Towards Sustainable Port Development in the Western Indian Ocean

Scenario Analysis

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(Final Draft)

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EXECUTIVE SUMMARY

Background

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

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

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

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

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

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

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

This document presents the Scenario Analysis which evaluates a series of generic port development pathways for the WIO region by 2050, ranging from 'Doing-nothing' to options incorporating 'Sustainable port' considerations. Given the diverse status of sustainable port development in countries of the WIO region, this Scenario Analysis adopted a range of generic port development futures or scenarios for the region. However, the method applied in the development and analysis of these generic scenarios can be applied within specific countries or ports to develop and analyse their own scenarios considering anticipated, site-specific conditions.

Scenario Analysis Method

The scenario analysis process applied a qualitative approach where inputs are provided as narratives, and where outcomes are expressed as anticipatory scenarios (i.e., anticipated outcomes by 2050), following a six-step process:

Step 1: Define perspective and context of scenario exercise

'Conduct a scenario analysis on possible future port development outcomes, ranging from 'doing nothing' to 'supporting sustainable ports', to make a business case for environmentally sustainable port development in the WO region by 2050.'

Step 2: Identify key driving forces likely to shape future outcomes by 2050

Anticipated external driving force categories likely to influence port development in the WIO region by 2050 are (to be assumed constant over scenarios):

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

Anticipated internal driving force categories likely to influence port development in the WIO region by 2050:

INTERNAL DRIVING FORCE CATEGORY	MOTIVATION FOR INCLUSION
Corporate culture and policies	• Economic development direction chosen by ports might influence their ability to balance environmental and social sustainability • Extent to which ports incorporate environmental and social accountability in official policies influences the extent to which port officials can enforce sustainable practices

INTERNAL DRIVING FORCE CATEGORY	MOTIVATION FOR INCLUSION
Institutional arrangements	• Establishment of dedicated and empowered institutions (e.g., environment departments in ports) provides a platform to enforce policies and coordinate activities. • Extent to which ports communicate and consider wellbeing of local communities/city (in and around ports) will determine social sustainability, as well as level of potential conflict to be dealt with
Technological development	• Fuel and energy sources will determine efforts towards climate change mitigation, • Technology development and adoption will influence a ports ability to address and mitigate impacts such as air, water and soil pollution, and destruction of coastal habitats and biota
Operational efficiency	• Skills, capacity, and access to funding is directly correlated to effective implementation of sound environmental/social policies. • Level of enforcement determines extent to which port authorities can ensure compliance with environmental/social policies

Step 3: Identify key sustainability criteria (or indicators) by which to measure future outcomes

INDICATOR	MOTIVATION
ENVIRONMENT	
GHG emissions	Commitment to climate change mitigation
Status of air quality	Commitment to manage and control atmospheric emissions
Status of port environmental quality	Commitment to manage and control wastewater, solid waste, and hazardous waste
Status of biodiversity & habitat intactness	Commitment to manage port infrastructure development and operations to protect biodiversity and habitat integrity (e.g., implementing biodiversity trade-off policies)
SOCIAL	
Community Well-being vs Conflict	Commitment to considering community needs, and their involvement in port matter that may affect their livelihoods
Port-City Collaboration vs Conflict	Commitment to consult and collaborate with adjacent urban centres
ECONOMIC	
Climate resilience	Commitment to consider climate change such as increased storminess, SLR etc.
Competitiveness (license-to-operate)	Level to which port environmental and social practices enable competitiveness (linked to international and client pressures re sustainability)

Step 4: Define possible trajectories for selected driving force categories

For the purposes of this scenario analysis, external driving force trajectories for port development in the WIO region by 2050 were assumed to remain constant across all scenarios:

EXTERNAL DRIVING FORCE CATEGORY	EXPECTED TRAJECTORY 2050
Climate Change	0.5 m SLR (from 2000 to 2050, assuming a ~1m rise by 2100 - Horton et al. 2020) together with a probable increase in occurrence and intensity of sea-storms
Shipping traffic in WIO Region	Shipping traffic to increase markedly, with an associated increase in port traffic
Societal pressure	Local societies, supported by international non-government organisations (NGOs), are increasingly empowered to challenge environmental and social decline
International market views	Increased international pressure for environmental/social accountability in ports, and therefore more effective competition in port market as 5th generation ports
Political stability	Political stability across WIO countries is expected to be variable, unstable at times.

