**Action Plan towards the SMART PORT concept in the Mediterranean Area**

**SMART-PORT**

<table>
<thead>
<tr>
<th>Deliverable n.</th>
<th>D1.1</th>
<th>Report describing the Smart Port criteria</th>
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<tbody>
<tr>
<td>Work package</td>
<td>WP 2</td>
<td>Technical</td>
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<tr>
<td>Editor(s)</td>
<td>IAT, UCA, ICCS, PROMETNI, TICASS</td>
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**MED Programme**

Priority-Objective 3.1.

Axe 3: Improvement of mobility and of territorial accessibility

Objective 3.1: Improvement of maritime accessibility and of transit capacities through multimodality and intermodality
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LIST OF ABBREVIATIONS AND TERMS

<table>
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<tr>
<th>ABBREVIATION</th>
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<tr>
<td>CCTV</td>
<td>Closed-circuit television</td>
</tr>
<tr>
<td>DGNSS</td>
<td>Differential Global Navigation Satellite System</td>
</tr>
<tr>
<td>Dx.x</td>
<td>Deliverable x.x</td>
</tr>
<tr>
<td>EFQM</td>
<td>European Foundation of Quality Model</td>
</tr>
<tr>
<td>EMAS</td>
<td>Eco-Management and Audit Scheme</td>
</tr>
<tr>
<td>EMS</td>
<td>Environmental Management System</td>
</tr>
<tr>
<td>ESPO</td>
<td>European Association of port Authorities</td>
</tr>
<tr>
<td>EU or EUR</td>
<td>European</td>
</tr>
<tr>
<td>GHG</td>
<td>Greenhouse Gas</td>
</tr>
<tr>
<td>GNSS</td>
<td>Global Navigation Satellite System</td>
</tr>
<tr>
<td>HVAC</td>
<td>Heating, ventilating, and air conditioning</td>
</tr>
<tr>
<td>IAT</td>
<td>Andalusian Institute of Technology</td>
</tr>
<tr>
<td>ICCS</td>
<td>Institute of Communication and Computer Systems</td>
</tr>
<tr>
<td>ICT</td>
<td>Information and Communication Technologies</td>
</tr>
<tr>
<td>ISO</td>
<td>International Standard Organization</td>
</tr>
<tr>
<td>IT</td>
<td>Information technologies</td>
</tr>
<tr>
<td>KPI /KPIs</td>
<td>key performance indicator/s</td>
</tr>
<tr>
<td>MED</td>
<td>Mediterranean</td>
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<tr>
<td>OCR</td>
<td>Optical character recognition</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>PCS</td>
<td>Port Community Systems</td>
</tr>
<tr>
<td>PM</td>
<td>Particulate Matter</td>
</tr>
<tr>
<td>PMR</td>
<td>Private mobile radio</td>
</tr>
<tr>
<td>PROMETNI</td>
<td>Prometni Institut Ljubljana/Institute of Traffic and Transport Ljubljana</td>
</tr>
<tr>
<td>RFID</td>
<td>Radio Frequency Identification</td>
</tr>
<tr>
<td>STS</td>
<td>Ship-to-Shore</td>
</tr>
<tr>
<td>TICASS</td>
<td>Innovative Technologies for Environmental Control and Sustainable Development</td>
</tr>
<tr>
<td>TOS</td>
<td>Terminal operation systems</td>
</tr>
<tr>
<td>UCA</td>
<td>University of Cádiz</td>
</tr>
<tr>
<td>ULCVs</td>
<td>Ultra Large Container Vessels</td>
</tr>
<tr>
<td>US</td>
<td>United States</td>
</tr>
<tr>
<td>WP</td>
<td>Work Package</td>
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<table>
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<tr>
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<td>0.1</td>
<td>14/10/2014</td>
<td>First Draft</td>
</tr>
<tr>
<td>0.2</td>
<td>23/12/2014</td>
<td>Final version</td>
</tr>
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The 2020 Strategy in Europe commits to the consolidation of a SMART, SUSTAINABLE and INCLUSIVE Europe. Aligned with these priorities, the SMART-PORT project aims at contributing to sustainable growth by establishing the appropriate conditions for the adoption of new management energy models based on low environmental impact and triggering innovation of both technologies and processes.

The strategic importance of the smart-port holistic concept (emphasizing particularly operational and energy efficiency, competitiveness and environmental impact aspects) within the Mediterranean space is beyond doubt, but this challenge clearly requires a coordinated effort, only reachable by transnational cooperation. Approaching the smart port concept at a Mediterranean level is impossible unless in a coordinated way and considering the different regional perspective of the main MED container ports.

This way, IAT (Andalusian Institute of Technology), ICCS (Institute of Communication and Computer Systems), TICASS (Innovative Technologies for Environmental Control and Sustainable Development), PROMETNI (Prometni Institute Ljubljana/Institute of Traffic and Transport Ljubljana) and UCA (University of Cádiz) form a consortium to lead and develop the SMART-PORT project.

The first stage in the proposed work is to define this smart-port concept to then study the current situation of the Mediterranean ports with regard to this standard. This concept has been approached to integrate the different key factors of port competitiveness, which includes: operational, energy, and environmental aspects. This way the smart-port concept will be shown through a graphic map of factors which determines a smart-port. Each factor will have a weight based on its relevance in the scope of the project.

With the objective of defining the smart-port concept, the consortium has taken into account the MED projects and the previous EU initiatives in the concerned field. Thus, it has compiled/gathered all the relevant information, which will lay the grounds for a holistic definition of the smart-port concept.

To ensure the optimum result in this stage of the project, the smart-port partners were selected very carefully, paying especial attention to their previous experience in international related projects,
expertise and skills. Their nature (operational bodies from scientific, public and private sectors) has allowed accessing to relevant and reliable sources at national and international level (not only through project partners but even through the Advisory Board Members) which have determined the accuracy of the analysis results.

SMART-PORT project includes an Advisory Board of 17 entities within the related sector. They have assessed every outcome achieved at the end of each step of the project, as it has happened in this one (Table 1).

Table 1. Advisory Board in SMART-PORT.

<table>
<thead>
<tr>
<th>Entity</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port of Genoa – Genova Port Authority</td>
<td>Italy</td>
</tr>
<tr>
<td>Spanish Technology Platform on Logistics, Intermodality and Mobility (LOGISTOP)</td>
<td>Spain</td>
</tr>
<tr>
<td>AFT – Languedoc Roussillon Delegation to Institutions and Professionals</td>
<td>France</td>
</tr>
<tr>
<td>Institution Regione Liguria – Environment Department</td>
<td>Italy</td>
</tr>
<tr>
<td>Port of Genova Ecological Service (Servizi Ecologici Porto di Genova- SEPG)-</td>
<td>Italy</td>
</tr>
<tr>
<td>Muvita Foundation</td>
<td>Italy</td>
</tr>
<tr>
<td>Province of Genoa – Istituzione Provincia di Genova</td>
<td>Italy</td>
</tr>
<tr>
<td>University of Genova – Department of Earth, Environment and Life Sciences</td>
<td>Italy</td>
</tr>
<tr>
<td>Asociación Comarcal de empresarios de transporte y maquinaria de obra pública del Campo de Gibraltar</td>
<td>Spain</td>
</tr>
<tr>
<td>Andalusian Energy Agency (Regional Government)</td>
<td>Spain</td>
</tr>
<tr>
<td>Andalusian Public Port Authority - APPA</td>
<td>Spain</td>
</tr>
<tr>
<td>Spanish Association for Standardization and Certification – AENOR International.</td>
<td>Spain</td>
</tr>
<tr>
<td>Port of Koper</td>
<td>Slovenia</td>
</tr>
<tr>
<td>Hanjin Shipping Spain</td>
<td>Spain</td>
</tr>
<tr>
<td>Cosco Iberica SA</td>
<td>Spain</td>
</tr>
<tr>
<td>Bahia de Algeciras Port Authority</td>
<td>Spain</td>
</tr>
<tr>
<td>Bahia Almeriport Foundation- Port of Almeria</td>
<td>Spain</td>
</tr>
</tbody>
</table>

The methodology applied to define the smart-port criteria has been based on the next stages:

1. **Consultation of bibliography:** All the criteria and key indicators used in the project and included in the smart-port concept must have a robust base in reliable bibliography and references (websites,
database, reports of relevant organization, etc.) before the beginning of the SMART-PORT, between the foreseen sources to be used in the project are those shown in Table 2. Then, they have been complemented with numerous references shown in the section at the end of this document.

