Towards Sustainable Port Development in the Western Indian Ocean

Toolkit For Green Ports

February 2023

(Draft confidential for review)

Published by the United Nations Environment Programme/Nairobi Convention Secretariat

Nairobi Convention Secretariat
United Nations Environment Programme,
United Nations Avenue, Gigiri,
P.O Box 47074, Nairobi, Kenya
Tel: +254 (0)20 7621250/2025/1270 Fax: +254 (0)20 7623203
Email: nairobi.convention@unep.org

Prepared by the Council for Scientific and Industrial Research (CSIR):

Dr Susan Taljaard
Steven Weerts
Dr Michelle Audouin

Council for Scientific and Industrial Research (CSIR)
Smart Places - Sustainable Ecosystems
Coastal Systems Research Group
Durban/Stellenbosch
South Africa

CSIR Report No:

For citation purposes this document may be cited as:

United Nations Environment Programme, Nairobi Convention Secretariat and Council for Scientific & Industrial Research. 2023. Towards Sustainable Port Development in the Western Indian Ocean. Toolkit for Green Ports. UNEP, Nairobi, Kenya, ….. pp.

EXECUTIVE SUMMARY

This project 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)* Project. The project is informed by an appreciation that port development and operations intersect with critical coastal and marine resources, the sustainable management of which is the focus of the Nairobi Convention. The scientific output generated from this project will be shared with national governments to support and guide the development on new policy and operational options on sustainable port development in the WIO region through the Science to Policy Platform supported by the Convention. Specifically, the project delivered:

- Situation Assessment, providing the context and backdrop for greener port operations and development in the WIO region
- Scenario Analysis evaluating development options from 'business as usual' to options incorporating environmental considerations ('green port' option)
- Toolkit on Green Ports, 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
- Policy Brief, capturing proposed recommendations for future sustainable port development in the WIO region.

This document presents the Toolkit for Green Ports.

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 early consideration of the natural environment in the early stages pf 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) posed 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).

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.

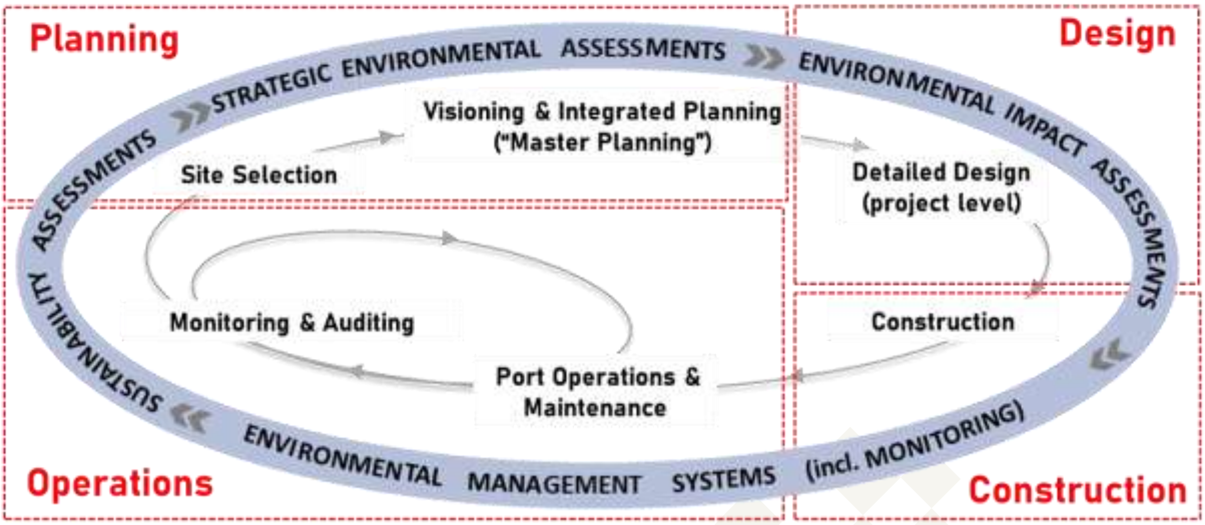


Figure 1: The Integrated Port Management Framework, conceptualizing alignment between the traditional port planning and development cycle, and key environmental assessment and management processes

To assist port operators with easy contextualisation of useful sustainable environmental tools that could be implemented within the context of the IPM Framework, the Toolkit for Green Ports presented here has been organised in accordance with the key stages in the framework. The table below summarises the various tools offered in the Green Port Toolkit within each of the four stages, that is planning, design, construction, and operations:

SECTION	TOOLS
A: Rationale	Rationale for Green Port Development (this section)
B: Planning	B.1 Site selection and Master Planning
	B.2 Planning for Climate Change
	B.3 Guidance on Strategic Environmental Assessment
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
	C.6 Ecosystem Restoration
D: Construction	D.1 Dredge Management (also relevant in Operations)
	D.2 Construction Environmental Management Plans
	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

SECTION	TOOLS
	E.12 Towards Improving Port Environmental Quality
	E.13 Marine Litter Clean up Technologies
	E.14 Oil Spill Contingency Planning
	E.15 Environmental Monitoring and Evaluation
	E.16 Environmental Information Systems
	E.17 Effective Capacity Development
	E.18 Introduction to Natural Capital Accounting
	E.19 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 Green Port 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 Green Port Toolkit should be adopted and embedded in national policies pertaining to sustainable port management, as appropriate.

CONTENT

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

AHP	Analytical Hierarchy Process
BAU	Business-as-usual
BOS	Biodiversity Offsets
CSIR	Council for Scientific and Industrial Research
CEC	Community of European Countries
CSIR	Council for Scientific and Industrial Research (RSA)
CWDP	Coastal Waters Discharge Permit
DEAT	Department of Environmental Affairs and Tourism
EIA	Environmental Impact Assessment
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
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

ACKNOWLEDGEMENTS

The following collaborators are thanked for their contribution:

- Jared Bosire - Nairobi Convention Secretariat, Kenya
- Maina Mbui – Macquarie University, Australia
- Lydia Ngugi - Maritime Technologies Cooperation Centre (MTCC), Africa
- Arthur Tuda - Western Indian Ocean Marine Science Association
- Jane Ndungu - Nairobi Convention Secretariat, Kenya
- Nathan Majwa - Nairobi Convention Secretariat, Kenya

The following representatives from the contracting parties are thanked for their contribution:

To be included…

INTRODUCTION

.

Background

In their simplest forms 1st generation 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, growing global trade, rapid coastal urbanization, depletion and degradation of natural resources, along with increasing expectations from stakeholders, greater social empowerment and awareness have demanded an accelerated quest for port sustainability. Ports are increasingly being pressurised to take actions, not merely focussing on economic growth, but also to include resilient sustainable strategies pertaining to the environment and society (Lu et al. 2016a; Alamoush et al. 2021). The port industry therefore faces a growing challenge to address societal and environmental considerations, and at the same time provide adequate capacity and cost-effective services to traders (e.g., working towards 5th generation ports) (Kaliszewski, 2018; Lam and Van der Voorde, 2012; Roh et al., 2016; Notteboom et al. 2022). Globally port authorities are being 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).

The Western Indian Ocean (WIO) region is no exception and is experiencing unprecedented growth in industrial, mining, agricultural and other economic sectors, and associated large-scale developments, including ports. This is principally driven by large infrastructure demands and financial inflows from different funding streams. Most of these developments are concentrated around coastal zones with rich natural resources and while the region has an opportunity to define sustainable trajectories for these investments, they have potential to significantly impact on the integrity of these critical habitats and the resource base that future developments may depend on. In the WIO Region coastal communities are particularly reliant on coastal resources for their lives and livelihoods.

Several initiatives in the WIO region have already started to adopt green initiatives in ports. These include (Nairobi Convention 2021):

- Kenya Ports Authority (KPA) adopting a Green Port Policy to enhance environmental conservation, for example requiring ships calling at the Port of Mombasa to use electric power while docked
- Tanzania Port Authorities (TPA) - in conjunction with Deltares - developing a GPP for the Port of Dar es Salaam, aligned with the World Banks's 'Green Growth', as well a climate-smart design for the port's expansion and improvement programme
- South Africa's Transnet National Ports Authority (TNPA) maintaining a green status in the Port of Ngqura through several initiatives including unique biodiversity conservation programmes. Other South African ports are at different levels in the greening initiative
- Port Management Association East and Southern Africa (PMAESA) together with the Maritime Technology Cooperation Centre-Africa being 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.

Building on these initiatives, and complementary to the *Strategic Framework for Coastal and Marine Water Quality Monitoring and Management in the Western Indian Ocean Region* (UNEP et al. 2022a), the Nairobi Convention Secretariat, on request of the Conference of Parties (CoP), initiated a project to support *sustainable growth and development of port in* the WIO region by proactively *assessing and addressing potential environmental and societal consequences.*

Purpose

This project 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).* Port operations invariably influence critical coastal and marine resources, the sustainable management of which is the focus of the Nairobi Convention. The scientific outputs generated from this project will be shared with national governments to support and guide development of new policy options on sustainable port development in the WIO region through the Science to Policy Platform supported by the Convention.

Specifically, to contribute to sustainable port development in the Western Indian Ocean the project delivered:

- Situation Assessment, providing the context and backdrop for greener port operations and development in the WIO region
- Scenario Analysis, evaluating development options from 'business as usual' to options incorporating environmental considerations ('green port' option)
- Toolkit on Green Ports, 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
- Policy Brief, capturing proposed recommendations for future sustainable port development in the WIO region.

This document presents the Toolkit for Green Ports.

Structure of this Report

This Introductory section in followed by an overview on the rationale for Green 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 Green Port Toolkit is presented as a series of useful tools focusing on relevant and innovative approaches and methods that could be adopted in WIO ports towards sustainable development within the key stages, or components, of the IPM Framework, that includes:

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

SECTION A: RATIONALE FOR GREEN PORT DEVELOPMENT

A Green Port adheres to the concept of resource saving and environment-friendly development, actively fulfils its social responsibilities, and comprehensively adopts technologies and management measures that are conducive to saving resources and energy, protecting environment and ecology and coping with climate change – Guo and Liu (2018).

Although rooted in ancient human history, sustainable development re-emerged as a paradigm in the early 1900s in response to failures in conventional development which focussed only on achieving growth in gross domestic product (Pintér et al., 2012; Villeneuve et al., 2017). Detrimental impacts on the natural environment and society and an inability to distribute wealth fairly are key failures of the conventional economic development model. These failures could be addressed by sustainable development principles that consider environmental, social, and economic issues in the light of cultural, historic and institutional perspectives (Waas et al. 2011).

Sea ports are complex environmental systems given their location at the interface of terrestrial, freshwater and marine ecosystems and the magnitude of potential impacts associated with their activities, such as dredging, wastewater discharge, atmospheric emissions and solid waste management. Environmental impacts can occur due to normal port activities or by accident (Darbra et al. 2004; Darbra et al. 2005). In their simplest forms 1st generation ports operated in areas of uncontested spaces, benefiting from seascapes in which they could be situated safely and cost-effectively without competition (Kaliszewski 2018; Lee et al. 2018). However, society has evolved, with rapid coastal urbanisation, growing global trade, stakeholder empowerment and depletion of natural resources (e.g., through physical alteration and destruction of habitat, pollution, and unsustainable levels of exploitation). As a result, port systems can no longer operate without acknowledging and incorporating societal and environmental considerations in their planning and management (the soc-called 5th generation ports). The port industry therefore faces increasing challenges in addressing societal and environmental considerations while at the same time having to provide adequate capacity and cost-effective services for trade (Lam and Van der Voorde 2012; Roh et al. 2016).

These challenges stimulated the development of concepts such as 'Green Ports' with the primary objective of 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). While some claim that green port management must include the broader topic of ecosystem protection (Schipper et al. 2017), others argue that green ports implicitly will lead to positive outcomes in their economic performance (Lam and Van de Voorde 2012). Nevertheless, 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). The concept of 'Sustainable Port Development' builds on that of 'Green Port' by 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).

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 encapsulate Agenda 2063 (Figure A.1. Of these Aspiration 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 and its contribution to sea-level rise, increased storminess and many other impacts (e.g., Azarkamand et al. 2020a) is a major threat to future port sustainability. Response to climate change can be into two types of process: (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).

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. Stages. Multi-use valuation (ecosystem services) needs to be embraced to gives 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, presented in a logical cyclical order in Figure A.2. It recognizes the 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 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 (Taljaard et al. 2021). To achieve this, the various environmental processes need to become aligned and integrated with traditional port planning and development stages as proposed in the IPM framework (Figure A.2).

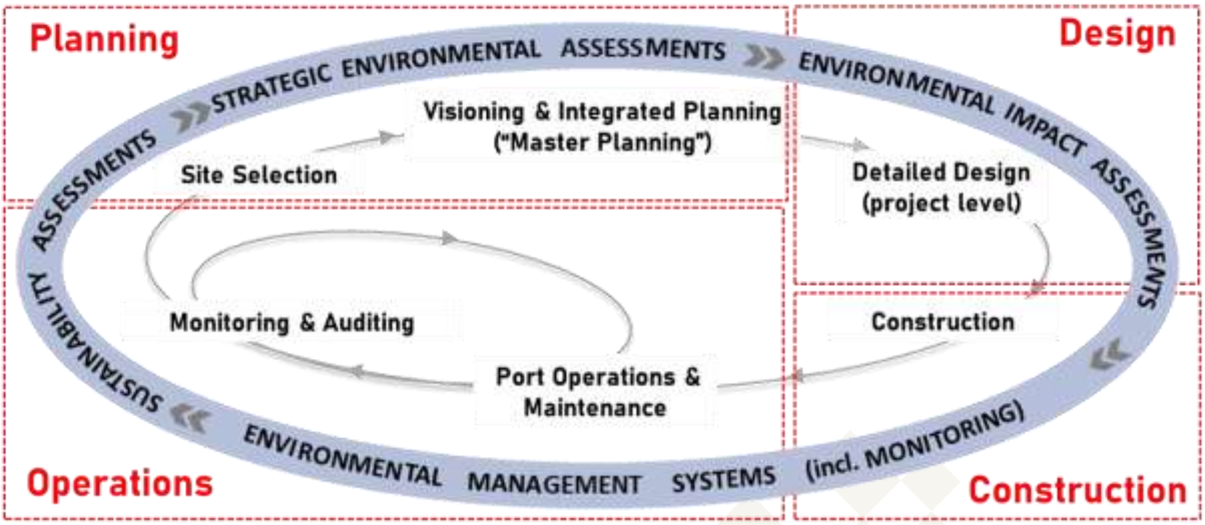


Figure A.2 The Integrated Port Management Framework, conceptualizing alignment between the traditional port planning and development cycle, and key environmental assessment and management processes (Source: Taljaard et al. 2021)

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, 21012a and 2012b). Also important is that Environmental Impact Assessments (EIAs) be initiated in the design stages of port development to allow for opportunities to adapt engineering designs to avoid or mitigate potential environmental impacts. This will allow much better integration of environmental issues into engineering principles at early design stages an avoid option foreclosure. At 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 sound 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.).

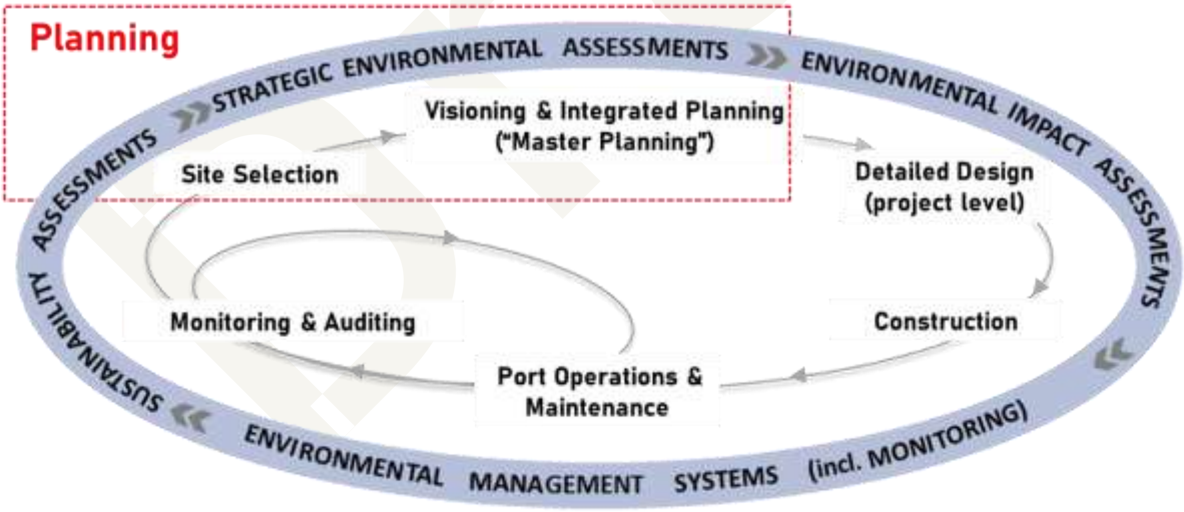
To assist port operators to contextualise sets that can be implemented to support sustainable port development the Toolkit for Green Ports presented here has been organised in accordance with the key stages in the IPM Framework illustrated in Figure A.2. Table A.1 summarises the various tools offered in the Green Port Toolkit within each of the four main stages: planning, design, construction, and operations.

Table A.1: Structure and content of this Green Port Toolkit

SECTION	TOOLS
A: Rationale	Rationale for Green Port Development (this section)
B: Planning	B.1 Site selection and Master Planning
	B.2 Planning for Climate Change
	B.3 Guidance on Strategic Environmental Assessment
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
	C.6 Ecosystem Restoration
D: Construction	D.1 Dredge Management (also relevant in Operations)
	D.2 Construction Environmental Management Plans
	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 Marine Litter Clean up Technologies
	E.14 Oil Spill Contingency Planning
	E.15 Environmental Monitoring and Evaluation
	E.16 Environmental Information Systems
	E.17 Effective Capacity Development
	E.18 Introduction to Natural Capital Accounting
	E.19 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 Green Port Toolkit at once, for reasons of human and financial resource limitations. However, by committing to a focussed, on-going process towards aligning environmental matters early on 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 Green Port Toolkit should be adopted and embedded in national policies pertaining to sustainable port management, as appropriate.

SECTION B: PLANNING



B.1 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.

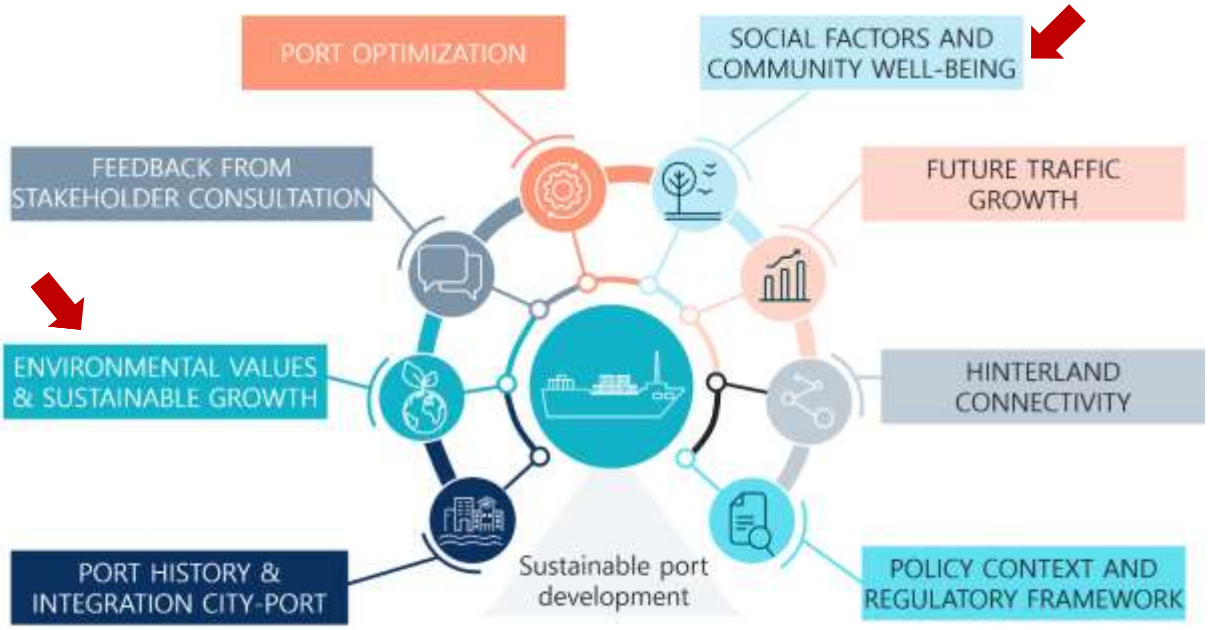


Figure B.1 Key factors to consider in site selection and master planning of port (source: ALG Transport & Infrastructure 2021) (arrows – added - point to social and environmental factors)

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.1). 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.

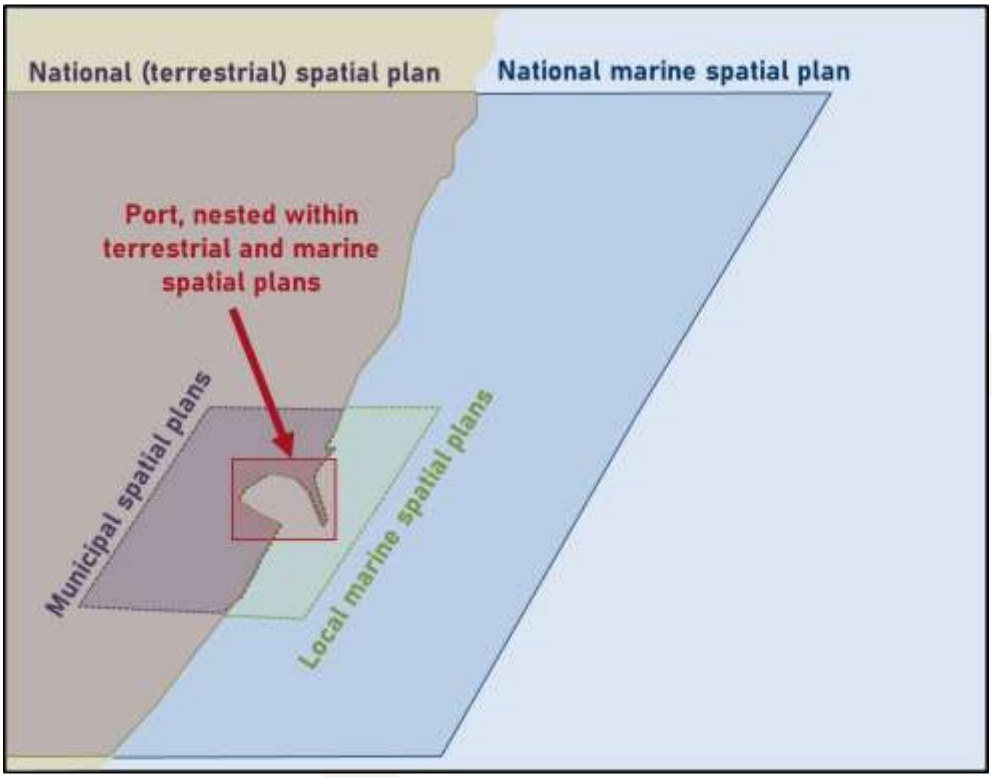


Figure B.2 Conceptualisation of port spaces nested within terrestrial and marine spatial plans

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 martime 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 planning projects.

