

# Towards Sustainable Port Development in the Western Indian Ocean

## Toolkit for Sustainable Port Development in a Blue Economy



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# EXECUTIVE SUMMARY

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The port industry faces a growing challenge to address societal and environmental issues while at the same time having to provide adequate capacity and cost-effective services to traders. With increasing societal and regulatory pressures port authorities around the world are compelled to pursue greater sustainability to safeguard their 'license to operate'. In response to these global challenges the concept of 'Green Ports' emerged, primarily focusing on balancing environmental challenges and economic demand, and striving for sustainability through increasing both economic and environmental competitiveness. The concept of 'Sustainable Port Development' builds on that of 'Green Ports' by also considering social sustainability, in essence advocating the need for a port development to create a balance between economic growth, environmental protection, and long-term social progress.

According to the World Bank, sustainable Blue Economy is the *"sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of ocean ecosystem"*. It strives *"to promote economic growth, social inclusion, and the preservation or improvement of livelihoods while at the same time ensuring environmental sustainability of the oceans and coastal areas"*. Aligned with this description, the *Africa Blue Economy Strategy* views the Blue Economy as *"an inclusive and sustainable economy that becomes a significant contributor to continental transformation and growth, through advancing knowledge on marine and aquatic biotechnology, environmental sustainability, the growth of an Africa-wide shipping industry, the development of sea, river and lake transport, the management of fishing activities in these aquatic spaces, and the exploitation and beneficiation of deep sea mineral and other resources"*.

The Western Indian Ocean (WIO) region is experiencing an unprecedented growth in large-scale development, including in ports, mining, roads and railways, agriculture, and oil and gas. Indeed, economic growth and development are inevitable if countries of the WIO region want to address social challenges such as poverty and inequality. Most of these developments are concentrated in coastal areas which support rich natural resources. While the region has an opportunity to define sustainable trajectories for these investments, they also have potential to significantly impact the integrity of critical coastal habitats and the natural resource base that future well-being and growth depend on. In the WIO Region coastal communities are especially reliant on coastal resources for their lives and livelihoods. Considering the rich diversity of coastal and marine ecosystems in the WIO region, and its potential to also contribute to socioeconomic benefits, sustainable Blue Economy growth holds great promise for the area.

Within this context, and complimentary to the *Strategic Framework for Coastal and Marine Water Quality Management in the Western Indian Ocean Region*, this Nairobi Convention project, undertaken on request of the Conference of Parties (CoP), seeks to facilitate sustainable port development in the WIO. It supports the *Implementation of the Strategic Action Programme for the protection of the Western Indian Ocean from land-based sources and activities (WIOSAP)* It is informed by the appreciation that ports intersect with critical coastal and marine resources. It is aligned with the WIO region's vision to grow a sustainable Blue Economy. Scientific outputs generated from this project will be shared with national governments to support and guide development of national policy options on sustainable port development through the Nairobi Convention's Science to Policy Platform.

The science-based output generated from this project will be shared with national governments to support and guide them in the development of national policies for sustainable port development. Further, the outputs will be shared with port developers and operators in the region to support and guide them with the implementation of sustainable port development options. This will be achieved through the Science-to-Policy Platform supported by the Nairobi Convention.

To this end, a series of science-based outputs were prepared as part of this project, including:

- A Situation Assessment, providing the context and backdrop for sustainable port operations and development in the WIO region
- A Scenario Analysis evaluating generic development pathways which range from 'doing-nothing' to options incorporating 'sustainable port' considerations, drawing on information in the Situation Assessment providing context and backdrop for more sustainable port development in the WIO region
- A Toolkit for Sustainable Port Development in a Blue Economy, comprising practical management and operational tools aimed at port operators and managers in the WIO region towards advancing sustainable port planning and operations aligned with international best practice.
- A Policy Brief, capturing proposed recommendations for future sustainable port development in a blue economy in the WIO region.

This report presents the Toolkit for Sustainable Port Development in a Blue Economy.

Key to sustainable ports is acknowledging the multi-use benefits derived from natural capital in ports and their surrounds and bridging the traditional disconnect between natural environmental issues and port planning and development. This requires consideration of the natural environment in the early stages of port planning and design, and not only focusing on environmental performance during operations and maintenance stages, embracing multi-use valuation (ecosystem services) that gives purpose to the need for environmental protection. To assist in practically bridging this disconnect, Taljaard et al. (2021) developed an Integrated Port Management (IPM) framework conceptually positioning and aligning environmental processes within the traditional port development cycle and highlighting the need for coordination and continuity across such environmental processes (Figure 1).

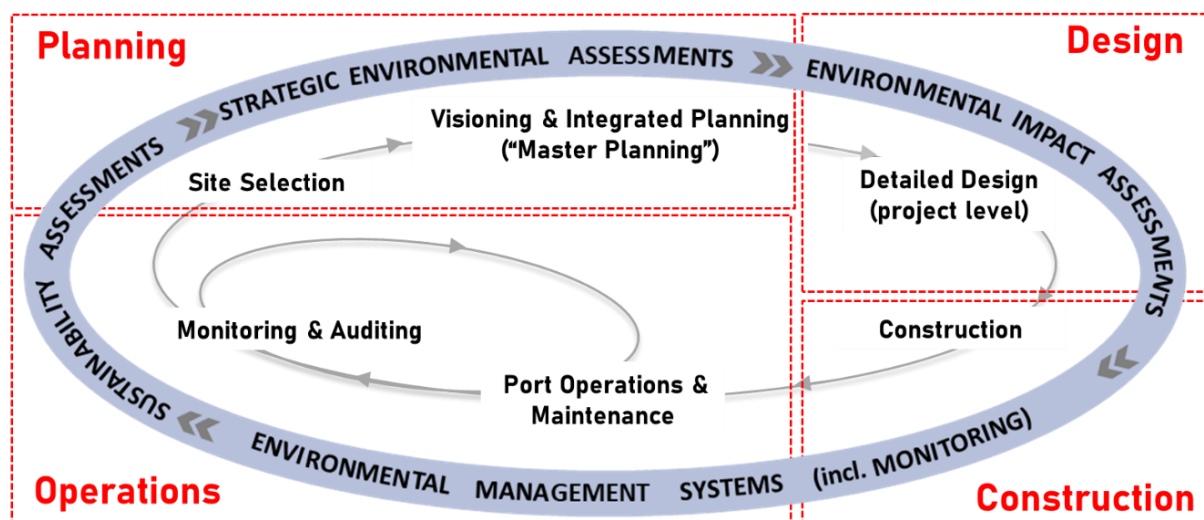


Figure 1: The Integrated Port Management Framework, conceptualizing alignment between the traditional port planning and development cycle, and key environmental assessment and management processes



The traditional development cycle comprises six key sequential stages: site selection, master planning, design, construction, operations, and monitoring, presented in a cyclical, logical order in Figure 1. It recognizes the different time frames in port planning and management in a nested loop arrangement. The larger cycle, involving site selection, planning, design, and construction of new or expansive port infrastructure, representing stages typically occurring at 5-year (or longer) intervals (i.e., longer time scales). The smaller cycle (operations and maintenance and monitoring and auditing) is nested within the larger cycle, and represents stages that occur continuously, on much shorter (i.e., day-to-day) time scales. To effectively address environmental matters in ports, it must be effectively integrated into existing planning and decision-making processes. Therefore, it is important that environmental aspects are proactively aligned and incorporated in all stages of port planning and operation, from the early planning stages through design, construction and into operation. To achieve this, the various environmental processes need to become aligned and integral to traditional port planning and development stages as proposed in the IPM framework.

This Toolkit for Sustainable Port Development in a Blue Economy comprises a selection of practical management and operational tools for port operators and managers in the WIO region to use to advance sustainable port planning and operations in the region, in alignment with international best practice. The tools included in the toolkit were largely distilled from international best practice, but they are applicable and workable in ports of the WIO region. To assist port operators with easy contextualisation of the tools, they have been organised in accordance with the key stages in the IPM framework comprising planning, design, construction, and operations (Figure 1). Table 1 summarises the various tools contained in the Toolkit within each of the four main stages.

Table 1: Structure and content of the Toolkit for Sustainable Port Development

| SECTION         | TOOLS   |
|-----------------|---|
| A: Introduction | A.1 Rationale   |
|                 | A.2 Framework for Integrated Port Management                |
|                 | A.3 Institutional Arrangements                              |
| B: Planning     | B.1 Guidance on Strategic Environmental Assessment          |
|                 | B.2 Site selection and Master Planning                      |
|                 | B.3 Planning for Climate Change                             |
|                 | B.4 Scenario Analysis Tool for Planning                     |
| C: Design       | C.1 Guidance on Environmental Impact Assessment             |
|                 | C.2 Concept of Nature-based Solutions                       |
|                 | C.3 Design for Biodiversity Offsets                         |
|                 | C.4 Building-with-Nature Design Approach                    |
|                 | C.5 Ecological Enhancement Options                          |
| D: Construction | D.1 Construction Environmental Management Plans             |
|                 | D.2 Dredge Management (also relevant in Operations)         |
|                 | D.3 Considerations for Port Decommissioning                 |
| E: Operations   | E.1 Guidance on Environmental Management Systems            |
|                 | E.2 Circular Economy in Ports                               |
|                 | E.3 Examples: Sustainable Port Development Actions          |
|                 | E.4 Securing External Finance for Port Development Projects |
|                 | E.5 Sustainable Use of Materials and Land                   |
|                 | E.6 Energy Efficiency Management                            |
|                 | E.7 Management of Carbon Footprint                          |

| SECTION | TOOLS  |
|---------|--|
|         | E.8 Management of Water Consumption                    |
|         | E.9 Waste Management                                   |
|         | E.10 Ballast Water Management                          |
|         | E.11 Guidance on Sustainable Hull Cleaning             |
|         | E.12 Towards Improving Port Environmental Quality      |
|         | E.13 Ecosystem Restoration                             |
|         | E.14 Marine Litter Clean up Technologies               |
|         | E.15 Oil Spill Contingency Planning                    |
|         | E.16 Environmental Monitoring and Evaluation           |
|         | E.17 Environmental Information Systems                 |
|         | E.18 Effective Capacity Development                    |
|         | E.19 Introduction to Natural Capital Accounting        |
|         | E.20 Sustainability Performance Index (linked to SDGs) |

It may not be practically possible for ports in the WIO region to implement all the tools in this Toolkit at once, due to human and financial resource limitations. However, by committing to a focussed, on-going process towards aligning environmental matters early in port planning and development, and in the operational and maintenance phases as is contextualised in the IPM framework, port operators can incrementally achieve environmental sustainability, implementing key priorities specific to their port environments, supported by the tools in this Toolkit. Ideally, the IPM Framework, as well as the guidance and best practice proposed in this Toolkit should be adopted and embedded in national policies pertaining to sustainable port management, as appropriate.

The execution and sustainability of integrated coastal management depends largely on sound multi-actor institutions and networks to facilitate integration, coordination, and implementation. This also holds for environmental management processes in ports, as conceptualised in the Integrated Port Management Framework (Figure 1). Various port authorities have acknowledged the importance and need for sound and coordinated environmental management by establishing dedicated environmental departments as part of their institutional arrangements. However, empowerment of such departments to implement and enforce sustainable environmental practice, largely relies on political will from governments and corporate commitment from the port authorities themselves through, for example, endorsing sound environmental and social policies and allocation of adequate human and financial resources for effectively implementing these policies. If ports are serious about being environmentally responsible, socially accountable and economically viable (in short, being truly sustainable) such environmental institutional structures must be considered as 'equal partners' with other port institutional structures (or departments) which oversee strategic port planning, development and operations.

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# ACRONYMS

|         |  |
|---------|--|
| AHP     | Analytical Hierarchy Process   |
| BAU     | Business-as-usual  |
| BOS     | Biodiversity Offsets   |
| CSIR    | Council for Scientific and Industrial Research   |
| CEC     | Community of European Countries  |
| CEDA    | Central Dredging Association   |
| CSIR    | Council for Scientific and Industrial Research (RSA)   |
| CWDP    | Coastal Waters Discharge Permit  |
| DEAT    | Department of Environmental Affairs and Tourism  |
| EIA     | Environmental Impact Assessment, used synonymously with Environmental and Social Impact Assessment (ESIA) in this report |
| EIR     | Environmental Impact Report  |
| EMP     | Environmental Management Plan  |
| EMS     | Environmental Management System  |
| GDP     | Gross domestic product   |
| GEF     | Global Environmental Facility  |
| GHG     | Green-house gas  |
| GPP     | Green Port Policy  |
| IADC    | International Association of Dredging Companies  |
| IAIA    | International Organisation of Impact Assessment  |
| IMO     | International Maritime Organisation  |
| IUCN    | International Union for Conservation of Nature   |
| KPA     | Kenya Ports Authority  |
| MTCC    | Maritime Technologies Cooperation Centre   |
| NSW     | New South Wales  |
| n.d.    | No date  |
| ODPM    | Office of the Prime Minister, London   |
| OECD    | Organisation for Economic Cooperation and Development  |
| OPS     | On-shore power supply  |
| PIANC   | World Association for Waterborne Transport Infrastructure  |
| PMAESA  | Port Management Association East and Southern Africa   |
| PPP     | Policies, Plans and Programmes   |
| RSA     | Republic of South Africa   |
| SD      | Sustainable Development  |
| SDG     | Sustainable Development Goals  |
| SEA     | Strategic Environmental Assessment   |
| SEMP    | Strategic Environmental Management Plan  |
| SES     | Socio-ecological systems   |
| SSPs    | Shared socio-economic pathways   |
| TBL     | Triple Bottom Line   |
| TNPA    | Transnet National Ports Authority (South Africa)   |
| TPA     | Tanzania Ports Authority   |
| UN      | United Nations   |
| UNDP    | United Nations Development Programme   |
| UNEP    | United Nations Environmental Program   |
| WIO     | West Indian Ocean  |
| WIO-Lab | Addressing Land-based Activities in the West Indian Ocean  |
| WIOSAP  | Western Indian Ocean Strategic Action Programme  |
| WPCI    | World Ports Climate Initiative   |



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- *Green port activities in the Seychelles*: Captain Joachim Valmont (Seychelles Maritime Safety Authority)
- *Green port achievements - Tanzania Ports Authority*: Claudianus D. Kunze (Tanzania Ports Authority)
- *Decarbonization initiatives in port of Maputo (Mozambique)*: Jeronimo Tamele (Maputo Port Development Company)
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# INTRODUCTION

## Background

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In their simplest forms - the 1<sup>st</sup> generation ports - ports operated in areas of uncontested spaces, benefiting from marine environments in which they could be situated safely and cost-effectively without competition (Kaliszewski 2018; Lee et al. 2018). However with growing global trade, rapid coastal urbanization, depletion and degradation of natural resources, along with increasing expectations from stakeholder and greater social empowerment and awareness are demanding an accelerated quest for port sustainability. Ports are increasingly being pressurised to take actions, not merely focussing on economic generation, but also to include resilient sustainable strategies pertaining to the environment and society (Lu et al. 2016; Alamoush et al. 2021). The port industry therefore faces a growing challenge to address societal and environmental issues while at the same time to improve their capacity to provide cost-effective services to traders (e.g., working towards 5<sup>th</sup> generation ports) (Kaliszewski, 2018; Lam and Van der Voorde, 2012; Roh et al., 2016). With increasing societal and regulatory pressures, port authorities around the world are compelled to pursue greater sustainability to safeguard their 'license to operate' and to grow their economic and environmental competitiveness (Lam and Van der Voorde, 2012; Roh et al., 2016). In response to these global challenges the concept of 'Green Ports' emerged, primarily focusing on balancing environmental challenges and economic demand (Bergqvist and Monios 2019; Lam and Notteboom 2014) and striving for sustainability through increasing both economic and environmental competitiveness (Maritz et al. 2014). The concept of 'Sustainable Port Development' builds on that of 'Green Ports' by also considering social sustainability, in essence advocating the need for a port development to create a balance between economic growth, environmental protection, and social progress to secure its long-term future (Hiranandani 2014; Taljaard et al. 2021).

According to the World Bank (2017), sustainable Blue Economy is the '*sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of ocean ecosystem*'. It therefore strives "*to promote economic growth, social inclusion, and the preservation or improvement of livelihoods while at the same time ensuring environmental sustainability of the oceans and coastal areas*". Aligned with this description, the *Africa Blue Economy Strategy* (AU 2019) views the Blue Economy as '*an inclusive and sustainable economy that becomes a significant contributor to continental transformation and growth, through advancing knowledge on marine and aquatic biotechnology, environmental sustainability, the growth of an Africa-wide shipping industry, the development of sea, river and lake transport, the management of fishing activities in these aquatic spaces, and the exploitation and beneficiation of deep sea mineral and other resources*'.

The Western Indian Ocean (WIO) region is no exception, as it is experiencing an unprecedented pace of large-scale developments, including ports, principally driven by infrastructure demands and financial inflows from different funding streams. Indeed, economic growth and development are becoming inevitable if countries of the WIO region want to address social challenges such as poverty and inequality. Most of these developments are concentrated in coastal areas, also supporting rich natural resources. While the region has an opportunity to define sustainable trajectories for infrastructure investments, they also have potential to significantly impact on the integrity of critical habitats and the natural resource base that future well-being and growth may depend on. In the WIO region coastal communities are especially reliant on coastal resources for their lives and livelihoods. Considering the rich diversity of coastal and marine ecosystems in the WIO region, and its potential to also contribute to socio-economic benefits, sustainable Blue Economy growth holds great promise for the area.

Several initiatives in the WIO region have already started to adopt sustainable port initiatives, including:

- Kenya Ports Authority (KPA) has adopted a Green Port Policy (GPP) that is intended to address the negative impacts of port operations and is geared towards integration of environmental



sustainability in port development/operations and significant reduction in greenhouse gas emissions. The policy focuses on initiatives on climate change mitigation/adaptation, use of renewable energy and recognizes the importance of stakeholders and partners towards achieving its sustainability objectives. Currently, the focus of the GPP is on the Port of Mombasa, but the KPA plans to expand its scope to include other ports managed by them, including the ports of Lamu and Kisumu, and the dry ports.

- The Port of Maputo is implementing initiatives to reduce the emission of greenhouse gases. Currently tugs and pilot boats turn off their generators when moored, and electricity is supplied by sources installed on the pier. The Maputo Port Development Company (MPDC) also is undertaking restoration of forests and tree planting.
- The government of Tanzania, through the Tanzania Ports Authority (TPA), has been taking steps to improve port sustainability to protect the marine environment. In consultation with Royal HaskoningDHV and Deltares a Green Port Policy (2018) has been developed specifically aimed at greening both existing operations as well as the design, implementation, and operations of new infrastructures in the Port of Dar es salaam.
- As Madagascar's largest and main seaport, the Port of Toamasina has been increasing its container reception and storage capacity, whilst still committed to environmental protection as per national law and adopting good examples from other countries 'going green'.
- Sustainability and sourcing new and alternative energy sources has been one of Transnet National Ports Authority's (TNPA) goals in recent years. To this end the TNPA is embarking on the installation of solar technologies to alleviate the country's power challenges and to support greener operations in its ports. One such successful initiative is the greening of energy sources at lighthouses and other marine aids to assist with navigation of vessels within port limits and along the coast.
- The Seychelles Port Authority (SPA) has been engaging in several green port initiatives, involving the development of a National Heritage Plan for Port Victoria, an Environmental and Social Policy, to be followed by the development of an Environmental Management System towards achieving ISO 14001 certification
- Port Management Association East and Southern Africa (PMAESA) together with the Maritime Technology Cooperation Centre-Africa (MTCC-Africa) is in consultation to sign a memorandum of understanding on baseline energy audit surveys and establishing the extent to which ports in the region have embraced GPP.

## Purpose

Building on these initiatives, and complimentary to the *Strategic Framework for Coastal and Marine Water Quality Management in the Western Indian Ocean Region* (UNEP et al. 2022), this project of the Nairobi Convention seeks to facilitate sustainable port development in the WIO on request of the Conference of Parties (CoP). It is part of and supports the *Implementation of the Strategic Action Programme for the protection of the Western Indian Ocean from land-based sources and activities (WIOSAP)*. It is informed by the appreciation that ports intersect with critical coastal and marine resources and is aligned with the WIO region's vision to grow a sustainable Blue Economy.

The science-based output generated from this project will be shared with national governments to support and guide them in the development of national policies for sustainable port development. Further, the outputs will be shared with port developers and operators in the region to support and guide them with the implementation of sustainable port development options. This will be achieved through the Science-to-Policy Platform supported by the Nairobi Convention.

To this end, a series of science-based outputs were prepared as part of this project, including:

- Situation Assessment, providing the context and backdrop for greener port operations and development in the WIO region (UNEP et al. 2023a)
- Scenario Analysis, evaluating development options from 'business as usual' to options incorporating environmental considerations ('sustainable port' option)
- Toolkit for Sustainable Port development in a Blue Economy, comprising practical management and operational tools aimed at supporting port operators in the WIO region towards achieving sustainable port development in WIO region in the future (UNEP et al. 2023b)
- Policy Brief, capturing proposed recommendations for future sustainable port development in the WIO region.

This document presents the Toolkit for Sustainable Port development in a Blue Economy.

## Structure of this Report

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This Introductory section is followed by an overview on the rationale for sustainable ports and presents an Integrated Port Management (IPM) Framework to facilitate effective implementation of sustainable port planning and operations in the WIO region (Section A). Thereafter the Toolkit is presented as a series of useful tools focusing on relevant and innovative approaches and methods that can be adopted in WIO ports towards sustainable development within the key phases, or components, of the IPM Framework, that include:

- Planning (Section B)
- Design (Section C)
- Construction (Section D)
- Operations (Section E).

# SECTION A: FRAMEWORK FOR SUSTAINABLE PORT DEVELOPMENT

## A.1 Rationale

With increasing public and regulatory pressures, port authorities around the world are compelled to pursue sustainable port development to safeguard their 'license to operate' and to grow their economic and environmental competitiveness (Lam and Van der Voorde 2012; Roh et al. 2016; Darbra et al. 2004).

Sustainable development also is a key aspiration of *Agenda 2063: The Africa We Want*, Africa's blueprint and master plan for transforming the continent into a future global powerhouse by 2063 (<https://au.int/en/agenda2063/overview>). Agenda 2063 provides "the shared strategic framework for inclusive growth and sustainable development and a global strategy to optimize the use of Africa's resources for the benefit of all Africans", including Africa's port environments (African Union 2015). Seven Aspirations are encapsulated in Agenda 2063 (Figure A.1). Of these Aspirations 1 explicitly calls for "A prosperous Africa, based on inclusive growth and sustainable development". Under Aspiration 1, *Blue/ocean economy for accelerated economic growth* is a specific goal (Goal 1.6), which includes *Port operations and maritime transportation* as a priority area.



Figure A.1 Eight Aspirations of Agenda 2063: The Africa we Want (Adapted from: African Union 2015)

Climate change, through sea-level rise, increased storminess, and many other vectors (e.g., Azarkamand et al. 2020a) presents a major threat to future port sustainability. Response to climate change can be categorised into two types of measures: (i) Adaptation - upgrading existing infrastructure and designing new infrastructure to withstand the main impacts of climate change, such as sea level rise and flooding, where appropriate measures depend on the extent and timing of future change and its impacts; and (ii) Mitigation - reducing greenhouse gas emissions to contribute to reducing future climate change (HR Wallingford and British Port Association 2021).

## A.2 Framework for Integrated Port Management

Key to sustainable ports is bridging the traditional disconnect between natural environmental issues and port planning and development, as well as acknowledging the multi-use benefits from its natural capital. This requires consideration of the natural environment in the early phases of port planning and design, rather than only considering environmental performance in the operation and maintenance phases. Multi-use valuation (ecosystem services) needs to be embraced to give purpose to

environmental protection. To assist in practically bridging this disconnect, Taljaard et al. (2021) developed an Integrated Port Management (IPM) framework which conceptually positions and aligns environmental processes within the traditional port development cycle and captures the need for coordination and continuity across environmental processes (Figure A.2).

The traditional port development cycle comprises six key sequential stages: site selection, master planning, design, construction, operations and monitoring (Taljaard et al. 2021). These are presented in a logical cyclical order in Figure A.2 which recognizes different time frames in port planning and management in a nested loop arrangement. The larger cycle involves site selection, planning, design and construction of new or expansive port infrastructure. This typically occurs on longer time scales, 5-year (or longer) intervals. The smaller cycle (operations and maintenance, and monitoring and auditing) is nested within the larger cycle, and represents stages that occur continuously, on much shorter (i.e., day-to-day) time scales. To effectively address environmental issue in ports the environment must be effectively integrated into existing planning and decision-making processes. It is important that environmental aspects are proactively aligned and incorporated in all stages of port planning and operation, from the early planning stages through design, construction and into operation (Taljaard et al. 2021). To achieve this, various environmental processes pertinent in port planning and operation, need to be aligned and integrated with traditional port planning and development stages as proposed in the IPM framework (Figure A.2).

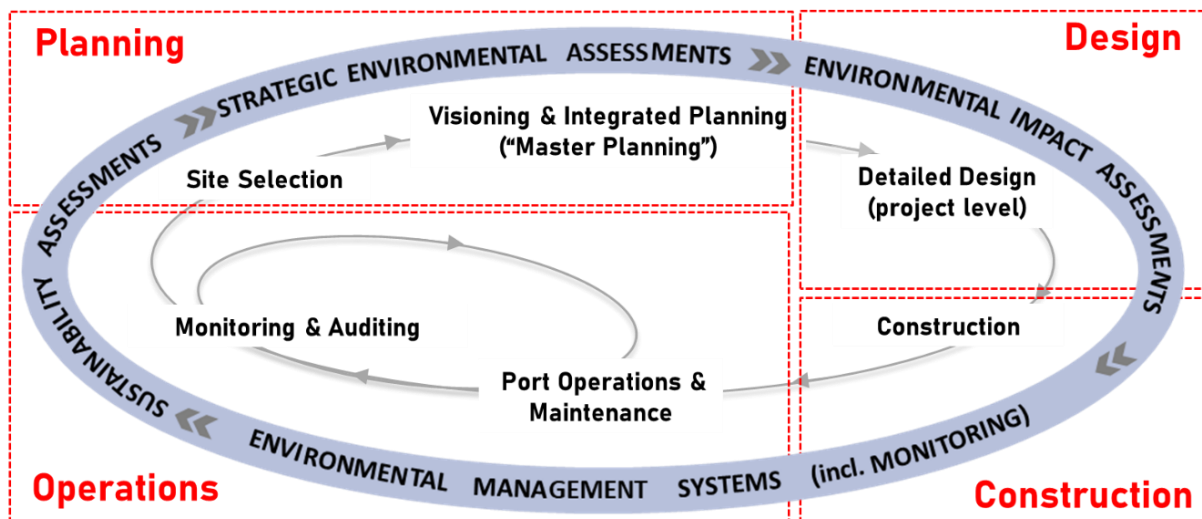


Figure A.2 The Integrated Port Management Framework, conceptualizing alignment between the traditional port planning and development cycle, and key environmental assessment and management processes (Source: Taljaard et al. 2021)

Internationally, the value of undertaking Strategic Environmental Assessments (SEAs) in a more integrative manner in early port planning stages is increasingly recognised (Deloitte Inc., 2015; Dublin Port Company, 2012a and 2012b). Also important is that Environmental Impact Assessments (EIAs, used synonymously with Environmental and Social Impact Assessments (ESIAs) in this report) be initiated in the design stages of port development to allow for opportunities to engineering designs to be developed which avoid or mitigate potential environmental impacts. This will allow much better integration of environmental issues into engineering principles at early design stages and avoid option foreclosure. During the port operation and maintenance stages the implementation of sound Environmental Management Systems (EMSs) is essential to address environmental compliance and stimulate continual improvement of sustainable environmental practices. Globally, Sustainability Assessments are finding their way into port management (e.g., Lu et al. 2016; Pope and Grace 2006; Schipper et al. 2017) embracing the inclusion of the United Nation's Sustainable Development Goals (SDGs) as captured in 2030 Agenda (e.g., Nitsenko et al. 2017).



Underpinning to all environmental assessments and systems is access to reliable long-term environmental data and information which should be acquired through sound long-term environmental monitoring programmes (Kusek and Rist, 2004). Therefore, sustainable environmental management in ports requires proper alignment and inclusion of environmental matters in port planning and management processes, but also continuity and coordination across the different environmental processes, as conceptualised in the IPM framework (Taljaard et al. 2021), Figure A.2).

This Toolkit for Sustainable Port Development in a Blue Economy comprises a selection of practical management and operational tools for port operators and managers in the WIO region to use to advance sustainable port planning and operations in the region, in alignment with international best practice. The tools included in the toolkit were largely distilled from international best practice, but they are applicable and workable in ports of the WIO region. To assist port operators with easy contextualisation of the tools, they have been organised in accordance with the key stages in the IPM framework comprising planning, design, construction, and operations (Figure A.2). Table A.1 summarises the various tools contained in the Toolkit within each of the four main stages.

Table A.1: Structure and content of the Toolkit for Sustainable Port Development

| SECTION                                      | TOOLS   |
|--|---|
| A: Introduction                              | A.1 Rationale   |
|  | A.2 Framework for Integrated Port Management                |
|  | A.3 Institutional Arrangements                              |
| B: Planning                                  | B.1 Guidance on Strategic Environmental Assessment          |
|  | B.2 Site selection and Master Planning                      |
|  | B.3 Planning for Climate Change                             |
|  | B.4 Scenario Analysis Tool                                  |
| C: Design                                    | C.1 Guidance on Environmental Impact Assessment             |
|  | C.2 Concept of Nature-based Solutions                       |
|  | C.3 Design for Biodiversity Offsets                         |
|  | C.4 Building-with-Nature Design Approach                    |
|  | C.5 Ecological Enhancement Options                          |
| D: Construction                              | D.1 Construction Environmental Management Plans             |
|  | D.2 Dredge Management (also relevant in Operations)         |
|  | D.3 Considerations for Port Decommissioning                 |
| E: Operations                                | E.1 Guidance on Environmental Management Systems            |
|  | E.2 Circular Economy in Ports                               |
|  | E.3 Examples: Sustainable Port Development Actions          |
|  | E.4 Securing External Finance for Port Development Projects |
|  | E.5 Sustainable Use of Materials and Land                   |
|  | E.6 Energy Efficiency Management                            |
|  | E.7 Management of Carbon Footprint                          |
|  | E.8 Management of Water Consumption                         |
|  | E.9 Waste Management  |
|  | E.10 Ballast Water Management                               |
|  | E.11 Guidance on Sustainable Hull Cleaning                  |
|  | E.12 Towards Improving Port Environmental Quality           |
|  | E.13 Ecosystem Restoration                                  |
| E.14 Marine Litter Clean up Technologies     |   |
| E.15 Oil Spill Contingency Planning          |   |
| E.16 Environmental Monitoring and Evaluation |   |

| SECTION | TOOLS  |
|---------|--|
|         | E.17 Environmental Information Systems                 |
|         | E.18 Effective Capacity Development                    |
|         | E.19 Introduction to Natural Capital Accounting        |
|         | E.20 Sustainability Performance Index (linked to SDGs) |

It may not be practically possible for ports in the WIO region to implement all the tools in this Toolkit at once, for reasons of human and financial resource limitations. However, by committing to a focussed, on-going process towards addressing environmental matters early in port planning and development, and in the operational and maintenance phases, port operators can incrementally work to achieve environmental sustainability, progressively implementing priorities specific to their port environments supported by tools in this Toolkit. Ideally, the IPM Framework, as well as the guidance and best practice proposed in this Toolkit should be adopted and embedded in national policies pertaining to sustainable port management, as appropriate.

### A.3 Institutional Arrangements

The execution and sustainability of integrated coastal management largely depends on sound multi-actor institutions and networks to facilitate integration, coordination, and implementation (Taljaard et al. 2012). This also holds for environmental management processes in ports, as conceptualised in the Integrated Port Management Framework (Figure A.2).

Port institutional arrangements largely determine a port’s governance configuration and allocation of responsibilities of port activities (Zhang et al. 2018), which ideally should also apply to environmental management activities. Port activities and associated institutional arrangements can be grouped into categories; Policies, regulation, and planning; Services to vessels or terminals; Other activities (e.g. security, customs, and immigration services); and Logistics and supply chains services (Zhang et al. 2018). Although environmental aspects might be embedded within these broader categories (e.g. determining applicable environmental policies under *Policies, regulation, and planning category*), they are typically not elevated to a separate category of port activities. However, given the growing challenge to address societal and environmental issues (e.g., working towards 5<sup>th</sup> generation ports) the inclusion of dedicated institutional arrangements addressing environmental management activities in the port governance configuration has become critical. Taljaard et al (2019) visualise this integral role of the natural environment by embedding ‘natural infrastructure’ in the traditional port infrastructure model (Figure A.3).

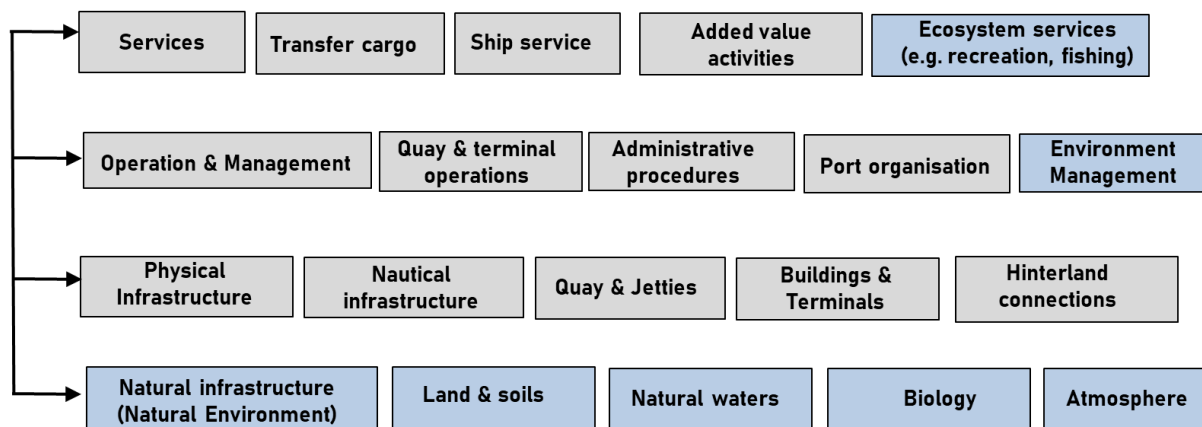
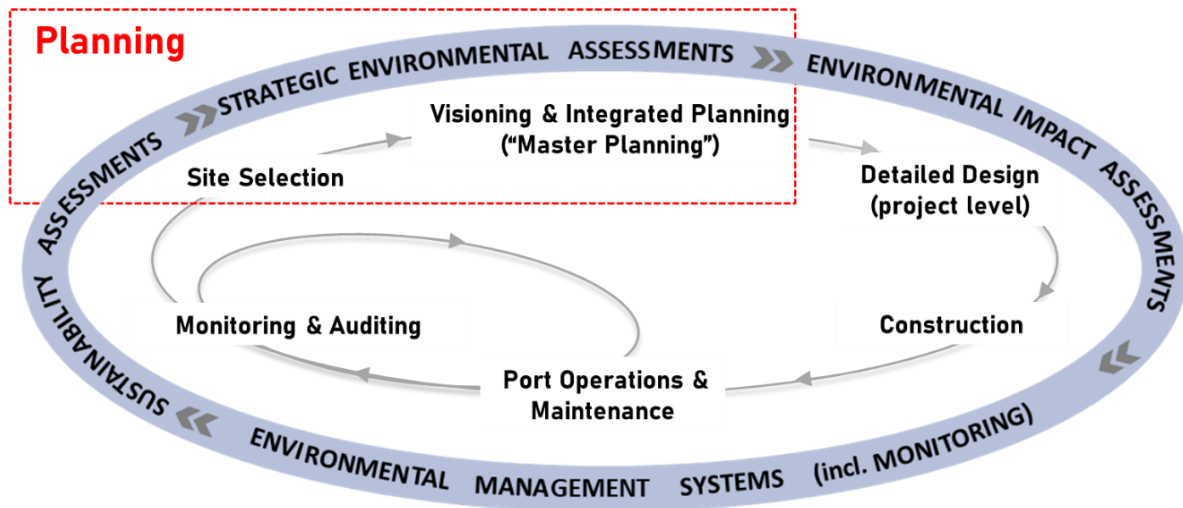


Figure A.3 An infrastructure model for ports, visualizing the natural environment (natural infrastructure) as an integral component (Source: Taljaard et al. 2019)

Various port authorities have acknowledged the importance and need for sound and coordinated environmental management by establishing dedicated environmental departments as part of their institutional arrangements. However, empowerment of such departments to implement and enforce sustainable environmental practice, largely relies on political will from governments and corporate commitment from the port authorities themselves through, for example, endorsing sound environmental and social policies and allocation of adequate human and financial resources for effectively implementing these policies. If ports are serious about being environmentally responsible, socially accountable and economically viable (in short, being truly sustainable) such environmental institutional structures must be considered as 'equal partners' with other port institutional structures (or departments) which oversee strategic port planning, development and operations.

# SECTION B: PLANNING



## B.1 Guidance on Strategic Environmental Assessment

Strategic Environmental Assessment (SEA) is a decision-making tool that was developed to integrate environmental concerns into proposed policies, plans and programmes (PPP), ideally early in the planning phase of port development (Dalal-Clayton and Sadler 1999). This is reflected in a widely used definition (Sadler and Verheem 1996: 27) as:

*“SEA is a systematic process for evaluating the environmental consequences of proposed policy, plan or programme initiatives in order to ensure they are fully included and appropriately addressed at the earliest appropriate stage of decision-making on par with economic and social considerations”*

With time the scope of SEA has expanded to consider the integration of sustainability concerns more broadly, into PPPs (RSA DEAT 2000):

*SEA is “a process of integrating the concept of sustainability into strategic decision-making”*

As illustrated in Figure A.2, SEA is part of the environmental assessment and management ‘toolbox’ for ports. It applies to the *strategic* level of decision-making, for example the development of policies, plans and programmes (PPP) for a particular sector (e.g., port sector) or a spatial area (e.g., a port precinct). Procedures and methods for mitigating and monitoring the impacts of PPP can be outlined in a Strategic Environmental Management Plan (SEMP). In contrast, Environmental Impact Assessment (EIA, see Section C.1) is undertaken for site-specific development proposals (e.g., expansion of a container terminal). Procedures and methods for mitigating and monitoring the impacts of a particular project are outlined in an Environmental Management Plan (EMP) (RSA DEAT 2004a). Both the SEMP or EMP should be informed, *inter alia*, by the mitigation measures and/or indicators that may have been identified through an SEA or EIA process respectively, as well as the legal framework relevant to the management and monitoring of environmental impacts (DEAT 2004a). In ports, SEMPs and EMPs are typically executed through the Environmental Management System (EMS).

The requirement to undertake SEAs is legislated in some countries in the WIO region (e.g., Kenya and Tanzania, through the Environmental Management and Co-ordination [Amendment] Act of 2015, and Environmental Management Act No. 20 of 2004 and SEA Regulations of 2008, respectively) but not all. However, the value of SEA in ensuring that environmental and/or sustainability concerns are proactively considered in policies, plans and programmes PPPs is increasingly being recognised around the world (Govender and Trumbic 2011). Benefits include that SEA (Sadler and Verheem 1996; RSA DEAT 2004a; Dalal-Clayton and Sadler 2005):

- Enables the systemic integration of environmental, social and/or economic concerns into PPPs
- May facilitate identification of sustainability principles into the planning process through, for example, the identification of sustainability objectives, targets and indicators, ensuring that development is within sustainable limits
- Enables the consideration of cumulative effects<sup>1</sup>
- Facilitates identification of a wider range of alternatives to a policy, plan or programme (e.g., port plan) than can be considered in project-level EIA
- Enables identification of measures to reduce the potential negative effects (e.g., water pollution) of a PPP; and enhance the positive ones (e.g., tourism and recreational opportunities)

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<sup>1</sup> “Cumulative effects arise, for instance, where several developments each have insignificant effects but together have a significant effect; or where several individual effects of the plan (e.g., noise, dust and visual) have a combined effect” (ODPM 2005: 78)

- May strengthen and streamline a project EIA through, for example, the prior identification of impacts and information requirements
- Provides a mechanism for the proactive inclusion of stakeholders in strategic-level decision-making through PPPs that are relevant to achieving sustainable development (e.g., SDGs).

There are many approaches to SEA, not least because the process is a flexible one that needs to be adapted to the context (e.g., the planning process) to which it is applied. For example, an SEA which is integrated into strategic planning for a particular port is likely to be different to that applied to urban development planning for a municipality. However, internationally, two broad approaches can be identified (Therivel and Partidário 1996; Partidário 1999; Eggenberger and Partidário 2000; Pope et al. 2004; Dalal-Clayton and Sadler 2005; RSA DEAT 2007; Pope et al. 2015; Bond et al. 2015):

- EIA-based SEA is generally modelled on the project-level EIA process, extending its basic steps (see Section C.1) to the PPP level of decision-making. Essentially EIA-based SEA focusses on determining the effects of a draft PPP and it is therefore undertaken at a stage in which the PPP is relatively well developed. For this reason, the EIA-based approach to SEA has been criticised (e.g., Pope et al. 2004) as being reactive and having less impact on the design of the PPP than the objectives-led approach described below. EIA-based SEA evaluates the potential impacts of a PPP against a baseline understanding of the environment under current situations, rather than against a vision (and objectives) of the future desired state. A narrow interpretation of the 'environment' that focuses on ecological and biophysical aspects can be adopted in this approach, or a broader scope that also includes social and economic issues can be applied.
- Objectives-led SEA involves the evaluation of predicted changes to the baseline environment, as a result of the PPP, against an aspirational vision and associated objectives. This approach to SEA is more proactive than the EIA-based approach, in that it begins earlier in the PPP design process and therefore provides more scope for the SEA to influence the PPP in its formulation stage. As in the case of EIA-based SEA, a narrow biophysical scope can be adopted in an objectives-led SEA; or a wider scope that also includes social and economic issues. An SEA in which the scope is broadened to include an integration of social, economic and biophysical issues and the identification of a sustainability vision, objectives, targets (and indicators) against which the PPP can be evaluated has become known internationally (e.g., to be a 'sustainability assessment' (e.g., Pope et al. 2004, Bond et al. 2015). It should be noted that "...there are very few examples of explicitly legislated sustainability assessment in the world, sustainability appraisal in England being one exception..." (Pope et al. 2015: 433).

A broad typology of four SEA types (including sustainability assessment for PPPs), based on the description above, is summarised in Table B.1. This typology is provided as an orientating guide only, as each SEA process will, in practice, be contextually defined and may combine aspects of more than one SEA type.

Table B.1: Broad typology of four SEA approaches (Therivel and Partidário 1996; Eggenberger and Partidário 2000; Pope et al. 2004; Dalal-Clayton and Sadler 2005; RSA DEAT 2007; Pope et al. 2015)

| APPROACH      | SCOPE  |   |
|---------------|--|---|
|               | ENVIRONMENTAL FOCUS<br>(mainly natural environment)  | INTEGRATED OR SUSTAINABILITY FOCUS  |
| EIA-BASED SEA | <ul style="list-style-type: none"> <li>• Focus of SEA is to assess environmental consequences of a (draft) PPP</li> <li>• Assessment is undertaken against baseline environmental conditions in the area to which the PPP applies</li> </ul> | <ul style="list-style-type: none"> <li>• Expansion of the SEA to include the assessment of the social, ecological and economic aspects of a (draft) PPP</li> <li>• This assessment is undertaken against social, ecological and economic objectives that are defined through the SEA</li> </ul> |

| APPROACH               | SCOPE   |  |
|------------------------|---|--|
|                        | ENVIRONMENTAL FOCUS<br>(mainly natural environment)   | INTEGRATED OR SUSTAINABILITY FOCUS   |
|                        | Examples of port environmental concerns:<br>water quality, air quality, mangrove degradation  | Examples of Integrated/sustainability concerns in Ports: local employment, energy use, greenhouse gas emissions  |
| OBJECTIVES-<br>LED SEA | <ul style="list-style-type: none"> <li>Focus of SEA is to assess environmental consequences of a (draft) PPP</li> <li>Assessment of (draft) PPP is undertaken against environmental objectives for relevant area that may be defined through SEA process itself and/or other policy/planning processes</li> </ul> | <ul style="list-style-type: none"> <li>Expansion of SEA to include assessment of social, ecological and economic aspects of a (draft) PPP</li> <li>Assessment is undertaken in relation to sustainability objectives defined through SEA</li> <li>This approach is also a form of 'sustainability assessment'</li> </ul> |
|                        | Examples of port environmental objectives:<br>reduce air emissions from diesel engines at the port, increase water quality through significantly decreasing waste from ships and other port activities  | Examples of Sustainability Objectives for Ports:<br>increase in the use of renewable energy, create employment through facilitating local procurement, harness opportunities for tourism development in the sphere of biodiversity conservation  |

### B.1.1 Performance criteria for SEA

The International Association of Impact Assessment (IAIA) developed a set of performance criteria for SEAs (IAIA 2002) (Table B.2). These principles align with an SEA approach which integrates social, economic and biophysical aspects within the process, and which facilitates the identification of PPP options and alternatives that enable sustainable development.

Table B.2: Strategic Environmental Assessment Performance Criteria (IAIA 2002)

|   |  |
|---|--|
| "A good-quality Strategic Environmental Assessment (SEA) process informs planners, decision makers and affected public on the sustainability of strategic decisions, facilitates the search for the best alternative and ensures a democratic decision-making process. This enhances the credibility of decisions and leads to more cost- and time-effective EA at the project level." A good-quality SEA process is one which: |  |
| Is integrated   | <ul style="list-style-type: none"> <li>Ensures an appropriate environmental assessment of all strategic decisions relevant for the achievement of sustainable development</li> <li>Addresses the interrelationships of biophysical, social and economic aspects</li> <li>Is tiered to policies in relevant sectors and (transboundary) regions and, where appropriate, to project EIA and decision making</li> </ul> |
| Is sustainability-led   | <ul style="list-style-type: none"> <li>Facilitates identification of development options and alternative proposals that are more sustainable (i.e., that contributes to the overall sustainable development strategy as laid down in Rio 1992 and defined in the specific policies or values of a country)</li> </ul>  |
| Is focused  | <ul style="list-style-type: none"> <li>Provides sufficient, reliable and usable information for development planning and decision making</li> <li>Concentrates on key issues of sustainable development</li> <li>Is customized to the characteristics of the decision-making process</li> <li>Is cost- and time-effective</li> </ul>   |
| Is accountable  | <ul style="list-style-type: none"> <li>Is the responsibility of the leading agencies for the strategic decision to be taken.</li> <li>Is carried out with professionalism, rigor, fairness, impartiality and balance</li> <li>Is subject to independent checks and verification - Documents and justifies how sustainability issues were taken into account in decision making</li> </ul>                            |
| Is participative  | <ul style="list-style-type: none"> <li>Informs and involves interested and affected public and government bodies throughout the decision-making process</li> <li>Explicitly addresses their inputs and concerns in documentation and decision making</li> <li>Has clear, easily understood information requirements and ensures sufficient access to all relevant information</li> </ul>                             |
| Is iterative  | <ul style="list-style-type: none"> <li>Ensures availability of the assessment results early enough to influence the decision-making process and inspire future planning</li> <li>Provides sufficient information on the actual impacts of implementing a strategic decision, to judge whether this decision should be amended and to provide a basis for future decisions."</li> </ul>                               |

### B.1.2 Overview of SEA phases

SEAs are typically commissioned and funded by governmental authorities or donor agencies. However, it is possible for an industry and/or sector to commission an SEA to assist in determining their strategic direction. It is important for SEAs to be undertaken by independent, certified environmental practitioners and typically they require inputs from subject specialists (e.g., ecologists, hydrologists

and economists) (Tarr n.d.). SEA processes should be adapted to the context in which they are undertaken (including the PPP to which the SEA is being applied and/or integrated). In general, policy SEA tends to be quite different to that of plans and programmes. The description of the main phases of an SEA process in the sections that follow relates to plans and programmes (rather than policy SEA), to ensure relevance to strategic port planning. The SEA phases described are broadly based on a guideline document to the European Union Directive on SEA (CEC 2001); *“A Practical Guide to the Strategic Environmental Assessment Directive: Practical guidance on applying European Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment”* (ODPM 2005); although some phases are combined and condensed here. It is critical that the reader consult any country-specific SEA legislation and guidance available before undertaking an SEA. The description in the sections that follow are for introductory purposes only. The main phases of SEA for plans and programmes (described below in terms of both an EIA-based approach and an objectives-led approach) include screening, scoping, developing alternatives to the plan or programme, and assessing effect, identifying mitigation measures and indicators for monitoring, and reporting, decision-making and monitoring.

#### B.1.2.1 Screening

Screening is undertaken to determine whether the plan or programme (e.g., port plan) has the potential to significantly affect the environment and therefore requires an SEA (RSA DEAT 2007). Where a wide definition of the environment is used in the SEA. Effects may be those that directly, or indirectly, impact the natural environment (e.g., quality and quantity of freshwater) or the socio-economic environment (e.g., people’s livelihoods which depend on fishing). An SEA should be undertaken for plans or programmes that could significantly influence a geographic area and/or a particular sector (e.g., transport); as well as for plans or programmes that could result in cumulative impacts (Tarr, n.d.) Where plans or programmes are likely to have significant transboundary effects, an SEA should be undertaken; especially in the WIO region where the main objective of the Nairobi Convention is to prevent such effects (Tarr, n.d.). Several methods can be used for screening (e.g., checklists of sensitive socio-ecological environments (e.g., coastal ecosystems, mangroves and coastal forests) and/or types of development that have significant environmental effects). Screening is also often dependent on the requirements of local legislation and/or those of a funding agency (IUCN 2004).

#### B.1.2.2 Scoping

Scoping involves determining the focus, nature and extent of the SEA including, for example (RSA DEAT 2002a):

- Spatial and temporal boundaries of the study
- SEA process to be followed (including timelines) and opportunities for the involvement of stakeholders
- Key strategic social, ecological and economic issues to be addressed (e.g., water and sediment quality, coastal processes and hydrology, energy use within a port, the livelihoods of local communities and processes for port governance and management).

The scoping process not only defines the boundaries of the study, but also forms the basis for the terms of reference for specialist studies in the subsequent assessment phase. Scoping is an open process that involves all key stakeholders including, for example, port authorities, local and regional authorities, Non-Governmental Organisations (NGOs), business, academia and civil society (RSA DEAT 2002). It is critical that the views and values of such stakeholders are included in the identification of key issues and feasible alternative plans and programmes.



Identifying key strategic issues should also be informed by the current state of the social, economic and biophysical environment, and predicted trends in the area or sector under consideration. This understanding is typically developed through a review and analysis of existing literature, policies and other relevant documentation, as part of a baseline study or situation assessment. In the context of sustainable ports, the analysis should include aspects related to port energy use, waste management, water consumption, land use, air quality, transportation, biodiversity and ecosystems, shoreline stability, local livelihoods and employment creation, port safety and security, as well as port governance and management, among other aspects (CSIR 2003; NSW Port Authority 2017).

In the objectives-led form of SEA, scoping also involves the identification of a vision, associated objectives and targets (as well as indicators) for the maintenance and enhancement of the environment within the area and/or sector under consideration. Where an integrated, or sustainability assessment approach is adopted, this vision (together with the objectives, targets and indicators) is based on sustainability principles that reflect integrated social, economic and biophysical priorities (such as the SDGs). The vision, objectives, targets and indicators can be referred to as a 'sustainability framework' or as 'sustainability parameters', against which the plan or programme is assessed (Therivel and Partidário 1996; RSA DEAT 2000; OECD 2006; RSA DEAT 2007). It is critical that the 'sustainability framework' is informed by existing local, regional and national guidelines, as well as standards and targets set in legislation (e.g., emissions reduction targets, waste recycling targets). The sustainability vision, objectives and targets should also reflect the views and values of key stakeholders and be informed by the situation assessment (or baseline study) mentioned above.

In an objectives-led SEA an iterative process is proposed, in which the situation assessment informs the development of the sustainability framework which, in turn, guides the identification of social, economic and biophysical opportunities and constraints as part of the situation assessment (RSA DEAT 2000). In other words, current opportunities and constraints are identified in relation to achieving the sustainability vision, objectives and targets articulated in the SEA. Enhancing these opportunities and addressing the constraints should guide the further design of the plan or programme and the identification of alternative options (as described in the section that follows) (RSA DEAT 2007). Examples of an objective, with an associated target and indicator that would be associated with a port SEA is provided in Table B.3.

### B.1.2.3 Alternatives to plans or programmes and assessing effects

This stage involves the iterative assessment of the plan or programme; and the generation of feasible alternatives (ODPM 2005). It is preferable to undertake the SEA at an early stage in formulating the plan or programme, so alternative options can be integrated into the design process.

The different alternatives (or options) identified may relate to aspects such as: different port layouts, including basins and terminals; options for potential port expansion; different locations for commercial, industrial and administrative uses; the use of different energy sources and options for waste recycling; among many others. As mentioned above, these alternatives should aim to address the constraints identified in the baseline study/situation assessment and enhance the opportunities (DEAT 2007). The generation of scenarios, including the 'no plan or programme' scenario and the 'business as usual' scenario, may assist in the identification of alternative options (ODPM 2005; OECD 2006). Only realistic, feasible plan and programme alternatives should be considered, and they should be sufficiently distinct from one another to enable a comparison of both their positive and negative environmental effects (ODPM 2005; Tarr n.d.).

Table B.3: Examples of sustainability objectives, targets and indicators (CSIR 2003)

| OBJECTIVE  | TARGET  | INDICATOR  |
|--|---|--|
| Ensure that historical-cultural resources within port area, as well as greater surrounds, are proactively researched so that they can be effectively considered during port planning, design and construction activities | <ul style="list-style-type: none"> <li>Initiate more detailed marine archaeological research in areas outside of port boundaries where port may expand in future</li> </ul> | <ul style="list-style-type: none"> <li>Number and quality of baseline studies undertaken by a qualified archaeologist prior to port expansion or other activities outside port boundaries</li> </ul> |
| Ensure highest level of control on fuel transfers to limit accidental discharges   | <ul style="list-style-type: none"> <li>Zero discharge from fuel transfer operations</li> </ul>  | <ul style="list-style-type: none"> <li>Number and volume of accidental discharges</li> </ul>   |
| To promote job creation and income generation within scope of activities of port   | <ul style="list-style-type: none"> <li>To increase number of jobs within the total value chain in port</li> </ul>   | <ul style="list-style-type: none"> <li>Total increase in number of employees per annum in port and port-related activities</li> </ul>  |

The assessment of the plan or programme and its alternatives involves identifying the changes likely to occur to the current environment. In the case of an integrated/sustainability-led SEA, this includes the social, biophysical and economic environment (e.g., biodiversity, soil, water, air, climate, landscape, human health, income levels, education and employment opportunities) (ODPM 2005). These changes or impacts (both positive and negative) should be described in terms of aspects such as their magnitude; geographical scale; the period over which they will occur; probability of occurring; whether they are permanent or temporary; their frequency and whether there are direct, secondary, cumulative and /or synergistic effects (ODPM 2005). In EIA-based SEAs, the plan or programme is largely evaluated against the baseline environment; whereas in objective-led SEAs, this evaluation is extended to include the implications of changes on the baseline environment for achieving the vision, objectives and targets set in the scoping phase of the SEA (RSA DEAT 2007). As mentioned earlier, this stage often involves an iterative process of evaluation and revision of the plan or programme alternatives, minimising the negative- and enhancing the positive effects (ODPM 2005).

There are multiple methods that can be used for assessing the impacts of a plan or programme and its alternatives. These methods include modelling, the use of Geographic Information Systems (GIS), multi-criteria analysis, economic valuation and stakeholder engagement, among others (ODPM 2005; RSA DEAT 2007). Often scientific specialist studies are undertaken, in which a range of these methods are used to identify and assess the impacts<sup>2</sup>. Such studies should be (Tarr, n.d.):

- Designed to address the key issues identified in the scoping stage
- Conducted by independent specialists
- Subjected to independent peer review in which the findings are checked and verified.