2. **Consultation of partners and stakeholders**: When all the criteria and key indicators were defined on the base of the bibliography and references by partners, some queries to the Advisory Board were performed and some local meetings with some of the stakeholders were held by each partner until reaching a consensual list of criteria and key indicators.

The methodology applied was DELPHI. This is a structured communication technique, originally developed as a systematic, interactive forecasting method which relies on a panel of experts. The experts answer questionnaires in two or more rounds (twice in this case).

3. **Assignation of a weight to each criteria group**: All the partners evaluated the importance of each criterion selected and the average of which was calculated as a representation of the weight for each one.

<table>
<thead>
<tr>
<th>Data/information</th>
<th>Scope</th>
<th>Origin/Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Med ports data regarding the ISO 9001, ISO 14001, ISO 28000, EMAS, EFQM certifications</td>
<td>International</td>
<td>AENOR International</td>
</tr>
<tr>
<td>Information general about the containers ports.</td>
<td>International</td>
<td>Containerisation International <a href="http://www.lloydslist.com">http://www.lloydslist.com</a></td>
</tr>
<tr>
<td>Technological data/information from Port of Naples, Port of Algeciras, Port of Genoa, Port of Almeria, Port of Malaga, Port of Koper, Port of Valencia</td>
<td>A specific number of ports</td>
<td>All partners and stakeholders in SMART-PORT project</td>
</tr>
<tr>
<td>SustainableShipping.com is an online news and information resource dedicated to marine transportation and the environment.</td>
<td>International</td>
<td>Sustainable Shipping <a href="http://www.sustainableshipping.com">www.sustainableshipping.com</a></td>
</tr>
<tr>
<td>Sustainability memories of Med ports and main international ports</td>
<td>International</td>
<td>Website of each port</td>
</tr>
<tr>
<td>Data regarding activities, infrastructures, etc. of Spanish ports</td>
<td>Spain</td>
<td>Puertos del Estado website <a href="http://www.puertos.es/">http://www.puertos.es/</a></td>
</tr>
<tr>
<td>Data about growth of the EU zone, ports activities, etc.</td>
<td>International</td>
<td>Eurostat- <a href="http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/">http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/</a></td>
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<tr>
<td>Data about transport, air, climate, employment, energy, industry,... of different countries</td>
<td>International</td>
<td>OCDE- <a href="http://www.oecd.org">http://www.oecd.org</a></td>
</tr>
<tr>
<td>Data about international trade and market access data, statistics database,...</td>
<td>International</td>
<td>OMC (maritime trade) - <a href="http://www.wto.org">http://www.wto.org</a></td>
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<tr>
<td>Data/information</td>
<td>Scope</td>
<td>Origin/Source</td>
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<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Data about international trade, economic trends, foreign direct investment, external financial resources, maritime transport,...</td>
<td>International</td>
<td>UNCTAD (specially, review of maritime transport) <a href="http://unctad.org">http://unctad.org</a></td>
</tr>
<tr>
<td>Quarterly statistics on European port traffic (quarterly data on: total tonnage (tons), total liquid bulk (tons), total dry bulk (tons), total general cargo (tons), containers (tons, TEU), passengers)</td>
<td>International</td>
<td>European Sea Port Organisation (ESPO) <a href="http://www.espo.be">http://www.espo.be</a></td>
</tr>
<tr>
<td>World Container Traffic Data (Country League, Port League), World Seaborne Trade (by country groups, by cargo, by region)</td>
<td>International</td>
<td>International Association of Ports and Harbours (IAPH) <a href="http://www.iaphworldports.org">http://www.iaphworldports.org</a></td>
</tr>
<tr>
<td>It is the global portal for freight transport by sea. In Infopuerto.com are links to most ports in the world, as well as international sea lines with services from and to any commercial port. It provides the location of marine cargo ports on 5 continents. Also be found the most shipping and maritime logistics companies operating in Spain, Portugal and Andorra, classified by service activities.</td>
<td>International</td>
<td>InfoPuertos <a href="http://www.infopuerto.com">http://www.infopuerto.com</a></td>
</tr>
<tr>
<td>This website provides visibility and credit to ports that are currently part of the EcoPorts network through the interactive map.</td>
<td>International</td>
<td>ECOPORT <a href="http://www.ecoports.com/map">http://www.ecoports.com/map</a></td>
</tr>
<tr>
<td>This website provides services for discovery and requesting access to bathymetric data as managed by an increasing number of data providers from government and research. The portal also provides a service for viewing and downloading a harmonised Digital Terrain Model (DTM) for the European sea regions that it is generated by the EMODnet Bathymetry partnership on the basis of the gathered data sources.</td>
<td>International</td>
<td>European Marine Observation and Data Network (EMODnet)</td>
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<td>Information about Med ports regarding the issues contended in the smart-port concept: operational, energy and environmental aspects.</td>
<td>International</td>
<td>Projects where PROMETNI and TICASS participate: OPTIMIZEDMED, MEDNET, BACKGROUND, APICE, LOSAMEDCHEM, TERCONMED  Projects where LOGISTOP and AFT participate: FUTUREMED  Project where University of Genoa participates: PORTOPIA  Projects where AFT participates: DEVELOPMENT.</td>
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<td>Energy efficiency data for ports Corfu, Igoumenitsa, Sarande</td>
<td>Specific ports</td>
<td>EL PORT AL, ICCS</td>
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<td>Energy consumption of ships during berth in Piraeus port</td>
<td>Piraeus Port</td>
<td>NTU School of Naval Architecture and Marine Engineering, ICCS</td>
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<td>Energy consumption for Piraeus container</td>
<td>Piraeus Terminal</td>
<td>PCT, ICCS</td>
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<td>Data/information</td>
<td>Scope</td>
<td>Origin/Source</td>
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<tr>
<td>terminal</td>
<td>Specific Med ports</td>
<td>APPA, ICCS</td>
</tr>
<tr>
<td>Energy consumption data for APPA</td>
<td>Specific Med ports</td>
<td>APPA, ICCS</td>
</tr>
<tr>
<td>Statistical Office of Slovenia, statistical data of Slovenian Railways, road database and transport model</td>
<td>Slovenian railways and road transport</td>
<td>PROMETNI</td>
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<td>Local Emission Inventory Socioeconomic trends and Air quality monitoring</td>
<td>Italian med ports</td>
<td>APICE project, TICASS</td>
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<td>Study for Assessment of Emissions from Port of Genoa, Savona and La Spezia and Possible Action to Reduce</td>
<td>Port of Genoa, Savona and La Spezia</td>
<td>Liguria region, TICASS</td>
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<td>Environmental energetic plan of Port of Genova</td>
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<td>Genova Port Authority</td>
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<td>MUVITA, TICASS</td>
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3

3.1 *The Smart-port concept*

3.1.1 **Scope.**

SMART PORT project supports on the knowledge that ports develop different activities simultaneously: cruise, containers, ro-ro,... The scope of this study is limited to the port activity with containers.

The SMART PORT concept studied in the project contains/has/includes three big groups of issues (Figure 1) regarding the next topics:

a) Operations.

b) Energy consumption.

c) Environment.
The deadlines defined for the project and the limitation of budget have not made possible to study other additional key areas that could be relevant in a smart port, such as the socio-economic impact in the region where they are or the level of innovation between others.

### 3.1.2 Limitations.

The limitations for SMART-PORT project are described below:

- Mainly because of the short deadlines, it is not possible to conduct a rigorous survey to Med ports about their activities and results, so the majority of the information to be analyzed must be obtained/gathered from the partners and their stakeholders (table 1) and from indirect resources. Some of them were identified at the beginning of the project (table 2).

- On the base of the limitation above, the criteria and key performance indicators (KPI) in the smart-port concept are based on general KPIs, not related to confidential or private information or data. The design of the smart port concept has been developed keeping in mind this very restrictive issue. This way, information about/on the level of satisfaction of the customers or the number of incidents has been avoided in the operational area. The other areas (energy and environment) have not been so limited by this restriction. In spite of that, these areas have been oriented towards
measurable criteria and KPIs by using information and data that can be published or that are usually published by companies (sustainability reports, social responsibility report, etc.).

