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A sustainability assessment of ports and port-city plans: Comparing ambitions with achievements

C.A. Schipper[a,*], H. Vreugdenhil[a,b], M.P.C. de Jong[a]

[a] Deltares, Postbus 177, 2600 MH Delft, The Netherlands
[b] Delft University of Technology, Faculty of Technology, Policy and Management, Delft, The Netherlands

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ABSTRACT

The challenge for port developments is to minimize long-term uncertainties associated with port operations, risk of increased costs, and large environmental impacts. The aim of this study is to develop a comparative methodology to assess the sustainability performance of a mixed set of ports (different locations, sizes). This methodology involves ranking various long-term port plans and port vision documents against a set of social, economic, and environmental key performance indicators (KPIs) in order to evaluate and interpret future sustainable port-city development plans. The assessment aims to determine the efficiency and sustainability of each of the case study port plans, relative to other ports. Furthermore, the assessment ranks the considered ports based on comparison of pressures within the ecosystems and society, using publically available data in order to evaluate future changes resulting from these pressures. The classification and ranking of each port have been used to gauge the ability of each port to achieve its sustainability goals for port planning as set out in their port plans. The comprehensive results have been compared with the long-term port plan KPIs to evaluate an array of measures both quantitatively and qualitatively. Most of the highest ranking ports have developed a combination of integrated plans, measures, and regulations for sustainable port developments. This indicates that green-port policies need to be interlinked via social, economic, and environmental dimensions utilizing an integrated approach in order to realize maximum potential and strengthen port processes aimed at developing a sustainable port.

1. Introduction

1.1. Port growth

On-going trends such as global trade growth, increasing vessel sizes, and the need to modernize port facilities are driving investments in ports (OECD, 2012; PIANC, 2014a). World container traffic is expected to keep growing substantially, along with the increase of world trade, continuing rapid economic growth in the developing world, and further increase in wealth worldwide (Port of Rotterdam, 2008; Port of Hamburg, 2012a; Lam and Notteboom, 2012). The summed population of the 10 middle to mega size port cities considered in this study (Antwerp, Ho Chi Minh, Dar es Salaam, Hamburg, Istanbul, Los Angeles, Melbourne, Rotterdam, Shanghai and Valparaiso) is expected to grow from a total of 70 million in 2014 to about 92 million people in 2030 (UN, 2014). The number of the population is relevant since it directly characterises the urban situation at or around a port and indirectly it indicates the type of local hinterland. Ducruet and Lee (2006) studied port-city interdependence by examining correlation between city

* Corresponding author.
E-mail address: cor.schipper@deltares.nl (C.A. Schipper).

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population and container throughput. A growing consensus recognises the need to shift economies and social structures towards more sustainable models; quantity *and* quality (Asgari et al., 2015; ESPO, 2016). This concept of 'Green Growth' (described further below) enables policy makers and companies to identify successful strategies they can adopt, and pitfalls they can avoid, when drafting, implementing, and realising green growth policies (World Bank, 2012).

1.2. Economic, environmental and social impact of port development

Port development is beneficial for investors and for economic development of a region, but such large infrastructural developments may have negative effects on the ecosystem, which can result in adverse social and health effects. The choice for a location of a port extension is typically restricted by the administrative borders of that port. Traditional port development influences the economy (usually positively), environment (often negatively, if not mitigated) and society (both positively and negatively). Activities associated with construction (Maes and Schrijvers, 2005), transportation (Briene et al., 2011), operating, and demolishing infrastructure also make use of natural resources. Furthermore, maintenance dredging is an issue for many both small and large ports (Stronkhorst and van Hattum, 2003); since the associated costs are often very high, it can be a critical element in the economic feasibility of a port. For example, the Port of Rotterdam, located at the mouth of the River Rhine, needs to dredge about 17 million m^3 per year (Stronkhorst et al., 2003; Schipper et al., 2010) for maintaining the design water depths in their port area.

Often seaports are located in coastal ecosystems with high biodiversity. The relatively shallow depths of these systems result in high light availability for primary production (Vinagre et al., 2012). This creates favourable conditions with ample food availability and shelter for many species to utilize as nurseries and maturation during larval phases (Beck et al., 2001; Thrush and Dayton, 2002). Several biotopes exist in these coastal areas, which results in a large biodiversity with complex food web and multiple interactions between different trophic level of species. Insight into the impact of a port on the social welfare of a country can be used to identify which impacts need to be minimized and which need to be promoted. Many people move into cities for the associated economic opportunities, however, the urban environment also adversely affect the quality of life, which may cause social issues (UN, 2012a). Additionally, the social impact of maritime transport, via sources such as air pollution, has a role in human health and chronic diseases (Dawson and Alexeeff, 2001; Cropper and Khanna, 2014).

1.3. 'Green growth' sustainable port development

The rising tide of political interest in combining 'growth' with 'green' is an explicit item on the agenda of many countries, particularly in East Asia, Latin-America, Africa, and Europe. This particularly applies to ports, since they possess the ability to retain competitiveness while still taking into account the integrated (eco)system (Asgari et al., 2015; Laxe et al., 2016). Port developments following a growing (transport) market can significantly affect natural ecosystems (Gimenez et al., 2012), but also contribute positive to socio-economic aspects (Schipper et al., 2015; Carter and Rogers, 2008; Heaver, 2016). On the other hand, ports may use a sustainable approach as a selling point. Furthermore, particularly ports may adopt a 'greener' approach to streamline and speed up port developments, since such large infrastructural projects, if done in a traditional way, nowadays may meet large social resistance.

Because of the growing emphasis on sustainable port development models, increased knowledge is needed to reduce the impact of climate change effects on port activities and the influence of port infrastructures on the natural (coastal) system. Furthermore, increasing demand on space in delta areas and various external pressures – such as climate change, accelerated sea level rise, and subsidence – exacerbate the situation. This means that new multi-functional approaches for the design and operation of ports and waterway infrastructure are required (Van Wesenbeeck et al., 2016). This can be achieved through a new way of thinking that considers specific knowledge and expertise in the field of sustainable port development. Sustainable port development is defined in this paper as: new port or port extension plans that meet (or even exceed) typical operational requirements and that provide economic growth that is compatible with environmental and social needs, including ways to manage the transition to this new and balanced paradigm. Through an integrated and ecosystem-based approach, i.e. taking a broad range of requirements (operational, economic, environmental, and social) into account from the start, port development can be realised in an inclusive way, resulting in a vital and modern port that has a 'societal licence to operate'.

1.4. The no-impact port growth

The authors introduce the concept of sustainable port growth via the three common fundamental aspects: society, environment, and economy, or "People", "Planet", and "Prosperity" (PPP) (Carter and Rogers, 2008; Fisk, 2010). Recognizing its importance, a growing number of financial institutions currently incorporate the PPP approach in their businesses (Slaper, 2011). Here, within the PPP framework, we define Key Performance Indicators (KPIs) that are intended as gauges for evaluating and steering port developments. These KPIs are used to quantify the effect of the (potential) implementation of measures on the port-city development in the broadest sense. The reference in this port impact assessment is called 'the no-[negative]-impact port', which defines a theoretical port concept envisaged as the ultimate realisation of an optimal sustainable port. The challenge is, however, determining whether a no-impact port is achievable in practice related to suitability of the port for its daily operations, in combination with economic growth, and under which boundary conditions. In fact, a paradigm shift is required in the approach commonly taken to port development programmes when looking to adapt to climate change, sea-level rise, and urbanization, whereby the emphasis will, next to technical port requirements, also need to lay on the functioning of a healthy local ecosystem.

In recent years, studies were made by port authorities to design a system of sustainable indicators (Peris-Mora et al., 2005;

Saengsupavanich et al., 2009; Puig et al., 2014, 2015; Roh et al., 2016; ESPO, 2016; Laxe et al., 2016; Xiao and Lam, 2017). Laxe et al. (2016) analysed a statistical framework to assess the economic and environmental dimension of sustainable ports. They showed that the size of the port, in accordance with specialisation conditions, and overall traffic emissions have a direct relationship with the level of sustainability of ports. These studies propose KPIs that are acceptable and feasible for measuring the performance of operational ports. In our study the KPIs were selected which can be used in studies to balance economic growth and welfare in combination with healthy ecosystems. This evaluation compares port plans for sustainable port development, which are in harmony with the ecosystem and are robust or adaptable under climate change.

1.5. The aim of this study

The aim of this paper is to present a method for interpreting and comparing sustainability in long-term port and port-city plans. The extent to which sustainability ambitions have been realised by ports is assessed in this methodology by considering both older and more recent plans and comparing those to actual developments. The application of the analysis is illustrated by considering a set of diverse ports (size, type, geographic location) but is applicable to any (combination of) ports or cities. To achieve this goal, the authors have applied a comparative method identifying and selecting KPIs to assess port management plans on the aspect of sustainable port-city development and to explore the anticipated impacts – positive and negative – related to social, economic, and environmental aspects. To illustrate the method in practice and to highlight its versatility and validity, this paper describes the application of the method to a selection of 10 port-city long-term plans as case studies.

2. Method

2.1. The port assessment methodology

Every (future) port location has its own requirements and the local port authority will also have its own specific ambitions, described in e.g. the port management plan, port vision plan or long-term port plan. The basis of the integrated port-city plans ranges from the point of view of the port authority only, up to a full joint plan between the port authority and the city council. When considering the basic infrastructure in a traditional port, it is essential to distinguish between the several port management models and the industrial stakeholders within a port and their objectives. Port management is structured around the ownership, the administrative management models, and the regulatory frameworks of ports (World Bank, 2013).

To explore port development in the context of optimizing and integrating system operation states, the impact of port growth, port expansion, and the type of governance structure must be considered and reported in the port long-term plan. Port authorities use such plans to define and monitor their development strategies. At the same time, such plans allow the researcher to study the various management strategies and, in turn, see the effects on services provided for sustainable development. We have devised an assessment methodology based on evaluating port and port-city plans with the focus on integrated environmental, social, and economic aspects by reviewing the plans and subsequently comparing the contents to actual sustainable impact development. The sustainable port-city assessment methodology is broken down into 5 steps, denoted I to V (described in further detail below), which allows the user of the methodology to see the effect of various impacts and services provided by sustainable port development in a step-by-step manner (Fig. 1).