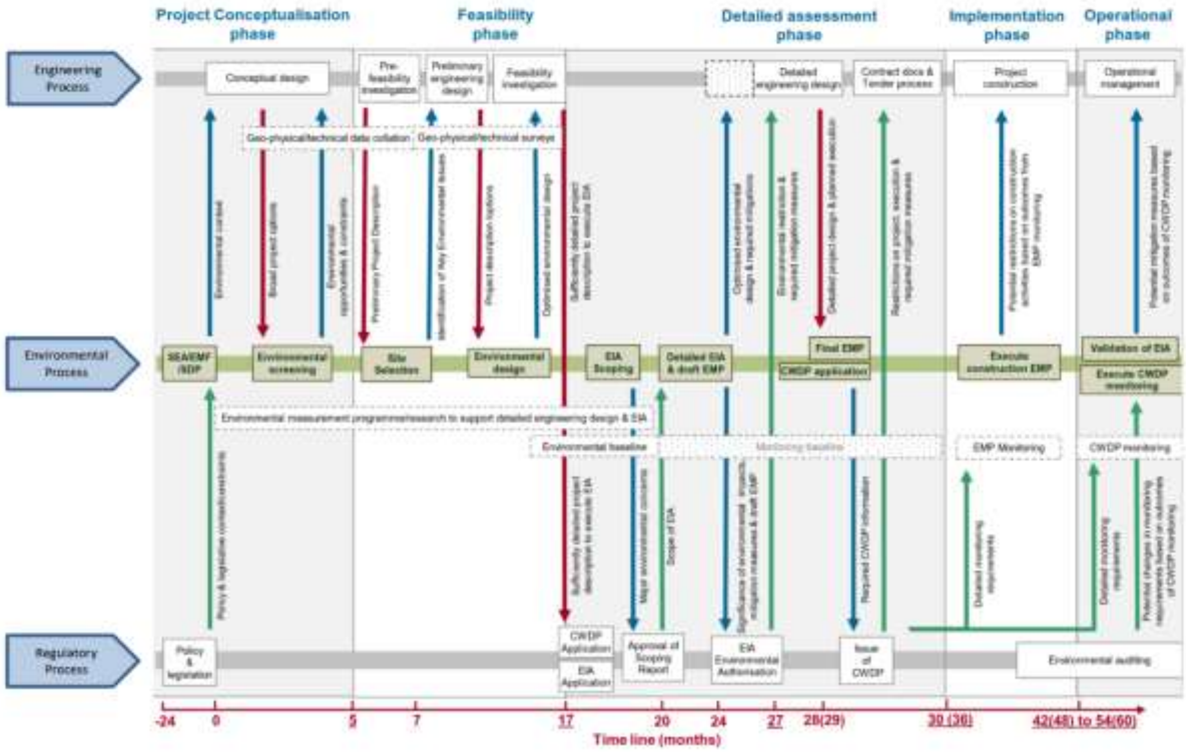


Figure B.3 Illustration of anticipated timelines and coordination between engineering, environment and regulatory processes typically encountered in marine infrastructure projects (source: Van Ballegooyen et al. 2016)

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.2 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) (Dalal-Clayton and Sadler 1999). This is reflected in an early, widely used definition as follows (Sadler and Verheem 1996: 27):

> *"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 also 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.1, 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[1]
- 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)

[1] "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 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 is 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 (mainly natural environment)	INTEGRATED OR SUSTAINABILITY FOCUS
EIA-BASED SEA	• Focus of SEA is to assess environmental consequences of a (draft) PPP • Assessment is undertaken against baseline environmental conditions in the area to which the PPP applies	• Expansion of the SEA to include the assessment of the social, ecological and economic aspects of a (draft) PPP • This assessment is undertaken against social, ecological and economic objectives that are defined through the SEA
	Examples of port environmental concerns: water quality, air quality, mangrove degradation	Examples of Integrated/sustainability concerns in Ports: local employment, energy use, greenhouse gas emissions
OBJECTIVES-LED SEA	• Focus of SEA is to assess environmental consequences of a (draft) PPP • 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	• Expansion of SEA to include assessment of social, ecological and economic aspects of a (draft) PPP • Assessment is undertaken in relation to sustainability objectives defined through SEA • This approach is also a form of 'sustainability assessment'
	Examples of port environmental objectives: 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: 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.2.1 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	• Ensures an appropriate environmental assessment of all strategic decisions relevant for the achievement of sustainable development • Addresses the interrelationships of biophysical, social and economic aspects • Is tiered to policies in relevant sectors and (transboundary) regions and, where appropriate, to project EIA and decision making
Is sustainability-led	• 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)
Is focused	• Provides sufficient, reliable and usable information for development planning and decision making • Concentrates on key issues of sustainable development • Is customized to the characteristics of the decision-making process • Is cost- and time-effective
Is accountable	• Is the responsibility of the leading agencies for the strategic decision to be taken. • Is carried out with professionalism, rigor, fairness, impartiality and balance • Is subject to independent checks and verification • Documents and justifies how sustainability issues were taken into account in decision making
Is participative	• Informs and involves interested and affected public and government bodies throughout the decision-making process • Explicitly addresses their inputs and concerns in documentation and decision making • Has clear, easily understood information requirements and ensures sufficient access to all relevant information
Is iterative	• Ensures availability of the assessment results early enough to influence the decision-making process and inspire future planning • 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."

B.2.2 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.2.2.1 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.2.2.2 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 green 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.2.2.3 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	• Initiate more detailed marine archaeological research in areas outside of port boundaries where port may expand in future	• Number and quality of baseline studies undertaken by a qualified archaeologist prior to port expansion or other activities outside port boundaries
Ensure highest level of control on fuel transfers to limit accidental discharges	• Zero discharge from fuel transfer operations	• Number and volume of accidental discharges
To promote job creation and income generation within scope of activities of port	• To increase number of jobs within the total value chain in port	• Total increase in number of employees per annum in port and port-related activities

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[2]. 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*[3] 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

---

[2] *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.*

[3] "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)

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):

- The nature of the impacts, as described in terms of the range of factors mentioned[4], should inform their significance. The degree of scientific uncertainty around impact prediction and its effects, should also inform significance ratings.
- 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 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 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.2.2.4 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 Section E.12)

[4] 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)

- Public-private partnerships to increase ownership of- and funding for- sustainability projects.

B.2.2.5 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.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, affect safety of staff, 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

Port, by their 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'* [5] (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.

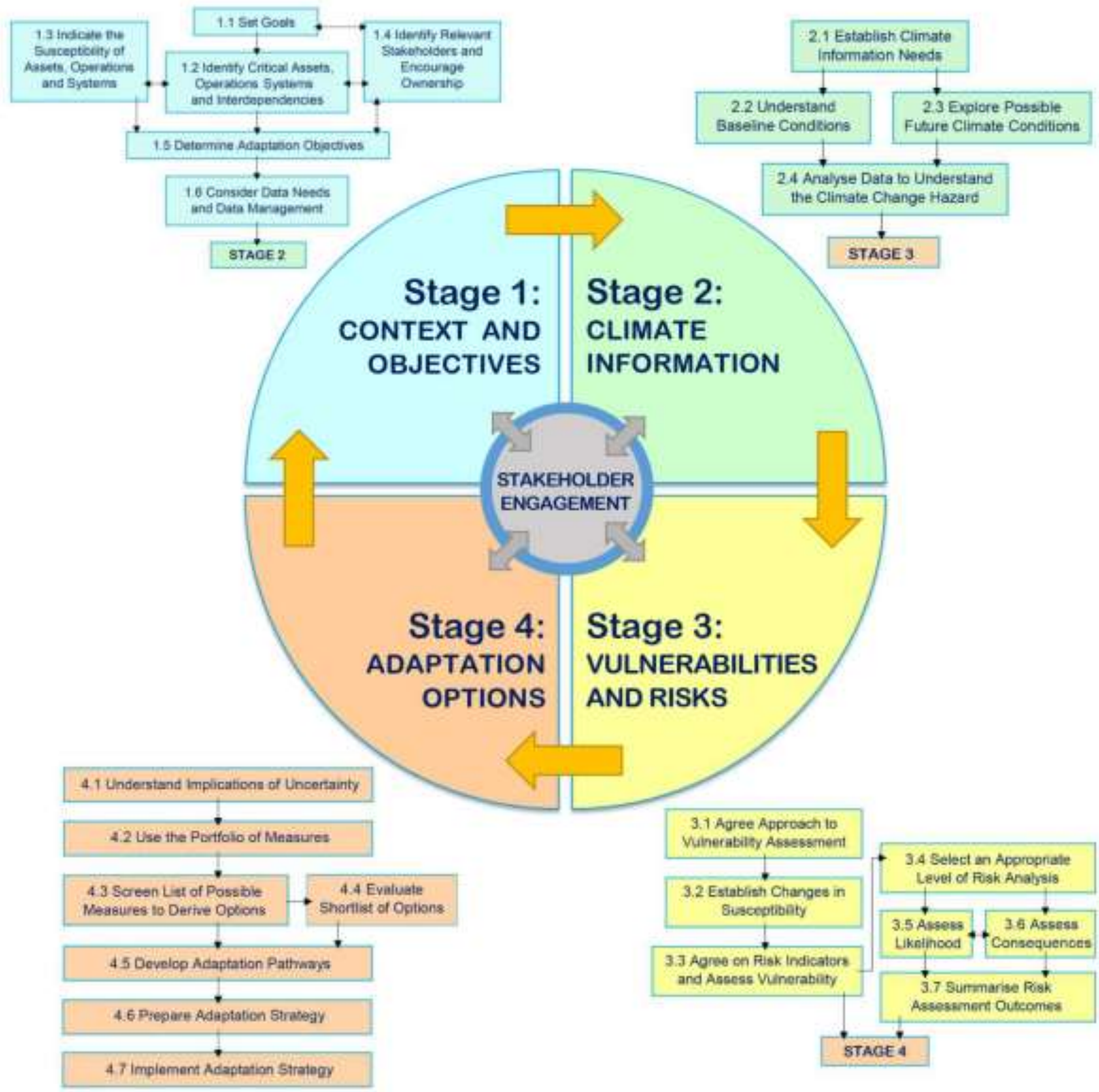


Figure B.5 PIANC's four stage methodological framework for climate change adaptation planning in ports (Source: PIANC 2020)

[5] 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, financers 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, already compromising social equity and human well-being (WWF 2016). Current environmental management approaches have simply became 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).

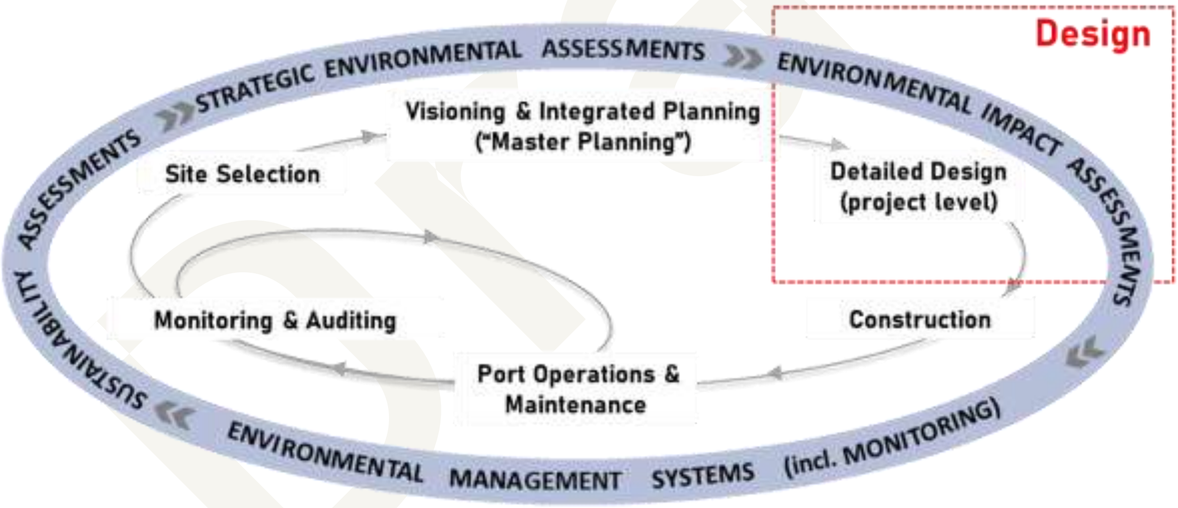
The IUCN defines the concept of NbS as *'actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits'* (Cohen-Shacham et al. 2016). The concept stems 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. It's a concept that represents considerable potential for sustainable ports, as is demonstrated in the Toolkit for Green Ports presented here. Indeed, several tools in this toolkit can be directly matched with ecosystem-based approaches in Figure B.5:

- 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).

SECTION C: DESIGN



C.1 Guidance on Environmental Impact Assessments

Environmental Impact Assessment (EIA) is an internationally recognised, and widely legislated tool within the environmental assessment and management 'toolbox' (Figure A.1). 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."*

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 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.
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[6]. 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
- 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.).

---

[6] 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)

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[7], 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 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,

[7] 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)

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.[8].

[8] See : http://www.iaia.org/publicdocuments/pdf/special-publications/SP6.pdf

C.2 Design for Biodiversity Offsets

IUCN (2004) defines Biodiversity offsets as '*Conservation activities intended to compensate for the residual, unavoidable harm to biodiversity caused by development project*". 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, for example the environmental mitigation hierarchy (Figure C.1) (IUCN 2004; World Bank Group 2016).

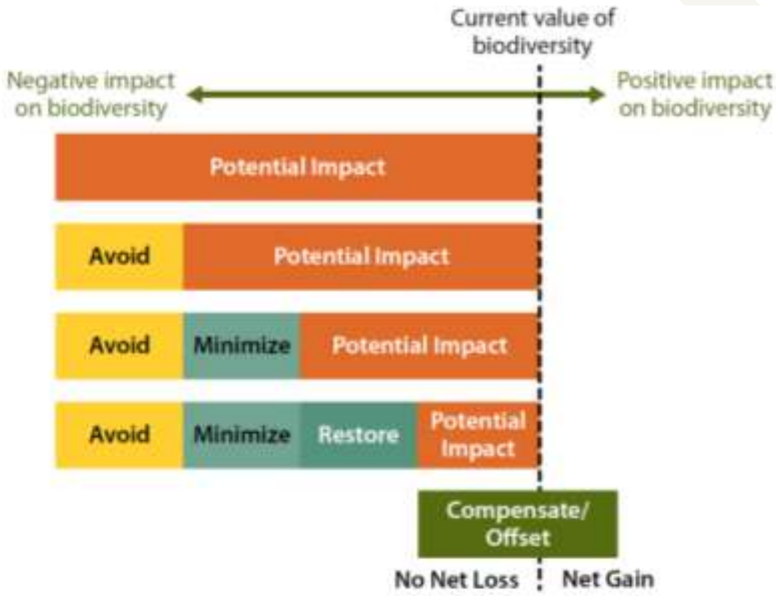


Figure C.1 Schematic of Environmental Mitigation Hierarchy (Source: World Bank Group 2016)

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 to Contracting Parties to the Nairobi Convention to 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 to explore by governments (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 permit 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, some good practice principles to apply to conservation related activities are:

- Use a 'landscape approach' considering relevant habitats and species of interest within the broader landscape, beyond the boundaries of interest
- Apply sound science as well as traditional knowledge
- Ensure diligent project supervision and effective institutional capacity building
- Address 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 viewed as inadequate or as '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 offsets are 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 also can pose a challenge and must therefore be considered when demarcating areas of potential impact associated with a development. Accurate and current ecosystem data also are key in understanding impacts and quantifying offset. While data often are more limiting in marine systems, expected changes in physical and abiotic parameters - such as geomorphological features, temperature, and salinity - could 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 be able 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 include (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, (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 offset 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'* motivating to regulators to grant permission for new operations and by securing support of local communities and non-governmental organisations. 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 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 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 renumeration 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 Ban 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 tend to 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 new 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 while still protecting natural ecosystems and the benefits 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 to use 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 waterways (including ports) two useful guidelines on BwN are those of 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.

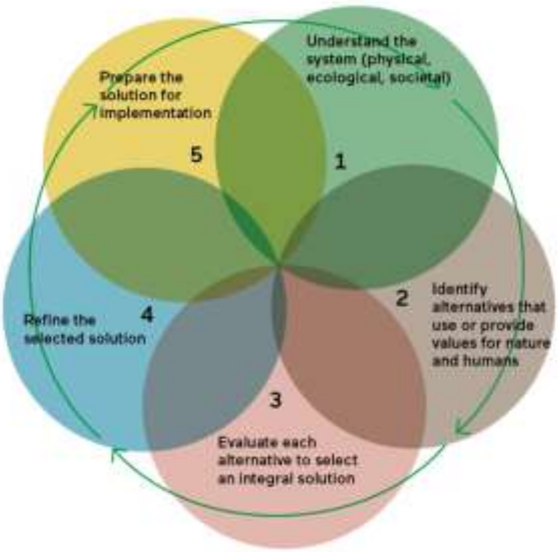


Figure C.2 Five step process for BwN design (Source: EcoShape 2022)

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

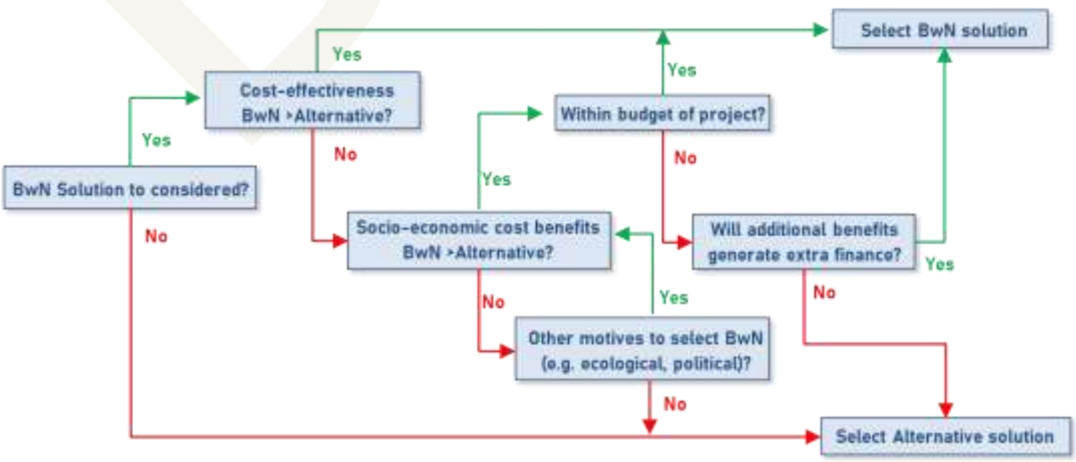


Figure C.3 Decision-making process in selecting BwN options (Source: adapted from Oerlemans et al. 2021)

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 to ports in the WIO regions. 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.
- 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 recirculation 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 improved water quality through filtration. 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) are effective in accumulating pathogens and toxic substances that can pose serious health risks.

C.4 Ecological Enhancement Options

While the concept of ecological enhancement can be view 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 organism, 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 sea walls, involves conventional 'hard' engineering (Morris et al. 2020). However, such hard engineering structure use weathered rock or concrete that typically lack smaller scale surface complexities encountered on natural substrates. They are therefore unable to act as microhabitat for most marine biota. For example, in nature microhabitats along rocky shore are typically in the centimeter scale, such as ledges and small pools (Figure C.4).

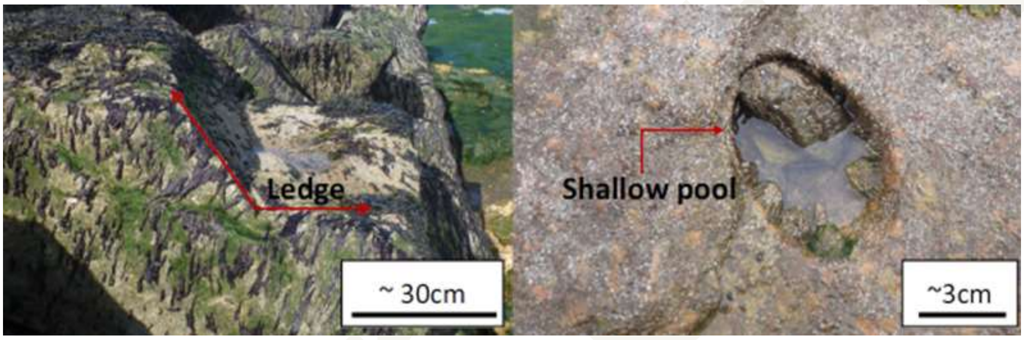


Figure C.4 Example of scale of natural microhabitats along rocky areas (source: MacArthur 2020)

To enhance ecological value, structures are now being designed to better mimic natural conditions becoming multifunctional to the benefit both humans and nature. For example, smaller 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. Studies conducted Israel with armouring units manufactured from ECOncrete®, a type of ecologically enhanced concrete, showed higher abundance, richness and diversity of invertebrates and fish on and around ecologically enhanced units compared with standard units. They also show greater ecological complexity and lower invasive species ratios (Perkol-Finkel et al. 2018; Ido and Perkol-Finkel 2015) (Figure C.6).

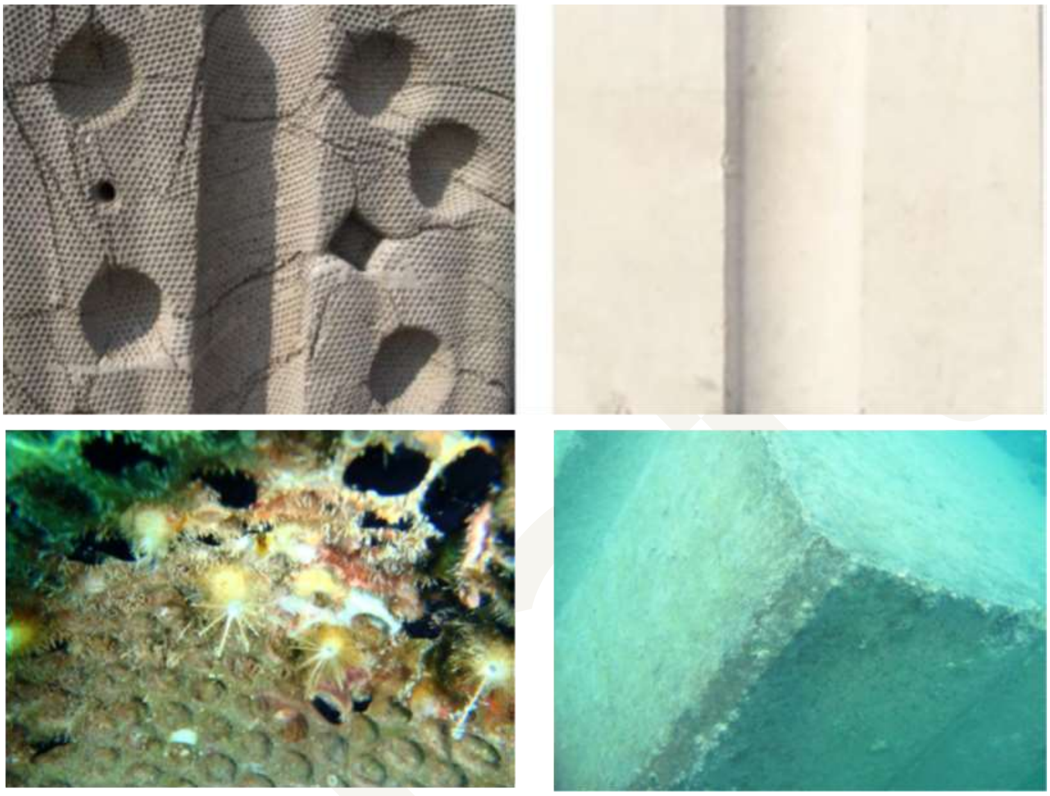


Figure C.6 Example of ecologically enhanced armouring units (left) and standard units (right), also showing colonisation over similar periods (source: Ido and Perkol-Finkel 2015)

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 port require large relatively deep, open water area (EcoShape 2020). Further, smooth steel and concrete structures, like sheet-pile walls or jetty piers, provide little hold for marine organisms to colonise. However, port water areas can be enhanced using artificial hanging substrates, for example pile and pontoon hulas - so-called based on 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 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 enhances 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).

C.5 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). While it is important to acknowledge the 'jargon' used in restoration science and management to position research efforts and/or policy development within the wider theoretical framework, 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) stresses 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.

Realising the 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 a mass extinction. This will require political support and technical capacity in both the public and private sectors to invest ecosystem restoration initiatives worldwide to 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.

C.5.1 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, staring from from reducing impact (e.g., mitigating pollution sources) through to ecological restoration (Figure C.9).

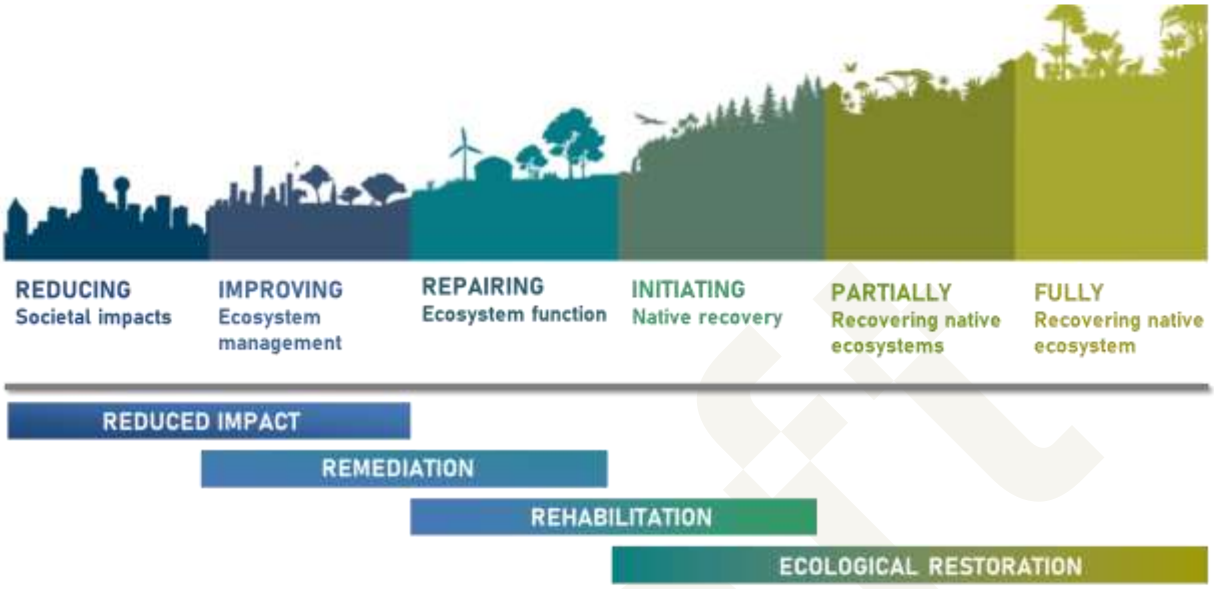


Figure C.9 Illustration of the restorative continuum (source: Gann et al. 2019)

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 C.1).

Table C.1: Key principles and supporting guidelines for successful restoration (source: Keenleyside et al. 2012)

PRINCIPLE	GUIDELINE
Effective in re-establishing and maintaining protected area values	• 'Do no harm' by first identifying when restoration is the best option • Re-establish ecosystem structure, function and composition • Maximize the contribution of restoration actions to enhancing resilience • (e.g., to climate change) • Restore connectivity within and beyond the boundaries of protected areas • 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 • Use research and monitoring, including from traditional ecological knowledge, to maximize restoration success
Efficient in maximizing beneficial outcomes while minimizing costs in time, resources, and effort	• Consider restoration goals and objectives from system-wide to local scales • Ensure long-term capacity and support for maintenance and monitoring of restoration • Enhance natural capital and ecosystem services from protected areas while contributing to nature conservation goals • Contribute to sustainable livelihoods for indigenous peoples and local communities dependent on the protected areas • Integrate and coordinate with international development policies and programming
Engaging by collaborating with partners and stakeholders, promoting participation, and enhancing visitor experience	• Collaborate with indigenous and local communities, neighbouring landowners, corporations, scientists and other partners and stakeholders in planning, implementation, and evaluation • Learn collaboratively and build capacity in support of continued engagement in ecological restoration initiatives • Communicate effectively to support the overall ecological restoration process • Provide rich experiential opportunities, through ecological restoration and because of restoration, that encourage a sense of connection with and stewardship of protected areas

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 an 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.