One of the key aspects of the assessment phase is determining the *significance*<sup>3</sup> of the impacts identified. This process should be informed by both subjective aspects such as societal values and preferences, as well as science-based criteria and standards (Sippe 1999). Internationally, there are many different approaches to determining impact significance, some of which are included in national guidelines, policies and/or legislation. In summary, however, important aspects to consider when developing an approach to significance ratings include, *inter alia* (Sippe 1999; RSA DEAT 2002; RSA DEAT 2007):

- In determining significance, the following should be considered: the value-judgements and preferences of stakeholders (e.g., the amount of change to the environment perceived to be

<sup>2</sup> Specialist studies can also support previous tasks within the SEA, such as the situation assessment and the identification of opportunities and constraints to the achievement of the sustainability vision, objectives and targets.

<sup>3</sup> Significance requires reference to the affected environment in terms of the receiving environmental context as well as the intensity of impacts and the importance communities place on them" (Sippe 1999:75)

acceptable by local communities); policy and legal requirements (e.g., related to air and water quality and the management of sensitive ecological environments) and scientific standards.

- The nature of the impacts, as described in terms of the range of factors mentioned<sup>4</sup>, should inform their significance. The degree of scientific uncertainty around impact prediction and its effects, should also inform significance ratings.
- The significance of any particular impact should be considered in terms of social (e.g., effects on human health), economic (e.g., impact on employment) and biophysical (e.g., impact on threatened species) aspects.
- In cases where an objectives-led SEA is being undertaken, the significance of impacts should also be determined in relation to those objectives. More specifically, in objective-led SEAs, this would concern the extent to which the impacts decrease/increase the ability of the area or sector to reach the sustainability objectives and targets outlined (e.g., extent to which a predicted increase in waste production will affect the ability of a port to achieve its recycling targets).

#### B.1.2.4 Mitigation measures and indicators for monitoring

This stage involves the identification of measures to avoid, reduce and/or off-set any expected significant adverse impacts of the proposed plan or programme that remain (after the previous stages) (ODPM 2005). Again, effects should be identified not only in relation to acceptable changes in the baseline environment, but also in relation to the opportunities and constraints to achieving the sustainability objective, targets and indicators, where these have been defined. Although the term 'mitigation measures' is often used for convenience, such measures include the proactive avoidance of negative effects (i.e., adaptation measures) as well as the implementation of actions once such effects are noticed (ODPM 2005). Examples of mitigation measures that might be identified to facilitate sustainable port development in a plan or programme include (Ports Australia 2020; WPSP 2020; Audouin and Sitas 2019):

- Institutional structures to facilitate improved stakeholder dialogue (e.g., the establishment of port-city forums and mechanisms for consistent community engagement)
- Green technologies to enable renewable energy use, improved water and waste management and a reduction in vessel emissions in ports
- Actions to ensure that port infrastructure is adaptable to climate change and unexpected disturbances (e.g., through ensuring diversity in renewable sources of energy and water supply)
- Innovative IT and digital technologies to support port communications, operations and maintenance
- Port policies and procedures for increased workplace equity and diversity, as well as improved employee wellbeing, health and safety
- Improved policies and procedures for aspects such as port efficiency, local procurement, asset management and financial performance
- Improved port environmental and/or sustainability monitoring and evaluation (see Chapter E.12)
- Public-private partnerships to increase ownership of- and funding for- sustainability projects.

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<sup>4</sup> These factors include the following: whether the predicted impacts are positive or negative; impact magnitude; geographical scale; the period over which they will occur (e.g., short-medium- or long-term); probability of occurring (e.g., high, low or negligible); whether they are permanent or temporary; their frequency and whether there are direct, secondary, cumulative and /or synergistic effects (ODPM 2005)

#### B.1.2.5 Reporting, decision-making and monitoring

The outcomes of the SEA process (including a non-technical summary) should be documented in a draft report that is made available to the public and all other relevant stakeholders (ODPM 2005). The draft report should be revised considering any comments received before it is finalised. It is good practice for a 'Comments and Response' Report to be compiled in which the comments received during stakeholder engagement processes from the beginning of the SEA are summarised and the responses are recorded (e.g., amendments made to the SEA process or report). The SEA, as well as the responses to engagement, should be considered in decision-making on the plan or programme (ODPM 2005). Monitoring recommended by SEA should be integrated into monitoring of the plan or programme; and should aim to determine whether the predicted impacts are experienced and/or the sustainability objectives achieved (Partidário 2003; RSA DEAT 2004b). The sustainability indicators identified through the SEA process can be used to determine the extent to which the sustainability objectives are achieved, as part of the overall monitoring programme for the plan or programme (RSA DEAT 2004a).

## B.2 Site Selection and Master Planning

PIANC, the World Association for Waterborne Transport Infrastructure, defines the principal objectives of a port masterplan to be *'To communicate the vision for the port to the wide range of stakeholders; develop the port in accordance with international and national legislation and guidelines; integrate economic, engineering, environmental and safety considerations in the overall plan; promote the orderly long-term development and growth of the port by establishing functional areas for port facilities and operations, and allow the port to respond to changing technology, cargo trends, regulations and legislation and port competition'*.

Two noteworthy publications pertaining guidance for port master planning are:

- MarCom WG 158 - Masterplans for the Development of Existing Ports (PIANC 2014)
- PIANC 2019: MarCom WG 185: Ports on Greenfield Sites – Guidelines for Site Selection and Master planning (PIANC 2019).

PIANC (2014) provides guidelines and recommendations for the preparation and application of port masterplans for existing ports, addressing trends in maritime engineering, port operations, handling equipment, as well as models of port management and conditioning factors that have a profound impact on the growth and development of ports. PIANC (2019) provides guidelines and recommendations for the preparation and application of port masterplans for greenfield ports and specialist marine terminals. Guidance includes:

- Identification and evaluation of development options and potential development sites
- Optimal location selection, considering various metocean, geophysical, hydrodynamic, environmental, and other parameters associated with the development site
- Consideration of marine access, exposure, and availability of the port, including open water terminals
- Consideration of operational performance and the economic needs of port and urban and transport networks planning
- Consideration of potential impacts of new logistics chains (or changes to existing logistics chains)
- Integration of the above-mentioned to optimise masterplan.

Building on PIANC (2014) the greenfield guide also provides guidelines for the preparation and application of port masterplans in greenfield (or new) ports, in particular:

- Identification, development and review of needs
- Functional and performance requirements
- Spatial needs
- Identification and evaluation of potential sites and preparation of development options
- Evaluation, screening and optimisation of development options
- Permitting and implementation of master plans.

PIANC (2019) also provides guidance on timeframes for implementation from design, tender processes and construction periods for typical developments, considering environmental aspects, constraints and requirements adopting PIANC's Working with Nature concepts. Detailed site selection and master planning are fundamental for sound management of environmental and social values affected in and around ports (GHD 2013). To ensure the sustainable development of a port there are different factors

that should be considered for the initial phases of the planning exercise (ALG Transport & Infrastructure 2021), as illustrated in Figure B.1.

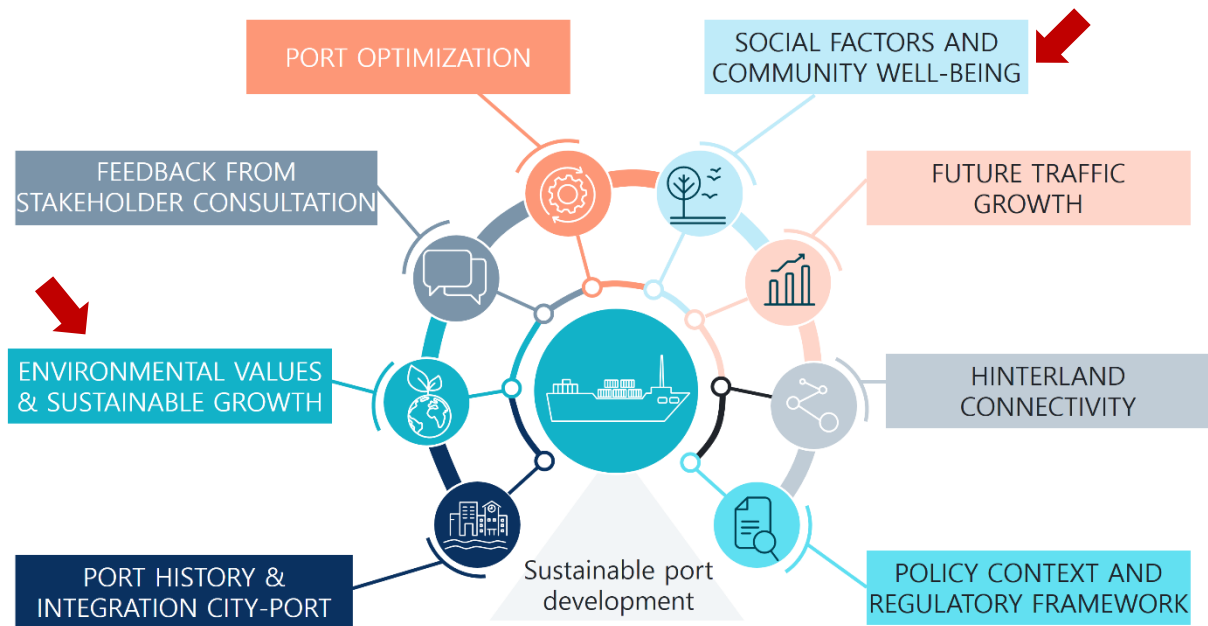


Figure B.1 Key factors to consider in site selection and master planning of port (source: ALG Transport & Infrastructure 2021) (arrows added point to social and environmental factors)

Clear from the listed factors to consider in master planning is the relevance of environmental values, social factors and community wellbeing. Internationally a useful approach to achieve this is to align port master planning with Strategic Environmental Assessment (SEA) (Taljaard et al. 2021, Figure A.2). This allows significant likely environmental impacts of different planning scenarios to be identified during the SEA, and design mitigations to be incorporated into the official master plan to avoid, reduce, or offset negative effects, and increase beneficial ones. Further mitigation measures and monitoring requirements identified as part of the SEA for the later implementation stages are also incorporated as part of the official master plan documentation. Running these processes concurrently ultimately influences and improves the development of the master plan by bringing together, and encouraging communication between teams facilitating better integration, awareness and understanding of their respective needs and aspirations, and ensuring an understanding of environmental and social assets, issues and opportunities to be incorporated into the development of options for expanding the port in order to increase efficiency and throughput capacity. Guidance on SEA planning and implementation in ports is addressed in greater detail in Section B.2.

Also critical in site selection and master planning of ports, is the consideration of overarching national and local spatial planning processes (Figure B.2). Ports are situated at the land-sea interface, and therefore span both terrestrial and marine space. Port planning is usually well aligned with national spatial plans, at least in terms of addressing hinterland interconnectivity. In contrast, port planning is often not well integrated or aligned with municipal spatial planning, largely because the former is undertaken at a national level and the latter at local level. This misalignment is usually one of the key causes of port-city conflicts. In the last decade marine spatial planning (MSP) has emerged; a *'comprehensive and strategic process to analyse and allocate the use of the sea areas to minimise conflicts between human activities and maximise benefits, while ensuring the resilience of marine ecosystems.'* (UNESCO 2021). In essence this process aims proactively to consider the interrelationships and cumulative impacts of the many various sectors that use marine spaces in order

to optimise sustainable use and to minimize potential conflicts. MSP is not a new concept but it has traditionally been primarily applied within sectors, for example for the demarcation of shipping routes, military security zones, mineral extraction zones, and marine protected areas. However, with burgeoning demand for marine space and associated resources, as well as an increased commitment to biodiversity protection, multi-use conflicts have emerged in marine areas, necessitating coordinated and comprehensive cross-sectoral spatial planning – paving the way for multi-use MSP.

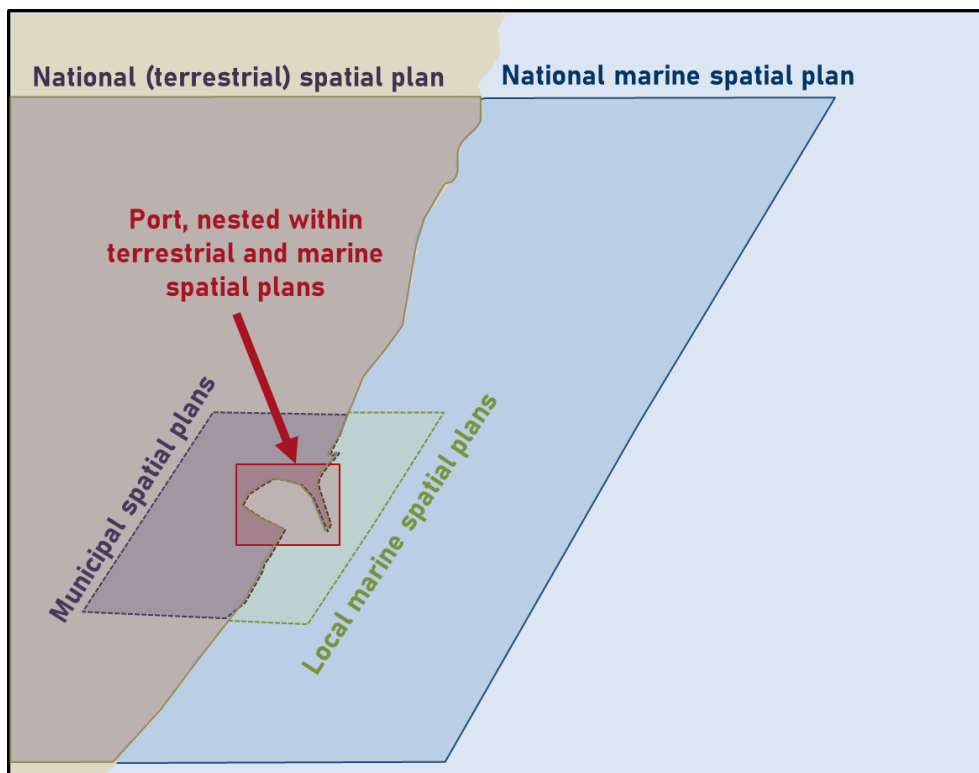


Figure B.2 Conceptualisation of port spaces nested within terrestrial and marine spatial plans

Ports are widely recognised as an important user of marine space, both in the case of expansion of existing ports (e.g., brown field port development) and new port development (e.g., green field port development) (UNESCO 2009; UNESCO 2021). In the case of port expansions, MSP is important to ensure that shipping routes to and from ports are kept free, but also to ensure that future expansion is planned and negotiated through a multi-sector MSP process. Similarly, in the case of new port developments, there is a need not only to consider the requirements of the proposed port development, but also to consider the needs of other marine uses.

Ultimately, well-developed port master plans are likely to be more marketable to ship operators and the wider maritime sector. They provide evidence to potential port users that port developers and operators have conducted a thorough economic, capital and infrastructure diagnostic of their facility, even more so when such plans consider associated environmental and social values (ALG Transport & Infrastructure 2021). The value of synchronising engineering, environmental and regulatory processes in infrastructure development with planning-design-construction-operation timelines, especially to prevent project delays, is illustrated in Figure B.3 (Van Ballegooyen et al. 2016). In this application, the focus was on the construction of marine outfalls for disposal of wastewater, and alignment with regulatory processes involving coastal water discharge permitting, but the concept can easily be applied to port development projects.



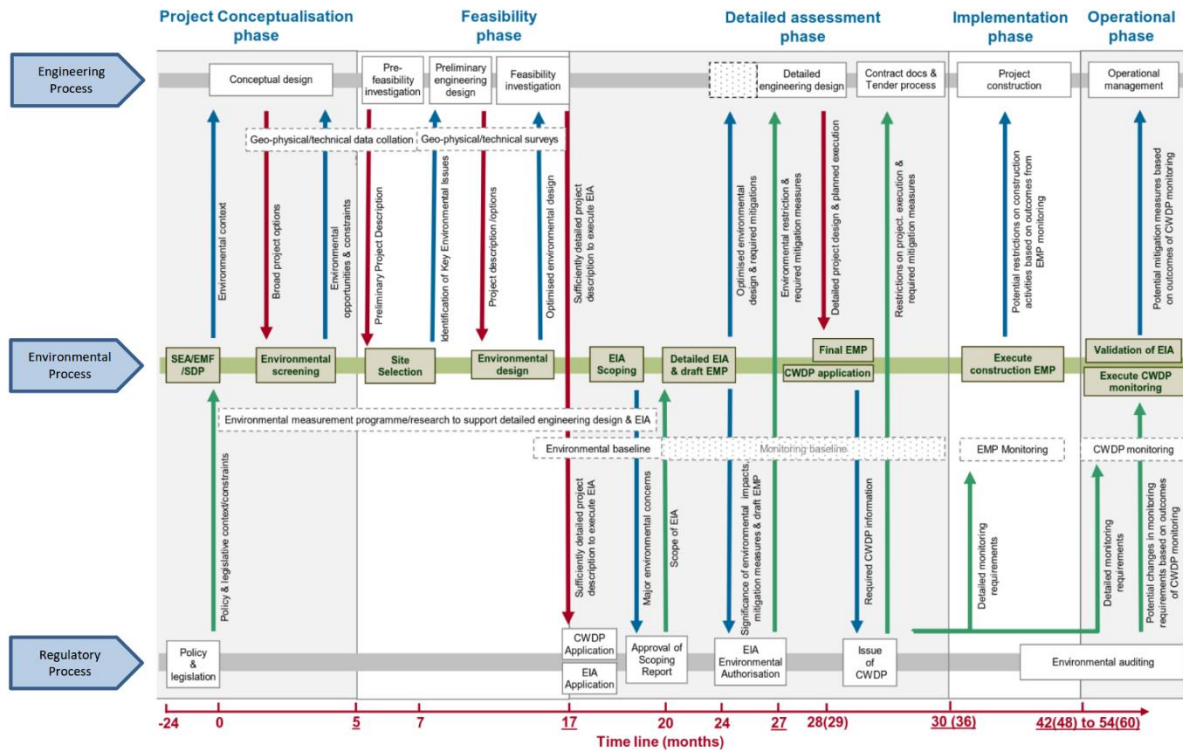


Figure B.3 Illustration of anticipated timelines and coordination between engineering, environment and regulatory processes typically encountered in marine infrastructure projects (source: Van Ballegooyen et al. 2016)

Evident from Figure B.3, is the importance of initiating environmental processes (e.g., SEAs) as early as the conceptual design phases (site selection and master planning in the IPM framework, Figure A.2). If potential environmental red flags are not identified early and only come to light in final design stages, or during the formal EIA process, substantial risks are posed to the timeous completion of the EIA approval process and to the overall project timelines. To address these risks the following should occur (Van Ballegooyen et al. 2016):

- Early and accurate identification of potential environmental issues
- Timeous commencement of environmental measurement programmes to account for interannual and/or seasonal variability
- Appropriately rigorous and detailed assessment techniques involving novel construction techniques to deal with specific engineering challenges and potential environmental constraints that may arise during projects.



## B.3 Planning for Climate Change

Climate change can negatively impact port environments in many ways. Ports worldwide are already experiencing temperature increases, rising sea levels, changes in seasonal rainfall, wind and wave conditions, as well as more frequent and severe extreme events such as storms, heatwaves and droughts. Without timely and effective planning and preparation, climate change is likely to result in increasing incidences of infrastructure damage, port closures, disruption and operational delays leading to downtime, and affecting safety of staff and the wider public, equipment and the environment. Therefore, there is an urgent need for port operators to strengthen resilience and adapt critical assets, operations and systems to climate change (PIANC 2020).

### B.3.1 Key Climate Change Risks

Ports by nature face a variety of environmental risks associated with meteorological, hydrological and oceanographic processes. Climate change will add to these risks and introduce additional ones. Vectors of climate change will contribute to a variety of potential impacts on port operations from navigation to hinterland transportation, as conceptualised in Figure B.4 (PIANC 2020).

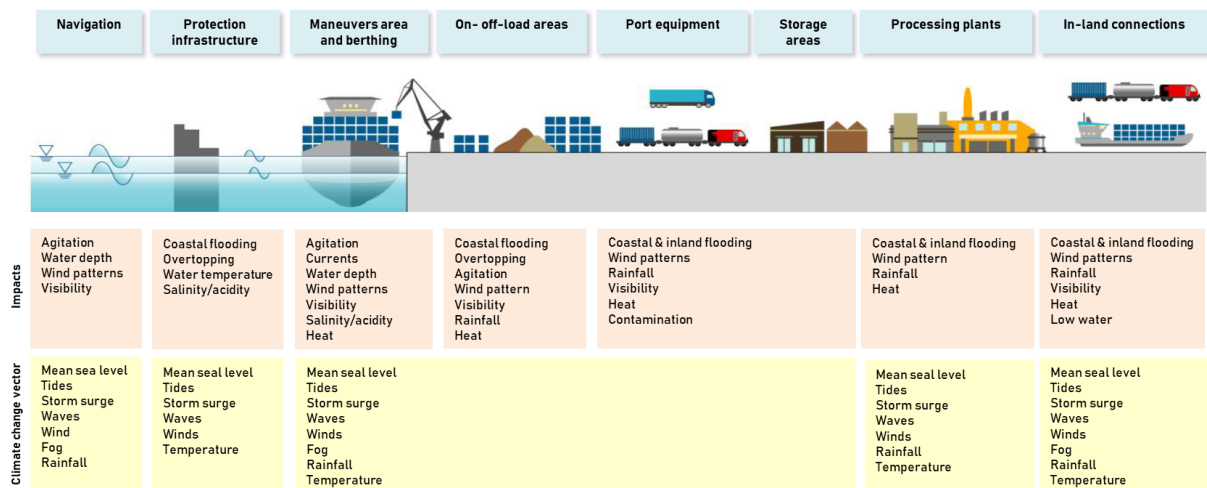


Figure B.4 Climate change vectors, potential impacts on port infrastructure, activities and operations (Source: adapted from PIANC 2020)

Climate change-related risks and impacts include (PIANC 2020):

- Sea-state changes (agitation, waves, winds and storm surges) are likely to endanger navigation into ports, as manoeuvring and berthing in ports
- Lack of visibility (increased fog or blizzard conditions) also endangering navigation and on land transport
- Flooding (high rainfall, high tides and storm surges) may overtop protection infrastructure and overwhelm drainage systems on land
- Changes in sediment processes (accretion/erosion) risk channel configuration for navigation, requiring costly remediation
- Low rainfall, resulting in low river flows and drought can markedly reduce freshwater supplies.

In addition to risks to port operations and safety, climate change can alter physicochemical properties of water (e.g., temperature and salinity) with ripple effects into biological characteristics (vegetation

growth rates, species migration, invasive species) affecting other valuable ecosystem services provided ports, such as artisanal fishing opportunities and tourism.

### B.3.2 Methodological Framework for Climate Adaptation

To assist port operators with planning and implementation of climate change adaptations, PIANC published a guidance document entitled '*Climate change adaptation planning for ports and inland waterways*'<sup>5</sup> (PIANC 2020). This introduces a four-stage methodological framework with which to tackle climate change adaptation planning and implementation in ports (Figure B.5). A brief overview of the framework is provided here, but port operators are referred to the original report for detailed guidance on each of the stages.

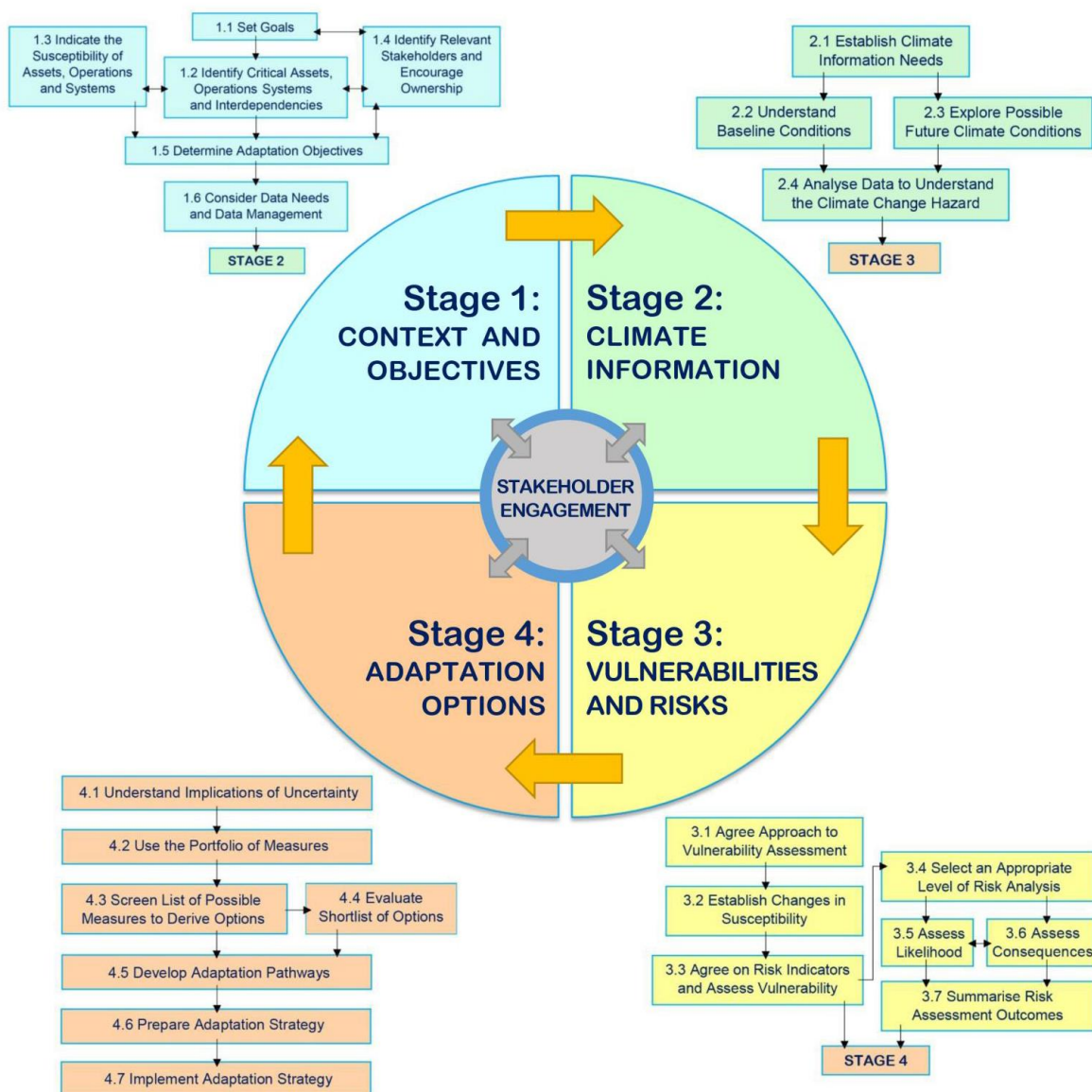


Figure B.5 PIANC's four stage methodological framework for climate change adaptation planning in ports (Source: PIANC 2020)

<sup>5</sup> A copy can be downloaded from <https://www.pianc.org/publications/envicom/wg178>

The four stages include:

- Stage 1: Context and Objectives, facilitating understanding of port assets, operations and systems potentially affected by climate change, possible interdependencies with other sectors that are also susceptible, to enables the setting of climate change adaptation objectives in consultation with internal and external stakeholders
- Stage 2: Climate Information, identifying data and information needs to determine baseline conditions and to investigate possible future changes related to climate change, including climate change scenarios envisaging possible futures
- Stage 3: Vulnerabilities and Risks, describing vulnerabilities of port infrastructure assets, operations and systems, including detailed risk analysis to understand likelihood and potential consequences of expected consequences of climate change
- Stage 4: Adaptation Options, introducing key concepts to considered when deciding how best practice to address climate risks and hazards, including potential measures (structural, operational and institutional) to be undertaken, as well as guidance on the screening and evaluation of options along the adaptation pathway.

Also useful in this PIANC guideline are several good practice case studies and templates for data collection and documentation relevant to climate change adaptation planning and implementation in ports. PIANC also produced a technical guide on good practice in managing climate change uncertainties in selecting, designing and evaluation options for resilient navigation structures (PIANC 2022). To manage uncertainties often associated with climate change and specifically to avoid 'maladaptation', port designers, financiers and operators project owners can reduce climate change-related risks by (PIANC 2022):

- Using a range of climate change scenarios to understand possible variation
- Reducing reliance on past data to predict low probability future events
- Considering unlikely-but-plausible scenarios when making long-term investments
- Preparing for "the unprecedented", including joint occurrences (e.g., in extreme hydro-meteorological or oceanographic conditions) and cascading failures
- Adopting adaptive and flexible solutions, both non-structural and structural
- Using monitoring to inform decision making through adaptive management
- Selecting evaluation methods that recognise and accommodate uncertainty.

## B.4 Concept of Nature-based Solutions

Worldwide rapid increase in populations, together with a persistent drive for economic growth is causing unsustainable consumption of natural resources, biodiversity loss, pollution and habitat degradation, all of which already compromise social equity and human well-being (WWF 2016). Current environmental management approaches have simply become ineffective to counter this rapid downward spiral, necessitating the development of specifically designed large scale, innovative and policy coherent solutions. The implementation of rigorous, evidence-based Nature-based Solutions (NbS) frameworks provides a sustainable way forward (Cohen-Shacham et al. 2019).

The IUCN defines the concept of NbS as *'actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits'* (Cohen-Shacham et al. 2016). The concept stems from the Ecosystem Approach, that underpins the Convention on Biological Diversity (CBD) to which numerous nations are signatories (CBD, 2004). The concept of NbS encompasses a suite of ecosystem-based approaches, as illustrated in Figure B.5.



Figure B.6 Key ecosystem-based approaches encompassed by the concept of Nature-based Solutions (adapted from Cohen-Shacham et al. 2019)

The concept of NbS can be viewed as a 'suitcase' of possible ecosystem-based solutions that can be implemented to counter rapid deterioration of natural resources and associated losses in benefits to economic and societal wellbeing – a concept that represents considerable potential for sustainable ports, as is demonstrated in this Toolkit. Indeed, several tools in this toolkit can be directly matched with ecosystem-based approaches in Figure B.6:

- Management: Ecosystem-based management (see Integrated Port Management Framework in Section A)
- Issue-Specific: Planning for Climate Change (see Section B.3)
- Protection: Design for Biodiversity Offset (see Restoration (see Section C.2)
- Infrastructure: Building-with-Nature Design Approach (see Section C.3)
- Ecological Engineering: Ecological enhancement option (see Section C.4)
- Restoration: Ecosystem Restoration (see Section C.5).

## B.5 Scenario Analysis Tool for Planning

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### B.5.1 Background

Port environments are complex socio-ecological systems (SES) where many facets of society and the environment interact, often resulting in conflict. Scenario analysis has proven to be useful as a technique to forecast possible futures in these types of complex systems. In this approach, a range of future conditions within which a SES might have to operate is created, generally involving a best case, a worst case, and one or two scenarios in between. In all scenarios, there will be trade-offs, but trade-offs do not eliminate the possibility of attaining a desired outcome. As a foresighting approach, scenario analysis is based on the idea that the future may be inherently uncertain (or open) but not entirely unknown nor totally out of our control (Elsawah et al. 2020).

Four features make scenarios analysis a particularly powerful tool for understanding uncertainty and making business decisions (Walker 2019). It:

- Expands thinking by developing a range of possible outcomes, each backed by a sequence of events that could lead to a desired outcome
- Protects against groupthink, which can inhibit the free flow of ideas
- Helps challenge conventional wisdom when *status quo*-based assumptions may no longer hold true in that it builds alternatives that provide a less threatening way to allowing deviation from *status quo*
- Enables management to steer a course between the false certainty of a single forecast and the confused paralysis that often strikes in chaotic times.

The process of scenario analysis also has other side benefits, such as (Walker 2019), it:

- Demonstrates how and why things could quickly become much better or worse thereby increasing preparedness for a range of future possibilities
- Assists in forming a better understanding of the major variables that may significantly impact and shape the business future, in both positive and negative ways
- Provides opportunity to employ strategic insights that could help in weathering uncertainty towards achieving a desired outcome.

To this end, a series of science-based outputs were prepared as part of this project, including:

- Situation Assessment, providing the context and backdrop for greener port operations and development in the WIO region (UNEP et al. 2023a)
- Scenario Analysis, evaluating development options from 'business as usual' to options incorporating environmental considerations ('sustainable port' option)

As part of the wider Sustainable WIO Port Development project a Scenario Analysis was undertaken to evaluate a series of generic future scenarios for port development in the WIO Region, ranging from options of 'Doing nothing' to scenarios incorporating an array of sustainable environmental considerations (UNEP et al. 2023b). The method applied in that regional scale scenario analysis can easily be adapted to develop and analyse site-specific scenarios within countries or for specific ports in the planning phase of port development. The method is briefly discussed here, but for details the reader is referred to the Scenario Analysis Report for the WIO region (UNEP et al. 2023b).

## B.5.2 Overview of Method

The scenario development and analysis process adopted for the WIO region follows six steps (adopted from Alcamo 2001; Alcamo and Henrichs 2008), namely:

- Step 1: Define perspective and context of scenario exercise  
It is important to explicitly define the specific aim and context of a scenario analysis.
- Step 2: Identify key driving forces likely to shape future outcomes  
Important is to define driving forces comprising both external and internal categories that are likely to shape port development outcomes in the future. These should ideally be defined and verified in consultation with stakeholders.
- Step 3: Identify key sustainability criteria (or indicators) by which to measure sustainability outcomes  
Then key sustainability criteria (or indicators) need to be selected to measure outcomes. These are typically organized into the three *common* sustainability pillars: environmental, social, and economic, to gauge sustainability 'patterns' across possible future scenarios. The list of key sustainability indicators also needs to be verified with stakeholders.
- Step 4: Define possible trajectories for selected driving force categories  
For each of the external and internal driving force categories, a range of potential trajectories, expressed as narratives, then needs to be defined within the context of key issues together with stakeholders.
- Step 5: Define anticipated influence of driving force trajectories on selected sustainability indicators  
As input to the scenario analysis process, matrices are constructed to rate the anticipated influence of various driving force trajectories on each of the selected sustainability indicators. This is necessary to provide a transparent and common understanding of the expected influence assumed for various driving force trajectories on indicators, and ultimately the sustainability scores.
- Step 6: Build scenarios and analyse anticipated sustainability outcomes  
A set of generic future scenarios for port development is then constructed using combinations of driving force trajectories. In this final step the results from Steps 3 to 5 were aggregated to obtain overall ratings for each of the future scenario for port development, based on a combination of driving force trajectories and associated weighted influences on sustainability indicators, using a spreadsheet-based index.

## B.5.3 Guidance on Application

This section provides practical guidance on setting up site-specific scenario analysis for port development, based on the Scenario Analysis conducted for the WIO region as part of this project (UNEP et al. 2023b). While it follows the method applied for the purposes of the regional assessment it is expressed more generally here with the intention of being explanatory so that it can be customised for specific use.

### Step 1: Define perspective and context of scenario exercise

*Conduct a scenario analysis on possible future port development outcomes, ranging from 'doing nothing' to 'supporting sustainable ports', to make a business case for environmentally sustainable port development in 'country' or 'port' by [date].*

**Step 2: Identify key driving forces likely to shape future outcomes**

Establish key external driving force categories and define expected trajectories considered relevant to the selected study area, e.g.:

- Climate Change
- Shipping traffic in WIO Region
- Societal pressure
- International market views
- Political situation.

Establish key external driving force categories and define expected trajectories considered relevant to the selected study area, e.g.:

- Corporate culture and policy
- Institutional arrangements
- Technological development
- Operational efficiency.

**Step 3: Identify key sustainability indicators by which to measure sustainability outcomes**

Select a set of key sustainability indicators to measure outcomes considered relevant to the selected study area, e.g.:

- GHG emissions
- Status of Air Quality
- Status of Port Environmental Quality
- Status of Biodiversity and Habitat Intactness
- Community relationship
- Port-City collaboration
- Competitiveness
- Climate resilience.

**Step 4: Define possible trajectories for selected driving force categories**

For each of the external driving force categories, provide an expected trajectory, expressed as a narrative considered relevant to the selected study area, e.g.:

| EXTERNAL DRIVING FORCE CATEGORY | EXPECTED TRAJECTORY 2050 |
|---------------------------------|--------------------------|
| Climate Change                  | ....                     |
| Shipping traffic in WIO Region  | ....                     |
| Societal pressure               | ....                     |
| International market views      | ....                     |
| Political stability             | ....                     |

For each of the internal driving force categories, provide a range of potential trajectories, expressed as narratives, considered relevant to the selected study area, e.g.:

| INTERNAL DRIVING FORCE CATEGORY | POTENTIAL TRAJECTORY |      |
|---------------------------------|----------------------|------|
| Corporate culture and policies  | A                    | .... |
|                                 | B                    | .... |
|                                 | C                    | .... |
|                                 | D                    | .... |
| Institutional arrangements      | A                    | .... |
|                                 | B                    | .... |

| INTERNAL DRIVING FORCE CATEGORY |   | POTENTIAL TRAJECTORY |  |
|---------------------------------|---|----------------------|--|
|                                 | C | ....                 |  |
|                                 | D | ....                 |  |
| Technological development       | A | ....                 |  |
|                                 | B | ....                 |  |
|                                 | C | ....                 |  |
|                                 | D | ....                 |  |
| Operational efficiency          | A | ....                 |  |
|                                 | B | ....                 |  |
|                                 | C | ....                 |  |
|                                 | D | ....                 |  |

#### Step 5: Define anticipated influence of driving force trajectories on selected sustainability indicators

Within the context of the external driving force trajectories, estimate the influence of each of the internal driving force trajectories on the selected sustainability indicators, using a 5-point rating system (-2 to +2) where:

- -2 = strong negative influence expected
- -1 = some negative influence expected
- 0 = no marked influence expected
- 1 = some positive influence expected
- 2 = strong positive influence expected.

The ratings can be decided in a participatory manner among a group of experts (see the text box dealing with Analytical Hierarchical Process below) with knowledge on such matters:

#### INTERNAL DRIVING FORCE CATEGORY X

| INDICATOR |   | EXPECTED INFLUENCE OF TRAJECTORY |      |      |      |
|-----------|---|----------------------------------|------|------|------|
|           |   | A                                | B    | C    | D    |
| 1         | GHG emissions                               | ....                             | .... | .... | .... |
| 2         | Status of Air Quality                       | ....                             | .... | .... | .... |
| 3         | Status of Port Environmental Quality        | ....                             | .... | .... | .... |
| 4         | Status of Biodiversity & Habitat Intactness | ....                             | .... | .... | .... |
| 5         | Community relationship                      | ....                             | .... | .... | .... |
| 6         | Port-City collaboration                     | ....                             | .... | .... | .... |
| 7         | Competitiveness                             | ....                             | .... | .... | .... |
| 8         | Climate resilience                          | ....                             | .... | .... | .... |

Different internal driving force categories may have varying influence on each of the selected sustainability indicators. To address, the method allows for a weighting to be attributed to reflect the contribution of a driving force category on an indicator, e.g.:

| INTERNAL DRIVING FORCE CATEGORY | WEIGHTING (EXPECTED RELATIVE INFLUENCE) OF DRIVING FORCE CATEGORY ON SPECIFIC INDICATORS |                       |                                      |   |                        |                         |                    |                 |
|---------------------------------|--|-----------------------|--------------------------------------|---|------------------------|-------------------------|--------------------|-----------------|
|                                 | 1  | 2                     | 3                                    | 4   | 5                      | 6                       | 7                  | 8               |
|                                 | GHG emissions  | Status of Air Quality | Status of Port Environmental Quality | Status of Biodiversity & Habitat Intactness | Community relationship | Port-City collaboration | Climate resilience | Competitiveness |
| Corporate culture & policy      | ...  | ...                   | ...                                  | ...   | ...                    | ...                     | ...                | ...             |
| Institutional arrangements      | ...  | ...                   | ...                                  | ...   | ...                    | ...                     | ...                | ...             |
| Technological development       | ...  | ...                   | ...                                  | ...   | ...                    | ...                     | ...                | ...             |
| Operational efficiency          | ...  | ...                   | ...                                  | ...   | ...                    | ...                     | ...                | ...             |

The method also allows for the weighting of sustainability indicators within each of the domains of environment, social and economic, as well as for domains to be weighted to achieve an overall sustainability score:



| DOMAIN      | WEIGHTING | INDICATOR                                   | WEIGHTING |
|-------------|-----------|---|-----------|
| Environment | ...       | GHG emissions                               | ...       |
|             |           | Status of Air Quality                       | ...       |
|             |           | Status of Port Environmental Quality        | ...       |
|             |           | Status of Biodiversity & Habitat Intactness | ...       |
| Social      | ...       | Community relationship                      | ...       |
|             |           | Port-City collaboration                     | ...       |
| Economic    | ...       | Climate resilience                          | ...       |
|             |           | Competitiveness                             | ...       |

#### *Analytical Hierarchical Process (AHP) – dealing with subjective decision-making processes*

Where ratings and weightings are derived in a participatory manner from a group of relevant experts, inputs can be expected to be subjective, based on the participants' backgrounds, their experience and even perceptions. It can often be difficult to negotiate consensus amongst participants. The Analytic Hierarchy Process (AHP) has proven to be a useful technique to reach outputs from subjective decision-making processes based on multiple attributes. The method was originally developed by Saaty (1980) and has since been adapted and refined for application in ports (e.g., Ugboma et al. 2006; Chiu et al. 2014). In essence the AHP method comprises four key steps (see details in Zahedi (1986):

- Structure decision hierarchy by breaking down the decision problem into a hierarchy of interrelated decision elements (e.g., indicators)
- Collect input data (e.g., participants' rating and weighting) depicted by matrices of pairwise comparisons of decision elements
- Use the eigenvalue method to estimate the relative weights of the decision elements
- Aggregate relative weights of decision elements to arrive at a set of ratings for decision alternatives.

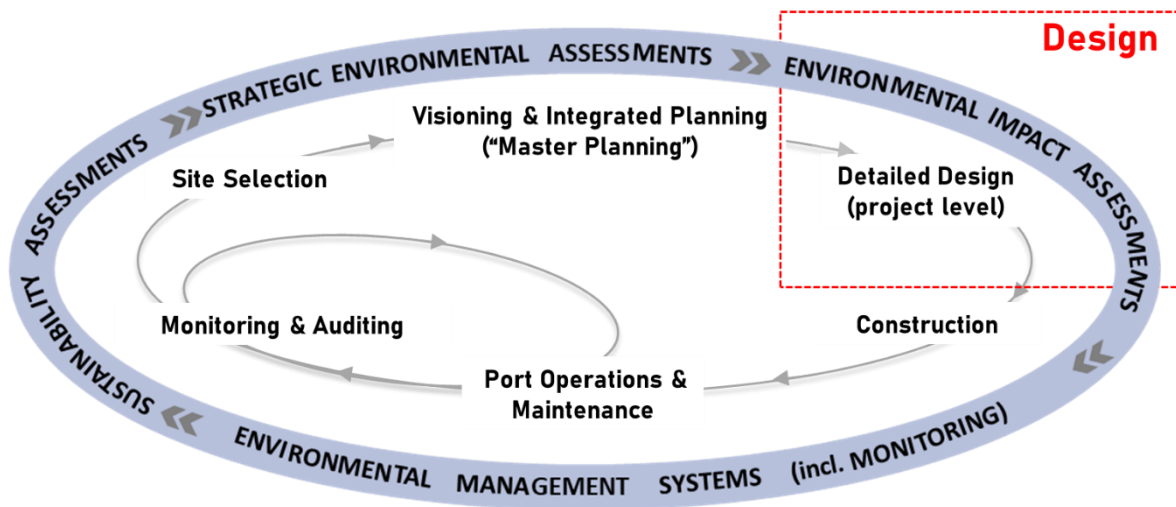
#### **Step 6: Build scenarios and analyse anticipated sustainability outcomes**

A set of site-specific scenarios for port development in a 'country' or 'port' can then be constructed using combinations of driving force trajectories, e.g.:

| NUMBER & DESCRIPTION |        | INTERNAL DRIVING FORCE TRAJECTORY COMBINATION |     |
|----------------------|--------|---|-----|
| 1                    | '....' | Corporate culture and policies                | D   |
|                      |        | Institutional arrangements                    | A   |
|                      |        | Technological development                     | C   |
|                      |        | Operational efficiency                        | C   |
| 2                    | '....' | Corporate culture and policies                | ... |
|                      |        | Institutional arrangements                    | ... |
|                      |        | Technological development                     | ... |
|                      |        | Operational efficiency                        | ... |
| 3                    | '....' | Corporate culture and policies                | ... |
|                      |        | Institutional arrangements                    | ... |
|                      |        | Technological development                     | ... |
|                      |        | Operational efficiency                        | ... |
| n                    | '....' | Corporate culture and policies                | ... |
|                      |        | Institutional arrangements                    | ... |
|                      |        | Technological development                     | ... |
|                      |        | Operational efficiency                        | ... |

The above input can then be populated in a spreadsheet model to calculate sustainability scores for each scenario for individual sustainability indicators, for each domain and an overall sustainability score, using a spreadsheet-based index, similar to that provided for the generic regional scenarios assessed in [UNEP et al. \(2023b\)](#).

# SECTION C: DESIGN



## C.1 Guidance on Environmental Impact Assessments

Environmental Impact Assessment (EIA) is an internationally recognised and widely legislated tool. It aims to determine potential negative and positive socio-economic and biophysical effects of a proposed project or activity on the environment to inform decision-making (Senécal et al. 1999). A typical definition of EIA, from the International Association of Impact Assessment (IAIA) and the Institute of Environmental Assessment (IEA) is as follows (Senécal et al. 1999: 2):

*“The process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made.”*

In many countries, including several in the WIO, Environmental Impact Assessment has been replaced by Environmental and Social Impact Assessment (ESIA), and for the purposes of this report, the two terms are used synonymously.

Within the Integrated Port Management Framework (Figure A.2) EIA takes a central place in the design phase of port development.

### C.1.1 Examples of Relevant Guidelines and Legislation

The importance of identifying, assessing and managing environmental impacts of port development at a project- and/or operational level of decision-making has been recognised for some time. In 1990 the World Bank in association with the International Maritime Organization (IMO) prepared a Technical Paper: *“Environmental considerations for port and harbour developments”* (Davis and MacKnight 1990). The paper highlights typical environmental problems that are likely to occur in ports in developing countries. It serves as an ‘aide memoire for those responsible for port development and who have need to know the complete range of issues to be considered, which are applicable in their particular situation and where to find more information on the subject’ (Davis and MacKnight 1990: iii). Information on how particular issues are normally resolved is also included in the paper. Another example of environmental implications of port development being long recognised (in this case related to environmental assessment) is provided by the 1992 publication of the United Nations guide: *“Assessment of environmental impact of port development – A guidebook of EIA for port development”*. This guide, drafted for the Asia and Pacific region, provides port planners with basic practical information on EIA for port development (UN 1992).

Amended Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Western Indian Ocean. Article 14: Environmental Impact Assessment (UNEP, 2010: 5)

1. “As part of their environmental management policies the Contracting Parties shall, in co-operation with competent regional and international organizations, if necessary, develop technical and other guidelines to assist in the planning of their major development projects in such a way as to prevent or minimize harmful impacts on the Convention area.
2. Each Contracting Party shall assess, within its capabilities, the potential environmental impacts of major projects, which it has reasonable grounds to expect may cause substantial pollution of, or significant and harmful changes to the Convention area.
3. With respect to the assessments referred to in paragraph 2, the Contracting Parties shall, if appropriate, in consultation with the Organization, develop procedures for the dissemination of information and, if necessary, for consultations among the Contracting Parties concerned.”

In the WIO region specifically, the Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environmental of the Eastern African Region (amended, 2010) requires, in Article 13 that *“...all appropriate measures to prevent, reduce and combat environmental damage in the Convention area in particular the destruction of marine and coastal ecosystem, cause by engineering*

*activities such as land reclamation and dredging*". Article 14 (see text box) specifically pertains to EIA and: (1) the formulation of guidelines by Contracting Parties 'to prevent or minimise harmful impacts of major development projects on the Convention area' (2) the assessment of substantial pollution and/or significant harmful changes to the Convention area; and (3) related to such assessments, the development of procedures for dissemination of information among the Contracting Parties concerned (UNEP, 2010: 5). It is important to note that all countries within the region have some form of EIA legislation (e.g., EIA regulations) (Tarr, n.d.; Bishoge and Mvile 2022). Lists of activities that require environmental assessments (at various levels of detail) are often promulgated in terms of this legislation and these lists (together with all other relevant environmental assessment provisions) should be consulted when undertaking projects related to ports (see Section C 1.3.1. below).

A guide entitled *EIA: Guidelines for Impact Assessment in the Western Indian Ocean Region* was published by UNEP-Nairobi Convention (Tarr, n.d.). This highlights environmental issues within the WIO Region, particularly transboundary impacts. Guidance is provided in this document *inter alia* on how these impacts should be assessed using SEA and EIA processes. The guide is primarily intended for those making decisions related to environmental issues through the impact assessment process (e.g., by commenting on impact assess reports and making decisions on development taking into account such reports) (Tarr n.d.).

### C.1.2 Basic Principles for EIA

The International Association of Impact Assessment (IAIA), with the Institute of Environmental Assessment (United Kingdom) (Senécal et al. 1999), developed a set of basic principles for EIA which apply to all stages of the environmental assessment process (Table C.2).

Table C.1: Summary of Basic Principles for EIA as developed by IAIA (Source: Senécal et al. 1999: 3)

| PRINCIPLE         | DESCRIPTION  |
|-------------------|--|
| Purposive         | The process should inform decision making and result in appropriate levels of environmental protection and community well-being.   |
| Rigorous          | The process should apply "best practicable" science, employing methodologies and techniques appropriate to address the problems being investigated.  |
| Practical         | The process should result in information and outputs which assist with problem solving and are acceptable to and able to be implemented by proponents.   |
| Relevant          | The process should provide sufficient, reliable and usable information for development planning and decision making.   |
| Cost-effective    | The process should achieve the objectives of EIA within the limits of available information, time, resources and methodology.  |
| Efficient         | The process should impose the minimum cost burdens in terms of time and finance on proponents and participants consistent with meeting accepted requirements and objectives of EIA.  |
| Focused           | The process should concentrate on significant environmental effects and key issues; i.e., the matters that need to be taken into account in making decisions.  |
| Adaptive          | The process should be adjusted to the realities, issues and circumstances of the proposals under review without compromising the integrity of the process, and be iterative, incorporating lessons learned throughout the proposal's life cycle. |
| Participative     | The process should provide appropriate opportunities to inform and involve the interested and affected publics, and their inputs and concerns should be addressed explicitly in the documentation and decision making.                           |
| Interdisciplinary | The process should ensure that the appropriate techniques and experts in the relevant bio-physical and socio-economic disciplines are employed, including use of traditional knowledge as relevant.  |
| Credible          | The process should be carried out with professionalism, rigor, fairness, objectivity, impartiality and balance, and be subject to independent checks and verification.   |
| Integrated        | The process should address the interrelationships of social, economic and biophysical aspects.   |

| PRINCIPLE   | DESCRIPTION  |
|-------------|--|
| Transparent | The process should have clear, easily understood requirements for EIA content; ensure public access to information; identify the factors that are to be taken into account in decision making; and acknowledge limitations and difficulties. |
| Systematic  | The process should result in full consideration of all relevant information on the affected environment, of proposed alternatives and their impacts, and of the measures necessary to monitor and investigate residual effects.              |

### C.1.3 Overview of EIA process

This section provides a generic description of the EIA process for introductory purposes only. The reader is referred to national EIA legislation for guidance on EIA within the relevant country and the requirements to be followed when undertaking, commissioning and/or reviewing an EIA. This legislation typically outlines specific process to be followed (with detailed requirements for each stage in the EIA), including the stages at which engagement with interested and affected parties should take place, and the way this should be undertaken (e.g., the registration of interested and affected parties, advertising and the recording of comments) (RSA DEA 2014). Useful detailed guidance on EIA practice is also provided on the IAIA official website (<https://www.iaia.org/>). It is important to note that typically it is responsibility of the project proponent to conduct the EIA, however, *in many cases national legislation requires that the project proponent, in fulfilling this obligation, makes use of government licenced or registered consultants/agencies* (UN Environment 2018).

#### C.1.3.1 Screening

The purpose of screening is to determine whether a project proposal should be subject to an EIA or not, and to what level of detail (Jones 1999; UN Environment 2018; Tarr n.d.). Screening is typically undertaken based on information provided by a project proponent when they apply for an environmental authorisation (UN Environment, 2018). Several methods can be used for screening, which often involve checking the proposed project against a list of criteria (e.g., sensitive areas or typical projects requiring an EIA) that may be contained in national environmental assessment legislation or the requirements of a funding agency (IUCN, 2004). In most WIO countries lists of activities have been legally promulgated, that require environmental assessments at different levels of detail, from scoping/initial assessments to full EIAs (Tarr, n.d.).

#### C.1.3.2 Scoping

Scoping involves determining the focus, nature and extent (i.e., level of analysis) of the EIA, including the spatial and temporal boundaries of the study, the key issues to be addressed, the feasible alternatives to be considered, interested and affected parties to be involved and the environmental assessment process to be followed (RSA DEAT 2002a).

The EIA process should include engagement with all interested and affected parties and it is best practice to include such engagement from the scoping phase<sup>6</sup>. This phase should (RSA Western Cape Government: Environmental Affairs and Development Planning 2015; RSA DEAT 2002a):

- Provide information on the proposed project and the receiving environment to those who will be providing their comments (i.e., interested and affected parties)
- Obtain agreement on the scoping and assessment process to be followed
- Obtain agreement on the key biophysical, social and economic issues to be considered in the EIA
- Obtain agreement on the feasible project alternatives to be considered

<sup>6</sup> Not all countries provide for engagement with interested and affected parties at the scoping phase. However, where engagement is required in the assessment phase, the terms of such engagement with interested and affected parties are agreed upon in the scoping stage (UNEP 2018)

- Obtain agreement on the terms of reference for specialist input in the assessment
- Provide details on further opportunities for engagement.

The output of scoping is often a scoping report, and it is best practice for all interested and affected parties to be provided with an opportunity to comment on this report before it is finalised (Tarr, n.d.).

### C.1.3.3 Assessment (including identification of mitigation measures)

This stage involves a detailed study of the potential negative impacts and benefits of the proposed project (and viable alternatives) on the social, biophysical and economic environment (IUCN, 2004). These impacts should be identified for all phases of the project life cycle (including construction, operation, and decommissioning) (RSA DEAT 2002b). Legislation may require that both direct and indirect (e.g., secondary) impacts are identified; as well as cumulative effects (e.g., Kenya and South Africa) (RSA DEA 2014; UN Environment 2018).

The significance of the potential impacts of the proposed project and its alternatives, should then be described in terms of factors such as: whether they are positive or negative, the time period over which they are likely to occur, their magnitude, probability of occurring, reversibility, frequency of occurring and whether they are temporary or permanent (RSA DEAT 2002c; ODPM 2005). It is also important to provide an indication of the distribution of potential impacts, particularly where negative effects are likely to affect vulnerable or disadvantaged communities (RSA DEAT 2004b). It should be noted that the content required for the assessment is often outlined in country legislation and may include a list of factors (e.g., biodiversity, human health, local livelihoods, cultural heritage and climate change) to be considered in identifying the likely impacts of a proposed project and its alternatives (UN Environment, 2018).

The assessment stage should include the identification of practical and cost-effective mitigation measures to avoid, reduce and/or off-set any significant impacts of the proposal and its alternatives (RSA DEAT 2004 b). The effectiveness of the mitigation measures<sup>7</sup>, as well as their predicted negative impacts and benefits should also be outlined (RSA DEAT 2004b). In addition, the significance of post-mitigation impacts (i.e., residual impacts once all mitigation measures have been considered) should be made explicit (RSA DEAT 2004c). These factors should contribute to a clear basis for a choice between alternative project options (RSA DEAT 2004b).

In many instances (e.g., in South Africa) it is a legal requirement for an Environmental Management Plan (EMP) to be developed and for this plan to be an integral part of the decision-making around the EIA (UN Environment 2018). In such cases, implementation of the measures in the EMP are binding on the project proponent (UN Environment 2018). The purpose of an EMP is to outline the methods and procedures that will be followed by the project proponent in mitigating and monitoring impacts and should apply to the entire project lifecycle (RSA DEAT 2004d). An EMP typically includes objectives and targets for managing the negative impacts - and enhancing the benefits - of the project; as well as a description of key processes and responsibilities for undertaking such management (RSA DEAT 2004d). This should include procedures for effective monitoring of the management actions identified and their outcomes. Where appropriate, EMPs need to be integrated into Environmental Management Systems (EMS) (see Section E.1) (RSA DEAT 2004b).