2.1.1. Consideration of environmental, social and economic performance indicators (Step I)

The indicators chosen in this manuscript are the sustainable indicators studied and published in the references: Antão et al., 2016; EPA, 2014; ESPO, 2016; Laxe et al., 2016; Puig et al., 2014, 2015; Peris-Mora et al., 2005; Roh et al., 2016; Rice, 2003; Rice and Rochet, 2005; Saengsupavanich et al., 2009. Before applying KPIs in sustainable measures, their suitability is verified in the present context by considering quality criteria (Rice, 2003; Rice and Rochet, 2005; Puig et al., 2014): (a) responsiveness, (b) specificity; (c) accuracy and (d) availability of data. (a) With the responsiveness, the indicator must detect environmental, social, or economic changes in a timely way. (b) With the specificity, the cause-effect relationship must be primarily responsive to human activity and show low responsiveness to other causes of change. (c). The accuracy of the indicator depends on whether the results are consistent for the port management plans when the indicator is used. (d). The indicator represented through data should be based on existing international, historically available time-series of data to allow realistic objectives to be set. The maximum scores by considering quality criteria responsive will be chosen as KPI.

2.1.2. Description of the port and port-city long-term plan (Step II)

In step II, the descriptions of the port, port-city and transportation long-term plans will be interpreted and analysed to compare the expressed ambitions to what has been realised in practice during the time period considered in the long-term port plan. If port plan data are not available this has been considered an indication for this topic not being a focus point for the port, which is reflected in a relative low sustainability score. From the port and port–city plan of the selected ports we have collected and inventorized: aggregated potential effects, data availability and impacts (including the environmental consequences), climate robustness, (physio) chemical exposure, social impacts, energy use, and port operational performances. Professionals from different academic disciplines (e.g. port engineers, economist, governance expert and marine biologists) have contributed to the discussions of the integrated evidence-based knowledge in the context of sustainability measures. They were chosen based on their experience (a minimum track record of 10 years) and their ability to deal with integrating evidence across disciplines. This ensured that they were able to assess a

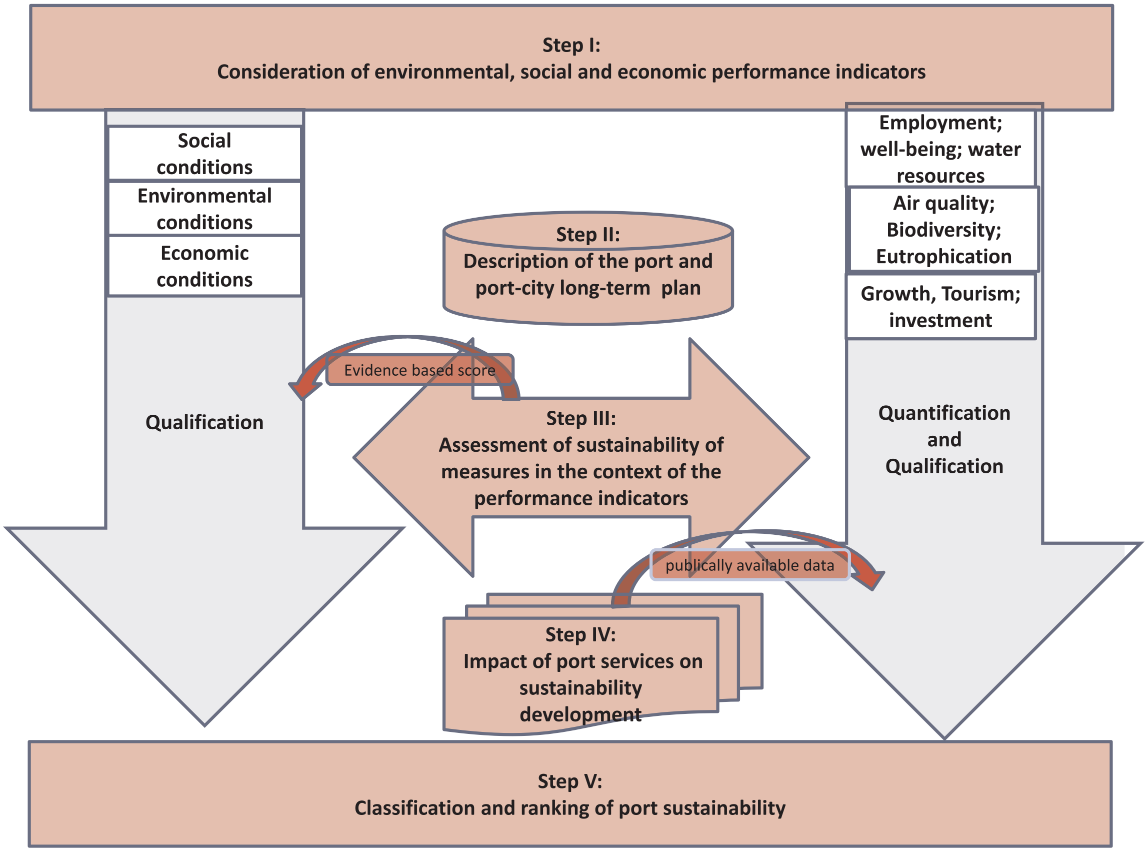

Fig. 1. The port assessment method has been developed for considering sustainability key performance indicators in port plans (Step I and II), by comparing the qualitative description of the sustainability in port and port-city long-term plans (Step III), with the sustainability assessment of publically available data from comprehensive studies in the port-city integration. (Step IV). The impact of port services on sustainability development expresses the sustainability conditions in classes in order to form synergies with the overall objectives of sustainable port development (Step V).
Source: own elaboration

wide variety of data and research results, supported by technical and societal interpretations. Such iterative interactions enabled experts to understand and evaluate key decision-making approaches.

2.1.3. Assessment of sustainability of measures in the context of the performance indicators (Step III)

In step III, a port plan comparison is made using KPI's. The main criterion for selecting KPIs for this analysis is to describe the consequences of the implementation of possible measures on each of the PPP categories as realistically and comprehensively as possible based on expert judgement. All measures which tackle problems are connected with a range of selected KPIs that can be used for broad impact assessment, which are divided into the follow subsets:

- Social indicators: Climate change protection, employment, well-being;
- Environmental indicators: Greenhouse gas; eutrophication, air quality;
- Economic growth indicators: Port cargo growth, investment, and tourism.

Using Evidence-Based Knowledge scores (Table 3) the assessment of long-term port plans are converted using Performance Indicator (PI) values to weigh the impacts of the measure. The total sum of the sustainable social- (SCSM), environmental- (EVSM), and economic- (ECSM) sustainable measures scores are expressed as a Sustainable Integrated Condition Index (SICI). The Sustainable Integrated Condition Index (SICI) quotient is derived for each maximum KPI measure score according to:

$$\mathrm{SICI} = \frac{\sum(\mathrm{PI1}+\mathrm{PI2}+\mathrm{PI3})SCSM = \sum(\mathrm{PI1}+\mathrm{PI2}+\mathrm{PI3}+)ECSM + \sum(\mathrm{PI1}+\mathrm{PI2}+\mathrm{PI3})EVSM}{\sum[\mathrm{SCSM}(1,2,3)\max+\mathrm{ECSM}(1,2,3)\max+\mathrm{EVSM}(1,2,3)\max)]*100} \quad (1)$$

The SCSM, EVSM, and ECSM measures scores are linearly standardized on a scale from 0 to a maximum of 100 points, so the SICI can reach a theoretical maximum of 300 points.

2.1.4. Impact of port services on sustainability development (Step IV)

In step IV, the impact of port services on sustainability development has been analysed by using publically available data from comprehensive studies on processes in the port-city integration. The information used for each KPI is based on location-specific information accessible from global databases, generic standardized data, and compliance of regulations and guidelines. The comprehensive port-city data will be used as Port Data Performance Indicator (PDPI) values to weight the impacts of the Sustainable Measures (SMs) (example Table 7). The total sum of the sustainable social- (SCSM), environmental (EVSM) and economic (ECSM) measures score is expressed as the Sustainable Integrated Condition Index (SICI) quotient were derived for each maximum PDPI measure score according to:

$$\text{SICI} = \frac{\sum(\text{PDPI1} + \text{PDPI2} + \text{PDPI3})SCSM = \sum(\text{PDPI1} + \text{PDPI2} + \text{PDPI3} + \text{PDPI4})ECSM + \sum(\text{PPDI1} + \text{PDPI2} + \text{PDPI3})EVSM}{\sum[\text{SCSM}(1,2,3)\text{max}+\text{ECSM}(1,2,3)\text{max}+\text{EVSM}(1,2,3)\text{max})]*100} \quad (2)$$

The output correlation variables from the comprehensive results can be compared with the KPIs to evaluate an array of port services both quantitatively and qualitatively.

2.1.5. Classification and ranking of port sustainability (Step V)

Step V distinguishes the impact of the items included in the long-term port plan on the (eco)system and expresses the sustainability conditions in classes in order to form synergies with the overall objectives of sustainable port development. The assessment classification is presented as the Sustainable Integrated Condition Index (SICI) introduced above, an integrated management requirement, which is evident from goals in the actual sustainable planning of the port. The classification and ranking of each port has been used to gauge the ability of each to achieve sustainability goals for port planning as set out in their port plans. The classification expressed as SICI, have been divided in 4 classes, ranging from the highest most resilient sustainable impact port classification of SICI: 250-300, 200-250, 150-200 and the lowest classification of SICI: 0-150.

2.2. The port assessment methodology used on 10 case studies

The presented port assessment methodology is applied here to several case studies by analysing the master-, long-term port-, port-city- and/or transportation plans of 10 ports and comparing the sustainability ambitions included in those plans (Section 2.1.1) to what has been realised. The studied ports include:

- Port of Antwerp (Port of Antwerp, 2012, 2015; WPCI, 2015a,b) (POA);
- Port of Hamburg (Port of Hamburg, 2012ab) (POH);
- Port of Rotterdam (Port of Rotterdam, 2008) (POR);
- Port of Istanbul (Istanbul Master Plan, 2007; Istanbul Metropolitan Municipality & JICA, 2009; Steele and Shafik, 2010; Karabiyik, 2013; Oguztimur and Canci, 2016) (POI);
- Port of Shanghai (Shanghai, 2002; He, 2012; Port of Shanghai, 2012) (POS);
- Port of Ho Chi Minh City (Socialist Republic of Vietnam, 2009; Port of Ho Chi Minh City, 2013; Brandenburg University, 2013; Morris, 2015) (POC);
- Port of Dar Es Salaam (Dar es Salaam City Council, 2008; World Bank, 2013; Tanzania Ports Authority, 2010, 2016) (POD);
- Port of Los Angeles (Port of Los Angeles, 2013; Los Angeles Department of City Planning, 2014) (POL);
- Port of Melbourne (Melbourne, 2008; Port of Melbourne, 2014) (POM);
- Port of Valparaiso (Port of Valparaiso, 2014) (POV).