C.5.2 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 C.10). 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

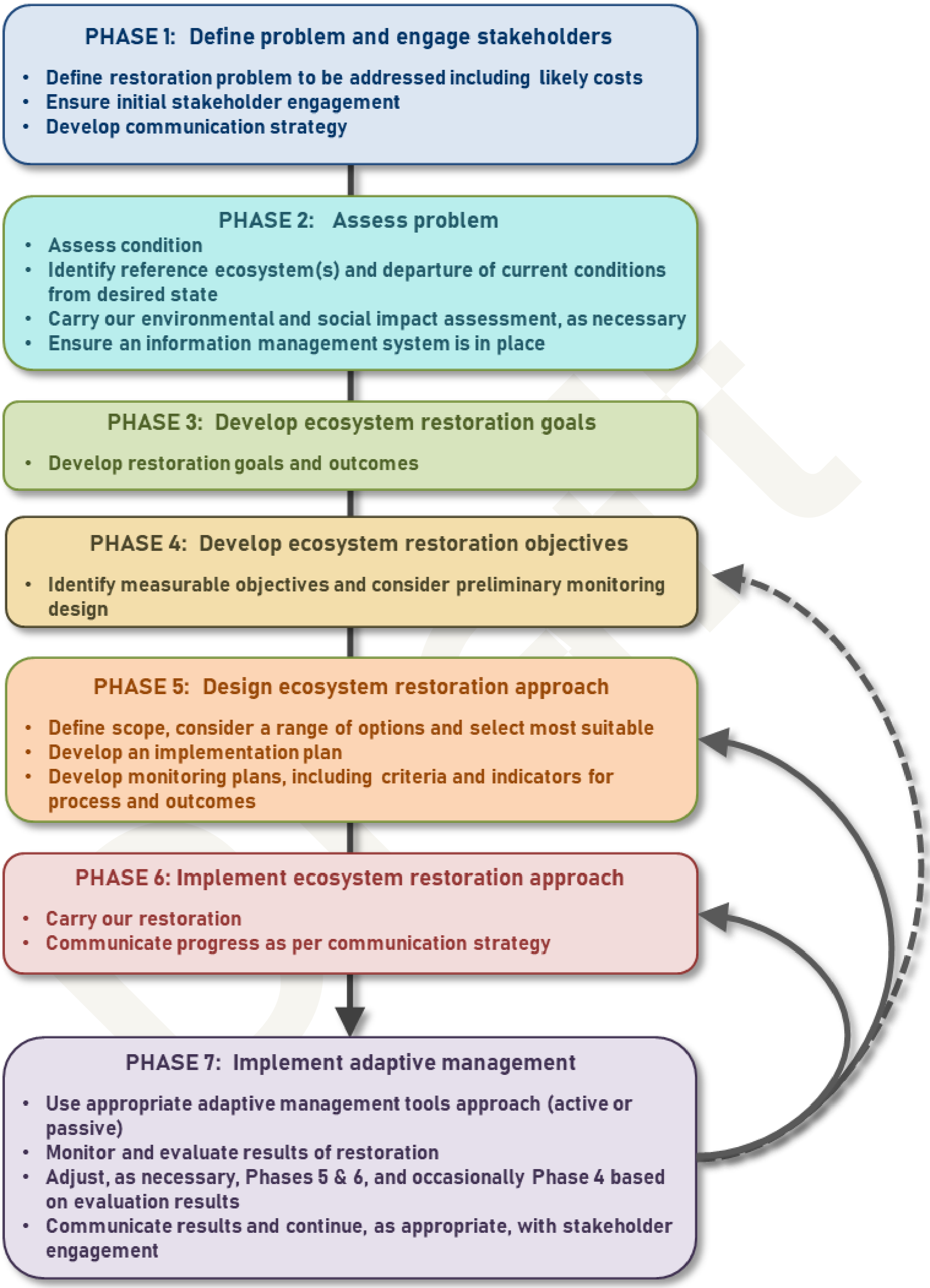
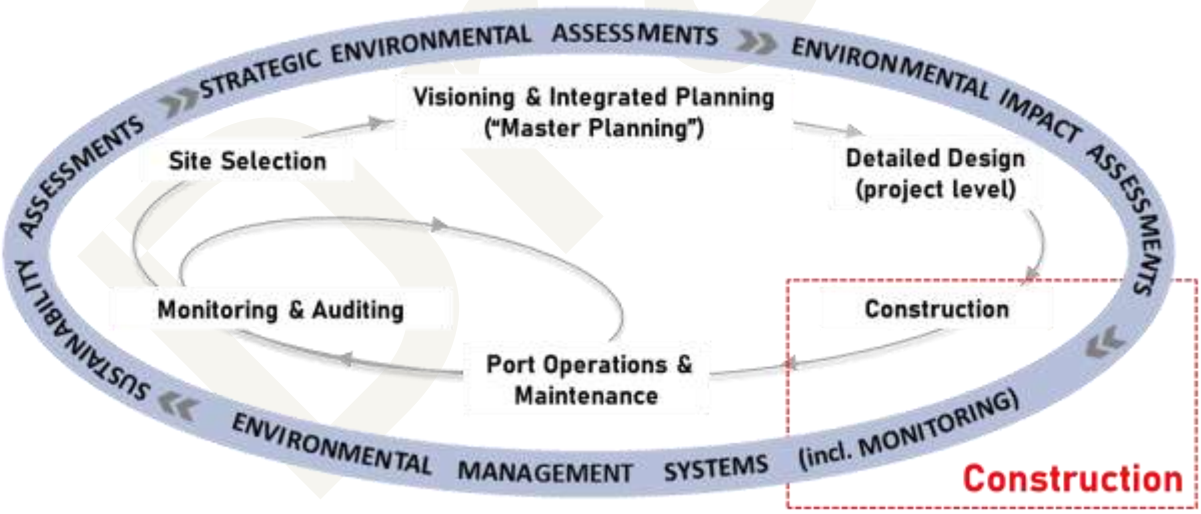


Figure C.10 Generic 7-step process proposed for planning and implementation of effective, efficient, and engaging ecosystem restoration programmes (adapted from: Keenleyside et al. 2012)

SECTION D: CONSTRUCTION



D.1 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.1.1 International Assessment Framework for Dredge Management

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention) (1972) and 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.1, IMO 2014[9]).

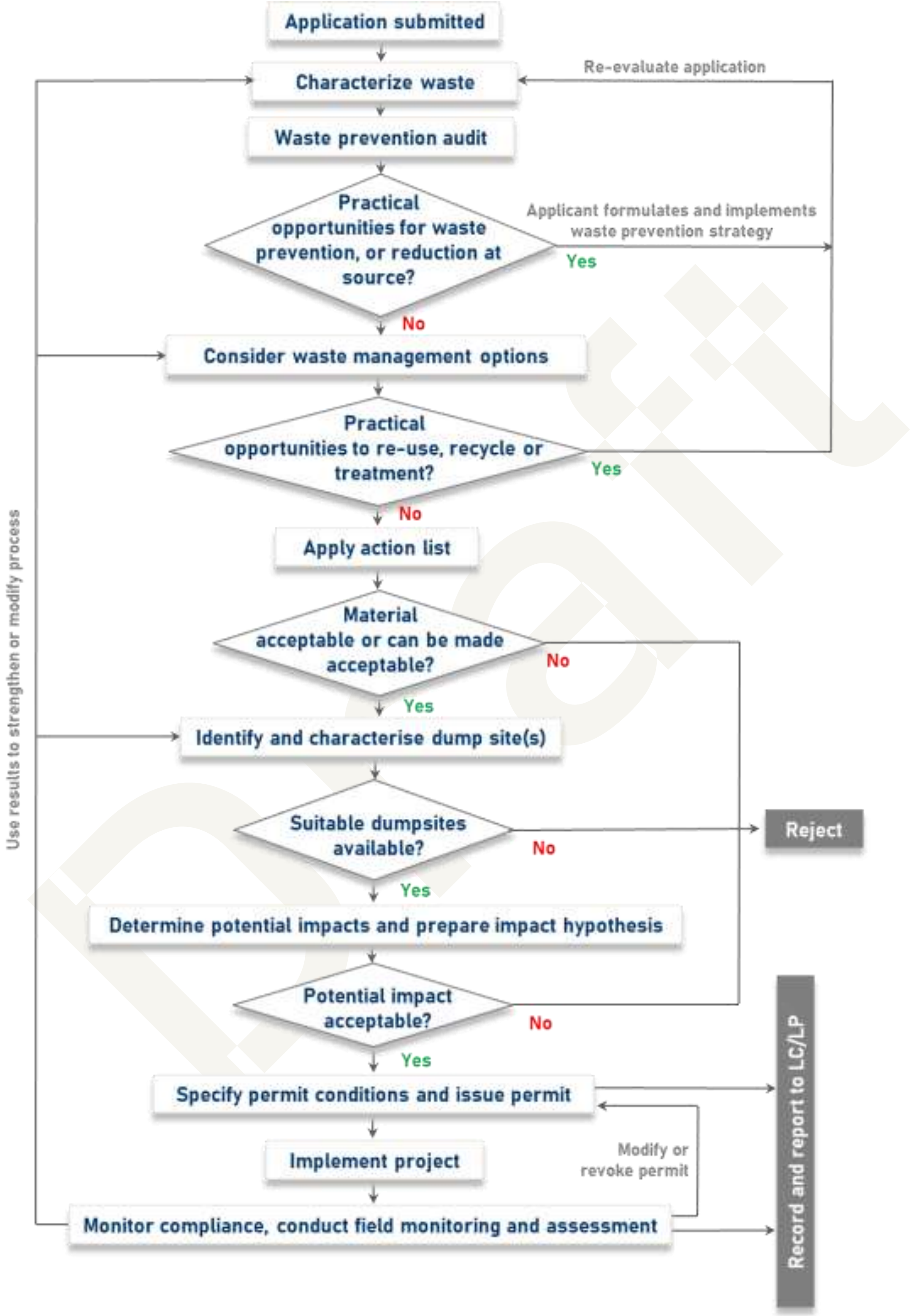


Figure D.1 London Convention & Protocol: Assessment framework (adopted from IMO 2014)

[9] 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 identify any feasible (or reasonable) opportunities for waste prevention and minimization at source, to prevent having to dispose of dredge material to sea. and whether disposal at sea is. Where alternative to disposal at sea is identified, applicants are is expected to formulate and implement a waste prevention strategy.
- Development of an action list - member states are required to develop national Action List 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.1.2 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)
- Dredged material as a resource (EnviCom WG 104, 2009)
- 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.2) 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.

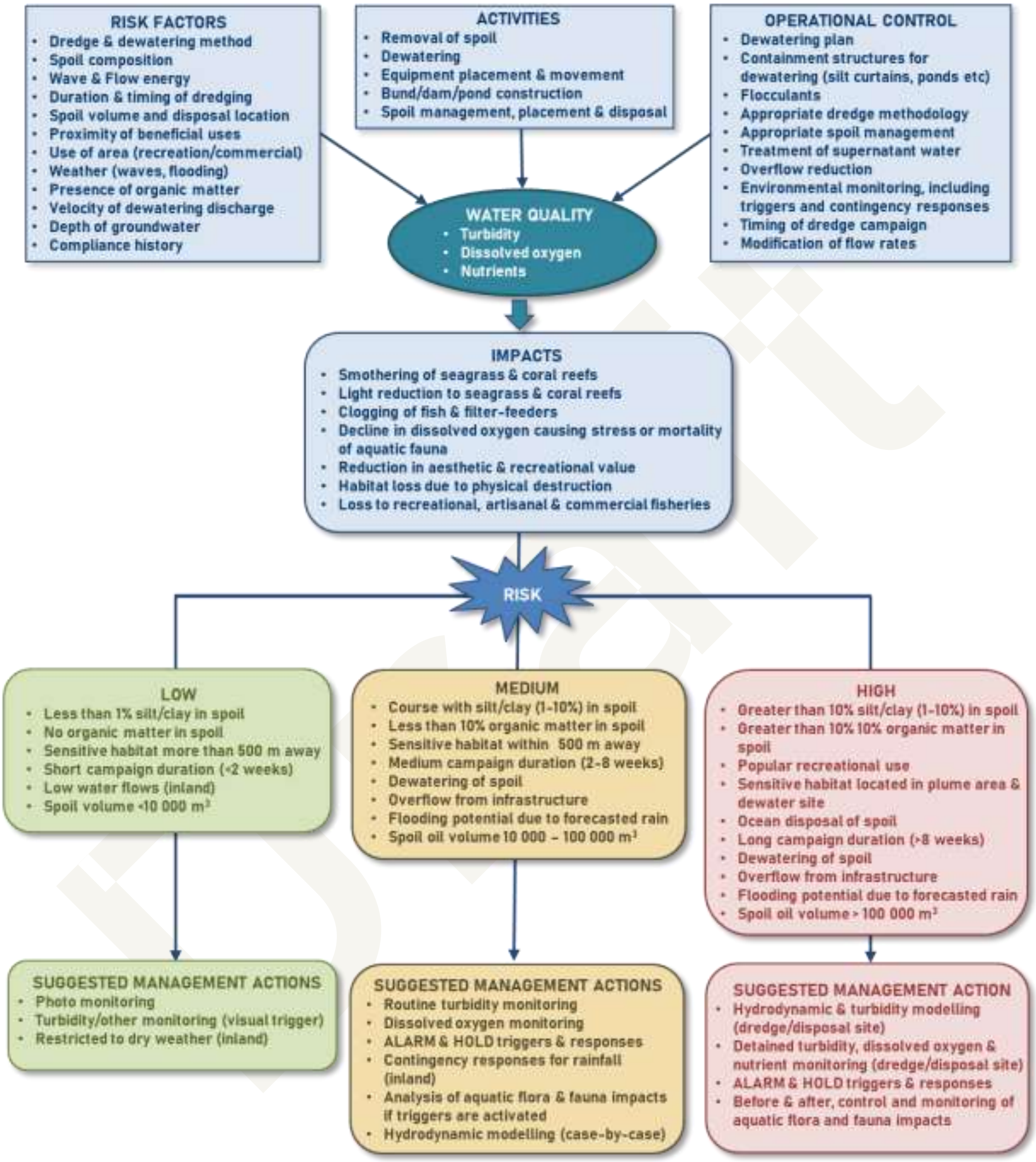


Figure D.2 Example: Synopsis of risks and proposed management linked to water quality as per EPA South Australia's dredge guideline (source: adapted from EPA South Australia 2020)

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 Construction Environmental Management Plans

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). Green 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 to protect against potential claims, and responsible contractors are often favoured by port developers (Nihon Kaetsu 2022).

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).

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.3. 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 & sedimentation, noise & 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 have to be 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.3 Process for development and implementation of a construction environmental management plan (source: adapted from LPC 2019)

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 defined as the process whereby infrastructure that has come to the end of its productive life, is dismantled in an environmentally responsible way, and the subsequent restoration of the site to its pre-construction status. Presently guidance on the decommissioning of port infrastructure is not readily available in the international space, 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.

Decommission should be a 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 considering appropriate technological solutions, as well as stakeholder considerations. Impact assessments should be undertaken by qualified specialists considering possible environmental, social and economic implication of decommission 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 materials or methods. This selection process may take the form of an Environmental Impact Assessment, further 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)

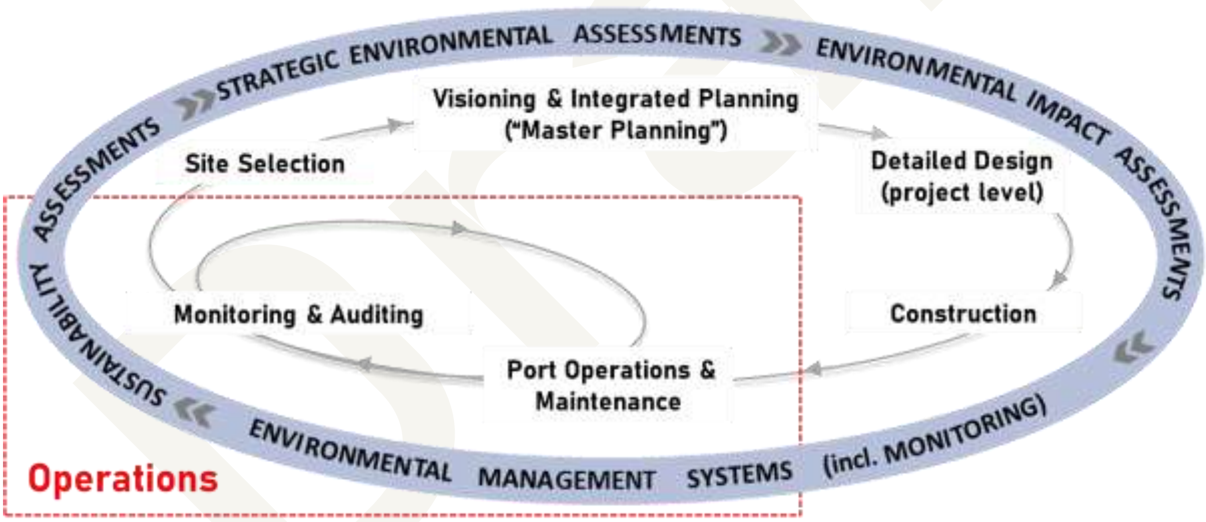
A decommissioning plan articulates management process and actions to be undertaken during decommissioning, addressing:

- 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 does 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 should be submitted at 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 however 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

Environmental Management Systems (EMS) are regulatory structures, developed within organisations, rather than being regulated by governments, that aim at proactive and systematic, continuous environmental improvements. Specifically, 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 stipulate 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 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, and 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 of 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. Most 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 on West African ports found that context-specific factors strongly influence the type of green 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.

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 (Figure E.1) building largely on these existing approaches but incorporating elements to address the latter challenges. 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).

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.

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

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.

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.1.2 '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.

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 is 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).

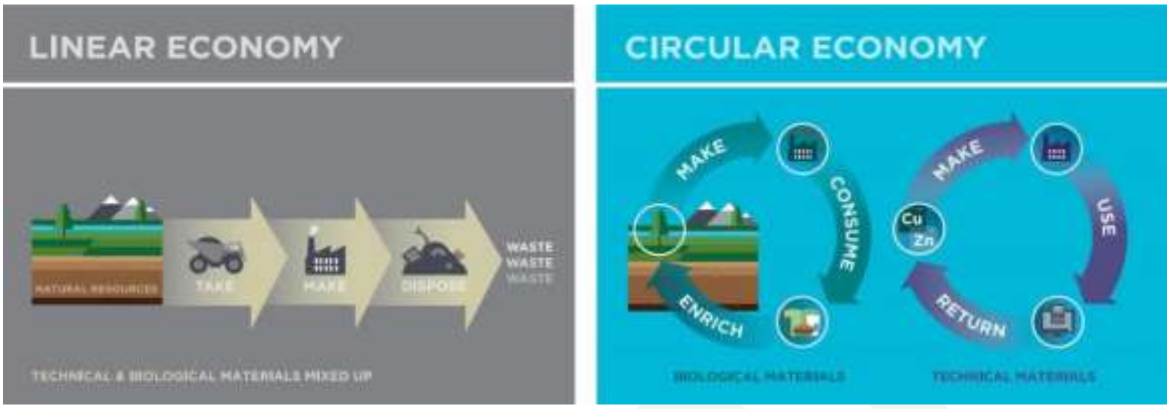


Figure E.2 Comparison between the linear and circular economy (source: https://ellenmacarthurfoundation.org/)

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 industry 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 Sornn-Friese 2017).

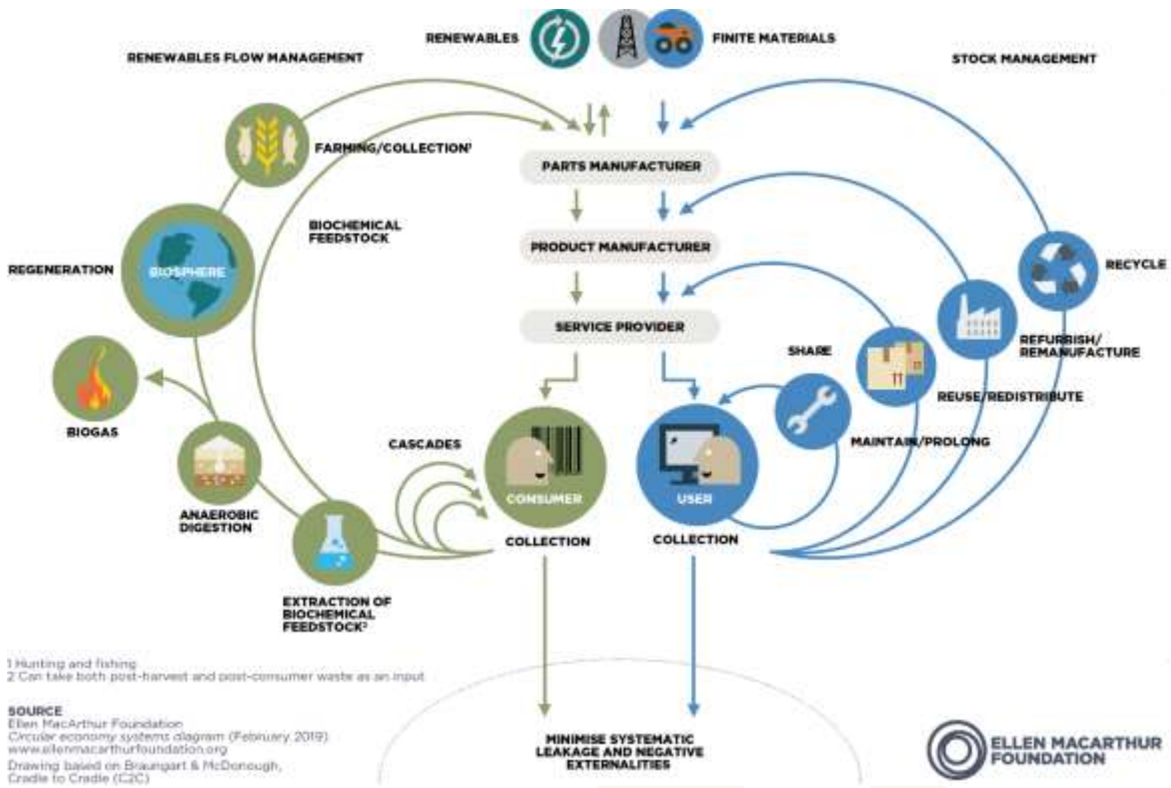


Figure E.3 The circular economy system, showing the biological and technical cycles (source: https://ellenmacarthurfoundation.org/)

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 for Green Port.

