried out in the port. Once the list of activities was completed, all of them were subjected to environmental analysis. Together with the identification of the activities, the analysis consisted of five general systematic stages, which mostly follow the usual procedure in environmental impact assessment (Peris-Mora et al. 2005):

- Identification of port activities and processes
- Identifying environmental aspects affected by each activity-process
- Evaluating their level of significance
- Ranking of impact
- Condensing data

The potentially significant aspects are determined using the step diagram and flow chart, like the one in Figure 7.5.

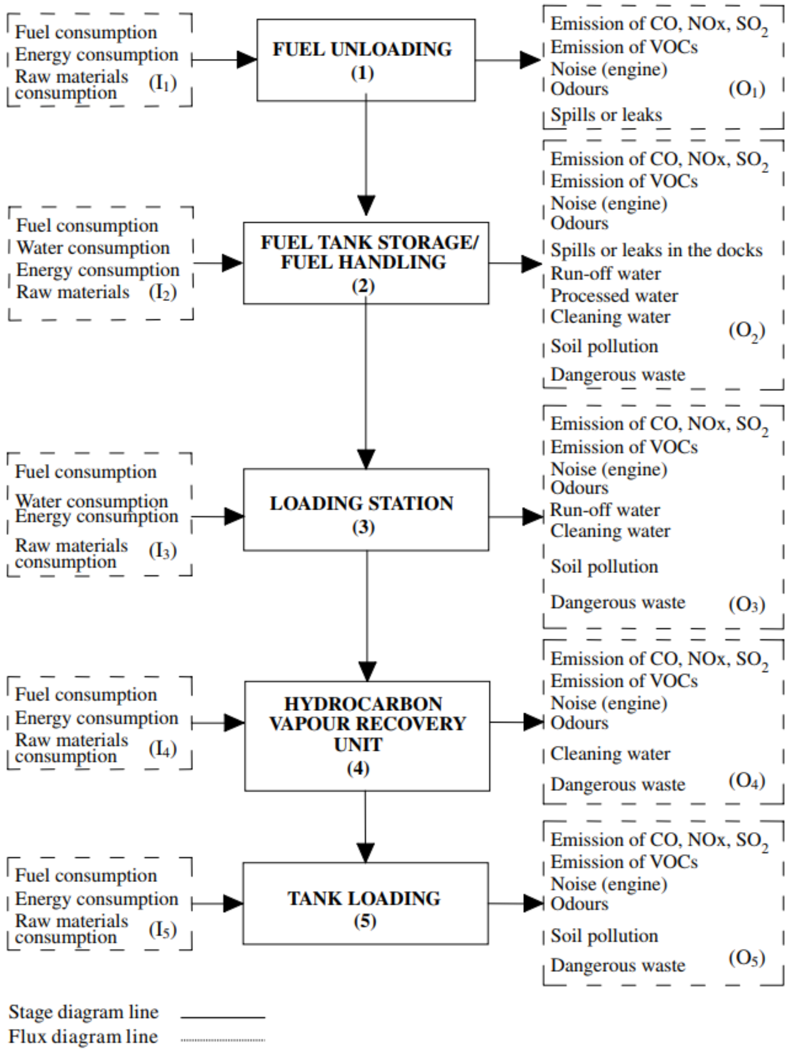

Figure 7.5 Flow diagram for the process of the determination of SEA, INDAPORT method (Peris-Mora et al. 2005)

The identified aspects shall be used for the characterization of the environmental impact. The user should (Peris-Mora et al. 2005):

- Analyse the potential impact
- Discover its level of significance
- Establish correlation between different impact (if possible)

All the identified potentially significant aspects are sorted in adequate groups and the process of determining the significance of their impact can start.

The impact/significance is determined using the following formula ("Var" represents variables, which are listed below):

$$I_i = \left[\log\left(\prod_{actual} Var\right) / \log\left(\prod_{maximum} Var\right)\right] \cdot 100 \qquad (7.4)$$

The actual environmental impacts are ranked based on the fact how close is its value to 100%, with the ones closest to the value being ranked as the most significant. It should be noted that different variables are used in assessing the significance value of each aspect. The variables are listed below and their relation to aspects is given in table 7.7 (Peris-Mora et al. 2005):

- Danger/toxicity
- Magnitude
- Frequency
- Fragility of medium
- Reversibility of impact
- Renewable resource
- Affect on residents
- Emergencies
- Abnormality
- Overtaking
- Existence of legislation
- Ease of management

Table 7.7 Aspects and variables relationships, INDAPORT method (Peris-Mora et al. 2005)

Aspects/impacts group	Variables											
	D/T	**M**	**F**	**FoM**	**RoI**	**RR**	**AoR**	**E**	**A**	**O**	**EoL**	**EoM**
Air pollution	x		x				x	x	x	x	x	
Noise pollution			x				x					
Odor pollution			x				x					
Water pollution	x	x	x	x	x		x	x	x		x	
Soil pollution	x		x	x				x	x		x	
Waste creation	x	x	x								x	x
Resource consumption		x	x			x						
Alteration of seafloor				x	x		x			x		
Alteration of coastal habitats				x	x		x			x		
Alteration of littoral dynamic				x	x		x			x		
Impact on landscape				x	x		x			x		
Soil occupation				x	x		x			x		

To sum things up on INDAPORT method, it is clear that it introduces some interesting elements, like the different variables for each of the environmental aspects and the calculation formula different from the other methods. While the use of different variables is not a new idea, some of the variables listed are not usually considered in the analyses (like the fragility of medium or ease of management). The main negative side is that the procedure doesn't use some kind of probability level as a factor. Frequency might be considered as similar, but an additional "probability" rating would be of great use. Also, the method is developed more as a help to identify the impacts that should be monitored than a methodology for the general assessment of significant environmental aspects and comparison between the ports. However, it presents an interesting approach and can give researchers some ideas for the development of SEA identification methodologies.

7.1.7. TEAP (Tool for the identification and assessment of Environmental Aspects in Ports) method

Like most of the methods described above, this one was also developed in the framework of a project, namely PERSEUS research project[11]. The aim of the methodology is to create a standardised method for the identification of significant environmental aspects. It should be noted that most of the team that has developed the method was also behind the creation of the previously described ECOPORT method.

In Puig et al. (2015), two main advantages of this method were stated:

- The method goes into more details considering environmental aspects (for example, “emissions to air” aspect was divided into more detailed aspects, based on the fact which gases are in question)
- The method minimizes subjective assessment of the port manager
- Unlike most of the existing methods, the TEAP method is not paper-based and can be filled online

The TEAP method was developed in six steps (Puig et al. 2015):

1. Identification of port activities – in order to identify the aspects, it is needed to identify all the significant activities from which those aspects are derived. In the final version of TEAP, 35 activities were identified, some of which are carried out by the port authority, some by a specialised company and some by terminal operators.
2. Identification of port environmental aspects – aspects were conducted from the available literature. The initial list of 55 aspects was later reduced to the list of 17 aspects in the final version.
3. Creation of the relationships between activities and aspects – this step was done using the ranking method and not just only a list of activities with their associated aspects. If an aspect is very specific and relevant for the activity, it would have the rating “5”, if it has medium influence, it would have the rating “3” and if it is considered to be of low importance and generic, it would have the rating “1”. An example of the aspects associated with the activities of bunkering and dredging is given in table 7.8
4. Definition of the criteria – this step is needed to assess the significance of the aspects. The eight criteria are shown in table 7.9. It should be noted that if an aspect is regulated by law, it is considered to be significant regardless of other criteria.
5. Establishment of the weighting of the criteria responses – weighting is based on the significance of the environmental impact. If the impact is more significant, higher weight should be assigned. An example of frequency and duration is given in table 7.10.
   Creation of the connection between aspects and criteria – not all criteria is applicable for all of the aspects, so the connection needs to be established. It is done with the help of a matrix shown in Figure 7.6 (yellow squares mean that there is an interaction).

[11] Official website of the project: http://www.perseus-net.eu/site/content.php

Table 7.8 Example of the aspects associated with the activities, TEAP (Puig et al. 2015)

Activity	Aspects	Points
Bunkering	Emissions of other gases	5
	Discharges of hydrocarbons	5
	Biodiversity affectation	3
	Emissions of combustion gases	1
	Fuel consumption	1
	Noise emissions	1
Dredging	Biodiversity affectation	5
	Noise emissions	3
	Discharges of other chemicals	1
	Generation of other wastes	1
	Fuel consumption	1
	Emissions of combustion gases	1

Table 7.9 Example of the weighting of the criteria, TEAP (Puig et al. 2015)

Criteria	Definition
Frequency	The number of times that the port activities can generate this aspect.
Aspect duration	The length of time that the aspect lasts.
Extent of the impact	The area of influence of the impact in relation to the port surroundings.
Stakeholders' complaints	It considers the port stakeholders and local community complaints on each environmental aspect.
Legal compliance	It considers if this aspect is affected by legal requirements and if permissible levels are exceeded.
Severity of the impact	It considers the degree of impact that this aspect generates.
Quantity of waste	This criterion measures the quantity or the volume of waste that has been generated.
Consumption of resources	It is determined by comparing the consumption of the current year with the consumption of the previous years.

Table 7.10 Example of the weighting of the criteria, TEAP (Puig et al. 2015)

Activity	Aspects	Points
Frequency	The aspect is generated continuously	5
	The aspect is generated at least once a day	4
	The aspect is generated at least once a week	3
	The aspect is generated less than once a week	1
Duration	The aspect lasts more than 1 day	5
	The aspect lasts between 8 h and 1 day	4
	The aspect lasts between 3 and 8 h	3
	The aspect lasts between 1 and 3 h	2
	The aspect lasts less than 1 h	1

Environmental Aspects	Frequency	Aspect duration	Extent of the impact	Stakeholders' complaints	Legal compliance	Severity of impact	Quantity of waste	Consumption of resources
Normal and abnormal conditions								
Emisions to air								
Emissions of combustion gases								
Emissions of other gases								
Emissions of particulate matter								
Odour emissions								
Discharges to water								
Discharges of wastewaters								
Discharges of hydrocarbons								
Discharges of other chemicals								
Discharges of particulate matter								
Emissions to soil								
Emissions to soil and groundwater								
Resource consumption								
Water consumption								
Electricity consumption								
Fuel consumption								
Waste production								
Generation of solid urban waste								
Generation of hazardous waste								
Generation of other wastes								
Noise								
Noise emissions								
Biodiversity affectation								
Biodiversity affectation								

Figure 7.6 Connections between aspects and criteria, TEAP (Puig et al. 2015)

TEAP sums the total number of points assigned for each of the aspects. The aspects are then ranked according to the achieved score. If the aspect has a score of at least three, it is considered to be significant. It is important to note that each of the aspects is assessed only with the criteria that apply for it, similarly to the previously described IDNAPORT method. The formula for the calculation is given in Puig et al. (2015):

$$Average\ value\ of\ each\ aspect = \frac{\sum punctuation\ of\ each\ criterion}{number\ of\ criteria\ applied} \quad (7.5)$$

The TEAP is among the most developed methods for the significant environmental aspect identification. The criteria are well-rounded, and it has the advantage of being an online tool, so there is no need to fill it on a paper. Like for some of the previously described methods, it lacks the "probability" rating, but all in all, it is a method that can be used as a good reference for the development of a new methodology.

The tool can be accessed online on the following link: http://www.eports.cat/. A more detailed description of the method can be found in Puig (2016).

7.1.8. Methodologies developed by the ports

In this section, seven of the methodologies developed by ports for the identification of significant environmental aspects are presented. The list is based on the one provided in Puig (2016), although some of the methodologies have been updated in the meantime, and it is reflected in this article. The list is not meant to be comprehensive but should give relatively good information on some other methodologies.

7.1.8.1. A Coruña

The method developed by the port in A Coruña describes only the method of evaluation of various environmental aspects and not the procedure of the identification of the aspects that need to have its significance evaluated. The methodology here was presented in Puerto de A Coruña (2013) and Puig (2016). The aspects considered belong in several different categories, such as normal or unusual functioning, incidents, accidents, and emergency situations. Also, both direct and indirect environmental aspects are considered. The aspects are divided into usual categories (emissions to air, noise, etc.).

There are three criteria for the significance assessment listed (Puerto de A Coruña 2013; Puig 2016):

- Magnitude (C_1) – takes into account the frequency and the amount of impact on the chosen environmental aspect. If there is no available data, a mean value derived from the available sources is used.
- Nature of the aspect (C_2) – a degree of the toxicity or danger of the aspect. It is based on the characteristics of its components.
- Influence on the receiving environment (C_3) – a possible impact that an aspect has on the medium that is receiving it

Each of the criteria/factors is assigned a value from 1 to 10, where 10 represents the highest significance. The three criteria are summed up for each of the aspects (ratings can go from 3 to 30 for each of the aspects):

$$S = C_1 \cdot C_2 \cdot C_3 \qquad (7.6)$$

Based on the score achieved, the scale is created. Only the aspects with the score in the highest 20% are considered to be significant. Exceptions to this rule are the aspects which are regulated by law. They are always considered to be significant.

There is also a method for identifying the significance of the possible environmental aspects, where the main factors are (Puerto de A Coruña 2013):

- Probability and frequency (P)
- Impact on the environment and nature (A)
- Impact on the population (B)
- Socio-economic impact (C)

The total risk is calculated using the following formula:

$$Risk = A \cdot P + B \cdot P + C \cdot P \qquad (7.7)$$

Probability is scored according to the table 7.11.

Table 7.11 Probability/frequency scoring system, A Coruña (Puerto de A Coruña 2013)

Probability or Frequency			Value
Very likely		>once a month	5
Once a month>	Highly probable	>once a year	4
Once a year>	Likely	>once in 10 years	3
Once in 10 years>	Possible	>once in 50 years	2
Once in 50 years>	Improbable		1

Each of the factors can have a value from 1 to 5, so the final score is from 3 to 75. Only the aspects that have risk values rated as "high" or "very high" are considered to be significant. The values are shown in table 7.12.

Table 7.12 Risk assessment, A Coruña (Puerto de A Coruña 2013)

Risk assessment		
Levels		
Very high risk	Between 61 – 75	5
High risk	Between 46 – 60	4
Medium risk	Between 31 – 45	3
Moderate risk	Between 16 – 30	2
Low risk	Between 3 – 15	1

The method developed by A Coruña takes into account both environmental aspects that are always present and those that happen less frequently or might not happen at all. It stands out from the others in a way that slightly different calculation is used for those aspects that happen always and those that are less frequent or are only possible. This approach has an advantage that all aspects are assigned their significance in a reliable way, but it makes the comparison of various aspects harder.