Internal driving force trajectories, therefore, were defined to construct anticipated generic future scenarios because those were aspects largely under the control of port managers. Based on stakeholder inputs, various options for each of the internal driving force categories were defined:

DRIVING FORCE		POTENTIAL TRAJECTORY
Corporate culture and policies	A	'Supporting sustainable ports': In response to global demand for environmental accountability to secure/grow their market share, port managers implement and enforce overarching policies for more sustainable ports. These are also reflected in lease agreements with private sector tenants. Lost revenue and rising infrastructure maintenance costs because of climate change impacts convince port authorities to act to increase climate resilience of port infrastructure and operations. Pressure from increasingly empowered communities/cities and resulting delays in development projects (with serious cost implications) necessitates port authorities to undertake joint, strategic, and integrated spatial planning of port development and expansion.
	B	'Greater sustainability focusing on climate change mitigation/adaptation': In response to global demand for environmental accountability to secure/grow market share, port managers implement and enforce overarching policies for more sustainable ports focusing on energy efficiency and renewable energy. These are also reflected in lease agreements with private sector tenants. Lost revenue and rising infrastructure maintenance costs because of climate change impacts convince port authorities to address greater climate resilience in port infrastructure development and operations. However, pollution, waste and wastewater management and control remain neglected. Ports still disregard societal responsibilities, reflected in uncoordinated spatial planning for port development and expansions impacting adjacent communities/cities.
	C	'Greater sustainability focusing on pollution management': In response to global demand for environmental accountability to secure/grow market share, port managers implement and enforce overarching policies for more sustainable ports focusing