3.1.3 Description.

23 criteria and 68 KPIs have been defined to guide the assessment of a port against this concept. Figure 2 shows the 23 criteria classified into the three topics where SMART-PORT project focuses on where the SMART-PORT project is focused.

Figure 2. Scheme of the criteria in the different topics (operations, energy consumption and environment) defined in the smart-port concept.

Below, the relationship between the criteria and KPIs in the different smart port topics studied as well as the justification and bibliography and references used for their selection are described.

a) Operations:

a.1. Background and justification: The correct planning and execution of operations on a container-carrier vessel is a decisive element in the strategy of a terminal. Numerous factors come
into play and some of these/which, but only some, can be controlled. Experience and knowledge of the problems that can arise is fundamental when attempting to deal with these operations.

The objective of this review is to present a general analysis of the various and different elements that comprise the operating chain or process, defining the operating ratios involved and the relationships between them; similarly, the parameters that influence the operational process are indicated.

The studies of Steenken (2004) and, more recently, of Stahlbock and Voß (2008), and Vis and Koster (2003) cover a wide range of experience with container terminals, including case studies, and serve to define the initial problem.

The operational process of a container terminal can be considered as a large productive process where the final element is not a tangible product but rather a specified service. The service to which we refer is the handling and storage of the containerized merchandise of a particular customer. Thus, we are talking either of reception terminals (import and export) or of trans-shipment terminals, where containers are transferred from one vessel to another. This service needs to be delivered, i.e. performed, on the date agreed with the customer, and in accordance with the same conditions that the seller, exporter, loader (or any other legal entity considered to be the person putting the container at the disposition of the carrier) has contracted with the customer. The basic objective is to carry out the operations as rapidly as possible, to enable the vessel to spend the minimum time necessary in port and, consequently, to obtain maximum economic utilization as well as Energy and Environmentally efficient.

Measures of port efficiency or performance use a certain form of output relative to input which quantifies various aspects of port operation. Literature lists several benefits associated with a properly used set of port performance indicators (Wong and Cullinane, 1999). These include improving the utilization of port resources, highlighting the cause of congestion as well as providing information for port planning and a justification for capital development. To measure, however, port performance and to compare it between ports is a very delicate matter (Suykens, 1983). Therefore, we introduce here some criteria to be analyzed.
The “Productivity” in containers ports:

Most of the previous studies widely accept that container throughput measured in twenty equivalent units (TEUs) as the most paramount indicator for a seaport or terminal performance measurement (see for e.g. Martinez-Budria (1999), Cullinane et al. (2004, 2005, 2006), Turner, Windle and Dresnor (2004), Cullinane and Wang (2006), Min and Park (2005)). Therefore, it is appropriate to use container throughputs to benchmark port efficiency because it is closely related to the need for cargo-related facilities and services. As stated by Cook and Seiford (2009), there has been considerable interest in the measurement of efficiency as organizations have focused strongly on improving productivity. Many researchers have studied the problem of measuring the productive efficiency of a particular port or terminal since the topic is important to both the economic theorist and the economic policy maker, according to Farrell (1957). It is also important to differentiate between studies aimed mainly at comparing different ports and terminals and those aimed at monitoring changes in productivity or efficiency in specific ports over a period of several years. A rigorous and comprehensive discussion on the definition of the variables to use in port efficiency studies is provided by Cullinane et al. (2004). Most of authors agree on the use of similar main variables as inputs, i.e.: the length of the berths or berths available for vessels, especially those of draft exceeding fourteen meters; the number of quay cranes, including gantry cranes, transtainers and straddle carriers; and the land area occupied by the terminal, among others. Similarly, in many studies, authors have chosen to analyze this efficiency using the number of TEUs (Twenty-foot Equivalents Units) handled in a given period of time as the measured output magnitude (output data), usually for a year or a period of several years analyzing the evolution of efficiency. Nevertheless, indicators such as: Number of total TEUS; Number of total TEUs of reefers; Number of total transhipment TEUS; Number of transhipment TEUs of reefers; Total in (TEUS); Number of total in of reefers (TEUS); Number of total out (TEUS) and Number of total out of reefers (TEUS) will help us to classify the containers ports taking into account their productivity and to know the current situation of the MED space against the North-European one from a productivity point of view. These indicators will be used to compare the different containers ports regarding their “smart-port” level.
a.2. Description:

**Smart port criterion O1 “Berth productivity”:**

Criterion 1 is obviously much related to productivity. Table 3 offers a review of several of the most important works in literature where the “productivity” term can be different in order to measure some specific aspect. The total production or berth productivity is the total number of movements or individual tasks performed on the vessel (including all the concepts) divided by the total berth time (the time taken from when the vessel begins this operation until it is completed).

In term of land input, one of the most common criteria for this is the container berth length. Cullinane et al. (2004), Cullinane, Ji and Wang (2005) defined the land input by using the total quay length whereas Tongzon (2001) and Rios and Macada (2006) used the number of berth to indicate the land input. Wang, Cullinane and Song (2005) justified that total berth length is most suitable compared to counting the number of berths. This is because the quay within a port or terminal can be reconfigured and restructured in order to meet the market requirements.

In SMART-PORT, the berth productivity has been defined as a smart port criterion and within it, a KPI has been highlighted: annual throughput measured as total TEUS against the meters of container quay. As mentioned above, the length of the berth or berths available is one of the most used input factors in literature. Besides, it is possibly to measure the berth productivity or berth efficiency taking this ratio as the output term (as a specific kind of productivity).

Table 3. List of most relevant works in port efficiency or port productivity (2005-2013).

<table>
<thead>
<tr>
<th>Year</th>
<th>Authors</th>
<th>Port</th>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>Cullinane, K., Ji, P. y Ang, T.</td>
<td>World’s leading container ports ranked in the top 30 in 2001</td>
<td>1) Terminal length 2) Terminal area 3) Quayside gantry 4) Yard gantry 5) Straddle carriers</td>
<td>1) TEUs handled</td>
</tr>
<tr>
<td>2007</td>
<td>Barros and PeyPOCH</td>
<td>34 Italian and Portuguese seaports,</td>
<td>1) Total operational cost</td>
<td>1) Total containers</td>
</tr>
<tr>
<td>Year</td>
<td>Authors</td>
<td>Port</td>
<td>Inputs</td>
<td>Outputs</td>
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<tr>
<td>2010</td>
<td>Barros et al.</td>
<td>48 observations from 16 Middle Eastern and East African seaports 2005 – 2007</td>
<td>1) Employees 2) Total costs 3) Cranes</td>
<td>1) Throughput Ships</td>
</tr>
<tr>
<td>2012</td>
<td>Halkos and Tzeremes</td>
<td>12 Greek Seaport authorities 2006 – 2010</td>
<td>1) Total Assets 2) Nº Employees</td>
<td>1) Nº Passengers 2) Nº Tn. merchandise</td>
</tr>
<tr>
<td>2013</td>
<td>Mokhtar and Shah</td>
<td>Container terminals in Peninsular Malaysia 2003 – 2010</td>
<td>1) Total Terminal Area in m² 2) Maximum draft in meter 3) Berth length in meter 4) Quay crane index 5) Yard stacking index 6) Vehicles 7) Number of gate lanes</td>
<td>1) Throughput TEUs</td>
</tr>
</tbody>
</table>

Smart port Criterion O2 “Infrastructure productivity”:

Dowd and Leschine (1990) pointed out that the productivity of the container terminals rely upon the efficient use of the labor, land and equipment. To ensure cost-effective yard
operations, what is required is not only more space but also better handling equipment for efficient using of infrastructures.

To optimize or to facilitate port operations, a variety of inputs are required. Based on the production framework, port inputs can be generalized as land, labor and capital. The major capital inputs in port operations are the number of berths, cranes and tugs. Productivity is always measured using TEUs or some similar feature or ratio. Sometimes productivity has been analyzed using some kind of normalization such as KPIs 2.1-2.5.