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 and assessment 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		• Setting a good minimum wage for the port employees and encouraging similar practices in the port community • Taking responsibility for the application of ethical standards throughout the supply chain (e.g., working conditions and human rights in developing countries) • Including sustainability requirements (e.g., Fairtrade label) in procurement • Supporting local communities in need through social projects targeting sustainable growth • Supporting local social institutions (e.g., schools, orphanages, NGOs)
		• Improving health and safety awareness of employees and local communities through training and transparent communication on health and safety risks • Minimizing environmental externalities (e.g., air pollution, water pollution, noise) of port operations and greening of the port and urban areas • Initiatives on sustainable / safe mobility and projects targeting congestion • Enhancing port safety and security and minimizing risks • Awareness raising and actions against the use of addictive substances (e.g., tobacco, alcohol, drugs) • Protecting habitats and biodiversity in and around the port area
		• Competence and talent policy for port employees • Enhance life-long learning for the port employees • Cooperating with local schools, universities and research centres in educational programs, internships and port visits. • Offering training to port professionals through dedicated institutions • Creating synergies with universities in port research and development projects
		• Gender-neutral hiring and remuneration policies • Promoting women to leadership roles; training and hiring more women for port operational positions (e.g., crane operators) • Leveling the male/female ratio of port employees for operational and managerial positions • Taking measures that make the port working environment more attractive to women (e.g., separate toilets, promotional campaigns, family-friendly HR-policy)
Sustainable production & consumption; equitable distribution of goods & services		• Supporting local projects targeting the provision of food to families/communities in need • Encouraging the transfer of food surpluses out of the warehouses in the port to charities, food banks and community organizations • Supporting the trade/storage of Fairtrade and other ethically produced agricultural products in cooperation with NGOs and community organizations • Sourcing Fairtrade food products for own catering
		• Providing drinking water and clean sanitation facilities for port employees and visitors (e.g., vessels' crew, truck drivers) • Minimizing/optimizing water consumption in the port area • Harvesting rainwater for port use • Protecting water-related ecosystems (e.g., estuaries, wetlands, mangroves) in and around the port area • Projects protecting freshwater resources (e.g., wastewater and stormwater treatment)
		• Locally producing and/or sourcing renewable energy • Supporting research and development on clean energy technology • Producing and/or recovering energy from industrial waste streams • Investing in energy-efficient port equipment (stationary and mobile material handling equipment, lighting and technology) • Encouraging clean energy initiatives from third parties (vessels, tenants and operators) through appropriate instruments (incentives, clauses in lease/concession agreements) • Providing Onshore Power Supply from renewable sources • Providing cleaner (marine) fuels in a safe and efficient manner • Optimizing port operations and processes (logistics, port calls)
Sustainable production & consumption; equitable distribution of goods & services		• Achieving economic growth through diversification, innovation and technological modernization • Generating economic growth in an environmentally sustainable manner • Ensuring that economic growth positively impacts local communities economically and socially • Promoting employment, including opportunities for disadvantaged groups and young people • Striving for a healthy and safe working environment for all: specific actions related to safety and ergonomics, and creating a good work/life balance • Generating a sustainable model for cruise tourism • Taking responsibility for applying ethical standards throughout the end-to-end supply chain (e.g., working conditions and human rights in developing countries)

ASPECT	SDG	EXAMPLES OF ACTIVITIES IN PORTS
	9	• Devising sustainable port development policies supported by relevant key performance indicators • Digitally optimizing infrastructure and port operations/processes/services • Piloting, testing and implementing innovative IT and digital technologies in the port for public and private use • Foreseeing the adaptation of port infrastructure to withstand climate change • Adapting port infrastructure and processes to meet market demands (such as increasing ship size) • Sustainable port development projects • Investing in infrastructure for all transport modes to enable a balanced modal split • Minimizing environmental impact of the port activities
	10	• Achieving equality within the port independent of gender, origin, belief, conviction etc. • Port community initiatives being all inclusive irrespective of socio-economic background (e.g., supporting sensitive social groups) • Social background-neutral hiring and renumeration policies • Taking responsibility for the application of ethical standards throughout the supply chain (e.g., working conditions and human rights in third world countries) • Financial support to local communities in need and social projects targeting sustainable growth of neighbouring communities • Ethical investment and banking
	11	• Improving sustainable mobility and reducing congestion for both employees and goods • Restoring ecosystems and making the port accessible and attractive for people in neighbouring urban areas • Minimizing environmental externalities of port operations (e.g., air pollution, water pollution, noise) • Disaster recovery planning • Community engagement programs and initiatives • Supporting local communities in need through social projects targeting decent living and working opportunities that generate sustainable growth of neighbouring communities • Supporting local social institutions (e.g., schools, orphanages, NGOs)
	12	• Sustainably managing natural resources, chemicals and waste • Implementing responsible procurement and sustainable investments in port area management and development as well as the end-to-end supply chain etc. • Encouraging circular economy and industrial reuse and mutually beneficial use of resources in the port community • Optimizing port operations/processes/services • 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)
Natural resource base	13	• Improving energy efficiency of port operations, processes and services • Enabling the reduction of carbon and greenhouse gas emissions within the port area • Adapting port infrastructure and port related operations to Climate Change • Providing services to reduce greenhouse gas emissions at sea and on the waterways, as well as the hinterland part of the supply chain • Producing and/or sourcing renewable energy • Encouraging third parties (vessels, tenants and operators) to take clean energy initiatives, by providing incentives and integrating clauses in lease and concession agreements
	14	• Taking measures to prevent waste from ending up in the oceans (e.g., port reception facilities, fishing for litter, cleanup actions) • Promoting sustainable fishing activities • Supporting research regarding sustainable use of maritime resources • Reducing the emission of CO_2, SO_2, NO_x, NH_3 from port- related activities to avoid acidification of the oceans • Minimizing water pollution through adequate wastewater treatment facilities • Protecting coastal and estuarine ecosystems • Minimizing disturbing factors such as underwater noise for marine mammals
	15	• Supporting local projects regarding nature development and biodiversity • Recovering and protecting nature and biodiversity in the port surroundings • Preventing deforestation through the usage/procurement of sustainably certified wood and paper • Offering nature and environmental education programs to employees • Port area development in balance with ecosystems • Minimising environmental externalities of port operations (e.g., air pollution, noise)
Governance & Institutions	16	• Constructive dialogue between employer and employees • Good governance (a clear policy statement, stakeholder analysis, defined measurements, consistent reporting) • Peace initiatives (e.g., peace education on the work floor, prevention of illegal arms trafficking) • Addressing security: cyber security measures, commercial and operational data protection, improving the careful use and protection of personal data • Open dialogue and collaboration with all stakeholders (including emergency services, customs and armed forces) and availability of a hotline for complaints and questions • Transparent internal and external communication
	17	• Partnerships with local communities for port-city relation initiatives • Partnering with other ports and parties in the logistics chain in joint projects of common interest • Public-private partnerships for funding and implementing sustainability projects • Establishing supply chain partnerships for ensuring CSR values throughout the chain • Cooperating with other ports for educational/training purposes (e.g., joint port training programs and centres) • Joint research and development projects involving port stakeholders, academia, industry and authorities

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).

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)
		Reuse existing building/facility where possible
		Purchase furniture/facility items of reused or recycled material
		Use recycled materials in building/facility construction
	Environmentally friendly production of materials	Use timber products from recycled or sustainably sourced resources.
		Avoid or minimise use of PVC plastic
		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
		Specify low maintenance and durable materials
		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
		Recycle material such has 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
		Greywater collection and treatment systems
		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
		Identify important habitats and implement measures for protection, enhancement, or restoration
		Incorporate existing topsoil and subsoil into development (where of suitable quality)
		Incorporate existing vegetation into development (where appropriate)
		Use environmentally friendly landscape products
		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 pollutant and GHG emissions, are placing energy consumption in ports under greater scrutiny (Iris and Lam 2019).

To assist port in their efforts, PIANC published their guideline entitled '*Renewables and energy efficiency for maritime* ports'[10] (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).

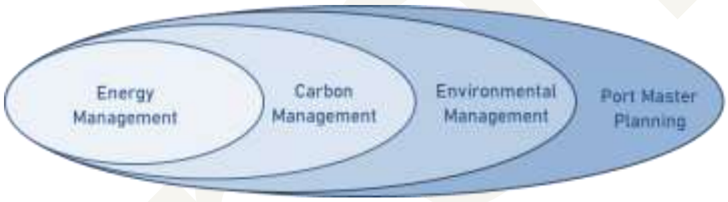


Figure E.4 Context of port energy management within broader framework of environmental management and port master planning (source: adapted from Sdoukopoulos et al. 2019)

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

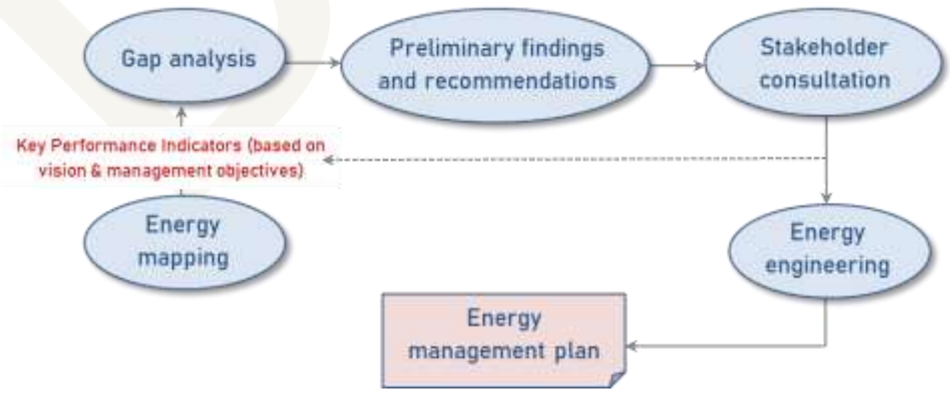


Figure E.5 Port energy management planning process (source: adapted from Boile et al. 2019)

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

[10] 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 but 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).

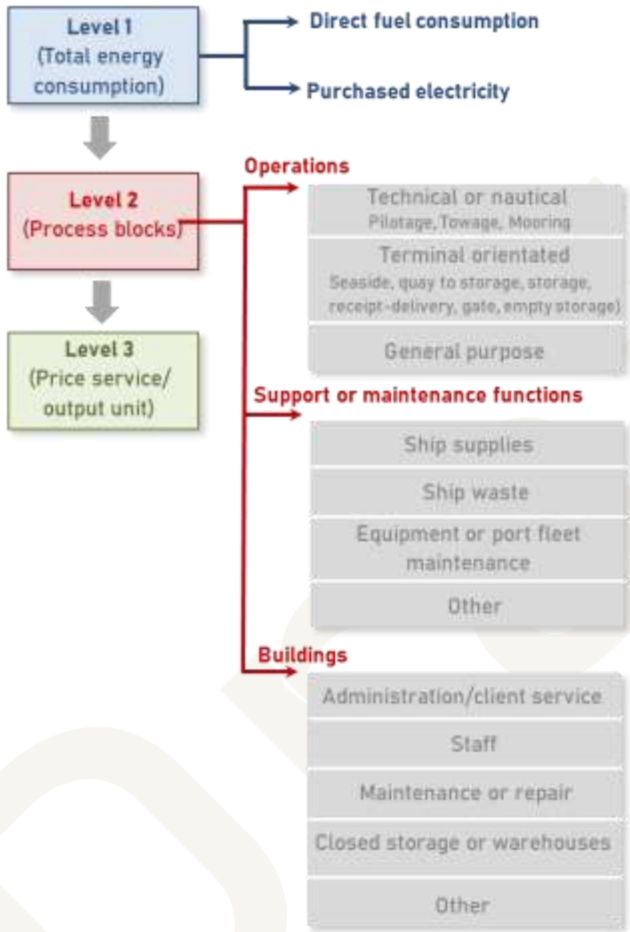


Figure E.6 Method to construct a port energy map (source: adapted from Boile et al. 2019)

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 meet 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.

Stakeholder consultation and buy-in remains and 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 as 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 set 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).

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 energy from water flows, either positioned at horizontal and vertical axes. 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 therefore 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 °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 (Bjerkan 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

While use of electricity as an alternative energy source is still a challenge for many African ports because of unreliable electricity supplies especially where they rely on local or national public grids. Generating own 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, enough capabilities of power supply companies, 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 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 account 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 up, 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 stead speed, and shifting gears at low rpm not only result 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
		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
		Clearly labelled and accessible individual switches for lighting zones, dimmers, and sensors
	Manage energy use and minimise consumption	Perform quality monitoring of building services performance
		Electrical and gas sub-metering for separate energy uses
		Install peak energy demand reduction systems

TYPE	CRITERIA	PROPOSED MEASURES
		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
		Facilities to reduce business travel (e.g., videoconferencing)
	Reduce GHG gas emissions from vehicles and equipment	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 (https://sustainableworldports.org/wpcap/)
	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
	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
	Providing conditions (e.g., IT systems, vessel traffic management) for efficient vessel servicing and handling (e.g., slot system)
Encouraging (incentives to port users)	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
	Provide incentives for reduced carbon footprint within concession agreements
	Provide visibility to performers through 'best performer of the year' type of awards
Engaging (sharing knowledge and skills)	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
	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
Enforcing (setting rules and ensuring compliance)	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:

- 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 perspective but an economic (ESPO 2012a). A use-friendly schematic illustrating the key elements in wise or sustainable water consumption practice is presented in Figure E.8 (Sensiba 2021).

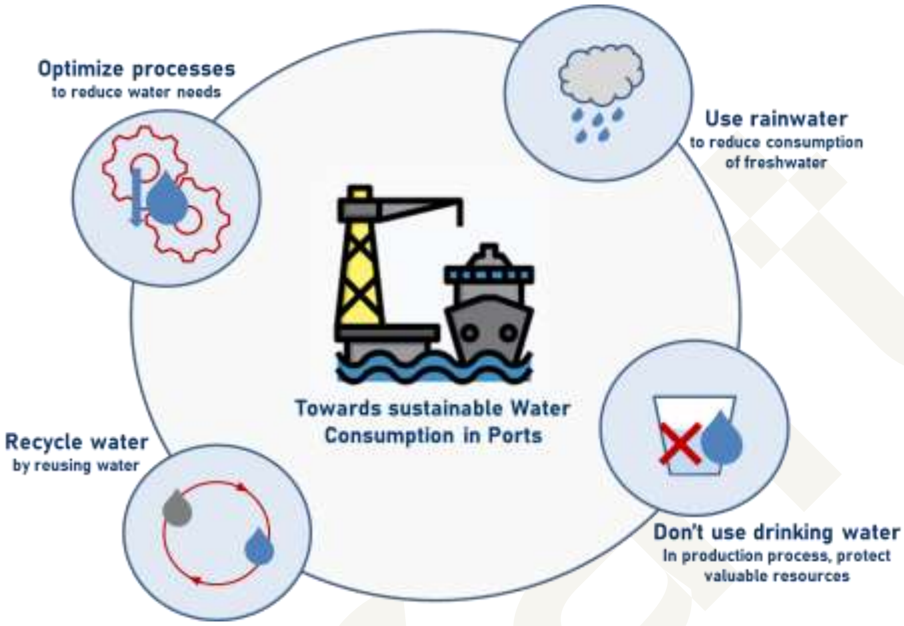


Figure E.8 Key elements of sustainable water consumption in ports (source: adapted from Sensiba 2021)

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 voidance 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 3rd Party verification through incentives;
	Promote and disseminate positive experiences such as proactively reducing port operators' costs by reducing their water usage
	Provide visibility to good performers through 'best performer of year' type of awards
Engaging (sharing knowledge and skills)	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).

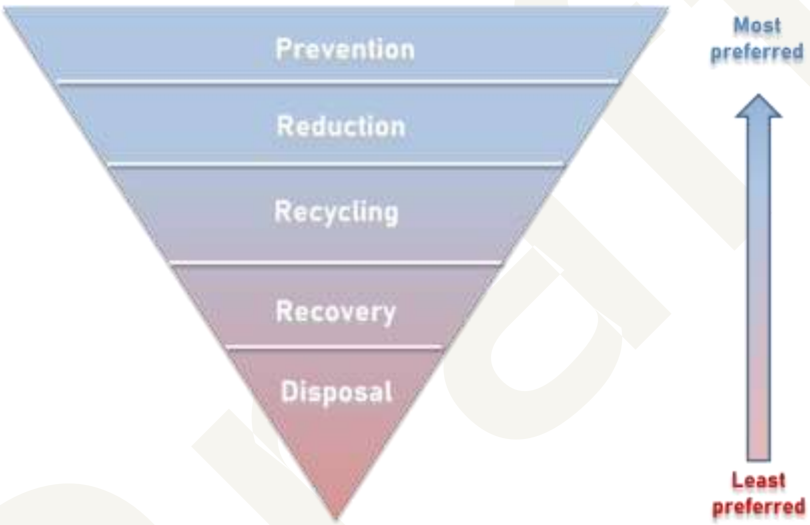


Figure E.9 A hierarchy to consider in waste (including wastewater) management (source: adapted from UNEP 2013)

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 has 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
	Apply incentive schemes rewarding vessels with less water in sludge
Engaging (sharing knowledge and skills)	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
	Sort biological waste (where possible) and monitor its green energy production
Enforcing (setting rules and ensuring compliance)	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 port 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 5.1 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 5.2).

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 results 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, socio-economic consequences such as loss of aesthetic value (e.g., suspended solids, nutrient loading resulting in excessive algal growth, solid waste), 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 within 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 guide includes 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
	Avoid toxic anti-fouling paints
Prevent damage from potential flood events and water tables changes	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 3rd 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 annoying degree of unwanted sound – is the 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 hierarch of noise controls indicates an order of preference for action to reduce noise pollution (Figure E.11) ranging from personal protective equiment (least preferred option to noise elimination (most preferred option) (NIOSH 2022).

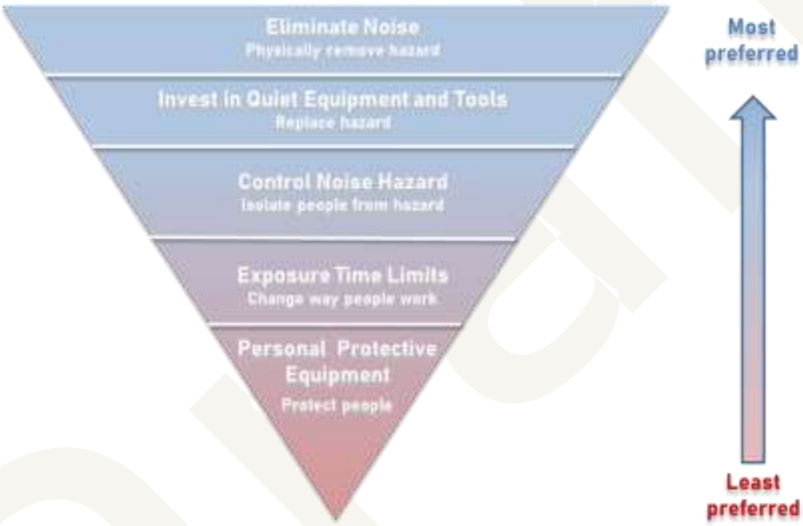


Figure E.11 A hierarchy to consider in noise pollution management (source: Adapted from NIOSH 2022)

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 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.13.1 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.13).

E.13.1.1 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.17. 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.13.1.2 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.17 lists some examples of litter booms currently in use. Litter booms are a simple intervention, a floating barrier anchored 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.17). This system is being replicated elsewhere.

Figure E.13 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.13.1.3 Barriers

There are several other types of barrier systems which rely on more complex design and technology. 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.17), 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.17: Examples of litter removal and clean-up technologies used internationally (adapted from Schmaltz et al. 2020)

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

E.13.1.4 Moored motorized systems

Moored motorized systems have also been successfully used as litter traps worldwide (Table E.17). 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.17) 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 place 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 (300 gallons) a minute.

Another litter skimmer is the Seabin (Table E.17), 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.13.1.5 Vessels, drones and robots (aquatic vacuums)

Litter trapping vessels are more sophisticated technologies deployed to control marine litter (Table E.17). 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.13.2 Proposed Decision Criteria

Table E.18 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 prosed by Armitage and Rooseboom (2000) and Schmaltz et al. (2020).

Table E.18: 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.14 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.14).

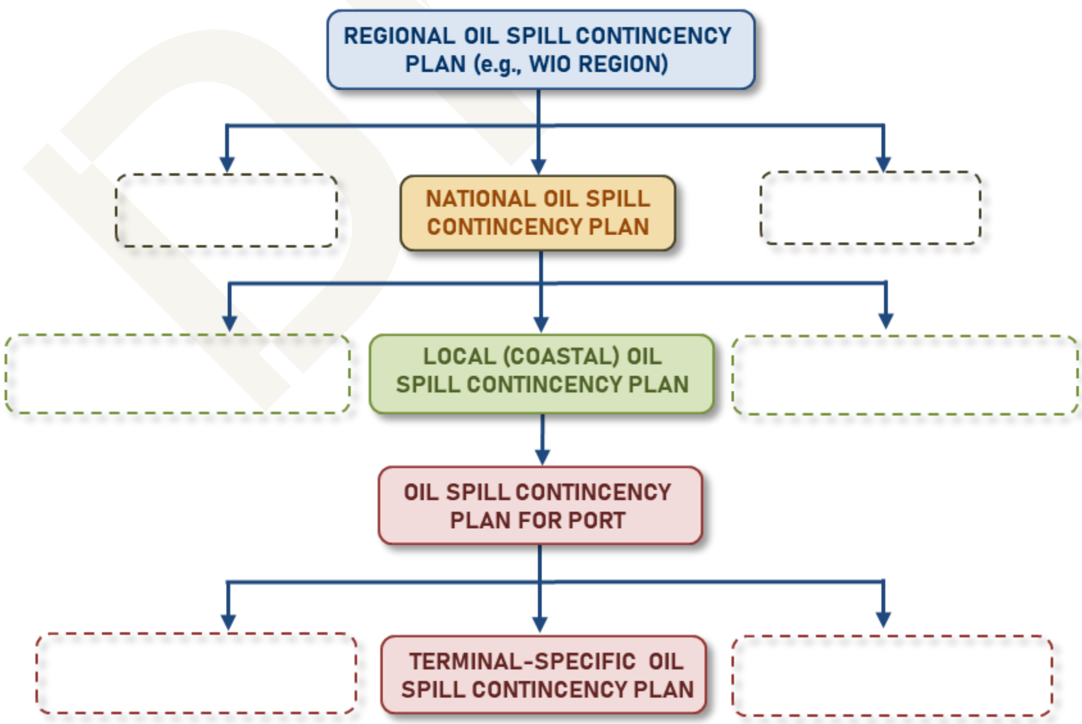


Figure E.14 Examples of different tiers of oils spill contingency planning

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.15, while an example for an environmental contingency plan, such as an oil spill contingency plan, is provided in Table E.19.

Table E.19: Example: Table of Content for an Environmental Contingency Plan (adapted from UNEP/OCHA 1996b)

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

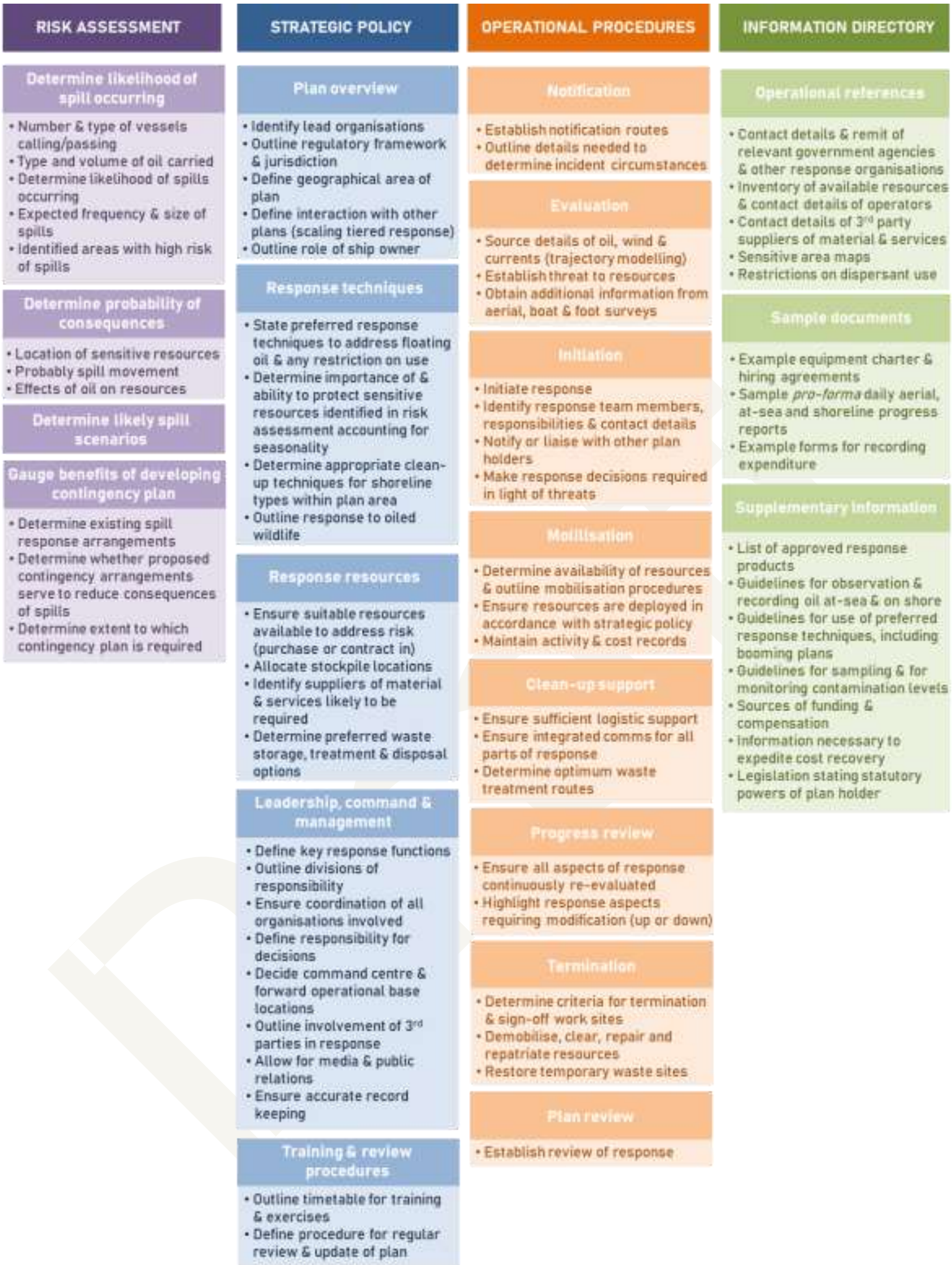


Figure E.15 Key elements within each of the four components of an oi spill contingency plan (source: ITOPF n.d.)

E.15 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 environment status, 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.16 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 therefore critical that before undertaking such a programme such resources are secured. Resources for monitoring, as for the other activity-based management interventions and actions, need to be planned and budgeted for by the responsible port authorities for such monitoring, 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.15.1 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.

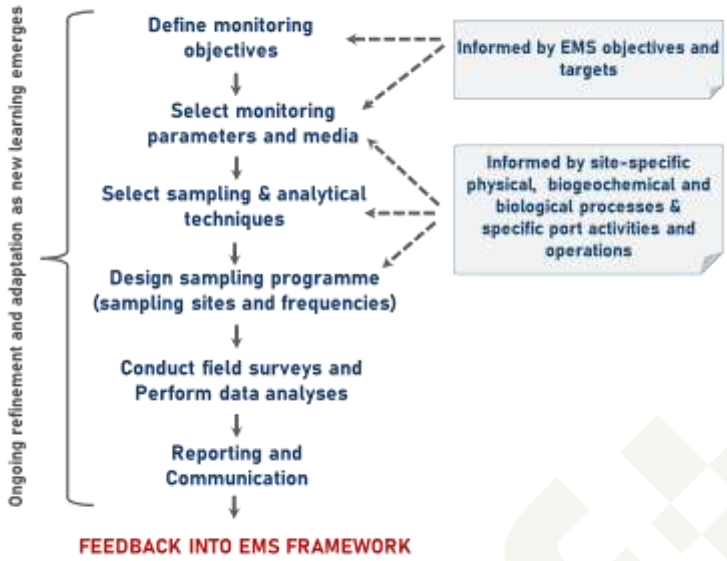


Figure E.16 Key components of in an environmental monitoring and evaluation programme

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

E.15.2 Monitoring Parameters and Media

The selection of measurement parameters (or indicators) is site-specific and should be suitable to quantify whether monitoring objectives (as defined above) are being complied with, as well as the defined pollution sources and associated pollutants. 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, this 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.20.