Specialist input/studies may be commissioned to inform this stage of the EIA process (as well as earlier stages, if needed). For example, a specialist may be commissioned to undertake a study on the potential impacts on current water quality in a particular port, that are likely to result from the

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<sup>7</sup> The term 'mitigation measures' is used for convenience; however, such measures include the proactive avoidance of negative effects (i.e., adaptation measures) as well as the implementation of actions once such effects are noticed (ODPM 2005)

proposed construction of a container terminal; and to identify potential mitigation measures for such impacts. Methods used in specialist studies include numerical modelling, surveys and interviews, among many others (RSA DEAT 2002b). Specialist studies should be subject to independent peer review (RSA DEAT 2002b).

#### C.1.3.4 Reporting, review and decision making

The outcome of the previous assessment stage is typically an Environmental Impact Report (EIR) or Environmental Impact Statement (EIS), which should include a non-technical summary (IUCN 2004; UN Environment 2018). The EIR/EIS should be subject to formal review before a decision is made on whether the proposed project is approved (UN Environment 2018). Such review should be undertaken by, *inter alia*: environmental agencies, other government authorities that are affected by the decision and may need to issue a permit or license before the project can be implemented, relevant intergovernmental committees and any relevant independent body (e.g., advisory committee) established by the environmental agency (e.g., for the purpose reviewing the EIA process and content) (UN Environment 2018). All interested and affected parties (including the public and representatives of business, academia, civil society and non-governmental organisations (NGOs), among others, should be provided an opportunity to comment on the EIR/EIS.

It is important that the environmental assessment is reviewed both in terms of the process followed (i.e., procedural review) as well as its content (i.e., substantive review) (UN Environment 2018). Procedural review relates to aspects such as the degree and effectiveness of engagement with interested and affected parties, appointment of specialists and compliance with procedural regulatory requirements (RSA DEAT 2004c). Substantive review is to ensure that, *inter alia*, the EIA is technically and scientifically sound and that the issues raised by interested and affected parties have been included and addressed (RSA DEAT 2004c). Procedural and substantive EIA review should be undertaken according to requirements that may be contained in national EIA legislation (e.g., review criteria) and against the terms of reference for the EIA that were established in the scoping phase (UN Environment 2018).

Once the EIA report is finalised a decision is made regarding the proposed project. This decision may include conditions of approval (e.g., regarding the implementation and monitoring of mitigation measures). Some national EIA legislation provides guidance related to final decision-making including aspects to consider and/or requirements regarding public access to the final decision. In most instances an opportunity to appeal the decision is provided (UN Environment 2018).

#### C.1.3.5 EIA follow-up

The purpose of EIA follow-up is *“...to ensure that the actual impacts of the project – whether predicted or not – are mitigated where negative, and enhanced where positive, and that the mitigation measures that were a condition of approving the EIA are complied with.”* (UN Environment 2018: 72). If an EMP is compiled, this typically forms part of the conditions of approval and therefore the basis, together with any other conditions, of EIA follow-up (UN Environment 2018). The EMP should also be adjusted during the project implementation phase considering *inter alia* the results of monitoring during the follow-up phase (UN Environment, 2018). Follow-up activities, such as monitoring and evaluation, can be driven by proponent themselves (e.g., implementation of EMS) and by EIA regulators (e.g., ensuring that conditions of approval are met) (Morrison-Saunders et al 2007). It is important to note that follow-up can also be initiated by formal community forums and/or local community members that are concerned about observed negative environmental impacts (Morrison-Saunders et al 2007). Arts and Morrison-Saunders (2022) have updated best practice principles for impact assessment follow-up; as part of IAIA’s international best practice principles series.<sup>8</sup>

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<sup>8</sup> See : <http://www.iaia.org/publicdocuments/pdf/special-publications/SP6.pdf>



## C.2 Design for Biodiversity Offsets

IUCN (2004) defines Biodiversity offsets as *'conservation actions intended to compensate for the residual, unavoidable impact on biodiversity caused by projects, to ensure at least a no net loss of biodiversity and, where possible, a net gain'*. The IUCN, World Bank and others have produced useful guidance on biodiversity offsets planning and implementation, for example:

- *'Biodiversity offsets: Views, experience, and the business case'* (IUCN 2004)
- *'Business and Biodiversity Offsets Programme'* (BBOP 2009)
- *'Biodiversity Offsets: A User Guide'* (World Bank Group 2016)

Port operators are encouraged to consult these tools when considering biodiversity offset options in their port. However, we provide a synthesis of useful insights into biodiversity offset practice to introduce its value in sustainable port development.

### C.2.1 Environmental Mitigation Hierarchy

Biodiversity offsets need to be considered within the broader, holistic principles of environmental management, most notably the environmental mitigation hierarchy (Figure C.1) (IUCN 2004; World Bank Group 2016).

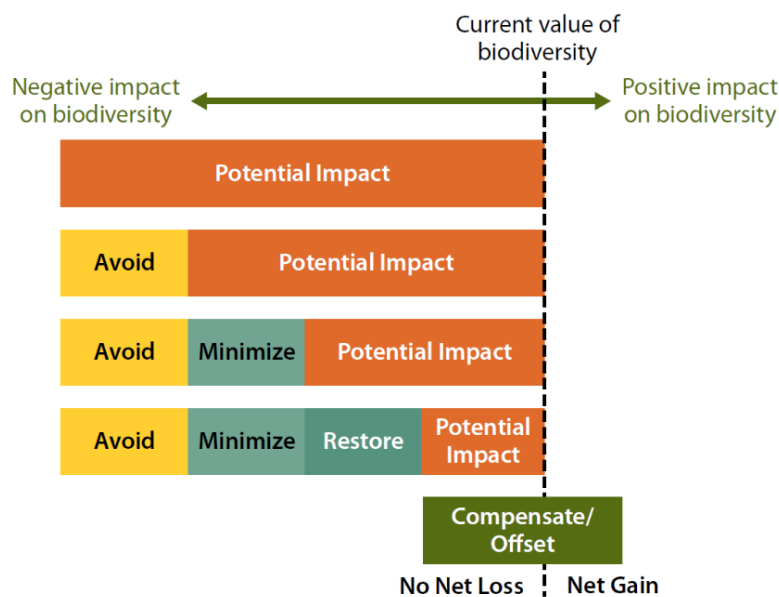


Figure C.1 Schematic of Environmental Mitigation Hierarchy (Source: World Bank Group 2016)

The mitigation hierarchy requires responses to potential impacts from development to follow a hierarchal decision-making process (i) first seeking avoidance impacts on biodiversity; (ii) then seeking minimization of impacts; (iii) then considering restoration of areas impacted development; and (iv) only when adverse impacts on biodiversity remains should biodiversity offsets be considered. Important to note in this hierarchy is the prioritisation of proactive avoidance and minimization, before implementation of corrective measures through restoration or biodiversity offsets (World Bank Group 2016). In this light the World Bank defined biodiversity offsets as *'measurable conservation outcomes resulting from actions designed to compensate for significant residual adverse biodiversity impacts'*



*arising from project development and persisting after appropriate avoidance, minimization, and restoration measures have been taken’.*

Biodiversity offsets usually aim to achieve ‘*no net losses*’, or preferably ‘*net gains*’ in biodiversity in comparison to the baseline situation before the implementation of a development. In 2018, the Wildlife Conservation Society proposed that Contracting Parties to the Nairobi Convention adopt the application of the mitigation hierarchy and biodiversity offsets following a ‘*no net loss of biodiversity and ecosystem services*’ approach, as tools to achieve sustainable development in the WIO region (Nairobi Convention 2018).

### C.2.2 Mechanisms to Trigger Implementation of Biodiversity Offsets

Various mechanisms can be implemented to trigger biodiversity offsets in countries. These include government laws and regulations that specifically require offsets, or they can be a specific requirement of project funders or lenders (<https://portals.iucn.org/offsetpolicy/>). The IUCN highlighted the following as possible avenues for to governments to explore (Ten Kate et al. 2004):

- Environmental impact assessments – including supplementary guidelines and ensuring process are robust and transparent, so that biodiversity offset is clearly motivated, and negotiations take place, and so that offsets are not seen as ‘buy-of’ attempts
- Planning laws – formal systems of applications and enquiries offering avenues to trigger dialogue on biodiversity offsets between developers and regulators where environmental and social conditions are often required as a condition for approvals
- Concession agreements – where biodiversity offsets can become part of, for example permits and license requirements issued to developers by designated government departments.

### C.2.3 Core Principles, Limits and Challenges

The World Bank (World Bank Group 2016) views three core principles as critical for achieving successful biodiversity offsets:

- **Additionality** - offsets must deliver conservation gains beyond those that would be achieved by ongoing or planned activities that are not part of the offset
- **Equivalence** - offsets should conserve same biodiversity values (species, habitats, ecosystems, or ecological functions) as those lost to original project
- **Permanence** - offsets are expected to persist at least as long as adverse biodiversity impacts from a development are expected to persist. Key features for successful long-term conservation include formal legal protection, on-the-ground protection and management, and financial sustainability.

In addition, good practice principles to apply to conservation related activities include:

- Using a ‘landscape approach’ considering relevant habitats and species of interest within the broader landscape, beyond the boundaries of interest
- Applying sound science as well as traditional knowledge
- Ensuring diligent project supervision and effective institutional capacity building
- Addressing livelihood concerns and ensure robust stakeholder engagement.

In most instances biodiversity offsets are viewed as positive from an environmental perspective, although they can be controversial when, for example, offsets are perceived to be inadequate or ‘a license to destroy’ (World Bank Group 2018). Also, there may well be legitimate instances where

biodiversity offsets are not appropriate tools to achieving *'no net losses,'* or even more modest conservation targets, such as:

- Development area contains highly threatened ecosystems or species, is important to the survival of endemic or restricted range species or provides habitat for nationally or globally significant group of migratory species
- Development affects a legally protected area (existing or proposed) or an internationally recognized important site
- Proposed offset areas have poor prospects for long-term conservation.

While biodiversity offsetting is increasingly being applied in terrestrial systems it remains a rarely used tool in the marine environment (World Bank Group 2016). Notwithstanding this, biodiversity offsets - as the last stage in the environmental mitigation hierarchy - do provide opportunities for more sustainable development given the vast demands on coastal and marine resources (Jacob et al. 2020), including port development. While conceptual principles and criteria for biodiversity offsets are similar for terrestrial and marine systems, there are some key differences to consider in marine implementation. First, is the dynamic and diffuse nature of the marine environment where impacts may span spatial and temporal scales beyond the development area. As a result, it is often also challenging to distinguish between the potential influence of a specific development and other existing impacts such as pollution and modification in catchment flows caused by previous development. The extensive connectivity in marine systems can also pose a challenge and must be considered when demarcating areas of potential impact associated with a development. Accurate and current ecosystem data are key in understanding impacts and quantifying offset. While data are often limited in marine systems, expected changes in physical and abiotic parameters - such as geomorphological features, temperature, and salinity - can be used as proxy indicators to identify potential impacts on threatened or important biodiversity. Lack or uncertainty in governance arrangements has been a major challenge in attributing responsibility for implementation of offsets beyond national boundaries but can be improved by considering international or regional governance avenues, and by applying holistic, regional participatory approaches to offset planning, rather than project-by-project (Jacob et al. 2020).

#### C.2.4 Key Steps in Biodiversity Offset Planning and Implementation

Biodiversity offsets planning and implementation involve a range of activities, but generally comprise the following four main steps (for details refer to World Bank Group 2016).

##### Step 1: Estimate residual biodiversity losses from development

To determine an offset it is important to estimate likely biodiversity losses of the proposed development, using environmental processes such as Environmental Impact Assessment (EIAs). Biodiversity information that is typically required includes (i) ecosystem types to be affected, (ii) species of conservation interest, (iii) special biodiversity values, (iv) protection status, (v) site ownership and control, (vi) baseline threats, and (vii) significance of residual adverse impacts. Where inadequate data is available the Precautionary Principle must be applied.

##### Step 2: Select offset activities and conservation site/s

Depending on expected impacts and desired outcomes, a variety of biodiversity activities can be considered. Potential options, or combination of options, include (i) new protected areas or expansion of existing areas, (ii) improving habitat management or habitat enhancement, (iii) habitat restoration or enhancement, (iv) livelihood or community support, and (v) species-specific interventions.

When selecting an offset site, the core principle of equivalence must be applied to seek like-for-like or trading-up conservation outcomes. For example, if the desired conservation outcome is *'no net loss'*, a suitable accounting method must be applied to determine the minimum offset that would provide adequate compensation for the damage from the development. These methods can range from simple to complex multi-variable approaches. Also important is to assess implementation risks, both in terms of the feasibility of the biodiversity offset, as well as maximizing prospects of successful outcome. Stakeholder engagement and information sharing is critical during this step to ensure a consultative and transparent process, and ultimately a successful outcome.

### Step 3: Prepare biodiversity offset project components

Certain key components must be in place to take biodiversity offsets from planning to implementation, adequately documented in project technical and legal documents. These include (i) identification of specific activities and inputs, (ii) institutional responsibilities, (iii) implementation schedule, (iv) budget, and (vi) funding sources.

Where the offset requires establishment or upgrading of protected areas, additional components are required including (i) verification of conservation value, (ii) verification of land tenure, socioeconomic, and political feasibility, (iii) selection of planned management category, (iv) delineation of boundaries, (v) consultation with stakeholders, and (vi) preparation of legal and supporting documents.

Finally, a checklist of issues to consider in the planning process needs to be compiled to serve as reference during early planning stages and pre-approval stages to verify that these have been addressed.

### Step 4: Monitor implementation of biodiversity offset activities and results

As with any conservation project, biodiversity offsets require ongoing monitoring and evaluation, including (i) operational procedures in offset areas, (ii) monitoring of implementation process, (iii) tracking of management effectiveness, and (iv) evaluation against desired outcomes.

## C.2.5 Benefits of Biodiversity Offsets

Besides the obvious (direct) benefit to conservation, biodiversity offsets also hold benefits to society at large (World Bank Group 2016), for example:

- **Business** - strengthening a company's *'license to operate'*, securing support of local communities and non-governmental organisations and thereby expediting regulatory authorisations for new operations. It can also provide a cost-effective means to earn society's trust for negotiating future operations.
- **Government** - offering a mechanism to encourage companies to make significant contributions to conservation, in many cases without the need for new legislation and at less cost than alternative policies.
- **Conservation groups** - influencing biodiversity offsets to secure more and better conservation value and obtaining additional opportunities and funding for conservation, as well as ensuring that national or regional conservation priorities are integrated into business planning.
- **Communities** - using biodiversity offsets to ensure functioning and productive ecosystems during and after development projects which contributes towards securing livelihoods and amenities.

## C.2.6 Securing Financial Sustainability of Biodiversity Offset Activities

Biodiversity offset activities inherently require continuous funding for ongoing management and monitoring, covering costs such as staff remuneration and various disbursements (e.g., fuel, supplies, spare parts). Therefore, already in the planning phase, attention should be given to financial mobilization to secure long-term sustainability (World Bank Group 2016).

Ideally, a developer should cover both set-up and long-term maintenance costs for related biodiversity offsets. However, in real life maintenance costs may be covered in the short- to medium-term, but generally not in perpetuity. It is therefore advisable to investigate alternative options to cover recurrent costs in the long-term, such as:

- Regular operating funds, for example where a protected area was established (or expanded) and where responsible authorities (or landowners) are required to budget for such costs.
- Donor-funding, although these types of 'boom and bust' funding usually only fund up-front investment costs, some may also support recurrent costs for a period.
- Self-generated revenues, generated through on-site attractions for which visitor fees can be charged or generating income through tourism accommodation and services, or the legal harvesting of resources.
- Private philanthropy, sourcing funding from corporate or individual sponsors.
- Carbon offset payments, where offset sites contain significant areas of ecosystems with high levels of carbon storage (e.g., mangroves).
- Project-specific revenue transfers, where areas can be sustained through dedicated revenue transfers from specific infrastructure projects.
- Conservation trust funds, for example where developers set up trust funds to cover recurrent costs.

## C.3 Building-with-Nature Design Approach

Within the context of this guide, 'Building with Nature' is viewed as a novel approach to *hydraulic engineering* that harnesses the forces of nature to benefit environment, economy, and society (EcoShape 2022). In essence, the concept of 'Building with Nature' is underpinned by the concept of ecological engineering, first introduced as a term in the 1960s by Odum, and which proposes that the ecosystem provides the biological 'design' and 'energy' required to 'engineer' social and economic benefits for society (Odum 1975). Since then, the concept has gradually expanded, to not only include 'biological processes' but also to include 'physical processes' (e.g., hydrodynamics and sediment dynamics) (Morris et al. 2019).

The concept of 'Building with Nature' (BwN) or 'Working-with-Nature' (WWN) emerged in response to the growing need for coastal engineering practice to provide for human welfare through development while still protecting natural ecosystems and the benefits they provide to society (Bergen et al., 2001). It was proposed in the late 1970s by the Czech hydraulic engineer Svašek and introduced to the field of coastal engineering in the late 1990s by Waterman (Waterman et al. 1998; Waterman, 2010). Specifically, it requires the integration of environmental and societal systems as early as possible in the design stages of coastal infrastructure (de Vriend et al., 2015; de Vriend and Van Koningsveld, 2012; Vikolainen et al., 2014). Central to the approach is using innovative infrastructure designs that meet socio-economic targets and that are in harmony with the natural environment (Vikolainen et al., 2014). Such ecosystem-based alternatives need to be considered early in the planning and design process to optimise nature-based opportunities (De Boer et al. 2019). The BwN concept adopts a development philosophy of integrating engineering and ecological design principles, where infrastructure design can no longer be driven only by economics but must also consider social values and ecological offerings (De Vriend and Van Koningsveld 2012). Thus, it has become essential for mankind to adapt infrastructure design that aligns with natural processes ('proactive') rather than focusing on mitigating impacts ('reactive'), and which are able to accommodate global change (De Vriend and Van Koningsveld, 2012).

With specific reference to waterways (including ports) useful guidelines on BwN are provided by PIANC (2018) and EcoShape (2022). Port operators are encouraged to consult these useful tools when considering biodiversity offset options in their port. However, we provide a synthesis of useful insights pertaining to BwN/WWN design and implementation to introduce its value in sustainable port development.

Schönborn and Junge (2021) set out seven key principles for successful ecological engineering (or BwN) as follows:

- Principle 1: Avoidance
- Principle 2: Ecological processes and organisms as tool or model for design
- Principle 3: Maximum of renewable energy (during operation)
- Principle 4: Maximum of recycling efficiency (during operation)
- Principle 5: Low externalized environmental costs during entire life cycle
- Principle 6: Design aims for multifunctionality
- Principle 7: Enhancement of quality for both humans and nature.

Prior to engaging in BwN options it is important to understand and ensure that the key driving forces of successful implementation are understood and addressed. EcoShape (2022) identified six such 'enablers':

- Technology and system knowledge – learn how to use knowledge of physical, social and ecosystem in design
- Multi-stakeholder approach – include stakeholders to understand how to add value
- Adaptive management monitoring and maintenance – deal with change to ensure longevity of project
- Embed institutionally – understand link between design and regulatory requirements and create enabling policy environment
- Business case – develop viable case that includes added values and avoided costs
- Capacity building – train and educate to sustain future of BwN and improve community involvement.

Based on experience, a cyclical five step process in generating BwN project design (EcoShape 2022), emerged (Figure C.2):

Step 1: Understand overall system (physical, social and ecosystem)

Step 2: Identify alternatives that use or provide values to nature and humans

Step 3: Evaluate each alternative to enable selection of integral solution

Step 4: Refine selected scenario

Step 5: Prepare solution for implementation.

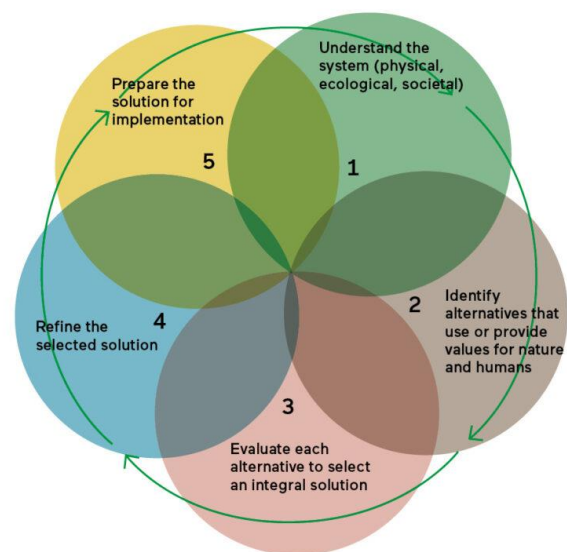


Figure C.2 Five step process for BwN design (Source: EcoShape 2022)

Viewed through a costing lens, Oeremans et al. (2021) proposed a decision-making process in the selection of BwN options (Figure C.3).

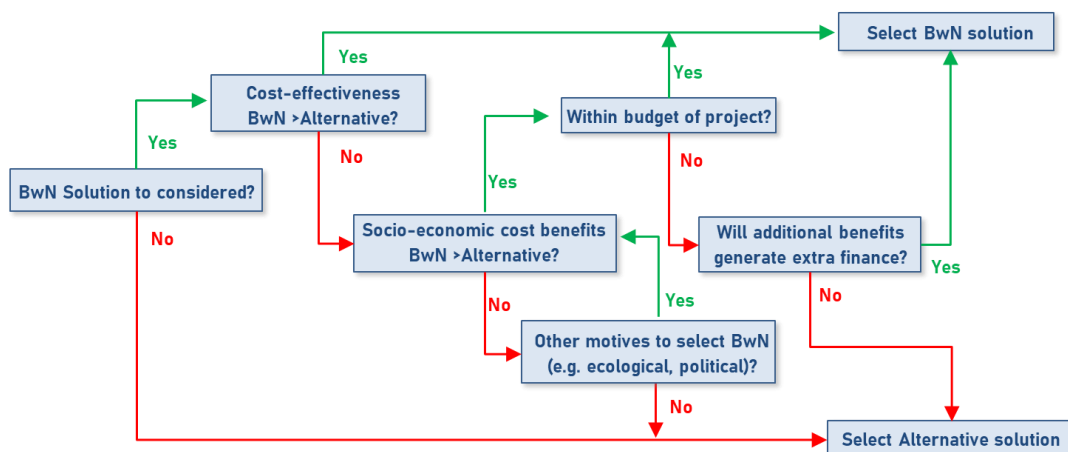


Figure C.3 Decision-making process in selecting BwN options (Source: adapted from Oerlemans et al. 2021)

A key aspect to address in BwN projects in complex natural systems is that of uncertainty. To assist port designers and operators in this regard EcoShape (2021) developed a guide which addresses:

- Overview on different types, sources and levels of uncertainty
- Description of uncertainties related to various problems (problem space)
- Description of uncertainties related to various solutions (solution space)
- Overview on dealing with uncertainties, including case studies.

EcoShape, comprising a network of organisations and individuals working together to advance the application of BwN, has been engaged in an array of related projects throughout the world. These include projects in ports which can provide ideas and inspiration for ports in the WIO region. Examples of BwN solutions applied in port environments include (see EcoShape website for more details):

- Establish mangrove forests and saltmarsh vegetation to enhance shoreline stability through trapping of sediment and promoting wave attenuation. [Specific guidelines on mangrove restoration in the WIO region also are available (UNEP et al. 2020).]
- Re-using uncontaminated dredge material to replenish shorelines instead of transporting and dumping it offshore, removing sediment from nearshore (coastal) system. [Beneficial use of dredged sediments is further discussed in Section D.2.3, this report.]
- Optimizing breakwater shapes in port entrances to reduce scouring, erosion, or limit undesirable sediment accumulation. For example, by accommodating natural sediment circulation processes in design, sediment retention could be limited, thus reducing demand for regular maintenance dredging.
- Establishing shellfish reefs as natural breakwaters, not only to mitigate exposure to physical wave and storm action, but also to improve water quality through biofiltration. Additionally, these organisms could be harvested for food although care must be taken as they also are very effective in accumulating pathogens and toxic substances that can pose serious health risks.
- Floating and hanging structures to smooth underwater environments that offer potential wave attenuation when heavily overgrown. In addition, these offer habitat for biota that could improve biodiversity and offer opportunities for harvesting of seafood, again taking care as some organisms (e.g., filter-feeders) accumulate pathogens and toxic substances in their tissues that can pose health risks if consumed.



## C.4 Ecological Enhancement Options

While the concept of ecological enhancement can be viewed as a component of BwN, its primary purpose does not necessarily have nature-based hydraulic solutions in mind, but rather the *adaptation or modification of infrastructure to increase or improve habitat for endemic marine plants and organisms, while still protecting human health and safety* (Taira et al. 2020; Hall et al. 2018; MacArthur et al. 2020). Here we expand on two key areas of ecological enhancement applicable to ports, that is breakwaters and seawalls, and floating or hanging structures.

### C.4.1 Breakwaters and seawalls

Currently, the most common option for coastal engineering structures, such as breakwaters and seawalls, involves conventional 'hard' engineering (Morris et al. 2020). However, such hard engineering structures use weathered rock or concrete that typically lacks smaller scale surface complexities encountered on natural substrates. They are therefore unable to act as microhabitat for marine biota. For example, in nature microhabitats along rocky shores, such as ledges and small pools, are typically in the centimetre scale (Figure C.4).

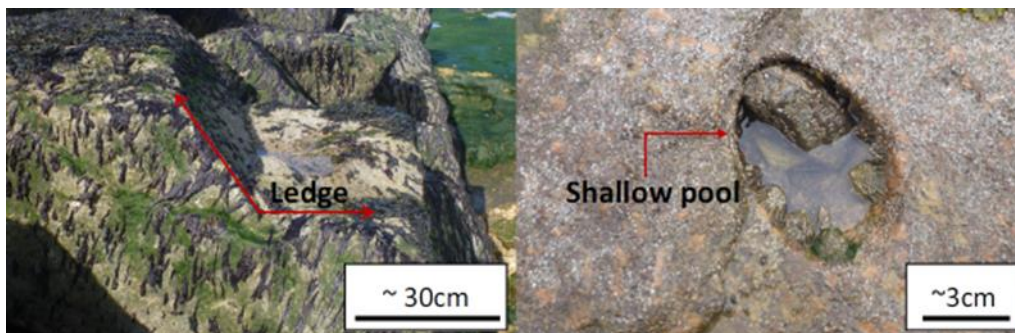


Figure C.4 Example of scale of natural microhabitats along rocky areas (source: MacArthur 2020)

To enhance ecological value, structures are now being designed to better mimic natural habitats and in so doing be multifunctional to the benefit both humans and nature. For example, small holes or grooves are created in boulders used in coastal defence structures (e.g., Chee et al. 2020; MacArthur et al. 2020; Hall et al. 2018; Naylor et al. 2017; Evens et al. 2016) (Figure C.5).



Figure C.5 Example of artificial microhabitats (holes and grooves) on boulders to mimic natural microhabitats (source: Hall et al. 2018)



Ecologically enhanced armouring units for breakwaters are also being manufactured to promote colonization of intertidal and subtidal marine biota. Higher abundance, richness and diversity of invertebrates and fish have been found on and around ecologically enhanced armouring units manufactured using by ecologically enhanced concrete compared with standard units. The ecologically enhanced armouring units also showed greater ecological complexity and lower invasive species ratios (Perkol-Finkel et al. 2018; Ido and Perkol-Finkel 2015) (Figure C.6).

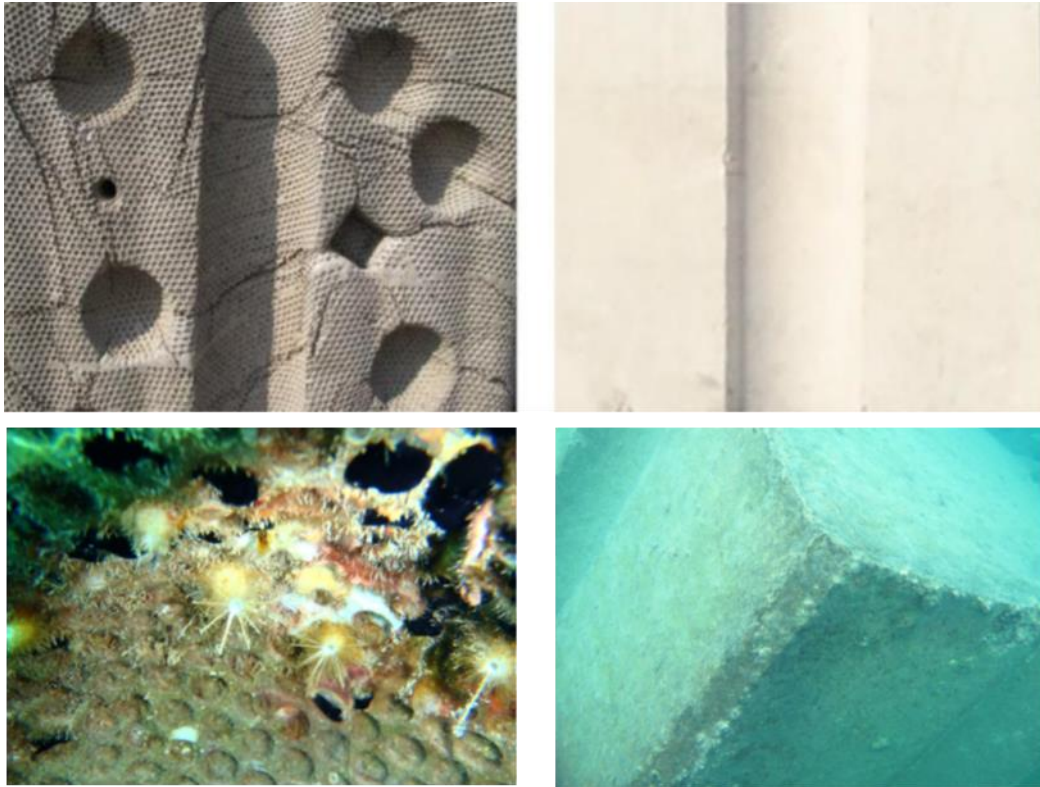


Figure C.6 Example of ecologically enhanced armouring units (left) and standard units (right), also showing colonisation over similar periods (source: Ido and Perkol-Finkel 2015)

Ecological enhancement of vertical seawalls (such as quay walls) also is increasingly being explored. For example, the use of cavity rock pools and so-called flowerpots have been deployed on seawalls to encourage colonization of marine life (Browne and Chapman 2014; Morris et al. 2017, 2018) (Figure C.7). These were found to be effective for benthic species, but still need refinement in relation to colonization of mobile species such as fish.



Figure C.7 Example of cavity pools (left) and flowerpots (right) on vertical seawalls (source: Morris et al. 2018)

Textured surface concrete tiles, mimicking microhabitat scales encountered in nature, have also been tested on vertical seawalls to enhance ecological value (e.g., Coombes et al. 2017; MacArthur 2019). Not surprisingly, these studies, conducted in the UK, showed that tiles with higher complexity developed greatest species richness and mobile species abundance compared with those of lower textured complexity (MacArthur et al. 2019).

#### C.4.2 Floating and hanging structures

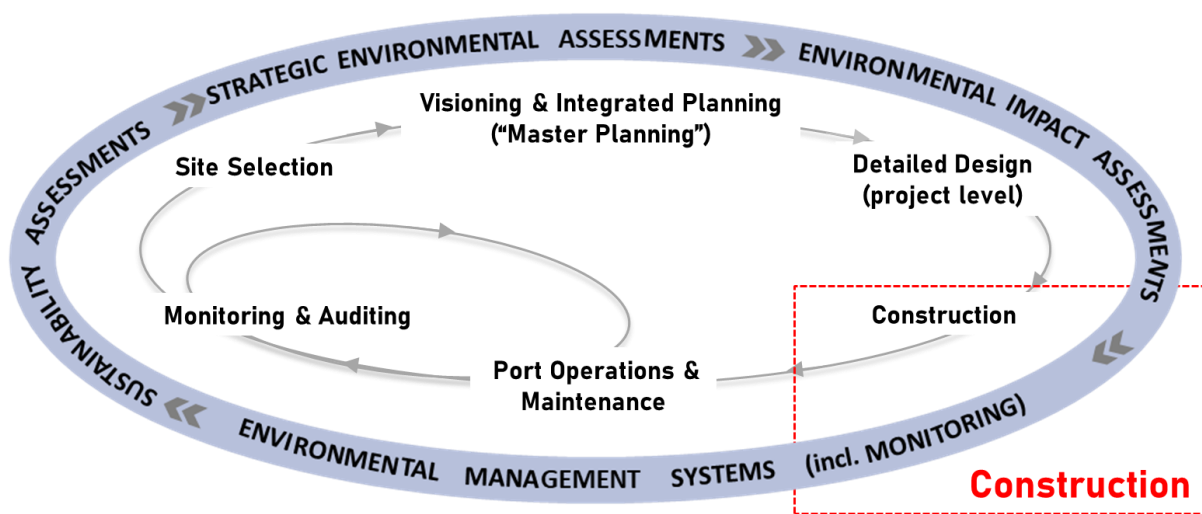
In working ports, restoration of original ecosystem habitat (e.g., seagrass beds or mangrove forests) is not always possible as ports require large relatively deep, open water area for safe navigation and shipping. Furthermore, traditional smooth steel and concrete structures, like sheet-pile walls or jetty piers, provide little hold for marine organisms to colonise. However, these areas and structures can be enhanced using artificial hanging substrates, for example pile and pontoon hulas - so-called because of their resemblance to the traditional Hawaiian skirt (Paalvast et al. 2012; EcoShape 2020) (Figure C.8).



Figure C.8 Example of pile hulas (left) and pontoon hulas (right) (source: Paalvast 2015)

Pile hulas are synthetic free-hanging rope assemblages, made up of quality plastic canvas bands with strings attached that can then be mounted around wooden and steel piles in underwater environments such as encountered in ports (Paalvast 2015). Pontoon hulas comprise floating frames inside of which nylon nets are stretched and to which nylon ropes are suspended. Pontoon hulas can be deployed between jetty piers or sheet-pile walls. Studies conducted in the port of Rotterdam showed the efficiency of these type of structure to enhance sessile biological production and biodiversity, typically including mussels, barnacles and a range of algae species. Mussels (filter feeders) were often the dominant species offering an additional ecosystem service of water purification in areas where residence times are relatively long (EcoShape 2020).

# SECTION D: CONSTRUCTION



## D.1 Construction Environmental Management Plans

Construction activities can result in the discharge pollutants to water courses or the marine environment, emission of noise, dust, or odours that can be aesthetically unacceptable or pose potential health risks, or excavation or importation of unsuitable materials. It is good practice to prepare a construction environmental management plan (CEMP) detailing the actions to be undertaken to manage and minimise such impacts (TNPA n.d.; LPC 2019; South Australia EPA 2021).

Port construction is typically categorised into expansion or improvement projects at existing ports (so-call 'Brownfield sites) or building of new ports (so-called 'Greenfield' sites) (Notteboom et al. 2022). Because Brownfield port construction usually involves rehabilitation and reuse of existing port real estate, it often requires large-scale clean-up operations of contaminated soil. This presents opportunity to remove dangerous structures and mitigate contamination of coastal environments. It also presents valuable opportunities to expand social benefits for the broader community through, for example, waterfront re-development. Redevelopment of previously used sites also can alleviate pressure on adjacent, more pristine coastal habitats (Notteboom et al. 2022). Sustainable port construction mostly involves port development at new sites in offering opportunities to incorporate social and environmentally sustainable practices from the onset.

Port construction primarily involves one or more of the following activities (Notteboom et al. 2022):

- Nautical access to channels, involving dredging
- Quay wall construction
- Embedded retaining walls
- Gravity walls
- Suspended deck structures (piles).

Potential environmental impacts during construction ideally need to be identified in preceding environmental impact assessment (EIA) studies. Demonstrating environmental commitment by considering the potential impact of construction on the surrounding environment is clearly important. During construction environmental monitoring is undertaken to ensure compliance with environmental plans, permits and other regulations, but also to mitigate and minimise environmental impacts. It also helps in managing liability risks and protect against potential claims, and responsible contractors are often favoured by port developers (Nihon Kaetsu 2022).

In the case of ports, a CEMP should be prepared by the responsible contractor, approved by competent environmental officers in the port authority, and implemented by a competent environmental consultant on behalf of the port authority. Key components of an CEMP are summarised in Figure D.1. A brief description of each element is provided below (LPC 2019; TNPA n.d.):

- A: Provide clear description of type of construction to be undertaken including activities, locations of works, timing of works, scale of works, duration of works and any legal requirements
- B: Determine potential environmental effects associated with construction activities including dust, contaminated soil, archaeology, erosion and sedimentation, noise and vibration, and hazardous substances
- C: Assess environmental risk, where risk = likelihood x consequence
- D: Control and monitoring of activities are the most important element of an CEMP as these are the physical actions that must be implemented to mitigate and managed environmental impacts

(also see Section E.11 for further guidance on the design and implementation of environmental monitoring programmes)

- E: Preparation of CEMP document, where the above is compiled into the required format to be determined by the responsible authority
- F: Approval of the CEMP by the authority responsible from the ports, or its owners
- G: Once approved the CEMP needs to be implemented, ensuring that actions are executed as planned, awareness of environmental issues are maintained throughout construction, effectiveness of mitigating actions are assessed, reporting problems for timeous intervention
- H: To maintain relevance, the CEMP must be reviewed when any changes are made, including scope of works or methodology, mitigation measure are ineffective, responsible parties change, season or time of day of work changes, area of works change, identified improvements that could be made, or duration of works changes



Figure D.1 Process for development and implementation of a construction environmental management plan (source: adapted from LPC 2019)



## D.2 Dredge Management (also relevant in Operations)

Dredging is often essential to maintain navigation channels in ports and harbours. Dredged material is typically disposed at sea (open-water disposal) although increasing standard practise is to investigate beneficial uses of dredged material as an alternative to disposal. Dredging can be necessary for various reasons (IMO 2014), including:

- Dredging for purposes of development and maintenance of water-based infrastructure, such as:
  - Capital dredging (usually in construction phase), undertaken for navigation purposes, to enlarge or deepen existing channel and port areas or to create new ones
  - Maintenance dredging (operations), undertaken to ensure that channels, berths or construction works are maintained within design dimensions
  - Dredging to support coastal protection/management (operations), undertaken to relocate sediments for activities as beach nourishment and construction of levees, dykes, jetties, etc.
- Dredging for the purposes of remediation including:
  - Environmental dredging (operations) to remove contaminated sediment for the purpose of reducing risks to human health and the environment or construction of confined aquatic disposal cells to hold contaminated sediments.
- Dredging for purposes of restoring structure and function of coastal and marine ecosystems including:
  - Restoration dredging (operations) to restore or create environmental features or habitats to establish ecosystem functions, benefits, and services
  - Dredging to support local and regional sediment processes (operations) such as engineering to reduce sedimentation (e.g., construction of sediment traps), or retaining sediment within natural sediment systems to support sediment-based habitats, shorelines and infrastructure.

### D.2.1 International Assessment Framework for Dredge Management

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (the London Convention 1972) and the related Protocol 1996 (the London Protocol 1996) is the official international convention dealing with dumping of waste to the marine environment, including dredged material. Several countries in the WIO region are signatories to this convention and protocol. Under the London Protocol, all dumping of waste and other matter at sea is prohibited, except for possibly acceptable wastes on the so-called 'reverse list' of which dredged material is one. Whether these wastes are permitted for dumping needs to be assessed using a procedure written into the London Protocol as set out in Annex II of the Protocol. The IMO views three overarching considerations important when planning and permitting for the disposal of dredged material at sea (IMO 2014):

- Dredged sediment is a resource that should be used for beneficial purposes, as an alternative to disposal in sea, when not contrary to aims of the Convention and Protocol, and is environmentally, technically and economically feasible
- Selection of management options for dredged material should be guided by a comparative risk assessment involving both dumping and the alternatives to dumping
- Management actions for dredged material should ensure, as far as practicable, that environmental disturbance and detriment are minimized, and the benefits maximized.

To assist countries, the International Maritime Organization (IMO) published waste assessment guidance documents, including an assessment framework for dumping of waste (Figure D.2, IMO 2014<sup>9</sup>).

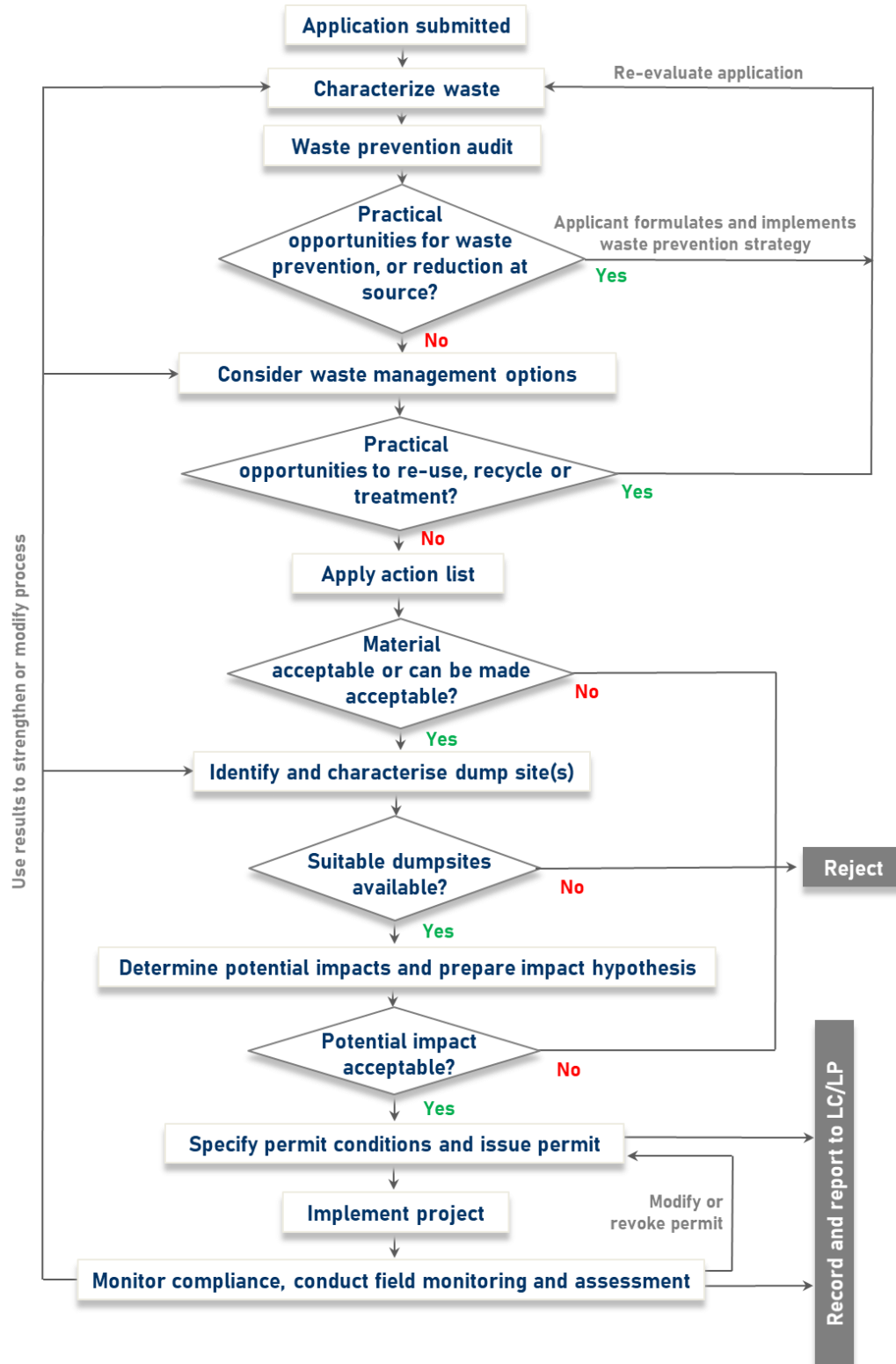


Figure D.2 London Convention & Protocol: Assessment framework (adopted from IMO 2014)

<sup>9</sup> 2021 update can be purchased through <https://www.imo.org/en/publications/Pages/Distributors-default.aspx>

The framework comprises seven main elements (detailed guidance on the implementation of each is provided in Waste Assessment Guidance documents – IMO 2014):

- Characterisation of potential waste material, including physical, chemical and biological characterisation.
- Waste prevention audit, with the purpose of identifying any feasible (or reasonable) opportunities for waste prevention and minimization at source, to prevent having to dispose of dredge material to sea. Where alternative to disposal at sea is identified, applicants are expected to formulate and implement a waste prevention strategy.
- Development of an action list - member states are required to develop national Action Lists to provide a mechanism for screening constituent concentrations in sediment earmarked for dredging and disposal thereof at sea. An Action List specifies the upper level and possibly also levels for constituent concentrations in sediments that would have acute or chronic effects on human health or sensitive marine ecosystems – known as Action Levels (e.g., DEA RSA 2012). The Action Levels provide the decision criteria for determining whether dredged material (i) is suitable for unconfined sea disposal without further testing, (ii) must undergo detailed testing before a decision can be made, or (iii) is unacceptable for unconfined disposal at sea and thus requires special management.
- Evaluation of dredged material management options, following a holistic process to consider potential impacts of different options into a broader perspective
- Selection of disposal sites, and assessment of potential impacts
- Permitting and permit conditions, where permit issuance shall assure compliance with any resulting waste reduction and prevention requirements
- Monitoring and evaluation, both materials to be disposed of and at disposal sites.

## D.2.2 Practical Tools for Application in Dredge Management

Complimentary to the IMO's waste assessment framework (Figure D.1), countries and international port organisation have developed useful supporting tools to assist with specific aspects of dredge management. Notably PIANC (purchasable from <https://www.pianc.org/publications/envicom>) offers a range of guidance documents related to dredge management, of which most recent ones include:

- Dredging and port construction: Interactions with features of archaeological or heritage Interest (EnviCom Guidance Document 124, 2014)
- Long-Term management of confined disposal facilities for dredged material (EnviCom WG 109, 2009)
- Dredging and port construction around coral reefs (EnviCom WG 108, 2010)
- Dredging management practices for the environment: A structured selection approach (EnviCom WG 100, 2009)
- Environmental risk assessment of dredging and disposal operations (EnviCom WG 10, 2006).

In 2020, the Environmental Protection Authority of the State of South Australia, published their dredge guideline (EPA South Australia 2020). While the legislative context of the guideline is based on state-specific requirements, guidance on various risks, and recommendations on appropriate management interventions to mitigate potential impacts on environmental factors such as water quality, noise, air quality, waste, and hazardous waste also are provided. The user-friendly manner in which such information has been collated in the guide (example illustrated in Figure D.3) allows for easy



connection between risks, impacts, and potential management interventions that can be applied in dredge management initiative elsewhere in the world, including the WIO region.

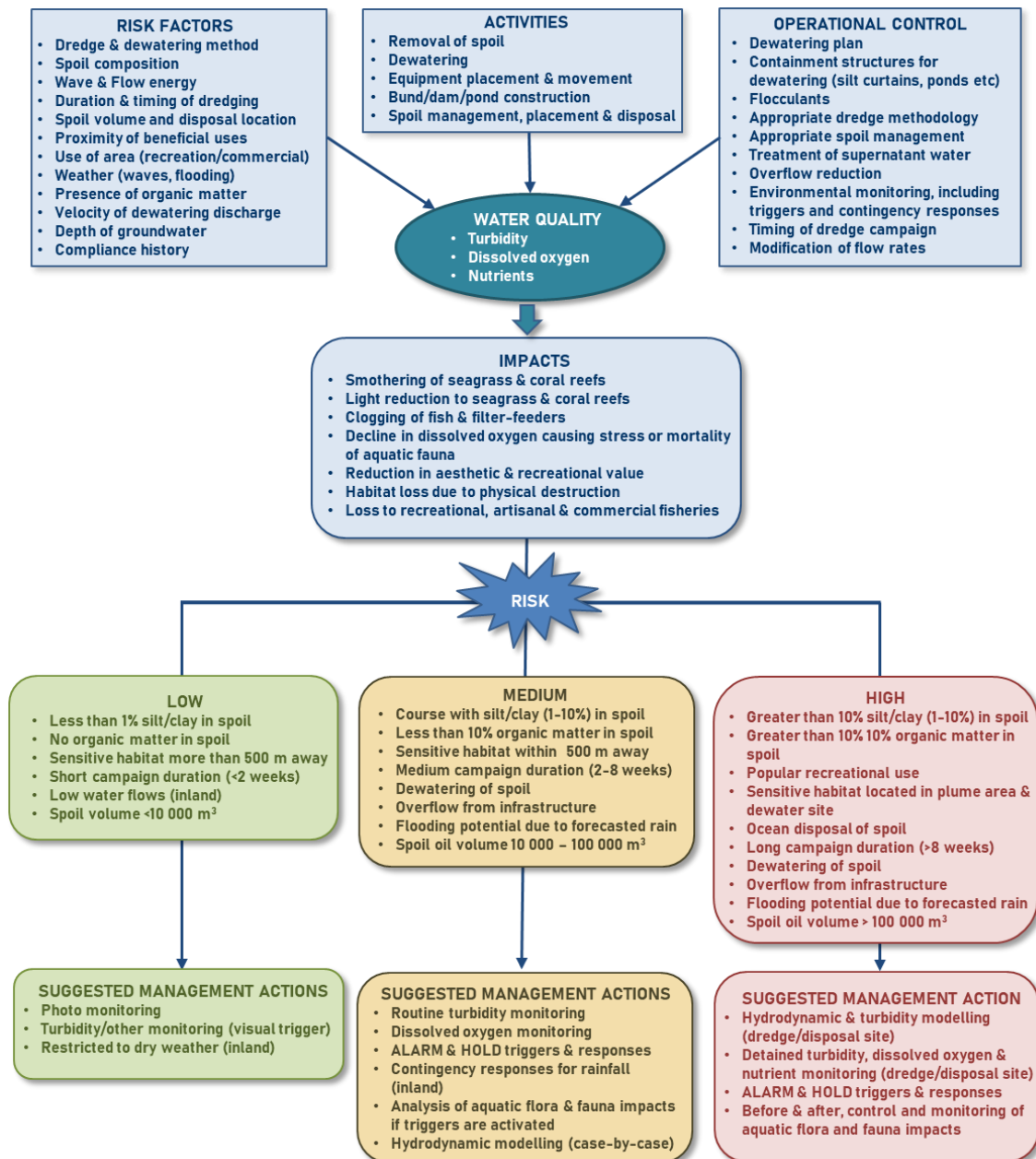


Figure D.3 Example: Synopsis of risks and proposed management linked to water quality as per EPA South Australia's dredge guideline (source: adapted from EPA South Australia 2020)

The South Australian guideline also provides useful insights on environmental data and information requirements to assess potential impacts of dredging, as well as practical guidance on dredge-specific monitoring and assessment (EPA South Australia 2020).

### D.2.3 Dredged Material as a Resource

Traditionally dredge material is viewed as contaminated sediment that needs to be disposed of. However, much of the material dredged for navigation purposes comprise natural occurring sediments that may be relatively uncontaminated and suitable for direct use in various application with no, or limited pre-treatment required. Smaller quantities discharged from industrial areas can be

contaminated with a range of chemicals that render such sediments less suitable for beneficial use, but theoretically they can also be pre-treated to remove or stabilise contaminants (IADC 2019).

Using dredged material is in line with current understanding of sustainable development of our aquatic environments, and many uses, both environmental and engineering, provide opportunities for working with nature in a sustainable way. Increasingly port operators are focusing on finding uses for dredged material and in coordinating supply with concurrent demand. For example, if a port is dredged, and a nearby beach needs replenishment, then the newly retrieved sediment may be suitable for beach nourishment and coastal protection (IADC 2019). To support port authorities in the re-use of their dredge material, PIANC developed guidance title: *Dredge Material as a Resource* (EnviCom WG 104, 2009). The re-use of dredge material is also promoted by the International Association of Dredging Companies (IADC) (<https://www.iadc-dredging.com/>).

Dredged material has been successfully used in various engineering application, including (IADC 2019):

- Construction projects (landfill and foundation materials) such as concrete and brick for (rail)roads
- Isolation of contaminated materials (capping of contaminated sediments)
- Flood and coastal protection
- Land improvement (fertile topsoil, restoration of quarries, and park and garden improvement)
- Placement on the banks (raising land levels and improve soil for agriculture).

There are also numerous environmental uses for dredged material, including (IADC 2019):

- Habitat creation and improvement
- Water quality improvement at engineered wetlands
- Aquaculture building fish farm impoundments near shorelines to supplement wild fishing
- Agricultural purposes such as new topsoil
- Recreational amenities such as non-intrusive trails through wetlands or other sensitive habitats
- Sustainable relocation of depleted natural sediments.

The Central Dredging Association (CEDA) website provides numerous case studies on the beneficial use of dredged material (<https://dredging.org/resources/ceda-publications-online/beneficial-use-of-sediments-case-studies>).

In general, dredged material can be categorised into five sediment types, namely rock, gravel and sand, consolidated clay, silt or soft clay and a mixture of rock, sand silt and soft clay. All can be re-used to varying degrees, e.g. (IADC 2019):

- Rock - construction material
- Gravel and sand - beach nourishment and wetland restoration
- Consolidated clay - production of bricks and ceramics
- Silt and soft clay - agricultural purposes wildlife habitat (often rich in nutrients).

Contaminated dredged material can be treated in various ways prior to re-use, for example (IADC 2019):

- Chemical immobilisation (e.g., removing contaminants by adding clay, cement, lime or fly ash)
- Thermal immobilisation (e.g., breaking down organic contaminants at high temperatures)
- Bioremediation (e.g., using micro-organisms to degrade contaminants)
- Biodegradation (e.g., removing organic contaminants through aeration and spreading of material).

Therefore, dredge material can be applied as a valuable resource, although the viability may be site-specific depending, for example, on the level degree of contamination and demand for such material.

## D.3 Considerations for Port Decommissioning

Decommissioning is the final stage in a holistic infrastructure project cycle (planning, design, construction, operations, and finally decommissioning). It is the process whereby infrastructure that has come to the end of its productive life, is dismantled in an environmentally responsible way, and subsequent restoration of the site to its pre-construction status is undertaken. Presently guidance on the decommissioning of port infrastructure is not readily available in the international literature, although guidance on decommissioning of offshore structures, such as oil platforms, is emerging as these structures are reaching the end of their useful life in many parts of the world (IOGP 2017; Melbourne-Thomas et al. 2021). However, as port infrastructure across the world is also aging, it could become necessary to decommission older berths, or whole ports (in the case of smaller coastal harbours that fall into disuse). Notwithstanding the caveat in specific decommissioning guidance for ports, the key components of a decommissioning process can be assumed to be mostly generic.

Decommissioning should be undertaken in a consultative manner, including both stakeholders and technologists (da Cunha Jácome Vidal et al. (2022), Figure D.4). The process should consider different decommissioning options and appropriate technological solutions, as well as stakeholder considerations. Impact assessments should be undertaken by qualified specialists considering possible environmental, social and economic implications of decommissioning and the operations involved. Considerations of decommissioning should be addressed early on in a project cycle, ideally in the structural design and construction phase. In doing so, potential detrimental impacts can be identified timeously and mitigated by adapting construction methods and materials. This selection process may take the form of an Environmental Impact Assessment, subject to expert review and final approval. Once a suitable option has been selected, the operationalisation thereof needs to be documented in a Decommissioning Plan.