We have attempted to retrieve publicly available data from a wide range of geographical locations and of ports of different sizes, to avoid subjectivity in the selection of ports as much as possible. Furthermore, the selected set is used as merely an example, and the method could be applied to other ports and other data could be added when they would become available. These particular ports have been selected for our analysis because : (1) their geographic locations are distributed worldwide; (2) they represent a wide range of port sizes and types; (3) they have plans at modernizing to meet the associated global economic growth; (4) have been developing advanced transportation and have recently extended their port infrastructure facilities and (5) because their port-city plans were readily available online. The relationships between the pressures and (eco)system of the 10 port-cities have been identified and compared with the results of public available data of the selected social, environmental, and economic KPIs of the port assessment methodology. The PPP scoring by KPIs of these sustainable port measures and services will be expressed in 4 categories: (1) port expansion and navigation; (2) coastal protection; (3) environment and governance and (4) green port-city infrastructure.

3. Results

The port assessment methodology applied to ten port case studies.

3.1. Analyses with key performance indicators (Step I)

The process of assigning the KPI values was used in the assessment of the 10 port-city and port plans published in the period

2002–2015 (Table 1). The highest scores for responsive (column A) and specificity (column B) are achieved in the social KPIs employment, well-being, and urbanization. The 5 highest scores for environmental KPIs are: water quality, sediment quality, air quality, ballast water treatment, and emission of greenhouse gasses; the highest 2 economic KPIs are: cargo growth and cruise tourism.

3.2. Description of port and port-city long-term plan (Step II)

In Table 2 we compare the plans of selected ports based on their management plans, port-city activities, port operation, port infrastructure, and port operational management related to the port functions. The case study that is used here to illustrate the method is based on long-term port vision documents. The time period considered in the master plans varied and ranged up to 20 years; some plans did not mention a time period explicitly. The authors found only sparse publicly available data for environmental data such as sediment quality assessment, emissions of emerging compounds, energy consumption, and level of erosion. The social and economic data in port-city area is widely available.

3.3. Assessment of sustainability measures in the context of the performance indicators (Step III)

In Table 3, 22 different sustainable port measures are presented which were selected for the analysis. These are based on social-economic efficiency and sustainable transportation for the port industry, mobility functions, and consideration of the environment.

3.3.1. The level of social dimensions

Table 4 presents the results of the long-term port plan assessment, identifying which port services are required for achieving high scores for sustainability KPIs related to social aspects (social dimension) in 10 urbanized and port areas. The results of the assessment reveals that the long-term port plans of several studied cities and ports were deficient in critical topics such as climate regulation, flooding potential and coastal protection, and public welfare. The master plans of POC and POD are missing a range of information about the social performances KPIs (e.g. employment, public welfare, the level of urbanization, human rights). This may be influenced by a combination of (external) factors such as overall wealth levels, an absence of institutions who's aim is to stimulate social well-being, standardisation of quality management, and regulations. The highest sustainable KPI values are calculated for the ports of Los Angeles, Melbourne, Rotterdam, and Valparaiso, which all score positive across all topics. Moreover these ports provide measures to stimulate well-being (e.g. sustainable growth and green blue program) and support sustainability plans (e.g. emergency management).

3.3.2. The level of environmental dimensions

Table 5 tabulates the results of the long-term port plan assessment in respect to the sustainable environmental dimensions in the port-cities. Sediment management and water quality is often not described in the port and city planning. The port plans of POC and POD are missing a range of information about the KPIs for environmental performances (e.g. sediment quality, ballast water, greenhouse gas regulation, climate regulation, water resources, soil formation, air quality, and water pollution and sediment quality). The highest sustainable impact values with KPI were calculated for sediment and water quality, air quality, and CO_2 emissions in the ports of Port of Los Angeles, Port of Melbourne, and Port of Rotterdam.

3.3.3. The level of port economic growth

Table 6 presents the results of the long-term port plan assessment highlighting sustainable economic dimension in the port-city. It shows high sustainable values in the assessment for all 10 ports. In general, it is clear that the economic port activities and actions are well described. This is to be expected, since this is the core activity of a port and the port is of great importance for the income of a wide range of stakeholders. The highest sustainable KPI values in achieving economic strategic conditions specific for traffic, investment or growth indicators is obtained for Port of Los Angeles, Port of Melbourne, Port of Rotterdam and Port of Shanghai. The lowest sustainable values were found in the master plans of Port of Ho Chi Minh and Port of Dar es Salaam for economic performances accessibility and tourism.

Fig. 2 shows the cumulative Sustainable Integrated Condition Index (SICI) expressed for PPP of the 10 long-term port- and city plans, with the outcome of the social (Table 4), environmental (Table 5) and economic (Table 6) sustainability KPIs. It presents the analyses of the PPP dimensions for the 10 port and port-city long-term vision plans with a low (e.g. POD, POC) to high (e.g. POR, POM, POH) integrated sustainable index values. The port plans of POC and POD are missing a wide range of background information related to the KPIs as applied here. The master plans of POR and POM deliver most of the needed sustainability information and also obtain the highest sustainable values.

The lowest SICI for the social indicators, which is not necessarily because of an extensive approach on those topics but merely the result of limited measures in those plans on other topics such as climate change or flood and coastal protection. The analyses of these plans on economic growth show a high SICI with the performance indicators related to productivity and cargo. This may be caused due to the successfully adaptation of e.g. air pollution technology, aggregated data to inform policies, and high levels of infrastructure planning.

Table 1
Assigning of 21 pre-selected social, environmental and economic key performance indicators (KPI) was used in the assessment of the port plans. The various references pertaining to the development of KPIs tested on responsiveness (Colum A); specificity (Colum B), accuracy (Colum C), and availability of global standardized data (D), on a scale of minimum (−) to maximum (= +) certainty.

Social subindicator	*A*	*B*	*C*	*D*	*Environmental subindicator*	A	B	C	D	*Economic subindicator*	A	B	C	D
Employment (amount of jobs) (OECD, 2013)	+	+	0	+	Water quality; Eutrophication (WRI, 2016)	+	0	+	−	Cargo growth (TEU) (World Shipping Council, 2014)	+	+	0	+
Well-being (human rights, education) (Bertelsmann, 2014)	+	+	+	+	Biodiversity loss of abundance and on biotopes (Firestone and Corbett, 2006)	0	0	−	−	Cruise tourism (amount of passengers) (EUROSTAT, 2016)	0	+	0	+
Climate robustness (IPCC, 2014)	+	+	0	−	Air quality (PM10) (AQICN,2016; Maigret, 2014)	+	+	+	+	Investment; Fisheries, benefit, market share (Guler, 2003)	0	0	−	−
Urbanization (UN, 2012a)	+	+	+	0	Habitat destruction; loss of benthos; sand extraction (Maes and Schrijvers, 2005)	−	+	0	−	Traffic: railways, RoRo traffic, seagoings vessels (Lam and Notteboom, 2012)	+	+	0	−
Safety against flood (Hiranandani, 2012)	+	+	−	0	Emission of greenhouse gasses (tCO_2e) (CDIAC, 2013)	+	+	+	+	Hinterland connection (De Langen and Pallis, 2007)	−	−	−	−
					Energy consumption (Kumar et al., 2017)	0	+	+	−	Quality of handling (Borsodi, 2015).	−	−	−	−
					Erosion, sedimentation, maintenance dredging (EPA, 2014)	−	−	−	−					
					Sediment quality (Alvarez Guerra et al., 2007)	+	+	+	−					
					Water purification (per m^3 per capital) (Henze et al., 2008)	0	−	−	+					
					Ballast water treatment (Firestone and Corbett, 2006)	+	+	+	−					

Table 2
Description of port and port-city long-term plans based on their management plans, port-city vision activities, port operation plan, port infrastructure, and/or port operational management related to the port functions of 10 port-cities, respectively Port of Antwerp (POA), Port of Dar es Salaam (POD), Port of Hamburg (POH), Port of Ho Chi Minh (POC), Port of Istanbul (POI), Port of Los Angeles (POL), Port of Melbourne (POM), Port of Rotterdam (POR), Port of Shanghai (POS), and Port of Valparaiso (POV).

Port City activities and plan	POA	POD	POH	POC	POI	POL	POM	POR	POS	POV
Metropolis and mainport	+	+	+	+	+	+	+	+	+	+
City inhabitants (*1000) in 2014 (Source: WHO, 2014)	990	4838	1822	7100	13,954	12,308	4151	993	22,991	902
Expected city inhabitants (*1000) in 2030 (Source WHO, 2014)	1068	10,760	1906	10,200	16,694	13,257	5071	1077	30,751	1029
Long term strategic vision present (considered time interval/ target year)	2030–2050	Transportation Policy and Master Plan 2030	2012–2025	Master Plan 2030	No	City Plan, Mobility Plan 2035	City Plan	2011–2030	2001–2020	No
Environmental- & climate protection plans and Special Protection Areas	Natura 2000	Legally protected coral reef and associated marine habitats	Climate Protection Master Plan	Management of environmental protection	Environmental Plan for urban development and transportation infrastructure	California Coastal Act	PoMC's Asset Management and Environment Policy	Rotterdam Climate Initiative and Port Vision 2030	Shanghai environment protection and greening project	Safety and health management system
(Eco)tourism stimulation	No known ecotourism, cruise terminal	National Tourism Policy	Ecological City Port	Ecotourism available	Preservation and utilization of natural tourism resources	LA waterfront and Clean marina program and Wilmington Marinas Planning Study	Tourism Industry Strategic Plan	Promoting Eco-sustainable tourism	Improving environment of the Old City	Stimulation of tourism recognition (UNESCO world heritage)
Port operation and infrastructure										
Sustainable port management aspects included in Master Plans	+	+	+ (EcoPort)[a]	–	–	+	+	+ (EcoPort)[a]	+	+ (ISO 14001, and Carbon Footprint Measurement Certifications)
Maritime Transport corridors/ network	Trans-European	SAGCOT	Trans-European	Transport Network Master Plan; Regional hub port	International hub port in cooperation with State Planning Organization on the logistics activities	Transport Network Master Plan;	PoM was established under the Port Management Act and the Transport Integration Act	Trans-European	Not known	Trans-Panama

(continued on next page)

Table 2 *(continued)*

Port City activities and plan	POA	POD	POH	POC	POI	POL	POM	POR	POS	POV
Road and railway development planning	+	Data gaps identified; Railway needed modernizing	+	+	+	+	+	+	+	+
Seaward port expansion planned	No	Construction of new multipurpose berth	+	+	+	+	+	+	+	+
Quay-side power (cruise) vessels (Onshore Power Supply/ OPS)	Yes	No	Yes	No	Yes	Yes	No	Yes	Yes	No
LNG terminal	Yes	No	No	No	No	No	No	Yes	No	No
Water and sediment management										
- Water resources (water consumption by service zone)	Integrated Water management	Increased demand on limited water resources has impact of high magnitude	Integrated Water management	Water Resources and groundwater Management	ND	Water Resources and Coastal Act	Integrated Water management	No impact	Yes, city	ND
-Sediment management	+	+	+	+	+	+	+	+	+	+
-Waste management	+	± waste water management	+	Waste water Reuse	+	+	+	+	+	+

[a] ESPO accreditation.