7.1.8.2. Algeciras

Like the port in A Coruña, Port Authority of Algeciras also has only a procedure to assess the significance, but not the one for identifying aspects. Like most of the methodologies, this one consists of scoring each aspect.

The scores were initially (in 2014) assigned for (Autoridad Portuaria de la Bahía de Algeciras 2014; Puig 2016):

- Magnitude (M)
- Seriousness (G, from Spanish word "*gravedad*")
- Spread (extension), spread and accumulation in 2017 (E)
- Reversibility of the impact (R)
- Probability of occurrence (P)

Since at least 2017, a couple of new criteria were added (Autoridad Portuaria de la Bahía de Algeciras 2017):

- Social sensitivity (S)
- Legislative regulation (L)

The formula for calculation of the significance is the following:

$$Sig = \sum f_X \cdot X \quad (7.8)$$

Where f_x represent the weighting factor and X various criteria (M,G,R,E,S,L,P)

An aspect is considered significant if it scores above some threshold. The threshold is usually around 50% of the maximum possible value, but it may vary according to the circumstances. It should be noted that each of the criteria is weighted according to its influence in global impact. More details about the procedure can be found in special instruction, which was not available at the time of writing this document (Autoridad Portuaria de la Bahía de Algeciras 2017).

As only some details are known about this methodology, it is hard to say more. However, some interesting things can be noted. The first of them is the consideration of social sensitivity and the reversibility of an environmental impact. Those two are often omitted. The other thing is that different weights are assigned considering the influence of some criteria on a global impact, which can be interesting as a mean to achieve higher precision but might also open door to new problems, such as an influence of human factor on the final results.

7.1.8.3. Cartagena

The Port of Cartagena is the first port in this review that has developed its own methodology for the identification of significant environmental aspects and not only for assessment of their significance.

This methodology is similar to the one proposed in this Deliverable in the way that it uses the following to criteria (Puerto de Cartagena 2014, Puig 2016):

- Frequency of occurrence (low, medium or high)
- Consequences (mild, medium or serious)

The decision if an aspect is significant or not is based on the table presented in table 7.13 ("Yes" means that an aspect is significant and "No" means that it is not significant).

Table 7.13 Signifiance assessment, Cartagena (Puerto de Cartagena 2014)

	Consequences		
Frequency	**Mild**	**Medium**	**Serious**
Low	NO	NO	YES
Medium	NO	YES	YES

High	NO	YES	YES

The main advantage of this method is that it is extremely simple to understand and apply. It can be seen as a simpler version of the one proposed in this Deliverable. In it, it was improved by introducing the more detailed scoring system, in a way that scores are from 1 to 5, and that it takes into account legislative regulation of various aspects.

7.1.8.4. Livorno

The Port of Livorno is the only port outside of Spain that has its own methodology presented in this document. Like the Port of Cartagena, it also has a methodology both to identify aspects and to evaluate their significance. To identify aspects, the environmental manager should complete a table of interactions between activities and aspects, which represent the most used method for the identification of the aspects (Puig 2016).

The significance is determined on the foundation of the following seven criteria (Autorità Portuale di Livorno 2012, Puig 2016):

- Compliance with legislation
- Hazardousness of the impacts
- Location
- Stakeholders concerns
- Probability of occurrence
- Lack of data
- Possibility to improve

Each of them is rated 1 (negligible), 2 (low significance), 3 (medium significance) or 4 (highly significant). The calculation formula is a simple sum of those seven criteria, with the overall score being between 7 and 28. The aspect is considered to be significant if the value for some aspect is equal or higher than 15. If it is lower, the aspect is automatically considered to be insignificant unless it is not in compliance with the legislation. In that case, the aspect in question is also considered to be significant, in spite of score being lower than 15 (Autorità Portuale di Livorno 2012).

In case of indirect environmental aspects, an additional criterion called "control capacity" is introduced. The sum from the formula is then multiplied by the value of the "control capacity" factor. The values for the factor are given in table 7.14.

Table 7.14 Values for the "control capacity" criterion, Livorno (Autorità Portuale di Livorno 2012)

Influence	CC values	Considerations
None	0 – 0.20	The institution has no possibility to control the aspect
Low	0.21 – 0.50	Possibility of control: actions to raise awareness, informative campaigns, etc.
Medium	0.51 – 0.75	Possibility of control: conclusions of agreement protocols, program agreements, loans and subsidies, etc.
High	0.76 – 0.90	Possibility of control: enactments of ordinances, regulations, prescriptive documents, issuing of authorizations, contractual prescriptions, technical specifications, etc.

The threshold of significance remains 15 for indirect aspects carried out by the companies that are related to the port (such as concessionaries) but is lowered to 8 for the activities carried in the port area (Autorità Portuale di Livorno 2012).

This method is also interesting in several ways, mostly because it assesses two important problems: lack of data and the possibility of improvement. Those two criteria are mostly neglected in other methodologies. As an aspect is immediately considered to be significant if it is not in compliance with the legislation, that criterion is sort of redundant in the main scoring formula. For that reason, it would be simpler if the criterion is left out of the main formula and if it is used as a criteria unrelated to the scoring system.

7.1.8.5. Roses

The Port of Roses also uses a methodology for the assessment of significance. It is based on the following four criteria (Ajuntament de Roses 2012; Ajuntament de Roses 2018; Puig 2016):

- Magnitude or Probability of occurrence (for emergency situations) (M)
- Consequences (importance) (I)
- Management factor (corrective and preventive measures applied to the assessed aspect during the current year) (F)

The values for each criterion can be from 1 to 3. The 2018 version of the method offers the following calculation formula for significance:

$$S = M \cdot I - F \cdot 0.2 \qquad (7.9)$$

The significance levels are shown in table 7.15. Only the aspects with the significance level of “High” are considered to be significant.

Table 7.15 Significance levels, Roses (Puig 2016)

Significance	Level
Significance ≤ 1	Low
1 < Significance ≤ 2	Medium
Significance ≥ 2	High

This method is another of the relatively simple methods. It has a rare introduction of a criterion that actually reduces the significance factor, in a way that if some corrective and/or preventive measures were applied, then the overall significance should be reduced. One of the points for further discussion in the correction factor of 0.2 by which the management factor is multiplied. It is not described why is this exact value chosen (for the 2017 version, the correction factor was mentioned but not assigned any value, but it can be deduced that it is also 0.2).

7.1.8.6. Valencia

The methodology used in the port of Valencia both identifies environmental aspects and assesses their significance. The port manager should identify both direct and indirect environmental aspects in both normal and abnormal situations. In the process of assessing environmental issues, past accidents and emergency situations are analysed. There are only two factors (criteria) that influence the significance of the aspects, analogous to those in Cartagena port (Puig 2016):

- Frequency - low, medium or high
- Severity (or consequence for indirect aspects) – low, moderate (only for severity), medium or high

In reality, only severity influences the final result for direct aspects, as an aspect is considered to be significant if the severity is rated as "high" (Puig 2016; Valenciaport 2013). In indirect aspects, an aspect is also considered significant if it has high frequency and medium impact (*Table 7.16*, an aspect is considered to be significant if it scores in green).

Table 7.16 Significance assessment for indirect aspects, Valencia (Valenciaport 2013)

	CONSEQUENCES		
FREQUENCY	**Low impact**	**Medium impact**	**High impact**
Low			
Medium			
High			

With only two criteria, this is one of the simplest methods possible. However, as only one aspect really matters for significance assessment of direct aspects, it makes the whole "methodology" label a bit doubtful and seems more like a subjective assessment without any real methodology behind it.

7.1.8.7. Vigo

Last of the ports presented here is the Port of Vigo. It has three criteria for ranking the significance of the aspects (Puig 2016):

- The frequency of the aspect generation
- The hazardousness of the aspect
- The area of influence of the aspect

The formula for scoring significance is a simple sum of the three criteria. It is mentioned that aspects that scored higher than eight points are considered to be significant, but no range of values is provided in the report for 2011 (Puig 2016). In the 2015 report, not even that methodology is described (Puerto de Vigo 2016).

7.2. PIXEL methodology for identifying significant environmental aspects

The main goal of this section is to explain the methodological approach to be used to identify the **Significant Environmental Aspects (SEA)** of port operations and the representative indicators for each aspect at the four pilot ports: (a) port of Bordeaux – France, (b) port of Monfalcone - Italy, (c) port of Thessaloniki - Greece and (d) port of Piraeus - Greece.

Once SEAs are identified, for each aspect a set of representative **(environmental) Key Performance Indicators (eKPIs)** will be identified using data published in the relevant technical and scientific literature. Upon identification and validation, the KPIs will be used as inputs in algorithms for computing the Port Environmental Index (PEI).

The procedure is represented using a flow diagram shown in Figure 7.7.

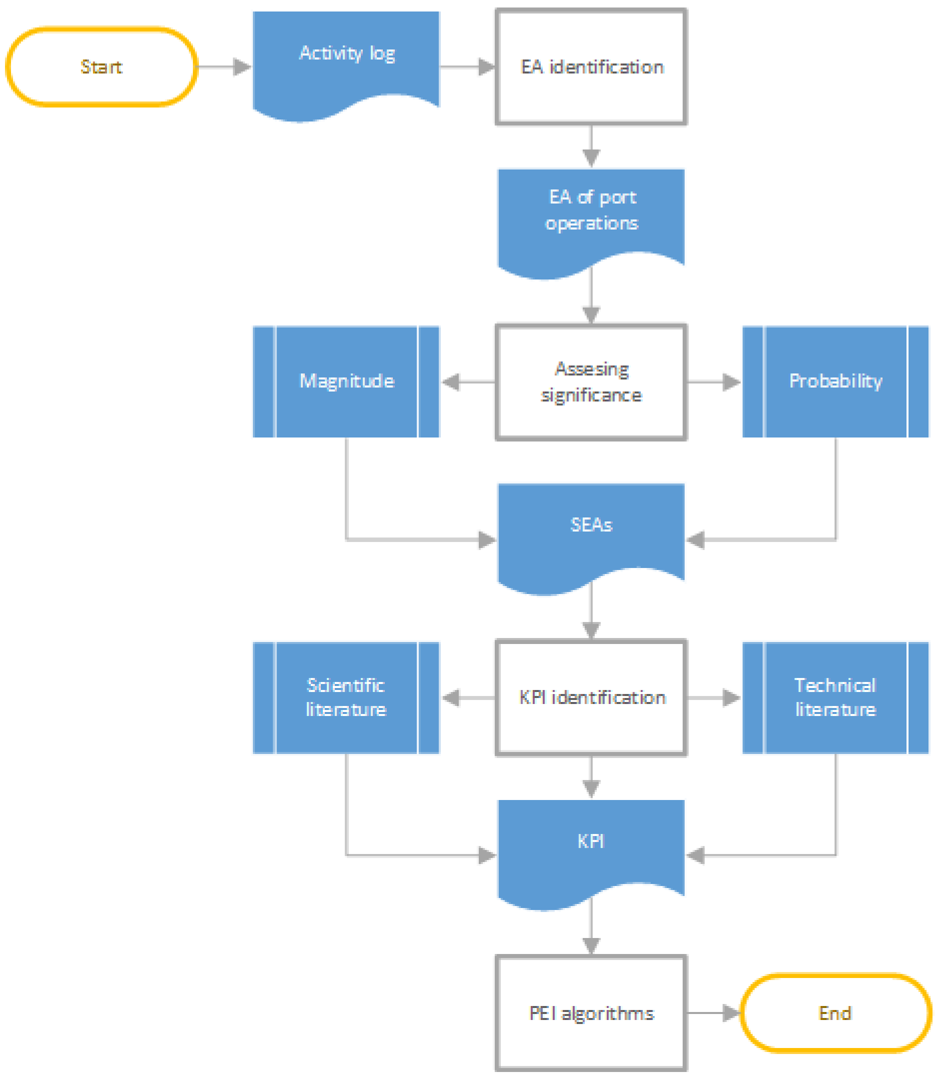

Figure 7.7 Flow diagram of the PEI assessment process

Correctly identifying the SEAs and the respective KPIs is extremely important. If the significant environmental aspects are not chosen properly or if the indicators are not representative any further development of the PEI would make no sense, even if the mathematical procedures behind it are done using state of the art protocols. In summary, identifying correctly the significant environmental aspects and their indicators is a necessary precondition for all the other steps in the development of the PEI.

Several existing approaches for identifying different environmental aspects and the relevant impacts of port operations were already presented in the first part of this chapter. Current approaches for identifying environmental aspects of port operations, and their strengths and weaknesses were identified. Taking this into consideration, the main goal of this section is to present an alternative approach for identifying the most significant environmental aspects using a similar approach and set the framework for developing PEI further. The approach is intended to be deployed to the four pilot ports but it is also scalable and can be used in identifying significant environmental aspects in other ports as well.

A Significant Environmental Aspect (SEA) is defined as an environmental aspect of an operation which has a significant environmental impact. As it will be discussed later in this section, the definition can also be re-conceptualized and rewritten to describe a significant environmental aspect as an environmental aspect that has both a significant environmental impact and a relatively high probability of occurring, to exclude those hypothetical impacts that could have a significant impact if they occur, but which are so extremely unlikely that they pose no environmental risk. A graphical representation of the above is given in Figure 7.8.

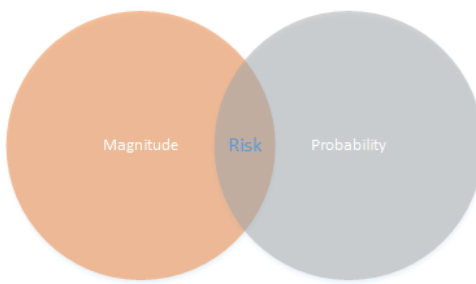

Figure 7.8 Risk as a function of "magnitude" and "probability"

In this exercise both “probability/likelihood” and “severity” are given as numerical values from 1 to 5, where 1 means “not severe/not very probable” and 5 means “extremely severe/extremely probable”. To avoid confusion, it should be noted that the term”probability” is not used here in the strict mathematical sense (values between 0 and 1), but it represents a likelihood of some outcome. For that reason, the possible values are between 1 and 5, same as for severity.

It is obvious that an activity which has both high severity and high probability rating will have a high impact rating and vice versa. However, some activities can have a very severe influence on the environment but are practically impossible to happen (the best example, not connected with ports, would be a disaster in nuclear power plant) and the inverse of it are various activities that happen all the time but have little influence on the environment.