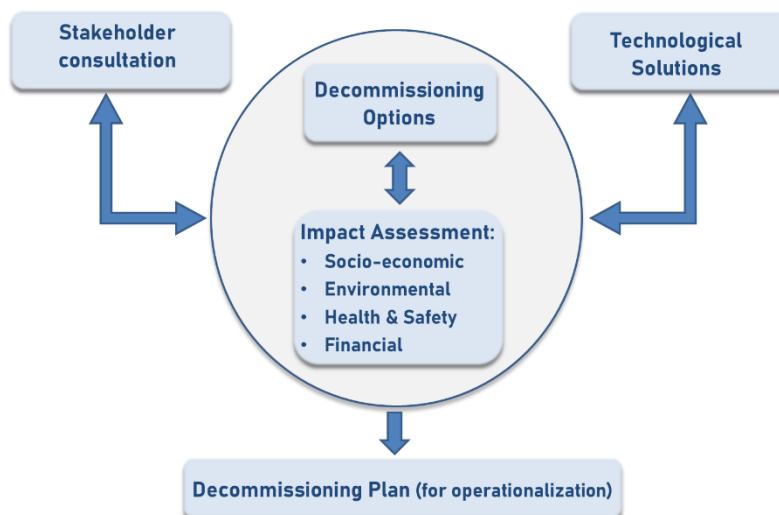


Figure D.4 Conceptual framework for a decommissioning process (adapted da Cunha Jácome Vidal et al. 2022)

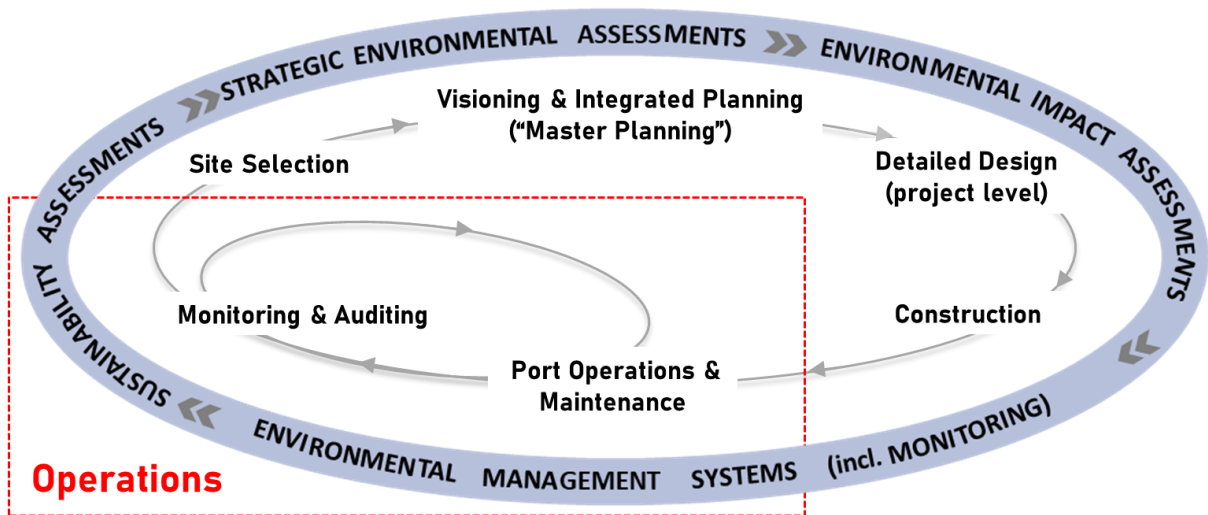
A decommissioning plan articulates management process and actions to be undertaken during decommissioning, addressing:

- Physical and ecological impact of removing structures or partially dismantling structures, including any long-term impact should structures be abandoned (i.e., not removed)

- Technical aspects and feasibility thereof (e.g., methods to remove structures or parts of structure and re-using, recycling or disposal thereof)
- Monitoring programme after decommissioning to ensure that any remaining structures do not adversely affect the marine environment or other uses, as well as to monitor the ecological rehabilitation of any impacted area
- Procedures for removing large marine structures are typically dangerous, lengthy, and costly, therefore, health and safety requirements must also be addressed
- Envisaged costs must be specified considering labour, equipment and any other resource requirements.

It may not be possible to formulate and submit a detailed decommissioning environmental management plan (EMP) for approval at the initiation of project but it should be submitted within reasonable timeframes (e.g., 6 months short term leases, 2 years long term leases) before decommissioning and vacation of land or infrastructure. The scope and terms of reference can be agreed upon signing of the lease or during construction approval phase. A decommissioning EMP should always be site-specific for the development location, considering characteristics of the natural environment, as well as the nature of development activities (TNPA n.d.).

# SECTION E: OPERATIONS



## E.1 Guidance on Environmental Management Systems

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Environmental Management Systems (EMS) are regulatory structures, developed within organisations, rather than being regulated by governments, aimed at proactive and systematic, continuous environmental improvements. In ports they are primarily of relevance in the operational phase. They provide a structured framework designed to achieve continual improvement beyond regulatory compliance to improve efficiency, reduce costs, and minimise negative impacts on human health and the environment. These frameworks address policy making, assessment, planning and implementation of actions, incorporating considerations and decision making into day-to-day operations, but also inform strategic planning (Darnall and Edwards 2006).

EMSs typically consist of an environmental policy and stipulates evaluation processes to be undertaken to assess environmental impacts, establish and implement goals, monitor achievements and review planning and management practices (Lamprecht 1997). Studies have shown the value of well-designed EMSs for environmental performance and technical and organisational innovation, but the degree to which these systems provide strong, competitive benefits depends on the extent to which the EMS permeates into organisational planning and management frameworks (Iraldo et al. 2009).

Benefits to having an EMS (US-EPA 2007) include:

- Improved environmental awareness, compliance, and performance
- Reduced costs and improved operational efficiency through more efficient use of materials, operational streamlining and strategic direction setting
- Reduced risk and liability, and improved security and emergency response capability
- Improved internal communication and cooperation, including between port authorities and terminal operators
- Enhanced credibility, public image and public confidence, as ports monitor and report on performance, and position themselves as leaders in environmental protection and management.

While each EMS is unique to an organisation's culture and priority issues, most follow the Plan-Do-Check-Act model. This model establishes a framework to examine and prioritise the environmental aspects of an organisation, then develop, implement, monitor, review and revise environmental programs and procedures to continually promote sound management and improvement. Importantly, an EMS should naturally leverage and build upon existing good practices and the practical knowledge base of employees throughout the organisation (US-EPA 2007).

EMS have been officially endorsed in many parts of the world. They have received recognition through the International Organisation for Standardisation Standard (ISO) 14001, providing a means of external certification. Such certification through EMS processes within ports is a growing trend aimed at demonstrating environmental compliance and commitment to continuous improvement in port environmental performance (Hossain 2018). Many ports already have components of an EMS in place, such as written and unwritten procedures, best management practices (BMPs) and regulatory compliance programs. Prominent EMS methods applied in ports worldwide include the International Organisation for Standardisation (ISO) 14001 standard (Brouwer and van Koppen 2008; Rebelo et al. 2014; ISO 2020a), the Eco-Management and Audit Scheme (EMAS) (Petrosillo et al. 2012; Testa et al. 2014), EcoPorts (Darbra et al. 2004, 2005; ESPO 2012a, 2012b, 2020) and the World Association for Waterborne Transport Infrastructure (PIANC) Environmental Management Framework (Whitehead 2000).

To facilitate effective environmental reform, EMS frameworks must be adapted to place-based issues (Balzarova et al. 2006). Indeed, a study of West African ports found that context-specific factors strongly influence the type of sustainable port measures adopted in the transition towards sustainability (Lawer et al. 2019). Ports here were found to focus on immediate priority issues such as waste management, rather than future priorities such as climate change mitigation because of limited financial capacity and relatively little public pressure to deal with climate change (Lawer et al. 2019). On the other hand, local challenges can hamper transition to sustainability, even in addressing immediate priorities, if not acknowledged and accounted for in tools such as EMS frameworks.

### GREEN PORT ACTIVITIES IN THE SEYCHELLES

*Captain Joachim Valmont (Seychelles Maritime Safety Authority)*

The Seychelles Port Authority (SPA) has engaged in several green port initiatives.

Through the SMART Port-Green Port cooperation with Grand Port Maritime de La Reunion, the SPA is developing a Natural Heritage Master Plan to identify various fauna, flora, and natural habitats in and around port areas, and subsequently, to identify and mitigate potential threats from port related activities.

As part of the Port of Victoria expansion project (Technical Assistance No. 2) the SPA is being aided with development and implementation of an Environmental and Social Policy. This includes assistance with the implementation of an environmental audit, to be followed by the development of an Environmental Management System towards achieving ISO 14001 certification for the Seychelles Port Authority. Additionally, capacity building activities to raise awareness and increase the ability of SPA to perform all the required and relevant environmental tasks and actions will be undertaken.

Supported by the Agence Francaise pour Development, awareness is being raised among L'Association des Ports des Îles de l'Océan Indien members on issues related to ecological and energy transition, adaptation to the consequences of climate change and port-city integration. This also includes a diagnostic analysis of existing initiatives, recommendation on actions to be implemented in ports, and drawing up of terms of reference for feasibility studies that will enable the implementation of concrete solutions.

As part of a project funded by the International Development Association a feasibility study to evaluate the available options for in-berth vessel emission reductions at Mahe commercial quay at Port Victoria has been completed. Results showed avenues for shore power connections, although the energy will have to come from renewable sources if to be ecologically and financially viable.

Going forward the SPA hopes to accelerate its effort in getting Port Victoria to becoming a Green Port.



Arabi et al. (2022) reviewed the international literature to identify key challenges facing port environmental management in African ports. Major challenges identified included *lack of legislation and environmental policies, managerial commitment, environmental institutionalisation, financial planning, technical capacity planning, general (public) education and awareness, and human resource planning and training*. Critical in the African context is acknowledgement of the *reliance of local communities on coastal environments in and around ports* (Mbalisi and Offor 2012; Pescatori and Franceschini 2017; Barnes-Dabban et al. 2018; Di Vaio and Varriale 2018; Barnes-Dabban and Karlsson-Vinkhuyzen 2018; Lawer et al. 2019; Taljaard et al. 2021). While existing EMS methods (e.g., ISO14001, EMAS and EcoPorts) acknowledge the importance of addressing legislation and environmental policies, managerial commitment, and human resource planning and training, they are not explicit on the importance of addressing environmental institutionalisation, financial planning, technical capacity planning, general (public) education and awareness, nor on the need to acknowledge and consider reliance of local communities on coastal environments in and around ports. Arabi et al. (2022), therefore proposed a framework for EMS in African ports (Figure E.1) building largely on existing approaches but incorporating elements to address the latter challenges.

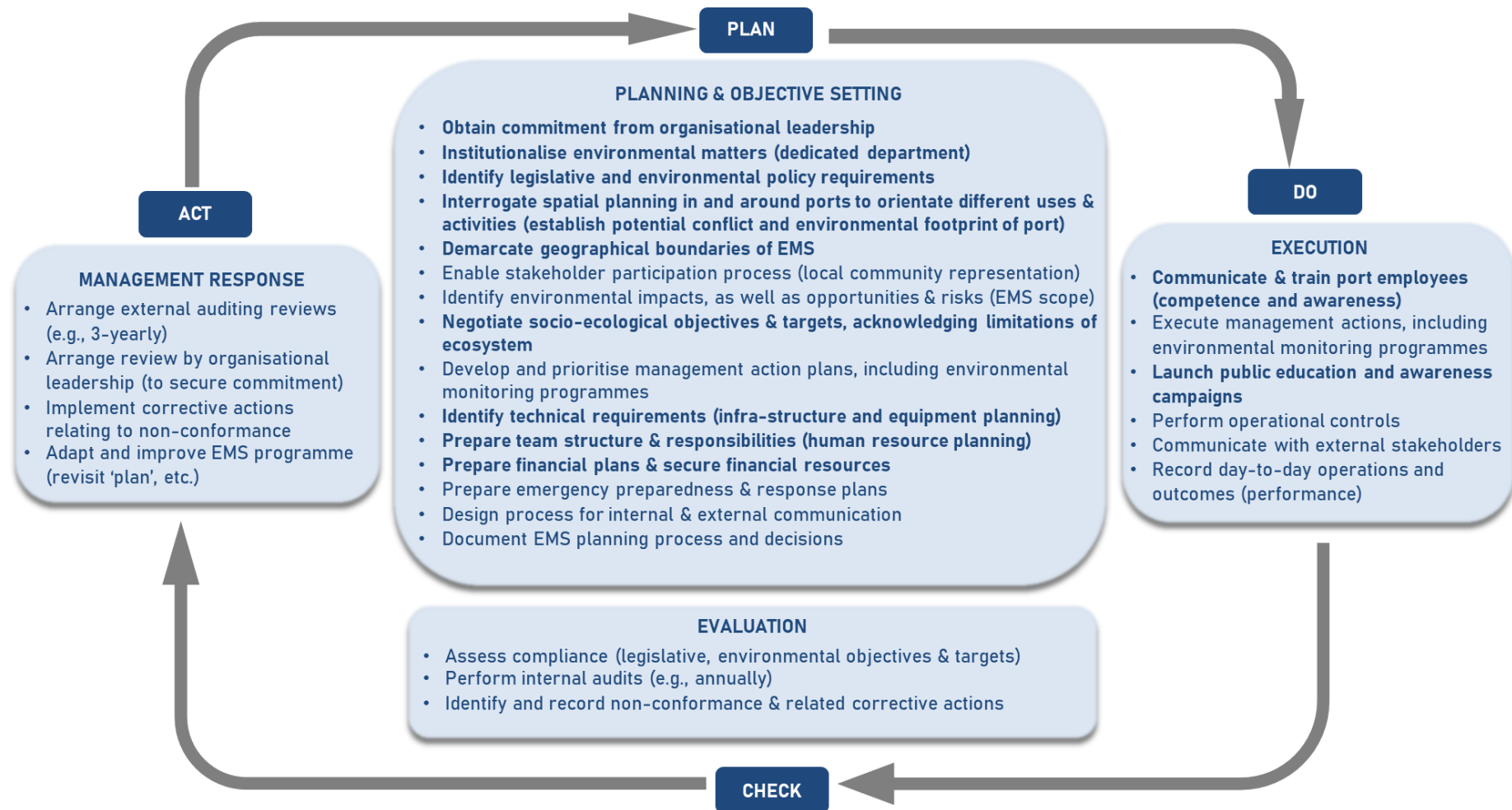


Figure E.1 EMS Framework for African ports explicitly accounting for key continental challenges (see in bold) (adapted from Arabi et al. 2022)



Whilst effective EMS implementation frameworks must be adapted to organisational culture and priority issues (Balzarova et al. 2006), most apply the generic Plan-Do-Check-Act (PDCA) model (Graham et al. 2011; Rebelo et al. 2014). The PDCA model (also referred to as the Deming cycle) was originally developed by Shewhart in the 1930s (Shewhart 1939) and improved by Deming in the 1950s (Deming 1986). The 'plan' stage involves the development of improvement plans, the 'do' stage entails implementation of the identified actions, the 'check' stage reviews the effectiveness of planning and implementation, and finally the 'act' stage addresses possible adaptations or changes to improve the effectiveness for the EMS following an adaptive management approach (Nguyen et al. 2020).

#### EUROPE'S ENVIRONMENTAL POLICY CODE (EPSO 2012A)

European port authorities believe in:

1. Achieving voluntary self-regulation that raises standards beyond regulations through a bottom-up approach
2. Cooperation and sharing of knowledge and experience between port authorities on environmental matters
3. Serving in parallel the interests of the business and the local communities aiming towards the sustainable operation of port areas
4. Applying a systematic approach to port environmental management through appropriate structures that enable continuous improvement of performance
5. Being transparent in communicating and reporting on the ports' efforts and environmental performance.

Towards improving environmental performance actions to focus on:

1. Exemplifying: Setting a good example towards the wider port community by demonstrating excellence in managing the environmental performance of their own operations, equipment and assets
2. Enabling: Providing the operational and infrastructural conditions within the port area that facilitate port users and enhance improved environmental performance within the port area
3. Encouraging: Providing incentives to port users that encourage a change of behaviour and induce them to continuously improve their environmental performance
4. Engaging: with port users and/or competent authorities in sharing knowledge, means and skills towards joint projects targeting environmental improvement in the port area and the logistic chain
5. Enforcing: Making use of mechanisms that enforce good environmental practice by port users where applicable and ensuring compliance.

### E.1.1 'Plan'

Within the PDCA cycle the 'plan' component deals with planning and addresses elements such as situational analyses, objective setting, identification of management actions, as well as allocating employee roles and responsibilities (Figure E.1). Managerial commitment and institutionalisation of environmental matters (e.g., through establishment of dedicated, resourced departments) are key elements to be secured early in the planning stages of EMS. Further, the interrogation of spatial plans establishing uses and activities in and around ports is important to identify potential conflicts and to establish environmental footprints, as has been demonstrated in successful ICM implementation. Such footprints typically dictate the geographical boundaries of the EMS.

A participatory process, involving key external stakeholders and local communities potentially affected by port operations, should be followed in the negotiation of socio-ecological objectives and targets. In the African context, environmental footprints of ports often extend into areas supporting community livelihoods, necessitating a participatory approach and ongoing communication to address and mitigate potential conflict.

Design of management action plans, as well as environmental monitoring programmes to evaluate environmental issues specific to the port also falls within the 'plan' phase. These programmes can be expensive and therefore need to be properly planned and coordinated. Realistic financial planning is

an important element in the planning phase as the execution of management actions and monitoring programmes is dependent on human resources and capacity. It may even be necessary to prioritise management interventions to align with budget availability. Proactive, emergency response planning is required to prevent detrimental impacts in the case of, for example oils spills. Finally, the documentation of EMS planning processes and outcomes, and the communication thereof is important.

### E.1.2 'Do'

The 'do' components within the PDCA model primarily entails execution of planned management actions (Figure E.1). Within the 'do' phase communication and training of identified employee teams are an integral element, creating the level of competence required to execute specific actions. Further, communicating with external stakeholders regarding significant environmental aspects, and implementation of operational controls and emergency response preparedness are key in this phase. Environmental monitoring comprises another key component within the 'do' phase as the acquisition of environmental data and information underpins the ability to evaluate. It also covers environmental monitoring and evaluating, highlighting the importance of properly calibrating and maintaining monitoring equipment.

The high reliance of communities on coastal resources and associated inter-relationships with port operations, especially within the African context, warrants broader education and awareness programmes. Such programmes can take on different forms from formal to informal initiatives, for example through meetings, workshops, print, electronic and audio-visual media. The use of environmental education materials like posters, leaflets, billboards has been shown to be effective in schools and public places to keep the citizens constantly informed. Finally, to enable sound evaluation control performance systems need to be in place, as well as accurate recording of the day-to-day operations and outcomes.

#### GREEN PORT ACHIEVEMENTS – TANZANIA PORTS AUTHORITY (TPA)

*Claudianus D. Kunze (Tanzania Ports Authority)*

The government of Tanzania, through the Tanzania Ports Authority (TPA), has been taking steps to improve port sustainability to protect the marine environment. In consultation with Royal HaskoningDHV and Deltares (for the Netherlands) TPA developed a Green Port Policy (2018) specifically aimed at greening both existing operations as well as the design, implementation, and operations of new infrastructures in the Port of Dar es salaam. Implementation of the associated action plan will enable the TPA to:

- Move towards the attainment of ISO14001 accreditation through a pro-active, comprehensive, and coordinated approach
- Make informed decisions on follow-up actions in strategic areas such as environmental management, energy efficiency, waste management, oil spill response, social impact and responsibility, stakeholder involvement and efficient port logistics and connectivity
- Base decision making on well-coordinated framework and vision on climate change and environmentally friendly port operations
- Create awareness among public and private stakeholders of the importance of being a green port.



*Presentation of Green Policy to TPA's Deputy Director General*

Expansions in the Port of Dar e Salaam (2018-2024), known as the Dar es Salaam Maritime Gateway Program (DMGP), also have been guided by Green Port Policy action plan from design, tendering, implementation, through to procurement and operation.

TPA is gradually transitioning into sustainable port operations although more efforts and resources need to be committed to speed up this transition.

### E.1.3 'Check'

The 'check' component in the framework focuses primarily on evaluation of operational outcomes and monitoring outputs. Compliance assessment involves the implementation of procedures to evaluate adherence to predefined legal and environmental objectives and targets, specifically with the aim of identifying nonconformities. The latter should be holistic, recording the causes and impacts, proposed mitigation, as well as the responsible departments and/or authorities. Internal audits are also a mechanism to control quality and should form of a port's overall management review process.

### E.1.4 'Act'

The 'act' component deals with management responses to outcomes of the 'check' phase. Corrective actions need to be implemented, and outcomes of the EMS process need to be communicated and reviewed by the organisational leadership to sustain buy-in and commitment. True to the cyclic, adaptive management approach, management responses also need to ensure that protocols are in place to revisit the entire EMS process from planning rippling through the other components within the PDCA model. External auditing by third party auditors is advisable to obtain a neutral, objective and critical evaluation of the EMS. Where required, adapting and improving the EMS process is an important final step in the 'act' phase, in line with the principle of adaptive management.

## E.2 Circular Economy in Ports

In *Reviving the Western Indian Ocean Economy* (Obura et al. 2017) the circular economy has been identified as one of the key tools towards achieving sustainable blue economies in the region. In contrast to the 'take-make-waste' linear economy, the circular economy adopts a systemic approach that tackles global challenges like climate change, biodiversity loss, waste, and pollution. It is regenerative by design and aims to gradually decouple economic growth from the consumption of finite natural resources (Figure E.2).

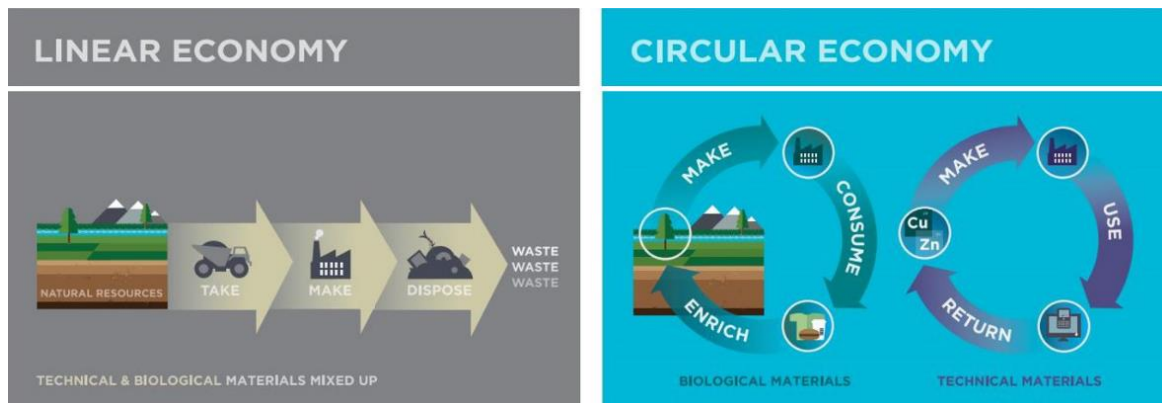


Figure E.2 Comparison between the linear and circular economy (source: <https://ellenmacarthurfoundation.org/>)

Three key principles underpin the circular economy (Ellen MacArthur Foundation 2022):

- Eliminate waste and pollution
- Circulate products and materials (at their highest value)
- Regenerate nature.

*"Recycling begins at the end - the 'get rid' stage of a product's lifecycle. The circular economy, however, goes right back to the beginning to prevent waste and pollution from being created in the first place. In the face of our current environmental challenges, recycling won't be enough to overcome the sheer amount of waste we produce."* Ellen MacArthur Foundation

*"In a properly built circular economy, one should rather focus on avoiding the recycling stage at all costs. It may sound straightforward but preventing waste from being created in the first place is the only realistic strategy."* World Economic Forum

There is substantial potential for the port sector to benefit from the application of the circular economy in their operations, not only to decrease negative externalities but also to boost economic growth and enhance competitiveness (Karimpour et al. 2019). This can be achieved through either of the two main cycles in the circular economy system, that is the technical cycle and biological cycle (Figure E.3). In the biological cycles, renewable resources could be used in energy generation, while within the technical cycle, products and materials generated or used in ports can be kept in circulation through processes such as reuse, repair, remanufacture and recycling. Ports across the world are realising this potential and several have set out visions for transition to the circular economy. For example, bio-based economies are emerging in several ports, including the generation of wind and solar power and the production of biomass and waste-based energy production. The transition to a circular economy also provides new business opportunities, for example the use of heat from waste for cooling systems or the use of ship waste for producing energy for ports and adjacent cities (De Langen and Soronn-Friese 2017).

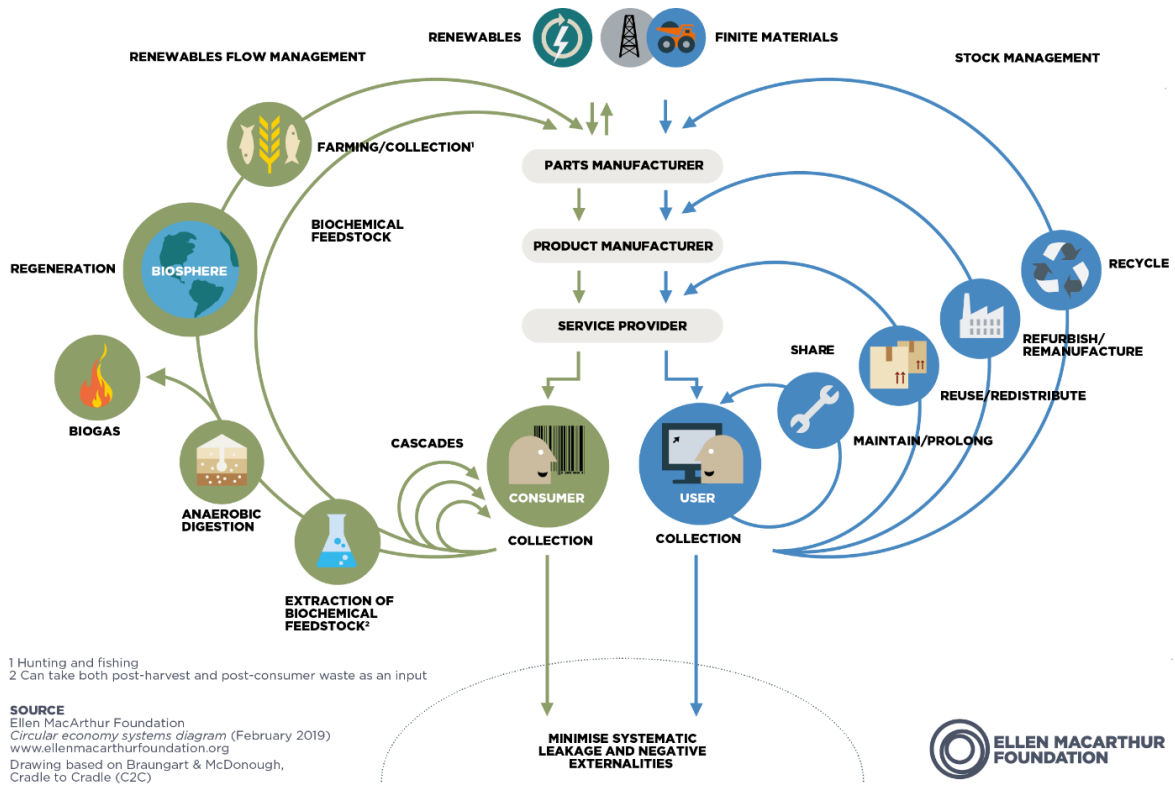


Figure E.3 The circular economy system, showing the biological and technical cycles (source: <https://ellenmacarthurfoundation.org/>)

The principles and spirit of the circular economy, therefore, largely underpin the achievement of sustainable port growth and development in the WIO region, as reflected in the many of the tools offered in this Toolkit.

## E.3 Examples of Sustainable Port Activities

In 2015 the United Nations adopted the 2030 Agenda for Sustainable Development with 17 Sustainable Development Goals (SDGs) (UN 2015). With the adoption and establishment of the concept, monitoring of progress to achieving Sustainable Development has become necessary, and the concept of sustainability assessment has emerged (Sala et al. 2015). The World Ports Sustainability Program (WPSP), launched in 2018, aims to contribute to the sustainable development of world ports aligned with the UN's Sustainability Agenda and SDGs. The programme is led by the International Association of Ports and Harbours (IAPH) in partnership with major port industry-related organizations (WPSP 2020). Their most recent sustainability report on world ports provided a list of potential actions in the port sector that would contribute to achieving the SDGs (Table E.1).

Table E.1: Example of port activities supporting SDGs (Source: WPSP 2020)

| ASPECT   | SDG   | EXAMPLES OF ACTIVITIES IN PORTS  |
|--|---|--|
| Poverty and human wellbeing  |  1 NO POVERTY                        | <ul style="list-style-type: none"> <li>Setting a good minimum wage for the port employees and encouraging similar practices in the port community</li> <li>Taking responsibility for the application of ethical standards throughout the supply chain (e.g., working conditions and human rights in developing countries)</li> <li>Including sustainability requirements (e.g., Fairtrade label) in procurement</li> <li>Supporting local communities in need through social projects targeting sustainable growth</li> <li>Supporting local social institutions (e.g., schools, orphanages, NGOs)</li> </ul>  |
|  |  3 GOOD HEALTH AND WELL-BEING        | <ul style="list-style-type: none"> <li>Improving health and safety awareness of employees and local communities through training and transparent communication on health and safety risks</li> <li>Minimizing environmental externalities (e.g., air pollution, water pollution, noise) of port operations and greening of the port and urban areas</li> <li>Initiatives on sustainable / safe mobility and projects targeting congestion</li> <li>Enhancing port safety and security and minimizing risks</li> <li>Awareness raising and actions against the use of addictive substances (e.g., tobacco, alcohol, drugs)</li> <li>Protecting habitats and biodiversity in and around the port area</li> </ul>   |
|  |  4 QUALITY EDUCATION               | <ul style="list-style-type: none"> <li>Competence and talent policy for port employees</li> <li>Enhance life-long learning for the port employees</li> <li>Cooperating with local schools, universities and research centres in educational programs, internships and port visits.</li> <li>Offering training to port professionals through dedicated institutions</li> <li>Creating synergies with universities in port research and development projects</li> </ul>  |
|  |  5 GENDER EQUALITY                 | <ul style="list-style-type: none"> <li>Gender-neutral hiring and remuneration policies</li> <li>Promoting women to leadership roles; training and hiring more women for port operational positions (e.g., crane operators)</li> <li>Leveling the male/female ratio of port employees for operational and managerial positions</li> <li>Taking measures that make the port working environment more attractive to women (e.g., separate toilets, promotional campaigns, family-friendly HR-policy)</li> </ul>   |
| Sustainable production & consumption; equitable distribution of goods & services |  2 NO HUNGER                       | <ul style="list-style-type: none"> <li>Supporting local projects targeting the provision of food to families/communities in need</li> <li>Encouraging the transfer of food surpluses out of the warehouses in the port to charities, food banks and community organizations</li> <li>Supporting the trade/storage of Fairtrade and other ethically produced agricultural products in cooperation with NGOs and community organizations</li> <li>Sourcing Fairtrade food products for own catering</li> <li>Providing drinking water and clean sanitation facilities for port employees and visitors (e.g., vessels' crew, truck drivers)</li> </ul>  |
|  |  6 CLEAN WATER AND SANITATION      | <ul style="list-style-type: none"> <li>Minimizing/optimizing water consumption in the port area</li> <li>Harvesting rainwater for port use</li> <li>Protecting water-related ecosystems (e.g., estuaries, wetlands, mangroves) in and around the port area</li> <li>Projects protecting freshwater resources (e.g., wastewater and stormwater treatment)</li> </ul>  |
|  |  7 AFFORDABLE AND CLEAN ENERGY     | <ul style="list-style-type: none"> <li>Locally producing and/or sourcing renewable energy</li> <li>Supporting research and development on clean energy technology</li> <li>Producing and/or recovering energy from industrial waste streams</li> <li>Investing in energy-efficient port equipment (stationary and mobile material handling equipment, lighting and technology)</li> <li>Encouraging clean energy initiatives from third parties (vessels, tenants and operators) through appropriate instruments (incentives, clauses in lease/concession agreements)</li> <li>Providing Onshore Power Supply from renewable sources</li> <li>Providing cleaner (marine) fuels in a safe and efficient manner</li> <li>Optimizing port operations and processes (logistics, port calls)</li> </ul>                                     |
| Sustainable production & consumption; equitable distribution of goods & services |  8 DECENT WORK AND ECONOMIC GROWTH | <ul style="list-style-type: none"> <li>Achieving economic growth through diversification, innovation and technological modernization</li> <li>Generating economic growth in an environmentally sustainable manner</li> <li>Ensuring that economic growth positively impacts local communities economically and socially</li> <li>Promoting employment, including opportunities for disadvantaged groups and young people</li> <li>Striving for a healthy and safe working environment for all: specific actions related to safety and ergonomics, and creating a good work/life balance</li> <li>Generating a sustainable model for cruise tourism</li> <li>Taking responsibility for applying ethical standards throughout the end-to-end supply chain (e.g., working conditions and human rights in developing countries)</li> </ul> |

| ASPECT                    | SDG   | EXAMPLES OF ACTIVITIES IN PORTS  |
|---------------------------|---|--|
|                           |    | <ul style="list-style-type: none"> <li>Devising sustainable port development policies supported by relevant key performance indicators</li> <li>Digitally optimizing infrastructure and port operations/processes/services</li> <li>Piloting, testing and implementing innovative IT and digital technologies in the port for public and private use</li> <li>Foreseeing the adaptation of port infrastructure to withstand climate change</li> <li>Adapting port infrastructure and processes to meet market demands (such as increasing ship size)</li> <li>Sustainable port development projects</li> <li>Investing in infrastructure for all transport modes to enable a balanced modal split</li> <li>Minimizing environmental impact of the port activities</li> </ul> |
|                           |    | <ul style="list-style-type: none"> <li>Achieving equality within the port independent of gender, origin, belief, conviction etc.</li> <li>Port community initiatives being all inclusive irrespective of socio-economic background (e.g., supporting sensitive social groups)</li> <li>Social background-neutral hiring and remuneration policies</li> <li>Taking responsibility for the application of ethical standards throughout the supply chain (e.g., working conditions and human rights in third world countries)</li> <li>Financial support to local communities in need and social projects targeting sustainable growth of neighbouring communities</li> <li>Ethical investment and banking</li> </ul>   |
|                           |    | <ul style="list-style-type: none"> <li>Improving sustainable mobility and reducing congestion for both employees and goods</li> <li>Restoring ecosystems and making the port accessible and attractive for people in neighbouring urban areas</li> <li>Minimizing environmental externalities of port operations (e.g., air pollution, water pollution, noise)</li> <li>Disaster recovery planning</li> <li>Community engagement programs and initiatives</li> <li>Supporting local communities in need through social projects targeting decent living and working opportunities that generate sustainable growth of neighbouring communities</li> <li>Supporting local social institutions (e.g., schools, orphanages, NGOs)</li> </ul>                                    |
|                           |   | <ul style="list-style-type: none"> <li>Sustainably managing natural resources, chemicals and waste</li> <li>Implementing responsible procurement and sustainable investments in port area management and development as well as the end-to-end supply chain etc.</li> <li>Encouraging circular economy and industrial reuse and mutually beneficial use of resources in the port community</li> <li>Optimizing port operations/processes/services</li> <li>Reducing food wastage and food loss in the production / supply chain (e.g., connecting the cruise industry with an NGO addressing poverty in your city or region)</li> </ul>  |
| Natural resource base     |  | <ul style="list-style-type: none"> <li>Improving energy efficiency of port operations, processes and services</li> <li>Enabling the reduction of carbon and greenhouse gas emissions within the port area</li> <li>Adapting port infrastructure and port related operations to Climate Change</li> <li>Providing services to reduce greenhouse gas emissions at sea and on the waterways, as well as the hinterland part of the supply chain</li> <li>Producing and/or sourcing renewable energy</li> <li>Encouraging third parties (vessels, tenants and operators) to take clean energy initiatives, by providing incentives and integrating clauses in lease and concession agreements</li> </ul>   |
|                           |  | <ul style="list-style-type: none"> <li>Taking measures to prevent waste from ending up in the oceans (e.g., port reception facilities, fishing for litter, cleanup actions)</li> <li>Promoting sustainable fishing activities</li> <li>Supporting research regarding sustainable use of maritime resources</li> <li>Reducing the emission of CO<sub>2</sub>, SO<sub>2</sub>, NO<sub>x</sub>, NH<sub>3</sub> from port- related activities to avoid acidification of the oceans</li> <li>Minimizing water pollution through adequate wastewater treatment facilities</li> <li>Protecting coastal and estuarine ecosystems</li> <li>Minimizing disturbing factors such as underwater noise for marine mammals</li> </ul>   |
|                           |  | <ul style="list-style-type: none"> <li>Supporting local projects regarding nature development and biodiversity</li> <li>Recovering and protecting nature and biodiversity in the port surroundings</li> <li>Preventing deforestation through the usage/procurement of sustainably certified wood and paper</li> <li>Offering nature and environmental education programs to employees</li> <li>Port area development in balance with ecosystems</li> <li>Minimising environmental externalities of port operations (e.g., air pollution, noise)</li> </ul>   |
| Governance & Institutions |  | <ul style="list-style-type: none"> <li>Constructive dialogue between employer and employees</li> <li>Good governance (a clear policy statement, stakeholder analysis, defined measurements, consistent reporting)</li> <li>Peace initiatives (e.g., peace education on the work floor, prevention of illegal arms trafficking)</li> <li>Addressing security: cyber security measures, commercial and operational data protection, improving the careful use and protection of personal data</li> <li>Open dialogue and collaboration with all stakeholders (including emergency services, customs and armed forces) and availability of a hotline for complaints and questions</li> <li>Transparent internal and external communication</li> </ul>                           |
|                           |  | <ul style="list-style-type: none"> <li>Partnerships with local communities for port-city relation initiatives</li> <li>Partnering with other ports and parties in the logistics chain in joint projects of common interest</li> <li>Public-private partnerships for funding and implementing sustainability projects</li> <li>Establishing supply chain partnerships for ensuring CSR values throughout the chain</li> <li>Cooperating with other ports for educational/training purposes (e.g., joint port training programs and centres)</li> <li>Joint research and development projects involving port stakeholders, academia, industry and authorities</li> </ul>   |



## E.4 Securing External Finance for Port Development

In the forward of the 2021 Report of the Inter-agency Task Force on Financing for Development (UN 2021) the Secretary-General of the United Nations emphasized that '*Financing for sustainable development is at a crossroads. Either we close the yawning gap between political ambition and development financing, or we will fail to deliver the Sustainable Development Goals (SDGs) by the deadline of 2030*'. To support funding institutions in selection of sustainable development projects linked to the blue economy (that is sustainable ocean development), UNEP's Finance Initiative (UNEP-FI) published '*Turning the Tide – how to finance a sustainable ocean recovery*' (UNEP-FI 2021). This document provides also useful guidance for investment in sustainable port development and highlights activities to avoid or to challenge, based on their sustainability credentials and overall environmental and social risks. To access international funding opportunities, it is important for port operators in the WIO region to have insight in such matters to make themselves eligible for such financial support. Port operators are encouraged to refer to the original documentation (UNEP-FI 2021) for specific details. A few innovative options proposed for possible financial investment is highlighted here (extracted from UNEP-FI 2021).

A wave of innovation is currently happening in the maritime industry, including in ports and associated services. Several areas of innovation in sustainable port development and operations are fast emerging, some of which have been considered good business opportunities for financiers. These include:

- Digital applications aimed at improving complex tasks such as traffic management, allocating and measuring energy usage, piloting, docking, cargo verification, environmental compliance, storage, and inland transport. Areas for product development include - Artificial intelligence, autonomous vessels, blockchain, cybersecurity, digitalization, and smart shipping, all offering benefits from resource efficiency to labour savings and risk reduction.
- Maritime accelerators that leverage ports to support start-up growth, such as testing facilities, heavy equipment, business contacts, capital and production capabilities to maritime innovators. In addition to sustainability gains, accelerators drive job creation and economic growth.
- Clean onshore power (or cold ironing), for example solar energy and wind turbines, are considered a strong area of innovation for technology and delivery. Production and storage of alternative fuels (hydrogen, ammonia, methanol, biofuels) are capital-intensive but essential parts of the IMO emissions-reduction trajectory.
- Clean auxiliary power for vessels, installing innovative systems on vessels in ports.
- Waste management, as ports are increasingly taking on this servicing role and therefore safe disposal of solid waste, ballast water, fuel residue and chemicals also are fast rising innovation. For example, recycling options offer the ability to create alternative revenue streams for ports.
- Port expansion that respects environmental codes creates opportunities for innovation for green and sustainable growth, including training of skilled workers and overall capacity building.

The Framework Document of *Agenda 2063: The Africa we Want* provides useful guidance on financing options towards achieving its aspirations and goals which is relevant to financing of sustainable port development in Africa (African Union 2015).



## E.5 Sustainable Use of Materials and Land

To encourage port developers and operators to adopt more sustainable approaches in the consumption of resources, the Port Authority of New South Wales developed guidelines to assist with the identification and evaluation of such innovations (NSW Port Authority 2017). Table E.2 provides an overview of specific criteria and recommended measures that can be applied towards greening material- and land-use in ports (NSW Port Authority 2017).

### DECARBONIZATION INITIATIVES IN PORT OF MAPUTO (MOZAMBIQUE)

*Jerónimo Tamele (Maputo Port Development Company, MPDC)*

The Port of Maputo is implementing initiatives to reduce the emission of greenhouse gases. Currently tugs and pilot boats turn off their generators when moored, and electricity is supplied by sources installed on the pier.



*Trees planted in Port of Maputo*

The Maputo Port Development Company (MPDC) also believes that the effect of greenhouse gases can be compensated by undertaking restoration of forests and tree planting. Hence, MPDC carries out awareness campaigns for workers to engage in the planting of trees.



*Source supplying electricity to boats when berthed*

Table E.2: Criteria and guidance on measures towards greener resource consumption (Source: NSW Port Authority 2017)

| TYPE                 | CRITERIA  | PROPOSED MEASURES  |
|----------------------|---|--|
| Material selection   | Reducing use of new materials by more efficient use, reusing or recycling | Set targets to promote reduction of materials use (e.g., % recycled materials to be used)<br>Reuse existing building/facility where possible<br>Purchase furniture/facility items of reused or recycled material<br>Use recycled materials in building/facility construction   |
|                      | Environmentally friendly production of materials                          | Use timber products from recycled or sustainably sourced resources.<br>Avoid or minimise use of PVC plastic<br>Preference to suppliers applying sound environmental management and with environmentally friendly supply chains   |
|                      | Materials with minimal embodied energy and environmental impact           | Undertake Life Cycle Assessment of building materials<br>Specify low maintenance and durable materials<br>Specify locally available materials (reduce transportation)  |
|                      | Holistic fate of materials, from 'cradle-to-grave'                        | Potential future recyclability and reusability of constructed buildings/facilities and components<br>Recycle material such as timber, concrete, bricks, cardboard, and aluminium, paper, glass, and PET plastic<br>Recycle green waste (e.g., by chipping and mulching on-site)<br>Monitor waste recovery quantities<br>Provide for future increase in recycling storage facilities<br>Greywater collection and treatment systems<br>On-site blackwater treatment with appropriate reuse |
| Sustainable land-use | Use landscaping to enhance biodiversity or create habitat                 | Use local native species for landscaping, adapted to local climate and to encourage native fauna<br>Identify important habitats and implement measures for protection, enhancement, or restoration<br>Incorporate existing topsoil and subsoil into development (where of suitable quality)<br>Incorporate existing vegetation into development (where appropriate)<br>Use environmentally friendly landscape products   |

| TYPE  | CRITERIA                       | PROPOSED MEASURES  |
|---|--------------------------------|--|
|   |                                | Contain and remove any noxious plants prior to site development and during operation |
|   |                                | Use non-chemical/poison control measures for weed and pest control                   |
|   | Enhance visual amenity         | Design landscaping to enhance existing amenities                                     |
|   |                                | Blend building finishes with surrounding areas not to cause adverse visual impacts   |
|   | Avoid impact on heritage areas | Identify protected heritage areas and ensure protection or relocation                |
|   |                                | Coordinate trucks to avoid unnecessary truck movements and idling                    |
| Maximise transport of freight via rail or water (rather than by road) |                                |  |

To assist with evaluation and prioritisation for implementation the guide summarises the business case for each intervention in terms of environmental and social benefits, relative ease of implementation and return on investment (e.g., capital cost, maintenance and cost savings) (NSW Port Authority 2017).

## E.6 Energy Efficiency Management

With continuous increases in energy prices and climate change mitigation becoming more urgent, ports have to explore avenues to enhance their energy efficiency. Also, greater environmental awareness and associated societal pressures, as well as more stringent legislation on pollution and GHG emissions, are placing energy consumption in ports under greater scrutiny (Iris and Lam 2019).

To assist port in their efforts, PIANC published a guideline entitled '*Renewables and energy efficiency for maritime ports*'<sup>10</sup> (PIANC 2019c). Iris and Lam (2019), Bjerkan and Seter (2019), Sdoukopoulos et al. (2019) and Boile et al. (2016) all provide insight on recent advances in energy efficiency management in ports. Brief guidance energy efficiency management in ports is provided here, but port operators are encouraged to consult these documents for detailed insight and guidance on energy efficiency management.

### E.6.1 Port Energy Management Plan

Within the overall framework of port planning and management, energy management is embedded in environmental management, and ultimately in port master planning (Figure E.4). For this reason, port energy management plans are often embedded in environmental management systems (Sdoukopoulos et al. 2019), or even early on in port master planning (PIANC 2019).

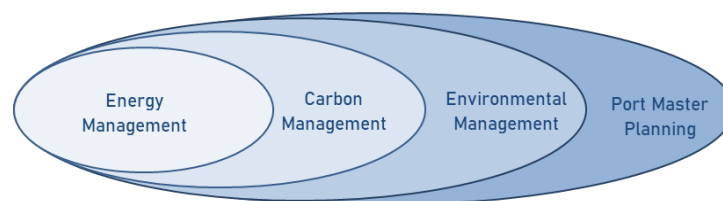


Figure E.4 Context of port energy management within broader framework of environmental management and port master planning (source: adapted from Sdoukopoulos et al. 2019)

The process to follow in the development of a port energy management plan is presented in Figure E.5 (Boile et al. 2016).

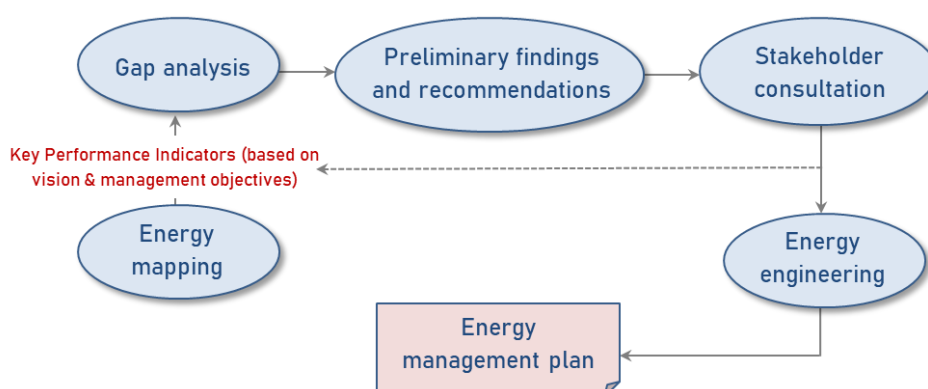


Figure E.5 Port energy management planning process (source: adapted from Boile et al. 2019)

Mapping of a port's energy consumption is a critical first step in the development process of an energy management plan (Figure E.6). This method of constructing an energy map is aligned with ISO 50001

<sup>10</sup> Purchasable from <https://www.pianc.org/publications/marcom/wg159>

'Energy Management', a tool that was introduced by the International Standards Organization (ISO) in 2011 to achieve energy consumption reduction goals (Boile et al. 2016; Sdoukopoulos et al. 2019). First, the total energy consumption needs to be established to understand overall energy costs, both in terms of direct fuel consumption and also purchased electricity. Thereafter, fuel consumption is organised into a few logical blocks or categories (operations, support and maintenance functions and buildings), and the key energy consuming activities within each of these is identified. Finally, energy consumption (fuel or electricity) of all the above is assessed, considering, for example, equipment deployment and time of operation (Boile et al. 2019).

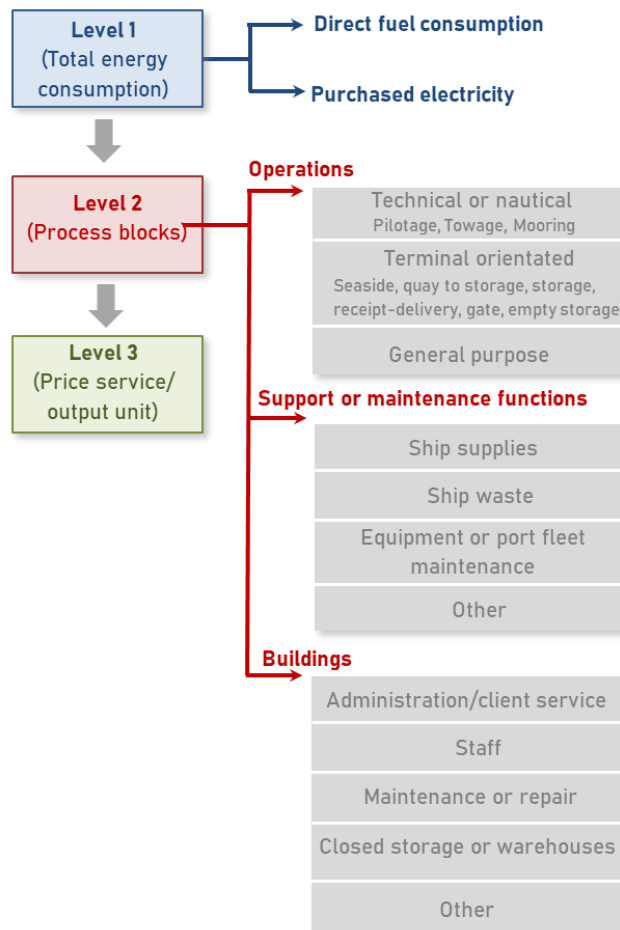


Figure E.6 Method to construct a port energy map (source: adapted from Boile et al. 2019)

Following mapping, a gap analysis is required to establish shortfalls to address in achieving energy efficiency, guided by a port's energy vision and management objectives (Figure E.3). In setting management objectives for energy efficiency in ports, five key pillars are considered important (Boile et al 2016):

- **Resilience** - ability to sustain business continuity during power outages and resuming operations after catastrophic events
- **Availability** - energy sources meet present and future power demands through energy generation, transmission, and distribution
- **Reliability** - high-quality and consistent energy that meets predicted peak demand
- **Efficiency** - reducing energy demand through effective management practices and technologies minimizing operational productivity and cost effectiveness

- Sustainability – integrating energy management practices and renewable power generation to minimize impacts on natural resources.

#### SOLAR ENERGY INITIATIVE FOR LIGHTHOUSES AND NAVIGATIONAL SYSTEMS, TRANSNET NATIONAL PORTS AUTHORITY (SOUTH AFRICA)

*Asakhile Maxama and Cebile Nzuza (Transnet National Ports Authority)*

Sustainability and sourcing new and alternative energy sources has been one of Transnet National Ports Authority's (TNPA) goals in recent years. To this end the TNPA is embarking on the installation of solar technologies to alleviate the country's power challenges and to support greener operations in its ports. One such successful initiative is the greening of energy sources at lighthouses and other marine aids to assist with navigation of vessels within port limits and along the coast. Lighthouses on Bird Island (Gqeberha), Dassen Island (Yzerfontein), and at the southern and northern entrances of Saldanha Bay are now exclusively powered by solar technology, replacing primarily diesel generators, and only using the older technology as backup power. Photovoltaic panels are used to produce electricity which is stored in batteries to provide power at night. The introduction of solar technology has also reduced fuel transport and storage costs, consequently, reducing environmental pollution risks. Another advantage of solar technology is that it can be monitored and controlled remotely, reducing first-line maintenance visits, and subsequently lowers costs and safety risks. Solar technology has also been introduced for marine lanterns on light buoys in all eight commercial ports, operating independently which are fully programmable, require minimal maintenance, and are cost-friendly upon replacement.



*Lighthouses powered by solar technology*

By reducing fossil fuel usage in its ports, the TNPA is reducing carbon emissions, promoting sustainability in line with the Sustainability Development Goals.

Stakeholder consultation and buy-in remains an important consideration in any environmental management planning process. Therefore, any preliminary recommendations on future actions identified by port operators, need to be communicated with all port community stakeholders. Findings should be updated, and recommendations distilled through the consultation process. This allows refinement and, ultimately, consensus. Only then can the energy re-engineering process to construct the energy management plan that should include the following elements (see Boile et al. [2016] for further details):

- Vision and management objectives for energy management (as agreed with key stakeholders)
- Energy-related policies, regulations, and standards
- Summary of energy consumption (derived from energy mapping exercise)
- Energy needs and potential measures for improvement (derived from gap analysis, key findings, and recommendations)
- Selection criteria against which to assess various energy-improving measures for suitability
- Selection of measures, including responsible actors, timelines, and estimated costs of implementation.

The adoption of a robust energy management plan can assist ports in prioritizing and setting pathways for short-, medium- and long-term actions towards achieving their energy-efficiency vision and objectives (Boile et al. 2016).

## E.6.2 Energy Efficient Technologies

Numerous technological options are available to enhance energy efficiency and reduce GHG emissions in ports, including the use of electricity, energy storage devices, reefer cooling technologies, renewable and clean fuels, and lighting technologies (Bjerkan and Seter 2019; Iris and Lam 2019; PIANC 2019c; Sdoukopoulos et al. 2019). A brief overview these technologies is provided in this section.

Realistically it may not always be possible to implement all energy-efficiency measures at once. Therefore, progression to energy efficiency should be viewed in the context of continuous investment in improved technologies, incrementally replacing equipment with energy efficient alternatives as they reach end-of-life because of economic or technical reasons (Boile et al. 2016).

### GREEN PORT ACHIEVEMENTS - KENYA PORTS AUTHORITY

*Mohamed Hassan, Kenya Ports Authority*

The Kenya Ports Authority (KPA) has adopted a Green Port Policy (GPP) that is intended to address the negative impacts of port operations and is geared towards integration of environmental sustainability in port development/ operations and significant reduction in greenhouse gas emissions. The policy focuses on initiatives on climate change mitigation/adaptation, use of renewable energy and recognizes the importance of stakeholders and partners towards achieving its sustainability objectives. The Authority has been undertaking several programmes toward implementation of the GPP and greening the port, including:

- Use of green renewable energy through the installation of grid-tiled roof-top solar power plants in the port
- Procurement of hybrid cranes
- Installation of energy efficient electrical equipment including LED lighting, power factor correction for electricity supply, energy efficient chiller plants, using energy efficient air conditioners
- Shore power for pilot/tugboats
- Purchasing eco-friendly hoppers and protection and conservation of both of terrestrial and marine biodiversity
- Switching from road to rail, estimated to reduce carbon dioxide emissions by about 70,000 t by the year 2028
- Eco-terracing of steep hillsides within the port following several incidences of small landslides.



*Roof-top solar PV installed at cruise ship terminal*

Currently, the focus of the GPP is on the Port of Mombasa, but the KPA plans to expand its scope to include other ports managed by them, including the ports of Lamu and Kisumu, and the dry ports. Implementing sustainability and green port projects envisaged in the policy is an expensive undertaking for the port considering all other ongoing port expansion infrastructure projects. The lack of adequate internal funds necessitates implementation of projects in phases, sometimes also having to delay or suspend some of the projects.

### E.6.2.1 Renewable energy sources

Renewable energy is generated from resources that are naturally replenishable such as solar, wind, and ocean energy (PIANC 2019c; Boile et al. 2016). While it main not be possible to solely rely on renewable sources of energy, at least in the short- to medium term, these sources can be used in hybrid modes with other more conventional energy forms.

Suitability for generating solar power depends on several factors including climatic conditions, availability of space to position panels or collectors, power and heat requirements, ability to feed into public electricity grid or other energy storage facility. Solar energy comprises three main types (PIANC 2019c):

- Photovoltaic (PV) energy, where photovoltaic cells convert solar irradiation into electricity

- Solar hot water, stationary heat absorbing collectors transferring heat to heat transmission fluids
- Concentrated solar power, based on absorption of solar heat concentrated with sun-tracking parabolic mirrors.

Ports, being located at the coast or within river flood plains areas that are subject to adequate wind velocities, are often well-situated to exploit wind energy. As with solar energy options the availability of space, and integration electricity grid integration or storage facilities are important considerations. Specific challenges with wind energy generation pertains to navigation and crane operation interference, noise, and impact on birds.

Tidal energy is generated by harnessing the kinetic energy of changing tides, especially in constricted coastal areas such as straits and passes between islands. For example, tidal stream turbines are placed in-stream to generate energy from water flows. Such energy is then converted into electricity using various conversion technologies (PIANC 2019c). Wave energy is another oceanic source of power. Its advantage is that it is a high-quality form energy traveling over long distances from offshore with little loss before being harvested at the coast. However, natural seasonal and interannual variability can be a disadvantage, and it is critical to properly assess place-based oceanic conditions prior to its inclusion in the energy portfolio of ports (PIANC 2019c).