**Smart port Criterion O3 “Capacity for receiving large vessels”:**

The terminals are being challenged by more Ultra Large Container Vessels (ULCVs) coming into service because they are forced to continue to invest/on investing huge amounts (of money) in infrastructure and equipment to make sure/ ensure that their customers – the shipping lines – do not run away/move/change to other ports/terminals. Nowadays, the Triple-E is the largest ship in the world, and it sets new standards in the container industry, not just for size, but also of energy efficiency and environmental performance. With unique design features for slower speeds and maximum efficiency, vessels in this series emit 50% less CO2 per container moved than the current average on the Asia-Europe route. The name "Triple E" is derived from the class three design principles: "Economy of scale, Energy efficient and environmentally improved". These ships are expected to be not only the world's longest ships in service, but also the most efficient container ships per twenty-foot equivalent unit (TEU) of cargo.

Port developments for mainline trades in general seem to be keeping up with the growth in vessel size, driven by a projected cargo volume increase and competition between ports. It is not surprising to find that the cost per TEU is strongly related to the vessel’s size and therefore the capacity for receiving large vessels is a very relevant feature to take into consideration.

Principal measures of a typical Triple-E vessel include (approximately):

- Beam (breadth): 59 meters
- Draught: 14.5 meters
• Deadweight: 165,000 metric tons

• Reefer container capacity: 600

Terminals across the globe should be ready to accommodate these ultra-large container vessels and therefore the depth of the quay must be larger than 14 m. That is because the smart-port concept includes the KPI 3.1. Length of quay with +14 m depth/Total quay length (only containers quay).

**Smart port Criterion O4 “Size and use of the maximum capacity”:**

An index of occupation of the terminal or adequate yard density must be obtained. There appears to be an inverse statistical relationship between the density and the productivity (Cañero et al., 2011). The operations in the yard are performed more slowly the greater the number of containers per unit of area; this is because the operating cycles of the machines (trucks, straddle carriers, etc.) needed to move the containers to and from the wharf are longer. More errors may be made and there may be more difficulties in locating the particular containers required, since they may be at lower levels in the stacks. There is a greater possibility of accidents occurring. Different terminals may measure this ratio in different ways (KPIs 4.1-4.3: 4.1. Annual TEUS/capacity of the containers terminals (static capacity), 4.2. Average annual number of hours (containers terminals are working), 4.3. Annual TEUS/Average annual number of hours (containers terminals are working)).

**Smart port Criterion O5 “Level of technology”:**

Integrated information systems are used to enhance the efficiency of terminal operations – and improve turnover. In the globalized environment the important competitive advantage of a port is to move cargo quickly and safely through the port. Ports face increasingly complex range of operational challenges in management of highly complex, multi-tenant port environments. From the operational point of view a consolidated, reliable, flexible and secure flow of information is vital in order to provide quick, reliable and cheap services at seaports. Deployment of consolidated technological solutions based on the IT is considered as a crucial factor in sound and efficient operation of the ports that considerably contribute to the ports competitiveness and efficiency (Merk, Dang, 2012).
Cross cutting issues of appropriate choice of technologies are reducing emission, improving energy efficiency and providing green logistics.

In various means of competition, seaport “digitalization” construction is important for improving seaport management ability, promoting management modernization, changing operation mechanism, building modern seaport enterprise system, reducing cost efficiently, accelerating technology development process, enhancing market competition ability, raising economic benefits and other aspects, and is the breach of driving seaport work innovation and function upgrade. Shipping lines as port customers are likely to select ports based on physical/operation ability of the ports (Chang at al. 2008) where ICT services play a crucial role.

Major IT world companies are constantly competing in improving IT solutions offered to seaport operators and terminals. Depending on the size of the ports, choosing appropriate technology that provides optimum benefits to seaports and its customers can be a burden. However, regardless the size, basic KPIs have selected to assess the level of technology deployment by ports in relation to the efficient and competitive operation:

a) Wireless and wireline communications (PMR for voice, WiFi for data,...)
   
   In the quest to improve their services, seaports are relying more and more on wireless technologies to enhance the flexibility of operations and improve efficiency. In a world where most workers still record container numbers on clipboards, wireless solutions can drive significant cost savings and faster operations.

   Wireless network equipment is used for better handling of equipment, to improve cargo integrity, real time surveillance, Wi-Fi access to vessels, effective administration through building connectivity etc.

b) RFID (Container identification, container security, entrance system,...)

   Application of RFID is driven by core benefits including labor productivity, safety and increased asset utilization. RFID are deployed to support the identification and tracking of assets typically associated with operations within a facility, to automatize processes, to improve operational productivity and equipment utilization as well as for safety (of people and assets) and security of containers.
Additional key element of deployment of RFID in the port communities and terminal markets is environmental, mostly minimizing ports carbon footprints.

c) OCR, CCTV (Container/Truck identification, security,...)
In addition to the RFID, OCR is one of many technologies now available for asset identification and process automation in ports and terminals. The key advantage is that it enables not only the automated ‘hands free’ identification and locating of assets, but also the recording of an object’s visual condition at that time. It also provides a device-less method of identification, without requiring the application of any tag or device to the asset.

d) GNSS, DGNSS (Crain guidance, container/truck positioning,...)
GNSS technology is the backbone of traffic management and modernization at seaport container terminals. One of the most important properties of GNSS-enabled systems is the ability of tracking container arrivals and their docking at the terminal (Bonaca at al., 2013).

e) TOS (Command and control integration, logistic support,...)
The reasoning behind deployment of the terminal operating systems lies in the fact that efficient cargo handling requires efficient data handling. Container and other marine terminals require increasingly versatile terminal operating and other IT systems to plan, schedule and manage operations. TOS are key part of the supply chain and primarily aim at controlling the movement and storage of various types of cargo in and around a container terminal or port.

f) Port Community System
The development and implementation of Port Community Systems (PCS) have been significant contributing factors to the more efficient movement of cargo across international borders. Ports are natural bottlenecks in the transport chain. Port Community Systems have played a major role in facilitating the most efficient movement of goods, while allowing Customs and other government departments to maintain effective controls. Such systems reduce the overall amount of clerical work by providing some means of capturing information at once and allowing controlled access by all appropriate members of the port community. Wasted effort is avoided because
duplication of entry and storage of data is reduced to a minimum. The time required to release cargoes is reduced because the necessary information is instantly available to those who (may) need it.

g) Logistics Collaborative Systems and B2B systems

Many different private companies – shipping lines, terminal operating companies, forwarders, hinterland transport providers, and inland terminal operators – are involved in hinterland transport. It is an important factor the integration of different companies’ back-end applications with each other in order to enable data exchange.

Taking into account this technologic context, the KPI 5.1 “Number of ITC that the port and terminals operators use and offer to the port community into a limited number of determined options” is included in the smart-port concept.

**Smart port Criterion O6 “Level of automation”:**

Marconsult (1994) pointed out that there is a fixed relation between the number of cranes deployed and the labor factor input employed in production. Therefore, Tongzon and Wu (2005) adopted his idea by using a number of quay crane to indicate the labor resources. For ULCVs, the shipping line will ask for the maximum number of gantry cranes able to reach the rows across on deck. Terminals consequently come under pressure to either rebuild/extend existing cranes or, when that is impossible, to buy/purchase new gantry cranes.

At first, the revised bibliography shows that it will be useful to measure the handle productivity. Kruk and Donner (2009) only use the number of Ship-to-Shore (STS) cranes - For example as "Annual throughput in TEU per number of STS quay cranes"- but the total number of quayside equipment could be more complete.

Another important factor influencing port outputs is the amount of delay time which is the difference between total berth time plus time waiting to berth and the time between the start and finish of ship working, and is an indicator of how well working time is being used (Tongzon, 2001). These delays could be due to labor disputes, work practices such as meal breaks, equipment breakdown, port congestion, perceived ship problems or bad weather. Automatized machinery is one of the new challenges to improve some of those wasted
times. We have introduced here some specific KPIs in order to measure not only the machinery available but also automated machinery (KPIs 6.1-6.7: 6.1. Annual throughput in TEU per number of quayside cranes, 6.2. Percentage of automatized quayside cranes, 6.3. Annual throughput in TEU per number of yard gantries, 6.4. Percentage of automatized yard gantries, 6.5. Annual throughput in TEU per number of equipment for internal movements (trucks, shuttle, etc.), 6.6. Percentage of automatized equipment for internal movements (trucks, shuttle, etc.), 6.7. Total percentage of automatized quayside cranes, yard gantries and equipment for internal movements).