Table 3
Selected 22 sustainable port measures for the analysis are based on social-economic efficiency, sustainable transportation for the port industry, and consideration of the environment. Using evidence-based knowledge scores the assessment of long-term port plans are converted using Performance Indicator (PI) values to weigh the impacts of the measure. The measures have a performance range from −5, meaning a very strong negative effect, 0 no effect, to +5, meaning a very strong positive effect.

			Sustainability sub-indicators								
		Total Sustainable Measure (SM)	Social			Environmental			Economic		
Sustainable Port measures and services in port-cities	Effect of measure		Climate change and sea level protection Safety against flooding	Employment	Human rights, well-being, education,	Greenhouse gas reduction	Biodiversity loss of functions; Eutrofication	Air quality	Port cargo growth	Investments, fisheries, benefit, market share	Tourism
Port expansion and navigation											
Water purification and waste water treatment	Effect of contaminant removal efficiency for aerobic and anaerobic treatment (Henze et al., 2008)	8	1	2	−2	−1	−1	−1	5	2	3
Accessibility maritime traffic	Provide economic benefits for the port, while the environmental impact is expected to be minimal, and social is mitigated (Hricko, 2012)	6	1	4	−5	0	0	0	5	0	1
Investment; Benefit area productivity	Increase in the port capacity, leading to an increase in economic growth, employment and lead to social benefits for (Sullivan, 2014)	6	3	5	3	−5	−5	−3	5	0	3
Sedimentation in port basins and channels	Negative effect for environment, while effective navigability of ships may lead to a positive effect for economic growth and increased employment	12	1	5	2	−2	−1	0	5	1	1
Port economic growth; Cargo tonnage	Smaller ships will have limited cargo capacity and, is expected to negatively influence the values of employment (Kosciolek, 2014)	1	1	−2	1	1	1	1	−2	0	0
Urbanization	Increase the employment opportunities in the port city area, leading to a positive effect on social aspect and to growth as well (European Commission, 2012)	9	0	3	2	−1	0	−1	5	−2	3
Coastal protection											
Flood protection	Negative effects to environment and growth is eliminated, while this system provides reliable protection against flooding (Linham, 2014)	3	3	0	0	0	0	0	0	0	0

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Table 3 *(continued)*

Sustainable Port measures and services in port-cities	Effect of measure	Total Sustainable Measure (SM)	Sustainability sub-indicators								
			Social			Environmental			Economic		
			Climate change and sea level protection Safety against flooding	Employment	Human rights, well-being, education,	Greenhouse gas reduction	Biodiversity loss of functions; Eutrofication	Air quality	Port cargo growth	Investments, fisheries, benefit, market share	Tourism
Coastal protection	Improves the city's defence against floods, while the improved coastline is expected to attract more tourists and increase the tourism industry's growth (Bishop and Peterson, 2005)	3	2	0	1	−1	−1	0	0	0	2
Contaminated dredged material,	Reused purposes raw material for various construction products (Van Maren et al., 2015)	4	2	0	1	−1	0	−1	2	0	1
Biodiversity	To promote biodiversity, mangroves, to improve the water quality and to contribute in protecting the hinterland from flooding events, what leads to increase of prosperity (Narayan et al., 2016)	21	2	1	3	5	4	3	0	2	1
Environment and governance											
Preventing invasive species	Eliminate the transfer of harmful aquatic organisms and pathogens, while they can disrupt fisheries (Noble, 2015)	12	0	0	0	2	5	0	1	2	2
Renewable energy	Effect will be clearly positive due to producing clean energy. It will generate economic growth, while the effect on society is neutral (Maehlum, 2015)	6	0	1	0	1	1	1	1	0	1
Well-being	Positive effect om safety and health of citizens (OSH, 2004)	7	0	1	2	1	0	1	2	0	0
Loss of ecosystem functions by water pollution	Effect on reducing water pollution and ultimately re-using the purified water and shows improvement of the everyday life (UN, 2012b)	23	0	3	5	3	3	5	1	2	1
Greenhouse gas reduction (ESI)	Improved air quality leads to a positive score for well-being. Voluntary nature, remarkable compliance rates and environmental benefits have been observed (WPCI, 2015a)	8	0	0	2	1	1	2	2	1	0
Greenhousegas	Eliminating negative side effects	8	0	1	2	1	0	0	2	1	0

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Table 3 *(continued)*

Sustainable Port measures and services in port-cities	Effect of measure	Total Sustainable Measure (SM)	Sustainability sub-indicators								
			Social			Environmental			Economic		
			Climate change and sea level protection Safety against flooding	Employment	Human rights, well-being, education,	Greenhouse gas reduction	Biodiversity loss of functions; Eutrofication	Air quality	Port cargo growth	Investments, fisheries, benefit, market share	Tourism
reduction (OPS)	such as emissions and noise, leading to a positive effect for society and environment (WPCI, 2015b)										
Habitats	Will enhance the water retention and therefore also the safety against flooding and will attract more tourism (Bracke et al., 2007)	12	1	1	1	2	2	1	0	2	2
Air Pollution limits	Emission reductions lead to the effect on society and environment will be positive (IMO, 2005)	6	0	2	2	1	0	2	−2	1	0
Green port city Infrastructure											
Quality of handling; operational performance	Reduction credits, expected to reduce emissions and waste, on air ports has stimulated low emission programmes (EPA, 2014)	11	0	3	3	−2	−0	0	4	0	3
Tourism	Ecotourism and cruise shipping benefit on increased focus on the environment, promotes a slightly positive score for planet, as both habitats and biodiversity will benefit (TPWD, 2015)	13	0	3	3	1	1	0	1	0	4
Jobmarket	Lead to a high score for people, while the proper disposal of the wastewater contributes to keeping the water quality high (USAID, 2014)	9	0	0	5	0	0	4	0	0	0
Climate change and sea level rise;	Safety against flooding leads to a positive score for people, while this natural area can serve as habitat for various species and improve biodiversity, leading to a slightly positive score for planet (Cambridge City Council, 2015)	8	2	0	0	2	2	1	0	1	0

Table 4
Assessment of long-term port-city plan with measures of port services in achieving sustainable **social dimension** related to port function. The Potential Impact (PI) values shows the level of sustainable port-city development. For the abbreviation of the port, see Table 2.

Port services in port cities	Example of Sustainable measure	Social performance sub-indicators	Social Sustainable Measure score (SCSM)	POA	POD	POH	POC	POI	POL	POM	POR	POS	POV
Climate regulation, adaptation to storms and river discharges	Sand nourishment	Climate robustness	8	Energy & Climate working group. No plan (PI:0)	1992 Convention on Climate Change. However no climate risk assessment plan (PI: 0)	LNG concept; Climate Protection Master Plan Expect stronger tidal and sediment Dynamics (PI: 8)	City Action Plan to Response to Climate Change, which is part of the National Target Program (PI: 8)	No plan Regulation reduce greenhouse gas emissions of the Europe 2020 strategy (PI: 0)	Greenhouse Gas Emission Tracking Program Citywide Climate Action Plan and the Climate Action Registry (PI: 8)	Asset Management and Environment Policy Plan (PI: 8)	Environmental management system; Sustainable port design; Rotterdam Climate Change Adaptation Strategy, Port Vision 2030 (PI :8)	Shanghai is threatened by fast-rising sea levels. No plan (PI:0)	WPCI and Carbon Footprint Measurement Certification. Program on reduce energy consumption (PI: 8)
Flood and Coastal protection	Storm surge barrier	Higher potential damage of floods	6	Sustainability report (PI: 6)	No climate risk assessment in Plan; Flooding of upper Gerezani Creek area (PI: 0)	Flood aid programme (Hamburg Bürgerschaftsdrucksache 18/6206 (PI: 6)	Guidelines for Climate change (Brandenburg University, 2013) (PI: 6)	Not particularly earthquake-resistant and no plan (PI: 0)	Los Angeles River Revitalization Master Plan (2007); California Coastal Act Section (PI: 6)	Victorian Coastal Strategy 2002; Flood-plain plans are prepared by waterway management authorities (PI: 6)	Climate adaptive measures in the city and port (PI: 6)	None info available (PI: 0)	Sustainability Report, (PI: 6)
Job market	Attract investors	Employment	9	Employment Sustainability report (PI: 9)	Employment (PI: 0)	Employment National Port Concept; (PI: 9)	Employment (PI: 0)	Efficiency, sustainability, creation of new jobs (PI: 9)	Employment (PI: 9)	Melbourne Planning for Sustainble growth (PI: 9)	Stimulation new jobs in the 'green-blue' economy and delta technology sectors (PI: 9)	Shanghai Master Plan (PI: 9)	Employment included ISO 26000 Diagnosis with regard to Social Responsibility (PI: 9)
Public welfare	Additional safety rules	Human rights, well-being, education, injures, prevention of health.	7	International ship and port facility security code (PI: 7)	Uncertain political stability in the landlocked countries (PI: 0)	Implementation of National Port Concept; (PI: 7)	Initiatives in rural water supply, sanitation as part of the National Target Program. Not mentioned in urban and port management	Bureaucracy and inefficiencies (PI: 0)	Los Angeles Department of City Planning (PI: 7)	Melbourne Planning for Sustainble growth (PI: 7)	Climate change adaptation contributes to a comfortable, pleasant and attractive (PI: 7)	Shanghai Master Plan (PI: 7)	Safety and health management system and offers social training (PI: 7)

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Table 4 *(continued)*

Port services in port cities	Example of Sustainable measure	Social performance sub-indicators	Social Sustainable Measure score (SCSM)	POA	POD	POH	POC	POI	POL	POM	POR	POS	POV
Urban and cultural values, urbanization	Sanitation	Accessibility of the market and the availability of territory and governance	9	Promoting accessibility and leisure Attractivenes-s (PI: 9)	Promoting ecological City Port; No decommis-sioning plan (PI: 0)	Promoting accessibility and leisure Attractivenes-s (PI: 9)	plans (PI: 3) Basic Support. Encourage people to build and use latrines hygiene (PI: 5)	Istanbul Master Plan (PI: 9)	Promoting accessibility and leisure Attractivenes-s (PI: 9)	Melbourne Planning for Sustainble growth'; Victorian Coastal Strategy 2002 (PI: 9)	Promoting accessibility and leisure Attractivenes-s (PI: 9)	Shanghai Master Plan (PI: 9)	Promoting accessi-bility and leisure Attractive-ness building "Puerto Baron" (PI: 9)
Sewage treatment	Water retention	Regulation Water pollution	8	Integrated Water Policy Degree (PI: 8)	Water Resource Management Act (PI: 8)	ARGE Elbe classification; Plant to mechanically separate port sediments and dewater dredged material (PI: 8)	No strategic environ-mental impact assessment report. However water treatment, water supply and sanitation plans as part of the National Target Program. (PI: 4)	Environment-al Plan (PI: 8)	California Coastal Act (PI: 8)	Melbourne Port Emergency Management Plan (PI: 8)	Integrated Water Act (PI: 8)	Environment-al Protection Law of People's Republic of China; Guidelines for Environment-al Management of Construction Projects (PI: 8)	Safety and health manage-ment system (PI: 8)
Maximal Social Sustainable Measure score			47	39	8	47	26	26	47	47	47	33	47

ESI = Environmental Ship Index; LNG = Liquid natural gas in shipping; AQM = Air Quality Management.