#### E.6.2.2 Cleaner fuels

Core to energy efficiency within the context of sustainability is the reduction of GHG emissions. One of the avenues to achieve this is using clear fuels, such as LNG, hydrogen and biofuels (Iris and Lam 2019). Decarbonisation of shipping is another key global climate action to limit GHG emissions. Indeed, a new IMO rule came into force in January 2020 that limits the sulphur in the fuel oil used on board ships operating outside designated emission control areas to 0.50% m/m (mass by mass). This rule (referred to as 'IMO 2020') was made compulsory following an amendment to Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL) (IMO 2020). Key to unlocking this challenge is investment in land-based infrastructure, such as port low-sulphur refuelling facilities.

When natural gas is turned into liquified natural gas (LNG) by cooling to  $-162^{\circ}\text{C}$ , volumes are dramatically reduced, allowing it to be transported safely and efficiently by suitably equipped vessels. Although not yet widely used as an energy source in ports, LNG is being widely promoted by international regulations because of its environmental advantages, having significantly less GHG emission risks compared with fossil fuels such as diesel (PIANC 2019c).

Hydrogen has a high energy density per unit mass making it a great source of power. This energy source can be produced from a wide range of resources using various raw materials, pathways, and technologies, including fossil fuels and renewable energy. When hydrogen is produced from renewable sources it is referred to as 'green' hydrogen. The technological and economic viability of green hydrogen production, however, depends on a country's specific resources and the character of its energy market. Therefore, cost competitiveness of this energy source is place-based and should be assessed accordingly (Macía et al. 2021).

Biofuels, such as bioethanol can be sustainably produced from waste and lignocellulosic feedstocks, and potentially offers a low carbon alternative energy source in ports (Bjerkkan and Seter 2019). At present the cost of biofuels remains higher than the cost of fossil fuels, but specific mandates on biofuels or carbon taxes is likely to make biofuels economically more competitive in future (IEA Bioenergy 2017). Such factors include:



- IMO 2020 regulations requiring reduced sulphur levels in marine fuels
- Increased demand for reducing GHG emissions by governments and customers of port services
- Ability to hedge fuel costs in local currency, away from fossil crude pricing.

#### E.6.2.3 Energy storage devices

Another avenue to optimize energy efficiency and reduce environmental impacts in ports is investment in energy storage systems. Development of such technologies is rapidly increasing, primarily driven by greater awareness to reduce fossil fuel consumption and be able to store output from renewable energy sources during period of low energy production. Energy storage technologies include (see PIANC [2019c] for details):

- Batteries
- Supercapacitors
- Flywheels.

#### E.6.2.4 Electrification

The use of electricity as an alternative energy source is still a challenge for many African ports because of unreliable electricity supply, especially where they rely on local or national public grids. Generating electricity from renewable sources, therefore offers great opportunities. Indeed, ports can become hubs for renewable energy, and in so doing contribute greatly to the decarbonisation of shipping.

Ships typically have two types of engines, the main or propulsion engines, and auxiliary engines that power hotelling activities (e.g., power system maintenance, lighting, refrigerating). Both engine types burn diesel oil, heavy fuel oil, liquefied natural gas (LNG), or a combination thereof. To reduce GHG emission when vessels are in ports, auxiliary power for hotelling activities can be obtained from a dockside electricity source - referred to as cold ironing. Cold ironing can be quite efficient in ports receiving cruise ships, as these vessels use a large amount of energy with many passengers staying on board during hotelling. Notwithstanding energy benefits, the implementation of cold ironing technologies can be challenging, requiring proper voltage, correct connection types, reliable power supply, specific grid characteristics, and security. Thorough site-specific assessments are therefore required prior to implementation in a port.

Ports operate a vast array equipment during operations and the electrification of such equipment also can contribute to significantly enhance energy efficiency. Diesel is often a popular energy source in ports, but Table E.3 illustrates different types of alternative energy sources that have been applied to power various types of port equipment (Iris and Lam 2019).

Table E.3: Examples of alternative energy sources for different types of port equipment (source: Iris and Lam 2019)

| EQUIPMENT TYPE             | DIESEL | ELECTRICITY | LNG | HYDROGEN |
|----------------------------|--------|-------------|-----|----------|
| Quay cranes                | ●      | ●           |     |          |
| Rail-Mounted Gantry cranes |        | ●           |     |          |
| Rubber-Tired Gantry cranes | ●      | ●           | ●   |          |
| Reach stackers             | ●      | ●           | ●   |          |
| Yard trucks                | ●      | ●           | ●   | ●        |
| Straddle carriers          | ●      | ●           | ●   |          |
| Automated guided vehicles  | ●      | ●           |     |          |
| Automated stackers         |        | ●           |     |          |

### E.6.2.5 Reefer cooling technologies

Across the world, containerized reefer (refrigerated container) trade is growing at a faster rate than conventional container trade (Boile et al. 2016; Sdoukopoulos et al. 2019; PIANC 2019c). These containers require continuous refrigeration, and it has been shown that energy use from these containers accounts for 20% to 45% of the total energy consumption in ports (Iris and Lam 2016). Technologies, therefore, are being developed to focus on optimizing the design of refrigerated containers to save energy.

To avoid heating, storage areas for containerized reefers in ports should be positioned to limit travel times, and preferably be covered. An optimal schedule should also be implemented to regularly monitored container areas to reduce unnecessary energy consumption and potential losses (Boile et al. 2019). Implementation of renewable energy technologies, for example covering the roof of a reefer area with solar panels to generate power, also offers opportunities (Sdoukopoulos et al. 2019).

### E.6.2.6 Lighting technologies

Lighting contributes significantly to energy consumption in ports, estimated at between 2% and 5% (Boile et al. 2016). Energy efficiency, therefore, also can be enhanced through smart lighting solutions. For example, using LED lamps instead of high-pressure sodium lamps in port facilities and outdoor terminals can improve energy efficiency (Iris and Lam 2019). Also, LED lighting allows for the installation of lighting control systems that uses light intelligently (PIANC 2019c).

### E.6.2.7 Efficient vehicle and ship handling

Energy efficiency can also be enhanced by appropriate operations of vehicles and ships in port areas. For example, driving vehicles in a more environmentally friendly ways, such as avoiding frequent or unnecessary braking and stopping, maintaining a steady speed, and shifting gears at low rpm not only results in lower fuel consumption, but can also reduce air pollution. A good balance between environment and operational efficiency should be strived for (Sdoukopoulos et al. 2019).

Speed control of ships in port area also contributes to lower fuel consumption and reduced air pollution (Zis et al. 2014; Iris and Lam 2019). An important contributing factor is quick turnaround times that will reduce port stay times, giving ships the opportunity to reduce sailing speed at sea and in approaching and leaving ports. Energy savings through speed reduction near ports can reach up to 25.4% (Chang and Jhang 2016).

## E.6.3 Guidance on Implementation

To encourage port developers and operators to adopt more sustainable approaches in the consumption of resources, the Port Authority of New South Wales developed guidelines to assist with the identification and evaluation of such innovations (NSW Port Authority 2017). Table E.4 provides an overview of specific criteria and recommended measures that could be applied towards greener energy use, including transportation. To assist with evaluation and prioritisation for implementation, the guide summarises the business case for each intervention in terms of environmental and social benefits, relative ease of implementation, and return on investment (e.g., capital cost, maintenance, and cost savings) (NSW Port Authority 2017).

Table E.4: Criteria and guidance on measures towards greener energy use, including transportation (source: NSW Port Authority 2017)

| TYPE       | CRITERIA                                       | PROPOSED MEASURES   |
|------------|--|---|
| Energy use | Reduce energy consumption and GHG as emissions | Passive solar and microclimate design through orientation, shading, ventilation, lighting, and insulation |
|            |  | Shading and insulation for refrigerated containers  |

| TYPE   | CRITERIA   | PROPOSED MEASURES   |   |
|--|--|---|---|
|  |  | Low energy and energy efficient terminal and operational equipment and appliances |   |
|  |  | Energy efficient light bulbs or compact fluorescent lights                        |   |
|  |  | Maintain low power densities for lighting workspaces                              |   |
|  | Manage energy use and minimise consumption           |   | Clearly labelled and accessible individual switches for lighting zones, dimmers, and sensors              |
|  |  |   | Perform quality monitoring of building services performance   |
|  |  |   | Electrical and gas sub-metering for separate energy uses  |
|  |  |   | Install peak energy demand reduction systems using water source heat rejection instead of dry air coolers |
| Use renewable energy sources                                     |  | Generate renewable energy on-site   |   |
|  |  | Purchase renewable or 'green' energy for use on-site                              |   |
| Alternate energy sources and use less greenhouse intensive fuels |  | Use on-site energy supply   |   |
|  |  | Alternative cleaner and less GHG intensive fuels                                  |   |
|  |  | Shore-to-ship power connections (cold ironing)                                    |   |
| Transportation   | Alternative modes of transport by employees          | Limit number of car parking spaces  |   |
|  |  | Cyclist facilities  |   |
|  |  | Cycle paths and/or footpaths within port area                                     |   |
|  |  | Bus (or other) link to nearby public transport                                    |   |
|  |  | Car share plan for employees and contractors                                      |   |
|  | Reduce GHG gas emissions from vehicles and equipment |   | Facilities to reduce business travel (e.g., videoconferencing)  |
|  |  |   | Select environmentally friendly fuel  |
|  |  |   | Coordinate trucks to avoid unnecessary truck movements and idling   |
|  |  |   | Maximise transport of freight via rail or water (rather than by road)                                     |
|  |  |   |   |

The European Sea Ports Organisation (ESPO) also provides guidance on sustainable energy use in ports in relation to four key themes as summarised in Table E.5 (ESPO 2012a).

Table E.5: Guidance of sustainable energy use in ports (source: ESPO 2012a)

| THEME  | PROPOSED MEASURES  |
|--|--|
| Exemplifying (setting good example with own operations)            | Manage own energy consumption systematically (e.g., passive/low energy office buildings, use electric vehicles) and improving energy efficiency)         |
|  | Calculate carbon footprint of port authority and set reduction targets towards carbon neutrality   |
|  | Use renewable energy where possible for port authority operations and producing renewable energy in port areas   |
|  | Adopt World Ports Climate Declaration ( <a href="https://sustainableworldports.org/wpcap/">https://sustainableworldports.org/wpcap/</a> )                |
| Enabling (provision of conditions to users to improve performance) | Report and communicate port authority achievements   |
|  | Provide preparatory or complete infrastructural facilities for OPS (cabling, frequency converters, transformers)   |
|  | Let port area be used for provision and generation of renewable energy as well as LNG, compressed natural gas, electrical charging infrastructure        |
|  | Create space, facilities and circumstances for companies to work together under an industrial ecology concept  |
| Encouraging (incentives to port users)                             | Providing conditions (e.g., IT systems, vessel traffic management) for efficient vessel servicing and handling (e.g., slot system)                       |
|  | Apply incentive schemes rewarding ship owners and operators that apply carbon management plans and demonstrate improvement                               |
|  | Apply incentive schemes to support ship owners/operators using OPS   |
|  | Apply incentive schemes to support terminal operators that invest in state of art terminal equipment using less energy and/or alternative energy sources |
| Engaging (sharing knowledge and skills)                            | Provide incentives for reduced carbon footprint within concession agreements   |
|  | Provide visibility to performers through 'best performer of the year' type of awards   |
|  | Work with port users and competent authorities by deploying right infrastructure to and from port area to allow carbon efficient use of transport modes  |
|  | Work with port users and competent authorities in deploying OPS and LNG bunkering infrastructure   |
| Enforcing (setting rules and ensuring compliance)                  | Work with port users to calculate carbon footprint of port area  |
|  | Share means and expertise with port users and terminal operators on improving energy efficiency and reducing carbon footprint                            |
|  | Control performance of contractors by introducing expected standards regarding energy consumption and efficiency into contract documents at tender stage |
|  | Incorporate energy consumption and efficiency criteria and good operational practices in tendering procedures of concession and lease agreements         |
|  | Undertake inspections to ensure that port users and/or contractors comply with rules and agreements  |

## E.7 Management of Carbon Footprint

Another useful guideline published by PIANC pertains to carbon management in ports (PIANC 2019a). Previously the World Ports Climate Initiative also provided guidance on carbon foot printing (WPCI 2010). Guidance on methods to calculate the carbon footprint in ports is provided in Azarkamand et al. (2020b), while De los Reyes et al. (2020) investigated carbon footprints of port infrastructure from life cycle perspective. Figure E.7 depicts a typical carbon management cycle, from design, through construction, operations and maintenance to end-of life considerations (PIANC 2019b).

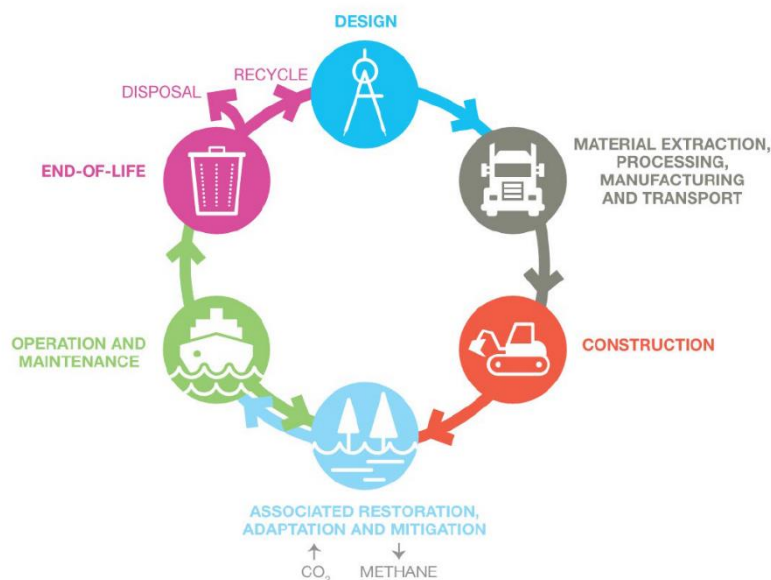


Figure E.7 Schematic of carbon management life cycles (source: PIANC 2019b)

The develop and implementation of a carbon management framework, allows a port to take proactive steps to effectively manage their carbon footprint (PIANC 2019b) specifically helping them to:

- Comply with emerging regulatory requirements
- Respond to general stakeholder and public pressure to reduce environmental burdens
- Take a leadership role in carbon management practices
- Address UN SDGs
- Drive innovation and investment while influencing future practice and regulation
- Cut costs through efforts to reduce energy consumption.

Information and guidance captured in this PIANC guideline (PIANC 2019a) include:s

- Description of carbon management framework, including methods to be used in its implementation, important management considerations and decisions, as well as potential challenges thereof
- Carbon emission quantification initiatives, discussing methodologies for the calculation of emissions of various activities encountered during design, construction, and operations
- Best practices on carbon emission reduction, discussing different opportunities to control and reduce carbon throughout the carbon lifecycle
- Financial aspects pertaining to carbon reduction measures, focusing on cost impacts of reduction programmes. Carbon emission reduction programmes are financially limited, and therefore need to be optimise reduction options at best limited cost.

## E.8 Management of Water Consumption

Port authorities have a clear interest in water consumption management as water is a valuable natural resource and as such needs to be used with caution. They therefore need to implement sustainable practices to avoid unnecessary consumption, not only from an environmental- but also an economic perspective (ESPO 2012a). A use-friendly schematic illustrating the key elements in sustainable water consumption practice is presented in Figure E.8 (Sensiba 2021).

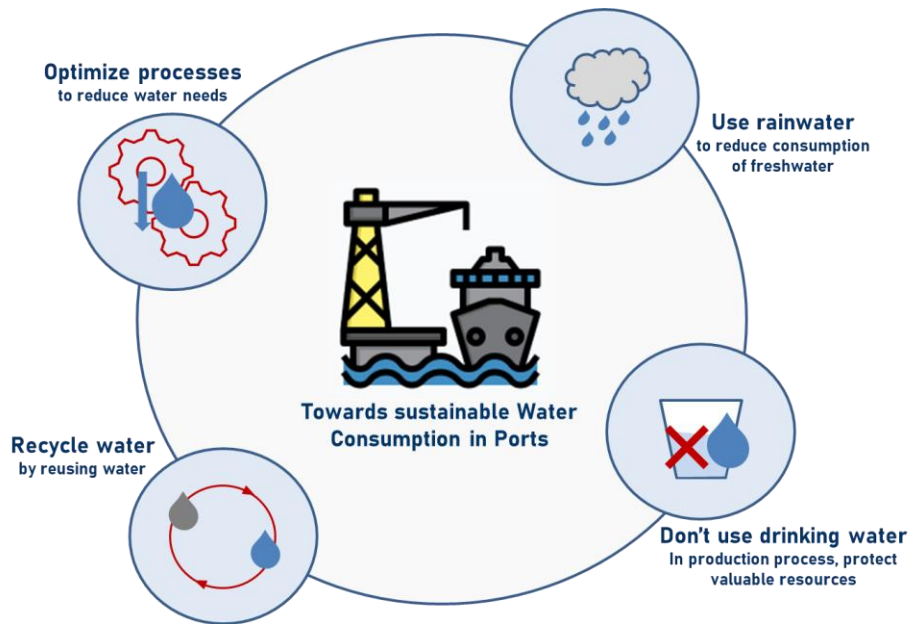


Figure E.8 Key elements of sustainable water consumption in ports (source: adapted from Sensiba 2021)

To encourage port developers and operators to adopt more sustainable approaches in the consumption of resources the Port Authority of New South Wales developed guidelines to assist in the identification and evaluation of such innovations (NSW Port Authority 2017). Table E.6 provides an overview of specific criteria and recommended measures that could be applied towards greener water consumption. To assist with evaluation and prioritisation for implementation, the guide summarises the business case for each intervention in terms of environmental and social benefits, relative ease of implementation, and return on investment (e.g., capital cost, maintenance, and cost savings) (NSW Port Authority 2017).

Table E.6: Criteria and guidance on measures towards greener water consumption (source: NSW Port Authority 2017)

| CRITERIA                                    | PROPOSED MEASURES  |
|---|--|
| Reduce consumption of potable water         | Install water efficient plumbing fixtures and fittings   |
|   | Use water efficient appliances   |
|   | Reduce potable water demand through efficient use or avoidance of evaporative or water-cooling tower systems |
|   | Ensure suitable water resources are used, with proper yield calculation from groundwater sources             |
| Manage and monitor water usage and leaks    | Install water sub-meters for all major water uses  |
| Reduce potable water used for irrigation    | Use local plants for landscaping to reduce water demand  |
|   | Irrigation water from on-site rainwater collection or recycled site water                                    |
|   | Water efficient irrigation systems   |
| Treat water on-site and reuse treated water | Rainwater harvesting systems   |
|   | Greywater collection and treatment systems   |
|   | On-site blackwater treatment with appropriate reuse  |
|   | Coordinate trucks to avoid unnecessary truck movements and idling  |
|   | Maximise transport of freight via rail or water (rather than by road)  |

The ESPO also provides guidance on sustainable water consumption in ports in relation to four key themes as summarised in Table E.7 (ESPO 2012a).

Table E.7: Guidance of sustainable water consumption practice for ports (source: ESPO 2012a)

| THEME  | PROPOSED MEASURES  |
|--|--|
| Exemplifying (setting good example with own operations)            | Establish water management plan (ideally as part of master plan)   |
|  | Setting targets on reducing own direct water usage and indirect consumption within the estate infrastructure using available technologies (e.g., continuous monitoring of water demand to identify leakages, spray nozzles on water taps, sensor operated flows, dry basins) |
|  | Disseminate efforts of port authority to reduce water consumption to public  |
| Enabling (provision of conditions to users to improve performance) | Provide infrastructure, support, training, operating and monitoring procedures necessary for good stewardship  |
| Encouraging (incentives to port users)                             | Apply incentive schemes rewarding port users comply beyond minimum compliance requirements   |
|  | Encourage external 3 <sup>rd</sup> Party verification through incentives;  |
|  | Promote and disseminate positive experiences such as proactively reducing port operators' costs by reducing their water usage  |
| Engaging (sharing knowledge and skills)                            | Provide visibility to good performers through 'best performer of year' type of awards  |
|  | Work together with port operators and on improvement process   |
| Enforcing (setting rules and ensuring compliance)                  | Systematically manage and enforce corrective and preventative actions raised following audits, reports, observations, or incidents   |
|  | Control performance of contractors by introducing expected standards regarding water consumption into contract documents at tender stage   |
|  | Incorporate water consumption criteria and good operational practices in tendering procedures associated with concession and lease agreements  |
|  | Undertake site audits and periodically request for reports to ensure port users and contractors comply with rules and agreements   |

## E.9 Waste Management

Ports are where ships need to dispose of garbage. They are often also locations where many industrial activities take place. The activities generate waste, ordinary rubbish and hazardous materials, which ports must handle. To be sustainable, ports must develop and implement waste management plans that regulate the handling of all types of waste. Three important aspects need to be considered:

- Technical and practical design of reception facilities
- Charging system for waste management
- Information relating to waste management.

A useful guide for the development of waste management strategies is UNEP's *Guidelines for National Waste Management Strategies* (UNEP 2013). Their waste management hierarchy indicates an order of preference for action to reduce and manage waste (Figure E.9) ranging from disposal (least preferred option to prevention (most preferred option).

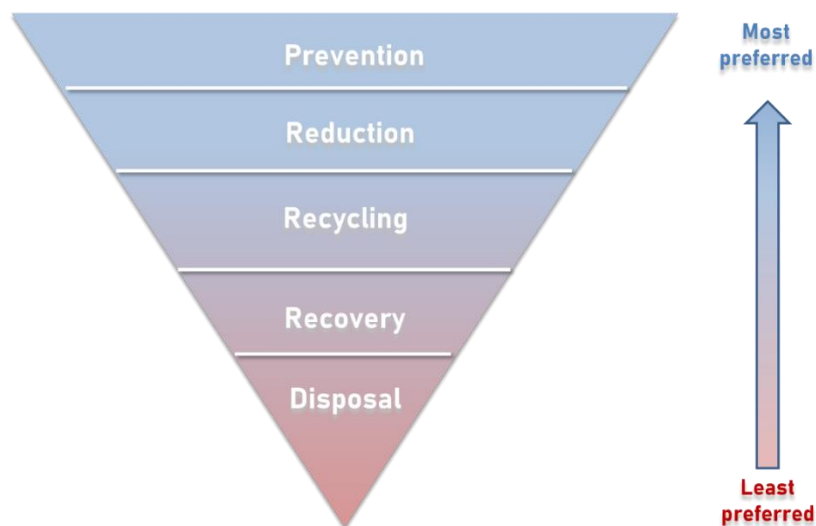


Figure E.9 A hierarchy to consider in waste (including wastewater) management (source: adapted from UNEP 2013)

To encourage port developers and operators to adopt more sustainable approaches to waste management the Port Authority of New South Wales developed guidelines to assist with the identification and evaluation of related innovations (NSW Port Authority 2017). Table E.8 provides an overview of specific criteria and recommended measures that could be applied towards improved waste management. To assist with evaluation and prioritisation for implementation, the guide also summarises the business case for each intervention in terms of environmental and social benefits, relative ease of implementation, and return on investment (e.g., capital cost, maintenance, and cost savings) (NSW Port Authority 2017).



Table E.8: Criteria and guidance on measures towards improved waste management (source: NSW Port Authority 2017)

| CRITERIA                  | PROPOSED MEASURES   |
|---------------------------|---|
| Minimise waste generation | Prepare Waste management plans, including options to reduce waste for landfill (ideally as part of master plan) |
|                           | Prefabricated materials (rather constructing on site) and standard sizes to avoid generating off-cut waste      |
|                           | Minimise packaging and select materials with less packaging   |
| Facilitate recycling      | Provide dedicated storage area for separation, collection and recycling of waste with good access               |
|                           | Recycle material such as timber, concrete, bricks, cardboard, and aluminium, paper, glass, and PET plastic      |
|                           | Recycle green waste (e.g., by chipping and mulching on-site)  |
|                           | Monitor waste recovery quantities   |
|                           | Provide for future increase in recycling storage facilities   |
|                           | Coordinate trucks to avoid unnecessary truck movements and idling   |
|                           | Maximise transport of freight via rail or water (rather than by road)   |

Other useful guide on sustainable waste management in ports is that of the ESPO which suggests measures under four key themes as summarised in Table E.9 (ESPO 2012a).

Table E.9: Guidance of sustainable waste management practice for ports (source: ESPO 2012a)

| THEME  | PROPOSED MEASURES  |
|--|--|
| Exemplifying (setting good example with own operations)            | Establish waste management plan (ideally as part of master plan)   |
|  | Consult with shipowners, tenants and other port users when planning and designing port's reception facilities and waste management plan              |
|  | Demonstrate excellence while managing port authority's own waste   |
|  | Invest equipment for optimal handling of waste   |
|  | Set targets for reducing amount of port authority generated waste  |
|  | Set targets for increasing recycling and reuse   |
| Enabling (provision of conditions to users to improve performance) | Build/establish port reception facilities for different types of waste   |
|  | Facilitate port users to separate and deliver waste in effective ways  |
|  | Establish simple systems for notification information on quantities and types of waste that vessels want to deliver to optimise reception on arrival |
|  | Provide easily accessible information through port's web site and through other means (leaflets, newsletters, information meetings).                 |
| Encouraging (incentives to port users)                             | Monitor waste volumes and types and report to vessels  |
|  | Include waste collection fees within port dues   |
|  | Apply incentive schemes rewarding waste separation   |
| Engaging (sharing knowledge and skills)                            | Apply incentive schemes rewarding vessels with less water in sludge  |
|  | Cooperate with agents to provide accurate and up-to-date waste related information to ship owners  |
|  | Collaborate with other ports and exchange waste related information (e.g., waste reception facilities)   |
|  | Monitor and communicate cost reductions due to waste sorting   |
| Enforcing (setting rules and ensuring compliance)                  | Sort biological waste (where possible) and monitor its green energy production   |
|  | Incorporate good waste management practices in tender procedures of concession and lease agreements  |
|  | Monitor and ensure that port users comply with rules and agreements  |

## E.10 Ballast Water Management

The International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 (BWM Convention) entered into force globally on 8 September 2017, through the UN's International Maritime Organisation (IMO), to help prevent the spread of potentially harmful aquatic organisms and pathogens in ships' ballast water (IMP 2022a). Five countries in the WIO region are signatories to this Convention: Kenya, Madagascar, Reunion (France), Seychelles and South Africa.

With a focus on ship ballast water management the Convention deals mostly with the shipping sector but it is important for port authorities to have knowledge on such matters to ensure that ships entering their ports are compliant, especially in those countries that are signatory to the Convention. Under the BWM Convention ships are required to manage their ballast water and sediments to a certain standard, according to a ship-specific ballast water management plan. Specifically, ships must have (IMO 2022b):

- A ballast water management plan that is specific to a ship and includes a detailed description of the actions to be taken to implement the management requirements and practices
- A ballast water record book in which it is recorded when ballast water is taken on board; circulated or treated for ballast water management purposes, and discharged to the sea or reception facility, or discharged accidental or under exceptional circumstances
- An International Ballast Water Management Certificate (ships of 400 Gross Tonnage and above - representing total internal volume of a ship), issued by or on behalf of the Administration (flag State) certifying that ballast water management is performed in accordance with the BWM Convention, including the standard that a ship is complying with and the expiry date of the certificate.

There are two ballast water management standards: D-1 that relates to ballast water exchange and D-2 that specifies the maximum number of viable organisms, including specified indicator microbes harmful to human health, allowed to be discharged (IMO 2022b).

The D-1 standard requires ships to conduct an exchange of ballast water such that at least 95% of water by volume is exchanged far away from the coast. The D-2 standard specifies that ships can only discharge ballast water that meets the following criteria:

- Less than 10 viable organisms per cubic metre which are greater than or equal to 50 micrometres in minimum dimension
- Less than 10 viable organisms per ml which are between 10 micrometres and 50 micrometres in minimum dimension
- Less than 1 colony-forming unit (cfu) per 100 ml of Toxicogenic *Vibrio cholerae*
- Less than 250 cfu per 100 ml of *Escherichia coli*
- Less than 100 cfu per 100 ml of Intestinal Enterococci.

Figure E.10 sets out the timelines and requirements pertaining to compliance to the BWM Convention. Since September 2017 new ships must meet the D-2 standard, while existing ships must meet at least the D-1 standard, and they may choose to install a ballast water management system or otherwise meet the D-2 (discharge) standard, but this is not mandatory until the corresponding compliance date. All ships must have a ballast water management plan, ballast water record book, and an International Ballast Water Management Certificate. Since September 2019, a ship undergoing a renewal survey linked to the ship's International Oil Pollution Prevention Certificate has to meet the D-2 standard by the date of renewal. By 2024 all ships of signatory countries will be required to meet the D-2 standard (IMO 2022b).

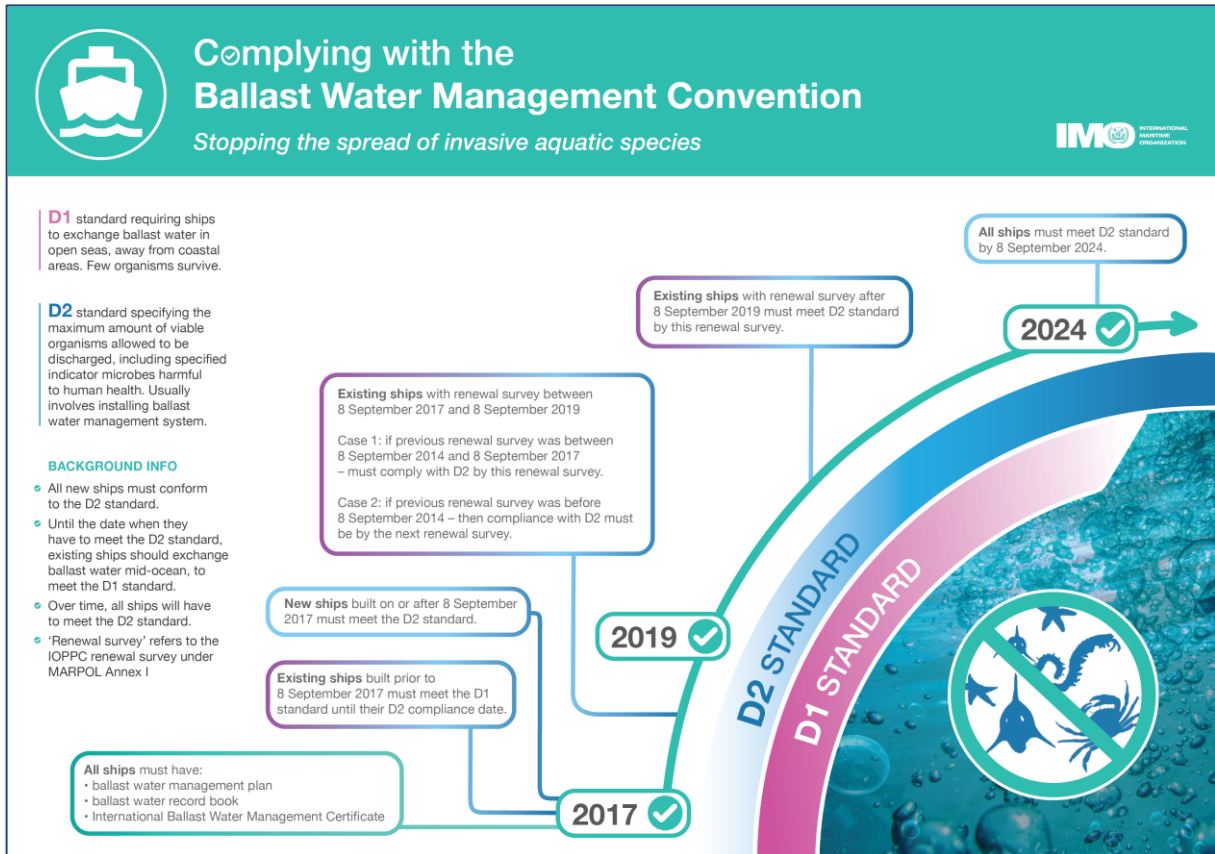


Figure E.10 Compliance timelines for the implementation of the Ballast Water Management Convention (source: IMO 2022b)

The IMO also provides a series of guidelines to ensure implementation of the BWM Convention. These are reviewed and updated as new technologies and knowledge emerge. They include (IMO 2022a):

- Guidelines for sediment reception facilities (G1) (resolution MEPC.152(55))
- Guidelines for ballast water sampling (G2) (resolution MEPC.173(58))
- Guidelines for ballast water management equivalent compliance (G3) (resolution MEPC.123(53))
- Guidelines for ballast water management and development of ballast water management plans (G4) (resolution MEPC.127(53))
- Guidelines for ballast water reception facilities (G5) (resolution MEPC.153(55))
- 2017 Guidelines for ballast water exchange (G6) (resolution MEPC.288(71))
- 2017 Guidelines for risk assessment under regulation A-4 of the BWM Convention (G7) (resolution MEPC.289(71))
- 2016 Guidelines for approval of ballast water management systems (G8) (resolution MEPC.279(70))
- Procedure for approval of ballast water management systems that make use of Active Substances (G9) (resolution MEPC.169(57))
- Guidelines for approval and oversight of prototype ballast water treatment technology programmes (G10) (resolution MEPC.140(54))
- Guidelines for ballast water exchange design and construction standards (G11) (resolution MEPC.149(55))

- 2012 Guidelines on design and construction to facilitate sediment control on ships (G12) (resolution MEPC.209(63))
- Guidelines for additional measures regarding ballast water management including emergency situations (G13) (resolution MEPC.161(56))
- Guidelines on designation of areas for ballast water exchange (G14) (resolution MEPC.151(55))
- Guidelines for ballast water exchange in the Antarctic treaty area (resolution MEPC.163(56))
- Guidelines for port State control under the BWM Convention (resolution MEPC.252(67)).

## E.11 Guidance of Sustainable Hull Cleaning

Ship hull cleaning is a necessary activity for many vessels and submerged marine surfaces. If done in an irresponsible manner it can pose serious threats to coastal ecosystems, especially by the introduction of invasive species. Useful guidance on sustainable hull cleaning practices includes that provided by the International Maritime Organisation (IMO) guidelines (IMO 2011, 2012), the US-EPA (US-EPA 2011) and Australia (Commonwealth of Australia 2015). In 2021 the Baltic and International Maritime Council (BIMCO), one of the largest international organisations of ship owners in the world, published the first global industry standards towards sustainable for ship hull cleaning aimed at ship owners and operators, cleaning companies, antifoul system manufacturers, as well as ports, or other approval authorities. These include:

- Approval procedure for in-water cleaning companies (BIMCO 2021a)
- Industry standard on in-water cleaning with capture (BIMCO 2021b).

Key principles to consider in the implementation of sustainable hull cleaning practices include (e.g., Commonwealth of Australia 2015):

- Risks posed by biofouling management measures should be balanced with risks of failing to manage biofouling
- It is an operational need to manage biofouling on vessels and movable structures
- Preferable to minimise accumulation of biofouling on vessels and movable structures
- Preferable for biofouling to be removed in locations where it was acquired before departing or moving to another location
- Release of potentially toxic chemicals and invasive aquatic species into environment should be minimised
- Where operationally practicable, vessels and movable structures should be removed from water for cleaning and maintenance, in preference to in-water operations.

The BIMCO procedures for approval of hull cleaning operations comprises five key steps (BIMCO 2021a):

1. Cleaning system and working procedures tested and approved by independent approval body in accordance with approval procedure for in-water cleaning companies
2. After approval, quality systems of cleaning company to be subject to periodic internal audits and external audits carried out by approval body
3. Ships, manufacturers, and cleaning companies to use requirements outlined in industry standard on in-water cleaning for planning, conducting and reporting on the cleaning process
4. For an approved cleaning company to operate in any given location, a local permit to be issued by port and other relevant authorities.

The implementation of an effective biofouling management regime is critical to minimize impact on coastal ecosystem and comprises both a biofouling management plan and a biofouling record book to record of biofouling management practices. Specifically, a biofouling management plan must include (IMO 2011, Commonwealth of Australia 2015; BIMCO 2021b):

- Description of anti-fouling systems, including type(s) of anti-fouling coating systems and details on where anti-fouling systems are to be applied
- Description of operating profile, including ship's operating profile determining performance specifications of the ship's anti-fouling systems and operational practices (e.g., typical operating

speeds, periods underway at sea compared with periods berthed, anchored or moored, typical operating areas or trading routes, and planned duration between dry dockings)

- Description of areas on ship susceptible to biofouling, identifying hull areas, niche areas and seawater cooling systems particularly susceptible to biofouling and describing management actions required for each area
- Operation and maintenance of anti-fouling system, containing a detailed description of operation and maintenance of anti-fouling system(s) used, including schedule(s) of activities and step-by-step operational procedures
- Timing of operational and maintenance activities, stipulating schedule of planned inspections, repairs, maintenance, and renewal of the anti-fouling systems.
- In-water cleaning and maintenance procedures, setting out planned maintenance procedures to be completed between dry-docking events to minimise biofouling
- Operation of onboard treatment processes, providing specific advice about marine growth prevention systems (MGPS), internal seawater cooling systems and any other associated maintenance and inspection schedule and procedures
- Safety procedures for the ship and the crew, detailing specific operational or safety restrictions
- Disposal of biological waste, containing procedures for disposal of biological waste generated by treatment or cleaning processes
- Recording requirements, containing details of types of documentation to be kept verifying operations and treatments for recording in the Record Book
- Crew training and familiarisation, containing information on provision of crew training and familiarisation.

These biofouling management plans should be updated as necessary.

## E.12 Towards Improving Port Environmental Quality

Numerous activities undertaken in ports contribute to an array of problems potentially causing negative impacts on the environment and associated socio-economic benefits (Darbra et al. 2004; Darbra et al. 2005; ESPO 2020). To facilities greening of ports such problems need to be identified and linked to the contributing activities to focus management and control interventions. For the purposes of this assessment environmental quality issues were broadly grouped into air pollution, water, sediment & soil pollution, noise pollution, and artificial light (Trozzi and Viccaro 2000; Jägerbrand et al. 2019; Moldanová et al. 2021). Table E.10 provides a summary of major port activities, as well as their potential environmental problems, illustrating the complexity and interconnectivity.

Table E.10: Port activities and potential environmental quality-related problems

| PORT ACTIVITY                          | ENVIRONMENTAL QUALITY PROBLEM |                           |        |                              |               |                       |                    |                          |                 |                       |                      |       |                  |
|--|-------------------------------|---------------------------|--------|------------------------------|---------------|-----------------------|--------------------|--------------------------|-----------------|-----------------------|----------------------|-------|------------------|
|  | Air pollution                 |                           |        | Water and sediment pollution |               |                       |                    |                          |                 |                       | Physical             |       |                  |
|  | Toxic chemical pollution      | Dust (particle) pollution | Odours | Thermal pollution            | High salinity | High suspended solids | Nutrient pollution | Toxic chemical pollution | Human pathogens | Hazardous solid waste | Solid waste (litter) | Noise | Artificial Light |
| Capital Dredging                       |                               |                           |        |                              |               | ●                     | ●                  | ●                        |                 |                       |                      | ●     |                  |
| Earth works                            |                               | ●                         |        |                              |               |                       |                    |                          |                 |                       |                      |       |                  |
| Night lights                           |                               |                           |        |                              |               |                       |                    |                          |                 |                       |                      |       | ●                |
| Energy consumption                     | ●                             |                           |        |                              |               |                       |                    |                          |                 |                       |                      |       |                  |
| Construction vehicle traffic           | ●                             | ●                         | ●      |                              |               |                       |                    |                          |                 |                       |                      | ●     |                  |
| Water consumption                      |                               |                           |        |                              |               |                       |                    |                          |                 |                       |                      |       |                  |
| Energy consumption                     | ●                             |                           |        |                              |               |                       |                    |                          |                 |                       |                      |       |                  |
| Maintenance dredging                   |                               |                           |        |                              | ●             |                       |                    | ●                        |                 |                       |                      | ●     |                  |
| Vehicle and railway traffic            | ●                             | ●                         | ●      |                              |               |                       |                    | ●                        |                 |                       |                      | ●     |                  |
| Fire or explosion                      | ●                             | ●                         | ●      |                              |               |                       |                    | ●                        |                 |                       |                      | ●     |                  |
| Night lights                           |                               |                           |        |                              |               |                       |                    |                          |                 |                       |                      |       | ●                |
| Waste disposal (general & hazardous)   |                               |                           |        |                              |               |                       |                    | ●                        |                 | ●                     | ●                    |       |                  |
| Urban stormwater runoff                |                               |                           | ●      |                              |               | ●                     | ●                  | ●                        | ●               |                       | ●                    |       |                  |
| Catchment runoff (rivers)              |                               |                           |        |                              |               | ●                     | ●                  | ●                        | ●               |                       | ●                    |       |                  |
| Dry docks and ship repairs - waste     | ●                             | ●                         | ●      |                              |               | ●                     | ●                  | ●                        |                 |                       | ●                    | ●     |                  |
| Industries - waste and wastewater      |                               |                           | ●      |                              |               | ●                     | ●                  | ●                        | ●               | ●                     | ●                    |       |                  |
| Industries - atmospheric emissions     | ●                             |                           | ●      |                              |               |                       |                    |                          |                 |                       |                      |       |                  |
| Industries - Cooling water             |                               |                           |        | ●                            |               |                       |                    | ●                        |                 |                       |                      |       |                  |
| Industries - Desalination brine        |                               |                           |        |                              | ●             |                       |                    | ●                        |                 |                       |                      |       |                  |
| Open stockpiles - dust                 | ●                             | ●                         |        |                              |               |                       |                    | ●                        |                 |                       |                      |       |                  |
| Storage facilities - spillage          |                               |                           | ●      |                              |               |                       |                    | ●                        |                 |                       |                      |       |                  |
| Vessels - solid waste (garbage, other) |                               |                           |        |                              |               |                       |                    | ●                        | ●               | ●                     |                      |       |                  |
| Vessels - spillage fuel/oil/cargo      |                               |                           | ●      |                              |               |                       |                    | ●                        |                 |                       |                      |       |                  |
| Vessels - emissions                    | ●                             |                           | ●      |                              |               |                       |                    | ●                        |                 |                       |                      |       |                  |
| Vessels - wastewater                   |                               |                           | ●      |                              |               | ●                     | ●                  | ●                        | ●               |                       |                      |       |                  |
| Vessels - ballast water exchange       |                               |                           |        |                              |               |                       |                    |                          |                 |                       |                      |       |                  |

Port activities potentially contributing to air pollution include (Trozzi and Viccaro 2000; Walker et al. 2018; Jägerbrand et al. 2019; Moldanová et al. 2021; Capelli et al. 2019; Široka et al. 2021):

- Vehicle and railway traffic (combustion products and volatile organic pollutants)
- On and offloading of cargo, specifically petroleum products generating volatile organic pollutants
- Ship and dry docks (producing volatile organic pollutants)
- Ship repair and demolition (e.g., heavy metals, volatile organic pollutants)
- Vessel emissions (greenhouse gases, particles, toxic organic pollutants)



- Emissions from industries and vessels, and cargo (e.g., fish processing plants livestock)
- Odours associated with inappropriate management of wastewater and solid waste.

Water and sediment pollution primarily arises from waste and wastewater spills or discharges such as (Trozzi and Viccaro 2000; Walker et al. 2018; Jägerbrand et al. 2019; Moldanová et al. 2021):

- Oil and fuel spillage from vessels
- Accidental spillage of oils and chemicals during on and off-loading
- Washing and cleaning of tanks either in ports or on vessels
- Wastewater disposal from vessel and activities in port (e.g., industries, sewage, bilge water)
- Leaching from chemical from vessels (e.g., antifouling paints)
- Ballast water exchange (e.g., harmful, or invasive organisms)
- Solid waste disposal (including garbage and hazardous waste) from port activities and vessels.

Noise problems in ports arise from activities such as (Trozzi and Viccaro 2000; Jägerbrand et al. 2019; Moldanová et al. 2021):

- Vehicle traffic (especially heavy vehicles)
- Cargo movement (e.g., quay cranes and pumps)
- Vessel propulsion mechanisms.

Artificial light in nearshore environments propagates easily and over long distances since aquatic landscapes are open without barriers that might hinder the spreading of light (Jägerbrand et al. 2019). Light from sources above the water surface also penetrates into the water, the extent to which depends on the light-transmittance qualities of the water and the character of the light source. In port, artificial light sources include:

- Night lights on vessels
- Night lights associated with port activities and facilities.

An array of ecological and socio-economic consequences stem from environmental problems potentially associated with port activities (Table E.11).

Table E.11: Typical ecological and socio-economic consequences associated with port environmental problems

| IMPACT/CONSEQUENCE                      | ENVIRONMENTAL QUALITY ISSUE |                           |        |                              |               |                       |                    |                          |                 |                       |                      |       |                  |
|---|-----------------------------|---------------------------|--------|------------------------------|---------------|-----------------------|--------------------|--------------------------|-----------------|-----------------------|----------------------|-------|------------------|
|   | Air pollution               |                           |        | Water and sediment pollution |               |                       |                    |                          |                 |                       | Physical             |       |                  |
|   | Toxic chemical pollution    | Dust (particle) pollution | Odours | Thermal pollution            | High salinity | High suspended solids | Nutrient pollution | Toxic chemical pollution | Human pathogens | Hazardous solid waste | Solid waste (litter) | Noise | Artificial light |
| Physical loss of important habitat      |                             |                           |        |                              |               |                       |                    |                          |                 |                       |                      |       |                  |
| Smothering/entablement of marine life   |                             |                           |        |                              |               | ●                     |                    |                          |                 | ●                     |                      |       |                  |
| Disorientation of marine life (birds)   |                             |                           |        |                              |               |                       |                    |                          |                 |                       | ●                    | ●     | ●                |
| Chronic/acute effects on marine life    | ●                           |                           |        | ●                            | ●             | ●                     | ●                  | ●                        |                 | ●                     | ●                    | ●     | ●                |
| Introduction of invasives               |                             |                           |        |                              |               |                       |                    |                          |                 |                       |                      |       |                  |
| Loss of aesthetic value                 |                             | ●                         | ●      |                              |               | ●                     | ●                  |                          |                 |                       | ●                    |       |                  |
| Human health risk (contact or food)     | ●                           | ●                         |        | ●                            |               |                       |                    | ●                        | ●               |                       | ●                    | ●     |                  |
| Human and property safety risk          |                             |                           |        |                              |               |                       |                    |                          |                 |                       |                      |       |                  |
| Loss of livelihoods (material & food)   |                             |                           |        |                              |               |                       |                    | ●                        | ●               |                       |                      |       |                  |
| Commercial losses (seafood & fisheries) |                             |                           |        |                              |               |                       |                    | ●                        | ●               |                       |                      |       |                  |

Air pollution problems can have chronic and even acute effects on marine biota, where such chemicals end up in adjacent coastal waters. Such problems also have socio-economic impacts related to health risk to humans (Ballini and Bozzo 2015), and result in loss in aesthetic value (e.g., dust) that affects port workers, but also other ecosystem services provided by ports such as tourism and recreational facilities. Odour problems manifest mainly in socio-economic implications (Capelli et al. 2019), greatly affecting aesthetic values in areas popular for real estate development, tourism, and recreational activities, also relevant to ports.

Water and sediment pollution typically has ecological impacts (UNEP et al., 2021). However, it also has socio-economic consequences such as loss of aesthetic value (e.g., suspended solids, nutrient loading resulting in excessive algal growth, solid waste) and for human health (e.g., toxic chemical, human pathogens, hazardous waste). Effects on seafood products and fisheries resources also can have socio-economic ripple effects, resulting in loss of product quality and revenue.

Marine ecosystems all emit levels of natural noise because of, for example, waves, bird and marine mammals vocals. However, human activities such as marine transportation, resource extraction, fishing and recreational activities have increased ocean ambient noise levels by about 15 dB over the past 5 decades (Pine et al. 2016). This is a problem as human induced noise differs from ambient underwater noise with respect to direction, frequency, and duration.

Seabirds attracted to artificial light from ships or offshore platforms can become disoriented, collide with structures, starve, become dehydrated, or be taken by predators. Species that are nocturnal or light-sensitive also can be affected even if the exposure is to low light intensities and temporary (Jägerbrand et al. 2019).

The following sections introduce useful guidance on improving environmental quality in ports, focusing on air quality, marine water and sediment quality, noise and light.

### E.12.1 Air Quality

Air quality is often a highest priority on environmental and political agendas as port are usually situated in close proximity to densely populated urban areas that are affected by air pollution. Port-related emissions also can negatively affect the image of ports *vis-à-vis* their surrounding residential zones and put serious pressure on port development ambitions. In fact, air quality is often at the heart of the political and societal debate on economic development plans and port development projects. Therefore, the management and reduction of air pollution associated with port operations should be of high priority to port authorities (ESPO 2012a).

Table E.12 provides an overview of specific criteria and recommended measures that could be applied to improve air quality in ports (NSW Port Authority 2017). To assist with evaluation and prioritisation for implementation, the guide also summarises the business case for each intervention in terms of environmental and social benefits, relative ease of implementation, and return on investment (e.g., capital cost, maintenance, and cost savings) (NSW Port Authority 2017).

Table E.12: Criteria and guidance on measures towards improving environmental air quality in ports (source: NSW Port Authority 2017)

| CRITERIA                                      | PROPOSED MEASURES  |
|---|--|
| Protect ozone layer and reduce global warming | Avoid using ozone depleting substances in equipment such as refrigerants or insulants      |
|   | Minimise global warming potential for refrigerants and other chemicals                     |
|   | Implement refrigerant and vapour leak detection systems in high-risk areas                 |
|   | Implement vapour recovery systems  |
| Limit generation of air pollutants            | Implement dust mitigation measures during construction and operations                      |
|   | Implement air pollution control, measures such as scrubbers                                |
|   | Monitor dust levels and other air pollutants during construction and operations            |
|   | Maintenance schedule for plant and equipment to ensure operations to appropriate standards |
| Minimise odours                               | Prevent odour pollution from construction and operations and monitor regularly             |
| Minimise noise pollution                      | Implement noise reduction measures   |
|   | Monitor noise levels during construction and operations                                    |
| Minimise light pollution                      | Use enclosed light fittings designed to minimise spread of light above horizontal          |
| Avoid accidental contact with hazardous goods | Separate hazardous goods and poisons during construction and operations                    |

Other useful guides include that of the ESPO on improving air quality in ports in relation to four key themes as summarised in Table E.13 (ESPO 2012a).

Table E.13: Guidance on improving air quality in ports (Source: ESPO 2012a)

| THEME  | PROPOSED MEASURES   |
|--|---|
| Exemplifying (setting good example with own operations)            | Invest in low emission and fuel-efficient own fleet (vehicles and vessels);   |
|  | Make use of state-of-the-art own terminal equipment (e.g., movable and non-movable cranes);   |
|  | Use low emission fuels (sulphur, carbon, PM) in operating own fleet (cars, trucks, service vessels) and terminal equipment (e.g., movable and non-movable cranes);                    |
|  | Invest in projects demonstrating feasibility of new technologies to reduce air pollution even further than existing state of the art  |
|  | Report and communicate port authority achievements  |
| Enabling (provision of conditions to users to improve performance) | Provide preparatory or complete infrastructural facilities for OPS (cabling, frequency converters, transformers)  |
|  | Provide suitable space in port area for LNG bunkering facilities  |
|  | Apply techniques (e.g., wind screens, buffering zones) to prevent dust dispersion from dry bulk operations and road traffic   |
| Encouraging (incentives to port users)                             | Apply incentive schemes rewarding ship owners and operators that demonstrate outstanding environmental performance (e.g., ahead of what it is required by legislation)                |
|  | Apply incentive schemes to support ship owners/operators that use OPS   |
|  | Apply incentive schemes to support terminal operators investing in state-of-the-art terminal equipment  |
|  | Provide visibility to performers through 'best performer of the year' type of awards  |
| Engaging (sharing knowledge and skills)                            | Create and maintain database on all port-related emissions and their contribution to air quality levels on local and regional scale, in close cooperation with the port users         |
|  | Organise joint pilot projects and feasibility studies with port users, especially in fields and areas of overlapping responsibilities to create a sense of co-ownership of challenges |
|  | Share means and expertise (e.g., co-organising workshops and co-hiring experts) to improve air quality  |
|  | Work with port users and competent authorities to deploy OPS and LNG bunkering infrastructure   |
| Enforcing (setting rules and ensuring compliance)                  | Restrict entrance of vehicles (trucks/barges/trains) in certain parts of port area by establishing low emission zones   |
|  | Control performance of contractors by introducing expected standards regarding emissions in contract documents at tender stage  |
|  | Incorporate air emissions criteria and good operational practices in tendering procedures of concession and lease agreements  |
|  | Undertake inspections to ensure that port users and/or contractors comply with rules and agreements   |

## E.12.2 Water and Sediment Quality

Port authorities have a clear interest in improving marine water and sediment quality in ports as they are increasingly pressured to demonstrate environmental and socially responsible practice. Good water and sediment quality is essential for ecosystems and biodiversity. Table E.14 provides an overview of specific criteria and recommended measures that could be applied to improve water quality in ports proposed by the NSW Port Authority (2017). To assist with evaluation and prioritisation for implementation, the guide also summarises the business case for each intervention in terms of environmental and social benefits, relative ease of implementation, and return on investment (e.g., capital cost, maintenance, and cost savings) (NSW Port Authority 2017).

Table E.14: Criteria and guidance on measures towards improving water quality in ports (source: NSW Port Authority 2017)

| CRITERIA  | PROPOSED MEASURES  |
|---|--|
| Manage stormwater   | Use water sensitive urban design measures such as permeable surfaces and wetlands  |
|   | Appropriate drainage where rainwater runoff does not flow directly to surface waterbody  |
|   | Implement stormwater treatment systems   |
| Manage water pollution sources                                      | Identify potential sources of land-based water pollution and implement measures to minimise impact, such as oil separators and gross pollutant traps |
|   | Containment for any spillage, including appropriate storage of liquid materials  |
|   | Emergency spill kits (including clean up material) together with training  |
|   | Implement water quality monitoring programmes  |
|   | Manage ballast water discharge to avoid introducing invasive aquatic organisms   |
|   | Avoid dumping rubbish, chemicals or untreated sewage, greywater and oily bilge and ensure high standard marine sanitation devices                    |
| Prevent damage from potential flood events and water tables changes | Avoid toxic anti-fouling paints  |
|   | Assess flood risk and potential water table changes and implement appropriate mitigation measures  |

The ESPO also provides guidance on the improvement of marine water quality in ports in relation to four key themes as summarised in Table E.15 (ESPO 2012a).

Table E.15: Guidance on improving marine water quality in ports (source: ESPO 2012a)

| THEME  | PROPOSED MEASURES   |
|--|---|
| Exemplifying (setting good example with own operations)            | Establish spill monitoring and proven emergency response procedures for both land and marine operations   |
|  | Ensure own cargo handling equipment is in line with best environmental practice (e.g., enclosed grabs, Eco-Hopper) that minimise spillages                    |
|  | Ensure that port authority staff are environmentally aware, trained and both proactive and exemplary in their behaviour                                       |
|  | Disseminate efforts of the port authority in improving water and sediment quality to public   |
| Enabling (provision of conditions to users to improve performance) | Provide infrastructure, support, training, operating and monitoring procedures necessary for good environmental stewardship                                   |
|  | Provide surface water infrastructure and monitoring systems to manage runoff water  |
|  | Maintain up to date knowledge on best equipment, technologies and service providers and keep port operators advised   |
| Encouraging (incentives to port users)                             | Apply incentive schemes rewarding port users that go beyond compliance requirements   |
|  | Encourage external 3 <sup>rd</sup> Party verification through incentives  |
|  | Provide visibility to good performers through 'best performer of the year' type of awards   |
| Engaging (sharing knowledge and skills)                            | Review and monitor ship ballast, sewage or bilge discharges   |
|  | Work with port operators and competent authorities on incident management, response procedures and improvement process  |
|  | Conduct joint exercises to improve partnership in handling incidents that impact on water quality (e.g., spills)  |
|  | Work with port operators and competent authorities on ongoing monitoring (e.g., water quality, surface water runoff quality, river and sediment quality)      |
| Enforcing (setting rules and ensuring compliance)                  | Systematically manage and enforce corrective and preventative actions raised following audits, reports, observations or incidents                             |
|  | Control performance of contractors by introducing expected standards regarding operations that may affect water quality in contract documents at tender stage |

| THEME | PROPOSED MEASURES   |
|-------|---|
|       | Incorporate criteria and good operational practices in tendering procedures of with concession and lease agreements   |
|       | Undertake site environmental audits and periodically request environmental reports to ensure that port users and contractors comply with rules and agreements |
|       | Enforcing 'polluter pays' principle when incidents occur  |

### E.12.3 Noise quality

Noise pollution - excessive or an annoying degree of unwanted sound - is a nuisance often cited in connection with transport. In addition to being unpleasant, disturbing sleep and work activities, noise contributes to health problems such as stress disturbances, cardiovascular disease and hearing loss. People feel more directly affected by noise than by any other form of pollution. Noise is a major social problem and has considerable implications for port operations (ESPO 2012a).