**Smart port Criterium O7 “Level of intermodality”:**

Intermodal freight transport means the transportation of freight inside the intermodal container or trailer by using different types of transport modes (rail, ship and truck). Intermodal transport has numerous advantages in logistics, for instance: it simplifies the logistics chains, reduces cargo handling, and improves safety damage or loss of the cargo inside the container or trailer (Matajič, 2010). Intermodal transport, compared to the other different transport, reduces transport costs and greenhouse gas emissions. It has a high ratio in the world transport trade and is still rising up.

Because of the importance of intermodal freight transport, the ports along the world spread up the intermodal port services. For handling a high volume of containers (trailers...) in the ports a high capacity infrastructure is needed.

The containers could be loaded/unloaded directly from the train/truck to the ship (or reverse/and vice versa). High capacity container ships could be loaded with 10,000 to 15,000 TEUs (Ključevšek, 2014). For that type of ships a storage area near the container terminal is needed with a numerous railway sidings for container trains.

The containers could leave the port by train, truck or by ship. A lot of ports include also transshipment – a container is handled from one ship to another ship. For the transshipment additional storage area should be available. For the movement of containers from the port to the hinterland terminals (final customers) railway or road transport is used. Containers could be also transported by the barges at the river transport (inland waterways).
To protect the environment the containers should be transported to the hinterland terminals by rail. One train composition (rail wagons) could replace around 50 road trucks (Jemenšek, 2011). It is necessary that the ports should increase the share of containers transported by rail. To reach that goal, the existed port and hinterland railway infrastructure should have enough capacities to carry a huge amount of containers (TEUs).

**Smart port Criterion O8 “Lines calling at the port”:**

A carrier is an individual, partnership or corporation engaged in the business of transporting goods or passengers and a feeder service or line is an ocean transport system involving use of centralized ports to assemble and disperse cargo to and from ports within a geographic area. Commodities are transported between major ports, and then transferred to feeder vessels for further transport to a number of additional ports. The number of both of them measures an important part of the vessel traffic or flow of a port. KPIs 8.1-8.4. provides us with specific information of different flows: 8.1. Number of carriers (only carriers of maritime transport), 8.2. Number of main lines (large intercontinental and inter-oceanic lines with large ships and tonnage arriving in port and with a large volume of goods) per total number of lines, 8.3. Number of feeder lines (through the secondary lines or feeders, cargo is distributed with vessels of less draft, to secondary and spoke ports) per total number of lines, 8.4. Total TEUS per number of vessels that stops in the port. Obviously, this last KPI that relates the TEUS with the number of vessels arriving, using or stopping in a port is a very relevant factor from an operational point of view and also from energy or environmental reasons.

**Smart port Criterion O9. “Quality, safety and security”:**

There are some important points that must also be taken into account such as those for the repositioning, repair and replacement of the general machinery of the terminal due to wear-and-tear and obsolescence; other expenses include investment in new technologies and implementing them, research, development and innovation, and all the specific investment and expenditure that the terminals must incur in order to comply with and to update the security systems, given heightened awareness of possible terrorist attacks since 11 September 2001, and for risk prevention, health and safety and hygiene of the employees (Piniella 2009 and 2008). In spite of all the expenditure, one of the most visible
and worrying effects of the crisis being felt in this industry is the slow disinvestment that some terminals are making in items such as the preventive maintenance of machinery and safety, as described in the study conducted by Trelleborg Marine (Trelleborg 2010).

On the other hand, the quality certifications (such as: ISO 9001 or EFQM among others) should be taken into consideration because they generally determine a good organizational culture, focused on the principles of efficacy and efficiency.

Criterion 9 is related to 4 due to the extensive use of a terminal that may increase the number of incidents. Three KPIs have been introduced here KPI9.1-9.3: 9.1. Number of safety and security arrangements and certificates, 9.2. Number of quality certificates or arrangements according any standard that can contribute to improve or ensure the operations’ efficiency, 9.3. Scope of the quality certificates or arrangements. All these KPIs determine more reliable and competitive companies and institutions, with a modern market approach.

a.3. Criteria and KPIs selected relative to the operational issue within the smart-port concept:

O1. Berth productivity.
   O1.1. Annual throughout (TEU/meter of container quay).

O2. Infrastructure productivity.
   O2.1. Annual TEUS/Total terminal area.
   O2.2. Annual TEUS/ Total storage or yard area.
   O2.3. Annual TEUS/(Total storage or yard area + Total hinterland storage areas)
   O2.4. Annual TEUS/ Number of containers terminals.
   O2.5. Annual TEUS reefers/Total number of electrical outlets for reefers (static capacity).

O3. Capacity for receiving large vessels.
   O3.1. Length of quay with +14 m depth (m)/ Total quay length (meters) - Only container quay-

O4. Size and use of the maximum capacity.
   O4.1. Annual TEUS/capacity of the containers terminals (static capacity).
   O4.2. Average annual number of hours (containers terminals are working).
   O4.3. Annual TEUS/Average annual number of hours (containers terminals are working).

O5. Technologic level.
O5.1. Number of ITC that the port and terminals operators use and offer to the port community, between the next list:

- Wireless communications (PMR for voice, WiFi for data, ...)
- Wireline communications (PABX, FO network, ...)
- RFID (Container identification, container security, entrance system, ...)
- OCR, CCTV (Container/Truck identification, security, ...)
- GNSS, DGNSS (Crain guidance, container/truck positioning, ...)
- TOS (Command and control integration, logistic support, ...)
- Port Community System.
- Logistics Collaborative Systems.
- B2B systems.


O6.1. Annual throughput in TEU per number of quayside cranes.

O6.2. Percentage of automatized quayside cranes.

O6.3. Annual throughput in TEU per number of yard gantries.

O6.4. Percentage of automatized yard gantries.

O6.5. Annual throughput in TEU per number of equipment for internal movements (trucks, shuttle, etc.)

O6.6. Percentage of automatized equipment for internal movements (trucks, shuttle, etc.)

O6.7. Total percentage of automatized quayside cranes, yard gantries and equipment for internal movements.

O7. Level of intermodality.

O7.1. Magnitude of the rail infrastructure (Total sidings in port area (Km)/Total terminal area).

O7.2. Use of the intermodality-railway option (Total TEUS transported by rail/Total TEUS).

O7.3. Use of the intermodality-road option (Total TEUS transported by road/Total TEUS).

O8. Lines calling at the port.

O8.1. Total number of TEUS/Number of carriers (only carriers of maritime transport).

O8.2. Number of main lines (large intercontinental and inter-oceanic lines with large ships and tonnage arriving in port and with a large volume of goods) /Total number of lines.

O8.3. Total TEUS per number of vessels that stops in the port.

O9.1. Number of safety and security arrangements and certificates.
O9.2. Number of quality certificates or arrangements according any standard that can contribute to improve or ensure the operations’ efficiency.
O9.3. Scope of the quality certificates or arrangements (Port activities covered by quality management systems) (%).
O9.4. Scope of the safety and security arrangements and certificates (Port activities covered by the safety and security management systems).

b) Energy consumption.

b.1. Background and justification:

In November 2010, the Energy Strategy for 2011-2020 was released. This strategy will be integrated in the long-term perspective, called Roadmap 2050, to reduce EU’s greenhouse gases by 80-95% before 2050. As gateways of most of Europe’s external trade, seaports are key parts of logistic chains designed to provide a vital link between industries and their market and supply sources. Ports are often also the location where industrial activities take place, which need energy for their production processes. Energy consumption and GHG emissions from shipping and the port sector are increasing in the focus of public and political attention (ESPO, 2012 tris).

Ports are characterized by the geographical concentration of high–energy demand and supply activities, because of their proximity to power generation facilities and metropolitan regions, and their functions as central hubs in the transport of raw materials. In the last decades the need to better understand and monitor energy-related activities taking place near or within the port has become more apparent as a consequence of the growing relevance of energy trades, public environmental awareness and a bigger industry focused on energy efficiency (Acciaro et al. 2014).