Table 5
Assessment of long-term port-city plans with measures in achieving sustainable **environmental- dimension**, related to port functions. For the abbreviation of the port, see Table 2.

Port services in port cities	Example of Sustainable measure	Environmental performance indicators	Environmental Sustainable Measure score (EVSM)	POA	POD	POH	POC	POI	POL	POM	POR	POS	POV
Air filtering by parks, forest, cultivated land	Pollution limits	Air quality [NOx/SOx/PM10]	6	ESI, LNG, AQM, Flemish Environment Agency air quality monitoring (PI: 6)	Working Environment Convention (No. 148) (PI: 6)	IMO initiatives; SECA regulation; Sulphur emission control Area (PI: 6)	No strategic environmental impact assessment (PI: 0)	None (PI: 0)	California Coastal Act; Clean Air Action Plan (PI: 6)	Guidelines port sagety and environment management plans (PI: 6)	ESI, LNG, AQM (PI: 6)	Air pollution management (PI: 6)	Air pollution management; dedicated road infrastructure (PI: 6)
Predict the behaviour of sensitive ecosystems	Reuse dredged material	Sediment quality	4	SQ mapping in docks (PI: 4)	Water Resource Management Act (PI: 0)	ARGE Elbe classification (PI: 4)	No strategic environmental impact assessment (PI: 0)	Black Sea Strategic Action Plan (PI: 4)	Diking, Filling, and Dredging of Water Areas (California Coastal Act (PI: 4)	Guidelines port sagety and environment management plans (PI: 4)	Sediment assessment (PI: 4)	Guidelines for Environmental Management (PI: 4)	No information (PI: 0)
Marine biodiversity as resources	Preventing invasive species	Ballast water treatment to prevent invasive species	12	IMO regulation No mentioned in Plan (PI: 0)	No regulation; Outbreaks of Crown-of-Thorns starfish (COTS) and harmful algal blooms (PI: 0)	IMO regulation No mentioned in Plan (PI: 0)	No regulation (PI: 0)	Black Sea Strategic Action Plan No mentioned in Plan (PI: 0)	Implementation of Clean Air Action Plan (CAAP); California Coastal Act (PI: 12)	IMO regulation; EPA Ballast water management (PI: 12)	IMO regulation No mentioned in Plan (PI: 0)	No info available (PI: 0)	No information (PI: 0)
Ecosystem health to prevent global warming	Renewable energy	Energy consumption	6	Energy efficiency program (PI: 6)	Environmental Management System (EMS) compatible t ISO 14001 (PI: 6)	Environmental protection management practised in 2025 (PI: 6)	No strategic environmental impact assessment (PI: 0)	None (PI: 0)	Renewable energy program; California Coastal Act (PI: 6)	Melbourne 2030, A greener city (PI: 6)	Port clustering, wind turbines (PI: 6)	Urban Energy Restructuring Strategy (PI: 6)	Carbon Footprint Measurement Certification consistent (PI: 6)
Climate regulation	EIS + OPS	Emission of Greenhouse gases World Ports Climate Initiative (WPCI) with Environmental Shipping Index (ESI); Onshore Power Supply (OPS)	16	WPCI, +OPS, +ESI, greenhouse gases monitoring (PI: 16)	Reduction of CO_2 Vehicular Emission Loading; Increase of air pollution, No OPS No ESI (PI: 0)	WPCI, +OPS, No ESI (PI: 9)	No strategic environmental impact assessment, No OPS No ESI (PI: 0)	Black Sea Strategic Action Plan, +OPS, No ESI (PI: 9)	Greenhouse Gas Emission Tracking Program +OPS, +ESI (PI: 6)	WPCI and Safety and Environment Management Plan, A greener city; no OPS, no ESI (PI: 9)	Rotterdam Climate initiative WPCI, +OPS, + ESI (PI: 16)	WPCI No known OPS, ESI (PI: 9)	WPCI, No OPS, No ESI (PI: 0)

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Table 5 *(continued)*

Port services in port cities	Example of Sustainable measure	Environmental performance indicators	Environmental Sustainable Measure score (EVSM)	POA	POD	POH	POC	POI	POL	POM	POR	POS	POV
Micro climate regulation	Habitat compensation	Habitat destruction, loss of benthos, sand extraction	12	Network of naturally plans, call for action COP 21 against climate change	Need for protection of sensitive habitats e.g. mangroves, coral reefs and sand banks; Beach erosion (PI: 0)	Areas of Special Conservation Interest within the scope of the Natura 2000 network (PI: 0)	No strategic environmental impact assessment (PI: 0)	Black Sea Strategic Action Plan (PI: 12)	Green infrastructure and low impact development to improve habitat quality; California Coastal Act (PI: 12)	Safety and Environment Management Plan (PI: 12)	Sand extraction (PI: 12)	Environmental Management Plan (PI: 12)	No information (PI: 0)
Water resources	Water treatment	Water quality	23	Integrated Water Policy Degree (PI: 23)	Need for Protection of sensitive habitats e.g. mangroves, coral reefs and sand banks (PI: 0)	Areas of Special Conservation Interest; Sustainable development concept to improve the hydromorphological conditions and sediment quality (PI: 23)	No strategic environmental impact assessment (PI: 0)	Black Sea Strategic Action Plan; No specific information in Plan (PI: 13)	California Coastal Act; No specific information in Plan (PI: 13)	Safety and Environment Management Plan (PI: 23)	Integrated Water Act (PI: 23)	Environmental Management Plan (PI: 23)	No information (PI: 0)
Soil formation	dredging	Erosion, sedimentation, maintenance dredging	12	Sediment management; (PI: 12)	Knowledge needed about coast and beach erosion by by adding the effects of climate change (PI: 0)	Relocation of sediments; and mechanically separate port sediments (PI: 12)	Needed planning for improvement of access in channels; deepen waterway (PI: 6)	Black Sea Strategic Action Plan; No specific plan (PI:6)	California Coastal Act Port Policies for maintenance dredging; California Coastal Act (PI: 12)	Safety and Environment Management Plan (PI: 12)	Integrated Water Act (PI: 12)	Environmental Management Plan (PI: 12)	No information (PI: 0)
Stability in dynamic ecosystems	Artificial mangroves	Biodiversity loss of abundance and on biotopes	21	Nature conservation, MPAs; Natura2000 (PI: 21)	The National Water Policy, 2002 (PI: 21)	Nature conservation, MPAs; Natura2000 (PI: 21)	No strategic environmental impact assessment (PI: 0)	Black Sea Strategic Action Plan (PI: 21)	Biological resource Management Program (PI: 21)	Safety and Environment Management Plan (PI: 21)	Nature compensation (PI: 21)	Environmental Management Plan (PI: 21)	No information (PI: 0)
Maximal Environmental Sustainable Measure score			112	94	30	92	6	69	102	105	105	93	21

ESI = Environmental Ship Index; LNG = Liquid natural gas in shipping; AQM = Air Quality Management; Onshore Power Supply (OPS).

Table 6
Assessment of long-term port-city plans with measures in achieving sustainable **economic dimension** related to port functions. Tor the abbreviation of the port, see Table 2.

Port services in port cities	Example of Sustainable measure	Economic performance indicators	Economic Sustainable Measure score (ECSM)	POA	POD	POH	POC	POI	POL	POM	POR	POS	POV
Accessibility	Inland expansion	Traffic: railways, RoRo traffic, seagoing vessels, Hinterland connection, modal split (PO12)	7	No limitations, monitoring traffic congestion density, Improving the infrastructure and sustainable modes (PI: 7)	Limitations in operational efficiency at the quay and lack of storage space, lengthening the time required to unload (PI: 0)	Improve and mitigate the accessibility (PI: 3)	Need break-throughs in moderniza-tion in uninterrupted connection between seaports and national traffic network (PI: 4)	No limitations (PI: 7)	No limitations (PI: 7)	No limitations (PI: 7)	No limitations (PI: 7)	No limitations (PI: 7)	No limitations (PI: 7)
Area productivity	Land reclamation	Investments, benefit, market share	6	Sustainability report (PI: 6)	Lack of coordination; Need for standard operating procedures, Terminal Operating Systems and Tariff review (PI: 2)	Improved fore see ability, flexibility and cooperation in 2025 (PI: 6)	Improving the socio-economic development, develop the seaport system under an overall and uniform planning (PI: 6)	Encourage the planning and management of the port facilities (PI: 6)	Long-term cargo forecast, demand through 2030 for container, dry bulk, liquid bulk, and general cargo (PI: 6)	PoMC is required under the TIA to carry out its functions consistently with State policies and strategies (PI: 6)	Sustainability report (PI: 6)	Shanhai Master Plan (PI: 6)	Sustainability Report; No master plan (PI: 0)
Growth in landings	Incline in cargo	Port cargo growth	1	8.98 (PI: 1)	0.6 (PI: 1)	9.73 (PI: 1)	6.39 (PI: 1)	3.38 (PI: 1)	8.33 (PI: 1)	2.49 (PI: 1)	12.3 (PI: 1)	35.29 (PI: 1)	0.99 (PI: 1)
Productivity	Optimisation of Inland connection	Quality of handling: inland connection/ air/railway/ water/road	36	Improving operational efficiency, safety, Sustainability report (PI: 36)	Port is underper-forming; Improve flow of traffic on public roads (PI: 6)	Introduction of mobile device infrastructure (PI: 18)	Improving the socio-economic development. renovating and upgrading existing key regional port (PI: 18)	Encourage the planning and management of the port facilities (PI: 18)	California Transportation Plan (2040) on integrated, multimodal transporta-tion system (PI: 36)	Melbourne 2030 plan; Safety and Environment Management Plan (PI: 36)	Sustainability report (PI: 36)	Shanhai Master Plan (PI: 36)	Sustainability Report; No master plan (PI: 6)
Recreation throughput of Passengers	Nature based (eco)tourism	Cruise passengers and tourism	13	Not mentioned in plan of Cruise shipping (PI: 0)	Cruise shipping and eco urban (PI: 13)	Cruise shipping (PI: 13)	Cruise shipping not mentioned in port plan (PI: 0)	Cruise shipping (PI: 13)	Cruise shipping (PI: 13)	Cruise shipping (PI: 13)	Cruise shipping (PI: 13)	Cruise shipping (PI: 13)	Cruise shipping (PI: 13)
Maximal Economic Sustainable Measure score			63	50	22	41	29	45	63	63	63	63	46

ESI = Environmental Ship Index; LNG = Liquid natural gas in shipping; AQM = Air Quality Management.