Once the probability and severity values are assigned, the process of the significance estimation can be done. The definition of significance can be equated with “risk” which is used here is the same vein as in Manuilova (2003) which states that the risk is: “the combination of the probability, or frequency, of occurrence of a hazard and the magnitude of the consequences of the occurrence.” It is given as a simple product of the values of probability and severity:

Since both “probability” and “severity” are given as numerical values from 1 to 5, where 1 means “not severe/not very probable” and 5 means “extremely severe/extremely probable it is clear that the significance (or risk) can have values from 1 to 25.

An additional consideration is that the pilot ports are not the only ports to which PEI will be deployed in the future. The procedure used to identify the SEAs for port operations under PIXEL pilot ports is a combination of a self-assessment procedures and regulatory context. Thus the methodology is not perfectly accurate but is independent of variables such as port size, type of port, country in which the port is located and the frequency of traffic or transportation in the ports.

In order to identify significant environmental aspects, first of all, an activity log which includes all of the activities and activity types performed in pilot ports must be filled. Activity and activity type are simply two levels on a ladder, with activity being more general (each activity encompasses several activity types). For example, if the activity is listed as *cargo handling and storage*, it can have several types of activities, such as work with containers and work with several types of dry and liquid bulk.

Once the activities are identified for each activity the corresponding environmental aspects are identified and graded according to the magnitude and the probability of the adverse effect occurring. If the environmental aspect is regulated it is considered a significant environmental aspect despite the magnitude and probability ratings.

In addition, the issue of weighting needs to be assessed. The suggested process of the weighting is relatively simple from the mathematical point of view and is dependent on the values of severity and probability given to each activity in the ports. The current plan is to have a value that would serve as a product of the values of severity and probability (called risk earlier in this section). With that approach, activities that are almost impossible to happen could be given a probability of, „0“ (or left blank in the questionnaire) and their impact, even if their severity can have a high rating, would be rated as „0“. The same applies to activities that are likely to happen but have very little impact on the environment.

The overall grade given to each environmental aspect is a product of the two criteria and can be described by the following formula:

$$Significance = Probability * Severity \quad (7.10)$$

Once the significance or risk of a certain type (aspect) of environmental impact occurring is established for each activity the significance values for each environmental aspect are summarized across activities.

In this deliverable, we did not assign strict significance for a certain environmental aspect but there are several ways in which this can be done which are summarized in the following paragraphs

Since the above approach is based on subjective ratings of magnitude and significance it can lead to significant bias. There are several ways that bias can be minimized:

- to maximize the number of people answering the questionnaire;
- to rely heavily on the published literature considering the impacts that ports have on their environment
- to compare the results between ports – if two ports with the similar activities and other characteristics have huge disproportion of a significance rating in some of the aspects, the more attention should be given to reasons why it happened and if those reasons are the product of the human error or of an outside factor.

In this study, we have consulted the published literature and compared the results between ports to identify possible inconsistencies between the obtained data.

Regarding the maximization of the people filling in the questionnaires, since the questionnaires were filled by a limited number of people per each pilot port, this line of minimizing bias has not been pursued.

To sum it up, the process of identifying significant environmental aspects would consist of the following steps:

- Making a list of possible aspects that a port can have on the environment (based on the available literature and on the other approaches for identifying significant environmental aspects).
- Making a questionnaire based on that list, which should be distributed to ports to fill and to make further suggestions considering missing activities or other irregularities in the questionnaire (also, completely blank questionnaire can be given, but the ports were less willing to cooperate that way).
- Checking the results of the questionnaire and correct some of the obvious mistakes or irregularities that exist because of the human error and subjective judgment.
- Weighting of the severity and probability of environmental impact that various port activities have on the environment.

Summing the product of severity and probability (risk/significance) across activities for each environmental aspect.

8. Significant environmental aspects - mapping to pilots

Activities are grouped into two areas, specifically, the port area and port authority, and each of these areas conducts specific activities. For each activity performed in a port the port operators estimated its severity, the likelihood of undesirable impact on a particular environmental aspect and whether the aspect is regulated or not. The aspects, which are regulated are therefore classified as significant aspects, Each activity is described in Figures 8.1 - 8.8 and in the Tables 10.1 – 10.4 (see *Appendix A*). The results of port operators assessment of activities carried out in the ports are summarized in the text and Figures below.

The analysis of the data obtained from the ports Grand Port Maritime de Bordeaux (GPMB), Port of Monfalcone (ASPM), Port Piraeus (PPA) and Thessaloniki (ThPA) show that port activities have the greatest impact on the atmosphere (emissions to air). The second environmental aspect in severity of impact is environmental noise. It should be emphasized that the Port of Monfalcone estimated that its port activities have the greatest impact on the aspect of resource usage. The ports ThPA and PPA estimate the impact of their activities to resource usage as minor. The analysis shows that the impact of port activities to the aspect of light pollution and odour are of minor or negligible significance in all the ports.

It can be concluded that depending on the size and type of the port, port activities have different environmental aspects with the exception of the aspect of atmospheric emissions, which was highlighted by all ports as the most significant, except for the Port of Monfalcone, which ranked it as third in significance.

8.1. Grand Port Maritime de Bordeaux (GPMB)

Table 10.1 (*Appendix A*), Figure 8.1 and Figure 8.2 show the impact of the Grand Port Maritime de Bordeaux (GPMB). Figure 8.1 shows the significance of ports environmental aspects. The rank (significance) has been calculated in the following way: for each activity the severity and probability of a certain environmental impact occurring are multiplied and the products are summarized across different activities. Figure 8.2 shows the average value of probability and severity of environmental impact for each environmental aspect. The values are averaged across port activities.

The activities conducted by GPMB have the highest impact on the aspect Emissions to air. Five activities stand out according to their impact on the atmosphere they are in order of significance: handling and storage of dry bulk (ores and minerals and organic), dredging & disposal of dredged material, as well as mooring, and towing.

The second most significant aspect of port activities impact is resource consumption (fuel/energy consumption, water, fuel for machinery) followed by by the aspect noise, followed by discharges to water and waste production. The activities conducted in the port GPMB also have a significant impact on the soil, contribute to light pollution and there create odours. According to the analysis the activities related to ship movement (have a minor impact on the environment).

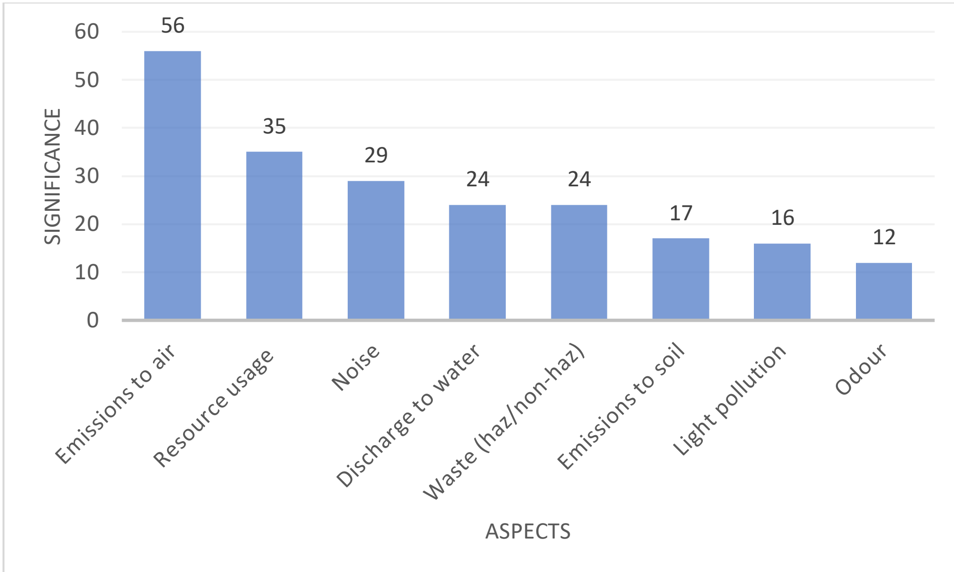

Figure 8.1 Ranking of the environmental aspects of activities in GPMB according to their significance.

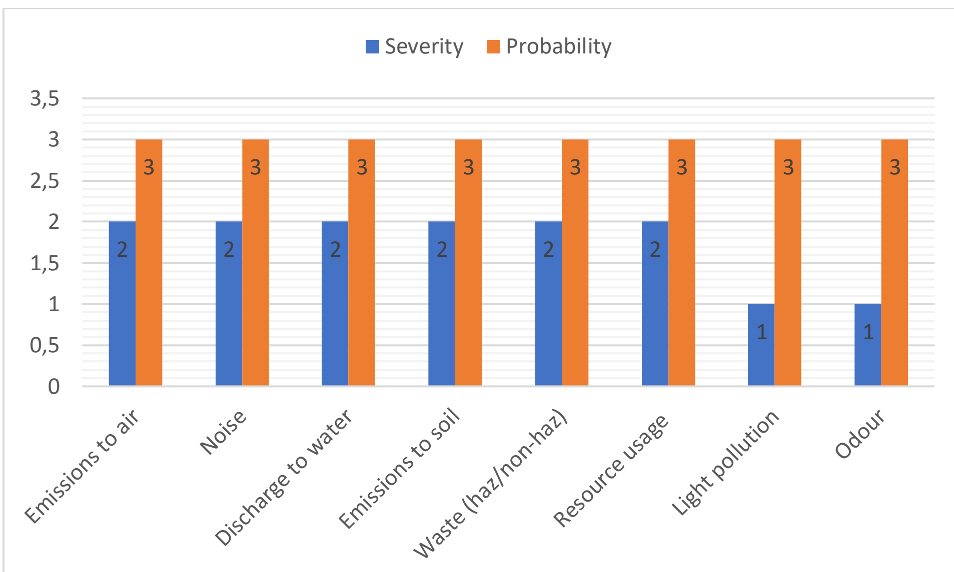

Figure 8.2 Estimate of severity and probability of environmental impact for environmental aspects of GPMB ports activities.

8.2. Port of Monfalcone (ASPM)

Table 10.2 (*Appendix A*), Figure 8.3 and Figure 8.4 show the impact of the Port of Monfalcone (ASPM) on the environment. Figure 8.3 shows the significance of ports environmental aspects. The rank (significance) has been calculated in the following way: for each activity the severity and probability of a certain environmental impact occurring are multiplied and the products are summarized across different activities. Figure 8.4 shows the average value of probability and severity of environmental impact for each environmental aspect. The values are averaged across port activities.

The activities conducted by the ASPM have the highest impact on resource usage (fuel/energy consumption, water consumption, fuel for machinery). Five activities stand out according to their impact on the environmental aspect of resource usage, while other activities have a certain impact on this aspect, but not so significant. The other aspects according to their significance of impact are noise, emissions to the atmosphere, light pollution, odour generation and discharges to water.

The environmental aspect of resource usage is most significantly influenced by the following port activities: dry bulk - ores & minerals, dry bulk – organic and general cargo from the activities grouped under cargo handling and storage; vehicle and equipment washing, fuelling and bunkering, building and open area maintenance and transhipment (Ro-Ro, Passenger, Container, …) from the activities grouped under Workshop and yard activities; ship movement from the activities grouped under Shipping; Maintenance dredging & disposal, mooring, towing from the group of activities entitled Users.

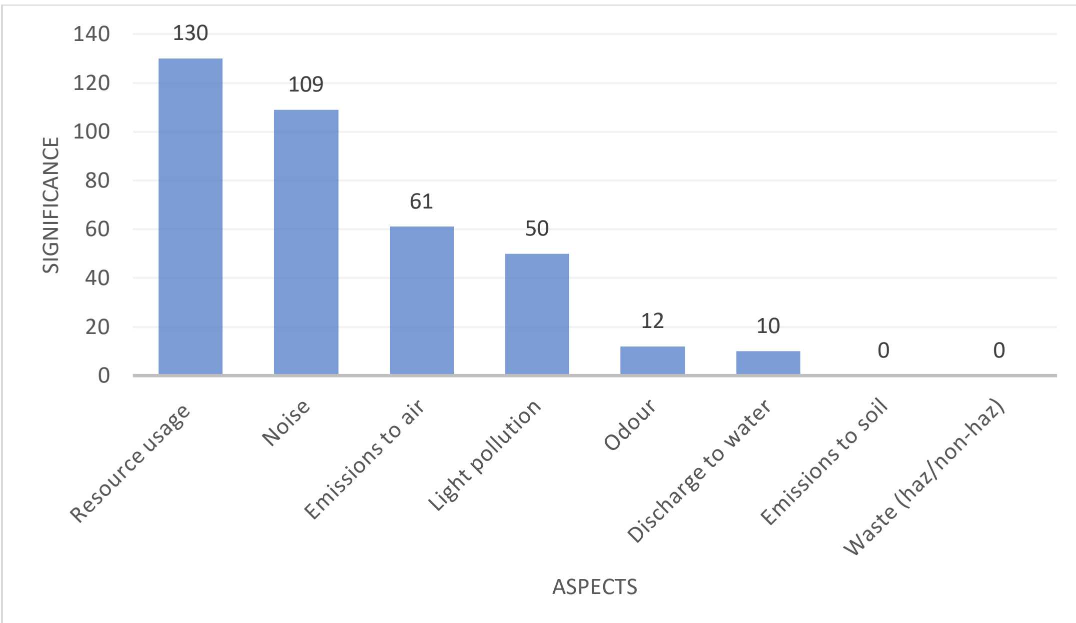

Figure 8.3 Ranking of the environmental aspects of activities in ASPM according to their significance

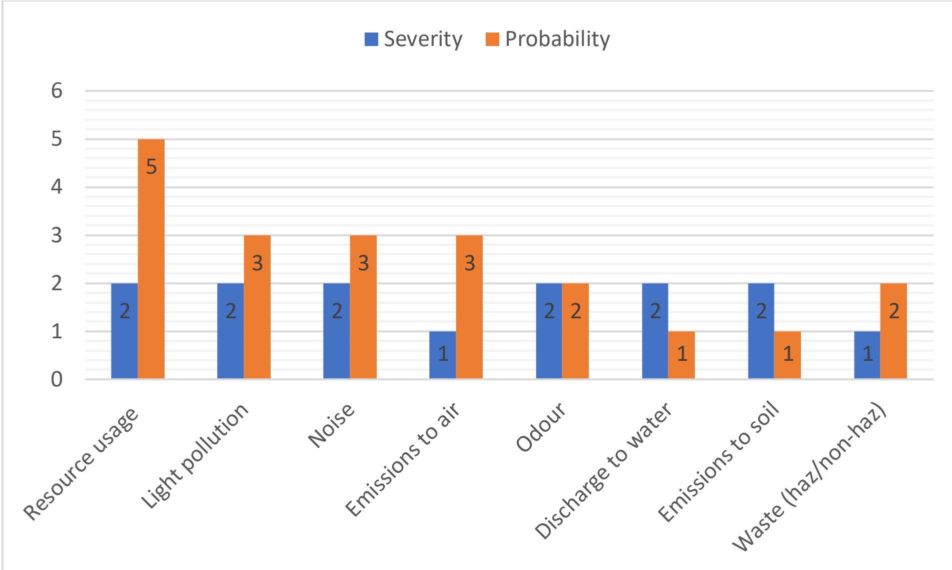

Figure 8.4 Estimate of severity and probability of environmental impact for environmental aspects of ASPM ports activities

8.3. Port of Piraeus (PPA)

Table 10.3 (*Appendix A*), Figure 8.5 and Figure 8.6 show the impact of the Port Piraeus (PPA) on environmental aspects. Figure 8.5 shows the significance of ports environmental aspects. The rank (significance) has been calculated in the following way: for each activity the severity and probability of a certain environmental impact occurring are multiplied and the products are summarized across different activities. Figure 8.6 shows the average value of probability and severity of environmental impact for each environmental aspect. The values are averaged across port activities.