The challenge of energy efficiency has been taken up by port authorities, as many of them are increasingly concerned with their emission profiles, and regulation in port areas have become more stringent, mostly in relation to sulphur and nitrogen oxides (Acciaro et al. in press; Acciaro, 2014), but in the future also with respect to particulate matters (PM) and CO₂. Energy consumption is also important in port operation and port-related activities, and with energy costs increasing also on land, port authorities and terminals are looking for ways to reduce their fuel bills. Examples of projects working on this issue are: GREEN EFFORTS Innovation (2010-2014), Greencranes (-), PPRISM (2010-2012), EFICONT (2008-2011) y CLIMEPORT (2009 – 2012).
The performance of port infrastructure and services in terms of energy consumption presents an important element to consider for the competitiveness of infrastructure services, port performance and the sustainability of transport and logistics (CIANAM, 2013).

This way, energy management by port authorities is presented as key when it comes to achieve the fact of being considered as a smart and sustainable port. There are many factors that have influence into the energy consumption of a port, from those elements whose consumption can be considered as direct and continuous as it is the lighting system of the port terminal area, offices and other facilities, the energy consumption of HVAC system of office buildings, the consumption of facilities of the garage, etc.; to other elements whose consumption can be considered more seasonal, it depends on the volume of activity that exists in the port. Inside this second group, it can be found the energy consumption by cranes, by the internal fleet of the port, or the consumption by the reefers, among others.

For both consumption groups, a deep analysis has to be developed to identify the existing saving possibilities, since the measures to carry out for both cases are too different between them. In the first case, the measures that have to be applied are more standard because they are related with the actions of energy efficiency that normally are implemented into buildings of the tertiary building sector for its energy demand reduction. In the second case, measures will be more related with actions of operational management and volume of activity of the port. To perform the identification of the measures to apply in each case, the port authorities could proceed to carry out a certification in some of the national or international regulations in this field.

On the other hand, besides the measures for the reduction of energy demand and consumption in a port, actions for the energy generation (electricity) can be carried out by means of renewable sources for self-consumption inside the port area. Thus, some technologies (wind technology, photovoltaic, marine technologies, etc.) can be applied to cover totally or partially the energy consumption of a specific equipment or facilities, or even for the whole port area.

**b.2. Description:**

The different smart-port criteria in the energy area are described below:

**Smart port Criterion EN1 “Total consumption of energy”:**

This criterion was selected in order to evaluate an overall vision on energy consumption, based on previous projects and ports’ experiences that validated it. Energy data should be
collected as a whole (KPI EN1.1) and detailed by energy sources (electrical, diesel and gas) as well as by energy consumer (port authority and container terminal operator).

These data were also selected because of their ease of obtaining which depends on their impact in terms of economic and financial aspects. It is possible to find reference on the use of these kind of indicators in studies such as Peris-Mora et al (2005), ESPO (2012)bis, EFICONT project and EcoPorts Foundation (2004).

It is important to highlight that the KPIs relative to the total consumption of energy should refer to both port authority and terminal operators. Additionally, it should be pointed out that, so as to develop a unique comparison and be able to compare the total energy consumption for each indicator, the consumption of electricity, fuel or diesel and gas, has to be calculated into primary energy. Not doing so, , one comparison for each energy source shall be done.

This first criterion considers the accumulated use of resources and is very important to evaluate the global influence of the port’s activities on society and environment. The following criteria consider different activities and port’s services individually.

**Smart port Criterion EN2 “Energy consumption by containers”:**

This criterion and associated KPIs are considered because reefer containers have the strongest impact in terms of energy consumption. KPI 2.2 takes into account eventual seasonality and periodicity (that could be due to climate temperatures and perishable goods transport). These KPIs have a relevant reference in the study of Wilmsmeier et al (2014), Climeport (2012) and in the research projects EFICONT (2008-2011) and CLIMEPORT (2009 – 2012).

**Smart port Criterion EN3 “Energy consumption by internal fleets”:**

This criterion highlights differences between transshipment and hub ports considering road transport within port boundaries. We can expect that these KPIs’ values will be lower for transshipment ports than for their hub counterparts. These KPIs have a relevant reference in the study of Wilmsmeier et al (2014), Climeport (2012) and in the research projects EFICONT (2008-2011) and CLIMEPORT (2009 – 2012).

**Smart port Criterion EN4 “Energy consumption by offices”:**

Every port activity consists of different services and processes. This criterion takes into account administrative and office activities consuming energy. This KPI is wide used in
different studies such as the one developed by Wilmsmeier et al (2014); Chiu R.H. & Lai I.C. (2014); Puig M. (2012); Climeport (2012). It was also adopted in the following research projects: EFICONT (2008-2011) and CLIMEPORT (2009 – 2012).

**Smart port Criterion EN5 “Energy consumption by lighting”:**

Lighting takes big part in energy consumption and costs that, in total, may represents up to 60 percent of a port’s operating expenses. Continuous rising energy costs became considerably important to port terminals operators. A challenge also provides opportunities for a port to lower its carbon footprint and energy consumption while increasing competitiveness by becoming greener and more efficient. Similar with automation for sustainability at operational level, in respect to lightening automating terminals also presents new opportunities to reduce lighting energy needs as well as lighting maintenance costs and environmental impacts.

Apart from operation buildings, lightening improvements in terminals of seaports can consider different energy-hungry areas such as crane lights, lightening of terminal storage areas, port roads and work areas, yards etc.

**Smart port Criterion EN6 “Energy consumption by the terminals’ equipment for movement of containers”:**

Electricity consumption at the ports includes the energy used in the routine operation of a port and tenant facilities (i.e., lighting, instrumentation, comfort cooling, computers, ventilation, etc.) electrified cargo handling equipment (electric wharf cranes, electric rail, mounted gantries, electric rubber tired gantries, etc.), shore powering of vessels, tenant industrial facilities and reefer plugs.

The huge increase in containers traffic in the last decade coupled with container ships increased size, a demanding need for larger, faster and smarter equipment of container handling occurred.

Electrified cargo handling equipment is considered as one of the most environmentally friendly means in comparison to other power sources. Through investments and proper planning, the electrical energy supplied can be used to the maximum possible extent by, for instance, modern electrical drive systems, ship to shore automation, introduction of automatic stacking cranes and synchronizes movement of equipment (Johnason, undated).
Smart port Criterion EN7 “Use of renewables”:

One of the European 2020 strategies referred to the “Sustainable growth” is to increase the share of renewables in final energy consumption to 20% (EU Directive 2009/28/EC on the promotion of the use of energy from renewable sources). This is one of the reasons why the criterion nº9 “Use of renewables” has been included in the smart port concept. In the document published by the Instituto Portuario de Estudios y Cooperación (FEPORTS) in 2012, energy coming from renewable resources is an indicator to point out friendly behaviors in enterprises.

In ports, possibilities of implementation and integration of renewable energies into their facilities in order to cover partially or totally their energy demand are huge. Although it will depend on the infrastructure of the port, the total energy demand, characteristics of the facilities, number of TEUS, etc., in general, the following aspects can be mentioned as examples of these possibilities:

- Wind technology: off-shore or installed in the terminal area to supply electricity to cranes, electric forklifts, reefers, etc.
- Small wind: integrated in buildings to cover the energy needs of office buildings, garage facilities or to charge electric cars or bus of the internal fleet in case that it exists).
- Photovoltaic technology: integrated in buildings to cover the energy needs of office buildings, garage facilities or to charge electric cars or bus of the internal fleet in case that it exists).
- Biodiesel: to supply fuel to internal fleet.
- Marine technologies: wave and tidal energy conversion to supply electricity to cranes, electric forklifts, reefers, etc.

As the previous criteria, due to covering energy demand of the port by renewable energies (reduction of fossil fuels), this is also relative to the initiatives geared towards safeguarding the environment.

Smart port Criterion EN8 “Energy management”:

To demonstrate the awareness of a port authority or a terminal operator towards the energy management, certificates concerning energy standards represent a successful
element because they express operational and managerial rationalization capacity to create reliability and competitiveness, what are highly valued by the group of a sector. These certificated standards determine a modern entrepreneurial mentality focused on the principles of sustainability development and on the respect of future generations (FEPORTEs, 2012). These certifications allow organizations to identify in which area of them the energy consumption is higher than it should be, if the required corrective measures have been applied in case of variations and failures in the system, to identify improves capacity regarding energy consumption reduction, etc.

Thanks to developed energy efficiency measures, on one hand and from an economic point of view, organizations can achieve important savings. On the other hand, tackling the climate change helps to conserve the existing energy resources.