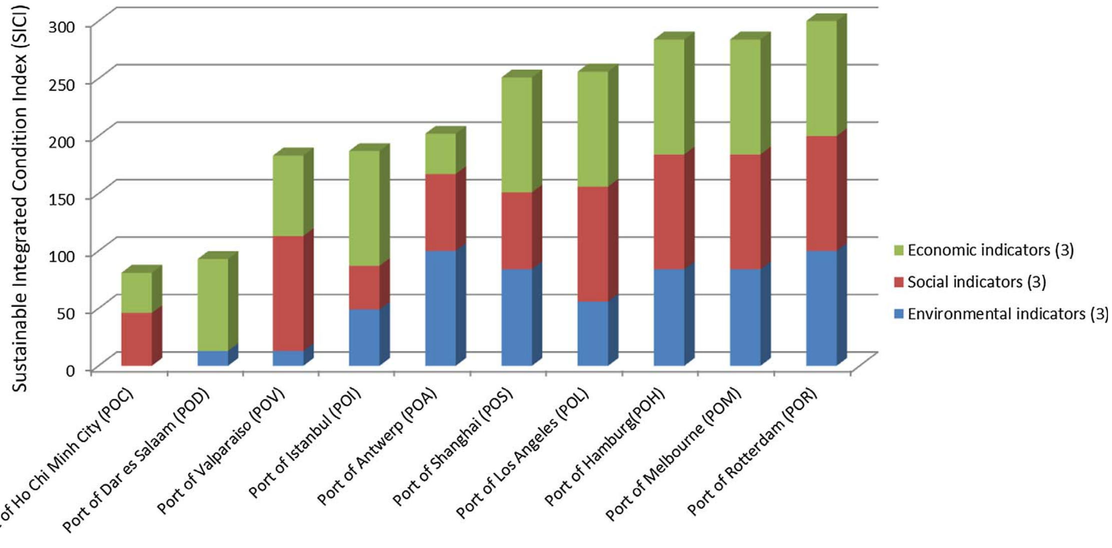

Fig. 2. The assessment of the long-term port plans as a scan of positive or negative impacts with the evidence-based knowledge calculation, expressed as Sustainable Integrated Condition Index (SICI), show low SICI scores for POD and POC based on the used nine KPI's.

3.4. Impact of port services on sustainability development (Step IV)

The impact of port services on sustainability development in the case studies of 10 ports were analysed with public available data respectively for the job market (UNCTAD, 2014; OECD, 2014), the political and policy management expressed as public well-fare (Bertelsmann, 2014), the water quality monitoring- and quantity (Gómez et al., 2015), earth observation for air quality (WHO, 2014; EUROSTAT, 2016) and emissions of greenhouse gasses (CDIAC, 2013), the biodiversity abundance (IUCN, 2004), eutrophication (WRI, 2016), the cargo tonnage (World Shipping Council, 2014), cruise passengers (EUROSTAT, 2016), and area productivity.

Fig. 3 shows the ranking of the impact of pressures in each port amongst all available PPP scores, each score linearly standardized on a scale from 0 to maximal 100 points. The ports POI, POD, and POC show the lowest sustainable growth based on the used KPIs. This may be influenced by a combination of factors such as impact of environmental degradation, limited environmental resources, limited resilience, and limited technological development.

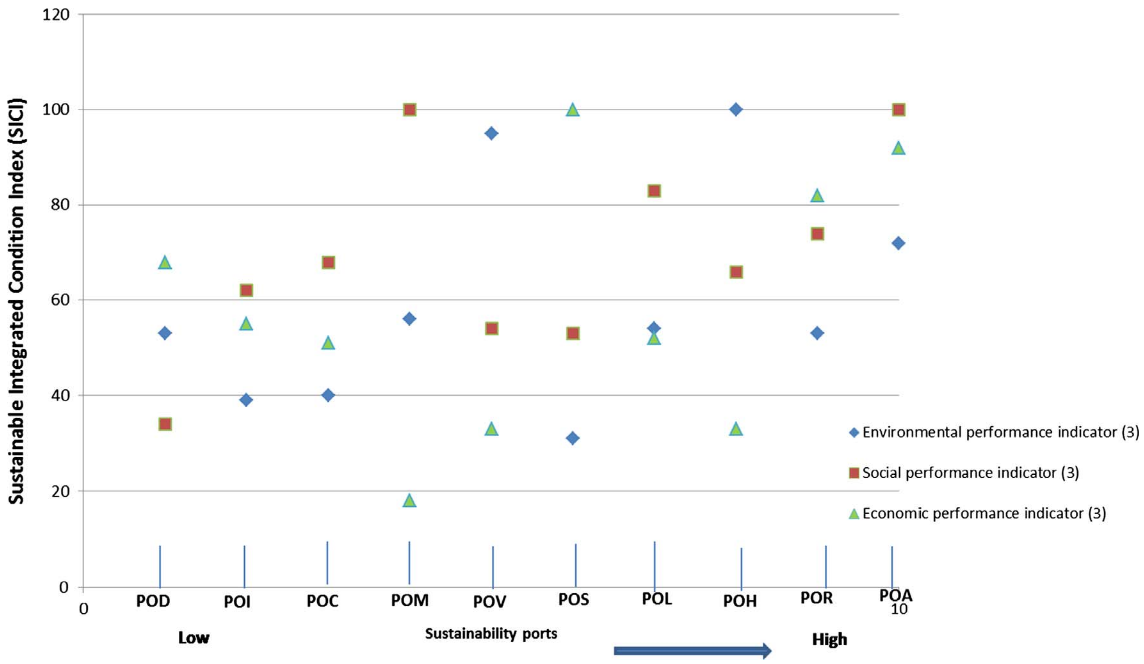

Fig. 3. Impact of port services on sustainability development by ranking the pressures of publically available data in each port expressed as Sustainable Integrated Condition Index (SICI) score, shows for POD, POI and POC the lowest sustainable growth on the used KPI's. For the abbreviation of the port see Table 2.

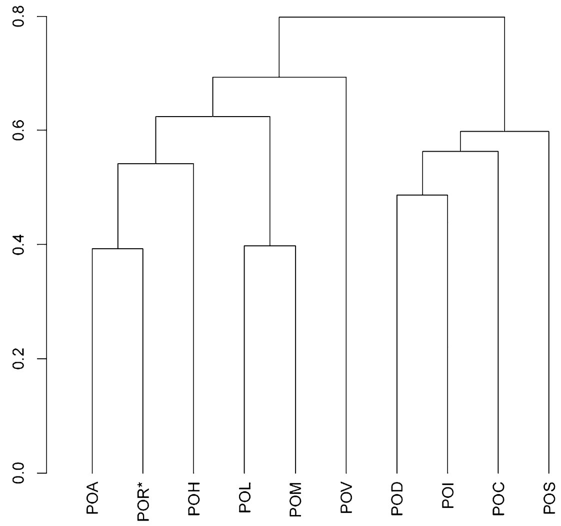

Fig. 4. Dendrogram pattern of different port services on sustainability development expressed as KPI. The clustering shows that of two main conglomerates of ports are distinguished, respectively (POH, POR, POH, POR, POA, POL, POM) and (POS, POD, POC, POI) will enable to highlight the various aspects of sustainable goals within port planning which are being achieved or left by the wayside.

3.5. Classification of port sustainability and ranking (Step V)

For the highest ranking ports (e.g. POA), which obtained a SICI score within the 200–250 range, adaptive resilient port ambitions are evident in their sustainable long-term plans. This may be the result of a combination of maximum environmental urban and city planning, optimum sustainable water management, and successfully limited air emissions and climate change mitigation measures. In the traditional port (SICI: 150-200) the sustainability goals are not yet reached, where the scoring system showed a minimized desirable output (e.g. POM, POS, POL, and POH. The lowest values of SICI (155) was found for port of POD.

3.6. Hierarchical conglomerate analysis of ports dendrogram pattern

In Fig. 4 the hierarchical conglomerate analysis is compiled and set out in a dendrogram. A dendrogram is a graphical representation of clustering of samples in a dataset. Such a clustering is based on the different port services on sustainability development expressed as KPI. The graph shows that two main groups are distinguished, respectively (POH, POR, POH, POR, POA, POL, POM) and (POS, POD, POC, POI). Four subgroups of ports are classified as follows: cluster A: POA, POR, POH and POl and POM shows similarity on social dimension with KPI's job; economic dimension TEU; cluster B: POL, POM shows similarity in environmental MPA, air quality; social dimension wellbeing; cluster C POS, POD, POC shows similarity with economic dimension cargo TEU, passenger tourism in combination with environmental dimension MPA, air quality and GHG-CO_2 (Data not shown). Interpreting this clustering we see that the classification for ranking port sustainability will enable to highlight the various aspects of sustainability goals within port planning which are being achieved or left outside the opportunity. Consider air quality, the critical environmental priority in emissions by transport operations, still POI, POC, POS, and POD show high concentration of air pollution, resulting in their very low classification within SICI. This will, in turn, increase the effectiveness and competition of development plans by allowing for the identification of areas where increased sustainable planning is required and allowing for relative comparisons of sustainable plans in order to realize a (competitive) sustainable port policy.

4. Discussion

4.1. Analyses with performance indicators (Step I)

Only a few studies considered the impact of integrated environmental, social as well as economic aspects of sustainability in port management (Asgari et al., 2015; Yap and Lam, 2013). In our study, all dimensions of sustainability were analysed with KPIs which demonstrated valid quality criteria derived for evaluating responsiveness, specificity, and accuracy indicators while retaining utility in the evaluation of port services both quantitatively and qualitatively. Data availability on both social and economic indicators were the most readily available across all plans, however, global exchange of environmental port performance indicator data will be encouraged to add in future long-term port plans. To assess the accuracy there is a need to collect and analyse historical data on such KPIs. This may prove problematic, since standardized data of KPIs collected in ports appears to be lacking or this information is not publically available.