The activities conducted by the Port of Piraeus have a significant impact on the following environmental aspects: emissions to air, noise, emissions to soil, waste and resource usage (fuel/energy consumption, water, fuel for machinery). The activities in this port do not have a significant impact on other environmental aspects.

The Piraeus port activities have the most significant impact on the atmospheric emissions. The other aspects according to the significance of impact are noise and waste. These are followed by emissions to soil and resource usage (fuel/ energy consumption, water, fuel for machinery). The port activities have almost negligible impact on odour generation and light pollution.

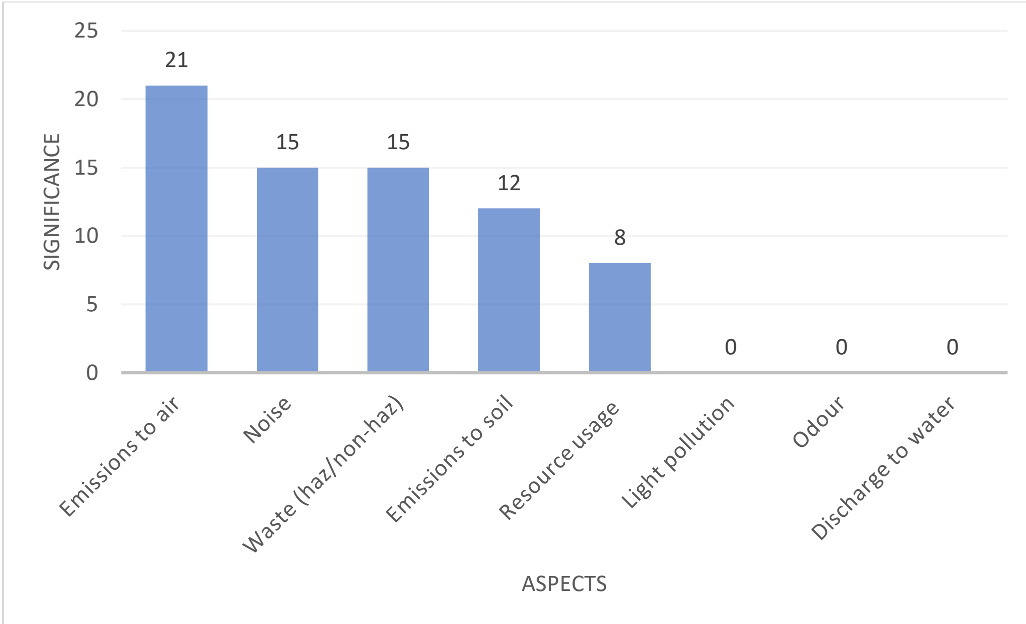

Figure 8.5 Ranking of the environmental aspects of activities in PPA according to their significance

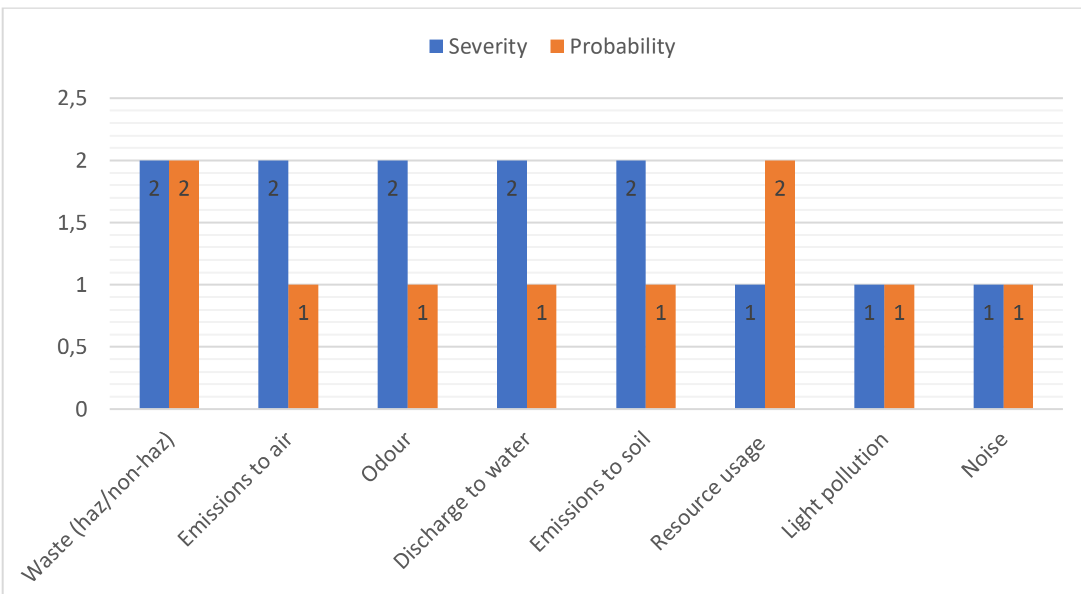

Figure 8.6 Estimate of severity and probability of environmental impact for environmental aspects of PPA ports activities

8.4. Port of Thessaloniki (ThPA)

Table 10.4 (*Appendix A*), Figure 8.7 and Figure 8.8 show the impact of activities of the port Thessaloniki (ThPA). Figure 8.7 shows the significance of ports environmental aspects. The rank (significance) has been calculated in the following way: for each activity the severity and probability of a certain environmental impact occurring are multiplied and the products are summarized across different activities. Figure 8.8 shows the average value of probability and severity of environmental impact for each environmental aspect. The values are averaged across port activities.

The activities conducted by the ThPA port have the greatest impact on atmospheric emissions. Five activities were recognized as having a significantly high impact on this aspect. The port activities having the most significant impact on atmospheric emissions are: dry bulk - ores & minerals, dry bulk – organic, containers, general cargo, included under Cargo handling and storage, and the activities of ship movement from the group of activities entitled Shipping.

The second environmental aspects of port activities is noise, followed by discharges and waste generation. The activities conducted by the ThPA port do not have minor or negligible impact to other environmental aspects. The port activities in this port have the least influence on the aspect of light pollution, and bit more on odour generation.

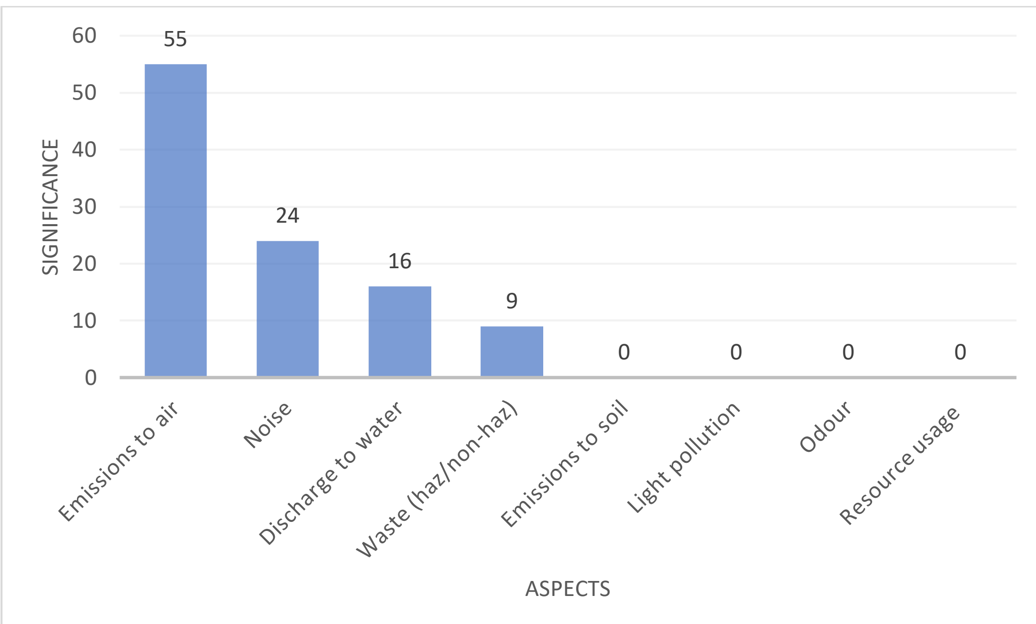

Figure 8.7 Ranking of the environmental aspects of activities in ThPA according to their significance.

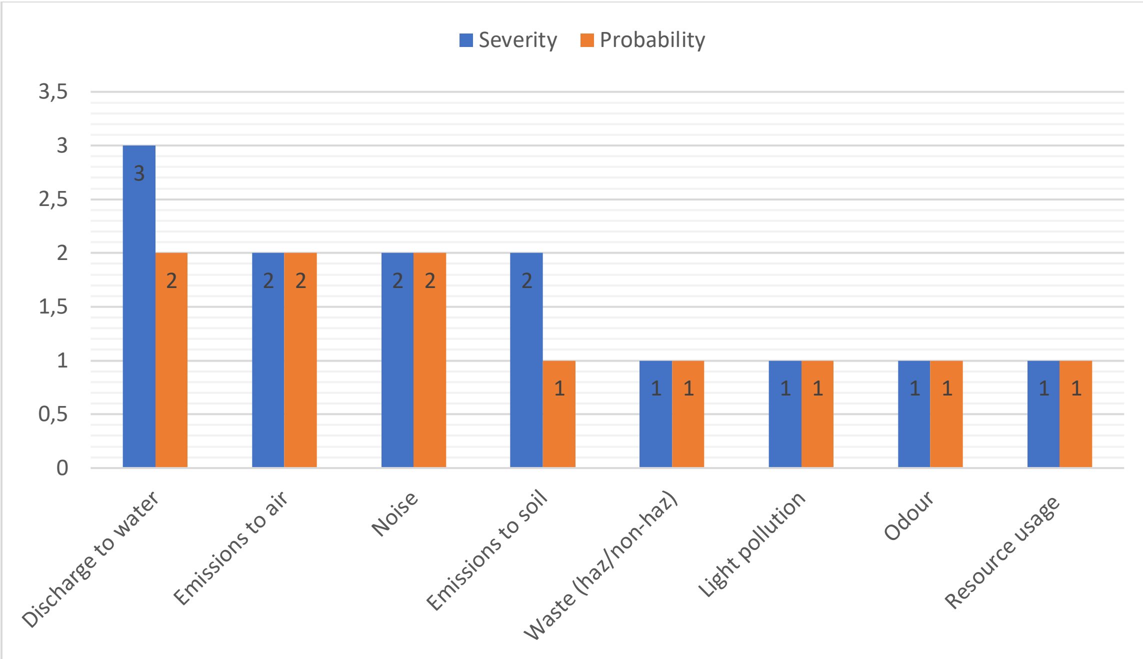

Figure 8.8 Estimate of severity and probability of environmental impact for environmental aspects of ThPA ports activities

9. Key performance indicators (KPIs) for environmental assessment

During the last thirty years, the environmental impacts of port activities have received increasing attention from the scientific community, institutions and economic operators. In this dynamic of competitiveness between seaports, port authorities must be more productive while following the environmental regulation for monitoring and reducing the negatives effects of their activities and operations.

To improve their environmental performance, ports can use different indicators. In all the environmental management or environmental certification program used actually, Key performance indicators (KPIs) are just qualitative (EcoPorts, GreenMarine).

In the PIXEL project, the environmental impact of the ports must be measured in a quantitative way, before being integrated into the calculation of a single metric: the PEI.

Environmental Key Performance Indicators (eKPIs) are needed to assess the port's overall environmental performance, and for computing the PEI.

In this part, the aim is to list all the different eKPIs existing. The methodology for defining and make a selection of the eKPIs is based on a literature review, a compilation and synthesis according to the factors needed for the PIXEL project's realisation. This list is the first step in the process of eKPI selection, which have to be further restricted with the special needs of PEI calculation, and with the data availability in the different port. This work will be done on deliverable 5.3. In this deliverable (D5.1), no conclusion of definitory eKPIs for each port has been reached dues to its tight relation with future work on PEI development (T5.3). The final goal of the deliverable 5.3 is to develop a minimal standardized set of eKPIs which must be measured or monitored in port

9.1. Characteristics of eKPIs

There are a multitude of environmental indicators or parameters whom variations can be related to the impacts of port activities. In general, these environmental indicators are grouped according to the environmental compartment investigated: air, water, soil or sediment ...

For all of these indicators, the environmental Key Performance Indicators (eKPIs) have to be selected, in order to be able to:

- be significant, according to the stakes defined by the impacts that they represent: **significant**;
- differentiate the effects of port activities from any other "outside" effect: the aim is not to monitor the quality of the environment that is related to all the activities present (not only port), and to the environmental background noise: **representative**;
- be measured in real time, and treated thanks to IoT systems or to use data produced by the ports if they are already existing: **measurable**;
- respond to monitoring protocols leading to pertinent and exploitable data as part of the PEI calculation process: **quantitative**;
- be useful in PIXEL uses-case application: In the D3.4 Uses cases, a set of common eKPIs has been identified to describe and to appoint the different use case stories: **usefulness.**

For the representativity of quality indicators, it is possible to avoid the influence of other factors not related to port activity but having an environmental impact. The method consist in modify data and use the deviation of the raw data to the environmental background noise. For this, a measure of environmental background is needed. For example: depending on the different port environments and the basin's geographical configuration, turbidity data can fluctuate strongly. To avoid these differences that are not related to the port's activity, it is sufficient to transform the raw turbidity data into a deviation to the environmental background (Figure 9.1). The environmental background level can be determined on literature reference or on long term data acquisition on site.