In this context, as an example of certification in this field, ISO 50001:2011— Energy Management System supports organizations in all sectors to use energy more efficiently, through the development of an energy management system (ISO website, 2014).

b.3. Criteria and KPIs selected relative to the energy issue within the smart-port concept:

EN1. Total consumption of energy (primary energy).

   EN1.1. Total energy consumption (primary energy) by port authority per total port area (kWh/m²).
   EN1.2. Total energy consumption (primary energy) by the containers terminals per total terminal area (KWh/m²).

EN2. Energy consumption by containers.

   EN2.1. Total energy consumption (primary energy) per container per total TEUS) (kWh/TEU).
   EN2.2. Total energy consumption (primary energy) by reefers per Total number of reefer TEUS (KWh/reefer TEU).

EN3. Energy consumption by internal fleet (Internal fleet: Trucks, bus or cars owned by the terminal operators).

   EN3.1. Total energy consumption (primary energy) by internal fleet per terminal area (kWh/m²).

EN4. Energy consumption by offices (terminal operators).

   EN4.1. Total energy consumption (primary energy) by office buildings per terminal area (kWh/m²).
EN5. Energy consumption by lighting.
  EN5.1. Total energy consumption (primary energy) by lighting system (port terminal area, not office buildings) per terminal area (KWh/m²).

EN6. Energy consumption by terminal’s equipment for movement of containers (quayside cranes, yard gantry, forklifts, ship-to-shore cranes and other equipment for internal movements of containers).
  EN6.1. Total energy consumption (primary energy) by the terminal’s equipment per total number of TEUs (kWh/TEU).
  EN6.2. Total energy consumption (primary energy) by the terminal’s equipment per total terminal area (kWh/m²).
  EN6.3. Total energy consumption (primary energy) by cranes per total number of cranes (kWh/crane).

EN7. Use of renewables.
  EN7.1. Percentage of heating fuels from renewable resources managed by the port authority.
  EN7.2. Percentage of heating fuels from renewable resources managed by terminal operators.
  EN7.3. Percentage of energy from renewable resources managed by port authority.
  EN7.4. Percentage of energy from renewable resources managed by terminal operators.

EN8. Energy management.
  EN8.1. Number of energy management certificates or arrangements according any standard (ISO 50001, etc. (by port authority and/or terminal operators)/ (Total number of terminal operators plus one).
  EN8.2. Port activities covered by energy management systems (%).

c) Environment.
   c.1. Background and justification:
Seaports connect the world through maritime transportation networks, promote international trade, and support global economic growth. They can also be the checkpoint for anthropogenic inputs of environmental pollution through maritime transportation activities, which presents new and critical challenges to port managers regarding the provision of efficient port services and utilization of their unique position to curb global environmental problems (Luo M., Yip T.L., 2013). The compromise between the development of maritime transport and environmental conservation
is a major issue. Background constraints imposed by EU regulations are related with nature preservation, but at the same time face the need to extend ports for further development of intermodal transport services (European Commission, 2006). To tackle the environmental pollution coming from the construction and operation of a port, the environmental performance indicators emerged as a requirement and solution (Chiu R.H., Lai I.C., 2014).

Environmental performance measurement in the port sector emerged since the last 10 years as a new challenge for port Authorities, which have to contribute to public policy in the EU to achieve a safe, efficient and environmentally sustainable European port sector, operating as a key element for the competitiveness of European economy. Following European recommendations different initiatives have been developed: European Association of port Authorities (ESPO) edited the ESPO Environmental Code of Practice (2004) and recently the ESPO Green Guide. Other initiatives include the foundation of the European Economic Interest Group for Port environment management EUROPHAR (Port Authorities of Genoa and Marseilles and Valencia). Coherently different research projects have been settled to develop practical measurement tool for environmental performance of European Ports: Eco-Information (1997), ECOPORTS (2002-2005), ECOPORT 8 (2009 – 2012), PPRISM (2010-2012), GREEN EFFORTS Innovation (2010-2014); PEARL (2006-2008), SuPorts (2012-2014), Apice (2011-2013).

Past experiences highlights that environmental performance indicators can be particularly useful both to the authority and to a wide range of stakeholders in providing evidence of progress and the achievement of environmental objectives. In addition, the use of effective EPIs may contribute to cost and risk reduction, review of the effectiveness of an authority's Environmental Management System, and act as an early warning system (Puig M., 2012). At the same time some criticalities emerged which are summarized below:

- Environmental Performance Indicators includes three different matrices (soil/waste, air and water) referring to different scientific backgrounds and engaged subjects;
- Port authorities generally don’t have a clear, exhaustive and updated overview of Environmental data, because many different companies operate in the Port Authority area in concession, collecting data in each specific field of activity;
• Available data are often detected with different protocols, unit of measure, based on different time-scales and frequencies. These aspects make difficult the results’ comparison and require an ad hoc elaboration.

From a technical point of view, the environmental performance of sea ports depends on some specific factors (ESPO, 2012tris), a potential correlation parameter to allow the comparison of different ports’ performances could be the number of ship’s stops at berths (Regione Liguria, 2012) or the direct number of employee (ESPO, 2013).

Moreover, regarding Environmental Performance Criteria, the most sensitive criteria in terms of sustainability improvements of European ports are the qualitative ones (i.e. pollutants concentration in environmental matrices ECOPORT 8), especially with reference to water and wastewater.

c.2. Description:

The different smart-port criteria in the environmental area are described below:

**Smart port Criterion EV1 “Environmental management systems”:**

Environmental management systems are a key tool that helps organizations to improve their environmental performance through the control of their operations. Environmental management systems provide organizations with a framework to evaluate, monitor and reduce their environmental aspects and in this way to comply with environmental regulations.

The implementation of EMS is suggested in a broad environmental regulation.

In the port sector the European Sea Port Organization recommended the implementation of EMS based on international standards such as ISO 14001 and EMAS.

Ports include a broad range of activities carried out by several actors (port authority and port operators). SMARTPORTS has introduced some specific indicators in order to identify the percentage of the port activities covered by the environmental management systems.

**Smart port Criterion EV2 “Wastes management”:**

Within the “Europe 2020 Strategy”, “The Flagship initiative for a resource-efficient Europe” put special attention on waste. This flagship initiative establishes a number of medium-term measures to be implemented and one of them is to make the EU a ‘circular economy’, based on a recycling society with the aim of reducing waste generation and using waste as a resource.
Ports generate a significant amount of waste. The main sources of wastes in ports are:

- Port activities: a broad range of different kind of activities is developed in ports. These activities generate different kind of wastes that must be managed according to their specific nature and the applicable regulations.
- Ships: waste from ships is classified according to MARPOL convention. According to MARPOL convention and European regulations, the European ports must provide waste management services to ships to ensure the appropriate waste management.

SMARTPORTS has introduced several indicators in order to facilitate an appropriate waste management according to the waste hierarchy and waste regulations.

Because ports generate a broad variety of wastes, the implementation of specific management plan for wastes (EV2.1) is suggested by many actors such as ESPO. In this way the EV2.2 indicator aims to ensure that the waste management plan cover the critical activities and process on waste generation.

Additionally, a set of indicators have been identified in order to ensure right management of different wastes streams produced by several actors.

The waste management plans should facilitate the management of waste according to the waste hierarchy. Likewise, the European regulations require the implementation of specific management plan for wastes from ships (Directive 2000/59/EC of the European Parliament and of the Council of 27 November 2000 on port reception facilities for ship-generated waste and cargo residue).

**Smart port Criterion EV3 “Water management”:**

Water is an essential natural resource for human health and economy. The Roadmap for a resource efficiency Europe identify several actions in order to promote a sustainable water management and to protect the ecosystems in Europe.

In the same way, ESPO identify several challenges for ports regarding water consumption and waste water generation.

Water Consumption has been selected because it is significant in accordance to previous projects dealing with Port Performance (Port Sector Performance Dashboard developed within PPRISM project, see ESPO, 2012; ESPO, 2012 bis; SuPorts project see Puiga M. et al. 2014). Water consumption is increasing in significance in terms of cost-reduction and
resource consumption. Tracking of water consumption encourages the culture of monitoring and reporting of environmental performance indicators because it is relatively straightforward to monitor via bills or meters. It was discussed and advised from Members of the ESPO Sustainable Development Committee that included this KPI into the Port Performance Dashboard. In addition the criterion was declined to monitor different users. The last KPI considers remediation actions in term of water re-use.