4.2. Description of port and port-city long-term plan case study (step II)

European port authorities consider air quality (including particulate matter) as the most critical environmental priority in emission activities inside ports (OECD, 2011; Maigret, 2014). Ports can indeed have negative air quality effects caused by their infrastructure and related transport activities, including the presence of trucks, vessels, and industrial sectors with air pollution (Bailey and Solomon, 2004; Muller et al., 2015). However, along with facilitating heavy industries, port activities also bring risks related to water quality (De Boer et al., 2001; Bolam et al., 2006; UN, 2007; Aloui-Bejaoui and Afli, 2012), possibly including pollution incidents with oil and grease (Schipper et al., 2009; Grifoll et al., 2011; Hiranandani, 2012). The analysis of the 10 long-term port plans, shows distinctiveness for both social and economic KPIs. To implement sustainable port measures, they should be integrated into a comprehensive effective green port policy as shown in Port of Melbourne. 50% of the urban and port master plans considered here were lacking information about climate regulation (change) or flood and coastal protection. In general there was a lack of availability and standardization of integrated environmental port-city and port information across may sites (e.g. Port of Melbourne). Roh et al. (2016) postulated that ports generally focus primarily on the short-term economic dimension of port development in combination with on-going infrastructure improvement projects.

Evaluating and interpreting the different port and port-city plans underscored that in order to achieve optimisation of port development measures, some port authorities use an integrated port master plan (e.g. Port of Ho Chi Min), however, more frequently a combination of several transport, sustainability-, port- and city plans are used (e.g. Port of Istanbul). Furthermore, there are successful sustainable port cases where even more comprehensive and integral regional plans are developed which consist of a combined port, city-, transport network, and climate change plan (e.g. Port of Antwerp; Port of Hamburg).

4.3. Assessment of sustainability of measures based on evidence-based knowledge in the context of the performance indicators in the master plan (Step III)

The ports' plans focus primarily on economic growth and on measures to stimulate financial investments in high technology. This is understandable, since for ports the activities related to the transportation of cargo forms the primary process (e.g. accessibility maritime traffic, cargo growth and operational performance of cargo handling) and are the main source of economic growth for the port area.

In step III, the assessment is focussing on analysing the long-term port plans as a first scan of positive or negative impacts with the evidence-based knowledge calculation as a desirable output. Since already for some years sustainability is a key aspect, and often a selling point of ports and port developments, one would expect that if such sustainability plans exists for a specific port, that the port authority would have included them in their communications. This made us assume that if not mentioned in these port plans, then such aspects apparently are not considered by the port as key aspects and therefore low scores are ascribed to their sustainability KPIs. However, if new data on these topics become available, the assessment should be updated and could lead to new results. Based on the quality criteria responsiveness, specificity and accuracy, in this study the highest SICI score (e.g. POR, POH, POM and POL) are respectively KPIs for port employment, wellbeing, air quality, greenhouse gas emissions, cargo growth, and cruise tourism. This may be caused by a combination of effective implementation and improvement of management plans (climate adaptation or action plan, environment policy plan), enforcement of the law, and infrastructural safety (e.g. Coastal Act, Water Act, City planning, Transport Master Plan, emission reduction). The optimum impact data for validating the sustainable adaptation of the ecosystem can be used as an incentive, since if sustainable rates increase there should be a relationship on the extent of the (eco)systems. The SICI showed that the scores of some of the ports were not sustainable e.g. POD and POC, there with forming groups of ports with similar basic port plan characteristics related to the evaluated KPIs.

The advanced sustainable port management plans show their focus on social measures to stimulate job growth opportunities, human equality, and integrated port-city planning. The analyses of the long-term port plans show that in some cases no clear sustainable objectives are incorporated into those social aspects. The effective environmental growth of ports focus mostly on the implementation of integrated policy action on green plans and enforcement of environmental law and green infrastructural (climate) adaptation.

4.4. Impact of port services on sustainability development (Step IV)

In step IV, ports which have publically available data sets related to the KPIs in question undergo a comparative analysis between the measured data and simulation outputs resulting from the step III analysis of impacts resulting from system pressures. By applying the combination of both evidence-based knowledge in the context of the long-term plans as well as the simulation result of comprehensive port city data, a port manager would able to evaluate the efficacy of various future strategies. The potential sustainable scenarios based on actual measured data (Table 7) classify the conglomerates of the obtained indicators; the main groups formed in accordance with the clusters of highest sustainable values for POA and POR (Fig. 3). The conglomerates of the main groups formed in accordance with the cluster lowest sustainable values are ports of POD, POI, POS and POC. In the dendrogram, the port clusters show similarity in combination with both economic dimensions as well as with the social or environmental dimension. This confirms the supposition that economic, social, and environmental dimension values are cross-linked, and when optimised together, obtain the highest SICI index. The combination of KPIs to evaluate the integration of economic, environmental and social aspects in the master plan, offer benefit in port plans. The Bertelsmann BTI scores (Bertelsmann, 2014) show the lowest value for Vietnam (POC), China (POS) and Tanzania (POD (4.7–5.5) and highest for Turkey (POI) and Chili (POV) (7.5–8.8). The countries Belgium (POA), USA

Table 7
Impact of port services on sustainability development in case studies of 10 port-cities with comprehensive public available data. For the abbreviation of the port, see Table 2.

Port services	Performance indicator	Unit	POA	POD	POH	POC	POI	POL	POM	POR*	POS	POV
Social												
Job market	Port Employment and metropolitan region	Number of Jobs in port city in 2014 (UNCTAD, 2014; OECD, 2014)	15,0000	2684 (2012)	15,3300 (2013)	1800 (2003)	10,3520	31,0000	13,400	106,100 (2010)	18,338	419
Public welfare	Well-being: democracy, human rights, education, injures, prevention of health	BTI scores* in 2014 (Bertelsmann, 2014)	≥9.5	5.5	≥9.5	4.7	7.5	≥9.5	≥9.5	≥9.5	5.0	8.8
Environmental												
Chronic human health effects by air pollution	Air quality respirable particulate matter (PM10)	Particle Mater (PM10) annual mean concentration, (μg/m^3) (WHO, 2014)	27	35	21	58	53	20	19	24	84	34
Greenhouse gas concentrations in the atmosphere of ports	National per capita estimates http://edgar.jrc.ec.europa.eu/overview.php?v=GHGts_pc1990-2012	(1000 tonnes CO_2/CAP) in city (CDIAC, 2013)	12.06	4.93	11.49	3.42	6.02	19.98	33.04	11.72	9.04	6.91
Biodiversity abundance	http://www.grida.no/wrr/pdf/wrr05_dt10.pdf	Number of IUCN categories marine protected areas number 2004	2	8	40	0	14	399	339	10	41	27
Eutrofication	http://www.wri.org/resources/data-sets/eutrophication-hypoxia-map-data-set	Classification in city (WRI, 2016)	Eutrophic	Eutrophic	Improved	Eutrophic	Eutrophic	Hypoxic	Hypoxic	Hypoxic	Eutrophic	Eutrophic
Water quality	Actual renewable water resources per capita	m^3 per person available (Gómez et al., 2015)	1770	2416	1866	10,805	3171	10,333	24,708	5608	2206	57,639
Economic												
Cargo tonnage	Port economic growth	Million TEU in 2014 in city (World Shipping Council, 2014)	8.98	0.6	9.73	6.39	3.38	8.33	2.49	12.3	35.29	0.99
Total throughput of Passengers	Tourism,	(Eurostat, Annual reports of ports) Number of cruise Passengers in 2014 in city	113.272	707,286	588,690	384,000	689,417	180,000	144,643	114,000	1,204,000	150,000
Area productivity	Investments, fisheries, benefit, market share	Fish Protein as % of animal protein supply per country	8	27	6	29	11	6	7	11	19	9

(POL), Australia (POM) and the Netherlands (POR) do not calculate the BTI score to measure successes and setbacks in relation to the quality of a democracy, market economy, and political management. It shows that when the social dimension is missing in long-term port plans (POD, POI, POS, POC), it may lead to hindrances in the development of port, urban and industrial growth in the region, primarily due to the lack of consideration of the employment opportunities for the local community. To design a port and implement sustainable measures, the combination of port, city, transport or mobility network and climate change plan are necessary to reach an effective green port policy as shown in Port of Melbourne.

4.5. Classification of port sustainability (Step V)

The assessment classification of Step V denotes the advanced sustainable impact port as an adaptive resilient port fulfilling multiple critical requirements as when considering an actual sustainable master plan. This type of plan actively reduces CO_2 emissions or promotes positive trends in employment and wellbeing for the area, while meeting demands on higher utilization rates from cargo shipping and cruise tourism utilizations. In the improved sustainable port the negative impacts with the scoring system would be a score value with a minimized desirable output (e.g. POM, POL, POR and POH) by investment and responsible air-water (Table 8). The mid-low range value of SICI (0-150) show impact on emissions, uncertain job market, low area productivity and possible focus of management on other topics than sustainability, e.g. POC and POD.

To preserve the sustainability goals of port planning, the management and development must be able to compensate for dynamic pressures placed on the system either internally or externally. The presented long-term port plan assessment methodology shows that many of the historically implemented plans (e.g. POH, POL, POS, POV, POM), do not show a potential sustainable scenario based on actual measured data (Table 9). There is not always sufficient quantity and quality of data in order to preform significant analysis of the key indicators when looking at longer historical periods. KPIs do not necessarily reveal the entire situation of a port-city and the used data from local ports from global data bases must be interpreted with care.

The POA showed intensive and sustainable improvements demonstrable through the associated positive effects on environmental processes, social impacts, and economic operational performances as was clearly defined in the plan. On the other hand, while POC and POD did not explicitly include sustainable development goals within their long-term port plans, after submission and implementation of those plans, the ports in practice did demonstrate shifts towards sustainable improvements.

The collaboration of the shipping industry has a positive contribution in performances and competencies in port plan development and helps to enhance port competitiveness (Yang et al., 2013). However, our study has shown imbalances in sustainable investments for worldwide port plan operations. The results of this study indicate that a wide combination of integrated plans, measures, the identification of ecosystem services and emission reduction regulations for sustainable improvement of cities, ports, transport, environment, or climate adaptations are needed to realize a no-(negative) impact port developments.