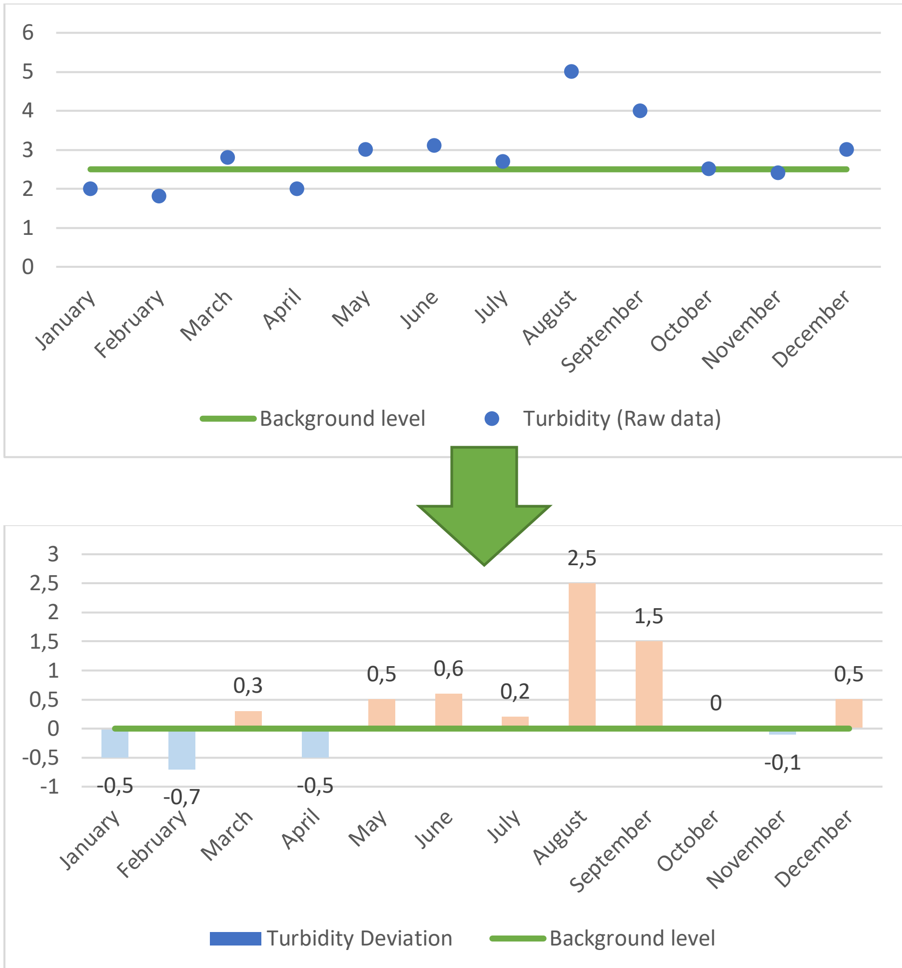

Figure 9.1 Example of data transformation for representativity of quality indicator

In the different eKPIs tables, when this data transformation is possible, it is indicated by an asterisk (*).

At this state of the project, the factors of robustness and availability of the indicators in port identified in the Grant Agreement cannot be used:

A questionnaire was sent to the port to know which data are collected and when. And in fact, a very few indicators are available in port. “Availability” factor must to be replaced by “measurable” factor. This modification of the choice factor allows to know if eKPI can be easily used and set up within the framework of the PIXEL project, although they are not currently available on the ports.

For robustness, this factor is statistical. To be robust, an indicator needs to give a stable and pertinent interpretation of activities modifications in time or space. In the environmental field, this factor is directly in link with the data quality provides by sensors, sampling plans of this sensors and the quality of treatment of this data. This factor will be taking in count in a second filtering process of the eKPIs done in Deliverable 5.3.

The chosen indices must also be able to be used for the comparison of the ports between them. They must therefore be proportional to the activities in place.

For each matrix or environmental compartment, a list of environmental indicators based on a literature review is given in the following chapters.

9.2. Emissions to the air

All this indicators are identified to be significant in different type of studies: environmental impact of port activities, environmental management in seaport, effects of ships pollution, and environmental indexes (Trozzi & Vaccaro 2000, Darbra et al. 2009, European Sea Ports Organization (ESPO) 2012, Puig et al. 2017, Kegalj et al. 2018).

All the indicators used for assessment of emissions to air are based on direct emissions of the port. These emissions result from activities which impact air pollution: On site fuel combustion, company vehicles manufacturing and process emissions, ship emissions, logistic activities of bunkering, dredging… Air indicators are all based on measurements or estimates of direct emissions, not environmental measures. Distinction between air quality and air emissions need to be done to ensures representativeness of eKPIs.

Indicators identified are very difficult to measure directly in the port environment because the sources of emissions are numerous, and it is difficult to equip all the port's services (fleet of vehicles and gear used for handling, all the vessels arriving in the port, …). But information can be drawn from literature to find emission factors, or engine manufacturer data, cargo's supply chain, fuel's sulphur content, … If the supply chain or the activities are well described in ports, emissions can be obtained by simple calculation, using indicators of activities (number of cargos, cranes used for loading or unloading, transit times of ships...). In fact some models developed in the WP4 Modelling, process analysis and predictive algotithms may help to provid these data estimations.

The different eKPIs can be obtain just for one type of activity on port, for example for dredging: emissions are easier to measure, because the impacts on air pollution are caused by the dredger or barge and it is possible to implement a sensor directly on their engine.

Finally, none of the identified parameters can be directly measured by sensors, except for a very precise activity and their quantitative definition will therefore require calculations. Pollutant concentrations measured in air by ports for quality control are useless for PEI calculation because they are not enough representative.

This aspect of air pollution is one of the challenges for the Port of Piraeus, the port of Thessaloniki, and the port of Monfalcone as identified on the "Deliverable 3.4 – Use cases and scenarios manual".

Indicators of emission in air are for some of them related to each other: for example, the total Greenhouse Gas (GHG) emissions is related to carbon dioxide (CO_2) concentrations because CO_2 is part of the GHG family. So, the choice of total GHG emissions as eKPI is more integrator and representative than CO_2 concentrations.

Table 9.1 eKPIs identified for emissions to air

Indicators	Description	Significant	Representative	Measurable	Usefulness
CO_2 emissions (g)	Measure or calculation of the total amount of CO_2 emissions that is directly and indirectly caused by an activity	✓	✓	×	
Fine particles emissions (NOx, SOx,..)	Measure or estimation of the total amount of particles emissions	✓	✓	×	✓
Fine particles emissions (NOx, SOx,.)	Total emission of fine particles linked to dredging activities in a year	✓	✓	✓	✓
Non-Methane volatile organic compounds emissions (NMVOC)	Total emissions of non-methane volatile organic compounds in ports	✓	✓	×	
Nitrogen Oxides (NOx) emissions (g)	Total emissions of Nitrogen oxides in ports	✓	✓	×	
Carbon monoxide (CO)	Measure or estimation of the total amount of CO emissions in ports	✓	✓	×	
Particulate Matter (PM) emissions (g)	Measure or estimation of the total amount of particulate matter emissions	✓	✓	×	
Total Greenhouse Gas (GHG) Emissions	Total amount of greenhouse gas (GHG) emissions that is directly and indirectly caused by an activity	✓	✓	×	✓

9.3. Wastewater discharges to the marine environment

The port environmental aspects which impact seawater are numerous. It can be summarized by all the different emissions that might arrive in the port basins directly or indirectly: discharges of wastewater, of hydrocarbons, oh heavy metals, of other chemicals, of faecal or particulate matters. These discharges come from spills or leaks during the unloading/loading of oil products, or bulk from vessel to lorry, rainwater in bulk storage areas, …

These environmental aspects of port activities are taken into account in several studies: PRISSM project (http://pprism.espo.be), EcoPorts project, studies on environmental performance, identification and assessment of environmental aspects in ports, port impacts determination, and environmental management (Peris-Mora et al. 2005, Puig et al. 2014, 2015, Roos & Kliemann Neto 2017, Saeedi Pash et al. 2017, Di Vaio et al. 2018, Kegalj et al. 2018).

The indicators identified for the assessment of wastewater emissions to seawater can be classified in three parts:

- The indicators which are used for hydrological marine water quality. They will not give results directly correlated to port activities (for example alkalinity, nutrients, dissolved oxygen [O_2]).
- The indicators which are related to port operational activities like sanitary wastewater or total water consumption.
- The indicators related to the port treatment systems efficiency and then limiting the discharge of pollutants into seawater (grey and black wastewaters recuperation, percentage of the port area equipped with a system for the collection and treatment of rainwater, ballast water recuperation…).

The environmental issues of this type of impact are due to the contamination of the water column: mainly by the addition of organic pollutants and metal compounds. These issues related to the bacterial pollution are low except with - in the surrounding area - aquaculture or recreational activities closed to the port. All eKPIs identified are significant except oil and grease because those compounds come from the uses of lubricant for engine maintenance. Their concentrations in seawater are low and their impact less than hydrocarbon pollution.

Regarding representativeness, hydrological marine water quality parameters (alkalinity, turbidity, O_2, nutrients, etc) are not only linked with port activities and a general environmental background diagnosis is needed for interpretation. Their use in the PIXEL project is not easy due to the data transformation required (explain in chapter 9.1), but this eKPI cannot be eliminated because these parameters are easy to measure. This issue is easy to solve thanks to a good implementation of environmental sensors or samples: one of them must be positioned in a site where the impacts of port activities are absent, and then will used as a reference. When this data transformation is possible, it is indicated by an asterisk (*) in the table.

For hydrological marine water quality parameters: alkalinity, salinity, oxygenation concentration, temperature and turbidity; sensors exist in the form of a single device called multiparameter probe. This probe can be implemented on a buoy, an autonomous underwater vehicle or directly fixed onto a dock/jetty. This probe can be equipped with Wi-Fi or VHF communication system to facilitate remote access or remote data acquisition. So it could be easily use for data acquisition in PIXEL project. For example, this technology is commonly used especially for monitoring dredging operations.

For Biochemical Oxygen Demand (BOD), probes are available and are used specially for monitoring control of sewage treatment plant effluents (urban and industrial plants). But clearly, if oxygen concentrations are available for PIXEL's ports, this measurement will be enough.

Some parameters cannot be measured directly in the water column by sensors. It is the case for: anionic detergents, Chemicals Oxygen Demand (COD), Trace heavy metals, Hydrocarbons, Minerals oils and Nutrients. Their measurement must be made using seawater sampling and samples have to be sent to the analytical laboratory. Following the analysis, results must therefore be computing in a database for integration.

Water pollution is not identified as a challenge by the ports participating in the PIXEL project, but it's an important aspect for having a pertinent and general approach of environmental impacts. This part will be keep in the PIXEL project.

Table 9.2 eKPIs identified for discharges to water

Indicator	Description	Significant	Representative	Measurable	Usefulness
Alkalinity (pH)	Measure of alkalinity in seawater	✓	✗*	✓	
Anion detergents (mg/L)	Measure of anion detergents in seawater	✓	✗*	✗	
Biochemical Oxygen Demand (BOD)	This indicator is a chemical procedure for determining the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period	✓	✗*	✓	
Chemical Oxygen Demand (COD)	This indicator is a chemical procedure determining the amount of oxygen that can be consumed by chemical reactions in a solution	✓	✗*	✗	
Dirty ballast water recuperation from ships (m^3)	Total volume of ballast water collected by port	✓	✓	✓	
E. coli or faecal coliforms concentrations in seawater (CFU/100ml)	Measure of faecal contamination in water. This indicator is used for water quality	✓	✗*	✗	
Grey and black wastewater recuperation (m3)	Total volume of grey and black wastewaters collected by port	✓	✓	✓	
Heavy metal concentrations (µg/L) in seawater	Measure of heavy metal concentration in seawater	✓	✗*	✗	
Hydrocarbons concentrations (mg/L) in seawater	Measure of Hydrocarbons concentrations in seawater	✓	✗*	✗	
Mineral oils (mg/L)	Measure of mineral oils concentration in seawater	✓	✗*	✗	
Nutrients condition / Dissolved nutrients in seawater	Measure of nutrients in seawater (C, N, P)	✓	✗*	✗	
Oxygenation conditions in seawater	Measure of dissolved oxygen in seawater	✓	✗*	✓	
Percentage of the port area that has a system for the collection and treatment of rainwater		✓	✓	✗	
Salinity in seawater	Measure of salinity variations in port basin	✓	✗*	✓	
Sanitary wastewater (m^3)	Sanitary wastewater produced by port activities	✓	✓	✓	
Thermal conditions in seawater	Measure of temperature variations in port basin	✓	✗*	✓	
Total oil and grease (mg/L) in seawater	Measure of oil and grease in seawater	✗	✗*	✗	
Total water consumption (^{m3})	Identify and report the total volume of water withdrawn for activities, the indicator should be normalized by the cargo handled	✓	✓	✗	
Turbidity/Transparency/suspended matter	Measure of turbidity variations in port basin	✓	✗*	✓	

in seawater					

9.4. Noise emissions

Ports activities are source of noise trough many sources. Within the harbour, ships berthed to the wharfs loading or unloading solids or liquids, represent significant sources of noise: propulsion engine and auxiliary engines providing vibrations to the hull, the use of cranes, winches, mechanical equipment, etc.

This part of impact is taken into account in numerous studies focused on the environments of port activities (Puig et al. 2014, Badino et al. 2016, Saeedi Pash et al. 2017, ESPO 2018, Kegalj et al. 2018)

9.4.1. Noise emissions in air

Noise emissions are among the most important environmental priorities for ports (ECOPORTS 2018). In terms of impacts, issues are of course linked to the proximity of cities and their impacts on human health, but not only.

Indicators in the air are well known, mostly linked with the national or European legal requirements or limits used for measurements and comparison of noise emissions.

The good representativeness of noise's indicators depends on the localisation of data's acquisition. If the sensor is not well located, the data will not be linked with the right port activities. For all eKPIs, an natural environmental background level is needed for interpretation. It could be given by a sensor located outside the port area influence.

The measurements of noise in air is quite simple to do using microphone(s) positioned to different locations of the port. The sampling plan depends on port's activities locations: microphones must be positioned on strategical sites (on wharfs, closed to the zone of storage/loading/unloading, …). Data acquisition can be done in real time with Wi-Fi communication and treatment of raw data is required.

9.4.2. Underwater noise

The issues are also environmental because underwater noise is now recognized as an important stressor for marine mammal populations but also for fish populations. The noise is a variation of pressure which can have consequences on the marine fauna from a simple annoyance to physical injuries on sense organs leading to loss of hearing sensitivity.