Table E.20: 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 exposing people to health and environmental impacts. Emission 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 often strong 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 a year 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 media (biota) are used in various ways in long-term monitoring programmes, for example surveys of living organisms (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 bio-accumulation studies in the marine environment. The basis for biomonitoring with bivalves is their ability to bio-accumulate 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 indicator species. Rather than measuring entire 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) and to 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
- 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/
- US-EPA (2000) Evaluation guidelines for ecological indicators. https://archive.epa.gov/emap/archive-emap/web/html/ecoind.html
- Environmental Protection Agency (Ireland) (2001) Parameters of water quality: Interpretation and standards. 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-stategy-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.ecoports.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.15.3 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
- 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
- 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
- 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.15.4 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.15.4.1 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.15.4.2 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
- 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.15.5 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
- 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 accessible to all relevant staff in the organisation to inform timeous and smart management responses (see Chapter E.15 for more detail).

E.15.6 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 timeously. Environmental monitoring programmes require less frequent reporting, e.g., usually six-monthly or annually. In general monitoring reports should include (Figure E.21):

- 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.21: 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

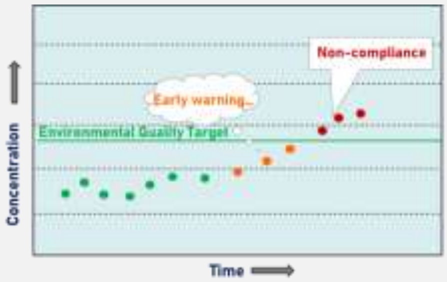
4.1 Sampling and *in situ measurements*

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.16 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 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 comprise six components (Bourgeois 2019), as is illustrated in Figure E.17:

- 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.

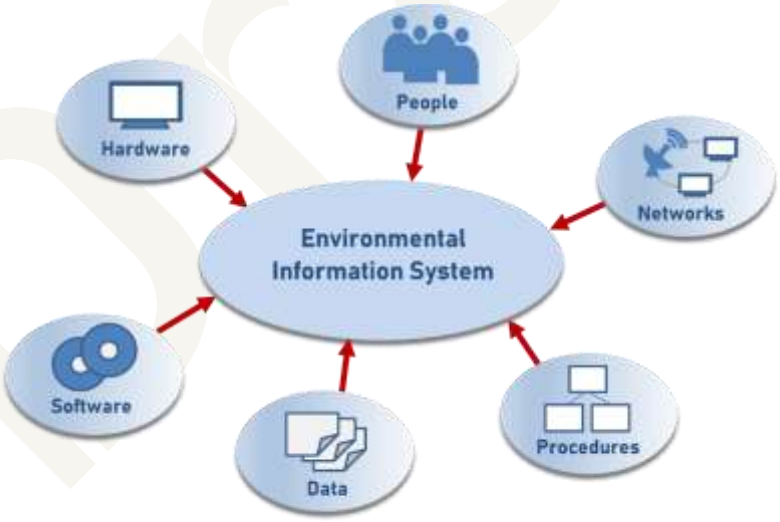


Figure E.17 Key components of an (environmental) information system

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.17 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* (CDSF) provides a holistic approach to capacity development that also hold relevance for port capacity building approaches. Within this holistic approach six underpinning elements (or principles) are considered 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.18).

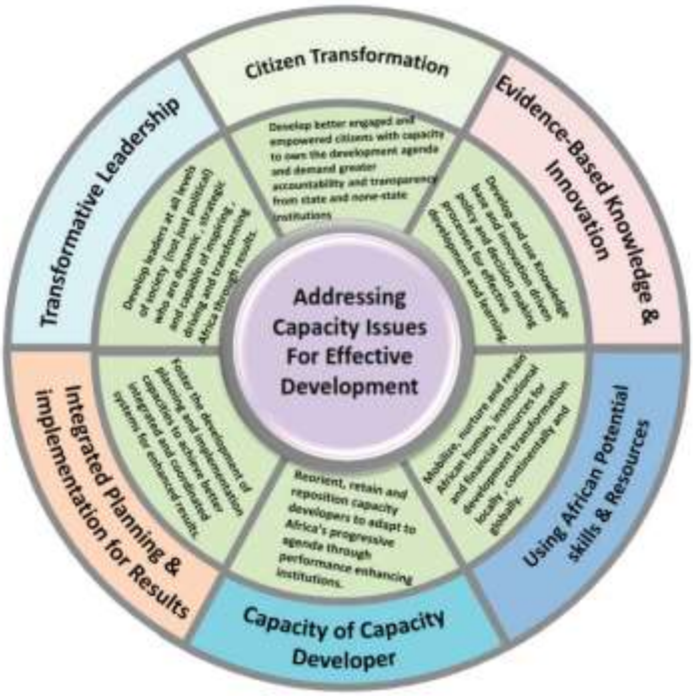


Figure E.18 Key principles underpinning effective capacity development in Africa (source: AU 2015)

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.19) (OECD 2008; Thapa et al. 2019; Bob-Manuel 2020):

- Assessment – during this stage skills gaps are identified within the contact 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.

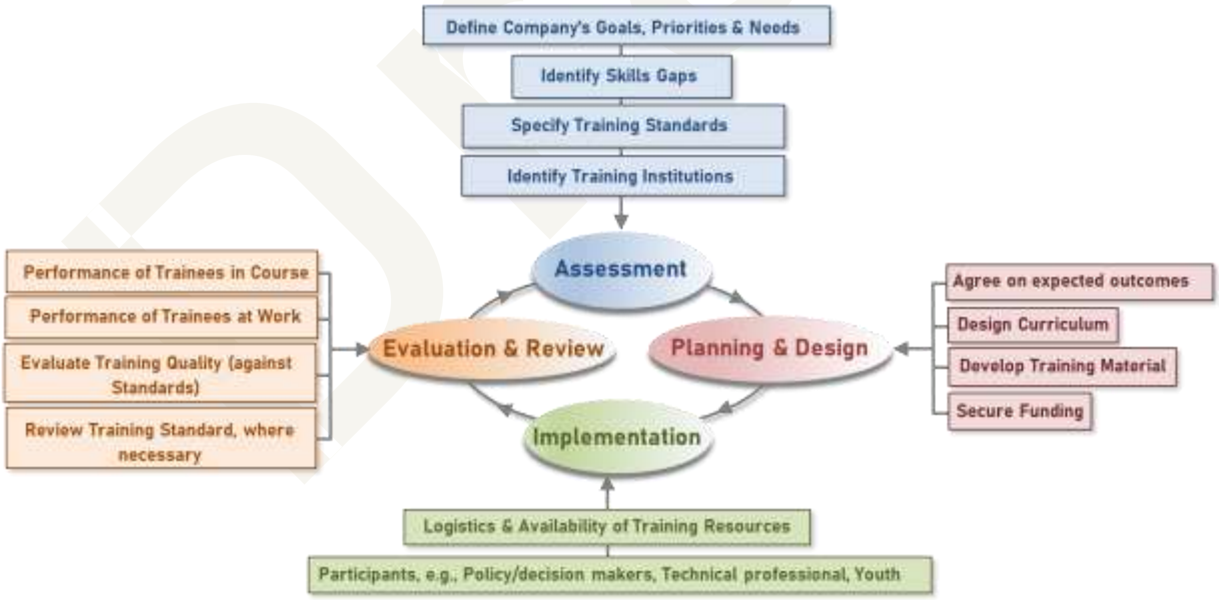


Figure E.19 Four key stages of capacity building programmes (adapted from: Thapa et al. 2019; Bob-Manuel 2020)

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 also is 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.18 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, referring to 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 infra-model 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 E.20).

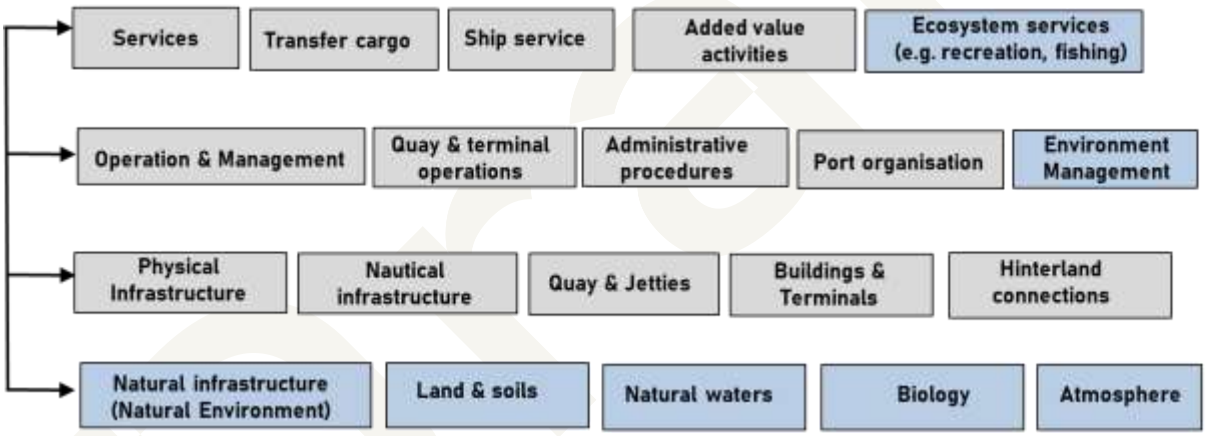


Figure E.20 The natural environment (natural infrastructure or natural capital) in port inframodel (source: Taljaard et al. 2021)

E.18.1 International Approaches

E.18.1.1 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.22.

Table E.22: 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 relates to the material benefits of environmental assets, whereas the other types of services related 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 poses five ecosystem accounts (UN 2019) (Figure E.21):

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 sequestrate 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 accounts (monetary terms).

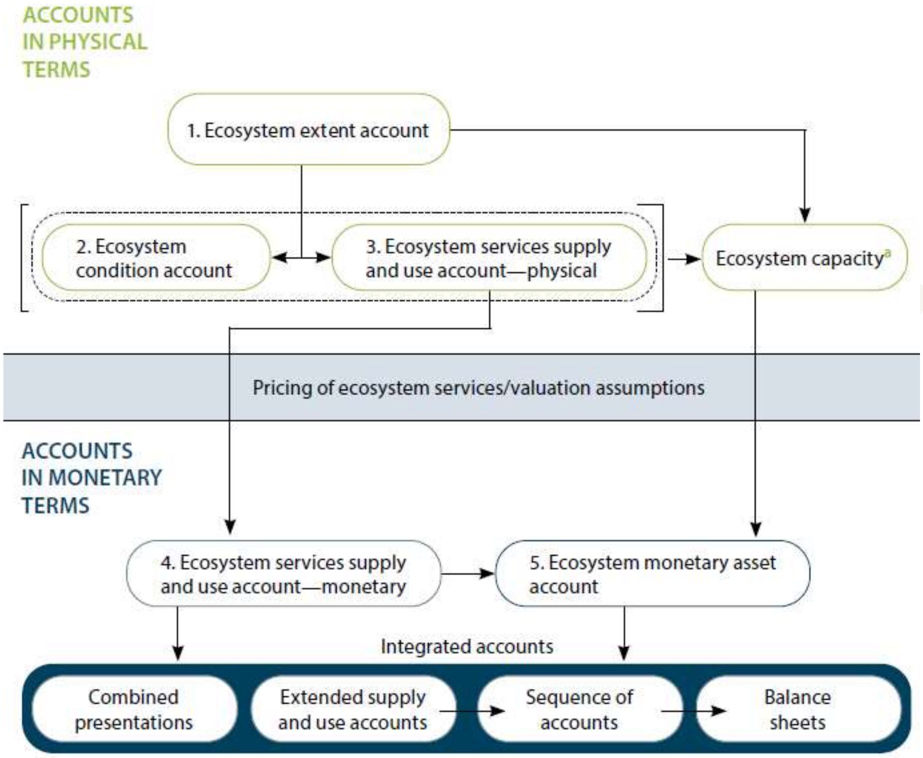


Figure E.21 Schematic of key ecosystem accounts and their relation (Source: UN 2019)

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.*

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 aimed at 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 the 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.18.1.2 Global Ocean Accounts Partnership

The Global Ocean Accounts Partnership (GOAP) has been collaborating with UN Statistics (UNSD) 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.22) 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.

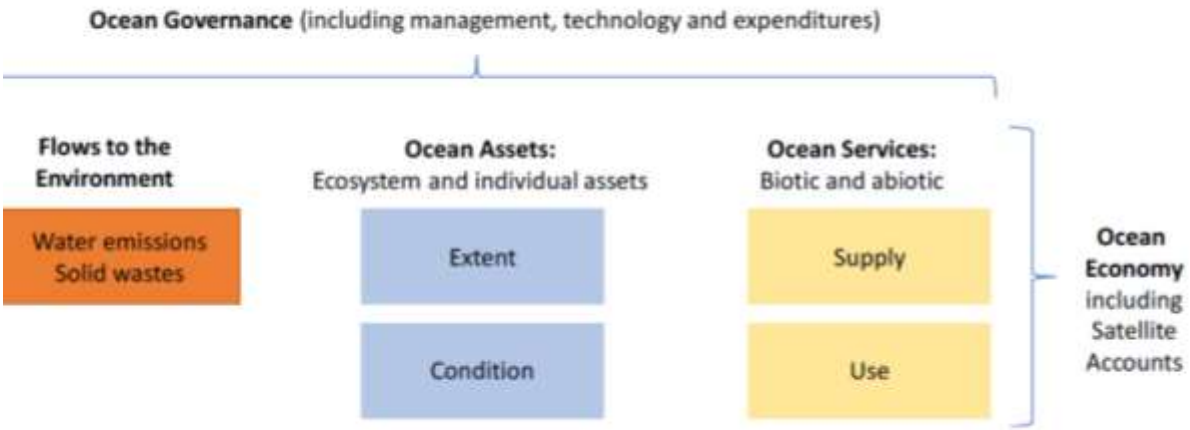


Figure E.22 Simple framework for Ocean Accounting (source: GOAP 2019)

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, such as the 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.18.2 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.

Adopting the basic spatial unit (BSU) as a means of organising delineation spatial units, Figure E.23 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.

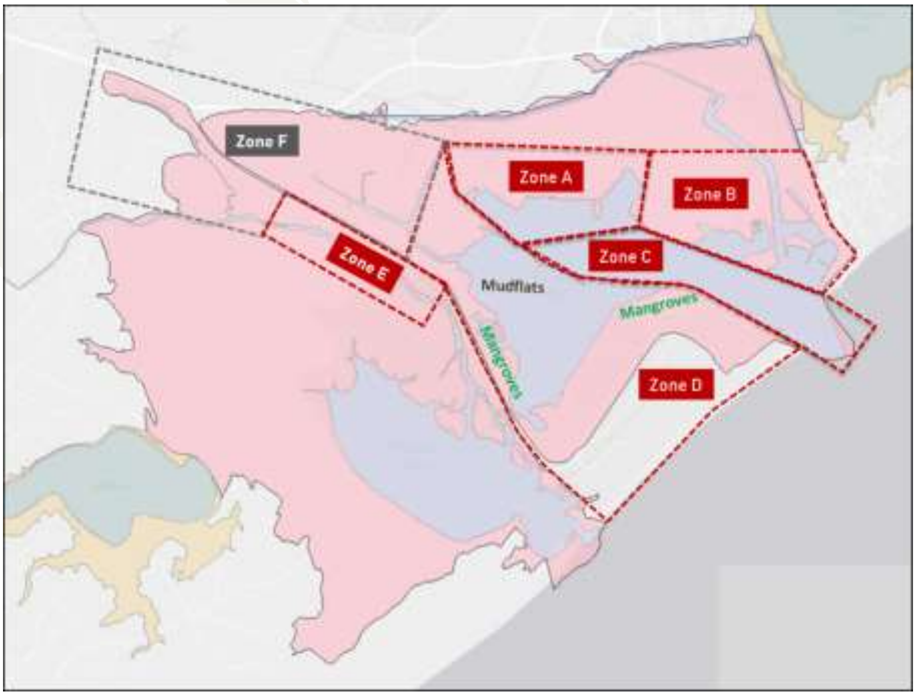


Figure E.23 Conceptualisation of basic spatial unit zonation in a port providing spatial resolution to ecosystem asset accounts

Table E.23: 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
Opening stock (Baseline):						
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	-
Increase/Decrease:						
Open water area	*0*	-	-	-	-	-
Mudflats	*0*	-	-	-	-	-
Sand banks	*0*	-	-	-	-	-
Dunes	*+10*	-	-	-	*+10*	-
Mangroves	*-20*	-	*-20*	-	-	-
Coastal Forests	*0*	-	-	-	-	-
Closing stock (Year n):						
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
Opening stock (Baseline):						
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	-
Increase/Decrease:						
Open water area	-	-	-	-	-	-
Mudflats	↑	↑	-	-	-	-
Sand banks	↓	-	-	↓	-	-
Dunes	-	-	-	-	=	-
Mangroves	↓	-		-	↓	-
Coastal Forests	-	-	-	-	-	-
Closing stock (Year n):						
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.24, while an example of ecosystem accounting is provided in Table E.25.

Table E.24: 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.25: Example: Proposed ecosystem services accounts for ports

ECOSYSTEM SERVICES ACCOUNT	Physical (#)	Monetary ($)
FISH (SUBSITENCE & RECREATION)		
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
Increase/Decrease:	*-100*	*-2 000*
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
NURSERY (COMMERCIAL FISHERIES)		
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
Increase/Decrease:	*-100*	*-2 000*
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
CARBON SEQUESTRATION		
Opening stock (Baseline):	300	14 000
Mangroves (Mt C)	200	7 000
Coastal forests (Mt C)	100	7 000
Increase/Decrease:	*-100*	*-2 000*
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.26.

Table E.26: 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
Market-based	Replace-ment 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
Market-based	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
Market-based	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
Non-market based	Travel cost	Travel costs to access a resource reflect value	Recreation sites (e.g., MPAs)	High data requirements
Non-market based	Contingent valuation	Respondents' direct willingness to pay	Any service (mostly used for non-market services)	Expensive, vulnerable to bias requiring careful survey design
Non-market based	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) Estimating value function from another location to predict values (function transfer)	Any service	Possible inconsistencies
Benefit transfer	Meta-analysis	Using statistical regression of multiple valuation studies to estimate value	Any service	Loss of important valuation information during due to aggregation

E.19 Sustainability Performance Index for Ports

E.19.1 Rationale

As trade facilitators, ports are crucial to the global economic system and have experienced phenomenal growth over the past decades. However, with this rapid growth came 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 increased, port authorities around the world were compelled to pursue the 'greening' of their port activities (Lam & Van der Voorde 2012; Roh et al. 2016). Port systems could no longer operate without acknowledging and incorporating societal and environmental considerations in their planning and management to safeguard their 'license to operate' (Kaliszewski, 2018). Climate change also started showing impacts, alerting to a need for greater climate resilience in port planning and development (Stein & Acciaro 2020).

These challenges stimulated the emergence of concepts such as 'Green Ports' aimed at balancing environmental challenges and economic demand and striving to establish sustainable ports by increasing both economic and environmental competitiveness – talking to the concept of the Green Economy (Bergqvist & Monios 2019; Lam & Notteboom 2014; Maritz et al. 2014). The concept of 'Sustainable Port Development' built on that of 'Green Ports' by including social sustainability, advocating the need for port development to balance economic growth, to 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, 2022) that could be applied to track the efficacy of port planning and management initiatives in achieving long-term sustainability – a tool within the sustainability assessment toolbox (see Figure A.2).

E.19.2 Construct of SPI for Ports

The SPI for Port 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.24 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, that is environment, social and economic. However, we chose to include governance as an explicit fourth dimension. Glass and Newig (2019) rightfully argued 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 explicitly included in existing port sustainability performance studies.

Figure E.24 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.24). In the following each of the components in the SPI for Ports will be discussed and explained in greater detail.

E.19.3 Selection of Outcomes, Categories & 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 is currently used as a benchmark against which to evaluate progress and achievements towards sustainable development (UN 2015). However, it is often difficult for those in directly involved in port practice to easily link each of these 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, while 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 depicted in Table E.27.

Table E.27: Sustainability dimensions, outcomes, categories and proposed indicators in SPI for Ports (Taljaard and Weerts 2023)

DIMENSION	SUSTAINABILITY OUTCOME	THEME/CATEGORY	INDICATOR
GOVERNANCE	Good governance	Legislation & Policy	1. Port's compliance with related international, national, and local legislation
			2. Port's compliance of port with in-house policies and requirements by port authority
			3. Tenants' compliance to policies and requirements of port authority
		Institutional arrangements	4. Organisational commitment towards sustainable development
			5. Organisational institutional structures dealing with sustainability issues
			6. Dedicated institutional structure (e.g., department) to oversee and coordinate sustainable development matters in a port
			7. Dedicated institutional structure/s to coordinate and communicate with port tenants in a port
			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)
			9. Dedicated (and sufficient) funding allocations towards sustainable development in a port
		Environmental management practices	10. Strategic environment assessment (e.g., as part of master planning)
			11. Environmental impact assessment (EIAs)
			12. Environmental Management Plans
			13. Accredited (or equivalent) Environmental Management Systems implementation
ENVIRONMENT	Pollution prevention & Ecosystem protection	Air quality	1. Air pollution management and control programme (including dust & GHG)
			2. Compliance of emission sources in port
			3. Status of ambient air quality in port
		Water/ sediment/soil quality	4. Wastewater management and control programme covering effluent and stormwater
			5. Solid waste management and control programmes addressing waste such as gally waste, oil slop, bio-foul waste
			6. Marine litter clean-up and prevention programmes
			7. Hazardous waste management and control programmes
			8. Soil and groundwater management and control programmes
			9. Hull cleaning management and control programmes
			10. Ballast water management and control programmes
			11. Dredge management and control programmes
			12. Oil/fuel spill management and control programmes
			13. Compliance of wastewater sources in port
			14. Status of ambient water quality in port
			15. Status of ambient sediment quality in port
			16. Status of soil and groundwater quality in port
			17. Status of oil/fuel spills originating in port
		Light, noise & odour	18. Noise management and control programmes
			19. Light management and control programmes
			20. Odour management and control programmes
			21. Status of ambient light quality in port
			22. Status of noise quality in port
			23. Status of odour quality in port
		Habitat & biodiversity	24. Physical and biological habitat/biodiversity management and control programmes (e.g., invasive species control, protection of sensitive areas, trade-offs)
			25. Status of invasive species in port
			26. Status of physical and biological habitat/biodiversity in port
	Eco-efficiency	Water use	1.
			2. Water use/consumption efficiency by port activities
			3. Water use/consumption efficiency of tenants
			4. Implementation of alternative water resources (e.g., rainwater harvesting, desalination)
		Climate	5. Greenhouse gas emissions by port activities
			6. Greenhouse gas emissions by tenants (e.g., non-port trucks and visiting ships)
		Energy	7. Use of environmental-friendly fossil fuels (e.g., low Sulphur fuel) in port by, e.g., tugs, vehicle, dredgers, and helicopters)
			8. Energy efficiency (use/consumption) by port activities
			9. Energy efficiency (use/consumption) by tenants

DIMEN-SION	SUSTAINABILITY OUTCOME THEME/CATEGORY		INDICATOR
			10. Use of alternative energy sources (e.g., solar, wind, ocean energy)
			11. Cold ironing (shore-to-vessel power)
		Recycling/ material	12. (Eco-friendly) material selection
			13. Recycling of construction and building materials/minimization of rubble waste generation (circular economy concept)
		Land-use	14. Port greenery (tree planting)
			15. Efficient of soil/ground occupation/use (space planning)
		Transport	16. Environmentally friendly public transport programmes
SOCIAL	Social accountability 	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)
			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)
			4. Port-City Memorandum of Understanding (MoU) (coordination/ collaboration) addressing environmental/social issues
			5. Port-city relationship
			6. Management and control programme for recognized cultural heritage assets in port, where relevant
			7. Status of cultural heritage assets in port
		Employee wellbeing	8. Environmental education and awareness programmes/events for port employees
			9. Port employee engagement forums
			10. Hiring from minority or previously disadvantage groups (equity)
			11. Status of port employee satisfaction
			12. Status of employee occupational health and safety
			13. Status of port security
ECONOMIC	Economic resilience 	Climate resilience (robustness)	1. Level of climate change (CC) preparedness (e.g., integrated CC adaptation programmes)
			2. CC early warning systems
			3. CC induced incident assessment
		Economic growth and development	4. Technical port capacity and efficiency (infrastructure, handling, equipment, refuelling, and safety)
			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.19.4 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 own experience and in consultation with port environmental staff, various measures for the expression of indicator performance are proposed in Table E.28 (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.28 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.28, 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.28: 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.... 1: 2: 3: 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.... 1: 2: 3: 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.... 1: 2: 3: 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 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 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. 1: 2: 3: 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 1: 2: 3: 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.... 1: 2: 3: 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. 1: Funding received, but only limited targets achieved 2: 3: 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 1: 2: 3: 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 1: Implemented, but limited compliance to Environmental Authorization (EA) requirements 2: Implemented, but some compliance to EA requirements 3: Implemented, mostly compliant to EA requirements 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 1: 2: 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 1: 2: 3: 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 1: 2: 3: 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) 1: 2: 3: 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) 1: 2: 3: 4: Full compliance/Great than… % compliance
Water/ sediment/soil 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 1: 2: 3: 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 1: 2: 3: 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 1: 2: 3: 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 1: 2: 3: 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 1: 2: 3: 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 1: 2: 3: 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 1: 2: 3: 4: Programme exists and fully implemented