DRIVING FORCE		POTENTIAL TRAJECTORY
		on pollution (waste and wastewater management and control). These are also reflected in lease agreements with private sector tenants. However, energy efficiencies and renewable energy issues remain neglected and port authorities fail to act on addressing climate resilience in port infrastructure development and operations. Ports also disregard societal responsibilities, reflected in uncoordinated spatial planning for port development and expansions impacting adjacent communities/cities.
	D	'Doing nothing': Management has a short-term economic focus, not acknowledging longer-term benefits of sustainable port policies or of strengthening climate resilience of port infrastructure and operations (e.g., associated with SLR and increased storminess). Sound lease agreements with private sector tenants, addressing their environmental and social responsibilities, are lacking. Uncoordinated spatial planning of port development and expansion impacts adjacent communities/cities.
Institutional arrangements	A	'Supporting sustainable ports': The financial and logistical value of functional, cross-sectoral institutional structures for environmental matters in cooperative port development is acknowledged. Dedicated port environmental departments are established and resourced. Increasing global pressure on ports (and port tenants) to account for their social and environmental responsibilities necessitates the establishment of dedicated institutional structures to communicate, coordinate and audit port user performance. Integrated climate change forums are established within port structures. These help drive increased climate resilience of port infrastructure development and operations. Pressure from increasingly empowered communities/cities (which otherwise object to and delay development projects with serious cost implications) necessitates port authorities to establish dedicated institutional structures to facilitate collaboration with society at large.
	B	'Greater sustainability focusing on climate change mitigation/adaptation': The financial and logistical value of functional, cross-sectoral institutional structures for environmental matters in cooperative port development is acknowledged. Dedicated port environmental departments are established and resourced, focusing on climate change mitigation/adaptation. These help drive increased climate resilience of port infrastructure and operations. Increasing global pressure on ports (and port tenants) to account for their social and environmental responsibilities necessitates the establishment of dedicated institutional structures to communicate, coordinate and audit port user performance. Integrated climate change forums are established within port structures. However, dedicated forums to facilitate collaboration/communication between port authorities and adjacent communities/cities are still lacking.
	C	'Greater sustainability focusing on improved pollution management': The financial and logistical value of functional, cross-sectoral institutional structures for environmental matters in cooperative port development is acknowledged. Dedicated port environmental departments are established and resourced, focusing on pollution management. However, integrated climate change forums are not established within port structures, and climate resilience of port infrastructure and operations is not increased. Increasing global pressure on ports (and port tenants) to account for their social and environmental responsibilities necessitates the establishment of dedicated institutional structures to communicate, coordinate and audit port user performance. Dedicated forums to facilitate collaboration/communication between port authorities and adjacent communities/cities are also still lacking.
	D	'Doing nothing': Silo-based management within authorities prevails, with no dedicated port environmental departments, resulting in uncoordinated planning and management, often with costly consequences (duplication of efforts, critical issues not addressed). No formal institutional structures are in place to coordinate activities across port users, risking potential detrimental environmental, social and economic consequences, especially during disasters and emergencies. No forums in place as platforms to facilitate communication and collaboration between port authorities and adjacent communities/cities.
Technological development	A	'Supporting sustainable ports': Pressured by global demand for environmental accountability and to secure/grow market share, ports focus on globally visible technological interventions linked to energy efficiency and renewable energy sources (this might also occur due to fossil fuel becoming increasingly expensive). Customer dissatisfaction (e.g., because of long vessel turnaround time) forces port authorities to invest in technologies for improved efficiencies. Pressure from empowered adjacent communities/cities (which otherwise result in increasingly costly legal conflicts) necessitate port authorities to implement innovative waste and wastewater management technologies to combat coastal water, air and land pollution.
	B	'Greater sustainability focusing on climate change mitigation/adaptation': In response to global demand for environmental accountability to secure/grow market share, port managers implement and enforce overarching policies for more sustainable ports focusing on energy efficiency and renewable energy. These are also reflected in lease agreements with private sector tenants. Lost revenue and rising infrastructure maintenance costs because of climate change impacts convince port authorities to act to increase climate resilience of port infrastructure and operations. However, pollution, waste and wastewater management and control remain neglected. Ports still disregard societal responsibilities, reflected in uncoordinated spatial planning for port development and expansions impacting adjacent communities/cities.
	C	'Greater sustainability focusing on improved pollution management': Pressure from empowered adjacent communities/cities necessitates port investment and implementation of innovative waste and wastewater management technologies to combat coastal water, air and land pollution. Port authorities fail to act to increase climate resilience of port infrastructure and operations and energy efficiencies and renewable energy issues remain neglected. Investment in renewable energy sources and technologies to improve port energy and logistical efficiencies is not made. Customer dissatisfaction remains high, and ports lose competitiveness.
	D	'Doing nothing': Energy efficient technologies (e.g., cold ironing) are not implemented and no investment is made in renewable energy. Ports remain strongly reliant on fossil fuels. Innovative waste and wastewater management technologies are also absent, resulting in coastal water and air pollution. Vessel turnover times are long due to poor vessel traffic management and inefficient traffic and cargo handling technologies.
Operational efficiency	A	'Supporting sustainable ports': Global pressure for greater environmental accountability and growing need to acquire port environmental certification (e.g., ISO14001) compel port authorities to implement and enforce environmental monitoring/auditing processes. Higher port traffic increases the risk of costly disasters, necessitating authorities to invest in improved disaster preparedness procedures. Improved pollution management enables port authorities to identify polluters and direct cost recoveries to their accounts (polluter pays principle) leading to improved compliance with waste regulations. Significantly improved environmental practices open lucrative funding opportunities with investors wanting to support sustainable port development (e.g., public-private partnerships). Port authorities acknowledge the value of more sustainable ports and the critical importance of adequately trained and motivated staff, to secure long-term (sustainable) economic growth.
	B	'Greater sustainability focusing on climate change mitigation/adaptation': Global pressure for greater environmental accountability necessitates port authorities to implement and enforce environmental monitoring/auditing processes (focusing on energy efficiency and renewable energy sources). Improved environmental practices open selected funding opportunities with investors interested in sustainable port development (e.g., public-private partnerships). Lost revenue and rising infrastructure maintenance costs because of climate change impacts convince port authorities to act to increase climate resilience of port infrastructure and operations. Investment is also made in training and capacity development to focus on energy efficiency and renewable energy, but not on pollution (waste and wastewater management and control).
	C	'Greater sustainability focusing on improved pollution management': Global pressure for greater environmental accountability and growing need to acquire port environmental certification (e.g., ISO14001) compel port authorities to implement and enforce environmental monitoring/auditing processes focusing on pollution (waste and wastewater management and control). Improved pollution management enables port authorities to identify polluters and direct cost recoveries to their accounts (polluter pays principle) leading to improved compliance with waste regulations. Improved environmental practices open selected funding opportunities with investors supporting sustainable port development (e.g., public-private partnerships). However, energy efficiencies and renewable energy issues remain neglected and port authorities fail to act to increase climate resilience of port infrastructure and operations. Investment in training and capacity development focusses on pollution (waste and wastewater management), but not energy efficiency and renewable energies.
	D	'Doing nothing': Effective environmental monitoring/auditing and disaster intervention preparedness (e.g., oil spills) are lacking due to inefficient funding, lack of training and capability development. Lack of management commitment to environmentally operational efficiency.