Regarding to underwater noise, studies in underwater bioacoustics demonstrated that noise pollution has dangerous consequences on marine wildlife and aquaculture. Underwater noise is considered as an indicator Good Environmental Status in the Marine Strategy Framework Directive (MSFD, Commission Decision 2010/477/EU). Sensors called hydrophones have been used for decades, especially for military applications. These sensors are now deployed for determination of underwater acoustic impacts. Data acquisition and processing can establish sound levels and make a distinction between anthropophony (anthropogenic sounds caused by ships for example) and biophony (biologicals sounds produced by marine mammals, fishes and other).

Table 9.3 eKPIs identified for noise emissions

Indicator	Description	Significant	Representative	Measurable	Usefulness
Compliance with limits at day, evening and night time	Measures of the number of overruns of the legal limits	✓	✓	✓	✓
Lden (overall day-evening-night noise level)	Measure of the average sound level over a 24-hour period	✓	✓	✓	✓
Lnight (23:00 - 7:00hrs noise level)	Measure of the average sound level by night	✓	✓	✓	✓
Noise emissions (dB)	Average noise emissions over a period	✓	×*	✓	✓
Noise level monitoring in seawater	Indicator based on monitoring which made distinction between biological and anthropogenic sounds	✓	✓	✓	✓

This aspect of noise pollution is one of the challenges of the Port of Piraeus identified in the "Deliverable 3.4 – Use cases and scenarios manual".

9.5. Production of waste

In a port, the waste production can be caused by different activities: administrative and planning activities of the Port Authorities (garbage), cargo handling operations, port industry, ships building and repair, cruise ships or ferries garbage, … (Darbra et al. 2005, CE Delft 2017). In the environmental report 2018 of ESPO, waste is the most monitored issue in port. And since 2013, waste has become a top priority monitoring issue. But, by focus on the port environmental priorities sector, ship's waste come in 5th position while the port's waste arrives in 10th and last place.

For waste production, a difference must be done between wastes produced by port or terminal activities and wastes generated by ships, because priorities and legislation are not similar.

Regulations existing in Europe require to monitor and identified wastes from production to treatment steps. This legislation facilitates obtaining waste data from ports. The waste production is very difficult to measure in fact, because it can be easily extrapolated from declaration forms for waste monitoring.

The indicators described in the following table 9.4 come from several studies on environmental impact of port activities, environmental management in seaport, effects of ships pollution, and environmental indexes (Trozzi & Vaccaro 2000, Puig et al. 2014, González Laxe et al. 2017, Roos & Kliemann Neto 2017, Saeedi Pash et al. 2017, Kegalj et al. 2018).

The indicators identified are all based on the actual production of port's activities and ships which ensures that they are significant and representative. None are measurables by real time sensors.

Table 9.4 eKPIs identified for waste production

Indicator	Description	Significant	Representative	Measurable	Usefulness
Amount or total of waste production (Kg)	Sum of all waste produced by port authorities and terminal operators	✓	✓	×	
Generation of hazardous waste (Kg)	Sum of hazardous waste produced by port authorities and terminal operators	✓	✓	×	
Generation of other wastes (Kg)	Sum of all other waste produced by port authorities and terminal operators	✓	✓	×	
Generation of solid urban waste (Kg)	Sum of all solid urban waste produced by port authorities and terminal operators	✓	✓	×	
Ratio of waste recuperation from ships	Ratio between the amount of garbage retained onboard and the waste to be landed from ships	×	✓	×	
Total garbage to be landed from ships	the amount of waste to be landed from ships	✓	✓	×	
Total of waste recycled (kg) on port	Sum of all recycled waste on port This indicator could be used in ratio between amount total of waste and recycled part	✓	✓	×	

This aspect of waste production is not identified as a challenge by the ports participating in the PIXEL project.

9.6. Energy consumption

Ports and terminals with associated transport networks and equipment-heavy operations are high energy consumers. In fact, energy consumption is identified in ESPO ECOPORTS surveys like the second environmental priorities of port since 2013: Energy consumption in port terminals can imply a significant additional cost for terminal operators.

The studies listed on environmental impacts of port activities, environmental management in seaport, effects of ships pollution, and environmental index (Peris-Mora et al. 2005, European Sea Ports Organization (ESPO) 2012, Saeedi Pash et al. 2017, Kegalj et al. 2018) allowed to the determination of different indicators given in table 9.5.

The energy sources used in ports are of different types: electric and mainly used by the premises of the port authorities, for the lighting and the maritime signalling in/to the port, or resulting from fossil resources like fuel used by ships, ports authorities vehicles, cranes…or from renewable energy produced in ports (wind turbines, solar, heat pumps or seawater conditioning system, ..).

A differentiation can be done on the different kind of energy used because their impacts have different issues on environment domain: electricity used have a very low impact regarding emissions in air comparing to fuel use.

Electricity consumption is an easy-to-use indicator to measure because it can be quantified using bills or electrics meters disposed in ports. For the fuel consumption it is more difficult, but it can be extrapolated starting from the supply chain and referring to the consummation characteristics of the engines used.

The energy consumption is clearly a challenge of the PIXEL project for the port of Bordeaux (GPMB), and two eKPIs are identified in the "Deliverable 3.4 – Use cases and scenarios manual: Electricity consumption and renewable energy ratio".

Table 9.5 eKPIs identified for energy consumption

Indicator	Description	Significant	Representative	Measurable	Usefulness
Electricity consumption of the port authority	Total electric power consumption due to port activities in a year	✓	✓	✓	✓
Fuel consumption	Total fuel consumption due to port activities in a year	✓	✓	✗	
Ratio of renewable energy per total energy consumed	Identified the ratio between renewable energy consumption and total energy consumption in port	✓	✓	✗	✓
Total energy consumption	Identify the total energy consumption per year	✓	✓	✗	

9.7. First advances on special needs for PEI calculation

9.7.1. Normalization by operational eKPIs

In the various Environmental Impact Assessments of Port (EIAP), the environmental indicators are standardized using operational indicators. These activity indicators can be: the number of cargos handled, the number of twenty foot Equivalent Unit (TEU), the number of employees of port authorities, or the gross tonnage of vessels, etc. This operational KPIs need to be measured in port an defined on the PEI methodology calculation and measured in port. The normalization by operational KPIs allows to compare the environmental data between different ports.

The methodology of normalization by operational KPI will be defined after the port's data census, and the definition of standardized set of eKPIs done in D5.2.

9.7.2. Direct and indirect eKPIs

In PIXEL project, innovation is based on the PEI calculation and IoT data acquisition. This index needs to be based on quantitative data measured directly on port. But clearly all KPIs cannot be acquired in the port without an implementation of numerous sensors which can be very expensive for small and medium ports. To avoid this issue, among all the indicators that can be used, two types of indicators can be defined:

- indicators based on direct measurements in the environment;
- and indirect indicators based on the calculation or indirect data.

This typology of data must be considered for the relevance of the calculation of the Environmental Index. In the methodology, this information could be included in the calculation of the PEI as an index or level of confidence.

9.7.3. Frequency of acquisition

In the framework of the PIXEL project, the calculation of the PEI must allow the ports to have a simple return on their environmental management, but also to allow them, thanks to the use of numerical models, to have an efficient decision support system. eKPIs must provide information on the current condition of the environment in the port area. They may help port managers to:

- Better recognise the potential of impacts of all the port activities separating them by administrative entities present on the ports: Port authorities, Terminals operators and ship owners.
- Identify actions/measures that can reduce their environmental impact and allowing them to decrease their budget or justify investments.

These two aspects do not require to collect data at a reduce frequency. In the scientific literature, most of the data are collected once a year or monthly specially to identified seasonal variability. Indeed, passenger traffic activities, or goods traffic activities are subject to strong seasonal variations that will significantly influence the environmental impacts.

10. Conclusion / Future Work

The most significant environmental aspects of port operations are emissions to the atmosphere, resource usage as well as environmental noise and waste production. Other aspects inducing odour generation and light pollution are considered of a lesser importance. An extensive list of eKPI which represent each environmental aspect has been identified an the indicators where assessed according to their significance, robustness and availability.

Future work will include the development of PEI based on the environmental aspects identified in this document and the related environmental key performance indicators (eKPI). The work will include narrowing of the extensive eKPI list identified in this deliverable, preferably coming to a standardized set of eKPIs to be measured in all European small and medium sized ports. In addition, mathematical algorithms for PEI calculation based on the identified eKPI's including, but not limited to, data imputation, normalization of values, weighing methods as well as aggregation will be developed. In a later stage, a manual for PEI adoption and a user interface (web based) software for PEI calculation will be developed. Finally, a transversal trial of PEI deployment to PIXEL ports will be carried out.

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Appendix A – Port activity survey

All the participating ports were asked to fill out a survey regarding port activities and operations performed by them, which have a specific impact on the environment (so called environmental aspect), and they had to assign the significance (weigh) of the environmental aspect of a particular activity according to the instructions below:

1	**minimal environmental impact** (not severe/not very probable/not significant=
2	**small environmental impact** (relatively severe/mildly significant)
3	**medium environmental impact** (severe/probable/significant)
4	**substantial environmental impact** (very severe/very probable/very significant)
5	**very significant environmental impact** (extremely severe/extremely probable/regulated)

An activity can have one or more environmental aspects. Please pay attention and list all of the environmental aspects of that particular activity.

Port activities could be the following: bunkering, manoeuvring, hoteling, cruising, cargo storage, cargo loading, etc. or… any other activity specific to your port.

Some examples of environmental aspects of a particular activity can be: emissions to air, discharges to water, emissions to soil, noise generation, waste production, changes in terrestrial habitats, changes in marine ecosystems, odour production, resource consumption, light pollution, etc.

A.1. Grand Port Maritime de Bordeaux (GPMB)

Table 10.1 GPMB survey

Cargo handling and storage				
Activity 1: **Dry bulk – organic** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	3	4	Not available	4
Noise	2	4	Not available	2
Discharge to water	2	4	Not available	2
Emissions to soil	2	4	Not available	3
Waste (haz/non-haz)	2	4	Not available	2
Light pollution	1	4	Not available	1
Odour	3	4	Not available	3
Resource usage (fuel/ energy consumption, water, fuel for machinery)	Not relevant (depends on the products and if import of export	Not relevant (depends on the products and if import of export	Not available	Not relevant (depends on the products and if import of export
Others (specify):	-	-	-	-
Activity 2: **Dry bulk - ores & minerals** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	3	3	Not available	3
Noise	3	3	Not available	2
Discharge to water	2	3	Not available	2
Emissions to soil	3	3	Not available	3
Waste (haz/non-haz)	2	3	Not available	2
Light pollution	1	3	Not available	1
Odour	1	3	Not available	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	Not relevant (depends on the products and if import of export	Not relevant (depends on the products and if import of export	Not available	Not relevant (depends on the products and if import of export
Others (specify):	-	-	-	-
Activity 3: **Liquid bulk organic/mineral** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	1	1	Not available	2
Noise	1	1	Not available	1
Discharge to water	1	1	Not available	1
Emissions to soil	2	1	Not available	2
Waste (haz/non-haz)	1	1	Not available	2

Light pollution	1	1	Not available	1
Odour	1	1	Not available	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	Not relevant (depends on the products and if import of export	Not relevant (depends on the products and if import of export	Not available	Not relevant (depends on the products and if import of export
Others (specify):	-	-	-	-
Activity 4: **Containers** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	2	3	Not available	2
Noise	1	3	Not available	2
Discharge to water	1	3	Not available	2
Emissions to soil	1	3	Not available	1
Waste (haz/non-haz)	1	3	Not available	2
Light pollution	1	3	Not available	2
Odour	1	3	Not available	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	2	3	Not available	2
Others (specify):	-	-	-	-
Activity 5: **General cargo** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	2	2	Not available	2
Noise	2	2	Not available	2
Discharge to water	1	2	Not available	2
Emissions to soil	1	2	Not available	3
Waste (haz/non-haz)	1	2	Not available	2
Light pollution	1	2	Not available	1
Odour	1	2	Not available	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	2	2	Not available	2
Others (specify):	-	-	-	-
Activity 6: **Refrigerated goods** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	-	-	Not available	-
Noise	-	-	Not available	-
Discharge to water	-	-	Not available	-
Emissions to soil	-	-	Not available	-
Waste (haz/non-haz)	-	-	Not available	-
Light pollution	-	-	Not available	-
Odour	-	-	Not available	-
Resource usage (fuel/ energy consumption, water, fuel for machinery)	-	-	Not available	-
Others (specify):	-	-	-	-
Workshop and yard activities				
Activity 1: **Vehicle and equipment**	**Severity**	**Probability**	**Legal**	**Significance**

maintenance			**requirements**	
ASPECTS:				
Emissions to air	2	3	Not available	2
Noise	2	3	Not available	1
Discharge to water	2	3	Not available	2
Emissions to soil	2	3	Not available	2
Waste (haz/non-haz)	2	3	Not available	1
Light pollution	1	3	Not available	1
Odour	1	3	Not available	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	3	Not available	1
Others (specify):	-	-	-	-
Activity 2: **Vehicle and equipments washing**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	2	3	Not available	2
Noise	2	3	Not available	1
Discharge to water	2	3	Not available	2
Emissions to soil	2	3	Not available	2
Waste (haz/non-haz)	1	3	Not available	2
Light pollution	1	3	Not available	1
Odour	1	3	Not available	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	3	Not available	1
Others (specify):	-	-	-	-
Activity 3: **Handling and storage of chemicals (non-bulk)**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	2	2	Not available	2
Noise	2	2	Not available	2
Discharge to water	2	2	Not available	2
Emissions to soil	2	2	Not available	2
Waste (haz/non-haz)	2	2	Not available	1
Light pollution	1	2	Not available	1
Odour	1	2	Not available	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	2	Not available	1
Others (specify):	-	-	-	-
Activity 4: **Fuelling and bunkering**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	-	-	Not available	-
Noise	-	-	Not available	-
Discharge to water	-	-	Not available	-
Emissions to soil	-	-	Not available	-
Waste (haz/non-haz)	-	-	Not available	-
Light pollution	-	-	Not available	-
Odour	-	-	Not available	-
Resource usage (fuel/ energy consumption, water, fuel for machinery)	-	-	Not available	-
Others (specify):	-	-	-	-