	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)	0: No programme 1: 2: 3: 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 1: 2: 3: 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) 1: 2: 3: 4: Full compliance/Greater than… % compliance
	14. Status of ambient water quality in port	Leel 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) 1: 2: 3: 4: Full compliance/Greater than… % compliance
	15. Status of ambient sediment quality in port	Leel 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) 1: 2: 3: 4: Full compliance/Greater than… % compliance
	16. Status of soil and groundwater quality in port	Leel 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) 1: 2: 3: 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 1: 2: 3: 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 1: 2: 3: 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 1: 2: 3: 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 1: 2: 3: 4: Programme exists and fully implemented
	21. Status of ambient light quality in port	Leel 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) 1: 2: 3: 4: Full compliance/Greater than… % compliance
	22. Status of noise quality in port	Leel 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) 1: 2: 3: 4: Full compliance/Great than… % compliance
	23. Status of odour quality in port	Leel of compliance against environmental/health standards/targets	Targets for quality as per international/ national legislation	0: More than t…% noncompliance (set minimum) 1: 2:

			and or permits/ license agreements /guidelines	3: 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 1: 2: 3: 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 1: 2: 3: 4: None
	26. Status of physical and biological habitat/biodiversity in port	Leel 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) 1: 2: 3: 4: Full compliance/Great than… % compliance

Dimension: Environment

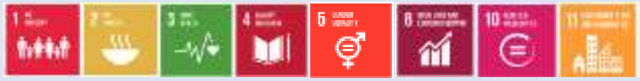
Sustainability Outcome: Eco-efficiency

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 1: 2: 3: 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) 1: 2: 3: 4: Full compliance/Greater than… % compliance
		Water loss through leakage (metering systems)	No leakages or a minimum percentage	0: More than …% water loss 1: 2: 3: 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) 1: 2: 3: 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 1: 2: 3: 4: More that …% obtained from alternative sources
Climate	5. Greenhouse gas emissions by port activities	Calculated CO_2 emission measured against carbon footprint target (t CO_2e)	Agreed annual carbon footprint target (t CO_2e) based on sustainable principles	0: No inventory of carbon emission 1: 2: 3: 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_2 emission measured against carbon footprint target (t CO_2e)	Agreed annual carbon footprint target (t CO_2e) based on sustainable principles	0: No inventory of carbon emission 1: 2: 3: 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 1: 2: 3: 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 1: 2: 3: 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 1: 2: 3: 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 1: 2: 3: 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 1: 2: 3: 4: 100%/More than ….% of berths
Recycling/ material	12. (Eco-friendly) material selection	Percentage of building material that is eco-friendly	Agreed annual target based on sustainable principles	0: None 1: 2: 3: 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 1: 2: 3: 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 1: 2: 3: 4: More than …. projects
	15. Efficient of soil/ground occupation/use (space planning)	Level of eco-efficiency	Agreed annual target based on sustainable principles	0: Not considered 1: 2: 3: 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 1: 2: 3: 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 1: 2: 3:

				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 1: 2: 3: 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 1: 2: 3: 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 1: 2: 3: 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 1: 2: 3: 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 1: 2: 3: 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 1: 2: 3: 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 sustainable principles and well attended	0: No programme/event 1: Programme/event planned but poorly received 2: 3: 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 1: Forum exists but poorly attended 2: 3: 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 1: 20-40% targets met 2: 40-70% targets met 3: 70-90% targets met 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 1: 2: 3: 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 1: 2: 3: 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 1: 2: 3: 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 IPPC data	0: No programme 1: Ad hoc 2: Programme exists, but very dated 3: Programme exists in accordance with latest IPPC data but no BCM 4: Programme exists in accordance with latest IPPC 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 1: Ad hoc with weak performance 2: Programme exists, but IPOSS only 3: Programme exists with SAWs plus IPOSS but not seasonal forecast 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 1: 2: 3: 4: No unplanned loss incurred
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 that …% of annual cargo target volumes met 1: 2: 3: 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 (5th generation port measure)	No loss or an agreed annual minimum limit	0: More than … % revenue loss 1: 2: 3: 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 1: 2: 3: 4: Meet/exceed revenue targets
	7. Contribution to tourism/recreation industry revenue	Estimate of tourism/recreation income	Agreed annual revenue target	0: No income 1: 2: 3: 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 1: 2: 3: 4: More than … % of average real estate value

E.19.5 Proposed Weighting Aggregation for Scoring

For each aggregation step (Figure E.24) 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.29 provides an example of a simple weighting system for the SPI for Ports.

Table E.29: 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)	Governance (0.25)
	Institutional arrangements (0.33)	
	Environmental processes (0.33)	
Pollution prevention & ecosystem protection (0.5)	Air quality (0.25)	Envrionment (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)	Social (0.25)
	Employee well-being (0.5)	
Economic resilience (1.0)	Climate resilience (0.5)	Economic (0.25)
	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 then prioritise interventions to achieve overall sustainability or to focus on outcomes deemed more critical to their situation. An example by which the outputs from the sustainability could be graphically illustrated are depicted in Figure E.25 (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).

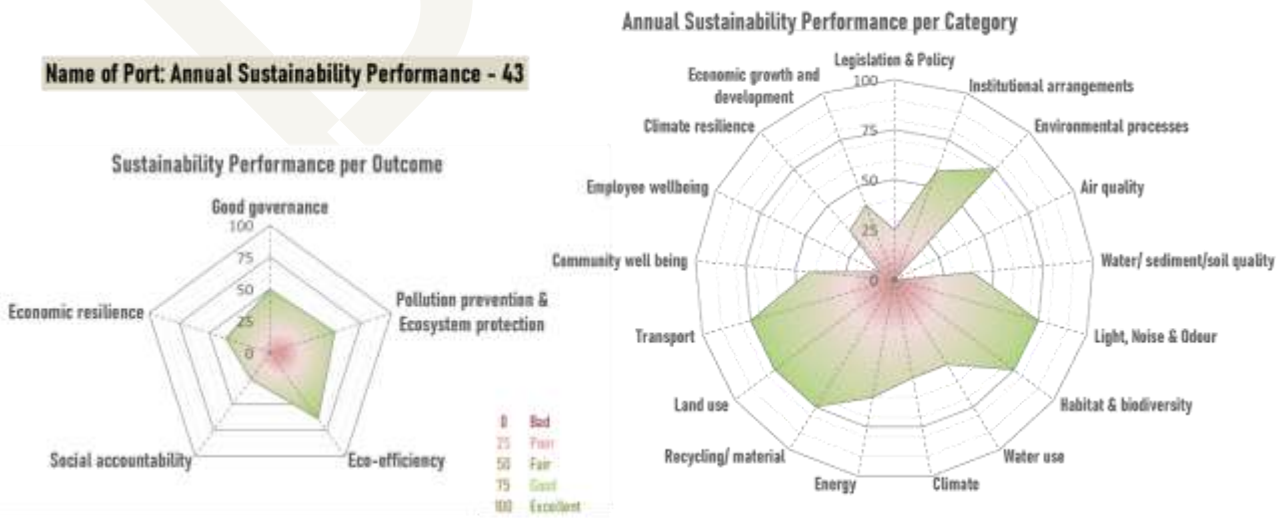


Figure E.25 Example of graphical illustrations from output of SPI for Ports (Source: Taljaard and Weerts 2023)

REFERENCES

African Union. 2015. Agenda 2063 – the Africa we want. Framework Document. https://au.int/sites/default/files/documents/33126-doc-framework_document_book.pdf

African Union. 2016. Agenda 2063. Capacity Development Plan Framework Buttressing Implementation of the First 10-Year Plan—"The Africa We Want". https://www.africaportal.org/publications/african-union-agenda-2063-capacity-development-plan-framework-buttressing-implementation-of-the-first-10-year-plan-the-africa-we-want/

Aguirre-Macedo ML, Vidal-Martinez VM, Herrera-Silveira JA, Valdés-Lozano DS, Herrera-Rodríguez M and Olvera-Novoa MA. 2008. Ballast water as a vector of coral pathogens in the Gulf of Mexico: The case of the Cayo Arcas coral reef. Marine Pollution Bulletin 56 (9): 1570-1577. https://doi.org/10.1016/j.marpolbul.2008.05.022

AIEA Bioenergy. 2017. Biofuels for the marine shipping sector An overview and analysis of sector infrastructure, fuel technologies and regulations. https://www.ieabioenergy.com/wp-content/uploads/2018/02/Marine-biofuel-report-final-Oct-2017.pdf

Alamoush AS, Ballini F and Ölçer AI. 2021. Revisiting port sustainability as a foundation for the implementation of the United Nations Sustainable Development Goals (UN SDGs). Journal of Shipping and Trade 6: 19. https://doi.org/10.1186/s41072-021-00101-6.

ALG Transport & Infrastructure. 2021. Port Master Planning; key aspects for a resilient port. AGL Newsletter #14. https://algnewsletter.com/maritime/port-master-planning-key-aspects-for-a-resilient-port/

Alshuwaikhat HM. 2005. Strategic environmental assessment can help solve environmental impact assessment failures in developing countries. Environ. Impact Assess. Rev. 25, 307–317.

ANZECC (Australia and New Zealand Environment and Conservation Council). 2000. Australian guidelines for water quality monitoring and reporting. National Water Quality Management Strategy No 7. Canberra, Australia. ISBN 0 642 19562 5.

Arabi S, Taljaard S and Weerts SP. 2022. Adapting environmental management systems for African ports. WMU Journal of Maritime Affairs. https://doi.org/10.1007/s13437-022-00262-6.

Arce R and Gullòn N. 2000. The application of Strategic Environmental Assessment to sustainability assessment of infrastructure development. Environmental Impact Assessment Review 20: 393-402.\

Armitage N and Rooseboom A. 2000. The removal of urban litter from stormwater conduits and streams: Paper 3 -Selecting the most suitable trap. Water SA 26 (2): 195-204.

Aronson J and Le Floc'h E. 1996. Vital landscape attributes: missing tools for restoration ecology. Restoration Ecology 4: 377–387. https://doi.org/10.1111/j.1526-100X.1996.tb00190.x

Arts J and Morrison-Saunders A. 2022. Impact Assessment Follow-up: International Best Practice Principles. International Association for Impact Assessment, Special Publication Series No. 6. Fargo, USA. SP6_22 Follow up_converted.pdf (iaia.org)

Asariotis R, Benemara H and Naray VH. 2019. Port industry survey on climate change impacts and adaptation. UNCTAD Research Report No. 18. UNCTAD/SER.RP/2017/18/Rev.1. https://unctad.org/en/PublicationsLibrary/ser-rp-2017d18_en.pdf

Audouin M. and Sitas N. 2020. Towards nature-based resilience in infrastructure development and assessment: an introductory guide. CSIR, Pretoria and Stellenbosch University: Centre for Complex Systems in Transition, Stellenbosch GRAID (Guidance for Resilience in the Anthropocene: Investments for Development) programme. FINAL_GRAID INFRASTRUCTURE GUIDE_27 APRIL 2020_Print.pdf

Azarkamand S, Balbaa A, Wooldridge C and Darbra RM. 2020a. Climate change— challenges and response options for the port sector. Sustainability 12: 6941. https://doi.org/10.3390/su12176941

Azarkamand S, Ferré G and Darbra RM. 2020b. Calculating the Carbon Footprint in ports by using a standardized tool. Science of The Total Environment 734: 139407. https://doi.org/10.1016/j.scitotenv.2020.139407

Baholli I, Stana A, Meka E and Karafili M. 2013. Can Albanian Port Area be Part of The European Network of Eco-Ports Based on Environmental Information systems? Journal of Educational and Social Research, 3(2): 139. https://www.richtmann.org/journal/index.php/jesr/article/view/150

Bailey S. 2015. An overview of thirty years of research on ballast water as a vector for aquatic invasive species to freshwater and marine environments. Aquatic Ecosystem Health & Management 18(3): 1–8. DOI:10.1080/14634988.2015.1027129

Ballini F and Bozzo R. 2015. Air pollution from ships in ports: The socio-economic benefit of cold-ironing technology. Research in Transportation Business & Management 17: 92-98. https://doi.org/10.1016/j.rtbm.2015.10.007

Barbier EB and Burgess JC. 2017. The Sustainable Development Goals and the systems approach to sustainability. Economics 11: 2017-2028. http://dx.doi.org/10.5018/economics-ejournal.ja.2017-28.

Barcelo D and Pico Y. 2020. Case Studies of macro- and micro-plastics pollution in coastal waters and rivers: Is there a solution with new removal technologies and policy actions? Case Studies in Chemical and Environmental Engineering 2: 100019. https://doi.org/10.1016/j.cscee.2020.100019

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

Barnardo T and Ribbink AJ (Eds.) 2020. African Marine Litter Monitoring Manual. African Marine Waste Network, Sustainable Seas Trust. https://www.wiomsa.org/wp-content/uploads/2020/07/African-Marine-Litter-Monitoring-Manual_Final.pdf

Barnes-Dabban H and Karlsson-Vinkhuyzen S. 2018 The influence of the Regional Coordinating Unit of the Abidjan Convention: implementing multilateral environmental agreements to prevent shipping pollution in West and Central Africa. Int. Environ Agreements 18: 469-489. DOI https://doi.org/10.1007/s10784-018-9399-8

Barnes-Dabban H, van Koppen CSA and van Tatenhove JPM. 2018. Regional convergence in environmental policy arrangements: a transformation towards regional environmental governance for West and Central African ports? Ocean and Coastal Management 163:151–161. https://doi.org/10.1016/j.ocecoaman.2018.06.013

BBOP (Business and Biodiversity Offsets Programme) 2009. Business, Biodiversity Offsets and BBOP: An Overview. BBOP, Washington, D.C. https://www.forest-trends.org/wp-content/uploads/imported/overview-phase-1-pdf.pdf

Bergmann M, Gutow L and Klages M. 2015. Marine Anthropogenic Litter. Springer, London.

Bergqvist R and Monios J. 2019. Green ports in theory and practice. In: Bergqvist, R., Monios, J. (Eds.), Green Ports; Inland and Seaside Sustainable Transportation Strategies. Elsevier, Cambridge, MA, pp. 1–17.

BIMCO (Baltic and International Maritime Council). 2021a. Approval procedure for in-water cleaning companies. https://www.bimco.org/about-us-and-our-members/publications/approval-procedure-for-in-water-cleaning-companies

BIMCO. 2021b. Industry standard on in-water cleaning with capture. Version 1.01. https://www.bimco.org/about-us-and-our-members/publications/industry-standard-on-in-water-cleaning-with-capture

Bishoge OK and Mvile BN. 2022. A critique of EIA report selected from the East African region considering what is required in ideal EIA report. Journal of Applied and Advanced Research 7: 8-17. https://doi.org/10.21839/jaar.2022.v7.7478

Bjerkan KY and Seter H. 2019. Reviewing tools and technologies for sustainable ports: Does research enable decision making in ports? Transportation Research Part D: Transport and Environment 72: 243-260. https://doi.org/10.1016/j.trd.2019.05.003

Bob-Manuel KDH. 2020. Capacity-building for sustainable maritime industry in developing coastal countries. Journal of Emerging Trends in Engineering and Applied Sciences 11(1): 6-13. https://hdl.handle.net/10520/EJC-1ce0fc5cac

Boile M, Theofanis S, Sdoukopoulos E and Plytas N. 2016. Developing a port energy management plan. Issues, challenges, and prospects. Transportation Research Record: Journal of the Transportation Research Board 2549: 19–28. https://doi.org/10.3141/2549-03

Bond A, Pope J and Morrison-Saunders A. 2015. Introducing the roots, evolution and effectiveness of sustainability assessment. In: Morrison-Saunders A, Pope J and Bond A (editors). 2015. Handbook of sustainability assessment. Edward Elgar Publishing, Cheltenham, UK, p3-19.

Bourgeois D. 2019. Information Systems for Business and Beyond (2019) https://opentextbook.site/informationsystems2019/

Brouwer MAC and van Koppen CSA. 2008. The soul of the machine: Continual improvement in ISO 14001. Journal of Cleaner Production 16:450-457. https://doi.org/10.1016/j.jclepro.2006.08.022

Browne MA and Chapman MG. 2014. Mitigating against the loss of species by adding artificial intertidal pools to existing seawalls. Mar Ecol Prog Ser 497: 119-129. https://doi.org/10.3354/meps10596

Capelli L, Bax C, Diaz C, Izquierdo C, Arias R and Seoane NS. 2019. Review on odour pollution, odour measurement, abatement techniques (D2.1). dnoses.eu/wp-content/uploads/2019/10/D2.1_Review-on-odour-pollution-measurement-abatement_v3.2.pdf.

Capelli L, Bax C, Diaz C, Izquierdo C, Arias R and Seoane NS. 2019. Review on odour pollution, odour measurement, abatement techniques (D2.1). dnoses.eu/wp-content/uploads/2019/10/D2.1_Review-on-odour-pollution-measurement-abatement_v3.2.pdf.

CBD (Convention on Biological Diversity), 2004. CBD Guidelines: The Ecosystem Approach. Montreal: Secretariat of the Convention on Biological Diversity. https://www.cbd.int/doc/publications/ea-text-en.pdf

CEC (Commission of the European Communities) 2001. Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment (SEA Directive). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32001L0042

Chang CC and Jhang CW. 2016. Reducing speed and fuel transfer of the Green Flag Incentive Program in Kaohsiung Port Taiwan. Transportation Research Part D: Transport and Environment 46: 1-10. https://doi.org/10.1016/j.trd.2016.03.007

Chapin FS and Starfield AM. 1997. Time lags and novel ecosystems in response to transient climatic change in arctic Alaska. Climatic Change 35:449-461. https://doi.org/10.1023/A:1005337705025

Chee SY, Wee JLS, Wong C, Yee JC, Yusup Y and Mujahid A. 2020. Drill-Cored Artificial Rock Pools Can Promote Biodiversity and Enhance Community Structure on Coastal Rock Revetments at

Reclaimed Coastlines of Penang, Malaysia. Tropical Conservation Science 13: 1-15. https://doi.org/10.1177/1940082920951912

Chen Z and Pak M. 2017. A Delphi analysis on green performance evaluation indices for ports in China. Maritime Policy & Management 44(5): 537-550. https://doi.org/10.1080/03088839.2017.1327726

Chenoweth JJ, Anderson AR, Kumar P, Hunt WF, Chimbwandira SJ and Moore TLC. 2018. The interrelationship of green infrastructure and natural capital. Land Use Policy 75: 137–144.

Chiu R-H, Lin L-H and Ting S-C. 2014. Evaluation of Green Port Factors and Performance: A Fuzzy AHP Analysis. Hindawi Publishing Corporation Mathematical Problems in Engineering Volume, Article ID 802976, 12 pp http://dx.doi.org/10.1155/2014/802976

Cohen-Shacham E, Andrade A, Dalton J, Dudley N, Jones M, Kumar C, Maginnis S, Maynard S, Nelson CR, Renaud FG, Welling R and Walters G. 2019. Core principles for successfully implementing and upscaling Nature-based Solutions. Environmental Science & Policy 98: 20-29. https://doi.org/10.1016/j.envsci.2019.04.014

Cohen-Shacham E, Walters G, Janzen C and Maginnis S. 2016. Nature-Based Solutions to Address Societal Challenges. Gland, Switzerland: International Union for Conservation of Nature. https://doi.org/10.2305/IUCN.CH.2016.13.en.

Coman, M and Cioruța B-V. 2013. Environmental Information Systems as a possible solution for strategic development of local and regional communities. https://www.researchgate.net/publication/324809118_2013_15_-_Environmental_Information_Systems_as_a_possible_solution_for_strategic_development_of_local_and_regional_communities

Commonwealth of Australia. 2015. Anti-fouling and in-water cleaning guidelines. Department of Agriculture, Canberra. CC BY 3.0. https://www.agriculture.gov.au/biosecurity-trade/aircraft-vessels-military/vessels/marine-pest-biosecurity/biofouling/anti-fouling-and-inwater-cleaning-guidelines

Coombes MA, La Marca EC, Naylor LA and Thompson RC. 2015. Getting into the groove: Opportunities to enhance the ecological value of hard coastal infrastructure using fine-scale surface textures. Ecological Engineering 77: 314-323. https://doi.org/10.1016/j.ecoleng.2015.01.032

CSIR (Council for Scientific and Industrial Research, RSA). 2003. Strategic Environmental Assessment of the Port of Cape Town: Sustainability Framework. Prepared for the National Ports Authority: Port of Cape Town. CSIR Report No. ENV-S-C 2003-074, Stellenbosch, South Africa.

da Cunha Jácome Vidal, P, Aguirre González MO, Cassimiro de Melo D, de Oliveira Ferreira P, Vasconcelos Sampaio PG and Lima LO. 2022. Conceptual framework for the decommissioning process of offshore oil and gas platforms. Marine Structures 85: 103262. https://doi.org/10.1016/j.marstruc.2022.103262

Dalal-Clayton B and Sadler B. 1999. Strategic Environmental Assessment: A Rapidly Evolving Approach. Environmental Planning Issues No. 18, International Institute for Environment and Development (IIED), London. Issue 18.PDF (iied.org)

Dalal-Clayton B and Sadler B. 2005. Strategic Environmental Assessment: A Sourcebook and Reference Guide to International Experience. International Institute for Environment and Development (IIED). Earthscan, London, UK.

Darbra RM, Ronza A, Casal J, Stojanovic TA and Wooldridge C. 2004. The Self Diagnosis Method A new methodology to assess environmental management in sea ports. Marine Pollution Bulletin 48: 420–428. https://doi.org/10.1016/j.marpolbul.2003.10.023

Darbra RM, Ronza A, Stojanovic TA, Wooldridge C and Casal J. 2005. A procedure for identifying significant environmental aspects in sea ports. Marine Pollution Bulletin 50 (8): 866-874. https://doi.org/10.1016/j.marpolbul.2005.04.037

Darnall N and Edwards D Jr. 2006. Predicting the cost of environmental management system adoption: The role of Capabilities, resources and ownership structure. Strategic Management Journal. Strat. Mgmt. J. 27:301–320. DOI: 10.1002/smj.518

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

Davis JD and MacKnight S. 1990. International Maritime Organization. Environmental considerations for port and harbor developments (English). World Bank technical paper ; no. WTP 126 Washington, D.C. : World Bank Group. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/931761468782116353/environmental-considerations-for-port-and-harbor-developments

DBA Group. 2019. ISMAEL: Environmental impact monitoring and prediction in ports. https://sustainableworldports.org/wp-content/uploads//gravity_forms/3-bd84b5b5f37889d5e2375dc98f054b49/2019/07/DSS-Line-Environmental-monitoring-and-prediction.pdf

De Alencar NMP, Le Tissier M, Paterson SK and Newton A. 2020. Circles of Coastal Sustainability: A Framework for Coastal Management. Sustainability 12(12): 4886. https://doi.org/10.3390/su12124886

De Boer WP, Slinger JH, wa Kangeri AK, Vreugdenhil HSI, Taneja P, Appeaning Addo K and Vellinga T. 2019. Identifying Ecosystem-Based Alternatives for the Design of a Seaport's Marine Infrastructure: The Case of Tema Port Expansion in Ghana. Sustainability 11(23): 6633. https://doi.org/10.3390/su11236633

De Langen P and Sornn-Friese H. 2019. Ports and the Circular Economy. In: Green Ports - Inland and Seaside Sustainable Transportation Strategies. Bergqvist R and Monios J (Eds.). Elsevier. pp 85-108. https://doi.org/10.1016/B978-0-12-814054-3.00005-0

de los Reyes RS.; Fernández-Sánchez G.; Esteban MD and Rodríguez RR. 2020. Carbon Footprint of a Port Infrastructure from a Life Cycle Approach. Int. J. Environ. Res. Public Health 17: 7414. https://doi.org/10.3390/ijerph17207414

De Vriend HJ and Van Koningsveld M. 2012. Building with Nature: Thinking, Acting and Interacting Differently. EcoShape, Building with Nature, Dordrecht, the Netherlands. https://www.ecoshape.org/app/uploads/sites/2/2016/07/ECOSHAPE_BwN_WEB.pdf

de Vriend HJ, Koningsveld M, Aarninkhof SGJ, De Vries MB and Baptist MJ. 2015. Sustainable hydraulic engineering through building with nature. J. Hydro Environ. Res. 9: 159–171. https://doi.org/10.1016/j.jher.2014.06.004

Deloitte Inc, 2015. Port 2050 Scenarios Update Final Report. https://www.portvancouver.com/wp-content/uploads/2015/03/2015-04-07-Port-2050-Scenario-Refresh-Final-Report-with-appendices.pdf

Department of Environmental Affairs, South Africa (DEA RSA) 2012. Review and update of South Africa's National Action List for the screening of dredged sediment proposed form marine disposal. Cape Town (https://www.gov.za/documents/review-and-update-south-africa%E2%80%99s-national-action-list-screening-dredged-sediment-proposed) & (https://www.environment.gov.za/sites/default/files/gazetted_notices/nemaicma_marinedisposal_actionlist_g35602_gon635_0.pdf).

Di Vaio A and Varriale L 2018. Management innovation for environmental sustainability in seaports: managerial accounting instruments and training for competitive green ports beyond the regulations. Sustainability10:783. https://doi.org/10.3390/su10030783

Dublin Port Company, 2012a. Dublin Port Masterplan Strategic Environmental Assessment Environmental Report: Non-Technical Summary. https://www.dublinport.ie/wp-content/uploads/2017/01/Dublin_Port_Masterplan_SEA_ER_NTS.pdf

Dublin Port Company. 2012a. Dublin Port Masterplan Strategic Environmental Assessment Environmental Report: Non-technical Summary. Dublin , Ireland https://www.dublinport.ie/wp-content/uploads/2017/01/Dublin_Port_Masterplan_SEA_ER_NTS.pdf

EcoShape. 2020. Pile and pontoon hulas. https://www.ecoshape.org/app/uploads/sites/2/2020/10/fact-sheet-pile-pontoon-hulas.pdf

EcoShape. 2021. Building with Nature: a future proof strategy for coping with a changing and uncertain world. Working with uncertainties. https://www.ecoshape.org/app/uploads/sites/2/2021/05/Whitepaper-a-future-proof-strategy-for-coping-with-a-changing-and-uncertain-world.pdf

EcoShape. 2022. Building with Nature. https://www.ecoshape.org/en/

Eger AM, Layton C, McHugh TA, Gleason M and Eddy N. 2022. Kelp Restoration Guidebook: Lessons Learned from Kelp Projects Around the World. The Nature Conservancy, Arlington, VA, USA. https://www.decadeonrestoration.org/publications/kelp-restoration-guidebook-lessons-learned-kelp-restoration-projects-around-world

Eggenberger M and Partidário MR. 2000. Development of a framework to assist the integration of environmental, social and economic issues in spatial planning. Impact assessment and project appraisal 18(3): 201-207.