From a human health and safety perspective, the hierarchy of noise controls indicates an order of preference for action to reduce noise pollution (Figure E.11) ranging from personal protective equipment (least preferred option) to noise elimination (most preferred option) (NIOSH 2022).

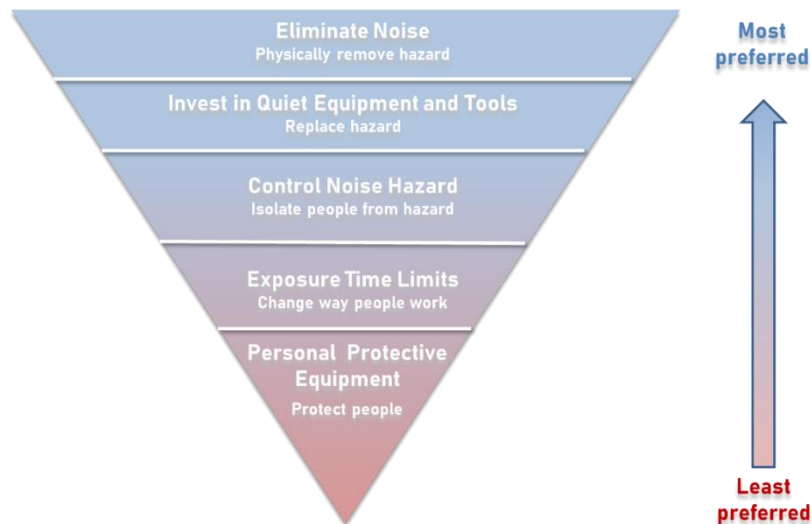


Figure E.11 A hierarchy to consider in noise pollution management (source: Adapted from NIOSH 2022)

A useful guide in the management of noise pollution in ports is that of the ESPO (Table E.16) (ESPO 2012a).

Table E.16: Guidance on improving noise quality in ports (source: ESPO 2012a)

| THEME  | PROPOSED MEASURES  |
|--|--|
| Exemplifying (setting good example with own operations)            | Establish noise management plan (ideally part of master plan) (e.g., see NoMePorts 2008)   |
|  | Monitor port noise to determine extent of problem, origin of significant noise risers and effectiveness of remedial actions  |
|  | Source best available techniques (silent technologies for own fleet and infrastructure)  |
|  | Invest in projects demonstrating feasibility of new technologies that go beyond current-state-of-the-art.  |
| Enabling (provision of conditions to users to improve performance) | Provide ongoing monitoring including continuous recording in order to define extent of noise nuisance, and to assist in determination of noise sources and effectiveness of remedial actions |
|  | Provide infrastructural preconditions for silent technologies such as OPS facilities   |
|  | Apply techniques (e.g., noise barriers, buffering zones) to prevent noise propagation from industrial operations and port traffic  |
|  | Establish noise complaints recording and management system   |
| Encouraging (incentives to port users)                             | Share and disseminate successful project implementations   |
|  | Provide favourable mooring locations or other incentives to more quiet ships   |
|  | Apply incentive schemes to support ship owners/operators that use OPS  |

| THEME   | PROPOSED MEASURES   |
|---|---|
|   | Apply incentive schemes to support terminal operators that invest in state-of-the-art terminal equipment  |
|   | Take initiatives or support actions to keep port related truck traffic out of residential areas in vicinity of the port (e.g., development of appropriate truck route plans)  |
| Engaging (sharing knowledge and skills)           | Interact with wider port community and assist with installation of noise insulation in residential areas or acoustic barriers at port boundaries  |
|   | Engage with shipping industry regarding on board practices and silent technologies  |
|   | Develop relationships with equipment suppliers to support development of 'whisper technology'   |
| Enforcing (setting rules and ensuring compliance) | Control performance of contractors by introducing expected standards regarding noise generation in contract documents at tender stage   |
|   | Incorporate noise management requirements in tendering procedures of concession and lease agreements  |
|   | Apply noise zoning systems that takes noise requirements into consideration in planning and location of activities (e.g., cruise terminals) in port areas acknowledging acceptable noise exposure limits to surrounding residential areas |
|   | Monitor and enforce rules, agreements and operational parameters (e.g., speed limits).  |

Further guidance on the management of noise pollution in port environments can be obtained from the *Good Practice Guide on Port Area Noise Mapping and Management* that was prepared by the partners of the Noise Management in European Ports (NoMEPorts) Project (NoMEPorts 2008, 2017).

#### E.12.4 Light Quality

While there may have been a tendency to assume that lighting is peripheral to effective port operations, it is increasingly accepted that lighting has a considerable impact on safety, efficiency, the environment, and operating costs. Light pollution disturbs wildlife, wastes energy and obscures our view of night skies (PEMA 2016). Considerable improvements have been made to industrial lighting technologies in recent years with, for example, the development of Light Emitting Diodes (LED) and Light Emitting Plasma (LEP). While the initial cost of installing newer lighting technologies is typically higher than conventional lighting options, energy savings and reduced maintenance can result in a return on investment being realised in a relatively short timeframe. Real case scenarios suggest that energy savings can amount to between 55–60% and maintenance costs around 90%. Because light pollution has become an issue for many ports, the directionality of newer lighting sources minimises nuisance levels of light and promotes better relationships with adjacent communities and reduces impact on wildlife (PEMA 2016).

The Mont-Mégantic International Dark Sky Reserve (2022) highlights the four key principles to consider in good practice for outdoor lighting: orientation, colour, intensity, and timing (Figure E.12).



Figure E.12 Four key principles to consider good practice for outdoor lighting (source: Mont-Mégantic International Dark Sky Reserve 2022)

Other important aspects to consider in lighting planning and design in ports include (PEMA 2016):

- Energy and cost saving (not only installation but also maintenance)
- Responsible use of light (control over potential impacts of light sources)
- Quality of light (considering colour and temperature)
- Disposal (limiting hazardous risks on disposal of fixtures after service life).



## E.13 Ecosystem Restoration

*Ecosystem restoration is defined here in its broader context as the act of returning an ecosystem to its natural state or the partial reinstating of structural or functional characteristics that lost.*

Numerous terminologies, approaches and concepts are involved in the broader context of ecosystem recovery including restoration, remediation and recreation (e.g., Aronson and Le Floc'h 1996; Elliot et al. 2007; NRC, 1992; Elliot et al. 2007), mitigation and compensation (e.g., Elliot and Cutts 2004), biodiversity offsetting (e.g., Maron et al. 2012), ecological engineering (e.g., Elliot et al. 2016), and novel ecosystems (e.g., Chapin and Starfield 1997; Hobbs et al. 2009). Not surprisingly the extensive semantics of ecosystem recovery has led to confusion (Elliot et al. 2007). It is important to acknowledge the 'jargon' used in restoration science to position research efforts and/or policy development within the wider theoretical framework, but for the purposes of meaningful implementation it is more important to focus on the strategic goals of ecosystem recovery within a particular geographical area rather than debating absolutely correctness of terminologies. Simenstad et al. (2006) stressed that the focus should not be on technical semantics in ecosystem recovery, but rather to communicate to restoration managers and society the differences in expectations, sustainability and investment associated with a range of recovery approaches.

In the light of rapid degradation of natural systems and the threat it poses for achieving the Sustainable Development Goals (SDGs) of Agenda 2030, the United Nations declared 2021–2030 as the *UN Decade on Ecosystem Restoration* (<https://www.decadeonrestoration.org/>). Their aim is to prevent, halt and reverse the degradation of ecosystems on every continent and in every ocean, to assist in ending poverty, combating climate change and preventing mass extinction. This will require political support and technical capacity in both the public and private sectors to invest in ecosystem restoration initiatives worldwide and achieve success at the global scale.

Numerous sources of guidance are available to support ecosystem restoration efforts. Focusing on coastal and marine systems, these include:

- Ecological Restoration for Protected Areas (Keenleyside et al. 2012)
- Society for Ecological Restoration: International principles and standards for the practice of ecological restoration. Second edition (Gann et al. 2019)
- Principles for ecosystem restoration to guide the UN Decade (UNEP 2021a)
- Ecosystem Restoration Handbook (UNEP 2021b)
- Restoration Guidelines for Shellfish Reefs (Fitzsimon et al. 2019)
- Guidelines for Seagrass Ecosystem Restoration in the WIO region (UNEP-Nairobi Convention/WIOMSA 2020)
- Guidelines on Mangrove Ecosystem Restoration for the WIO region (UNEP-Nairobi Convention/USAID/WIOMSA 2020)
- Restoration of Coral Reefs and associated Ecosystems (Léocadie et al. 2020)
- Training Guide for Coral Reef Restoration (González et al. 2020)
- Kelp Restoration Guidebook (Eger et al. 2022)
- A guide to Coral Reef Restoration for the Tourism sector (Escovar-Fadul et al. 2022)
- Restoration Project Information Sharing Framework (Gann et al. 2022).

A brief overview of key aspects on ecosystem restoration is highlighted here, but readers are referred to the above documents for specific details.

### E.13.1 Key Principles for Ecological Restoration

A fundamental principle to be recognised at the outset is that ecosystem restoration exists on a continuum of intervention strategies to deal with ecosystem degradation, starting from reducing impact (e.g., by addressing sources of pollution) through to ecological restoration (Figure E.13).

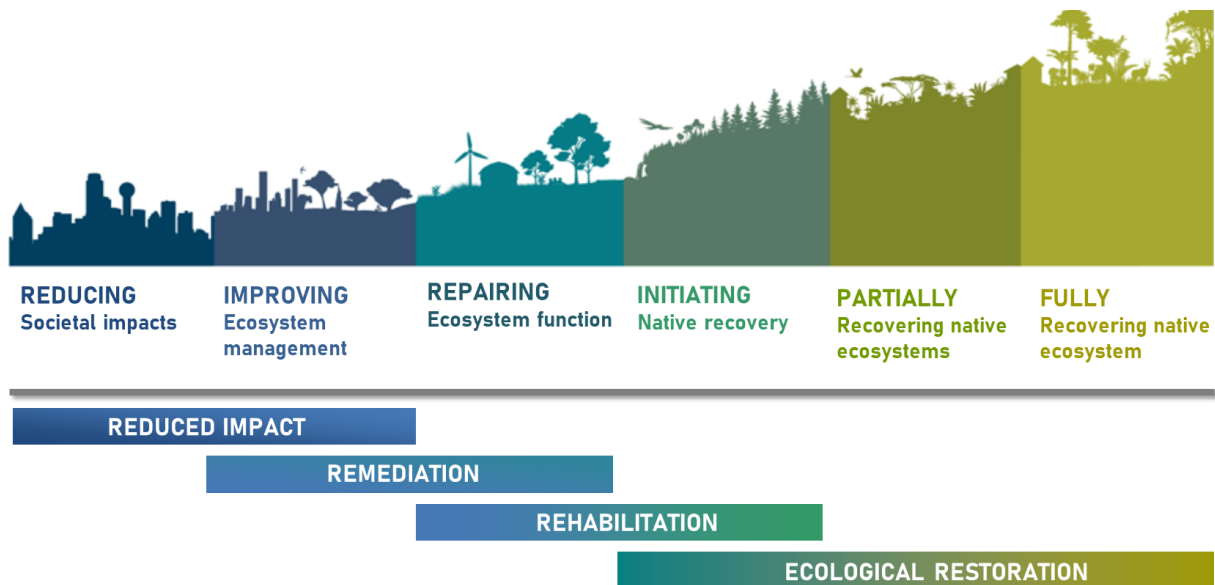


Figure E.13 Illustration of the restorative continuum (source: Gann et al. 2019)

The IUCN's Guidelines for Ecological Restoration, albeit focused on protected areas, defines three basic principles (effective, efficient and engaging) supported by specific guidelines (Table E.17).

Table E.17: Key principles and supporting guidelines for successful restoration (source: Keenleyside et al. 2012)

| PRINCIPLE   | GUIDELINE   |
|---|---|
| Effective in re-establishing and maintaining protected area values  | <ul style="list-style-type: none"> <li>• 'Do no harm' by first identifying when restoration is the best option</li> <li>• Re-establish ecosystem structure, function and composition</li> <li>• Maximize the contribution of restoration actions to enhancing resilience (e.g., to climate change)</li> <li>• Restore connectivity within and beyond the boundaries of protected areas</li> <li>• Encourage and re-establish traditional cultural values and practices that contribute to the ecological, social and cultural sustainability of the protected area and its surroundings</li> <li>• Use research and monitoring, including from traditional ecological knowledge, to maximize restoration success</li> </ul> |
| Efficient in maximizing beneficial outcomes while minimizing costs in time, resources, and effort                   | <ul style="list-style-type: none"> <li>• Consider restoration goals and objectives from system-wide to local scales</li> <li>• Ensure long-term capacity and support for maintenance and monitoring of restoration</li> <li>• Enhance natural capital and ecosystem services from protected areas while contributing to nature conservation goals</li> <li>• Contribute to sustainable livelihoods for indigenous peoples and local communities dependent on the protected areas</li> <li>• Integrate and coordinate with international development policies and programming</li> </ul>   |
| Engaging by collaborating with partners and stakeholders, promoting participation, and enhancing visitor experience | <ul style="list-style-type: none"> <li>• Collaborate with indigenous and local communities, neighbouring landowners, corporations, scientists and other partners and stakeholders in planning, implementation, and evaluation</li> <li>• Learn collaboratively and build capacity in support of continued engagement in ecological restoration initiatives</li> <li>• Communicate effectively to support the overall ecological restoration process</li> <li>• Provide rich experiential opportunities, through ecological restoration and because of restoration, that encourage a sense of connection with and stewardship of protected areas</li> </ul>  |

The Society for Ecological Restoration (SER), an international non-profit organization with members in about 70 countries, also developed a set of international principles and standards to assist in the practice of ecological restoration (Gann et al. 2019). These standards recognise the importance of appropriate design, good planning and implementation, sufficient knowledge, skill, effort and resources, understanding of specific social contexts and risks, appropriate stakeholder involvement, and adequate monitoring for adaptive management for effective outcomes. Most recently, the UN Decade on Ecosystem Restoration set out ten key principles for effective ecosystem restoration, echoing most of the SER Principles (UNEP 2021a):

|               |  |
|---------------|--|
| Principle 1:  | Ecosystem restoration contributes to the UN SDGs and the goals of the RIO Conventions  |
| Principle 2:  | Ecosystem restoration promotes inclusive and participatory governance, social fairness and equity from the start and throughout the process and outcomes |
| Principle 3:  | Ecosystem restoration includes a continuum of restorative activities   |
| Principle 4:  | Ecosystem restoration aims to achieve the highest level of recovery for biodiversity, ecosystem health and integrity, and human wellbeing                |
| Principle 5:  | Ecosystem restoration addresses the direct and indirect causes of ecosystem degradation  |
| Principle 6:  | Ecosystem restoration incorporates all types of knowledge and promotes their exchange and integration throughout the process                             |
| Principle 7:  | Ecosystem restoration is based on well-defined short-, medium and long-term ecological, cultural and socio-economic objectives and goals                 |
| Principle 8:  | Ecosystem restoration is tailored to the local ecological, cultural, and socio-economic contexts, while considering the larger landscape and seascape    |
| Principle 9:  | Ecosystem restoration includes monitoring, evaluation, and adaptive management throughout and beyond the lifetime of the project or programme            |
| Principle 10: | Ecosystem restoration is enabled by policies and measures that promote its long-term progress, fostering, replication and scaling-up.                    |

To facilitate global sharing of information on ecosystem restoration Gann et al (2022) developed a framework for coordinated monitoring and reporting comprising a set of headline, core, and secondary indicators organised under the ten UD Decade principles. Also provided is a set of project descriptors (metadata, project, and site variables) typically used to document project information.

### E.13.2 Key Steps in Restoration Planning & Implementation

Planning and implementing of ecosystem restoration programmes is an iterative process, where adaptive management becomes a vital requirement for success. To assist with the planning and implementation of holistic and adaptive restoration, Keenleyside et al. (2012) proposed a generic seven step approach defining key aspects that should be addressed in achieving effective, efficient, and engaging ecological restoration (Figure E.14). These include:

|          |  |
|----------|--|
| Phase 1: | Define problem and identify stakeholders |
| Phase 2: | Assess problem                           |
| Phase 3: | Develop ecosystem restoration goals      |
| Phase 4: | Develop ecosystem restoration objectives |
| Phase 5: | Design ecosystem restoration approach    |
| Phase 6: | Implement ecosystem restoration approach |
| Phase 7: | Implement adaptive management.           |

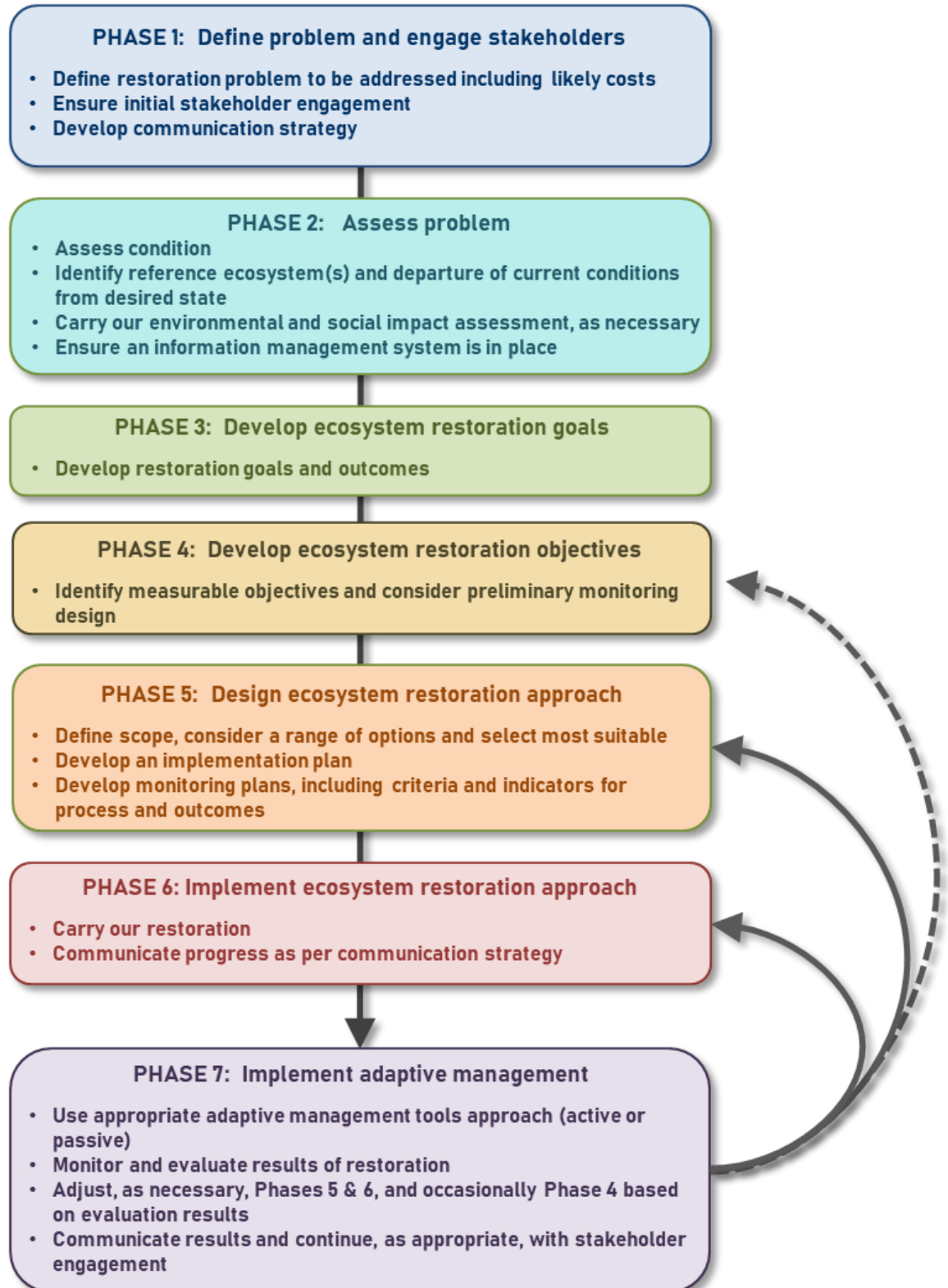


Figure E.14 Generic 7-step process proposed for planning and implementation of effective, efficient, and engaging ecosystem restoration programmes (adapted from: Keenleyside et al. 2012)

## E.14 Marine Litter Clean-up Technologies

Marine litter is a major problem worldwide. This has triggered increasing attention across the globe to monitor marine litter more effectively, to explore ways of reducing plastics and other sources of marine litter, and technologies to remove and clean-up marine litter from the environment (Barnardo and Ribbink 2020; Schmaltz et al. 2020).

Removal and clean-up interventions to remove marine litter already polluting the coasts and oceans of the world has received much attention. Numerous technologies have been developed worldwide to address this issue, including various types of litter traps and booms (e.g., Barcelo and Pico 2020). Ports are areas on the coast which are particularly prone to marine litter, and which experience significant economic impacts from this pollution. Substantial costs are incurred in removing marine litter from these facilities in order to keep them safe and attractive to users, and to prevent interference with propellers, anchors, rudders and blocked intake pipes and valves (Bergmann et al. 2015). Ideally marine litter in ports should be addressed by prevention, but in most cases, it arises from areas outside of port jurisdiction and management influence. Investment in litter clean-up and removal is therefore an inevitable requirement.

### E.14.1 Clean-up Technologies

Technologies employed and management interventions should be appropriately selected, based on consideration of site-specific characteristics and requirements. These can be broadly categorized into (e.g., Schmaltz et al. 2020) litter traps, litter booms, net traps, barriers, moored motorized systems and vessels, drones and robots (aquatic vacuums) (see examples in Figure E.15).

#### E.14.1.1 Litter traps

Litter traps are floating devices installed at strategic locations along waterways to collect and retain floating litter, vegetation and other debris. They operate silently without any mechanical assistance, capturing and retaining debris ready for removal and disposal. Examples of commercially available litter traps are listed in Table E.18. They include the Bandalong Litter Trap™ which utilizes natural energy of flowing water to capture and remove litter from waterways. It floats on waterways, given buoyancy by strong and durable polyethylene pipes, held in place by chains attached to ground anchors or fitted to rider poles for canal installations. Outspread collection booms direct floating litter through a one-way gate into the trap where it is retained ready for removal. Re-entrainment is prevented by a system of counterweights and paddles that close the entry gate when the water flow stops or there is a change in flow direction due to tide or wind. A polyethylene side skirt beneath the waterline prevents debris escaping under the main floats. These traps are suitable for most waterways wider than 2 meters, including waterways subject to tidal action, rivers, streams, channels and open bodies of water.

#### E.14.1.2 Litter booms

Litter booms (also referred to as floating debris traps) are devices consisting of partly submerged floating booms, installed across waterway to trap buoyant litter, e.g., plastic containers. Table E.18 lists some examples of litter booms currently in use. Litter booms are a simple intervention, a floating barrier fixed across a water course to prevent downstream transport of large, floating (mainly plastic) litter. Some newer designs use floating polyethylene arms deflect debris through flap gates into a storage compartment. Floating litter booms are not suited to fast moving waters and not effective in removing non-floatable debris. This can lead to significant leakage of litter as usually only a small fraction of litter remains buoyant for significant time periods. Nevertheless, placed strategically close to known sources of large floating litter, and serviced frequently, this simple technology can play a



meaningful role in reducing litter in waterways, and transport to coastal waters. Its value lies in the wide scope of materials which can be used and the ease with which they can be installed in a range of waterways. In Guatemala an artisanal fencing system has been developed, made of mesh and plastic bottles and which is very easy to implement (Table E.18). This system is being replicated elsewhere.



Figure E.15 Examples of a (a) litter trap, (b) litter boom, (c) net trap, (d) barrier (e) litter skimmer and (f) aquatic vacuum (Sources: see Table E.17)

#### E.14.13 Barriers

There are several other types of barrier systems which rely on more complex designs and technologies. Bubble barriers, or bubble screens, are generated by pumping air through a tube with holes positioned on the bottom of the waterway. The barrier creates an upwards thrust that brings litter to the surface. In the case of the The Great Bubble Barrier (Table E.18), the screen is placed diagonally in the waterway, and uses the natural current to direct litter to a collection system on the edge of the water way. This design captures waste but does not obstruct vessels or migration of marine organisms (e.g., fish). Another advantage of this system is that it is effective in redirecting sub-surface litter. Test have shown the systems to capture 70-80% of floating and about 50% of sub-surface plastic litter down to a size of 1 mm.

Table E.18: Examples of litter removal and clean-up technologies used internationally (adapted from Schmaltz et al. 2020)

| TYPE                                       | TECHNOLOGY  | LINK  |
|--|---|---|
| Litter traps                               | Bandalong   | <a href="https://stormwatersystems.com/bandalong-litter-trap/">https://stormwatersystems.com/bandalong-litter-trap/</a>   |
|  | Clear Rivers  | <a href="https://www.clearrivers.eu/litter-traps">https://www.clearrivers.eu/litter-traps</a>   |
|  | SCG-DMCR Litter Trap  | <a href="https://www.scg.com/innovation/en/scg-dmcr-litter-trap/">https://www.scg.com/innovation/en/scg-dmcr-litter-trap/</a>   |
| Litter booms                               | Litter boom project   | <a href="https://www.thelitterboomproject.com/">https://www.thelitterboomproject.com/</a>   |
|  | Bandalong   | <a href="https://stormwatersystems.com/bandalong-boom-systems/">https://stormwatersystems.com/bandalong-boom-systems/</a>   |
|  | AlphaMERS Floating Barrier                                    | <a href="https://alphamers.com/">https://alphamers.com/</a>   |
|  | Plastic fisher trash boom                                     | <a href="https://plasticfisher.com/">https://plasticfisher.com/</a>   |
|  | Artisanal boom design   | <a href="https://www.reciclacion.cl/noticias/soluciones-para-residuos-solidos-en-el-agua/">https://www.reciclacion.cl/noticias/soluciones-para-residuos-solidos-en-el-agua/</a> |
| Net traps                                  | StormX  | <a href="https://stormwatersystems.com/stormx-netting-trash-trap">https://stormwatersystems.com/stormx-netting-trash-trap</a>   |
|  | Project Storm Net Development                                 | <a href="https://dict.org.za/blog/project-storm-net-development/">https://dict.org.za/blog/project-storm-net-development/</a>   |
| Barriers                                   | Great Bubble Bar  | <a href="https://thegreatbubblebarrier.com/en/">https://thegreatbubblebarrier.com/en/</a>   |
|  | Buoy Barrier System   | <a href="https://rivercleaning.com/river-cleaning-system/">https://rivercleaning.com/river-cleaning-system/</a>   |
| Moored motorised systems                   | Trash skimmer   | <a href="http://www.marinatrashskimmer.com/">http://www.marinatrashskimmer.com/</a>   |
|  | Seabin  | <a href="https://seabinproject.com/seabin-for-sydney/city-pilot-program/">https://seabinproject.com/seabin-for-sydney/city-pilot-program/</a>                                   |
|  | Trash wheel   | <a href="https://www.mrtrashwheel.com/technology/">https://www.mrtrashwheel.com/technology/</a>   |
|  | Ocean Cleanup's Inceptor                                      | <a href="https://theoceancleanup.com/rivers/">https://theoceancleanup.com/rivers/</a>   |
| Vessels, Drones & Robots (Aquatic vacuums) | Versi-Cat   | <a href="https://waterwitch.com/ww/versi-cat-2/">https://waterwitch.com/ww/versi-cat-2/</a>   |
|  | SeaVax  | <a href="https://www.blue-growth.org/Blue_Growth_Technology_Innovation/SeaVax.htm">https://www.blue-growth.org/Blue_Growth_Technology_Innovation/SeaVax.htm</a>                 |
|  | Seahamster  | <a href="https://oneearth-oneocean.com/en/the-seehamster/">https://oneearth-oneocean.com/en/the-seehamster/</a>   |
|  | Seekuh  | <a href="https://oneearth-oneocean.com/en/the-seekuh/">https://oneearth-oneocean.com/en/the-seekuh/</a>   |
|  | CollectiX   | <a href="https://garbage-boat.com/en/product/">https://garbage-boat.com/en/product/</a>   |
|  | FRED (Floating Robot for Eliminating Debris)                  | <a href="https://www.clearblueseas.org/meet-fred/">https://www.clearblueseas.org/meet-fred/</a>   |
|  | Wasteshark  | <a href="https://www.ranmarine.io/products/wasteshark/">https://www.ranmarine.io/products/wasteshark/</a>   |
|  | Jellyfishbot  | <a href="http://www.iadys.com/en/jellyfishbot-2/">http://www.iadys.com/en/jellyfishbot-2/</a>   |
| Bluephin                                   | <a href="http://www.bluephin.io/">http://www.bluephin.io/</a> |   |

#### E.14.1.4 Moored motorized systems

Moored motorized systems have also been successfully used as litter traps worldwide (Table E.18). An example is the Trash Wheel, a semi-autonomous moored vessel using a combination of solar and hydro power. The system uses rotating forks to remove litter and to guide it onto a conveyor belt that moves it into a dumpster. It can be control remotely. Another example is Ocean Cleanup's Inceptor which is solar powered also using a barrier (boom) to direct litter towards receptor.

The Marina Trash Skimmer (Table E.18) is an apparatus that fulfils the dual function of removing marine litter and also oil sheens. This system comprises a stationary unit (or network of units) that can be strategically placed at specific problem areas in a marina or harbour. It works with natural currents,



tides and prevailing winds. The system has a relatively small footprint (1.8 m wide x 1.2 m deep x 0.5 m freeboard) and operates on 20 Amp 125 Volt power but is able to move over 1 000 litres a minute.

Another litter skimmer is the Seabin (Table E.18), designed to be installed in marinas, yacht clubs, ports and any waterway with calm conditions and with access to suitable services. It acts as a floatable garbage bin moving up and down with the tide and skimming the water surface by pumping water through the device and intercepting floating debris, macro and micro plastics and even micro fibres. It uses an underwater pump that can displace about 25 000 litres per hour. It can also be equipped with oil absorbent pads able to absorb petroleum-based surface oils and detergent.

#### E.14.1.5 Vessels, drones and robots (aquatic vacuums)

Litter trapping vessels are more sophisticated technologies deployed to control marine litter (Table E.18). For example, the Versi-Cat is a motorised vessel that collects floatable and semi-submerged litter, debris and aquatic vegetation into a removal basket that can be lifted and tipped directly into a shore receptacle. The design allows for collection of litter between the hulls with no complex equipment or machinery. Drone and robotic technologies have also been deployed in *in situ* marine litter removal systems, ranging from larger systems (e.g., FRED) to small easy deployable systems (e.g., Wasteshart, Jellyfishbot and Bluephin).

### E.14.2 Proposed Decision Criteria

Table E.19 compares the removal efficiency, environmental suitability, and economic implications of various marine litter clean-up technologies to inform decision-making in the selection of most appropriate place-based technology for a specific port, based on criteria proposed by Armitage and Rooseboom (2000) and Schmaltz et al. (2020).

Table E.19: Comparison of removal efficiency, environmental suitability, and economic implications of various marine litter clean-up technologies (Removal efficiency and Economic consequences: 'High' = high efficiency/suitability, 'Med' = medium efficiency/suitability, 'Low' = low efficiency/suitability; Economic implication: 'High' – high cost/effort, 'Med' medium cost/effort, 'Low' – low cost/effort)

| TECHNOLOGY                           | REMOVAL EFFICIENCY          |                |                |              | ENVIRONMENTAL SUITABILITY |             |                 |                   |                | ECONOMIC IMPLICATIONS |                              |               |
|--------------------------------------|-----------------------------|----------------|----------------|--------------|---------------------------|-------------|-----------------|-------------------|----------------|-----------------------|------------------------------|---------------|
|                                      | Organic litter (vegetation) | Macro-plastics | Micro-plastics | Oil & Grease | Interference/aesthetics   | Tidal areas | High flow rates | Medium flow rates | Low flow rates | Set-up cost           | Maintenance/labour intensity | Skills levels |
| Litter traps                         | High                        | High           | Low            | High         | Med                       | Med         | Low             | Med               | High           | Med                   | High                         | Low           |
| Litter booms                         | High                        | High           | Low            | High         | Med                       | Med         | Low             | Med               | High           | Low                   | High                         | Low           |
| Net traps (end of pipe)              | High                        | High           | Low            | High         | Low                       | Low         | High            | High              | High           | Med                   | High                         | Med           |
| Barriers                             | High                        | High           | Low            | High         | Low                       | High        | Low             | Med               | High           | Med                   | Med                          | Med           |
| Moored, motorised systems (skimmers) | High                        | High           | High           | High         | Low                       | High        | Low             | Med               | High           | High                  | Med                          | High          |
| Vessels, Drones & Robots (vacuums)   | High                        | High           | Med            | Low          | Low                       | High        | Low             | Med               | High           | High                  | High                         | High          |

## E.15 Oil Spill Contingency Planning

Oil spill contingency planning aims to pre-emptively plan for mitigating and controlling detrimental impacts on the coastal and marine environment during unexpected malfunctions or accidents. Oil spill contingency planning addresses requirements under several international conventions to which most countries in the WIO region are signatories to, for example:

- International Convention on Civil Liability for Oil Pollution Damage (CLC) (1969)
- International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties (INTERVENTION) (1969)
- International Convention for Prevention of Pollution from Ships (MARPOL) (1973)
- United Nations Convention on the Law of the Sea (UNCLOS) (1982)
- International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC) (1990)
- International Convention on Civil Liability for Bunker Oil Pollution Damage (BUNKER) (2001).

The Nairobi Convention calls for the development of contingency plans, as well as notification procedures. In addition, the Protocol Concerning Co-operation in Combating Marine Pollution in Cases of Emergency in the Eastern African Region (Emergency Protocol) was adopted and came into force in 1996. This Protocol sets out the legal institutional framework for regional cooperation in addressing accidental marine pollution. Further, it provides for the establishment of contingency plans and notification procedures necessary for an effective response within the region, based on mutual support between national systems.

Oil spill contingency plans are typically prepared at different tiers, ranging from regional plans (e.g., WIO region), national plans, local coastal plans, to port plans, and even plans for specific terminals within a port (Figure E.16).

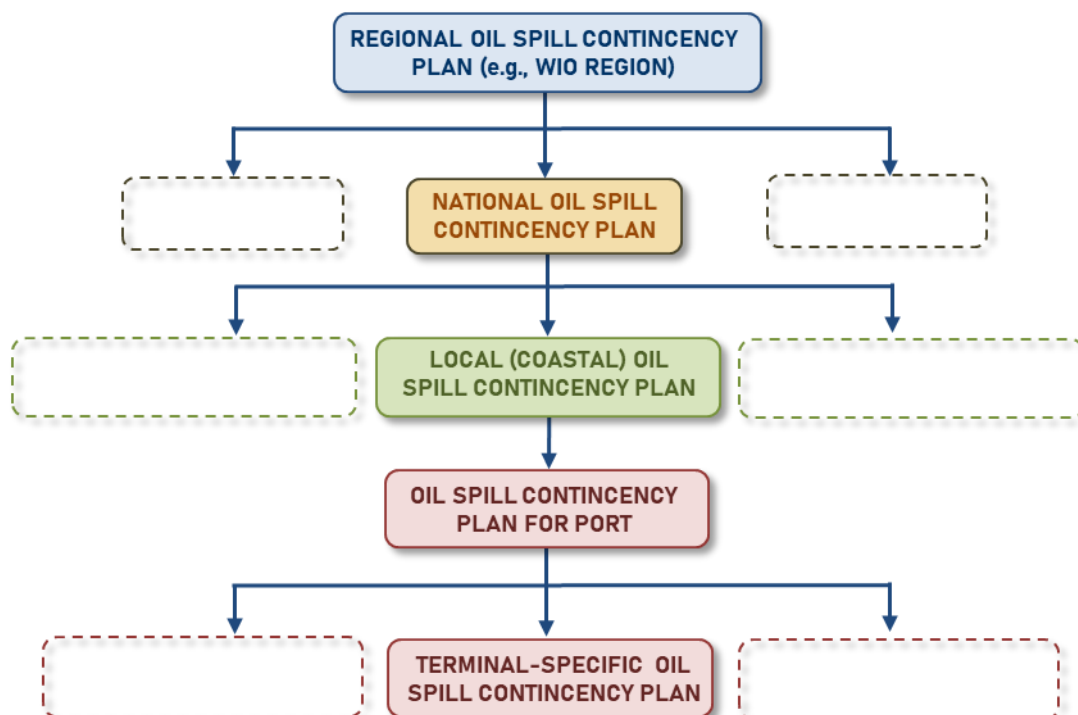


Figure E.16 Examples of different tiers of oils spill contingency planning

Alignment and cooperation across all these tiers is critical to ensure efficient, coordinated, and cost-effective intervention during emergencies. Efforts to assist contracting parties to the Nairobi Convention to meet their obligations under the Emergency Protocol included the WIO Islands Oil Spill Contingency Planning (OSCP) project (1999–2004) and the WIO Marine Highway Development and the Coastal and Marine Contamination Prevention Project (WIOMH Project, 2007–2012) (Swanepoel 2020). In recent years, efforts have focused on assessing the preparedness of the region for oil spill emergencies, with plans to improve regional collaboration (UNEP et al. 2020a, 2020b). National preparedness still poses challenges for various countries in the region, as highlighted by Swanepoel (2020). It remains critically important for port authorities to develop site-specific oil spill contingency plans for areas under their jurisdiction, that could ultimately be nested in higher levels planning.

Useful guidance on the development of oil spill contingency plans includes:

- IMO Oil spill contingency planning (IMO 2022c)
- Guidelines for the development of a national environmental contingency plan (UNEP/OCHA 1996a, 1996b)
- Contingency planning for marine oil spills – Technical information paper 16 (ITOPF n.d.)
- Contingency Planning for Marine Pollution Preparedness and Response – Guidelines for Ports (Marine Coast Maritime and Coastguard Agency, UK 2021).

An oil spill contingency plan generally comprises a four-stage process, including (e.g., ITOPF n.d):

- Risk assessment, determining the risk of spills and anticipated consequences
- Strategic policy, defining the roles and responsibilities and providing the rationale for operations
- Operational procedures, establishing specific procedures to follow when a spill occurs
- Information directory, gathering and collating supporting data.

Each of these components is elaborated on in Figure E.17, while an example for an environmental contingency plan, such as an oil spill contingency plan, is provided in Table E.20.

Table E.20: Example: Table of Content for an Environmental Contingency Plan (adapted from UNEP/OCHA 1996b)

|   |  |
|---|--|
| Chapter 1: Introduction                                 | Chapter 6: Emergency Response Actions      |
| 1.1 Purpose   | 6.1 General Response to Emergency          |
| 1.2 Scope   | Environmental Incidents                    |
| Chapter 2: Legal and Other Requirements                 | 6.2 Resources for Response Action          |
| 2.1 International/regional                              | 6.3 Key contact lists                      |
| 2.2 National  | 6.4 Response and management teams          |
| 2.3 Local   | 6.5 Emergency preparedness plans           |
| Chapter 3: Roles and Responsibilities                   | 6.6 Emergency equipment                    |
| 3.1 Responsible government authorities                  | 6.7 Training                               |
| 3.2 Owners or designated managers of related activities | Chapter 7: Environmental Monitoring        |
| Chapter 4: Relationship with Other Contingency Plans    | Chapter 8: Communication                   |
| 4.1 International/regional plans                        | 8.1 Internal notification                  |
| 4.2 National Disaster plan                              | 8.2 Regulatory notifications and reporting |
| 4.3 Local plans   | 8.3 Stakeholder and community notification |
| Chapter 5: Emergency Preparedness Framework             | Chapter 9: Environmental Recovery          |
| 5.1 Emergency organisation structure                    | 9.1 Site assessment                        |
| 5.2 Emergency response plans and procedures             | 9.2 Remediation and rehabilitation         |
|   | 9.3 Cost recovery                          |
|   | Chapter 10: Evaluation and Review          |

| RISK ASSESSMENT  | STRATEGIC POLICY   | OPERATIONAL PROCEDURES   | INFORMATION DIRECTORY  |
|--|--|--|--|
| <p><b>Determine likelihood of spill occurring</b></p> <ul style="list-style-type: none"> <li>Number &amp; type of vessels calling/passing</li> <li>Type and volume of oil carried</li> <li>Determine likelihood of spills occurring</li> <li>Expected frequency &amp; size of spills</li> <li>Identified areas with high risk of spills</li> </ul> | <p><b>Plan overview</b></p> <ul style="list-style-type: none"> <li>Identify lead organisations</li> <li>Outline regulatory framework &amp; jurisdiction</li> <li>Define geographical area of plan</li> <li>Define interaction with other plans (scaling tiered response)</li> <li>Outline role of ship owner</li> </ul>  | <p><b>Notification</b></p> <ul style="list-style-type: none"> <li>Establish notification routes</li> <li>Outline details needed to determine incident circumstances</li> </ul>   | <p><b>Operational references</b></p> <ul style="list-style-type: none"> <li>Contact details &amp; remit of relevant government agencies &amp; other response organisations</li> <li>Inventory of available resources &amp; contact details of operators</li> <li>Contact details of 3<sup>rd</sup> party suppliers of material &amp; services</li> <li>Sensitive area maps</li> <li>Restrictions on dispersant use</li> </ul>  |
| <p><b>Determine probability of consequences</b></p> <ul style="list-style-type: none"> <li>Location of sensitive resources</li> <li>Probably spill movement</li> <li>Effects of oil on resources</li> </ul>  | <p><b>Response techniques</b></p> <ul style="list-style-type: none"> <li>State preferred response techniques to address floating oil &amp; any restriction on use</li> <li>Determine importance of &amp; ability to protect sensitive resources identified in risk assessment accounting for seasonality</li> <li>Determine appropriate clean-up techniques for shoreline types within plan area</li> <li>Outline response to oiled wildlife</li> </ul>  | <p><b>Evaluation</b></p> <ul style="list-style-type: none"> <li>Source details of oil, wind &amp; currents (trajectory modelling)</li> <li>Establish threat to resources</li> <li>Obtain additional information from aerial, boat &amp; foot surveys</li> </ul>                              | <p><b>Sample documents</b></p> <ul style="list-style-type: none"> <li>Example equipment charter &amp; hiring agreements</li> <li>Sample <i>pro-forma</i> daily aerial, at-sea and shoreline progress reports</li> <li>Example forms for recording expenditure</li> </ul>   |
| <p><b>Determine likely spill scenarios</b></p>   | <p><b>Response resources</b></p> <ul style="list-style-type: none"> <li>Ensure suitable resources available to address risk (purchase or contract in)</li> <li>Allocate stockpile locations</li> <li>Identify suppliers of material &amp; services likely to be required</li> <li>Determine preferred waste storage, treatment &amp; disposal options</li> </ul>   | <p><b>Initiation</b></p> <ul style="list-style-type: none"> <li>Initiate response</li> <li>Identify response team members, responsibilities &amp; contact details</li> <li>Notify or liaise with other plan holders</li> <li>Make response decisions required in light of threats</li> </ul> | <p><b>Supplementary information</b></p> <ul style="list-style-type: none"> <li>List of approved response products</li> <li>Guidelines for observation &amp; recording oil at-sea &amp; on shore</li> <li>Guidelines for use of preferred response techniques, including booming plans</li> <li>Guidelines for sampling &amp; for monitoring contamination levels</li> <li>Sources of funding &amp; compensation</li> <li>Information necessary to expedite cost recovery</li> <li>Legislation stating statutory powers of plan holder</li> </ul> |
| <p><b>Gauge benefits of developing contingency plan</b></p> <ul style="list-style-type: none"> <li>Determine existing spill response arrangements</li> <li>Determine whether proposed contingency arrangements serve to reduce consequences of spills</li> <li>Determine extent to which contingency plan is required</li> </ul>                   | <p><b>Leadership, command &amp; management</b></p> <ul style="list-style-type: none"> <li>Define key response functions</li> <li>Outline divisions of responsibility</li> <li>Ensure coordination of all organisations involved</li> <li>Define responsibility for decisions</li> <li>Decide command centre &amp; forward operational base locations</li> <li>Outline involvement of 3<sup>rd</sup> parties in response</li> <li>Allow for media &amp; public relations</li> <li>Ensure accurate record keeping</li> </ul> | <p><b>Mobilisation</b></p> <ul style="list-style-type: none"> <li>Determine availability of resources &amp; outline mobilisation procedures</li> <li>Ensure resources are deployed in accordance with strategic policy</li> <li>Maintain activity &amp; cost records</li> </ul>              |  |
|  | <p><b>Training &amp; review procedures</b></p> <ul style="list-style-type: none"> <li>Outline timetable for training &amp; exercises</li> <li>Define procedure for regular review &amp; update of plan</li> </ul>  | <p><b>Clean-up support</b></p> <ul style="list-style-type: none"> <li>Ensure sufficient logistic support</li> <li>Ensure integrated comms for all parts of response</li> <li>Determine optimum waste treatment routes</li> </ul>   |  |
|  |  | <p><b>Progress review</b></p> <ul style="list-style-type: none"> <li>Ensure all aspects of response continuously re-evaluated</li> <li>Highlight response aspects requiring modification (up or down)</li> </ul>   |  |
|  |  | <p><b>Termination</b></p> <ul style="list-style-type: none"> <li>Determine criteria for termination &amp; sign-off work sites</li> <li>Demobilise, clear, repair and repatriate resources</li> <li>Restore temporary waste sites</li> </ul>  |  |
|  |  | <p><b>Plan review</b></p> <ul style="list-style-type: none"> <li>Establish review of response</li> </ul>   |  |

Figure E.17 Key elements within each of the four components of an oi spill contingency plan (source: ITOPF n.d.)

## E.16 Environmental Monitoring and Evaluation

Environmental and evaluation monitoring programmes form an integral part of a port's EMS (Figure E.1). Their purpose is to assess the effectiveness of management actions to meet agreed objectives, and to highlight areas for future improvement. Because coastal ecosystems are complex, it may not always be possible to pre-empt all ecosystem responses in, for example, EIA studies. Cumulative effects associated with multiple activities are especially difficult to predict. Environmental and evaluation monitoring programmes provide information on trends in the status of the environment, allowing for timeous management response to mitigate negative impacts.

### *Important considerations for long-term monitoring programmes*

- **Competent skills:** A range of skills and competencies are required to successfully develop and implement a long-term monitoring programme. The team therefore should include scientists with experience and expertise in various physical, chemical and biological disciplines the various fields of the programme that need to be addressed (as are identifiable at this early stage). Statistical skills are also important. While many natural scientists have a basic knowledge of statistics, most do not have a sufficiently strong grounding for the design of statistically defensible programmes. Therefore, involving a statistician from the outset can avoid numerous problems.
- **Budget constraints:** Environmental monitoring can be expensive, especially for programmes that cover large spatial and temporal scales. There are very few occasions when the budget is tailored to fit a long-term monitoring programme. Rather, water quality monitoring programmes are usually tailored to fit budgets. Therefore, it is important from a practical point to understand budget realities. If an available budget is insufficient to meet the requirements of a detailed monitoring programme, prioritisation of key components will be required, planning for an incremental roll out of the programmes. Reducing the scope of a monitoring programme to suit a budget also necessitates an assessment of whether the statistical validity of the programme can be maintained.
- **Stakeholder communication:** When designing long-term monitoring programmes, it is important to engage with key role players or affected parties pertaining to coastal and marine water quality through dedicated institutional platforms. This is important to ensure alignment with the needs and concerns of the stakeholders, and to get buy-in. Scientists must resist the urge to plan long-term monitoring programmes to align with their research expertise and interests, and rather focus on the requirements for C&MWQM within the context of the strategic framework.

Figure E.18 illustrates the key components of an environmental monitoring and evaluation programme (e.g., after UNEP et al. 2022a), embedded in the broader EMS process. Even though a structured approach is recommended for the design and implementation of environmental monitoring programmes, such processes should remain dynamic and iterative continuously adjusting efforts to incorporate new knowledge arises.

Environmental monitoring programmes can be costly in terms of human, material and financial resources. It is critical these resources are secured before undertaking a monitoring programme. Resources for monitoring, as for the other activity-based management interventions and actions, needs to be planned and budgeted for by the responsible port authorities, or they need to be alternatively resourced. In accordance with the *Principle of Polluter pays*, operators of activities posing pollution risks in ports could be held accountable for the execution of monitoring programmes or to contribute towards the cost of such programmes.

### E.16.1 Monitoring Objectives

Measurable site-specific objectives are a key component of a sound long-term monitoring programme. Without clear monitoring objectives the danger exists that a long-term monitoring programme will become 'monitoring-for-the-sake-of-monitoring' rather than fulfilling the critical role of informing and subsequently providing a means of adapting and improving EMS in ports. Clear monitoring objectives are fundamental to the design of a focused and cost-effective monitoring programme.

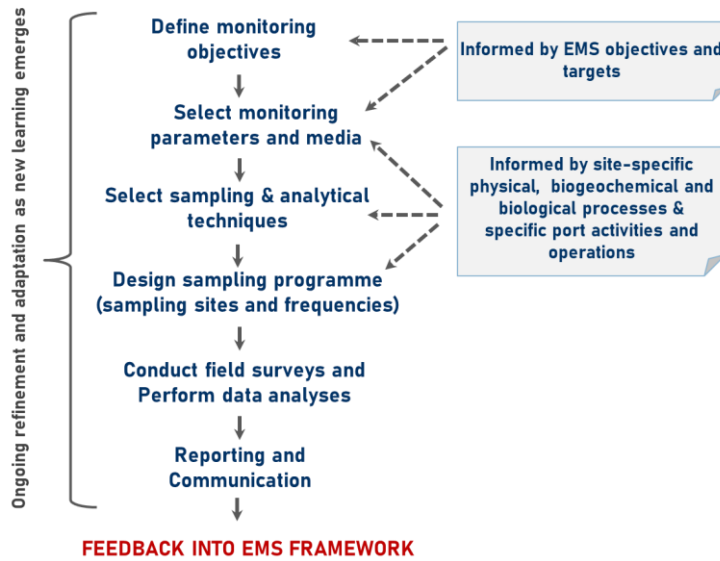


Figure E.18 Key components of an environmental monitoring and evaluation programme

To assist with the selection of specific targets for pollutants in coastal waters and sediments, *Guidelines for Setting Water and Sediment Quality Targets for Coastal and Marine areas* for the WIO region were published in 2022 (UNEP et al. 2022b). In 2021, the World Health Organisation published the *WHO Global Air Quality Guidelines* to assist with setting targets or objective for air pollutants (WHO 2021).

#### ENVIRONMENTAL COMMITMENT AND ACHIEVEMENTS IN PORT OF TOAMASINA (MADAGASCAR)

*Yves Mong (National Environmental Research Centre)*

The Port of Tomasina, located along the east coast of Madagascar, is managed by 'La Société du Port à Gestion Autonome de Toamasina' (SPAT). Since 2005, the Madagascar International Container Terminal Services LTD (MICTSL) manages the container terminal and set itself the challenge of modernizing the port in close collaboration with SPAT. Committed to preserve and protect the environment around the port, SPAT has transplanted more than 300 colonies of IUCN red listed coral reef species that were going to be damaged by port extension. Further, SPAT collaborates with the Ministry of Fishery and Blue Economy to implement a 3-year project on surveying environmental components likely be affected by the port expansions. MICTSL also has voluntarily adopted the standards of the ISPS Code, ISO 28000 in 2007, ISO 14001 in 2015 and ISO 9001 for its management of security, environmental aspects as well as the management of quality.



*View of expansions in the Port of Toamasina*

As Madagascar's largest and main seaport, the Port of Toamasina has been increasing its container reception and storage capacity, whilst still committed to environmental protection as per national law and adopting good examples from other countries 'going green'.



## E.16.2 Monitoring Parameters and Media

The selection of measurement parameters (or indicators) is site-specific, should be appropriate for the defined pollution sources and associated pollutants and should be suitable to quantify whether monitoring objectives (as defined above) are being complied with. Key determining factors in the selection of monitoring parameters include (UNEP et al. 2022a):

- Range of natural variability for the indicator since this will influence its ability to detect change (very often, however, natural variability will be unknown until the monitoring programme has generated data)
- Characteristics of existing or anticipated pollution sources
- Anticipated impacts on air, water and sediment quality that may affect the required environmental quality targets of aquatic ecosystems and other beneficial uses
- Collection, measurement, and analysis costs involved.

Useful criteria to apply in the identification of suitability of indicators are provided in Table E.21.

Table E.21: Useful criteria for identification of indicator suitability (ANZECC 2000)

|                  |   |
|------------------|---|
| Relevance        | Does the measurement parameter reflect directly on the issue of concern?  |
| Validity         | Does the measurement parameter respond to changes in the environment and have some explanatory power?   |
| Diagnostic value | The measurement parameter must be able to detect changes and trends in conditions for the specified period. Can the amount of change be assessed quantitatively or qualitatively? |
| Responsiveness   | Does the measurement parameter detect changes early enough to permit a management response, and will it reflect changes due to the manipulation by management?                    |
| Reliability      | The measurement parameter should be measurable in a reliable, reproducible and cost-effective way.  |
| Appropriateness  | Is the measurement parameter appropriate for the time and spatial scales that need to be resolved?  |

Four primary media are typically the focus of environmental monitoring, namely air, water column, sediment and living organisms (adapted from UNEP et al. 2022a). In addition, noise and light pollution should also be monitored in ports in terms of their potential impact on wildlife and people.

The atmosphere (air) in and around ports is potentially a major recipient of pollutants which may expose people to health and environmental impacts. Emissions occur from a wide range of sources including fuel-powered cargo handling equipment, ships and harbour crafts, locomotives and power plants providing energy for port operations. Pollutants include particulate matter, nitrogen dioxide, sulphur dioxides, and methane. Management of sources of air pollution requires near real time data to ensure that potential human health risks are mitigated timeously. As a result, data need to be collected at weekly or two-weekly intervals (and even daily during high usage periods).

The water column is typically a highly variable environment, due to factors such as turbulence, tidal action and diurnal influences. Thus, data collected from the water column provides only a snapshot of conditions at the time of sampling, or at most about an hour prior to sampling. For this reason, the collection of numerous samples is usually required to characterise adequately conditions in the water column. This has obvious cost implications. Therefore, it is usually appropriate (and cost effective) to focus on those environmental components that tend to integrate impacts or change over time, such as sediments and organisms. However, in some cases the choice of indicator, or need for real time data, dictates sampling media choice. For example, sampling of the water column is essential in monitoring microbiological indicators (e.g., Enterococci or *E. coli*) at recreational or marine aquaculture areas in a port. Management of such areas requires near real time data to ensure that potential risks to human



health are mitigated timeously. As a result, data need to be collected at weekly or two-weekly intervals (and even daily during high usage periods).

Sediment integrates environmental conditions over periods lasting at least several weeks, but it can take months or even years to observe changes in the quality of deposited sediments. Thus, fewer samples are required to characterise the quality of sediment compared to the water column. Such pragmatic considerations also play a role in the selection of the media, for example concentrations of most contaminants are much higher in sediments than in the water column which makes detection and measurement in the laboratory far easier.

Living organism (biota) are used in various ways in long-term monitoring programmes, for example biological surveys (e.g., benthic invertebrate community composition), toxicity tests, histological and enzymatic studies, and the chemical analysis of body tissues. Filter feeding bivalves (such as mussels and oysters) are internationally recognised as suitable indicators for bioaccumulation studies in the marine environment. The basis for biomonitoring with bivalves is their ability to bioaccumulate contaminants to a degree that is proportional to the contaminant's bioavailability. Such bioaccumulation results in relatively high concentrations which makes detection and measurement easier. These organisms are also sessile, making them useful indicators for site-specific change, and when collected regularly over a wide area they provide useful insight into temporal and spatial contaminant trends. Further bivalves are consumed by humans (and indeed other organisms) and thus provide a measure of potential health implications associated with consumption.