This Criterion, also adopted in the environmental certification system (ISO 14001), is a resource consumption indicator and it is a practical and measurable indicator (Puig M., 2012).

Regarding wastewater criterion, again a resource consumption indicator, the identified KPIs aim at quantifying the total wastewater according to producers and management bodies, previously adopted in SuPorts project and by Chiu R.H. & Lai I.C. (2014). American Association of Port Authorities mentioned waste water as one of the main environmental concerns due to the fact that seaports were often situated in or near residential communities and/or environmentally sensitive estuaries (Bailey and Solomon, 2004). Darbra et al. (2009) considers discharges to water (e.g., waste waters, accidental releases during loading/unloading operations) as a significant environmental aspects in sea ports. Among the reasons, we remember that the high organic concentration in waste waters help the proliferation of a large number of bacteria. Due to the presence of polluting substances (high concentration of organic substances) in the vicinity of waste water discharging areas, a drastic alteration in water quality can be noted, especially during the summer, when the concentration of organic substances from domestic activities increases (ANPA, 1999).

**Smart port Criterion EV4 “Emissions to air”:**

In ports, several sources of air emission such as ships, road transport, industry and bulk goods are identified.

Air pollution remains the main environmental factor linked to preventable illness and premature mortality in the EU and still has significant negative effects on much of Europe's natural environment (European Commission, 2013).

In December 2013, the European Commission adopted of a new Clean Air Programme for Europe with new air quality objectives for the period up to 2030.
In this context ESPO identify air pollution as the second environmental priority for European ports. For this reason several indicators have been proposed in order to monitor the air quality in ports.

On the other hand, Climate change has long been recognised as one of the long-term shaping factor where coherent EU action is needed, both inside the EU and internationally (European Commission, 2011). In this way energy consumption and GHG emissions from shipping and the port sector are increasing in the focus of public and political attention (ESPO, 2012). SMARTPORTS has introduced specific indicators in order to assess greenhouses gas emissions from port activities.

**Smart port Criterion EV5 “Noise pollution”:**

Noise pollution is identified by ESPO as the first environmental priority for European port sector. That priority takes special relevancy in ports that are close to urban areas. The Noise Directive required to Member States to use the specified noise indicators of $L_{den}$ and $L_{night}$ and report the noise exposure of the population. SMARTPORT has introduced specific indicators to monitor the noise pollution in ports.

**Smart port Criterion EV6 “Leaks and spills of polluting substances at sea”:**

The main objective of the Marine Directive is to achieve good environmental status of EU marine waters by 2020 in order to preserve the ecosystems conditions and biodiversity. SMARTPORTS has introduced specific indicators in order to support an effectiveness assessment and control of discharges of polluting substance and to monitor the water quality.

c.3. Criteria and KPIs selected relative to the environmental issue within the smart-port concept:

**EV1. Environment management systems.**

EV1.1. Number of environmental management systems based on international standards - EMAS or ISO 14001- implemented by port authority or/and port operators /Total number of terminal operators plus one.

EV1.2. Port activities covered by environmental management systems (%).

**EV2. Wastes management.**

EV2.1. Number of wastes management plans implemented by port authority or/and port operators/Total number of terminal operators plus one.

EV2.2. Port activities covered by waste management plans (%).
EV2.3. Total wastes generated by all port activities (Tons) - Wastes from ships - MARPOL wastes- are not included per total port area.

EV2.4. Total wastes generated by terminal operators per TEUS (Tons/TEUS) - The wastes from ships -MARPOL wastes- are not included.

EV2.5. Total wastes generated by ships (MARPOL wastes) disaggregated per kind of wastes and per vessels stops (Tons/vessels stops).

EV2.6. Total hazardous wastes generated by all port activities disaggregated by sources per total port area - The wastes from ships -MARPOL wastes- are not included. (Tons/m²)

EV2.7. Total hazardous wastes generated by the terminal operators disaggregated by sources and per TEUS - The wastes from ships -MARPOL wastes- are not included. (Tons/TEUS)

EV2.8. Total wastes collected in a selective way from all port activities (organic, plastic, paper, wood, electronics, etc.) per total port area. Wastes from ships - MARPOL wastes- are not included. (Tons/m²)

EV2.9. Total wastes generated that are intended to operations of reuse, recycling and/or valorization operations disaggregated per kind of wastes per total port area (Tons/m³).

EV3. Water management.

EV3.1. Total water consumption by all port activities per total port area (m³/m²).

EV3.2. Total water consumption by terminal operators per TEUS (m³/TEUS).

EV3.3. Total water consumed by ships per vessel’s stops (m³/vessels’ stops).

EV3.4. Volume of water consumed that come from reuse operations (in all port area) against the total volume of water consumed (%).

EV3.5. Total wastewaters generated by all port activities per total port area (m³/m²).

EV3.6. Total wastewaters generated by the terminal operators per TEUS (m³/TEUS).

EV3.7. Total volume of wastewaters from all port activities that are treated for reuse against the total volume of wastewaters in the port (%).

EV4. Emissions to air.

EV4.1. Number of monitoring systems to assess air quality in port area per total port area.
EV4.2. Greenhouse gas emissions from all port activities per total port area (CO₂ equivalents Tons/m²).

EV5. Noise pollution.

EV5.1. Lden - noise pollution (Lden is an indicator of the overall noise level during the day, evening and night which is used to describe the annoyance caused by exposure to noise. These are long-term averaged sound levels, determined over all the correspondent periods of a year. All of these indicators are defined in terms of A-weighted decibels (dBA, dB(A)).

EV5.2. Lnight* - noise pollution (Lnight is an indicator for the sound level during the night used to describe sleep disturbance).


EV6.1. Total leaks and spills (Tons) of polluting substances at sea per vessels stops.

EV6.2. Number of monitoring systems to assess water quality (temperature, salinity, fecal coliforms, etc.) in port area per total quay berth.

3.2 The weight of each smart-port criteria

In the smart-port concept, the weight of each criterion is its relevance according with the opinion of a group of experts. To determine values for these weights, an excel file was sent to 11 experts appointed by each partner in the project.

In this excel, the participant had to assess the level of importance of different issues associated to the criteria. The weights obtained for each area and criterions are shown in the table 4 and figure 3 and the result to calculate the average in each case:

Table 4. Weights of each smart port area.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operations</td>
<td>5.9</td>
</tr>
<tr>
<td>Energy</td>
<td>4.5</td>
</tr>
<tr>
<td>Environment</td>
<td>4.8</td>
</tr>
</tbody>
</table>
Figure 3. Scheme of the criteria in the different topics (operations, energy consumption and environment) defined in the smart-port concept and their weights.

The different areas (operational, energy and environment) in the graphics shown in the Figure 3 are noticed: the operational side larger than the environmental and energy ones, and the environmental area a little larger than the energy one).
On the base of 77 bibliographic references and 22 participants, 23 criteria and 68 KPIs have been defined to know about the measure of the smart port concept in a container port. The criteria are divided in three areas: operational (9 criteria and 28 KPIs), environment (6 criteria and 24 KPIs) and energy (7 criteria and 16 KPIs), although possibly others should be considered (the social area for example), the SMART PORT project schedule and deadlines have been impossible to study these.

The correct planning and execution of operations on a container-carrier vessel is a decisive element in the strategy of a terminal and of a port authority. Numerous factors come into play and some of these, but only some, can be controlled. Experience and knowledge of the problems that can arise is fundamental when attempting to deal with these operations.

Following a scale defined as: 1 – Not at all important; 2 – Low importance; 3 – Slightly important; 4 – Neutral; 5 – Moderately important; 6 – Very important; 7 – Extremely important, in general, the participants agree in the most relevance of the operational issues for ports and port terminal (5.9: very important) than the environmental (4.8: close to be moderately important) or energy (4.5: neutral) ones. In general, both environmental and energy issues have a very similar weights in the minds of the stakeholders of the port authorities and port terminals participating in the project.

The proposed criteria and methodology as a means of port or terminal efficiency measurement, has great potential and may provide governments, port authorities and other interests with information on and guidelines for the implementation of port policies and organizational reforms. Moreover, research and application of the chosen methodology to a port or container terminal sectors has enormous possibilities.


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