Activity 5: **Building and open area maintenance**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	-	-	Not available	-
Noise	-	-	Not available	-
Discharge to water	-	-	Not available	-
Emissions to soil	-	-	Not available	-
Waste (haz/non-haz)	-	-	Not available	-
Light pollution	-	-	Not available	-
Odour	-	-	Not available	-
Resource usage (fuel/ energy consumption, water, fuel for machinery)	-	-	Not available	-
Others (specify):	-	-	-	-
Activity 6: **Transhipment (Ro-Ro, Passenger, Container, …)**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	-	-	Not available	-
Noise	-	-	Not available	-
Discharge to water	-	-	Not available	-
Emissions to soil	-	-	Not available	-
Waste (haz/non-haz)	-	-	Not available	-
Light pollution	-	-	Not available	-
Odour	-	-	Not available	-
Resource usage (fuel/ energy consumption, water, fuel for machinery)	-	-	Not available	-
Others (specify):	-	-	-	-
Shipping				
Activity 1: **Ship movement**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	1	3	Not available	2
Noise	1	3	Not available	1
Discharge to water	1	3	Not available	2
Emissions to soil	1	3	Not available	1
Waste (haz/non-haz)	1	3	Not available	1
Light pollution	1	3	Not available	1
Odour	1	3	Not available	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	3	Not available	1
Others (specify):	-	-	-	-
Activity 2: **Ship discharge - ballast waters**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	1	1	Not available	1
Noise	1	1	Not available	1
Discharge to water	1	1	Not available	1
Emissions to soil	1	1	Not available	1
Waste (haz/non-haz)	1	1	Not available	1
Light pollution	1	1	Not available	1

Odour	1	1	Not available	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	1	Not available	1
Others (specify):	-	-	-	-
Activity 3: **Ship discharge - sewage** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	1	1	Not available	1
Noise	1	1	Not available	1
Discharge to water	1	1	Not available	1
Emissions to soil	1	1	Not available	1
Waste (haz/non-haz)	1	1	Not available	1
Light pollution	1	1	Not available	1
Odour	1	1	Not available	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	1	Not available	1
Others (specify):	-	-	-	-
Activity 4: **Ship discharge - bilge** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	2	1	Not available	1
Noise	2	1	Not available	1
Discharge to water	2	1	Not available	1
Emissions to soil	1	1	Not available	1
Waste (haz/non-haz)	2	1	Not available	1
Light pollution	1	1	Not available	1
Odour	1	1	Not available	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	1	Not available	1
Others (specify):	-	-	-	-
Users				
Activity 1: **Maintenance dredging & disposal** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	4	4	Not available	4
Noise	3	4	Not available	2
Discharge to water	4	4	Not available	3
Emissions to soil	1	4	Not available	2
Waste (haz/non-haz)	4	4	Not available	2
Light pollution	2	4	Not available	1
Odour	1	4	Not available	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	4	4	Not available	1
Others (specify):	-	-	-	-
Activity 2: **Ship and shore solid waste collection** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	1	2	Not available	2
Noise	1	2	Not available	2
Discharge to water	1	2	Not available	2
Emissions to soil	3	2	Not available	3

Waste (haz/non-haz)	3	2	Not available	3
Light pollution	1	2	Not available	1
Odour	2	2	Not available	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	2	Not available	1
Others (specify):	[redacted]	[redacted]	[redacted]	[redacted]
Activity 3: **Public access /areas and recreation in harbour** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	[redacted]	[redacted]	Not available	[redacted]
Noise	[redacted]	[redacted]	Not available	[redacted]
Discharge to water	[redacted]	[redacted]	Not available	[redacted]
Emissions to soil	[redacted]	[redacted]	Not available	[redacted]
Waste (haz/non-haz)	[redacted]	[redacted]	Not available	[redacted]
Light pollution	[redacted]	[redacted]	Not available	[redacted]
Odour	[redacted]	[redacted]	Not available	[redacted]
Resource usage (fuel/ energy consumption, water, fuel for machinery)	[redacted]	[redacted]	Not available	[redacted]
Others (specify):	[redacted]	[redacted]	[redacted]	[redacted]
Activity 4: **Vehicles storage and transport in car terminals** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	[redacted]	[redacted]	Not available	[redacted]
Noise	[redacted]	[redacted]	Not available	[redacted]
Discharge to water	[redacted]	[redacted]	Not available	[redacted]
Emissions to soil	[redacted]	[redacted]	Not available	[redacted]
Waste (haz/non-haz)	[redacted]	[redacted]	Not available	[redacted]
Light pollution	[redacted]	[redacted]	Not available	[redacted]
Odour	[redacted]	[redacted]	Not available	[redacted]
Resource usage (fuel/ energy consumption, water, fuel for machinery)	[redacted]	[redacted]	Not available	[redacted]
Others (specify):	[redacted]	[redacted]	[redacted]	[redacted]
Activity 5: **Mooring** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	2	5	Not available	2
Noise	1	5	Not available	1
Discharge to water	1	5	Not available	1
Emissions to soil	1	5	Not available	1
Waste (haz/non-haz)	1	5	Not available	1
Light pollution	1	5	Not available	1
Odour	1	5	Not available	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	2	5	Not available	2
Others (specify):	[redacted]	[redacted]	[redacted]	[redacted]
Activity 6: **Towing** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	3	3	Not available	3
Noise	2	3	Not available	2

Discharge to water	2	3	Not available	2
Emissions to soil	1	3	Not available	1
Waste (haz/non-haz)	1	3	Not available	1
Light pollution	1	3	Not available	1
Odour	1	3	Not available	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	3	3	Not available	3
Others (specify):	-	-	-	-

A.2 Port of Monfalcone (ASPM)

Table 10.2 ASPM survey

Cargo handling and storage				
Activity 1: **Dry bulk – organic** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	1	1	Y	1
Noise	2	5	Y	2
Discharge to water	2	1	Y	2
Emissions to soil	2	3	Y	2
Waste (haz/non-haz)	2	3	Y	2
Light pollution	2	5	Y	1
Odour	1	3	Y	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	2	5	N	1
Others (specify):				
Activity 2: **Dry bulk - ores & minerals** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	2	4	Y	3
Noise	3	4	Y	3
Discharge to water	2	3	Y	2
Emissions to soil	2	3	Y	2
Waste (haz/non-haz)	2	3	Y	2
Light pollution	2	5	Y	1
Odour	1	3	Y	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	2	5	N	1
Others (specify):				
Activity 3: **Liquid bulk organic/mineral** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air				
Noise				
Discharge to water				
Emissions to soil				
Waste (haz/non-haz)				
Light pollution				
Odour				
Resource usage (fuel/ energy consumption, water, fuel for machinery)				
Others (specify):				
Activity 4: **Containers** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air				
Noise				

Discharge to water				
Emissions to soil				
Waste (haz/non-haz)				
Light pollution				
Odour				
Resource usage (fuel/ energy consumption, water, fuel for machinery)				
Others (specify):				
Activity 5: **General cargo**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	1	5	Y	1
Noise	4	3	Y	3
Discharge to water	1	1	Y	1
Emissions to soil	1	1	Y	1
Waste (haz/non-haz)	1	4	Y	2
Light pollution	2	5	Y	1
Odour	1	1	Y	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	2	5	N	1
Others (specify):				
Activity 6: **Refrigerated goods**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air				
Noise				
Discharge to water				
Emissions to soil				
Waste (haz/non-haz)				
Light pollution				
Odour				
Resource usage (fuel/ energy consumption, water, fuel for machinery)				
Others (specify):				
Workshop and yard activities				
Activity 1: **Vehicle and equipment maintenance**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	1	3	Y	1
Noise	2	3	Y	2
Discharge to water	4	1	Y	1
Emissions to soil	1	3	Y	1
Waste (haz/non-haz)	2	3	Y	2
Light pollution	2	5	Y	1
Odour	1	1	Y	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	5	N	1
Others (specify):				
Activity 2: **Vehicle and equipment washing**	**Severity**	**Probability**	**Legal requirements**	**Significance**

ASPECTS:				
Emissions to air	1	1	Y	1
Noise	2	3	Y	2
Discharge to water	3	1	Y	1
Emissions to soil	1	1	Y	1
Waste (haz/non-haz)	2	3	Y	2
Light pollution	1	1	Y	1
Odour	1	3	Y	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	3	5	N	1
Others (specify):				
Activity 3: **Handling and storage of chemicals (non-bulk)**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	1	1	Y	1
Noise	1	1	Y	1
Discharge to water	5	1	Y	1
Emissions to soil	5	1	Y	1
Waste (haz/non-haz)	2	3	Y	1
Light pollution	1	1	Y	1
Odour	3	1	Y	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	5	N	1
Others (specify):				
Activity 4: **Fuelling and bunkering**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	2	3	Y	2
Noise	1	3	Y	1
Discharge to water	5	1	Y	2
Emissions to soil	5	1	Y	2
Waste (haz/non-haz)	1	1	Y	1
Light pollution	1	1	Y	1
Odour	3	4	Y	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	2	5	N	1
Others (specify):				
Activity 5: **Building and open area maintenance**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	2	4	Y	1
Noise	2	5	Y	1
Discharge to water	1	1	Y	1
Emissions to soil	1	1	Y	1
Waste (haz/non-haz)	2	3	Y	1
Light pollution	1	1	Y	1
Odour	1	1	Y	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	2	5	N	1
Others (specify):				

Activity 6: **Transhipment (Ro-Ro, Passenger, Container, …)**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	1	5	Y	1
Noise	4	3	Y	3
Discharge to water	1	1	Y	1
Emissions to soil	1	1	Y	1
Waste (haz/non-haz)	1	4	Y	2
Light pollution	2	5	Y	1
Odour	1	1	Y	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	2	5	N	1
Others (specify):				
Shipping				
Activity 1: **Ship movement** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	2	5	Y	3
Noise	2	5	Y	1
Discharge to water	1	1	Y	1
Emissions to soil	1	1	Y	1
Waste (haz/non-haz)	1	1	Y	1
Light pollution	1	1	Y	1
Odour	2	3	Y	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	3	5	N	1
Others (specify):				
Activity 2: **Ship discharge - ballast waters** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	1	1	Y	1
Noise	1	1	Y	1
Discharge to water	3	1	Y	1
Emissions to soil	3	1	Y	1
Waste (haz/non-haz)	1	1	Y	1
Light pollution	1	1	Y	1
Odour	1	1	Y	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	3	N	1
Others (specify):				
Activity 3: **Ship discharge - sewage** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	1	1	Y	1
Noise	1	1	Y	1
Discharge to water	4	1	Y	1
Emissions to soil	4	1	Y	1
Waste (haz/non-haz)	1	1	Y	2
Light pollution	1	1	Y	1
Odour	4	1	Y	1
Resource usage (fuel/ energy consumption,	1	5	N	1

water, fuel for machinery)				
Others (specify):				
Activity 4: **Ship discharge - bilge** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	1	1	Y	1
Noise	1	1	Y	1
Discharge to water	5	1	Y	1
Emissions to soil	5	1	Y	1
Waste (haz/non-haz)	1	1	Y	3
Light pollution	1	1	Y	1
Odour	2	3	Y	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	5	N	1
Others (specify):				
Users				
Activity 1: **Maintenance dredging & disposal** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	2	5	Y	1
Noise	3	5	Y	1
Discharge to water	2	5	Y	2
Emissions to soil	1	3	Y	1
Waste (haz/non-haz)	2	3	Y	1
Light pollution	2	3	Y	1
Odour	2	1	Y	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	3	5	N	1
Others (specify):				
Activity 2: **Ship and shore solid waste collection** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	1	1	Y	1
Noise	2	3	Y	1
Discharge to water	2	1	Y	1
Emissions to soil	2	1	Y	1
Waste (haz/non-haz)	1	5	Y	2
Light pollution	2	3	Y	1
Odour	2	3	Y	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	5	N	1
Others (specify):				
Activity 3: **Public access /areas and recreation in harbour** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	1	3	Y	1
Noise	1	3	Y	1
Discharge to water	1	1	Y	1
Emissions to soil	1	1	Y	1
Waste (haz/non-haz)	1	1	Y	1

Light pollution	1	1	Y	1
Odour	1	1	Y	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	5	N	1
Others (specify):				
Activity 4: **Vehicles storage and transport in car terminals** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	1	5	Y	1
Noise	2	4	Y	2
Discharge to water	1	1	Y	1
Emissions to soil	2	1	Y	1
Waste (haz/non-haz)	1	1	Y	1
Light pollution	2	5	Y	1
Odour	1	1	Y	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	5	N	1
Others (specify):				
Activity 5: **Mooring** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	2	5	Y	2
Noise	2	5	Y	1
Discharge to water	1	1	Y	1
Emissions to soil	1	1	Y	1
Waste (haz/non-haz)	1	1	Y	1
Light pollution	2	3	Y	1
Odour	2	3	Y	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	2	5	N	1
Others (specify):				
Activity 6: **Towing** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	3	5	Y	3
Noise	2	5	Y	1
Discharge to water	1	1	Y	1
Emissions to soil	1	1	Y	1
Waste (haz/non-haz)	1	1	Y	1
Light pollution	2	3	Y	1
Odour	2	3	Y	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	3	5	N	2
Others (specify):				

A.3 Port of Piraeus (PPA)

Table 10.3 PPA survey

Cargo handling and storage				
Activity 1: **Dry bulk – organic** *ASPECTS*:	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air				
Noise				
Discharge to water				
Emissions to soil				
Waste (haz/non-haz)				
Light pollution				
Odour				
Resource usage (fuel/ energy consumption, water, fuel for machinery)				
Others (specify):				
Activity 2: **Dry bulk - ores & minerals** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air				
Noise				
Discharge to water				
Emissions to soil				
Waste (haz/non-haz)				
Light pollution				
Odour				
Resource usage (fuel/ energy consumption, water, fuel for machinery)				
Others (specify):				
Activity 3: **Liquid bulk organic/mineral** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	2	1	YES	3
Noise	1	1	YES	1
Discharge to water	3	1	YES	3
Emissions to soil	3	1	YES	3
Waste (haz/non-haz)	2	1	YES	2
Light pollution	1	1	YES	1
Odour	2	1		2
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	1	YES	1
Others (specify):				
Activity 4: **Containers** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	1	1	YES	3
Noise	3	3	YES	2
Discharge to water	1	1	YES	1
Emissions to soil	2	1	YES	2
Waste (haz/non-haz)	2	1	YES	2

Light pollution	2	2	YES	2
Odour			N/A	N/A
Resource usage (fuel/ energy consumption, water, fuel for machinery)	2	3	YES	3
Others (specify):				
Activity 5: **General cargo**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	2	2	YES	3
Noise	1	1	YES	2
Discharge to water	1	1	YES	2
Emissions to soil	2	1	YES	2
Waste (haz/non-haz)	2	2	YES	1
Light pollution	1	1	YES	2
Odour			YES	N/A
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	1	YES	1
Others (specify):			YES	
Activity 6: **Refrigerated goods**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air				
Noise				
Discharge to water				
Emissions to soil				
Waste (haz/non-haz)				
Light pollution				
Odour				
Resource usage (fuel/ energy consumption, water, fuel for machinery)				
Others (specify):				
Workshop and yard activities				
Activity 1: **Vehicle and equipment maintenance**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air				
Noise	1	1	YES	1
Discharge to water	2	2		2
Emissions to soil	2	3		2
Waste (haz/non-haz)	2	2		2
Light pollution				
Odour				
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	2		2
Others (specify):				
Activity 2: **Vehicle and equipment washing**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air				
Noise	2	2	YES	1