Since it is expensive to perform detailed biological monitoring programmes it is important that scientifically sound reasons are provided for the selection of specific biotic indicators. Rather than surveying and quantifying whole biotic communities, indicator species are often identified as proxies for evaluating ecosystem health. In studies throughout the world, macroinvertebrate communities are used successfully in monitoring programmes. Fish have also been successfully used in coastal systems, particularly in areas that support resident populations. Biotic indices based on biological communities usually integrate conditions over the time required for the organisms' life cycles or development. This can range from a few weeks to several months (meiofauna, macroinvertebrates), years (fish, macrophytes), decades and longer (coral reefs). Where the port environment supports biotic species of economic importance (e.g., fisheries species such as prawns) the distribution and abundance of these species are also effective monitoring parameters.

Other practical considerations in the selection of parameters and media, are the availability of appropriate technical expertise and analytical facilities to accurately measure selected parameters and logistical challenges in transferring samples from the field to the laboratory within specified holding times and conditions for analysis. Although samples of most media can be preserved in the field and frozen in the laboratory until analysis, the analysis of many water column parameters must proceed within relatively short timeframes after sample collection (a few hours in the case of bacteria, for example).

Finally, a tiered approach in the selection of media and parameters is recommended, especially where resource constraints are encountered. For example, in monitoring sediment quality, the first tier may focus only on the measurement of contaminant concentrations in sediment, the second tier on sediment toxicity testing, and the third tier on analysis of benthic invertebrate community composition and structure. The logic behind a tiered approach is that it is pointless to proceed to the next tier if the first-tier results do not point to a significant problem, only advancing to the next tier if a high probability for adverse environmental effects is expected.

## Suggested reading:

- Mocerino L, Murena F, Quaranta F and Toscano D (2020) A methodology for the design of an effective air quality monitoring network in port areas, <https://doi.org/10.1038/s41598-019-57244-7>
- Sivertsen B (2008) Monitoring air quality, objectives, and design. [https://www.researchgate.net/publication/26543786\\_Monitoring\\_air\\_quality\\_objectives\\_and\\_design](https://www.researchgate.net/publication/26543786_Monitoring_air_quality_objectives_and_design)
- Snyder EG, Watkins TH, Solomon PA et al. (2013) The Changing Paradigm of Air Pollution Monitoring. <https://pubs.acs.org/doi/10.1021/es4022602>
- Scheltinga DM, Counihan R, Moss A, Cox M and Bennett J (2004) Users' guide for Estuarine, Coastal and Marine indicators for regional NRM monitoring. Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management. [https://ozcoasts.org.au/management/emf\\_frame/user-guide-nrm/](https://ozcoasts.org.au/management/emf_frame/user-guide-nrm/)
- US-EPA (2000) Evaluation guidelines for ecological indicators. <https://archive.epa.gov/emap/archive-emap/web/html/ecoin.html>
- Environmental Protection Agency (Ireland) (2001) Parameters of water quality: Interpretation and standards. [https://www.epa.ie/pubs/advice/water/quality/Water\\_Quality.pdf](https://www.epa.ie/pubs/advice/water/quality/Water_Quality.pdf)
- European Union (2014) Technical guidance on monitoring for the Marine Strategy Framework Directive. <https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/technical-guidance-monitoring-marine-strategy-framework-directive>
- Fredianelli L et al. 2021. Classification of noise sources for port area noise mapping. *Environments* 8: 12. <https://doi.org/environments8020012>
- NoMePorts. 2008. Good Practice Guide on Port Area Noise Mapping and Management. [https://www.ecoport.com/assets/files/common/publications/good\\_practice\\_guide.pdf](https://www.ecoport.com/assets/files/common/publications/good_practice_guide.pdf)
- Barentine JC. 2019. Methods for assessment and monitoring of light pollution around ecologically sensitive sites. *Journal of Imaging* 5 (5): 54. <https://doi.org/10.3390/jimaging5050054>
- Ferrario F, et al. 2022. Holistic environmental monitoring in ports as an opportunity to advance sustainable development, marine science, and social inclusiveness. *Elem Sci Anth* 10: 1. <https://doi.org/10.1525/elementa.2021.00061>

### E.16.3 Sampling and Analytical Techniques

Once monitoring parameters and media have been selected, appropriate sampling and analytical techniques must be identified. A wide range of field and laboratory methods can be applied, and these are far too numerous to discuss in this document. It is strongly recommended that an accredited analytical laboratory perform chemical analyses of marine biogeochemical parameters. Below are suggested literature sources that can give insight on the sampling and analytical technique for water, sediments and biological activity.

## Suggested reading:

- Davis BE (2005) A guide to the proper selection and use of federally approved sediment and water-quality samplers: Vicksburg, MS, U.S. Geological Survey, Open File Report 2005-1087. [https://pubs.usgs.gov/of/2005/1087/pdf/OFR\\_2005-1087.pdf](https://pubs.usgs.gov/of/2005/1087/pdf/OFR_2005-1087.pdf)
- Washington State Department of Ecology (2007) Standard operating procedure for sampling bacteria in water. [http://www.ecy.wa.gov/programs/eap/qa/docs/ECY\\_EAP-SOP\\_012SamplingBacteriaInWater.pdf](http://www.ecy.wa.gov/programs/eap/qa/docs/ECY_EAP-SOP_012SamplingBacteriaInWater.pdf)
- European Union (2014) Technical guidance on monitoring for the Marine Strategy Framework Directive <https://publications.jrc.ec.europa.eu/repository/handle/JRC88073>
- British Columbia, Canada (2019) Marine monitoring guidance (aimed mainly at marine outfall monitoring). [https://www2.gov.bc.ca/assets/gov/environment/waste-management/waste-discharge-authorization/guides/forms/2021-01-05-marine\\_monitoring\\_guidance.pdf](https://www2.gov.bc.ca/assets/gov/environment/waste-management/waste-discharge-authorization/guides/forms/2021-01-05-marine_monitoring_guidance.pdf)
- US-EPA (2001) Methods for collection, storage and manipulation of sediments for chemical and toxicological analyses: Technical manual. EPA 823-B-01-002. U.S. Environmental Protection Agency, Office of Water, Washington, DC. <https://www.epa.gov/sites/default/files/2015-09/documents/collectionmanual.pdf>

### E.16.4 Design of Sampling Programmes

The spatial boundaries of a long-term monitoring programme are informed by the demarcation port boundaries, and potentially adjacent areas that may be impacted by port activities. This will be informed by spatial planning aspect in the 'plan' component of a ports EMS (see Figure E.1) as well as the anticipated footprint of pollutant transport, dispersion and impact, based on the understanding gained

of site-specific physical, biogeochemical and biological characteristics during the baseline measurement programmes.

Placement of sampling stations is one of the most challenging aspects of designing long-term (or impact) monitoring programmes. For example, to assess change in environmental condition relative to a (spatial) reference condition some monitoring stations (so-called 'impact stations') must be situated in the immediate vicinity of the disturbance, while others ('reference or control stations') must be in areas that are beyond the influence of the disturbance. Ideally, physical, and chemical conditions at reference stations should be identical in all ways to the impact stations except for the influence of the disturbance. There are situations when locating sampling stations is much easier as they are fixed by the presence of the disturbance being monitoring and/or the location of designated beneficial use areas. For example, marine aquaculture facilities are logical sampling locations if located in areas where port activities pose potential risks to human health or the quality of farmed organisms. Practical considerations, accessibility and safety concerns also play a role in the locations of sampling stations. It is pointless identifying a sampling station location that cannot be accessed under normal conditions. Preliminarily identified locations for sampling stations should be marked on a map or an aerial photograph, but the final locations should be decided upon only after a field reconnaissance. This reconnaissance may reveal important issues that the design team was not aware of from the map or photograph, such as the inability to access a station or safety concerns posed by sampling at the station. Should such issues arise, then the stations should be re-located. Google Earth™ (<http://earth.google.com/>) is a handy tool for the preliminarily identifying the locations of sampling stations.

#### E.16.4.1 Sampling strategy

There are two main categories of sampling strategy, namely probability-based and authoritative. Probability-based sampling strategies apply sampling theory and involve the random selection of sampling units. An essential feature of a probability-based sample is that each member of the population from which the sample was selected has a known probability of inclusion. When a probability-based design is used, statistical inferences may be made about the sampled population from the data obtained from the sampling units. Authoritative sampling strategies involve the selection of sampling units based on expert knowledge or professional judgment. Authoritative sampling is not equi-probable, meaning that each member of the population from which the sample was selected does not have an equal or known probability of inclusion. Therefore, it is not possible to draw inferences about the sampled population because an authoritative bias is introduced. Thus, the validity of the data gathered is dependent on the knowledge of the sampler, and if new knowledge comes to light or previous knowledge is discredited then the validity of the data is called into question.

##### Methods of Probability based sampling:

- *Simple random sampling* – selecting particular sampling units (e.g., locations and/or times) using random numbers resulting in all possible selections of a given number of units being equally likely. Simple random sampling is most useful when the population of interest is relatively homogeneous (i.e., no major patterns of contamination or hotspots are expected). The main advantages of this design are that it provides a statistically unbiased estimate of the mean, proportions, and variability, it is easy to understand and easy to implement, and sample size calculations and data analysis are straightforward. Despite its simplicity, simple random sampling is rarely used in environmental monitoring programmes, because aquatic ecosystems are rarely homogenous, either spatially or temporally. Because every portion of the site has an equal opportunity to be selected, if contaminant hotspots constitute only a small portion of the total study area, random sampling will likely fail to detect them. Under these circumstances, random sampling will give undue weight to the less contaminated portions of the site. Random sampling may also be less efficient and, as a result, more expensive than other sampling strategies because it requires more samples to obtain the same result. It is most viable when the target population or study area is small.
- *Stratified random sampling* – separating target population into non-overlapping strata or subpopulations known (or thought to be) more homogeneous (relative to the environmental medium or the contaminant). This approach allows focusing on areas of greatest concern while retaining the benefits of a random sampling plan. One of the principal reasons for using a stratified design is to ensure a more representative

sample by distributing the sample throughout the population's spatial and/or temporal dimensions. Advantages of this sampling design are that it has potential for achieving greater precision in estimates of the mean and variance, and that it allows computation of reliable estimates for population subgroups of special interest. The main disadvantage of this design is that the design team needs to have prior knowledge of the population to effectively define the strata and allocate the sample sizes. This type of knowledge is often not available in aquatic ecosystems.

- *Systematic sampling* – collecting samples at regular intervals over space or time. An initial location or time is chosen at random, and then the remaining sampling locations are defined so that all locations are at regular intervals over an area (grid) or time (systematic). Systematic designs are good for uniform coverage, ease of use, and the intuitive notion that important features of the population being sampled will not be missed. Also, samples taken at regular intervals, such as at every node of an area defined by a grid, are useful when estimating spatial or temporal correlations or identifying a pattern. Examples of systematic grids include square, rectangular, triangular, or radial grids. In random systematic sampling, an initial sampling location (or time) is chosen at random and the remaining sampling sites are specified so that they are located according to a regular pattern. Systematic and grid sampling is used to search for hot spots and to infer means, percentiles, or other parameters and estimate spatial patterns or trends over time. This design provides a practical and easy method for designating sample locations and ensures uniform coverage of a site, unit, or process.
- *Composite sampling* – involves physically combining and homogenizing environmental samples or subsamples to form a new sample (i.e., a composite sample). The chemical or biological analyses of interest are then performed on (aliquots of) the composite sample. Because compositing physically averages the individual samples, averaging few composites' analytical results can produce an estimated mean that is as precise as one based on many more individual sample results. Compositing can be very cost effective because it reduces the number of chemical analyses needed. It is most cost effective when analysis costs are large relative to sampling costs. However, it demands that there are no safety hazards or potential biases (for example, loss of volatile organic components) associated with the compositing process. Compositing is often used in conjunction with other sampling designs when the goal is to estimate the population mean and when information on spatial or temporal variability is not needed. Perhaps the most well-known form of composite sampling in the marine environment is that used for Mussel Watch programmes. In these programmes, numerous mussels are collected from a sampling site, and the tissue is then composited and homogenised before laboratory analysis for targeted chemicals.
- *Cluster sampling* – identifying pre-defined sites and collecting several replicate samples within the site. This type of sampling is commonly used for impact monitoring programmes, especially for sampling benthic invertebrate communities since these often display considerable small-scale spatial variability. Therefore, the collection of a single sample is considered insufficient to provide an adequate understanding of the community composition and structure. Furthermore, the collection of replicate samples at each site permits the statistical comparison of data through such procedures as Analysis of Variance.

Methods of Authoritative sampling:

- *Haphazard sampling* – Samples are taken in a haphazard (not random) manner, usually at the convenience of the sampler when time permits. This is only possible with a very homogeneous condition over time and space; otherwise, biases are introduced in the measured population parameters. It is not recommended because of the difficulty in verifying the homogeneous assumption.
- *Judgmental sampling* – In this sampling, the selection of sampling units (i.e., the number and location and/or timing of collecting samples) is based on the investigators knowledge of the system or condition under investigation and on professional judgment. Judgmental sampling is distinguished from probability-based sampling in that inferences are based on professional judgment, not statistical theory. Therefore, conclusions about the target population are limited and depend entirely on professional judgment's validity and accuracy. Probabilistic statements about parameters are not possible. This type of sampling is commonly used in screening surveys, to document whether there is, or is not a problem regarding a specific issue. For example, investigators may have a good understanding of the most probable sources of a contaminant in a specific area and, based on this knowledge, may focus attention on these sources only.

#### E.16.4.2 Sampling frequency and timing

Sampling frequency (number of samples collected over a set period) largely depends on the:

- Variability in the load of contaminants from marine pollution sources
- Variability in processes driving transport and fate in the receiving environment
- Temporal sensitivity of the ecosystem to pollutant loading, i.e., exposure time versus negative impact.

Thus, to adequately define the sampling frequency, the design team must understand how the system operates and the issue that is being investigated (scientific assessment studies, baseline monitoring programmes and conceptual models previously mentioned become important once again). Expected methods and requirements of statistical analyses also influence the frequency of sample collection. For example, the objective for the monitoring programme may be to determine the frequency that a parameter exceeds a water quality guideline at a certain level of confidence. In this case the number of sampling periods can be determined using appropriate statistics.

The sampling frequency should at least resolve the main source of natural variability of the constituent under investigation. Scales of change over time differ widely in the water column (minutes - days) compared with sediments (days - seasons - decades), as noted above. Non-periodic events, such as storms, can also have a dramatic influence that needs to be considered.

Therefore, a sampling frequency that is too low relative to the underlying natural variability will result in biased data that will make it difficult to separate a human-derived impact from a natural anomaly. In the same way, sampling at a frequency that is too low relative to the variability in waste inputs may result in marked negative impacts being missed. In the water column, high frequency physical processes, such as tides, currents, wind, and waves are the primary influences on variability. In order to resolve the problem of the variability in the water column, sampling frequencies generally have to be high (e.g., hourly-daily-weekly). As a result, the use of water column measurement parameters as part of monitoring programmes is often not cost-effective, and sediment parameters are usually more pragmatic.

Sediment sampling frequency is strongly linked to the timescale within which the sediments act as 'particle traps'. As with sampling of the water column, sediment sampling at a frequency that is lower than the periodic re-suspension events will make trends difficult to interpret and could lead to spurious conclusions. Therefore, where cost constraints necessitate limitations on sampling frequencies, it will be inappropriate to select sampling locations that are situated in areas reflecting short-term variability. In such instances, longer-term depositional areas should rather be targeted. For example, because sediment processes often show strong seasonal trends, sampling is often confined to a particular season. Depositional sites can be designated as short- or long-term. A location on an open coast may be a depositional site for a period of days to weeks whereas an estuary may be a depositional site for a period of months to years. The ecological impact of both does not have to be linearly related to the persistence. Both provide important insights into the sediment and pollutant dynamics of the coastal and estuarine environments and are key to the design of optimal monitoring programmes, particularly in terms of sampling frequency.

#### Use of numerical modelling:

To overcome the inherent uncertainties of inherent spatial and temporal variability of coastal aquatic systems, long-term monitoring programmes have traditionally relied on frequent monitoring of spatially extensive sampling grids. However, with the use of numerical modelling many of the inherent problems of the traditional approach can be overcome. Numerical modelling has proven to be very useful in enhancing the design of long-term monitoring programmes and improving the interpretation of the results of monitoring. Such numerical models provide process links that enhance the ability to diagnose problem areas, as well as anticipating problems through their predictive capacity. The benefits of numerical modelling in the design of long-term monitoring programmes include:

- Definition of the most critical spatial and temporal scales of impact in the system. Important insights are provided by a combination of the synthesis of the existing understanding of the key processes and the model assumptions and inputs
- Improved interpretation and understanding of monitoring results in the context of a dynamic environment that determines the transport and fate of pollutants.

The aim, therefore, is to use the capability of numerical models to reduce uncertainties in relation to system variability, key processes, and how these influence the transport and fate of contaminants. Because this increased understanding provides greater confidence in the predicted outcomes, investment in the monitoring can be limited to only a few critical parameters measured at critical spatial and temporal scales. Although long-term monitoring programmes may, initially, still require relatively extensive spatial and intensive temporal scales to address uncertainties in a system's response, over several years these can be reduced to only a few selected points through an iterative process, as the predicted responses of the system are verified.

The use of biological media is commonly resorted to as a technique to overcome the problem of high temporal variability, particularly analysis of body tissues of filter feeders (e.g., mussels, oysters). However, it is important to realise that the body mass of these organisms also has a strong seasonal variability related to spawning cycles. Natural variability therefore needs to be separated from potential long-term signals caused by human interference. To address this issue, the following are required as a minimum:

- Samples need to be taken at appropriate intervals determined by ambient variability
- Long-term sampling needs to be performed within a narrow time-window each year to reduce seasonal uncertainty.

Lastly, beneficial uses and patterns of usage of a waterbody may determine sampling frequency. For example, one objective for monitoring bathing waters is to determine potential exposure of humans to sewage derived pathogens. If there is a strong seasonality in bathing, then it makes sense to focus most of the sampling effort during the bathing season. As previously noted, in such cases where there are potential risks to human health, near real time data are needed and peak bathing seasons might require daily sample collection.

#### Suggested reading:

- Keough MJ and Mapstone BD (1995) Protocols for designing marine ecological monitoring programs associated with BEK Mills. National Pulp Mills Research Program, Technical Report No. 11, CSIRO, Canberra. [https://www.vgls.vic.gov.au/client/en\\_AU/vgls/search/detailnonmodal/ent:\\$002f\\$002fSD\\_ILS\\$002f0\\$002fSD\\_ILS:61504/ada?qu=Mills%2C+Michael.&d=ent%3A%2F%2FSD\\_ILS%2F0%2FSD\\_ILS%3A61504%7EILS%7E0&ps=300&h=8](https://www.vgls.vic.gov.au/client/en_AU/vgls/search/detailnonmodal/ent:$002f$002fSD_ILS$002f0$002fSD_ILS:61504/ada?qu=Mills%2C+Michael.&d=ent%3A%2F%2FSD_ILS%2F0%2FSD_ILS%3A61504%7EILS%7E0&ps=300&h=8)
- Underwood AJ (1997) On beyond BACI: sampling designs that might reliably detect environmental disturbances, *Ecological Application* 4: 3-15.
- Underwood AJ (2000) Importance of experimental design in detecting and measuring stresses in marine populations. *Journal of Aquatic Ecosystem Stress and Recovery* 7: 3-24.

### E.16.5 Field Sampling and Data Analysis

The successful execution of the sampling strategy is clearly critical to the success of the monitoring programme. In essence, this requires considerable organisational and logistical skills. The correct calibration of instruments, safe deployment and use of sampling equipment, sample collection, handling and storage, field measurement and metadata collection require experienced multi-disciplinary field teams. Returning samples to laboratories within prescribed time periods, their analysis and quality control similarly involves a high level of planning and co-ordination. A skilled project manager is therefore required.

Although the data analysis step of the monitoring programme design intuitively occurs after implementation of sample collection and availability of results, statistical considerations should inform the entire sampling design process. Therefore, a large proportion of the data analysis procedures should be during the sampling design process. Of course, there are instances where this cannot be anticipated. For example, an unknown relationship between two parameters could be found to be strongly correlated, permitting correlation analysis.



There are three basic approaches for data assessment:

- Assessment over long periods of record for the purpose of determining trends and changes over time (e.g., for trend monitoring)
- Analysing the relationships between measured values for variables in the monitoring program to determine differences and the significance of the differences (e.g., for impact monitoring)
- Assessment of the extent to which measured water quality meets published guidelines, criteria or objectives (e.g., for compliance monitoring).

There are numerous ways to represent data graphically. Typical presentation formats include:

- Time series plots, which constitute a simple means to illustrate trends, cyclical variations and outliers
- Plots to illustrate spatial and temporal variability (e.g., contour plots, scatter plots, and bar graphs), for example, to show the spatial or temporal effects of pollution sources in an area
- Statistical summary of variable, for example, using box and whisker plots (e.g., ranges, mean, percentiles)
- Seasonal or periodical variations, illustrated through plots of statistical parameters (e.g., ranges, percentiles, means) of discrete monthly or seasonal data sets collected over a long period
- Correlation plots between two or more variables, illustrating relationships between these different variables.

To be useful from a management perspective, data must be presented in a clear format to provide the appropriate scientific and engineering knowledge for informed and effective decision-making. The most effective way to communicate environmental data and information is through graphical presentation of numerical and statistical data. The advantages of the graphical presentation of data are:

- Large data sets can be illustrated effectively
- Qualitative aspects, such as correlations and trends, as well as quantitative aspects such as outliers, are illustrated effectively
- Provides a user-friendly means of communicating complex numerical and statistical outputs.

#### Suggested reading:

- Helsel DR and Hirsch RM, Ryberg KR, Archfield SA and Gilroy EJ. (2020) Statistical methods in water resources: U.S. Geological Survey Techniques and Methods, book 4, chap. A3, 458 p., <https://doi.org/10.3133/tm4a3>.
- US-EPA (2006) Data Quality Assessment: Statistical Methods for Practitioners. EPA/240/B-06/003. <https://www.epa.gov/sites/default/files/2015-08/documents/g9s-final.pdf>
- Schwarz CJ (2008) Sampling, regression, experimental design and analysis for environmental scientists, biologists, and resource managers. [https://static.aminer.org/pdf/PDF/000/367/816/a\\_mu\\_lambda\\_gp\\_algorithm\\_and\\_its\\_use\\_for\\_regression.pdf](https://static.aminer.org/pdf/PDF/000/367/816/a_mu_lambda_gp_algorithm_and_its_use_for_regression.pdf)
- US-EPA (2022) Exposure Assessment Tools by Media - Water and Sediment <https://www.epa.gov/expobox/exposure-assessment-tools-media-water-and-sediment>

Environmental quality monitoring programmes lead to the generation of large amounts of data. These data are expensive to collect and require substantial investments of both human and financial resources. The sheer volume of data generated as part of ongoing monitoring programmes dictates that computer-based data management systems must provide the basis for data storage and management, that is an Environmental Information System (EIS) (ANZECC, 2000b). Therefore, it is



desirable to develop a port EIS which is accessible to all relevant staff in the organisation to inform timely and smart management responses (see Chapter E.17 for more detail).

### E.16.6 Reporting and Communication

There is little logic in conducting environmental monitoring if the information is not disseminated. The findings of monitoring programmes are usually of interest to a wide range of stakeholders, including the scientific community, policymakers, non-governmental organisations, and the public. Reporting and dissemination is therefore a key part of environmental programmes. Given the usually strong differences in the level of understanding of technical details by different target audiences, an information dissemination strategy to account for different needs must be developed as the monitoring programme matures.

The most common form of information dissemination is through the preparation of technical reports. Further information dissemination occurs through the publication of findings in peer-reviewed scientific journals, although this is targeted at the scientific community. Most stakeholders interested in monitoring programme findings do not have a scientific background. Technical reports are usually difficult for these stakeholders to understand. It is important that the needs of these stakeholders be accommodated through the preparation of non-technical (summary) reports. Another useful way of communicating with non-technical audiences is by summarising data in graphical plots and the presentation of data summaries in maps wherever possible. All these tools can also be used in public presentations, which are useful for disseminating programme findings. While printed reports were historically the dominant form of disseminating data, the internet is increasingly being used for this purpose. Various other communication routes can be utilised to communicate findings to wider stakeholder groups, such as pamphlets and media reporting.

The frequency of reporting is important. Source monitoring (referring to monitoring of composition and volumes of marine pollution sources) requires near real-time reporting (i.e., as close as possible to the time of sampling) to ensure that mitigating measures can be implemented timely. Environmental monitoring programmes require less frequent reporting, e.g., usually six-monthly or annually. In general monitoring reports should include (Figure E.22):

- A list of monitoring objectives (or hypotheses) and how these relate to the overall objectives of the EMS
- Details of the design and implementation of the monitoring programme (also indicating the relationship between selected measurement parameters and monitoring objectives)
- An evaluation of the monitoring data in relation to the monitoring objectives (or hypotheses). This evaluation should make use of data summaries and graphical presentations to enhance readability
- A statement on whether the monitoring objectives have been met
- In the event of non-compliance, possible reasons for the non-compliance
- Management strategies and actions required to address non-compliance
- Recommendations on refinements to the monitoring programme
- Appendices containing cruise and laboratory reports, raw data tables and other relevant background information.

#### Artificial intelligence in port monitoring and prediction - ISMAEL

The ISMAEL Platform is an innovative monitoring and decision support system developed for the Port of Bari (Italy in collaboration with the DBA Group (<https://sustainableworldports.org/project/port-of-bari-artificial-intelligence-for-environmental-monitoring-and-prediction/>)). The platform monitors environmental pollutant generated by traffic within port and evaluates the impact on port, as well as surrounding urban areas. The

platform collects environmental data, weather condition data and traffic data through a network of sensors which is transmitted and aggregated in a central system. Information is presented in a user-friendly tool for prompt decision making. Its goal is to simulate environmental conditions to predict potential impacts of port activities on environmental quality due to, for example, arrival and departure of cargo and passenger vessels (DBA Group 2019).

Table E.22: Example: Template for Monitoring Report

#### Chapter 1: Introduction

- 1.1 Background
- 1.2 Reason for Monitoring Programme

#### Chapter 2: Study Area and Specific EMS Objectives

- 2.1 Brief description of port environment (map)
- 2.2 Specific environmental objective and targets applicable to port area and surrounds
- 2.3 Specific activities and operations to be considered in investigation
- 2.4 Environmental standards applicable to activities and operations

#### Chapter 3: Design of Monitoring Programme

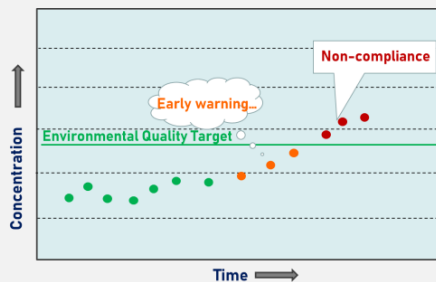
- 3.1 Selection monitoring parameters (motivation and frequency of sampling)
- 3.2 Location of sampling stations
- 3.3 Frequency of sampling

#### Chapter 4: Description of Sampling, Analytical and Data Analysis Procedures

- 4.1 Sampling and *in situ* measurements
- 4.2 Laboratory analysis procedures
- 4.3 Data analysis methodology

#### Chapter 5: Results and Discussion

Present results from monitoring programme and interpret in relation to required environmental objectives/targets/standards, e.g.:



#### Chapter 6: Key Findings

Summarise key findings from results and discussion, e.g., compliance/non-compliance, trends, etc.

#### Chapter 7: Recommendations

- 7.1 Identify management strategies and actions to address non-compliance
- 7.2 Identify refinement to monitoring programme (if relevant)

Appendices: Field and laboratory reports, raw data tables and other relevant background information considered relevant

## E.17 Environmental Information Systems

An Environmental Information System (EIS) can be viewed as a system for systematically collating and processing environmental data and making available relevant environmental information for decision-making on changes in ecosystem health and services, and potential impacts on people's livelihoods (El-Gayar and Fritz 2006). It is an integral component of an Environmental Management System (EMS) (see Chapter E.1), managing the data and information necessary for effective environmental planning and actions. While traditionally EIS focused on addressing regulatory requirements, its value in informing and supporting environmental sustainability, by using innovative information technologies and processes, is growing fast (Melville 2010). For example, smartphone technology holds major innovation for easy access and processing information (Pitt et al. 2011).

Sustainable development has become an important public policy goal throughout the world. Society is taking a greater interest in environmental matters and governments increasingly establishing environmental policies control and manage resource use (Günter 1998). Therefore, companies are increasingly pressurised to take accountability for and be able to report on potential environmental impacts of their activities, or otherwise. Evident is the vital importance of the collection and analysis environmental data (Coman and Cuorita 2013):

- Relying on science and technology to detect, avoid or limit threats to the environment and to solve environmental problems for the good of society
- Encouraging countries, especially developing countries, to engage in scientific and technical activities, and to allow international free movement of latest information aimed at solving environmental problems
- Providing factual environmental education, taking due account of the less fortunate to create a sense of local responsibilities and empowerment regarding safeguarding and improving the environment.

There are many parallels between EIS and traditional business information system. However, environmental data poses some unique challenges that must be considered in the development of such systems (Günter 1998). These include:

- Amount of data is unusually large, especially satellite imagery, challenging data storage capabilities
- Data is widely distributed sometimes being captured, processed and stored by a broad range of agencies institutions
- Data systems can be extremely heterogenous, both in terms of hardware and software platforms, organised for application in a wide range of data models, depending on the primary purpose of individual institutions
- Environmental data frequently have a complex internal structure, including different meta-data and associated images
- Environmental data are often spatio-temporal, i.e., they have a location and a spatial extension, that changes over time
- Environmental data is frequently uncertain where statistical or artificial intelligence techniques must be applied to manage such uncertainty
- Because environmental issues are cross-sectoral, processing of user queries may be complex – data often must be used for purposes that are very different from its original intended use.

The construct of an information system, including EIS, typically comprises six components (Bourgeois 2019), as is illustrated in Figure E.19:

- Hardware resources in a computer-based EIS refer to the physical devices and materials used to create content and manage and communicate information, including computers, scanners, and data media.
- Software constitutes all the sets of instructions that are required for processing data into information. Software programmes typically accept input in the form of data, process that into information, and provides output useful to the intended end users.
- Data comprises the raw facts and figures that are unorganized and later processed to generate information. Data can take numerous forms, for example alphanumeric, text, image and audio data.
- People are the indispensable component for the operation of an EIS, including the information specialists (e.g., systems analysts, programmers, technicians, engineers, network managers, IS manager, data entry operators, and computer operators) as well as the end-users (e.g., customers, managers, engineers, accountants, salespersons, or clerks). For instance, the system analysts design the information systems based on the information needs of the end users. In the design of an EIS needs of these end-users probably constitute the most critical consideration.
- Process and procedures are the policies, rules, and guidelines that govern the operation of EIS, including access control. Information systems are becoming more integrated with organizational processes, bringing greater productivity and better control to those processes. Therefore businesses hoping to gain a competitive advantage over their competitors are usually highly focused on this component of information systems.
- Networking communication refer to the way computers and other technologies within an EIS system communicate with one another, through various means including simple cables, phones, satellites, fibre, and Wi-Fi. While this component may not always be required for every information system, networks are becoming vital in today's virtually connected society.

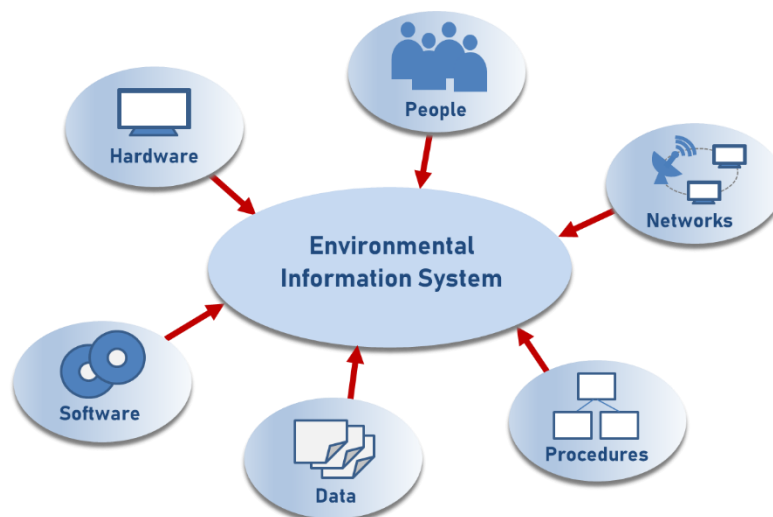


Figure E.19 Key components of an (environmental) information system

EIS use a variety of software technologies to facilitate the interpretation of environment-related information to inform decision making. These can include (Baholli et al. 2013):

- Computer simulation models
- Relational databases
- Expert systems
- Geographical Information Systems
- Decision support systems.

Such software technologies typically have specific data format requirements, and it is imperative that these requirements are understood prior to designing the EIS to avoid unnecessary and time-consuming data conversion. Although detailed specifications for EIS will be site-specific, it is important to consider the following factors in the selection of hardware framework and software packages:

- Physical capability of handling the data load and the implications of expansion
- Ability to transfer data to other data storage systems
- Compatibility of the data storage with facility available data sources
- Choice of software (commercial or developed) about:
  - Expansion and support
  - Delivery of suitable outputs
  - Robustness regarding changing data formats
  - Data transfer capabilities between different platforms (e.g., Desktop PC, Server, Webserver, Palm devices, smart phones, and sampling/analysis equipment).

Further, the selection of an EIS needs to consider the existing port organisational infrastructure supporting environmental management and the chosen system must interoperate with existing systems. Compatibility to existing systems, as well as specific end-user needs will then determine whether an off-the-shelf EIS could be acquired, or whether it should be custom built.

## E.18 Effective Capacity Development

“Capacity development” is understood as the process whereby people, organisations and society unleash, strengthen, create, adapt, and maintain capacity over time. The phrase capacity development is used advisedly in preference to the traditional capacity building. The “building” metaphor suggests a process starting with a plain surface and involving the step-by-step erection of a new structure, based on a preconceived design. Experience suggests that capacity is not successfully enhanced in this way.’ (OECD 2008).

Useful guidance on aspects to consider for effective capacity development is provided in:

- Challenge of Capacity Development: Working Towards Good Practice OECD 2008)
- Agenda 2063 (African Union 2015)
- Agenda 2063 - Capacity Development Plan Framework (African Union 2016)
- Guidelines on Human Capacity Building in Ports (EC 2019).

A brief overview of key considerations is provided here.

Capacity development is viewed as critical in achieving *Agenda 2063: The Africa we Want* (African Union 2015). Specifically, the *Capacity Development Strategic Framework* provides a holistic approach to capacity development that also hold relevance for port capacity building approaches. Within this holistic approach six underpinning principles are vital for effective capacity development in Africa: (i) transformative leadership, (ii) citizen transformation (iii) evidence-based knowledge and innovation, (iv) using African potential skills and resources, (v) capacity of the capacity developer, and (vi) integrated planning and implementation for results (African Union 2016) (Figure E.20).

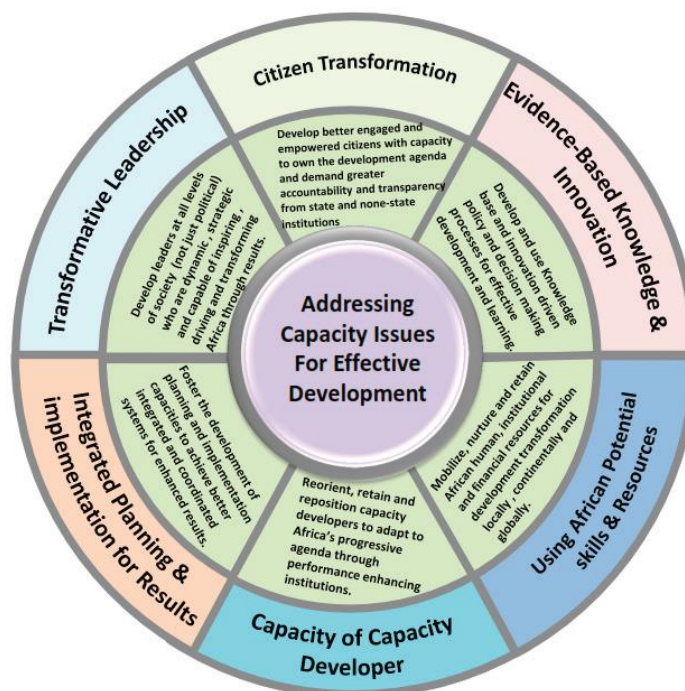


Figure E.20 Key principles underpinning effective capacity development in Africa (source: AU 2015)

Traditionally capacity development was viewed mainly as a technical process, involving the simple transfer of knowledge, and not enough emphasis was given to broader political and social contexts within which capacity development occurs – capacity development approaches are ‘similar for all’, as opposed to considering those best fit to country’s circumstances and needs. Therefore, effective

capacity development does not only entail the enhancement of the *individual's* knowledge and skills, but depends crucially on qualities of the *organisation*, and in turn, the organisation's *enabling environment* (e.g., structures of power and influence, and institutions). It is not only about skills and procedures, but also incentives and governance (OECD 2008; African Union 2016). Also critically important is a country's ownership of capacity development initiatives. The consensus, as articulated by the 2005 Paris Declaration on aid effectiveness views capacity development as a necessarily endogenous process, strongly led from within a country, with donors playing a supporting role (OECD 2008).

Capacity Development Programmes typically comprise four stages (Figure E.21) (OECD 2008; Thapa et al. 2019; Bob-Manuel 2020):

- **Assessment** – during this stage skills gaps are identified within the context of a company's goals, priorities, and needs. This is critical to give purpose and direction to capacity development programmes. Training standards are identified and appropriate institutions that could be used in the training programmes are identified
- **Planning and design** – To inform the curriculum and design of training material, expected outcomes need to be agreed upon. Thereafter funding for needs to be secured timeously to ensure successful execution
- **Implementation** – during this stage participants to be included need to be identified for example management and decision-making staff, technical professional, or train and awareness earmarking youth
- **Evaluation and Review** – this stage is an important part of any capacity development programme where performance is monitored against training standards and expected outcomes, providing a means for improving such programmes in future.

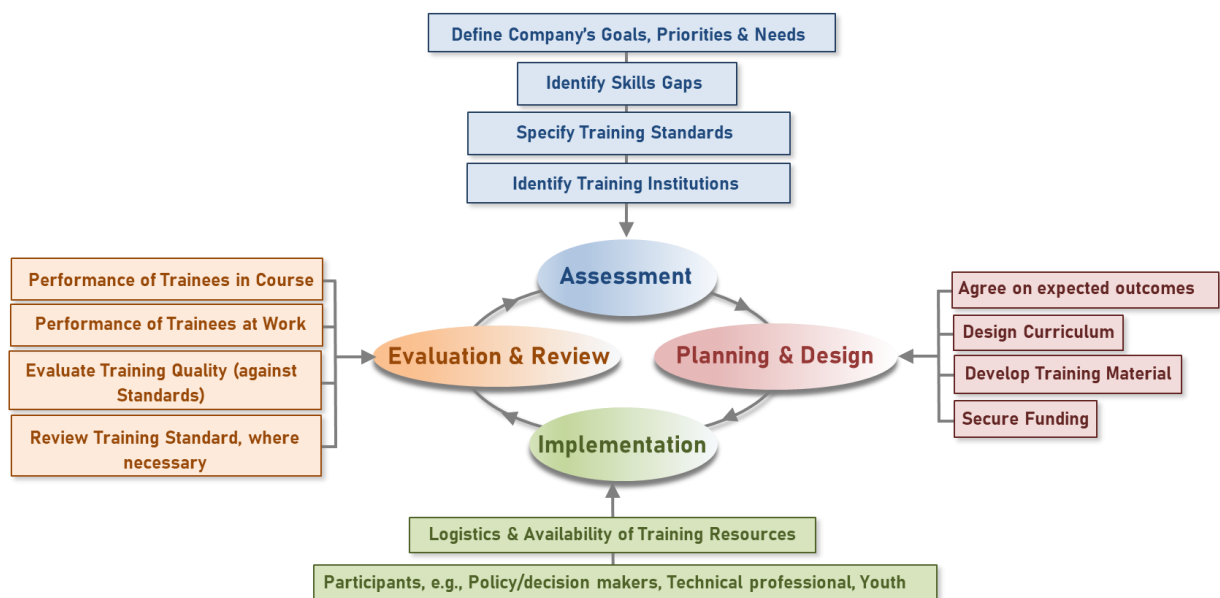


Figure E.21 Four key stages of capacity building programmes (adapted from: Thapa et al. 2019; Bob-Manuel 2020)

While capacity development in the port sector typically focuses on technical and managerial skills development, there has been a growing acknowledgement by this industry that port performance is also enhanced by appropriately motivated staff (EU 2019). Further, to encourage diversity in



preparation for ports as future sustainable economic hubs, the following emerged as important considerations in capacity development programmes:

- Create general awareness on ports as workplace
- Promote ports as attractive workplace for young people, e.g., at schools and tertiary education institutions
- Promote ports as attractive workplace for women
- Life-long learning to continuously provide up-to-date training to current employees, ensuring equal learning and labour opportunities for them (i.e., not only focusing on 'new' employees).

## E.19 Introduction to National Capital Accounting

Rapid degradation of coastal ecosystems has sparked interest in developing information systems to evaluate and report change in value of these systems to society (Eden and Hein 2013; Hein et al. 2015, Farrell et al. 2021). This led to the development of the concept of natural capital or ecosystem accounting, a systematic approach that incorporates measures of ecosystem services and assets into an accounting structure. Indeed, Agenda 2063 sets the development of national accounting systems for the valuation of oceanic natural (blue) capital as an indicative strategy under Aspiration 1: *A prosperous Africa, based on inclusive growth and sustainable development* (African Union 2015).

It is important to stress that using the concept of natural 'capital' to highlight the economic value of nature does not preclude nature's other important values, such as cultural and spiritual values as well as a natural heritage perspective and the intrinsic value of nature beyond what humans need. Rather, it provides additional understanding of how economic and social outcomes are dependent on natural capital (Ruijs and Vardon 2018). Within this context Taljaard et al. (2021) adapted a port inframodel proposed by Taneja et al. (2012) to contextualise the natural environment within port systems as natural infrastructure (or natural capital), an asset to be accounted for along with services or physical infrastructure (Figure A.3).

### E.19.1 International Approaches

#### E.19.1.1 System of Environmental-Economic Accounting

One of the emerging assessment tools to account for natural capital and its multi-use benefits is the UN's System for Environmental-Economic Accounting (SEEA). The primary aim of SEEA is to gather and organise environmental information consistently and enable its integration with socio-economic information, such as System of National Accounts (SNA) (e.g., Chenoweth et al. 2018; UN 2014a and 2014b; UN 2019). The SEEA comprises three main documents:

- SEEA Central Framework (SEEA-CF)
- SEEA Ecosystem Accounting (SEEA-EEA)
- Natural Capital Protocol.

The SEEA Central Framework (SEEA-CF) (UN 2014a) provides a multipurpose, conceptual tool to relate the interactions between the economy and the environment, identifying stocks and flows of individual environmental assets, where such assets are defined as *"the naturally occurring living and non-living components of the Earth, together constituting the biophysical environment, which may provide benefits to humanity"*. The SEEA-CF classifies environmental assets into a range of resource types as illustrated in Table E.23.

Table E.23: SEEA Central Framework: Classification of environmental assets (Source: UN 2014a)

|                              |                                |
|------------------------------|--------------------------------|
| Mineral and energy resources | Oil resources                  |
|                              | Natural gas resources          |
|                              | Coal and peat resources        |
|                              | Non-metallic mineral resources |
|                              | Metallic mineral resources     |
| Land                         | Soil resources                 |
| Timber resources             | Cultivated timber resources    |
|                              | Natural timber resources       |
| Aquatic resources            | Cultivated aquatic resources   |
|                              | Natural aquatic resources      |
| Other biological resources   | Excluding timber and aquatic   |
| Water resources              | Surface water                  |
|                              | Ground water                   |

## Soil water

The specific focus of the SEEA-CF is the material benefits from the direct use of environmental assets as natural inputs for the economy, and it does not consider the non-material benefits from the indirect use of environmental assets (e.g., water purification, storage of carbon and flood mitigation). Another clarification is that coverage of individual environmental assets typically does not extend to the individual elements that are embodied in the various natural and biological resources (e.g., nutrients in soil resources) (UN 2014a).

The SEEA Ecosystem Accounting (UN 2014b, 2019) poses a second perspective that encompasses the same environmental assets but focuses on the interactions between individual environmental assets within ecosystems, and the material and non-material economic and social benefits that flow from ecosystem services. In this context, an ecosystem is defined as *“a dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit”*. This focus on ecosystems, including both material and non-material benefits of environmental assets, provides a means of analysing the extent to which economic and other human activities may reduce an ecosystem’s capacity to generate ecosystem services.

Ecosystem services are the contributions of ecosystems (i.e., combined capacity of both abiotic and biotic components within the ecosystem) to benefits derived through economic and other human activity. Such ecosystem services are typically sub-divided into four groups, namely provisioning, regulating and cultural services. In general, provisioning services relate to the material benefits of environmental assets, whereas the other types of services relate to the non-material benefits of environmental assets (UN 2014a).

The way ecosystem accounts are presented mimics the internationally accepted accounting concepts in terms of gathering and organising information in a consistent manner that enables integration with socio-economic information in the System of National Accounts (SNA). The SEEA EEA comprises of five core ecosystem accounts (UN 2019) (Figure E.22):

1. Ecosystem extent account (physical terms) – providing information on the extent (typically expressed as area coverage) of specific ecosystem assets in an opening stock and closing stock, identifying specific ‘gains/losses’ over a given period.
2. Ecosystem condition account (physical terms) – providing information on the health condition of specific ecosystem assets (e.g., good, fair or poor), and changes over a given period. This is important as the condition of an ecosystem asset component may affect its ability to provide ecosystem services flows, or alternatively the monetary value of a service. For example, the same area of mangroves may be less effective in its ability to sequester carbon, depending on the health condition of the plants.
3. Ecosystem services supply and use account (physical terms)
4. Ecosystem services supply and use account (monetary terms)
5. Ecosystem monetary asset account (monetary terms).

The ecosystem service flow accounts (3 and 4 above) express the ‘amount’ of a service that can be delivered by specific environmental components/s, depending on both the extent and condition of the component/s. These accounts require information on ecosystem delivery capacity, e.g., *Carbon sequestration (C t/a) = Mangrove (ha) \* f (dependent on condition)*. Finally, ecosystem benefit accounts (5 above) translate the ‘amount’ of ecosystem service flows into a monetary value (if relevant), e.g., *Monetary value (R 000’K) = Carbon sequestration (C t/a) \* Unit market value*.

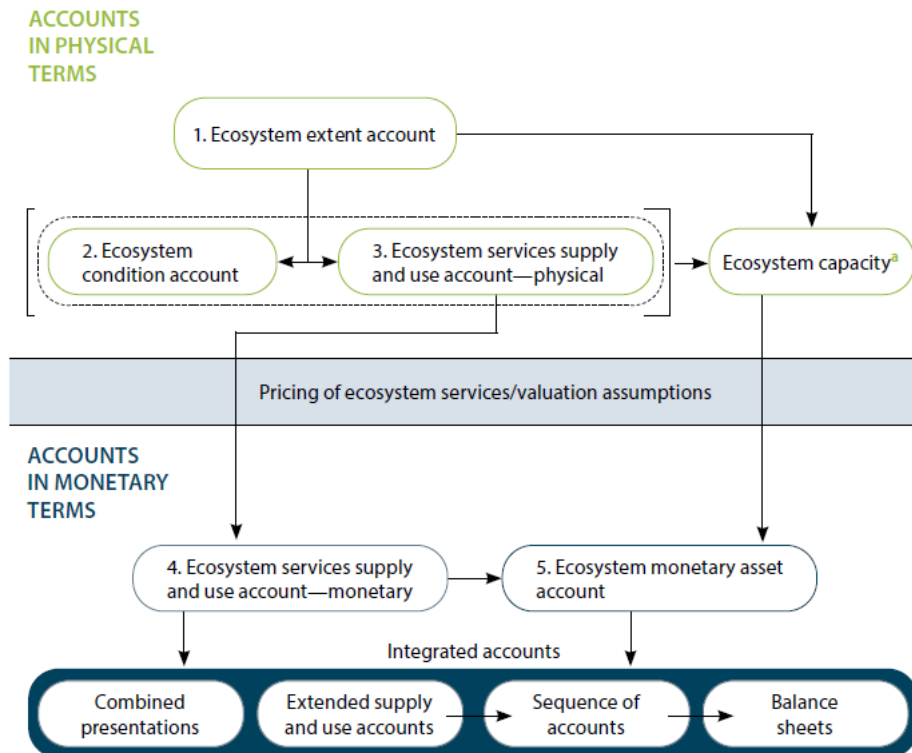


Figure E.22 Schematic of key ecosystem accounts and their relation (Source: UN 2019)

#### Africa Natural Capital Accounting Community of Practice

The Africa Natural Capital Accounting Community of Practice (<https://naturalcapitalcoalition.org/a-natural-capital-accounting-community-of-practice-for-africa-launched/>) aims to build momentum and mainstream natural capital accounting in statistical production and policy across Africa through capacity building and knowledge sharing between government institutions, non-governmental organizations and academia. This is an essential next step in unifying stakeholders around a shared ambition and in driving tangible commitments and actions to accelerate the uptake of the natural capital approach.

An Oceans Accounts Working Group (<https://www.oceanaccounts.org/africa-community-of-practice/>) was established with the aim of assessing and discussing the use of information on oceans and ocean resource-uses in the advancement of ocean governance in African coastal countries. Particularly important is sustainability and inclusivity of ocean goods and service benefits, impacts on ocean assets arising from production or consumption of ocean goods and services and the estimation of the contribution of oceans to the welfare of coastal nations, and not only the ocean's contribution to GDP.

#### E.19.1.2 Global Ocean Accounts Partnership

The Global Ocean Accounts Partnership (GOAP) has been collaborating with the UN Statistics Division on the System for Environmental Economic Accounting (SEEA) Ecosystems. Through the SEEA Ecosystems Technical Committee on spatial units, ecosystem condition, ecosystem services and valuation, GOAP has sought to align the Technical Guidance on Ocean Accounting to ensure that the values and benefits of oceans are recognized and accounted for in social and economic development decisions, aligned with the UN's Sustainability Development Goals (SDGs).

GOAP defines accounting as “...the standardization of data, including maps, so that data collected using different standards [concepts, classifications and methods] can be combined to tell a broader story—often the kind of story that is required to monitor progress towards policy objectives” (GOAP 2019).

To provide an overarching structure, GOAP proposes a simple framework for ocean accounting (Figure E.23) comprising five key components:

- Pressures (or flows to the ocean), that account for external flows or inputs potentially affecting ocean assets
- Ocean assets, accounting for the extent and conditions
- Ocean services, accounting for ecosystems services (supply and use) considering both abiotic and biotic assets
- Ocean economy, accounting for the economic value of ocean ecosystems services
- Governance, accounting for efforts in terms of technologies and costs linked to the management of ocean assets.

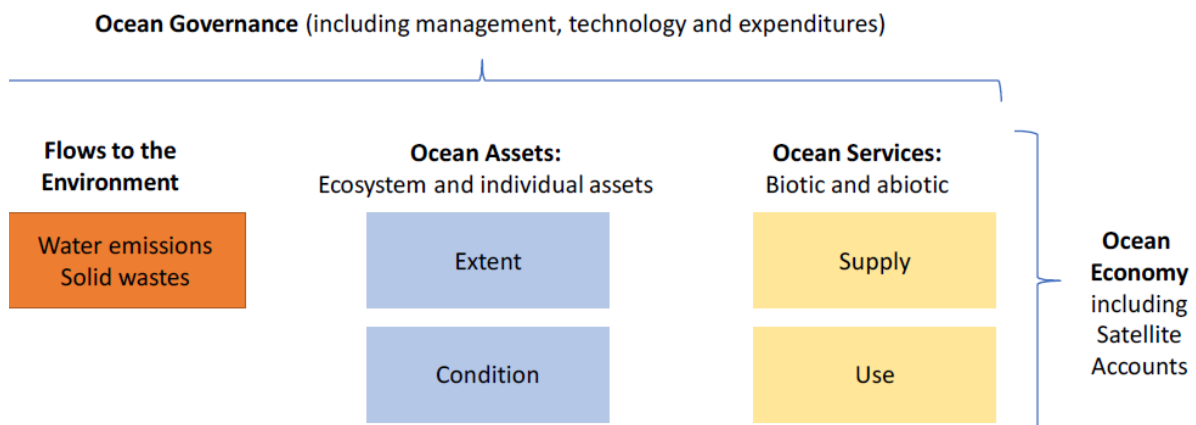


Figure E.23 Simple framework for Ocean Accounting (source: GOAP 2019)

Of note is that the Ocean Accounts Framework defines ‘value’ in a broad sense, recognising that not all values of ocean assets can easily be expressed in monetary terms. Examples of such values are the ocean’s contribution to climate stability, species diversity and cultural heritage. In designing ocean accounts, the Basic Spatial Unit (BSU) is typically implemented as an “operational” concept, providing a common reference or basis for organising accounts (GOAP 2019; Chen et al. 2020). The resolution of available data may determine the homogeneity within BSUs. For example, a BSU can be small enough to represent a particular ecosystem asset (EA) (e.g., mangroves) or at a larger scale it can comprise several EAs. The general concept of individual environmental assets (SEEA-CF - UN 2014a) and the ecosystem assets (SEEA-EEA UN 2014b, 2019) can also be applied to asset classification for ocean accounting.

Important to note is that there could be an overlap between individual environmental assets and ecosystem assets, e.g., seagrass beds include biotic resources (fish and crustaceans) living within. Such overlap is not an issue for the physical accounts because the ecosystem asset (seagrass bed) is represented in area cover (e.g., ha), while the biotic resource (e.g., fish) is represented as weight (e.g., tonnes). However, caution is required for monetary accounts, as the value of a hectare of seagrass bed most likely includes the value of the biotic resources living within. It is therefore important to understand the links between ecosystem assets and individual assets when preparing monetary accounts to avoid double counting (GOAP 2019).

### E.19.2 Application of Natural Capital Accounting in Ports

Various examples of the application of natural capital or ecosystem accounting in coastal and marine systems are emerging. For example, Wang et al. (2018) proposed a framework of marine ecosystem asset accounting, Schenau et al. (2019) applied accounting to the Dutch North Sea, Van Niekerk et al (2020) demonstrated its application for South African estuaries and Chen et al. (2020) explored the potential of ecosystem accounting to support marine and coastal governance. In 2021, the UK’s Office

of National Statistics published its Marine Accounts. Port Phillip Bay, a large embayment in Australia provides an example of a natural capital account at the local scale (Eigenraam et al. 2016), a case study at similar spatial scale as would apply in port environments.

Examples of natural capital accounting in ports could not be sourced for this review, but learning from natural capital accounts for the coastal and marine environment can be used to propose a prototype approach for port environments, as provided below. This approach will need to be customised and refined through specific case studies.