Ehler CN and Douvere F. 2009. Marine Spatial Planning: a step-by-step approach toward ecosystem-based management. Intergovernmental Oceanographic Commission and Man and the Biosphere Programme. IOC Manual and Guides No. 53, ICAM Dossier No. 6. Paris: UNESCO. 2009. https://unesdoc.unesco.org/ark:/48223/pf0000186559

El-Gayar, O and Fritz, BD. 2006. Environmental Management Information Systems (EMIS) for Sustainable Development: A Conceptual Overview," Communications of the Association for Information Systems 17: Article 34. https://aisel.aisnet.org/cais/vol17/iss1/34

Ellen MacArthur Foundation. 2022. Let's build a circular economy. https://ellenmacarthurfoundation.org/

Elliott M and Cutts ND. 2004. Marine habitats: loss and gain, mitigation and compensation. Marine Pollution Bulletin 49: 671–674. https://doi.org/10.1016/j.marpolbul.2004.08.018

Elliott M, Burdon D, Hemingway KL and Apitz SE. 2007. Estuarine, coastal and marine ecosystem restoration: Confusing management and science - A revision of concepts. Estuarine, Coastal and Shelf Science 74: 349-366. https://doi.org/10.1016/j.ecss.2007.05.034

Elliott M, Mander L, Mazik K, Simenstad C, Valesini F, Whitfield A and Wolanski E. 2016. Ecoengineering with Ecohydrology: Successes and failures in estuarine restoration. Estuarine, Coastal and Shelf Science 176: 12-35. https://doi.org/10.1016/j.ecss.2016.04.003

EPA South Australia (Environmental Protection Authority, South Australia) 2020. Dredge guideline. https://www.epa.sa.gov.au/files/14712_dredge_guideline_2020.pdf

EPA South Australia. 2021. Industry: Construction environmental management plan (CEMP). http://www.epa.sa.gov.au/files/12330_guide_cemp.pdf

Escovar-Fadul X, Hein MY, Garrison K, McLeod E, Eggers M and Comito F. 2022. A Guide to Coral Reef Restoration for the Tourism Sector. Partnering with Caribbean Tourism Leaders to Accelerate Coral Restoration. The Nature Conservancy. https://www.unep.org/resources/report/coral-reef-restoration-guidelines-tourism-sector

ESPO (European Sea Ports Organisation) 2012a. ESPO Green Guide. Towards excellence in port environmental management and sustainability. https://www.espo.be/media/espopublications/espo_green%20guide_october%202012_final.pdf.

ESPO. 2012b. Port Performance Indicators: Selection and Measurement (PPRISM). Project Executive Report. https://www.espo.be/media/pages/12-01-25_-_PPRISM_WP4_Deliverable_4.2_Website.pdf.

ESPO. 2020. ESPO Environmental Report 2020. https://www.espo.be/media/Environmental%20Report-WEB-FINAL.pdf.

EU (European Union). 2019. Guidelines on Human Capacity Building in Ports. Interreg, Danube Transnational Programme. https://www.interreg-danube.eu/uploads/media/approved_project_output/0001/27/ee31f6e3a7b7063fc5f3b6b2649c1c805b3c49f6.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-stategy-framework-directive

Evans AJ, Firth LB, Hawkins SJ, Morris ES, Goudge H and Moore PJ. 2015. Drill-cored rock pools: an effective method of ecological enhancement on artificial structures. Marine and Freshwater Research 67: 123-130. https://doi.org/10.1071/MF14244

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

Fischer TB. 2002. Strategic Environmental Assessment in Transport and Land Use Planning, Earthscan Publications, London.

Fisher TB. 2003. Strategic environmental assessment in post-modern times. Environmental Impact Assessment Review 23:155–170.

Fitzsimons J, Branigan S, Brumbaugh RD, McDonald T and zu Ermgassen PSE (Eds.) 2019. Restoration Guidelines for Shellfish Reefs. The Nature Conservancy, Arlington VA, USA. https://www.decadeonrestoration.org/publications/restoration-guidelines-shellfish-reefs

Fredianelli L, Bolognese M, Fidecaro F and Licitra, G. 2021. Classification of noise sources for port area noise mapping. Environments 8: 12. https://doi.org/environments8020012

Gann GD, McDonald T, Walder B, Aronson J, Nelson CR, Jonson J, Hallett JG, Eisenberg C, Guariguata MR, Liu J, Hua F, Echeverría C, Gonzales E, Shaw N, Decleer K and Dixon KW. (2019), International principles and standards for the practice of ecological restoration. Second edition. Restor Ecol, 27: S1-S46. https://doi.org/10.1111/rec.13035 or https://www.ser.org/page/SERStandards/International-Standards-for-the-Practice-of-Ecological-Restoration.htm

Gann GD, Walder B, Gladstone J, Manirajah SM, Roe S. 2022. Restoration Project Information Sharing Framework. Society for Ecological Restoration and Climate Focus. Washington, D.C. https://www.ser.org/resource/resmgr/publications/restoration-project-informat.pdf

GHD. 2013. Environmental best practice port development: An analysis of international approaches. Report prepared for the Department of Sustainability, Environment, Water, Population and Communities, Canberra, Australia.

https://www.awe.gov.au/environment/epbc/publications/environmental-best-practice-port-development-analysis-international-approaches.

Glass L-M and Newig J. 2019. Governance for achieving the Sustainable Development Goals: How important are participation, policy coherence, reflexivity, adaptation and democratic institutions? Earth System Governance 2: 100031. https://doi.org/10.1016/j.esg.2019.100031.

Global Ocean Accounts Partnership (GOAP. 2019). Technical Guidance on Ocean Accounting for Sustainable Development (United Nations, 1st edition, 2019). https://www.oceanaccounts.org/technical-guidance-on-ocean-accounting-2/.

Gollasch S, Minchin D and David M. 2015. The Transfer of Harmful Aquatic Organisms and Pathogens with Ballast Water and Their Impacts. In: David M., Gollasch S. (eds) Global Maritime Transport and Ballast Water Management. Invading Nature - Springer Series in Invasion Ecology, vol 8. Springer, Dordrecht. https://doi.org/10.1007/978-94-017-9367-4_3

González Laxe F, Martīn Bermúdez F, Martīn Palmero F and Novo-Corti I. 2016. Sustainability and the Spanish port system. Analysis of the relationship between economic and environmental indicators. Marine Pollution Bulletin 113: 232–239.

González MJ, Ruiz C, Rivas MCG, Gereda C, Castañeda E, Segovia G and Paiz M (Eds.) 2020. Training guide for coral reef restoration. https://www.decadeonrestoration.org/publications/training-guide-coral-reef-restoration

Govender K and Trumbic I. 2011. SEA and Coastal Zone Management. In: Sadler B, Aschemann R, Dusik J et al (editors) Handbook of Strategic Environmental Assessment. International Association of Impact Assessment (IAIA). Earthscan, London, p 220-231.

Günter O. 1998. Chapter 1: Introduction. In: Environmental Information Systems. Publisher: Springer Berlin. pp 1-7. https://doi.org/10.1007/978-3-662-03602-0

Guo X and Liu L. 2018. Approach to the Construction of Green Port in Tianjin Port. MATEC Web Conf. 175 04012.

Gupta AK, Gupta SK and Patil RS. 2005. Environmental management plan for port and harbour projects. Clean Technol. Environ. Policy 7: 133–141.

Hall AE, Herbert RJH, Britton JR and Hull SL. 2018. Ecological enhancement techniques to improve habitat heterogeneity on coastal defence structures. Estuarine Coastal and Shelf Science 210: 68-78. https://doi.org/10.1016/j.ecss.2018.05.025

Hanson SE and Nicholls RJ. 2020. Demand for ports to 2050: Climate policy, growing trade and the impacts of sea-level rise. Earth's Future 8: e2020EF001543. https://doi.org/10.1029/2020EF001543

Helsel DR, 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

Hiranandani, V., 2014. Sustainable development in seaports: a multi-case study. WMU Journal of Maritime Affairs 13, 127–172.

Hobbs RJ, Higgs E and Harris JA. 2009. Novel ecosystems: implications for conservation and restoration. Trends in Ecology and Evolution 24(11): 599-605. https://doi.org/10.1016/j.tree.2009.05.012

Hossain MT. 2018. Assessment of sustainability initiatives in port operations: an overview of global and Canadian ports. In: Submitted in Partial Fulfilment of the Requirements for the Degree of Master of Environmental Studies. Dalhousie University, Halifax, Nova Scotia, Canada.

HR Wallingford and British Port Association. 2021. Climate change and ports Impacts and adaptation strategies. HR Wallingford, UK. https://www.hrwallingford.com/sites/default/files/2021-10/climate_change_for_ports_-_impacts_and_adaptation_strategies_by_hr_wallingford_bpa_r3-0.pdf

Humphreys M, Stokenberga A, Dappe MH, Iimi A and Hartmann O. 2019. Port Development and Competition in East and Southern Africa. Prospects and Challenges. World Bank Group. https://doi.org/10.1596/978-1-4648-1410-5

IAIA (International Association of Impact Assessment). 2002. Strategic Environmental Assessment: Performance Criteria. IAIA, Special Publication Series No. 1, Fargo, USA.

IAIA. 2022. Impact Assessment follow-up. https://www.iaia.org/wiki-details.php?ID=15

Ido S and Perkol-Finkel S. 2015. Blue is the new green – Ecological enhancement of concrete based coastal and marine infrastructure. Ecological Engineering 84: 260-272. https://doi.org/10.1016/j.ecoleng.2015.09.016

IMO (International maritime organisation 2014. Waste Assessment Guidance. https://www.imo.org/en/OurWork/Environment/Pages/wag-default.aspx

IMO. 2011. Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species. Resolution MEPC.207(62). https://www.imo.org/en/OurWork/Environment/Pages/Biofouling.aspx

IMO. 2012. Guidance for minimizing the transfer of invasive aquatic species as biofouling (hull fouling) for recreational craft. Resolution MEPC.1/Circ.792. https://www.imo.org/en/OurWork/Environment/Pages/Biofouling.aspx

IMO. 2020. IMO 2020 – cutting sulphur oxide emissions (https://www.imo.org/en/MediaCentre/HotTopics/Pages/Sulphur-2020.aspx)

IMO. 2022a. Ballast Water Management Convention. https://www.imo.org/en/OurWork/Environment/Pages/BallastWaterManagement.aspx

IMO. 2022b. Implementing the Ballast Water Management Convention. https://www.imo.org/en/MediaCentre/HotTopics/Pages/Implementing-the-BWM-Convention.aspx

IMO. 2022c. Oil spill contingency planning. https://www.imo.org/en/OurWork/Environment/Pages/Oil%20Spill%20Contingency%20Planning.aspx

IOGP (International Association of Oil & Gas Producers). 2017. Overview of International Offshore Decommissioning Regulations. Volume 1 – Facilities. Report 584. https://www.iogp.org/bookstore/product/overview-of-international-offshore-decommissioning-regulations-volume-1-facilities/

Iraldo F, Testa F and Frey M. 2009 Is an environmental management system able to influence environmental and competitive performance? The case of the eco-management and audit scheme (EMAS) in the European Union. Journal of Cleaner Production 17:1444–1452. https://doi.org/10.1016/j.jclepro.2009.05.013

Iris C and Lam JSL. 2019. A review of energy efficiency in ports: Operational strategies, technologies and energy management systems. Renewable and Sustainable Energy Reviews 112: 170–182. https://doi.org/10.1016/j.rser.2019.04.069

ISO (International Organisation for Standardisation) 2020a. ISO 14000 Family Environmental Management. https://www.iso.org/iso-14001-environmental-management.html.

ITOPF (International Tanker Owners Pollution Federation Limited). n.d. Contingency planning for marine oil spills. Technical Information paper 16. https://www.itopf.org/knowledge-resources/documents-guides/technical-information-papers/

IUCN (International Union for Conservation of Nature and Natural Resources).2004. Managing Marine Protected Areas: A Toolkit for the Western Indian Ocean. Environmental impact assessment: A6. Nairobi, Kenya. A6_Environmental_impact_assessment.pdf (wiomsa.org)

Izaguirre C, Losada IJ, Camus P. et al. 2021. Climate change risk to global port operations. Nat. Clim. Chang. 11: 14–20. https://doi.org/10.1038/s41558-020-00937-z

Jacob C, van Bochove J-W, Livingstone S, White T, Pilgrim J and Bennun L. 2020. Marine biodiversity offsets: Pragmatic approaches toward better conservation outcomes. Conservation Letters 13: e12711. https://doi.org/10.1111/conl.12711

Jägerbrand AK, Andreas A, Svedén JB, Gren I-M. 2019. A review on the environmental impacts of shipping on aquatic and nearshore ecosystems. Science of the Total Environment 695: 133637. https://doi.org/10.1016/j.scitotenv.2019.133637

James P. 2014. Urban Sustainability in Theory and Practice: Circles of sustainability, 1st ed.; Routledge: London, UK. https://doi.org/10.4324/9781315765747

Jay S, Jones C, Slinn P and Wood C. 2007. Environmental impact assessment: Retrospect and prospect. Environmental Impact Assessment Review 27:287–300. https://doi.org/10.1016/j.eiar.2006.12.001

Jones CE. 1999. Screening, Scoping and Consideration of Alternatives. In: Petts J. Handbook of Environmental Impact Assessment. Volume 1: Environmental Impact Assessment: Process, Methods and Potential. Blackwell Science, Oxford.

Kaliszewski A, 2018. Fifth and sixth generation ports (5GP, 6GP) – evolution of economic and social roles of ports. https://www.researchgate.net/profile/Adam_Kaliszewski2.

Karimpour R, Ballini F and Ölcer, AI. 2019. Circular economy approach to facilitate the transition of the port cities into self-sustainable energy ports—a case study in Copenhagen-Malmö Port (CMP). WMU J Marit Affairs 18: 225–247. https://doi.org/10.1007/s13437-019-00170-2

Keenleyside KA, Dudley N, Cairns S, Hall CM and Stolton S. 2012. Ecological Restoration for Protected Areas: Principles, Guidelines and Best Practices. Gland, Switzerland: IUCN. https://www.iucn.org/resources/publication/ecological-restoration-protected-areas-principles-guidelines-and-best

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

Kørnøv L and Thissen WAH. 2000. Rationality in Decision and Policy- Making: Implications for Strategic Environmental Assessment. Impact Assessment and Project Appraisal 18(3): 191 – 200. https://doi.org/10.3152/147154600781767402

Kusek JZ and Rist RC. 2004. A handbook for development practitioners. Ten steps to a results-based monitoring and evaluation system. World Bank, Washington, DC.

Lam JSL and Van de Voorde E. 2012. Green port strategy for sustainable growth and development. In: Yip TL, Fu X and Ng AKY. (Eds.), Transport Logistics for Sustainable Growth at a New Level.

Proceedings of the International Forum on Shipping, Ports and Airports (IFSPA), Hong Kong, May 28-30, 417-427. The Hong Kong Polytechnic University, Hong Kong.

Lam JSL and Van de Voorde E. 2012. Green port strategy for sustainable growth and development. In: Yip, T.L., Fu, X., Ng, A.K.Y. (Eds.), Transport Logistics for Sustainable Growth at a New Level. Proceedings of the International Forum on Shipping, Ports and Airports (IFSPA), Hong Kong, May 28-30, 417-427. The Hong Kong Polytechnic University, Hong Kong.

Lam, JSL and Notteboom T. 2014. The greening of ports: a comparison of port management tools used by leading ports in Asia and Europe. Transport Rev. 34 (2): 169–189. https://doi.org/10.1080/01441647.2014.891162

Lamprecht JL. 1997. ISO 14000. Issues and Implementation Guidelines for Responsible Environmental Management, AMACOM. https://www.amazon.com/ISO-14000-Implementation-Responsible-Environmental/dp/0814403530

Lawer ET, Herbeck J and Flitner M. 2019. Selective adoption: how port authorities in Europe and West Africa engage with the globalizing 'green port' idea. Sustainability 11: 5119. https://doi.org/10.3390/su11185119

Lee PT-W, Lam JSL, Lin C-W, Hu K-C and Cheong I. 2018. Developing the fifth-generation port concept model: an empirical test. The International Journal of Logistics Management 29(3): 1098-1120. https://doi.org/10.1108/IJLM-10-2016-0239

Léocadie, A., Pioch, S., Pinault, M. 2020. Guide to Ecological Engineering: The restoration of coral reefs and associated ecosystems. Published by IFRECOR. https://www.decadeonrestoration.org/publications/guide-ecological-engineering-restoration-coral-reefs-and-associated-ecosystems

LPC (Lyttelton Port Company, New Zealand). 2019. Construction environmental management plan manual. Edition 2. https://www.lpc.co.nz/wp-content/uploads/2020/05/LPC-Construction-Enviornmental-Management-Plan-FULL-DOCUMENT.pdf

Lu C-S, Shang K-C and, Lin C-C. 2016. Identifying crucial sustainability assessment criteria for container seaports. Marit. Bus. Rev. 1 (2): 90–106. https://doi.org/10.1108/MABR-05-2016-0009

MacArthur M, Naylor LA, Hansom JD and Burrows MT. 2020. Ecological enhancement of coastal engineering structures: Passive enhancement techniques. Science of The Total Environment 740: 139981. https://doi.org/10.1016/j.scitotenv.2020.139981.

Macía YM, Rodríguez MP, Machuca P, Rodríguez SAA and Carmona CR. 2021. Green Hydrogen Value Chain in the Sustainability for Port Operations: Case Study in the Region of Valparaiso, Chile. Sustainability 13: 13681. https://doi.org/10.3390/su132413681

Maritime and Coastguard Agency, UK. 2021. Contingency Planning for Marine Pollution Preparedness and Response. Guidelines for Ports. https://www.gov.uk/government/publications/contingency-planning-for-marine-pollution-preparedness-and-response-guidelines-for-ports

Maritz A, Shieh CJ and Yeh SP. 2014. Ecology – green ports – risk assessment innovation and success factors in the construction of green ports. J. Environ. Protect. Ecol. 15 (3a): 1255–1263.

Maron M, Hobbs RJ, Moilanen A, Matthews JW, Christie K, Gardner TA, Keith DA, Lindenmayer DB and McAlpine CA. 2012. Faustian bargains? Restoration realities in the context of biodiversity offset policies. Biological Conservation 155: 141–148. https://doi.org/10.1016/j.biocon.2012.06.003

Mbalisi OF and Offor BO. 2012. Imperatives of environmental education and awareness creation to solid waste management in Nigeria. Part 11: Education Sciences 3(2) September

Melbourne-Thomas J, Hayes KR, Hobday AJ, Little LR, Strzelecki J, Thomson DP, van Putten I and Hook SE. 2021. Decommissioning Research Needs for Offshore Oil and Gas Infrastructure in Australia. Front. Mar. Sci. 8: 711151. https://doi.org/10.3389/fmars.2021.711151

Melville NP. 2010. Information Systems Innovation for Environmental Sustainability. MIS Quarterly 34(1): 1–21. https://doi.org/10.2307/20721412

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

Moldanová J, Hassellöv IM, Matthias V et al. 2021. Framework for the environmental impact assessment of operational shipping. Ambio. https://doi.org/10.1007/s13280-021-01597-9

Mont-Mégantic International Dark Sky Reserve. 2022. New lighting guide. https://en.cieletoilemontmegantic.org/guide

Morris RL, Heery EC, Loke LHL, Lau E, Strain EMA, Airoldi L, et al. 2019. Design options, implementation issues and evaluating success of ecologically engineered shorelines. Oceanography and Marine Biology: An Annual Review 57: 169–228.

Morrison-Saunders A, Marshall R and Arts J. 2007. EIA Follow-Up International Best Practice Principles. International Association for Impact Assessment, Special Publication Series No. 6. Fargo, USA. SP6.indd (iaia.org)

Nairobi Convention. 2018. No Net Loss of Biodiversity and Ecosystem Services: Applying the Mitigation Hierarchy and Biodiversity Offsets as Tools to Achieve Sustainable Development in the Western Indian Ocean. Nairobi, Kenya. https://nairobiconvention.org/clearinghouse/taxonomy/term/5566)

Nairobi Convention. 2021. Green Port Development in the WIO Region. https://www.unep.org/nairobiconvention/green-port-development-wio-region

National Research Council (NRC) 1992. Restoration of Aquatic Ecosystems—Science, Technology and Public Policy. National Academy Press, Washington, DC, 576 pp. https://nap.nationalacademies.org/catalog/1807/restoration-of-aquatic-ecosystems-science-technology-and-public-policy

Naylor LA, MacArthur M, Hampshire S, Bostock K, Coombes MA, Hansom JD, Byrne R and Folland T. 2017. Proceedings of the Institution of Civil Engineers - Maritime Engineering 170(2): 67-82. https://doi.org/10.1680/jmaen.2016.28

Nihon Kasetsu. 2022. Environmental monitoring for construction projects. https://nihonkasetsu.com/environmental-monitoring-for-construction-projects/

Nitsenko V, Nyenno I, Kryukova I, Kalyna T and Plotnikova M. 2017. Business model for a sea commercial port as a way to reach sustainable development goals. Journal of Security and Sustainability Issues 7(1): 155-166.

NoMePorts (Noise Management in European Ports) 2008. Good Practice Guide on Port Area Noise Mapping and Management. https://www.ecoports.com/assets/files/common/publications/good_practice_guide.pdf.

NoMePorts 2017. Good Practice Guide on Port Area Noise Mapping and Management. Technical Annex. https://www.scribd.com/document/236190819/NoMEPorts-Good-Practice-Guide-Technical-Annex

Notteboom T, Pallis A and Rodrigue J-P. 2022. Port Economics, Management and Policy. New York: Routledge. https://doi.org/10.4324/9780429318184; https://porteconomicsmanagement.org/

NSW (New South Wales) Port Authority. 2017. Green port guidelines. Sustainable strategies for port developments and operations. Port Authority of New South Wales, Australia. https://www.portauthoritynsw.com.au/media/2363/green-port-guidelines.pdf

NSW Port Authority. 2017. Green port guidelines. Sustainable strategies for port developments and operations. Port Authority of New South Wales, Australia. https://www.portauthoritynsw.com.au/projects-planning/planning-and-approvals/guidelines-policies/

Obura, D. et al. 2017. Reviving the Western Indian Ocean Economy: Actions for a Sustainable Future. WWF International, Gland, Switzerland. 64 pp. https://sustainabledevelopment.un.org/content/documents/13692WWF2.pdf

ODPM (Office of the Deputy Prime Minister, London) 2005. Crown copyright. ODPM Publications. 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". https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/7657/practicalguidesea.pdf

Odum HT. 1975. Combining energy laws and corollaries of the maximum power principle with visual systems mathematics. In Ecosystem Analysis and Prediction, S.A. Levin (ed.). Philadelphia: Society for Industrial and Applied Mathematics, pp. 239–263.

OECD (Organisation for Economic Cooperation and Development). 2006. Applying Strategic Environmental Assessment: Good Practice Guidance for Development Co-operation. DAC Guidelines and Reference Series. OECD Publishing.

OECD (Organization for Economic Cooperation and Development). 2008. The Challenge of Capacity Development Working Towards Good Practice (Part 4). OECD Journal on Development 8(3): 233-276. https://doi.org/10.1787/journal_dev-v8-art40-en

Oelermans C, Wegman C, Jinkman B and Aarninhof S. 2021. The impact and costs of Building with Nature projects. Terra et Aqua 165: 37-43. https://www.iadc-dredging.com/article/impact-costs-building-with-nature/

Paalvast P, van Wesenbeeck BK, van der Velde G and de Vries MB. 2012. Pole and pontoon hulas: An effective way of ecological engineering to increase productivity and biodiversity in the hard-substrate environment of the port of Rotterdam. Ecological Engineering 44: 199-209. https://doi.org/10.1016/j.ecoleng.2012.04.002

Paalvast P. 2015. Application of string and rope structures, pole and pontoon hulas, to increase productivity and biodiversity in man-made hard substrate aquatic environments. Proceedings of the RECIF Conference on Artificial Reefs: From Materials to Ecosystem, Caen, France, 27-29 January 2015. https://www.researchgate.net/publication/272823258_Application_of_string_and_rope_structures_pole_and_pontoon_hulas_to_increase_productivity_and_biodiversity_in_man-made_hardsubstrate_aquatic_environments

Partidário M. 2003. Strategic Environmental Assessment (SEA): current practices, future demands and capacity-building needs. Course manual (IAIA Training Courses). Lisbon, Portugal. Microsoft Word - Course Manual 2003.doc (iaia.org).

Partidário MR. 1999. Strategic Environmental Assessment – Principles and Potential, In: Petts, J. (editor) Handbook of Environmental Impact Assessment: Volume 1, Environmental Impact Assessment: Process, Methods and Potential, Blackwell Science, Oxford, p 60-73.

PEMA (Port Equipment Manufacturers Association) 2016. Lighting Technologies in Ports and Terminals. http://www.pema.org/wp-content/uploads/downloads/2016/06/PEMA-IP10-Lighting-Technologies-in-Ports-and-Terminals.pdf.