Discharge to water	3	1	YES	3
Emissions to soil	3	2	YES	3
Waste (haz/non-haz)	2	2	YES	2
Light pollution				
Odour				
Resource usage (fuel/ energy consumption, water, fuel for machinery)	2	2	YES	2
Others (specify):				
Activity 3: **Handling and storage of chemicals (non-bulk) ***	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	1	1	YES	2
Noise	1	1		1
Discharge to water	2	1		2
Emissions to soil	2	1		2
Waste (haz/non-haz)	1	1		2
Light pollution	1	1		1
Odour	2	1		1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	1		1
Others (specify):				
Activity 4: **Fuelling and bunkering (**)**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air				
Noise				
Discharge to water				
Emissions to soil				
Waste (haz/non-haz)				
Light pollution				
Odour				
Resource usage (fuel/ energy consumption, water, fuel for machinery)				
Others (specify):				
Activity 5: **Building and open area maintenance**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	1	1	YES	2
Noise	1	1	YES	1
Discharge to water	2	2	YES	2
Emissions to soil	2	1	YES	2
Waste (haz/non-haz)	3	2	YES	2
Light pollution	1	1	YES	
Odour				
Resource usage (fuel/ energy consumption, water, fuel for machinery)	2	2	YES	2
Others (specify):				
Activity 6: **Transhipment**	**Severity**	**Probability**	**Legal requirements**	**Significance**

(Ro-Ro, Passenger, Container, …) (***)				
ASPECTS:				
Emissions to air				
Noise				
Discharge to water				
Emissions to soil				
Waste (haz/non-haz)				
Light pollution				
Odour				
Resource usage (fuel/ energy consumption, water, fuel for machinery)				
Others (specify):				
Shipping				
Activity 1: **Ship movement** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	3	2	YES	3
Noise	2	2	YES	2
Discharge to water	2	2	YES	2
Emissions to soil	2	2	YES	1
Waste (haz/non-haz)	3	3	YES	2
Light pollution	1	2		1
Odour				
Resource usage (fuel/ energy consumption, water, fuel for machinery)	3	2	YES	2
Others (specify):				
Activity 2: **Ship discharge - ballast waters (****)** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	1	1	YES	1
Noise	1	1	YES	1
Discharge to water	2	1	YES	2
Emissions to soil	1	1	YES	1
Waste (haz/non-haz)	2	2	YES	2
Light pollution				
Odour				
Resource usage (fuel/ energy consumption, water, fuel for machinery)				
Others (specify):				
Activity 3: **Ship discharge – sewage (****)** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	1	1	YES	1
Noise	1	1	YES	1
Discharge to water	2	2	YES	2
Emissions to soil	2	1	YES	1
Waste (haz/non-haz)	1	1	YES	1
Light pollution				
Odour				

Resource usage (fuel/ energy consumption, water, fuel for machinery)				
Others (specify):				
Activity 4: **Ship discharge – bilge (****)**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	1	1	YES	1
Noise	1	1	YES	1
Discharge to water	2	2	YES	1
Emissions to soil	2	1	YES	2
Waste (haz/non-haz)				
Light pollution				
Odour	1	1	YES	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)				
Others (specify):				
Users				
Activity 1: **Maintenance dredging & disposal**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	3	2	no	3
Noise	1	1	no	1
Discharge to water	2	2	YES	2
Emissions to soil	2	2	YES	2
Waste (haz/non-haz)	2	2	YES	2
Light pollution				
Odour	1	1		1
Resource usage (fuel/ energy consumption, water, fuel for machinery)				
Others (specify):				
Activity 2: **Ship and shore solid waste collection**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	1	1	YES	1
Noise	1	1	YES	1
Discharge to water	2	1	YES	2
Emissions to soil	2	2	YES	2
Waste (haz/non-haz)	3	2	YES	2
Light pollution				
Odour	1	1	YES	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)				
Others (specify):				
Activity 3: **Public access /areas and recreation in harbour**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	2	1	YES	2
Noise	1	1	YES	1
Discharge to water	2	1	YES	1

Emissions to soil	1	1	YES	1
Waste (haz/non-haz)	2	2	YES	1
Light pollution	1	1	YES	1
Odour				
Resource usage (fuel/ energy consumption, water, fuel for machinery)	2	2	YES	2
Others (specify):				
Activity 4: **Vehicles storage and transport in car terminals**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	3	3	YES	3
Noise	2	3		2
Discharge to water	1	1		2
Emissions to soil	1	2		1
Waste (haz/non-haz)	2	2		1
Light pollution	2	2		2
Odour				
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	1		1
Others (specify):				
Activity 5: **Mooring (*****)**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	2	2	No	2
Noise	2	2	No	3
Discharge to water	1	2	No	2
Emissions to soil	1	1	No	1
Waste (haz/non-haz)	1	1	No	1
Light pollution	1	1	No	1
Odour				
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	2	No	1
Others (specify):				
Activity 6: **Towing (**)**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air				
Noise				
Discharge to water				
Emissions to soil				
Waste (haz/non-haz)				
Light pollution				
Odour				
Resource usage (fuel/ energy consumption, water, fuel for machinery)				
Others (specify):				

(*) The estimation in the Excel file is included in the container terminal operations

(**) Out of the scope of port authority's activities

(***) It is not clear the reason that we have to assess the aspects of the transhipment separetly from the Cargo handling and storage !!!

(****) Regarding the ballast water dischsrge it is taking into the account the BWM Convention that is in force

Regarding the sewage discharge the discharge is permitted only to the authorised waste port reception facilities

Regarding the assessment of the aspect of the bilge water has been assassed in the section of waste in shipping field (ANNEX I_MARPOL 73/78 Convention _Port Reception facilities)

(*****) The estimation in the Excel file is included in the ship's operations

A.4 Port of Thessaloniki (ThPA)

Table 10.4 ThPA survey

Cargo handling and storage				
Activity 1: **Dry bulk – organic (fodder, cereals)** *ASPECTS*:	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	4	3	Yes	4
Noise	2	2	Yes	3
Discharge to water	1	1	Yes	4
Emissions to soil	2	1	Yes	2
Waste (haz/non-haz)	1	3	Yes	4
Light pollution	1	1	Yes	3
Odour	1	1	Yes	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	2	2	No	2
Others (specify):				
Activity 2: **Dry bulk - ores & minerals** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	4	4	Yes	4
Noise	3	2	Yes	3
Discharge to water	4	2	Yes	4
Emissions to soil	2	1	Yes	2
Waste (haz/non-haz)	1	1	Yes	1
Light pollution	1	1	Yes	1
Odour	1	1	Yes	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	2	2	No	2
Others (specify):				
Activity 3: **Liquid bulk organic/mineral** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	2	1	Yes	2
Noise	1	1	Yes	1
Discharge to water	3	2	Yes	4
Emissions to soil	1	1	Yes	2
Waste (haz/non-haz)	1	1	Yes	1
Light pollution	1	1	Yes	1
Odour	1	1	Yes	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	1	No	2
Others (specify):				
Activity 4: **Containers** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	3	3	Yes	3
Noise	3	4	Yes	4
Discharge to water	2	1	Yes	2
Emissions to soil	2	1	Yes	2

Waste (haz/non-haz)	1	1	Yes	1
Light pollution	1	1	Yes	1
Odour	1	1	Yes	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	2	2	No	3
Others (specify):				
Activity 5: **General cargo** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	3	3	Yes	3
Noise	3	4	Yes	4
Discharge to water	2	1	Yes	2
Emissions to soil	2	1	Yes	2
Waste (haz/non-haz)	1	1	Yes	1
Light pollution	1	1	Yes	1
Odour	1	1	Yes	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	3	2	No	3
Others (specify):				
Activity 6: **Refrigerated goods** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	3	1	Yes	2
Noise	2	2	Yes	2
Discharge to water	3	1	Yes	2
Emissions to soil	3	1	Yes	2
Waste (haz/non-haz)	1	1	Yes	1
Light pollution	1	1	Yes	1
Odour	1	1	Yes	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	3	2	No	3
Others (specify):				
Workshop and yard activities				
Activity 1: **Vehicle and equipment maintenance** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	2	1	Yes	2
Noise	3	2	Yes	3
Discharge to water	3	1	Yes	2
Emissions to soil	2	1	Yes	1
Waste (haz/non-haz)	2	1	Yes	1
Light pollution	1	1	Yes	1
Odour	2	1	Yes	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	3	2	No	3
Others (specify):				
Activity 2: **Vehicle and equipment washing** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	2	1	Yes	2

Noise	3	2	Yes	3
Discharge to water	3	1	Yes	2
Emissions to soil	2	1	Yes	1
Waste (haz/non-haz)	1	1	Yes	1
Light pollution	1	1	Yes	1
Odour	1	1	Yes	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	2	2	No	3
Others (specify):				
Activity 3: **Handling and storage of chemicals (non-bulk)**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air				
Noise				
Discharge to water				
Emissions to soil				
Waste (haz/non-haz)				
Light pollution				
Odour				
Resource usage (fuel/ energy consumption, water, fuel for machinery)				
Others (specify):				
Activity 4: **Fuelling and bunkering**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	1	1	Yes	1
Noise	1	1	Yes	1
Discharge to water	2	1	Yes	2
Emissions to soil	2	1	Yes	1
Waste (haz/non-haz)	2	1	Yes	1
Light pollution	1	1	Yes	1
Odour	1	1	Yes	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	1	No	1
Others (specify):				
Activity 5: **Building and open area maintenance**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	2	2	Yes	2
Noise	2	2	Yes	3
Discharge to water	1	1	Yes	2
Emissions to soil	2	1	Yes	1
Waste (haz/non-haz)	2	2	Yes	1
Light pollution	1	1	Yes	1
Odour	1	1	Yes	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	2	2	No	2
Others (specify):				
Activity 6: **Transhipment (Ro-Ro, Passenger, Container, …)**	**Severity**	**Probability**	**Legal requirements**	**Significance**

ASPECTS:				
Emissions to air	3	2	Yes	3
Noise	2	2	Yes	2
Discharge to water	2	1	Yes	2
Emissions to soil	1	1	Yes	1
Waste (haz/non-haz)	1	1	Yes	1
Light pollution	1	1	Yes	1
Odour	1	1	Yes	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	3	2	No	2
Others (specify):				
Shipping				
Activity 1: **Ship movement** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	3	3	Yes	3
Noise	2	2	Yes	2
Discharge to water	3	1	Yes	4
Emissions to soil	1	1	Yes	1
Waste (haz/non-haz)	2	1	Yes	1
Light pollution	1	1	Yes	1
Odour	1	1	Yes	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	1	No	1
Others (specify):				
Activity 2: **Ship discharge - ballast waters** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	1	1	Yes	1
Noise	1	1	Yes	1
Discharge to water	2	4	Yes	4
Emissions to soil	1	1	Yes	1
Waste (haz/non-haz)	2	1	Yes	1
Light pollution	1	1	Yes	1
Odour	1	1	Yes	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	1	No	1
Others (specify):				
Activity 3: **Ship discharge - sewage** *ASPECTS:*	**Severity**	**Probability**	**Legal requirements**	**Significance**
Emissions to air	1	1	Yes	1
Noise	1	1	Yes	1
Discharge to water	4	1	Yes	4
Emissions to soil	1	1	Yes	1
Waste (haz/non-haz)	2	1	Yes	1
Light pollution	1	1	Yes	1
Odour	1	1	Yes	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	1	No	1
Others (specify):				
Activity 4: **Ship discharge - bilge**	**Severity**	**Probability**	**Legal**	**Significance**

ASPECTS:			**requirements**	
Emissions to air	1	1	Yes	1
Noise	1	1	Yes	1
Discharge to water	3	1	Yes	3
Emissions to soil	1	1	Yes	1
Waste (haz/non-haz)	2	1	Yes	1
Light pollution	1	1	Yes	1
Odour	1	1	Yes	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	1	No	1
Others (specify):				
Users				
Activity 1: **Maintenance dredging & disposal**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	1	1	Yes	2
Noise	1	2	Yes	1
Discharge to water	3	2	Yes	2
Emissions to soil	2	2	Yes	1
Waste (haz/non-haz)	3	3	Yes	2
Light pollution	1	1	Yes	1
Odour	1	1	Yes	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	2	1	No	2
Others (specify):				
Activity 2: **Ship and shore solid waste collection**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	2	2	Yes	2
Noise	1	1	Yes	1
Discharge to water	2	1	Yes	1
Emissions to soil	2	1	Yes	1
Waste (haz/non-haz)	1	1	Yes	1
Light pollution	1	1	Yes	1
Odour	1	3	Yes	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	1	No	1
Others (specify):				
Activity 3: **Public access /areas and recreation in harbour**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	1	1	Yes	1
Noise	1	1	Yes	1
Discharge to water	2	1	Yes	2
Emissions to soil	1	1	Yes	1
Waste (haz/non-haz)	1	1	Yes	1
Light pollution	1	1	Yes	1
Odour	1	1	Yes	1
Resource usage (fuel/ energy consumption,	1	1	No	1

water, fuel for machinery)				
Others (specify):				
Activity 4: **Vehicles storage and transport in car terminals**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	2	2	Yes	2
Noise	1	1	Yes	1
Discharge to water	2	1	Yes	1
Emissions to soil	1	1	Yes	1
Waste (haz/non-haz)	1	1	Yes	1
Light pollution	1	1	Yes	1
Odour	1	1	Yes	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	1	2	No	1
Others (specify):				
Activity 5: **Mooring**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	2	2	Yes	2
Noise	2	2	Yes	2
Discharge to water	2	2	Yes	2
Emissions to soil	1	1	Yes	1
Waste (haz/non-haz)	1	1	Yes	1
Light pollution	1	1	Yes	1
Odour	1	1	Yes	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	2	2	No	2
Others (specify):				
Activity 6: **Towing**	**Severity**	**Probability**	**Legal requirements**	**Significance**
ASPECTS:				
Emissions to air	2	2	Yes	2
Noise	2	2	Yes	2
Discharge to water	2	2	Yes	2
Emissions to soil	1	1	Yes	1
Waste (haz/non-haz)	1	1	Yes	1
Light pollution	1	1	Yes	1
Odour	1	1	Yes	1
Resource usage (fuel/ energy consumption, water, fuel for machinery)	2	2	No	2
Others (specify):				