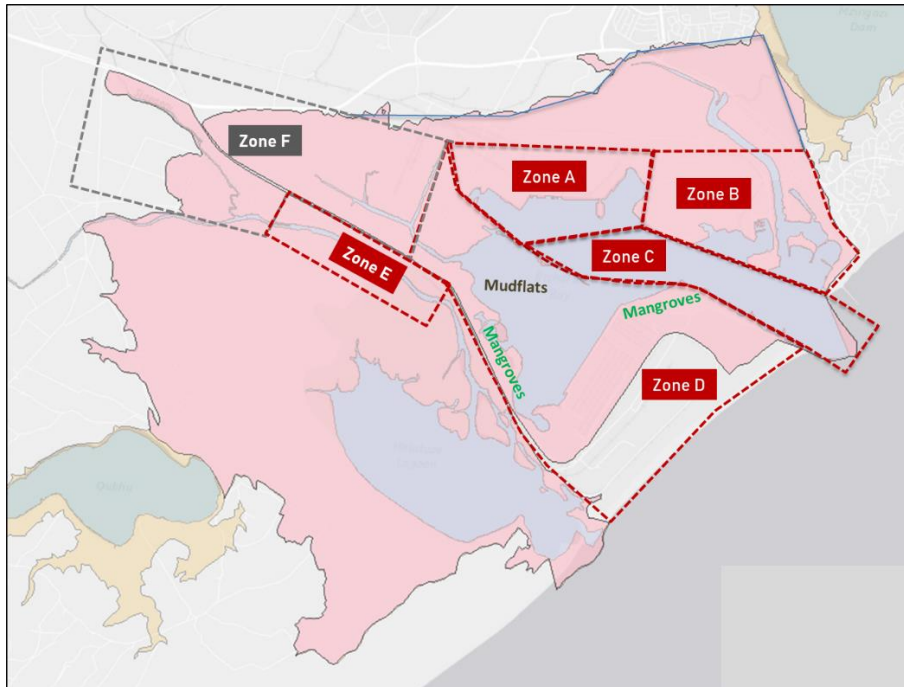


Figure E.24 Conceptualisation of basic spatial unit zonation in a port providing spatial resolution to ecosystem asset accounts

Adopting the basic spatial unit (BSU) as a means of organising delineation spatial units, Figure E.24 illustrates the concept (here we use the Port of Richards Bay, South Africa as a template port). Typical ecosystem assets considered within the boundaries of ports include open water area, mudflats, sand banks, mangroves, seagrass beds, coastal forests, and dunes. A proposed construct for ecosystem extent and condition accounts for ports are illustrated in Table E.23.

Table E.24: Proposed construction of ecosystem asset extent and condition accounts for ports (populated with hypothetical data sets as illustration)

|                                  | ECOSYSTEM ASSET EXTENT ACCOUNT (in ha) |        |        |        |        |        |
|----------------------------------|--|--------|--------|--------|--------|--------|
|                                  | Total                                  | Zone A | Zone B | Zone C | Zone D | Zone E |
| <b>Opening stock (Baseline):</b> |  |        |        |        |        |        |
| Open water area                  | 17 000                                 | 100    | 400    | 500    | 300    | 400    |
| Mudflats                         | 14 000                                 | 400    | 200    | 200    | 200    | 400    |
| Sand banks                       | 10 000                                 | 100    | 400    | 100    | 100    | 300    |
| Dunes                            | 10                                     | -      | -      | -      | 10     | -      |
| Mangroves                        | 1 700                                  | 10     | 40     | 50     | 30     | 40     |
| Seagrass beds                    | 10                                     | -      | -      | -      | 10     | -      |
| <b>Increase/Decrease:</b>        |  |        |        |        |        |        |
| Open water area                  | 0                                      | -      | -      | -      | -      | -      |
| Mudflats                         | 0                                      | -      | -      | -      | -      | -      |
| Sand banks                       | 0                                      | -      | -      | -      | -      | -      |
| Dunes                            | +10                                    | -      | -      | -      | +10    | -      |
| Mangroves                        | -20                                    | -      | -20    | -      | -      | -      |
| Coastal Forests                  | 0                                      | -      | -      | -      | -      | -      |
| <b>Closing stock (Year n):</b>   |  |        |        |        |        |        |
| Open water area                  | 17 000                                 | 100    | 400    | 500    | 300    | 400    |
| Mudflats                         | 14 000                                 | 400    | 200    | 200    | 200    | 400    |

|                 |        |     |     |     |     |     |
|-----------------|--------|-----|-----|-----|-----|-----|
| Sand banks      | 10 000 | 100 | 400 | 100 | 100 | 300 |
| Dunes           | 20     | -   | -   | -   | 20  | -   |
| Mangroves       | 1 500  | 10  | 20  | 50  | 30  | 40  |
| Coastal Forests | 10     | -   | -   | -   | 10  | -   |

| ECOSYSTEM ASSET CONDITION ACCOUNT (rating, e.g., Good-Fair-Poor) |         |        |        |        |        |        |
|--|---------|--------|--------|--------|--------|--------|
|  | Average | Zone A | Zone B | Zone C | Zone D | Zone E |
| <b>Opening stock (Baseline):</b>                                 |         |        |        |        |        |        |
| Open water area  | F       | G      | G      | F      | F      | F      |
| Mudflats   | P       | F      | F      | P      | P      | P      |
| Sand banks   | P/F     | F      | F      | G      | P      | P      |
| Dunes  | F       | -      | -      | -      | F      | -      |
| Mangroves  | F       | G      | G      | P      | F      | F      |
| Coastal Forests  | G       | -      | -      | -      | G      | -      |
| <b>Increase/Decrease:</b>  |         |        |        |        |        |        |
| Open water area  | -       | -      | -      | -      | -      | -      |
| Mudflats   | ↑       | ↑      | -      | -      | -      | -      |
| Sand banks   | ↓       | -      | -      | ↓      | -      | -      |
| Dunes  | -       | -      | -      | -      | =      | -      |
| Mangroves  | ↓       | -      | -      | -      | ↓      | -      |
| Coastal Forests  | -       | -      | -      | -      | -      | -      |
| <b>Closing stock (Year n):</b>                                   |         |        |        |        |        |        |
| Open water area  | F       | G      | G      | F      | F      | F      |
| Mudflats   | P       | G      | F      | P      | P      | P      |
| Sand banks   | F       | F      | F      | F      | P      | P      |
| Dunes  | F       | -      | -      | -      | F      | -      |
| Mangroves  | F       | G      | F      | P      | P      | F      |
| Coastal Forests  | G       | -      | -      | -      | G      | -      |

In the case of ports, potential ecosystem services and associated benefits are listed in Table E.25, while an example of ecosystem accounting is provided in Table E.26.

Table E.25: Proposed ecosystem services for inclusion in port accounts

| TYPE                  | ECOSYSTEM SERVICE                          | BENEFIT                    |
|-----------------------|--|----------------------------|
| Provisioning services | Fish                                       | Subsistence food provision |
|                       | Bait (e.g., prawns)                        | Recreational fishing       |
|                       | Sheltered environments                     | Coastal infrastructure     |
| Supporting services   | Nursery                                    | Commercial fisheries       |
| Regulating services   | Attenuation of high waves and storm surges | Coastal protection         |
|                       | Attenuation of river floods                | Prevention of flood damage |
|                       | Carbon sequestration                       | Healthy climate            |
| Cultural services     | Recreational places & seascapes            | Recreation & Tourism       |

Table E.26: Example: Proposed ecosystem services accounts for ports

| ECOSYSTEM SERVICES ACCOUNT                 |              |               |
|--|--------------|---------------|
|  | Physical (#) | Monetary (\$) |
| <b>FISH (SUBSISTENCE &amp; RECREATION)</b> |              |               |
| Opening stock (Baseline):                  | 300          | 14 000        |
| Delivery from Ecosystem asset 1 (tons/a)   | 200          | 7 000         |
| Delivery from Ecosystem asset 2 (tons/a)   | 100          | 7 000         |
| <b>Increase/Decrease:</b>                  |              |               |
| Ecosystem asset 1                          | -100         | -2 000        |
| Ecosystem asset 2                          | -            | -             |
| Closing stock (Year n):                    | 200          | 124 000       |
| Delivery from Ecosystem asset 1 (tons/a)   | 100          | 5 000         |
| Delivery from Ecosystem asset 2 (ton/as)   | 100          | 7 000         |
| <b>NURSERY (COMMERCIAL FISHERIES)</b>      |              |               |
| Opening stock (Baseline):                  | 300          | 14 000        |
| Delivery from Ecosystem asset 1 (tons/a)   | 200          | 7 000         |
| Delivery from Ecosystem asset 2 (tons/a)   | 100          | 7 000         |
| <b>Increase/Decrease:</b>                  |              |               |
| Ecosystem asset 1                          | -100         | -2 000        |
| Ecosystem asset 2                          | -            | -             |
| Closing stock (Year n):                    | 200          | 124 000       |
| Delivery from Ecosystem asset 1 (tons/a)   | 100          | 5 000         |
| Delivery from Ecosystem asset 2 (tons/a)   | 100          | 7 000         |
| <b>CARBON SEQUESTRATION</b>                |              |               |
| Opening stock (Baseline):                  | 300          | 14 000        |
| Mangroves (Mt C)                           | 200          | 7 000         |
| Coastal forests (Mt C)                     | 100          | 7 000         |
| <b>Increase/Decrease:</b>                  |              |               |
| Mangroves                                  | -100         | -2 000        |
| Coastal forests                            | -            | -             |
| Closing stock (Year n):                    | 200          | 124 000       |
| Mangroves (Mt C)                           | 100          | 5 000         |



Coastal forests (Mt C)

100

7 000

A variety of methods are applied in the economic valuation of ecosystem services provided by natural capital as illustrated in Table E.27.

Table E.27: Examples of economic valuation methods for coastal ecosystem service (Source: WRI 2014)

|                  | METHOD                 | DESCRIPTION   | RELEVANT APPLICATION  | LIMITATION   |
|------------------|------------------------|---|---|--|
| Market-based     | Market price           | Observed market prices of economic activity generated by use of ecosystem   | Services traded in market (e.g., fisheries, tourism, mangrove timber)   | Can be distorted (e.g., subsidies) or overestimated if current use is above sustainable levels, and many are not traded in markets |
|                  | Replacement cost       | Estimate cost of replacing ecosystem service with man-made service  | Services that have man-made equivalent providing similar benefit (e.g., shoreline protection by reefs & mangroves) or water filtration by wetlands) | May not reflect true value of service or inaccurately suggest that man-made is appropriate substitute                              |
|                  | Cost of avoided damage | Estimate damage avoided due to service  | Services providing protection to houses, infrastructure (e.g., protection by reefs & mangroves)   | Difficult to relate damage levels to ecosystem quality   |
|                  | Production function    | Estimate value of service as input in production of marketed good   | Services that provide an input in the production of a marketed good (e.g., commercial fisheries)  | High data requirements   |
| Non-market based | Hedonic pricing        | Influence of environmental characteristics on price of marketed goods   | Characteristics influencing real estate prices (e.g., house prices)   | High data requirements   |
|                  | Travel cost            | Travel costs to access a resource reflect value   | Recreation sites (e.g., MPAs)   | High data requirements   |
|                  | Contingent valuation   | Respondents' direct willingness to pay  | Any service (mostly used for non-market services)   | Expensive, vulnerable to bias requiring careful survey design  |
|                  | Choice modelling       | Respondents' trade off to services (indicative of willingness to pay)   | Any service (mostly used for non-market services)   | Expensive, vulnerable to bias requiring careful survey design  |
| Benefit transfer | Benefits transfer      | Estimating value from other locations (value transfer)<br>Estimating value function from another location to predict values (function transfer) | Any service   | Possible inconsistencies   |
|                  | Meta-analysis          | Using statistical regression of multiple valuation studies to estimate value  | Any service   | Loss of important valuation information during due to aggregation  |

## E.20 Sustainability Performance Index for Ports

### E.20.1 Rationale

As trade facilitators, ports are crucial to the global economic system. They have experienced rapid growth over the past decades. However, with this growth has come increased physical alteration and destruction of coastal habitat and pollution, affecting both the environment and society (e.g., Riekhof et al. 2019). As public awareness and regulatory pressures have increased, port authorities around the world are compelled to pursue the 'greening' of their port activities (Lam & Van der Voorde 2012; Roh et al. 2016). Port systems can no longer operate without acknowledging and including societal and environmental considerations in their planning and management to safeguard their 'license to operate' (Kaliszewski, 2018). Climate change impacts have also motivated the need for greater climate resilience in port planning and development (Stein & Acciaro 2020).

These challenges stimulated the emergence of concept of 'Green Ports' aimed at balancing environmental challenges and economic demand and striving to establish sustainable ports by increasing both economic and environmental competitiveness, with obvious links to the concept of the Green Economy (Bergqvist & Monios 2019; Lam & Notteboom 2014; Maritz et al. 2014). The concept of 'Sustainable Port Development' builds on that of 'Green Ports' by including social sustainability, advocating the need for port development to balance economic growth, protect the environment, but also acknowledge societal accountability to secure its long-term future (Hiranandani 2014; Taljaard et al. 2021).

In 2015 the United Nations adopted the 2030 Agenda for Sustainable Development with 17 Sustainable Development Goals (SDGs) (UN 2015). With the adoption of these goals, it became necessary to embed these concepts in port planning and operations and to develop tools to measure progress, and so the concept of sustainability (performance) assessment emerged (Sala et al. 2015; Villeneuve et al. 2017). Various sustainability assessment tools have been developed, including the Sustainable Development Analytical Grid, which is recognised by the UN as part of their SDG Acceleration Toolkit (UNDG 2019).

To assist port authorities to monitor their performance in achieving sustainability outcomes, as defined in terms of the UN's Sustainability Development Goals [SDGs], the CSIR, in consultation with researchers from the Technical University of Delft (Netherlands) and South Africa's national port authority developed a Sustainability Performance Index (SPI) for Ports (Taljaard and Weerts, 2023) that can be applied to track the efficacy of port planning and management in achieving long-term sustainability. This has clear value as a tool within the sustainability assessment toolbox (see Figure A.2).

### E.20.2 Construct of SPI for Ports

The SPI for Ports is constructed to enable the design of a simple spreadsheet model (e.g., MS Excel) for easy application by port managers should they wish to perform these assessments in their own ports. Figure E.25 provides a schematic of the structure of the proposed SPI for Ports. Drawing on international best practice in sustainability performance in ports (e.g., Peris Mora et al. 2005; Chiu et al. 2014; González Laxe et al. 2016; Lu et al. 2016; Schipper et al. 2017; Chen and Pak 2017; Roh et al. 2016; Stein and Acciaro 2020), the SPI is organised into the three main pillars of sustainability, environmental, social and economic. However, we chose to include governance as an explicit fourth dimension. Glass and Newig (2019) rightfully point out that the achievement of the 17 SDGs depends on effective governance arrangements. The importance thereof has been acknowledged in the 'circles of sustainability', a method applied in the monitoring of sustainability outcomes in urban centres by with the inclusion of 'politics' as a fourth dimension, together with environment, social and economics (James 2014), also later adopted

in 'circles of coastal sustainability' (de Alencar et al. 2020). However, it has not been previously explicitly included in existing port sustainability performance studies.



Figure E.25 Schematic of the structure of the Port Sustainability Index (PSI) for Ports (Taljaard and Weerts 2023)










Within each of the dimensions, drawing on international best practice (e.g., Peris Mora et al. 2005; Chiu et al. 2014; González Laxe et al. 2016; Lu et al. 2016; Schipper et al. 2017; Chen and Pak 2017; Roh et al. 2016; Stein and Acciaro 2020), a number of sustainability outcomes have been included, which lead into specific categories and associated indicators. Using a rating system (dealt with in detail later) the index provides performance scores for various categories, which are then integrated into performance scores for sustainability outcomes, sustainability domains, and finally into an overall sustainability performance score.

In determining the scores for categories, sustainability outcomes, dimensions, and the final sustainability performance, the SPI for Ports also allows for the weighted aggregation of contributing indicator ratings (Figure E.26). In the following each of the components in the SPI for Ports will be discussed and explained in greater detail.

### E.20.3 Selection of Outcomes, Categories and Indicators

In the selection of the sustainability outcomes within each of the sustainability domains, we primarily draw on key outcomes applied in the international studies. Worldwide, the 17 SDGs are currently used as a benchmark against which to evaluate progress and achievements towards sustainable development (UN 2015). However, it is often difficult for those directly involved in port practice to easily link each of these SDGs to port-specific actions or intervention. To this end Barbier et al. (2017) showed the relationship among SDGs and the sustainability dimensions of environmental, or social system goal, and WPSP (2020) provided a comprehensive list of potential actions in the port sector that would contribute to achieving each of these goals. This approach also has been adopted in the prototype, explicitly highlighting the connection between index outcomes and SDGs. Therefore, using the 17 SDGs, these were consolidated into larger sustainability outcome themes under each of the four domains as listed in Table E.28.

Table E.28: Sustainability dimensions, outcomes, categories and proposed indicators in SPI for Ports (Taljaard and Weerts 2023)

| DIMENSION  | SUSTAINABILITY OUTCOME THEME/CATEGORY   | INDICATOR  |   |  |   |
|------------|---|--|---|--|---|
| GOVERNANCE | <p><u>Good governance</u></p>   | <p>Legislation &amp; Policy</p> <ol style="list-style-type: none"> <li>1. Port's compliance with related international, national, and local legislation</li> <li>2. Port's compliance of port with in-house policies and requirements by port authority</li> <li>3. Tenants' compliance to policies and requirements of port authority</li> </ol>  |   |  |   |
|            |   | <p>Institutional arrangements</p> <ol style="list-style-type: none"> <li>4. Organisational commitment towards sustainable development</li> <li>5. Organisational institutional structures dealing with sustainability issues</li> <li>6. Dedicated institutional structure (e.g., department) to oversee and coordinate sustainable development matters in a port</li> <li>7. Dedicated institutional structure/s to coordinate and communicate with port tenants in a port</li> <li>8. Dedicated institutional structure/s for a port to coordinate collaboration with adjacent communities and/or urban areas (outside port with affected parties and cities, communities)</li> <li>9. Dedicated (and sufficient) funding allocations towards sustainable development in a port</li> </ol> |   |  |   |
|            |   | <p>Environmental management practices</p> <ol style="list-style-type: none"> <li>10. Strategic environment assessment (e.g., as part of master planning)</li> <li>11. Environmental impact assessment (EIAs)</li> <li>12. Environmental Management Plans</li> <li>13. Accredited (or equivalent) Environmental Management Systems implementation</li> </ol>  |   |  |   |
|            |   | ENVIRONMENT  | <p><u>Pollution prevention &amp; Ecosystem protection</u></p>   | <p>Air quality</p> <ol style="list-style-type: none"> <li>1. Air pollution management and control programme (including dust &amp; GHG)</li> <li>2. Compliance of emission sources in port</li> <li>3. Status of ambient air quality in port</li> </ol>   |   |
|            |   |  |   | <p>Water/sediment/soil quality</p> <ol style="list-style-type: none"> <li>4. Wastewater management and control programme covering effluent and stormwater</li> <li>5. Solid waste management and control programmes addressing waste such as gally waste, oil slop, bio-foul waste</li> <li>6. Marine litter clean-up and prevention programmes</li> <li>7. Hazardous waste management and control programmes</li> <li>8. Soil and groundwater management and control programmes</li> <li>9. Hull cleaning management and control programmes</li> <li>10. Ballast water management and control programmes</li> <li>11. Dredge management and control programmes</li> <li>12. Oil/fuel spill management and control programmes</li> <li>13. Compliance of wastewater sources in port</li> <li>14. Status of ambient water quality in port</li> <li>15. Status of ambient sediment quality in port</li> <li>16. Status of soil and groundwater quality in port</li> <li>17. Status of oil/fuel spills originating in port</li> </ol> |   |
|            |   |  |   | <p>Light, noise &amp; odour</p> <ol style="list-style-type: none"> <li>18. Noise management and control programmes</li> <li>19. Light management and control programmes</li> <li>20. Odour management and control programmes</li> <li>21. Status of ambient light quality in port</li> <li>22. Status of noise quality in port</li> <li>23. Status of odour quality in port</li> </ol>   |   |
|            |   |  |   | <p>Habitat &amp; biodiversity</p> <ol style="list-style-type: none"> <li>24. Physical and biological habitat/biodiversity management and control programmes (e.g., invasive species control, protection of sensitive areas, trade-offs)</li> <li>25. Status of invasive species in port</li> <li>26. Status of physical and biological habitat/biodiversity in port</li> </ol>   |   |
|            |   |  |   | <p><u>Eco-efficiency</u></p>     | <p>Water use</p> <ol style="list-style-type: none"> <li>1. Water use/consumption efficiency by port activities</li> <li>2. Water use/consumption efficiency of tenants</li> <li>3. Implementation of alternative water resources (e.g., rainwater harvesting, desalination)</li> </ol>  |
|            |   |  |   |    | <p>Climate</p> <ol style="list-style-type: none"> <li>4. Greenhouse gas emissions by port activities</li> <li>5. Greenhouse gas emissions by tenants (e.g., non-port trucks and visiting ships)</li> </ol>  |
|            |   |  |   |   | <p>Energy</p> <ol style="list-style-type: none"> <li>6. Greenhouse gas emissions in port by, e.g., tugs, vehicle, dredgers, and helicopters</li> <li>7. Use of environmental-friendly fossil fuels (e.g., low Sulphur fuel) in port by, e.g., tugs, vehicle, dredgers, and helicopters</li> <li>8. Energy efficiency (use/consumption) by port activities</li> <li>9. Energy efficiency (use/consumption) by tenants</li> </ol> |

| DIMENSION   | SUSTAINABILITY OUTCOME THEME/CATEGORY | INDICATOR   |   |
|---|---------------------------------------|---|---|
| SOCIAL  |                                       | 10. Use of alternative energy sources (e.g., solar, wind, ocean energy)   |   |
|   |                                       | 11. Cold ironing (shore-to-vessel power)  |   |
|   |                                       | 12. (Eco-friendly) material selection   |   |
|   |                                       | 13. Recycling of construction and building materials/minimization of rubble waste generation (circular economy concept)   |   |
|   | Recycling/<br>material                | 14. Port greenery (tree planting)   |   |
|   |                                       | 15. Efficient of soil/ground occupation/use (space planning)  |   |
|   | Land-use                              | 16. Environmentally friendly public transport programmes  |   |
|   | Transport                             | 1. Corporate social initiatives (e.g., school support, support of cultural activities, port open days, supporting public events, job creation and social support) |   |
|   | SOCIAL                                | <u>Social<br/>accountability</u>  | 2. Access rights for communities (e.g., fishers, harvesting of material, cultural activities, legal and managed bait collection)                          |
|   |                                       |   | 3. Support to community-based environmentally related enterprises (e.g., alien vegetation removal, mangrove planting, seaweed harvesting, litter removal) |
|   |                                       | Community<br>wellbeing  | 4. Port-City Memorandum of Understanding (MoU) (coordination/collaboration) addressing environmental/social issues  |
|   |                                       |   | 5. Port-city relationship   |
|   |                                       | Employee<br>wellbeing   | 6. Management and control programme for recognized cultural heritage assets in port, where relevant   |
| 7. Status of cultural heritage assets in port                                 |                                       |   |   |
| 8. Environmental education and awareness programmes/events for port employees |                                       |   |   |
| 9. Port employee engagement forums  |                                       |   |   |
| 10. Hiring from minority or previously disadvantaged groups (equity)          |                                       |   |   |
| 11. Status of port employee satisfaction                                      |                                       |   |   |
| 12. Status of employee occupational health and safety                         |                                       |   |   |
| 13. Status of port security   |                                       |   |   |
| ECONOMIC  |                                       |   | <u>Economic<br/>resilience</u>  |
|   | 2. CC early warning systems           |   |   |
|   | Climate<br>resilience<br>(robustness) |   | 3. CC induced incident assessment   |
|   |                                       | 4. Technical port capacity and efficiency (infrastructure, handling, equipment, refuelling, and safety)   |   |
|   | Economic<br>growth and<br>development | 5. Port competitiveness as influenced by ecoefficiency and waste management   |   |
|   |                                       | 6. Revenue generation through formal port activities  |   |
|   |                                       | 7. Contribution to tourism/recreation industry revenue  |   |
|   |                                       | 8. Contribution to local real estate value  |   |
|   |                                       |   |   |
|   |                                       |   |   |

For the environment, social and economic domains, the key categories were primarily derived from those previously encountered in the literature, focusing on those most widely applied internationally. For the *governance* dimension, the categories linked to sustainability outcomes were based on aspects of port governance considered key in facilitating sustainable development (e.g., Glass and Newig 2019).

A vast array of indicators has been used in port sustainability performance investigations (e.g., Peris Mora et al. 2005; Chiu et al. 2014; González Laxe et al. 2016; Lu et al. 2016; Schipper et al. 2017; Chen and Pak 2017; Roh et al. 2016; Stein and Acciaro 2020). In the selection of key sustainability indicators for the SPI for Ports, those most applied in previous studies were selected first. However, we also wanted to explicitly reflect the *effectiveness* of management in value creation, therefore we also included indicators reflecting environmental, social, and economic status, albeit not commonly used in previous studies. Finally, the list of indicators was also refined in consultation with environmental staff from South Africa's national ports authority.

#### E.20.4 Measures with Proposed Targets and Rating Systems

Important in the application of the PSI for Ports is the selection of appropriate measures to express change in performance across the indicators. Drawing on the international practices, as well as our own experience and in consultation with port environmental staff, various measures for the expression of indicator performance are proposed in Table E.29 (Taljaard and Weerts 2023). In applying this index, the selection of indicators and measures will obviously depend on the availability of data and information in the selection of ports in which the index is to be applied. Therefore, from a practical perspective, it might not be possible to include all the indicators from the start in a sustainability performance assessment process. Recognising such limitation, users may opt to include a sub-selection of indicators initially, provided a reasonable reflection of sustainability across outcomes and domains is still provided. In instances where only limited data on proposed measures are available, it might be more appropriate to explicitly acknowledge shortfalls, and only include domains and outcomes for which sufficient data and information are available, with the aim of improvement going forward.

Also included in Table E.29 are proposed targets against which to measure performance. Specific targets for various indicators, however, may vary from country to country. For example, in developing countries less stringent, more realistic sustainability targets may be set depending on resource availability, compared to those that may be set for well-resourced develop countries. The index is flexible to adjust targets, however, when sustainability performance is compared across ports or over time in the same port, targets applied must be similar.

To generate a numerical score for sustainability performance, a rating system was developed. In this instance a 5-point rating system from zero (0) to four (4) was used, where zero reflects the 'worst' rating and four the 'best' rating. This 5-point rating system was largely selected based on the typical, expected extent of data and information available on the various measures, and realistic resolution to detect shifts in performance. Examples of proposed rating systems for various indicators are provided in Table E.29, by giving proposed description for endpoint values (that is 0 and 4). The endpoint ratings, as well as interim ratings can be changed provided that the same rating system is applied when comparing sustainability performance across ports or over time in the same port.

Table E.29: Measure for expression of indicators, as well as examples for proposed targets and ratings systems in the SPI for Ports (Taljaard and Weerts 2023)

| Dimension: Governance                   |   |   |  |   |
|---|---|---|--|---|
| Sustainability Outcome: Good Governance |   |   |  |   |
| CATEGORY                                | INDICATOR   | PROPOSED SEMEASURE  | PROPOSED TARGET (Examples)   | PROPOSED RATING SYSTEM (Examples)   |
| Legislation & Policy                    | 1. Port's compliance with related international, national, and local legislation  | No. of non-compliance findings received from government authorities   | Full compliance or agreed percentage compliance                          | 0: More than...<br>1:<br>2:<br>3:<br>4: No non-compliance   |
|   | 2. Port's compliance of port with in-house policies and requirements by port authority  | No. of non-compliance findings against port policies and requirements   | Full compliance or agreed percentage compliance                          | 0: More than...<br>1:<br>2:<br>3:<br>4: No non-compliance   |
|   | 3. Tenants' compliance to policies and requirements of port authority   | No. of non-compliance findings to permit and license requirements or to other applicable legislation by tenants | Full compliance or agreed percentage compliance                          | 0: More than...<br>1:<br>2:<br>3:<br>4: No non-compliance   |
| Institutional arrangements              | 4. Organisational commitment towards sustainable development  | Sustainable development outcomes explicitly acknowledge and addressed by port authority                         | Binary reply (Yes)   | 0: No<br>4: Yes   |
|   | 5. Organisational institutional structures dealing with sustainability issues   | Existence of institutional structure explicit mandated to deal with sustainability strategies                   | Binary reply (Yes)   | 0: No<br>4: Yes   |
|   | 6. Dedicated institutional structure (e.g., department) to oversee and coordinate sustainable development matters in a port   | Existence of dedicated department in port dealing with environmental matters, and positions filled              | Fully resourced department as per agreed resource plan                   | 0: No department/No resources.<br>1:<br>2:<br>3:<br>4: Fully resourced environmental department   |
|   | 7. Dedicated institutional structure/s to coordinate and communicate with port tenants in a port  | Existence of a port tenant forum  | Established forum, meeting as per agreed frequency                       | 0: No form/no meetings<br>1:<br>2:<br>3:<br>4: Forum established and convened as per stipulation  |
|   | 8. Dedicated institutional structure/s for a port to coordinate collaboration with adjacent communities and/or urban areas (outside port with affected parties and cities, communities) | Existence of stakeholder engagement forum   | Established forum, meeting as per agreed frequency                       | 0: No forum...<br>1:<br>2:<br>3:<br>4: Well-established stakeholder forum in place  |
|   | 9. Dedicated (and sufficient) funding allocations towards sustainable development in a port   | Budget allocation towards improving for sustainable development in port   | Achievement of sustainable development agreed targets/budget             | 0: No funding.<br>1: Funding received, but only limited targets achieved<br>2:<br>3:<br>4: Funding received, and all targets achieved   |
| Environmental management practices      | 10. Strategic environment assessment (e.g., as part of master planning)   | Level of SEA implementation   | SEA undertaken and outcomes implemented in port                          | 0: No SEA implementation in port<br>1:<br>2:<br>3:<br>4: SEA developed and implemented  |
|   | 11. Environmental impact assessment (EIAs)  | Level of EIA implementation in port   | EIA undertaken for projects and requirements as per EA fully implemented | 0: No EIAs<br>1: Implemented, but limited compliance to Environmental Authorization (EA) requirements<br>2: Implemented, but some compliance to EA requirements<br>3: Implemented, mostly compliant to EA requirements<br>4: Implemented and full compliance with EA requirements |
|   | 12. Environmental Management Plans  | Existence and implementation of Environmental Management Plans (EMPs) in port                                   | EMP established as per stipulations and implemented                      | 0: No Plan<br>1:<br>2:<br>3:  |



|  |  |   |  |   |
|--|--|---|--|---|
|  |  |   |  | 4: Plan exist with satisfactory implementation  |
|  | 13. Accredited (or equivalent) Environmental Management Systems (EMS) implementation | Existence and implementation of EMS in port | Accredited EMS systems in place and satisfactory implemented | 0: No EMS<br>1:<br>2:<br>3:<br>4: Accredited EMS exist with satisfactory implementation |

Dimension: Environment



Sustainability Outcome: Pollution prevention & Ecosystem protection

| CATEGORY                           | INDICATOR   | MEASURE   | PROPOSED TARGET (Examples)  | PROPOSED RATING SYSTEM (Examples)   |
|------------------------------------|---|---|---|---|
| Air quality                        | 1. Air pollution management and control programme (including dust & GHG)  | Existence of programme and level of implementation (incl. monitoring of sources and ambient quality)  | Programme established as stipulated and fully implemented (sources and ambient quality)                           | 0: No programme<br>1:<br>2:<br>3:<br>4: Programme exists and fully  |
|                                    | 2. Compliance of emission sources in port   | Level of compliance of emission sources to targets/standards as set in permit/licenses/legislation    | Standards/targets for sources as per international/national legislation and/or permits/ license agreements        | 0: More than t...% noncompliance (set minimum)<br>1:<br>2:<br>3:<br>4: Full compliance/Great than... % compliance |
|                                    | 3. Status of ambient air quality in port  | Level of compliance against environmental/health standards/targets                                    | Targets for air quality as per international/ national legislation and or permits/ license agreements /guidelines | 0: More than t...% noncompliance (set minimum)<br>1:<br>2:<br>3:<br>4: Full compliance/Great than... % compliance |
| Water/<br>sediment/soil<br>quality | 4. Wastewater management and control programme covering effluent and stormwater                                 | Existence of programme and level of implementation (incl. monitoring of sources and ambient quality)  | Programme established as stipulated and fully implemented (sources and ambient quality)                           | 0: No programme<br>1:<br>2:<br>3:<br>4: Programme exists and fully implemented                                    |
|                                    | 5. Solid waste management and control programmes addressing waste such as gally waste, oil slop, bio-foul waste | Existence of programme and level of implementation (incl. monitoring of sources and disposal methods) | Programme established as stipulated and fully implemented (sources and disposal sites)                            | 0: No programme<br>1:<br>2:<br>3:<br>4: Programme exists and fully implemented                                    |
|                                    | 6. Marine litter clean-up and prevention programmes   | Existence of programmes and level of implementation   | Programme established as stipulated and fully implemented (sources and environment)                               | 0: No programme<br>1:<br>2:<br>3:<br>4: Programme exists and fully implemented                                    |
|                                    | 7. Hazardous waste management and control programmes  | Existence of programme and level of implementation (incl. monitoring of sources and disposal methods) | Programme established as stipulated and fully implemented (sources and disposal sites)                            | 0: No programme<br>1:<br>2:<br>3:<br>4: Programme exists and fully implemented                                    |
|                                    | 8. Soil and groundwater management and control programmes   | Existence of programme and level of implementation (incl. monitoring of sources and ambient quality)  | Programme established as stipulated and fully implemented (sources and ambient quality)                           | 0: No programme<br>1:<br>2:<br>3:<br>4: Programme exists and fully implemented                                    |
|                                    | 9. Hull cleaning management and control programmes  | Existence of programme and level of implementation (incl. monitoring of sources and disposal methods) | Programme established as stipulated and fully implemented (sources and disposal sites)                            | 0: No programme<br>1:<br>2:<br>3:<br>4: Programme exists and fully implemented                                    |
|                                    | 10. Ballast water management and control programmes   | Existence of programme and level of implementation (incl. monitoring of sources and disposal methods) | Programme established as stipulated and fully implemented (sources and disposal sites)                            | 0: No programme<br>1:<br>2:<br>3:   |



## Dimension: Environment

## Sustainability Outcome: Pollution prevention &amp; Ecosystem protection

| CATEGORY             | INDICATOR  | MEASURE   | PROPOSED TARGET (Examples)   | PROPOSED RATING SYSTEM (Examples)   |
|----------------------|--|---|--|---|
|                      | 11. Dredge management and control programmes         | Existence of programme and level of implementation (incl. monitoring of sources and disposal methods)                                       | Programme established as stipulated and fully implemented (sources and disposal sites)                                 | 4: Programme exists and fully implemented<br>0: No programme<br>1:<br>2:<br>3:<br>4: Programme exists and fully implemented |
|                      | 12. Oil/fuel spill management and control programmes | Existence of programme and level of implementation (incl. monitoring of sources and disposal methods) in accordance with relevant standards | Programme established as stipulated as per standards and fully implemented   | 0: No programme<br>1:<br>2:<br>3:<br>4: Programme exists and fully implemented  |
|                      | 13. Compliance of wastewater sources in port         | Level of compliance of emission sources to targets/standards as set in permit/licenses/legislation  | Standards/targets for sources as per international/national legislation and/or permits/ license agreements             | 0: More than ...% noncompliance (set minimum)<br>1:<br>2:<br>3:<br>4: Full compliance/Greater than... % compliance          |
|                      | 14. Status of ambient water quality in port          | Level of compliance against environmental/health standards/targets  | Targets for water quality as per international/ national legislation and or permits/ license agreements /guidelines    | 0: More than ...% noncompliance (set minimum)<br>1:<br>2:<br>3:<br>4: Full compliance/Greater than... % compliance          |
|                      | 15. Status of ambient sediment quality in port       | Level of compliance against environmental/health standards/targets  | Targets for sediment quality as per international/ national legislation and or permits/ license agreements /guidelines | 0: More than ...% noncompliance (set minimum)<br>1:<br>2:<br>3:<br>4: Full compliance/Greater than... % compliance          |
|                      | 16. Status of soil and groundwater quality in port   | Level of compliance against environmental/health standards/targets  | Targets for quality as per international/ national legislation and or permits/ license agreements /guidelines          | 0: More than ...% noncompliance (set minimum)<br>1:<br>2:<br>3:<br>4: Full compliance/Great than... % compliance            |
|                      | 17. Status of oil/fuel spills originating in port    | No. of incidents originating within port boundaries   | No incidents or an agreed annual minimum limit   | 0: More than... incidents<br>1:<br>2:<br>3:<br>4: No incidents  |
| Light, noise & odour | 18. Noise management and control programmes          | Existence of programme and level of implementation (incl. monitoring of sources and ambient quality)  | Programme established as stipulated and fully implemented (sources and ambient quality)                                | 0: No programme<br>1:<br>2:<br>3:<br>4: Programme exists and fully implemented  |
|                      | 19. Light management and control programmes          | Existence of programme and level of implementation (incl. monitoring of sources and ambient quality)  | Programme established as stipulated and fully implemented (sources and ambient quality)                                | 0: No programme<br>1:<br>2:<br>3:<br>4: Programme exists and fully implemented  |
|                      | 20. Odour management and control programmes          | Existence of programme and level of implementation (incl. monitoring of sources and ambient quality)  | Programme established as stipulated and fully implemented (sources and ambient quality)                                | 0: No programme<br>1:<br>2:<br>3:<br>4: Programme exists and fully implemented  |
|                      | 21. Status of ambient light quality in port          | Level of compliance against environmental/health standards/targets  | Targets for quality as per international/ national legislation and or permits/ license agreements /guidelines          | 0: More than t...% noncompliance (set minimum)<br>1:<br>2:<br>3:<br>4: Full compliance/Greater than... % compliance         |

| Dimension: Environment  |   |  |   |   |
|---|---|--|---|---|
| Sustainability Outcome: Pollution prevention & Ecosystem protection |   |  |   |   |
| CATEGORY  | INDICATOR   | MEASURE  | PROPOSED TARGET (Examples)  | PROPOSED RATING SYSTEM (Examples)   |
|   | 22. Status of noise quality in port   | Level of compliance against environmental/health standards/targets                                   | Targets for quality as per international/ national legislation and or permits/ license agreements /guidelines | 0: More than t...% noncompliance (set minimum)<br>1:<br>2:<br>3:<br>4: Full compliance/Great than... % compliance   |
|   | 23. Status of odour quality in port   | Level of compliance against environmental/health standards/targets                                   | Targets for quality as per international/ national legislation and or permits/ license agreements /guidelines | 0: More than t...% noncompliance (set minimum)<br>1:<br>2:<br>3:<br>4: Full compliance/Greater than... % compliance |
| Habitat & biodiversity  | 24. Physical and biological habitat/ biodiversity management and control programmes (e.g., invasive species control, protection of sensitive areas, trade-offs) | Existence of programme and level of implementation (incl. monitoring of sources and ambient quality) | Programme established as stipulated and fully implemented (sources and environment)                           | 0: No programme<br>1:<br>2:<br>3:<br>4: Programme exists and fully implemented                                      |
|   | 25. Status of invasive species in port  | No. of invasive species recorded   | No invasive species   | 0: More than... species recorded<br>1:<br>2:<br>3:<br>4: None   |
|   | 26. Status of physical and biological habitat/biodiversity in port  | Level of compliance against environmental/health standards/targets                                   | Targets for status as per international/ national legislation and or permits/ license agreements /guidelines  | 0: More than t...% noncompliance (set minimum)<br>1:<br>2:<br>3:<br>4: Full compliance/Great than... % compliance   |

| Dimension: Environment                 |   |  |   |  |
|--|---|--|---|--|
| Sustainability Outcome: Eco-efficiency |   |  |   |  |
| CATEGORY                               | INDICATOR   | MEASURE  | PROPOSED TARGET (Examples)  | PROPOSED RATING SYSTEM (Examples)  |
|  | 1. Water consumption metered  | Metering systems in place for tenants  | All port activities and tenants water use metered                           | 0: No metering of water use<br>1:<br>2:<br>3:<br>4: All port activities and tenants metered                        |
| Water use                              | 2. Water use/consumption efficiency by port activities                                      | Water consumption (metering system) against sustainability targets set for port                    | Agreed annual water consumption target based on sustainable principles      | 0: More than ...% noncompliance (set minimum)<br>1:<br>2:<br>3:<br>4: Full compliance/Greater than... % compliance |
|  |   | Water loss through leakage (metering systems)  | No leakages or a minimum percentage   | 0: More than ...% water loss<br>1:<br>2:<br>3:<br>4: No water losses/Less than ... % water losses                  |
|  | 3. Water use/consumption efficiency of tenants  | Water consumption (metering system) against estimated targets based on water efficiency assessment | Agreed annual water efficiency target based on sustainable principles       | 0: More than ...% noncompliance (set minimum)<br>1:<br>2:<br>3:<br>4: Full compliance/Greater than... % compliance |
|  | 4. Implementation of alternative water resources (e.g., rainwater harvesting, desalination) | % of water used in port from alternative water sources   | Agreed target for alternative water sources based on sustainable principles | 0: None<br>1:<br>2:  |

Dimension: Environment

Sustainability Outcome: Eco-efficiency



| CATEGORY               | INDICATOR   | MEASURE  | PROPOSED TARGET (Examples)  | PROPOSED RATING SYSTEM (Examples)  |
|------------------------|---|--|---|--|
| Climate                | 5. Greenhouse gas emissions by port activities  | Calculated CO <sub>2</sub> emission measured against carbon footprint target (t CO <sub>2</sub> e) | Agreed annual carbon footprint target (t CO <sub>2</sub> e) based on sustainable principles | 3:<br>4: More than ...% obtained from alternative sources<br>0: No inventory of carbon emission<br>1:<br>2:<br>3:<br>4: Inventory of carbon emission and compliant top carbon footprint target |
|                        | 6. Greenhouse gas emissions by tenants (e.g., non-port trucks and visiting ships)   | Calculated CO <sub>2</sub> emission measured against carbon footprint target (t CO <sub>2</sub> e) | Agreed annual carbon footprint target (t CO <sub>2</sub> e) based on sustainable principles | 0: No inventory of carbon emission<br>1:<br>2:<br>3:<br>4: Inventory of carbon emission and compliant top carbon footprint target  |
| Energy                 | 7. Use of environmental-friendly fossil fuels (e.g., low Sulphur fuel) in port by, e.g., tugs, vehicle, dredgers and helicopters) | Percentage of low sulphur fossil fuel usage (<500 ppm)   | 100% low sulphur fuels or agreed annual target  | 0: None<br>1:<br>2:<br>3:<br>4: 100% low sulphur usage   |
|                        | 8. Energy efficiency (use/consumption) by port activities   | Energy consumption against sustainability targets  | Agreed annual energy efficiency target based on sustainable principles                      | 0: No target/Less than... % of target<br>1:<br>2:<br>3:<br>4: Meet targets   |
|                        | 9. Energy efficiency (use/consumption) by tenants   | Energy consumption of tenants against targets (e.g., key performance measure)                      | Agreed annual energy efficiency target based on sustainable principles                      | 0: No target/Less than... % of target<br>1:<br>2:<br>3:<br>4: Meet targets (sources and ambient quality)   |
|                        | 10. Use of alternative energy sources (e.g., solar, wind, ocean energy)   | Percentage of energy use derived from alternative energy source other than fossil fuel             | 100% use of alternative energy sources or an agreed annual minimum target                   | 0: None<br>1:<br>2:<br>3:<br>4: 100% /More than ...% of energy used  |
|                        | 11. Cold ironing (shore-to-vessel power)  | Percentage of berths with cold ironing facilities  | 100 % of berth has cold ironing facilities  | 0: None<br>1:<br>2:<br>3:<br>4: 100%/More than ...% of berths  |
| Recycling/<br>material | 12. (Eco-friendly) material selection   | Percentage of building material that is eco-friendly   | Agreed annual target based on sustainable principles  | 0: None<br>1:<br>2:<br>3:<br>4: 100%/More than ...% of material  |
|                        | 13. Recycling of construction and building materials/minimization of rubble waste generation (circular economy concept)           | Percentage of construction and building waste re-used/recycled/ regenerated vs generated           | Agreed annual target based on sustainable principles  | 0: None<br>1:<br>2:<br>3:<br>4: 100%/More than ... % of material   |
| Land-use               | 14. Port greenery (tree planting)   | No. greening projects undertaken (e.g., tree plants, greening spaces)                              | Agreed annual target based on sustainable principles  | 0: None<br>1:<br>2:<br>3:<br>4: More than .... projects  |

**Dimension: Environment**

**Sustainability Outcome: Eco-efficiency**



| CATEGORY   | INDICATOR  | MEASURE                 | PROPOSED TARGET (Examples)                           | PROPOSED RATING SYSTEM (Examples)  |
|------------|--|-------------------------|--|--|
|            | 15. Efficient of soil/ground occupation/use (space planning) | Level of eco-efficiency | Agreed annual target based on sustainable principles | 0: Not considered<br>1:<br>2:<br>3:<br>4: Demonstrate optimal spatial planning/use         |
| Trans-port | 16. Environmentally friendly public transport programmes     | Level of eco-efficiency | Agreed annual target based on sustainable principles | 0: Not consider<br>1:<br>2:<br>3:<br>4: % of transport system optimized for eco-efficiency |

**Dimension: Social**

**Sustainability Outcome: Social Accountability**



| CATEGORY            | INDICATOR   | MEASURE   | PROPOSED TARGET (Examples)   | PROPOSED RATING SYSTEM (Examples)  |
|---------------------|---|---|--|--|
| Community wellbeing | 1. Corporate social initiatives (e.g., school support, support of cultural activities, port open days, supporting public events, job creation and social support) | Existence of a corporate social initiative (CSI) and level of implementation in port        | CSI as stipulated and effectively implemented  | 0: No CSI<br>1:<br>2:<br>3:<br>4: Implement appropriately budgeted CSI                               |
|                     | 2. Access rights for communities (e.g., fishers, harvesting of material, cultural activities, legal and managed bait collection)                                  | No. of legitimate complaints from community/access requests denied                          | No complaints or an agreed annual minimum limit  | 0: No complaints<br>1:<br>2:<br>3:<br>4: More than... complaints                                     |
|                     | 3. Support to community-based environmentally related enterprises (e.g., alien vegetation removal, mangrove planting, seaweed harvesting, litter removal)         | No. of enterprises supported (measured against a target)                                    | Agreed targets for enterprise support based on sustainable principles  | 0: None supported<br>1:<br>2:<br>3:<br>4: Target met   |
|                     | 4. Port-City Memorandum of Understanding (MoU) addressing environmental/social issues   | Existence of MoU and level of implementation  | MoU established and effectively implemented  | 0: No MoU or any other agreement<br>1:<br>2:<br>3:<br>4: MoU established and effectively implemented |
|                     | 5. Port-city relationship   | No. of legitimate conflict/ complaints received from city/municipality                      | No complaints/conflict or an agreed annual minimum limit   | 0: More than... complaints/conflicts<br>1:<br>2:<br>3:<br>4: No complaints/conflict                  |
|                     | 6. Management and control programme for recognized cultural heritage areas in port, where relevant  | Existence of programme and level of implementation  | Programme established as stipulated and fully implemented (sources and environment)                          | 0: No programme<br>1:<br>2:<br>3:<br>4: Programme exists and fully implemented                       |
|                     | 7. Status of cultural heritage assets in port   | Condition of recognised cultural heritage assets in port boundaries                         | Targets for status as per international/ national legislation and or permits/ license agreements /guidelines | 0: More than ...% in bad condition<br>1:<br>2:<br>3:<br>4: 100% in good condition                    |
| Employee wellbeing  | 8. Environmental education and awareness programmes/events for port employees   | Existence of employee programme/event organised or published and, level of staff engagement | Agreed annual targets for programmes/events based on   | 0: No programme/event<br>1: Programme/event planned but poorly received<br>2:                        |

Dimension: Social

Sustainability Outcome: Social Accountability



| CATEGORY | INDICATOR   | MEASURE  | PROPOSED TARGET (Examples)   | PROPOSED RATING SYSTEM (Examples)   |
|----------|---|--|--|---|
|          |   |  | sustainable principles and well attended                             | 3:<br>4: Programme exists and well received by staff  |
|          | 9. Port employee engagement forums                                  | Existence of employee forums and level of staff engagement   | Established forum, meeting as per agreed frequency and well attended | 0: No forum<br>1: Forum exists but poorly attended<br>2:<br>3:<br>4: Forum exists and well attended by staff                                |
|          | 10. Hiring from minority or previously disadvantage groups (equity) | Compliance to port employment equity targets (e.g., racial, gender)  | Agreed target based on sustainable principles                        | 0: No employment equity targets met<br>1: 20-40% targets met<br>2: 40-70% targets met<br>3: 70-90% targets met<br>4: All (>90%) targets met |
|          | 11. Status of port employee satisfaction                            | No. of legitimate complaints/grievances received   | No complaints/grievances or an agreed annual minimum limit           | 0: More than... received<br>1:<br>2:<br>3:<br>4: None (less than ...) received  |
|          | 12. Status of employee occupational health and safety               | No. of workplace injuries incidents (lost time injuries/fatalities)  | No injuries or an agreed annual minimum limit                        | 0: More than ... injuries<br>1:<br>2:<br>3:<br>4: None less than ...) injuries  |
|          | 13. Status of port security   | No. of crime events, cyber-attacks (international protocols for port safety can be used to set your targets) | No events or an agreed annual minimum limit                          | 0: More than ... incidents<br>1:<br>2:<br>3:<br>4: None (less than ...) incidents   |

Dimension: Economic

Sustainability Outcome: Economic Resilience



| CATEGORY                        | INDICATOR  | MEASURE   | PROPOSED TARGET (Examples)   | PROPOSED RATING SYSTEM (Examples)  |
|---------------------------------|--|---|--|--|
| Climate resilience (robustness) | 1. Level of climate change (CC) preparedness (e.g., integrated CC adaptation programmes) | Existence of integrated CC programme                                      | Integrated CC programmes established and institutionalised in accordance with latest IPCC data             | 0: No programme<br>1: Ad hoc<br>2: Programme exists, but very dated<br>3: Programme exists in accordance with latest IPCC data but no BCM<br>4: Programme exists in accordance with latest IPCC data including BCM   |
|                                 | 2. CC early warning systems  | Existence of early warning systems for CC early warning systems           | Fully operational early warning systems for e.g., weather (waves, wind, flooding) and seasonal forecasting | 0: No early warning systems<br>1: Ad hoc with weak performance<br>2: Programme exists, but IPOSS only<br>3: Programme exists with SAWs plus IPOSS but not seasonal forecast<br>4: Full suite of early warning systems, including SAWs plus IPOSS available at port level, also seasonal forecast |
|                                 | 3. CC induced incident assessment  | Loss of unplanned business days/ damage incurred lost to severe CC events | No loss or an agreed annual minimum limit  | 0: More than ...% business days or more than ...% annual revenue<br>1:<br>2:<br>3:<br>4: No unplanned loss incurred  |

Dimension: Economic

Sustainability Outcome: Economic Resilience



| CATEGORY                        | INDICATOR  | MEASURE  | PROPOSED TARGET (Examples)                | PROPOSED RATING SYSTEM (Examples)   |
|---------------------------------|--|--|---|---|
| Economic growth and development | 4. Technical port capacity and efficiency (infrastructure, handling, equipment, refueling, and safety) | Ship turnaround time in port (measures in cargo volumes vs targets)  | Agreed annual cargo volume targets        | 0: Less than ...% of annual cargo target volumes met<br>1:<br>2:<br>3:<br>4: Annual target volumes met              |
|                                 | 5. Port competitiveness as influenced by ecoefficiency and waste management                            | Estimate of port revenue loss because of lack of pollution management and eco-efficiency (5 <sup>th</sup> generation port measure) | No loss or an agreed annual minimum limit | 0: More than ... % revenue loss<br>1:<br>2:<br>3:<br>4: No revenue loss   |
|                                 | 6. Revenue generation through formal port activities   | Port revenue generation vs revenue targets   | Agreed annual port revenue target         | 0: Less than ...% of revenue target<br>1:<br>2:<br>3:<br>4: Meet/exceed revenue targets                             |
|                                 | 7. Contribution to tourism/recreation industry revenue   | Estimate of tourism/recreation income  | Agreed annual revenue target              | 0: No income<br>1:<br>2:<br>3:<br>4: More than ...% of total port revenue generation                                |
|                                 | 8. Contribution to local real estate value   | Estimate of real estate value vs average real estate value in municipality   | Agreed annual revenue target              | 0: Less than ...% of average real estate value<br>1:<br>2:<br>3:<br>4: More than ... % of average real estate value |



### E.20.5 Proposed Weighting Aggregation for Scoring

For each aggregation step (Figure E.26) different indicators can be given different weightings to arrive at a category score, and similarly various categories can be given different weighting to arrive at a sustainability outcome score. Table E.30 provides an example of a simple weighting system for the SPI for Ports.

Table E.30: Illustration of proposed weighting aggregation in SPI for Ports (Taljaard and Weerts 2023)

| OUTCOME/SUB-CATEGORY                              | DIMENSION                             |
|---|---------------------------------------|
| Good governance (1.0)                             | Legislation & Policy (0.33)           |
|   | Institutional arrangements (0.33)     |
|   | Environmental processes (0.33)        |
| Pollution prevention & ecosystem protection (0.5) | Air quality (0.25)                    |
|   | Water/ sediment/soil quality (0.25)   |
|   | Noise & Light (0.25)                  |
|   | Habitat & biodiversity (0.25)         |
| Eco-efficiency (0.5)                              | Water use (0.167)                     |
|   | Climate (0.167)                       |
|   | Energy (0.167)                        |
|   | Recycling/ material (0.167)           |
|   | Land-use (0.167)                      |
|   | Transport (0.167)                     |
| Social accountability (1.0)                       | Community well-being (0.5)            |
|   | Employee well-being (0.5)             |
| Economic resilience (1.0)                         | Climate resilience (0.5)              |
|   | Economic growth and development (0.5) |

However, these weightings can easily be adjusted to reflect organisational/country/regional priorities. By designing this flexibility into the index, port authorities can reflect site-specific factors, provided that the same weightings are applied when comparing temporal variation or spatial variation across ports. Also, by incrementally building up to an overall sustainability score, port authorities can identify specific categories, or sustainability outcomes, contributing most (or least) to achieving sustainability. This type of information allows port authorities to prioritise interventions to achieve overall sustainability or to focus on outcomes deemed more critical to their situation. An example of how the outputs from the sustainability can be graphically illustrated is provided in Figure E.26 (normalised to scores between 0 and 100), borrowing from the ‘circles of sustainability’, a method applied in the monitoring of sustainability outcomes in urban centres (James 2014), also later adopted in ‘circles of coastal sustainability’ (de Alencar et al. 2020).

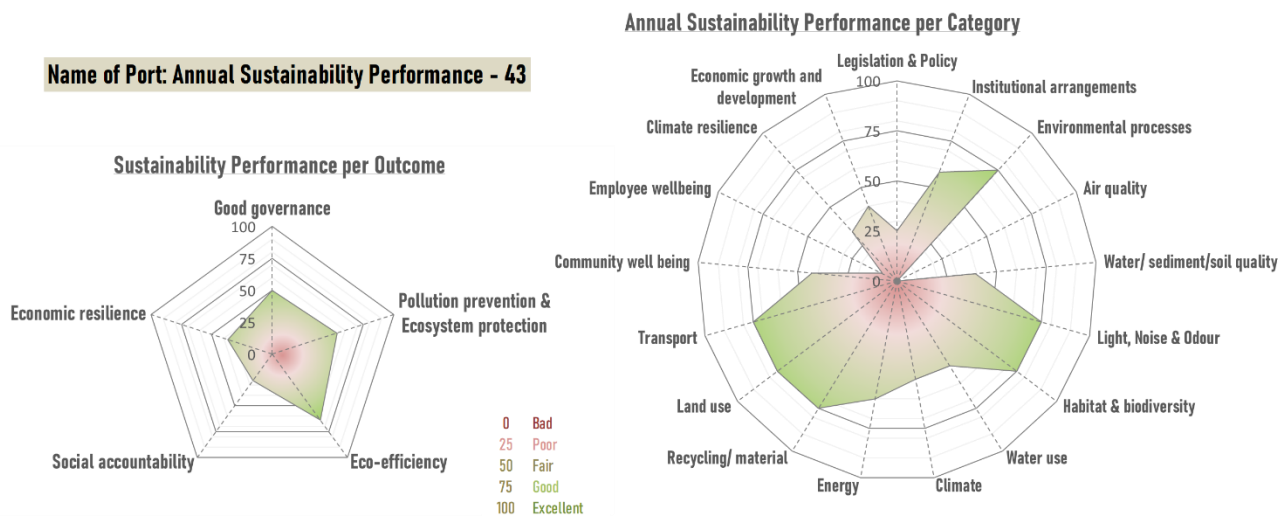


Figure E.26 Example of graphical illustrations from output of SPI for Ports (Source: Taljaard and Weerts 2023)

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