Peris-Mora E, Diez Orejas JM, Subirats A, Ibáñez S and Alvarez P. 2005. Development of a system of indicators for sustainable port management. Marine Pollution Bulletin 50: 1649–1660. https://doi.org/10.1016/j.marpolbul.2005.06.048

Perkol-Finkel S, Hadary T, Rella A, Shirazi R and Ido S. 2018. Seascape architecture – incorporating ecological considerations in design of coastal and marine infrastructure. Ecological Engineering 120: 645-654. https://doi.org/10.1016/j.ecoleng.2017.06.051

Pescatori V, Franceschini L (2017) Becoming a "green port" in Africa. Private Sector & Development. Issue 26 – African Ports: gateway to development. https://blog.private-sector-and-development.com/2017/05/09/becoming-a-green-port-in-africa/

Petrosillo I, De Marcoa A, Botta S and Comoglio C. 2012. EMAS in local authorities: Suitable indicators in adopting environmental management systems. Ecological Indicators 13: 263–274. https://doi.org/10.1016/j.ecolind.2011.06.011

PIANC (World Association for Waterborne Transport Infrastructure). 2014. 'Sustainable Ports' A Guide for Port Authorities. PIANC Report No. 150.Brussles, Belgium.

PIANC 2006. EnviCom WG 10: Environmental risk assessment of dredging and disposal operations. https://www.pianc.org/publications/envicom/environmental-risk-assessment-of-dredging-and-disposal-operations

PIANC 2009. EnviCom WG 100: Dredging management practices for the environment: A structured selection approach. https://www.pianc.org/publications/envicom/dredging-management-practices-for-the-environment-a-structured-selection-approach

PIANC 2009. EnviCom WG 104: Dredged material as a resource. https://www.pianc.org/publications/envicom/dredged-material-as-a-resource

PIANC 2009. EnviCom WG 109: Long-Term management of confined disposal facilities for dredged material. https://www.pianc.org/publications/envicom/long-term-management-of-confined-disposal-facilities-for-dredged-material

PIANC 2010. EnviCom WG 108: Dredging and port construction around coral reefs. https://www.pianc.org/publications/envicom/dredging-and-port-construction-around-coral-reefs

PIANC 2014. EnviCom Guidance Document 124: Dredging and port construction: Interactions with features of archaeological or heritage interest. https://www.pianc.org/publications/envicom/envicom-guidance-document-124-dredging-and-port-construction-interactions-with-features-of-archaeological-or-heritage-interest

PIANC 2018. Guide for applying Working with Nature to navigation infrastructure projects. https://www.pianc.org/publications/envicom/wg176

PIANC 2019a. EnviCom 188: Carbon Management for Port and Navigation Infrastructure. https://www.pianc.org/publications/envicom/wg188

PIANC 2019b. Press release: Carbon Management for Port and Navigation Infrastructure. https://bit.ly/2H5EN4z

PIANC 2019c. Report 159: Renewables and energy efficiency for maritime ports. https://www.pianc.org/publications/marcom/wg159

PIANC 2020. EnviCom WG 178: Climate Change Adaptation Planning for Ports and Inland Waterways. https://www.pianc.org/publications/envicom/wg178

PIANC 2022. Managing climate change uncertainties in selecting, designing and evaluating options for resilient navigation infrastructure. https://www.pianc.org/publications/envicom/ptgcc-1

Pine MA, Jeffs AG, Wang D and Radford CA. 2016. The potential for vessel noise to mask biologically important sounds within ecologically significant embayments. Ocean and Coastal Management 127: 63-73. https://doi.org/10.1016/j.ocecoaman.2016.04.007

Pintér L, Hardi P, Martinuzzi A and Hall J. 2012. Bellagio STAMP: principles for sustainability assessment and measurement. Ecol. Indicat. 17: 20–28. https://doi.org/10.1016/j.ecolind.2011.07.001

Pitt LF, Parent M, Junglas I, Chan A and Spyropoulou S. 2011. Integrating the smartphone into a sound environmental information systems strategy: Principles, practices and a research agenda. The Journal of Strategic Information Systems 20(1): 27-37. https://doi.org/10.1016/j.jsis.2010.09.005

Pope J and Grace W. 2006. Sustainability assessment in context: Issues of process, policy and governance. Journal of Environmental Assessment Policy and Management 8(3): 373–398. https://doi.org/10.1142/S1464333206002566

Pope J, Annandale D and Morrison-Saunders A. 2004. Conceptualising sustainability assessment. Environmental impact assessment review 24(6): 595-616.

Pope J, Bond A, Morrison-Saunders A. 2015. Conclusion: reflections on the stage of the art of sustainability assessment. In: Morrison-Saunders A, Pope J and Bond A (editors). 2015. Handbook of sustainability assessment. Edward Elgar Publishing, Cheltenham, UK, p427-443.

Ports Australia. 2013. Leading Practice: Port Master Planning Approaches and Future Opportunities. http://www.portsaustralia.com.au/assets/Publications/Master-Planning-Report-Final-low-res.pdf

Ports Australia. 2020. Leading Practice: Port Sustainability Strategy Development Guide: Approaches and Future Opportunities. 5f6a83dc05a0951f90a9bb86_Port Sustainability Strategy Development Guide.pdf (webflow.com)

Rebelo M, Santos G and Silva R. 2014. A Methodology to Develop the Integration of the Environmental Management System with Other Standardised Management Systems. Computational Water, Energy, and Environmental Engineering 3(4): 170-181. DOI: 10.4236/cweee.2014.34018

Riekhof MC, Regnier E and Quaas MF. 2019. Economic growth, international trade, and the depletion or conservation of renewable natural resources. Journal of Environmental Economics and Management 97: 118-133.

Roh S, Thai VV and Wong YD. 2016. Towards sustainable ASEAN port development: challenges and opportunities for Vietnamese ports. Asian J. Shipp. Logistics 32 (2): 107–118. https://doi.org/10.1016/j.ajsl.2016.05.004

RSA (Republic of South Africa). 1998. National Environmental Management Act 107 of 1998. Government Printer, Pretoria, South Africa.

RSA DEA (Department of Environmental Affairs). 2014. National Environmental Management Act No. 107 of 1998: Environmental Impact Assessment Regulations, 2014. Department of Environmental Affairs, Government Gazette No. 10328 (Volume 594), Pretoria, South Africa. 38282_4-12_EnvAffairsP1_Layout 1

RSA DEAT 2007 Strategic Environmental Assessment Guideline, Integrated Environmental Assessment Guideline Series 4. Department of Environmental Affairs and Tourism (DEAT), Pretoria, South Africa.

RSA DEAT. 2000. Strategic Environmental Assessment in South Africa: Guideline Document. Department of Environmental Affairs and Tourism, Pretoria, South Africa.

RSA DEAT. 2002a. Scoping, Integrated Environmental Management, Information Series 2. Department of Environmental Affairs and Tourism (DEAT), Pretoria, South Africa.

RSA DEAT. 2002b. Specialist Studies. Information Series 4, Department of Environmental Affairs and Tourism (DEAT), Pretoria, South Africa.

RSA DEAT. 2002c. Impact Significance. Information Series 5, Department of Environmental Affairs and Tourism (DEAT), Pretoria, South Africa.

RSA DEAT. 2004a. Strategic Environmental Assessment, Integrated Environmental Management, Information Series 10. Pretoria, South Africa.

RSA DEAT. 2004b. Environmental Impact Reporting, Integrated Environmental Management, Information Series 15. Department of Environmental Affairs and Tourism (DEAT), Pretoria, South Africa.

RSA DEAT. 2004c. Review in Environmental Impact Assessment, Integrated Environmental Management, Information Series 13. Department of Environmental Affairs and Tourism (DEAT), Pretoria, South Africa.

RSA DEAT. 2004d. Environmental Management Plans, Integrated Environmental Management, Information Series 12. Department of Environmental Affairs and Tourism (DEAT), Pretoria, South Africa.

RSA Western Cape Government: Environmental Affairs and Development Planning. 2015. Environmental Impact Assessment: An Introduction. EIA_2015.pdf (westerncape.gov.za)

Ruijs A and Vardon M. 2018. Chapter 4: Natural capital accounting: growing experience and testing the 10 living principles to make it fit-for-policy In: 2nd Policy Forum on Natural Capital Accounting for Better Decision Making: Applications for Sustainable Development (Eds. Ruijs A and Vardon M.) Publisher: World Bank. https://www.wavespartnership.org/sites/waves/files/images/4.%20Natural%20capital%20accounting_Growing%20experience.pdf

Sadler B and Verheem R. 1996. Strategic Environmental Assessment: Status, Challenges and Future Directions. Report No. 53, Ministry of Housing, Spatial Planning and the Environment, The Hague, The Netherlands.

Sala S, Ciuffo B and Nijkamp P. 2015. A systemic framework for sustainability assessment. Ecological Economics 119: 314–325. https://doi.org/10.1016/j.ecolecon.2015.09.015

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/

Schenau S, Rietveld H, Bosch D. 2019. Natural capital accounts for the Dutch North Sea 2019. https://www.cbs.nl/en-gb/background/2019/51/natural-capital-accounts-for-the-dutch-north-sea-2019

Schipper CA, Vreugdenhil H and De Jong MPC. 2017. A sustainability assessment of ports and port-city plans: Comparing ambitions with achievements. Transportation Research Part D: Transport and Environment 57: 84-111. https://doi.org/10.1016/j.trd.2017.08.017

Schmaltz E, Melvin EC, Diana Z, Gunady EF, Rittschof D, Somarelli JA, Virdin J and Dunphy-Daly MM. 2020. Plastic pollution solutions: emerging technologies to prevent and collect marine plastic pollution. Environment International 144: 106067. https://doi.org/10.1016/j.envint.2020.106067

Schönborn A and Junge R. 2021. Redefining ecological engineering in the context of circular economy and sustainable development. Circular Economy and Sustainability 1: 375–394. https://doi.org/10.1007/s43615-021-00023-2.

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

Sdoukopoulos E, Boile M, Tromaras A and Anastasiadis N. 2019. Energy Efficiency in European ports: State-of-practice and insights on the way forward. Sustainability 11: 4952. https://doi.org/10.3390/su11184952

Senécal P, Sadler B and Goldsmith B et al. 1999. Principles of Environmental Impact Assessment Best Practice. International Association for Impact Assessment (IAIA) and Institute of Environmental Assessment (UK). Principles of IA (iaia.org)

Sensiba J. 2021. Audi To Cut Water Consumption In Half By 2035. https://cleantechnica.com/2021/03/26/audi-to-cut-water-consumption-in-half-by-2035/

Simenstad C, Reed D and Ford M. 2006. When is restoration not? Incorporating landscape-scale processes to restore self-sustaining ecosystems in coastal wetland restoration. Ecological Engineering 26: 27–39. https://doi.org/10.1016/j.ecoleng.2005.09.007

Sippe R. 1999. Criteria and Standards for Assessing Significant Impact. In: Petts J. (editor) Handbook of Environmental Impact Assessment: Volume 1, Environmental Impact Assessment: Process, Methods and Potential. Blackwell Science, Oxford, p 74-92.

Široka M, Piličić S, Milošević T, Lacalle I and Traven L.2021. A novel approach for assessing the ports' environmental impacts in real time – The IoT based port environmental index. Ecological Indicators 120: 106949. https://doi.org/10.1016/j.ecolind.2020.106949

Sivertsen B (2008) 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/es402260 2

Stein M and Acciaro M. 2020. Value Creation through Corporate Sustainability in the Port Sector: A Structured Literature Analysis. Sustainability 12: 5504. https://doi.org/10.3390/su12145504

Swanepoel, E. 2020. Oil spills in the Western Indian Ocean. National contingency plans fall short. Institute for Security Studies Africa. https://issafrica.org/research/africa-report/oil-spills-in-the-western-indian-ocean-national-contingency-plans-fall-short

Taira D, Heery EC, Loke LHL, Teo A, Bauman AG and Todd PA. 2020. Ecological engineering across organismal scales: trophic-mediated positive effects of microhabitat enhancement on fishes. Mar Ecol Prog Ser Vol. 656: 181–192. https://doi.org/10.3354/meps13462

Taljaard S and Weerts SP. 2023. Environmental Solutions for African Ports. Sustainability Performance Index for Ports: Prototype Method. CSIR Report No. CSIR/SPLA/SECO/IR/2023/0008/B. South Africa.

Taljaard S, Slinger JH, Arabi S Weerts SP and Vreugdenhil H. 2021 The natural environment in port development: A 'green handbrake' or an equal partner? Ocean Coast Manag. 199: 105390. https://doi.org/10.1016/j.ocecoaman.2020.105390

Taneja P, Ligteringen H and Walker WE. 2012. Flexibility in port planning and design. European Journal of Transport and Infrastructure Research 12 (1): 66–87.

Tarr P. n.d. Southern African Institute for Environmental Assessment (SAIEA). EIA: Guidelines for Impact Assessment in the Western Indian Ocean Region. United Nations Environment Programme (UNEP): Nairobi Convention. WIO-Lab EA Guidelines.pdf (nairobiconvention.org)

Ten Kate K, Bishop J and Bayon R. 2004. Biodiversity offsets: Views, experience, and the business case. IUCN, Gland, Switzerland and Cambridge, UK and Insight Investment, London, UK (https://www.iucn.org/content/biodiversity-offsets-views-experience-and-business-case).

Thapa RB, Matin MA and Bajracharya B. 2019. Capacity Building Approach and Application: Utilization of Earth Observation Data and Geospatial Information Technology in the Hindu Kush Himalaya. Front. Environ. Sci. 7: 165. https://doi.org/10.3389/fenvs.2019.00165

Therivel R and Partidário MR. 1996. The Practice of Strategic Environmental Assessment. Earthscan, London, UK.

TNPA (Transnet National Ports Authority). n.d. Port of Durban EMP Guidelines (Construction, Operational & Decommissioning). https://www.transnet.net/TenderBulletins/TC/Lists/Tenders/Attachments/118/EMP%20Guidelines%20-Port%20of%20Durban.pdf

Transnet. 2020. Integrated Report 2020. South Africa. https://www.transnet.net/InvestorRelations/AR2020/Transnet%20IR%202020.pdf

Trozzi C and Vaccaro R. 2000. Environmental impact of port activities. In: Brebbia CA, Olivella J (eds) Maritime Engineering and Ports II. DOI: 10.2495/PORTS000131

UN (united Nations) 2021. Financing for Sustainable Development Report 2021. Inter-agency Task Force on Financing for Development New York. https://www.un.org/sustainabledevelopment/wp-content/uploads/2022/03/2021-Report.pdf

UN Environment. 2018. Assessing Environmental Impacts – A Global Review of Legislation. Nairobi, Kenya. Environmental_Impacts_Legislation (6).pdf

UN. 1992. Assessment of the environmental impact of port development. A guidebook for EIA of port development. Economic and Social Commission of Asia and the Pacific https://www.unescap.org/sites/default/files/pub_1234_fulltext.pdf

Underwood AJ. 1994. On beyond BACI: sampling designs that might reliably detect environmental disturbances. Ecological Application 4: 3-15. https://doi.org/10.2307/1942110

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. https://doi.org/10.1023/A:1009983229076

UNDG (United Nations Development Group) 2019. Sustainable Development Goals Acceleration Toolkit. https://undg.org/2030-agenda/sdg-acceleration-toolkit/

UNEP et al. (United Nations Environment Programme, Nairobi Convention and International Maritime Organization) 2020a. Regional oil spill preparedness in eastern African and the western Indian Ocean. Background Document https://www.nairobiconvention.org/clearinghouse/sites/default/files/Regional%20Oil%20Spill%20Preparedness.pdf

UNEP et al. (United Nations Environment Programme, Nairobi Convention and International Maritime Organization) 2020b. Regional oil spill preparedness in eastern African and the western Indian Ocean. Workshop Report – 3 to 5 March 2020.

https://www.nairobiconvention.org/clearinghouse/sites/default/files/Report%20Oil%20Spills%20Workshop.pdf

UNEP, Nairobi Convention Secretariat and CSIR. 2022a. Western Indian Ocean: Strategic Framework for Coastal & Marine Water Quality Management UNEP, Nairobi, Kenya. xx pp.

UNEP, Nairobi Convention Secretariat and CSIR. 2022b. Western Indian Ocean: Guidelines for Setting Water and Sediment Quality Targets for Coastal and Marine areas. UNEP, Nairobi, Kenya. xx pp.

UNEP, Nairobi Convention, USAID and WIOMSA. 2020. Guidelines on Mangrove Ecosystem Restoration for the Western Indian Ocean Region. UNEP, Nairobi, 71 pp. https://wedocs.unep.org/20.500.11822/33253

UNEP. 2010. Final text of the Amended Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Western Indian Ocean. UNEP-DEPI-EAF-COP8-2015-10-en-Amended-Nairobi-Convention.pdf (nairobiconvention.org)

UNEP. 2013. Guidelines for National Waste Management Strategies: Moving from challenges to opportunities. https://www.unep.org/ietc/resources/toolkits-manuals-and-guides/guidelines-national-waste-management-strategies-moving

UNEP. 2021a. Principles for ecosystem restoration to guide the United Nations Decade 2021-2030. https://www.decadeonrestoration.org/

UNEP. 2021b. Ecosystem Restoration Playbook. A practical guide to healing the planet. https://www.decadeonrestoration.org/publications/ecosystem-restoration-playbook-practical-guide-healing-planet

UNEP/GPA and WIOMSA. 2004 Regional overview of the physical alteration and habitat destruction (PADH) in the Western Indian Ocean region. wedocs.unep.org/bitstream/handle/20.500.11822/30364/HabOR.pdf?sequence=1&isAllowed=y

UNEP/OCHA (United Nations Environmental Programme and United Nations Office for the Coordination of Humanitarian Affairs – Environment Unit). 1996a. Guidelines for the development of a national environmental contingency plan. https://www.unocha.org/sites/dms/Documents/Guidelines_Development_NI_Env_Contingency_Plan.pdf

UNEP/OCHA. 1996b. Sample of national environmental contingency plan (https://www.eecentre.org/Modules/EECResources/UploadFile/Attachment/Sample_of_a_National_Environmental_Contingency_Plan.pdf)

UNEP-FI (United Nations Environment Programme Finance Initiative) 2021. Turning the Tide: How to finance a sustainable ocean recovery—A practical guide for financial institutions. Geneva. https://www.unepfi.org/publications/turning-the-tide/

UNEP-Nairobi Convention/USAID/WIOMSA. 2020. Guidelines on Mangrove Ecosystem Restoration for the Western Indian Ocean Region. UNEP, Nairobi, 71 pp. https://www.nairobiconvention.org/CHM%20Documents/WIOSAP/guidelines/GuidelinesonMangroveRestorationForTheWIO.pdf

UNEP-Nairobi Convention/WIOMSA. 2020. Guidelines for Seagrass Ecosystem Restoration in the Western Indian Ocean Region. UNEP, Nairobi, 63 pp. https://www.nairobiconvention.org/clearinghouse/sites/default/files/Guidelines%20for%20Seagrass%20Ecosystem%20Restoration%20in%20the%20Western%20Indian%20Ocean%20Region.pdf

UNESCO-IOC/European Commission. 2021. MSPglobal International Guide on Marine/Maritime Spatial Planning. Paris, UNESCO. (IOC Manuals and Guides no 89). https://unesdoc.unesco.org/ark:/48223/pf0000379196

United Nations (UN) 2014a. System of Environmental Economic Accounting 2012: Central Framework. New York City, USA (https://seea.un.org/content/seea-central-framework).

United Nations (UN) 2014b. System of Environmental-Economic Accounting 2012: Experimental Ecosystem Accounting. New York City, USA (https://seea.un.org/ecosystem-accounting).

United Nations (UN) 2015. Transforming Our World: The 2030 Agenda for Sustainable Development. https://sdgs.un.org/

United Nations (UN) 2015. Transforming Our World: The 2030 Agenda for Sustainable Development https://sdgs.un.org/

United Nations (UN) 2019. Technical Recommendations in support of the System of Environmental-Economic Accounting 2012: Experimental Ecosystem Accounting. New York City, USA (https://seea.un.org/ecosystem-accounting).

United Nations Development Group (UNDG) 2019. Sustainable Development Goals Acceleration Toolkit. https://undg.org/2030-agenda/sdg-acceleration-toolkit/.

US-EPA (United State Environmental Protection Agency). 2021. Ports Primer: 7.1 Environmental Impacts. www.epa.gov/community-port-collaboration/ports-primer-71-environmental-impacts

US-EPA. 2000. Evaluation guidelines for ecological indicators. https://archive.epa.gov/emap/archive-emap/web/html/ecoind.html

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

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

US-EPA. 2007. An Environmental Management System (EMS) Primer for Ports: Advancing Port Sustainability. https://archive.epa.gov/sectors/web/pdf/ems_primer.pdf

US-EPA. 2022. Exposure Assessment Tools by Media - Water and Sediment https://www.epa.gov/expobox/exposure-assessment-tools-media-water-and-sediment

Van Ballegooyen, R, Retief M, Els R, Smith G and Van Eeden F. 2016. Environmental authorisation of land-based effluent discharges into the coastal environment: Synchronising engineering design, environmental impact assessment and regulatory approval processes to minimize the risk of project delays. 80th EMISA Conference, East London, South Africa (https://www.imesa.org.za/wp-content/uploads/2016/11/Paper-14-Roy-van-Ballegooyen-Environmental-authorisation-of-land-based-effluent-discharges-into-the-coastal-environment-Synchronising-engineering-design-environmental-impact-assessment-regulator.pdf

Van Niekerk L, Taljaard S, Adams JB, Lamberth SJ and Weerts SP. 2020. Experimental ecosystem accounts for South Africa's estuaries: Extent, Condition and Ecosystem Services Accounts. Report produced by the Council for Scientific and Industrial Research (CSIR), South Africa. Report No CSIR/SPLA/SECO/IR/2020/0026/A. CSIR 2020. https://seea.un.org/content/experimental-ecosystem-accounts-south-africas-estuaries-extent-condition-and-ecosystem

Vikolainen V, Bressers H and Lulofs K. 2014. A shift toward building with nature in the dredging and port development industries: managerial implications for projects in or near natura 2000 areas. Environ. Manag. 54: 3–13. https://doi.org/10.1007/s00267-014-0285-z

Villeneuve C, Tremblay D, Riffon O, Lanmafankpotin GY and Bouchard S. 2017. A Systemic Tool and Process for Sustainability Assessment. Sustainability 9: 1909. https://doi.org/10.3390/su9101909

Villeneuve C, Tremblay D, Riffon O, Lanmafankpotin GY and Bouchard S. 2017. A Systemic Tool and Process for Sustainability Assessment. Sustainability 9: 1909.

Waas T, Hugé J, Verbruggen A and Wright T. 2011. Sustainable development: a bird's eye view. Sustainability 3: 1637–1661. https://doi.org/10.3390/su3101637

Walker TR, Adebambo A, Del Aguila Feijoo MC, Elhaimer E, Hossain T, Edwards SJ, Morrison CE, et al. 2018. Chapter 27 - Environmental Effects of Marine Transportation. World Seas: an Environmental Evaluation (Second Edition) Volume III: Ecological Issues and Environmental Impacts: 505-530. https://doi.org/10.1016/B978-0-12-805052-1.00030-9

Wang T, He GS, Zhou QL, Gao JZ, Deng LJ. 2018. Designing a framework for marine ecosystem assets accounting. Ocean & Coastal Management 163: 92-100. https://doi.org/10.1016/j.ocecoaman.2018.05.019

Waterman RE, Misdorp R and Mol A. 1998. Interactions between water and land in The Netherlands. J. Coast Conservation 4: 115–126. https://doi.org/10.1007/BF02806503

Waterman RE. 2010. Integrated Coastal Policy via Building with Nature. Doctoral Thesis. Technical University of Delft, The Netherlands.

Whitehead P. 2000. Environmental management framework for ports and related industries. Terra et Aqua 80: 22-30.

World Bank Group. 2016. Biodiversity Offsets. A User Guide. https://www.cbd.int/financial/doc/wb-offsetguide2016.pdf

World Bank. 1990. Environmental Considerations for Port and Harbor Developments. World Bank Technical Paper number 126. Transport and the Environment Series http://documents.worldbank.org/curated/en/931761468782116353/pdf/multi-page.pdf

World Health Organisation (WHO) 2021. WHO gloval air quality guidelines. Particulate matter ($PM_{2,5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide https://apps.who.int/iris/handle/10665/345329

WPCI (World Ports Climate) 2010. Carbon foot printing for ports. Guidance document. https://sustainableworldports.org/wp-content/uploads/Carbon_Footprinting_Guidance_Document.pdf

WPSP (World Ports Sustainability Program) 2020. World ports sustainability Report. 2020. https://sustainableworldports.org/wp-content/uploads/WORLD-PORTS-SUSTAINABILITY-REPORT-2020-FIN.pdf

WPSP (World Ports Sustainability Program) 2020. World ports sustainability Report. 2020. https://sustainableworldports.org/wp-content/uploads/WORLD-PORTS-SUSTAINABILITY-REPORT-2020-FIN.pdf

Wright C. 2002. Sea ports: Can strategic environmental assessment improve environmental assessment in the port sector? Thesis presented in part-fulfilment of the degree of Master of Science in accordance with the regulations of the University of East Anglia, United Kingdom https://www.uea.ac.uk/documents/541248/10799665/Wright_Claire.pdf

WWF (World Wildlife Fund). 2016. Living Planet Report. Risk and Resilience in a New Era. WWF International, Gland Switzerland. https://wwf.panda.org/wwf_news/?282370/Living%2DPlanet%2DReport%2D2016

Zis T, North RJ, Angeloudis P, Ochieng WY and Bell MGH. 2014. Evaluation of cold ironing and speed reduction policies to reduce ship emissions near and at ports. Maritime Economics & Logistics 16(4): 371-398. https://doi.org/10.1057/mel.2014.6