There is a high need to specify sustainable guidelines (PIANC, 2014b; ESPO, 2016) or on sustainable development in terms of better product quality associated with the port management certification ISO 14001 (Saengsupavanich et al., 2009). Several studies present acceptable indicators to assess and improve their sustainability performances (Antão et al., 2016). In our study we have shown that the combined use of integrated dimensions such as port employment, incline of wellbeing, air quality and greenhouse gas emission reduction, cargo growth and cruise tourism can be used efficiently to demonstrate the sustainable port performances in e.g. Port of Rotterdam and Port of Antwerp. Somewhat older port plans have been considered, the planning period of which has since then already (almost fully) passed. This allows for comparing the plans for the planning period described and the actual situation achieved at the end of that planning period. Discrepancies (plan vs. realisation) are interpreted as goals not achieved, as a signal that those topics may not have received sufficient attention, or that unforeseen circumstances have impeded reaching those goals. By improving master long-term port plans with development goals and linking this with standardized processes and guidelines, the foundations for a more efficient future state is set. The combination of lessons learned with the assessment methodology on the sustainability of port development is valuable for policy-making in regards to wider socio-economic factors and sustainable design. Different methods exist, including serious games (e.g. World Bank, 2012; Van Leeuwen, 2013; Schipper, 2017), to develop a green policy and to teach planners and policy makers in understanding balanced environmental- social and economic choices.

5. Conclusions

The aim of this study was to develop and apply a comparative methodology to assess port long-term management plans on the level of sustainable port and port-city development and to verify the realised impacts related to social, economic, and environmental aspects. The use of relevant and reliable KPIs is valuable to evaluate the long-term port plans. We evaluated a set of port KPIs in order to obtain an improved understanding of the sustainable port management application of data-based results to minimize the long-term risks associated with port operations, costs, and environmental impact management.

We conclude in this study that the presented assessment methodology allows for a retrospective approach to learn from comparing older long-term port and port-city plans to the situation actually achieved within the time span of those plans. The method can cross-link port plans with conditions using the economic, environmental and social data exploration of publicly available data. The establishment of sustainable ports, typically near urban development areas, is useful for optimizing the integration of economic, environmental and social benefits of ports. Based on the evidence-based knowledge in the context of KPIs, this methodology is promising when new local data are available or in case of updated expert judgement. It improves the assessment and comparison of the different port plans by giving a wider view on sustainability by comparing the theoretical long-term port plan values with comprehensive port-city data of the situation actually achieved. Placing a quantitative and objective value on port services is a

Table 8
Sustainble port classification based on the evaluation of the performance indicators in long-term port plans expressed as Sustainable Integrated Condition Index/SICI. For the abbreviation of the port, see Table 2.

Port classification (SICI range)	Characteristics description	Port	Sustainable Integrated Condition Index (SICI) of Port Master Plan	Summarized port-city characteristic based on port management, long-term- or vision port plan
High sustainable port plan (250–300)	Advanced adaptive integrated and multidisciplinary port management; Environmental Protection Plan; Climate change adaptation; Transport mobility plan; Port Master Plan, City Plan, Long term port or city vision; Accreditation e.g. 'Green Port', EcoPort or ISO 14001; Sustainable port vision; Greenhouse and/or air emission reduction; 'Green Energy', 'Green Ship' and + OPS or ESI; Good employment and well being	POR	300	Environmental management system; Strategic vision 2011–2030; Sustainable port design; Rotterdam Climate Change Adaptation Strategy, Port Vision; Promoting green-blue' economy; IMO regulation; sediment management; LNG, WPCI, +OPS, + ESI; Integrated water act; 'EcoPort'
		POH	284	Climate Protection Master Plan; Port Vision 2012–2025; Flood aid programme; Employment National Port Concept; Improve and mitigate the accessibility; Promoting accessibility and leisure Attractiveness; Sulphur air emission control; Environmental protection management; WPCI, +OPS, No ESI; Areas of Special Conservation Interest; Relocation of sediments; Nature conservation, MPAs
		POM	284	Environment Policy Plan; City Plan; Tourism Industry Strategic Plan; Safety and Environment Management Plan; Ballast water plan; IMO Coastal Strategy 2002; Flood-plain plans; Guidelines Port safety; WPCI, A greener city; Transport integration Act
		POL	256	Clean Air Action Plan; Greenhouse Gas Emission Tracking; Climate Action Plan; City Plan, Mobility Plan; Transport Master Plan; Coastal Act; Mobility Plan 2035
Resilient sustainable port plan (200–250)	Integrated and multidisciplinary port management; Sustainable report; Advanced cruise terminal; Accreditation e.g. 'Green Port'; Energy strategy; Sustainable port management; Promoting accessibility; Implementation 'Green Port' plan. Greenhouse and/or air emission reduction; no OPS and/or no ESI; no climate regulation plan	POS	251	City Plan; Environmental Protection Law of People's; Strategic port vision 2001–2020; No climate regulation plan; Guidelines for environmental management; Air pollution management; Urban Energy Restructuring Strategy; WPCI, Not known OPS, not known ESI; Environmental management plan
		POA	202	Sustainability report; Port vision 2030–2050; Employment Sustainability report; Employment Sustainability report; International ship and port facility security code; Promoting accessibility and leisure Attractiveness; Integrated Water Policy Degree; +ESI, LNG, AQM, Flemish Environment Agency air quality monitoring; Energy efficiency program; IMO ballast water program; sediment management; Nature conservation, MPAs; monitoring traffic congestion density; operational efficiency, and safety; No climate regulation plan
Traditional port plan (150–200)	Innovative technological solutions for logistic and cargo shipping; City or Port plan available; Environmental or Sustainability plan; Efficiency of water consumption and control emissions. Basic or no climate action plan; no Green housegas or air emission reduction plan	POI	187	Environmental Plan for urban development and transportation infrastructure; No plan Regulation reduce greenhouse gas emissions; Bureaucracy and inefficiencies; City Master Plan; Environmental Plan; No air quality reduction plan; No greenhouse gas reduction plan; Black Sea Strategic Action Plan; +OPS, No ESI; no climate action plan
		POV	183	Sustainability report; + ISO 14001, and Carbon Footprint Measurement Certifications; Employment included ISO 26000 Diagnosis; Safety and health management system; Promoting accessibility and leisure Attractiveness WPCI, No OPS, No ESI; Air pollution management; Sustainability Report; No master plan
Basic port plan (0–150)	Basic port master plan; Water- and air pollution. Instable well fare, Uncertain job market and disabled area productivity; weak political	POD	93	Transportation Policy and Master Plan; MasterPlan 2030; National Tourism Policy; Convention on Climate Change; Low BTI scores;

(continued on next page)

Table 8 *(continued)*

Port classification (SICI range)	Characteristics description	Port	Sustainable Integrated Condition Index (SICI) of Port Master Plan	Summarized port-city characteristic based on port management, long-term- or vision port plan
	management, moderate water consumption; poor coastal protection; Basic or no climate action plan;			Promoting Ecological city port; Working Environment Convention; Water Resource Management Act; No OPS, No ESI; no air quality reduction plan and no greenhouse gas plan
		POC	81	No strategic environmental impact assessment; Guidelines for climate regulation; National Target Program; Port master Plan; Low BTI scores; City Action Plan; Basic support cultural values; Water Resources and groundwater Management; No Air quality regulation; No OPS, No ESI; No regulation on GHG-CO_2. No cruise passengers policy; Transport Network Master Plan

Table 9
Sustainable port classification based on actual measured public available data of nine PIs expressed as Sustainable Integrated Condition Index (SICI). For the abbreviation of the port, see Table 2.

Port classification SICI range	Classification of the studied worldwide port-cities	Sustainable Integrated Condition Index (SICI) of real port data	Percentage incline (+) or decline (−) based on public available data SICI of PIs compared to the long-term port plan SICI	Sustainble data impact SICI characteristic compared to masterplan
Highest level of sustainable port (250–300)	POA	264	+131	Indicator show contribution of sustainability with renewable water, air emissions, with improvement on related positive effects on environmental, social impacts and economic operational performances
Resilient sustainable port (200–250)	POR	209	−30	Release in reduced CO_2 emissions, positive changes in employment and wellbeing for the area. High extraction rates from cargo growth and cruise tourism
Traditional port (150–200)	POH	199	−30	Port development in combination with environmental dimension; High area productivity; Some cases relative high air quality PM10 concentrations; High cargo tonnage; Relative low number of cruise passengers; River and coastal hypoxia or eutrophic
	POL	189	−17	
	POS	184	−27	
	POV	182	−1	
	POM	174	−39	
	POC	159	+96	Port social dimension is missing, it shows inequality in society based on BSI; Lack of employment opportunities; Relative high air pollution PM10 concentrations; Relative low tonnages GHG-CO_2; Relative high number of cruise passengers
	POI	156	−17	
	POD	155	+67	
Basic port (0–150)	none	0–150	None	–

critical challenge in assessing whether measures are sustainable and efficient. Once this limitation is overcome, the outputs of such an analysis can be used to evaluate an array of a qualitative as a quantitative sustainable port services.

The analyses of the port plans show that in some cases no clear sustainable objectives have been incorporated, however in half of studied ports it was legally recorded. Although maybe not required everywhere, nearly no awareness was found in the plans concerning flood risks and climate robustness. Some ports increase the effectiveness of their development plans to realize a sustainable port policy by implementing the combination of port, urban, transport network, environment, and climate change plans. The results from our set of selected ports indicate that this is an efficient approach, since the ports that have such integrated plans, show the highest scores on many KPIs, although developing an integrated long-term port plan may also merely indicate that developing such plans (and subsequently abiding to it) receives ample attention at those particular port locations. A joint plan is not a guarantee for success, and a separately developed plan does not necessarily mean that there is no wide support for it. Nevertheless, although exceptions may always be possible, the results from our selected group of ports indicated in co-creation a strong positive correlation between their scores on the KPIs and the comprehensiveness of their long-term plans. The assessment classification is applicable to rank the global port performances to contribute to a long-term sustainable economic growth.

Correlating a wide set of environmental, social, and economic parameters, highlighted the heterogeneity, representativeness and applicability of the available data for interpretation. However, the lack of standardized, publicly available environmental data hinders reliable and objective analysis. This pleads for the development of a worldwide standard set of KPIs for ports, which can then be used by ports to formulate long-term plans and for evaluating the progress realised by ports on the three main aspects of People, Planet and Prosperity. It is of large importance that ports worldwide develop and adopt a uniform set of KPIs to assess and develop port operations, wealth, social welfare and sustainability. Only in that way can port plans be developed based on a proper set of optimised KPIs and can plans and results realised be compared directly to the performance of other ports.

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