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

The anticipated influence of various driving force trajectories on selected sustainability indicators was estimated and scored using a 5-point scaling (-2 to +2) as follows:

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

INTERNAL DRIVING FORCE CATEGORY 1: CORPORATE CULTURE & POLICY

INDICATOR		EXPECTED INFLUENCE OF TRAJECTORY			
		A	B	C	D
1	GHG emissions	2	2	-2	-2
2	Status of Air Quality	2	1	1	-2
3	Status of Port Environmental Quality	2	-2	2	-2
4	Status of Biodiversity & Habitat Intactness	2	-2	2	-2
5	Community relationship	2	-1	1	-2
6	Port-City collaboration	2	-1	1	-2
7	Competitiveness	2	1	0	-2
8	Climate resilience	2	2	-2	-2

INTERNAL DRIVING FORCE CATEGORY 2: INSTITUTIONAL ARRANGEMENTS

INDICATOR		EXPECTED INFLUENCE OF TRAJECTORY			
		A	B	C	D
1	GHG emissions	2	1	1	-2
2	Status of Air Quality	2	1	1	-2
3	Status of Port Environmental Quality	2	1	1	-2
4	Status of Biodiversity & Habitat Intactness	2	1	1	-2
5	Community relationship	2	-1	-1	-2
6	Port-City collaboration	2	-1	-1	-2
7	Competitiveness	2	1	0	-2
8	Climate resilience	2	2	-2	-2

INTERNAL DRIVING FORCE CATEGORY 2: TECHNOLOGICAL DEVELOPMENT

INDICATOR		EXPECTED INFLUENCE OF TRAJECTORY			
		A	B	C	D
1	GHG emissions	2	2	-2	-2
2	Status of Air Quality	2	1	1	-2
3	Status of Port Environmental Quality	2	-2	2	-2
4	Status of Biodiversity & Habitat Intactness	2	-2	2	-2
5	Community relationship	2	-1	2	-2
6	Port-City collaboration	2	-1	1	-2
7	Competitiveness	2	1	0	-2
8	Climate resilience	2	2	-2	-2

INTERNAL DRIVING FORCE CATEGORY 4: OPERATIONL EFFICIENCY

INDICATOR		EXPECTED INFLUENCE OF TRAJECTORY			
		A	B	C	D
1	GHG emissions	2	2	-2	-2
2	Status of Air Quality	2	1	1	-2
3	Status of Port Environmental Quality	2	-2	2	-2
4	Status of Biodiversity & Habitat Intactness	2	-2	2	-2
5	Community relationship	2	-1	2	-2
6	Port-City collaboration	2	-1	1	-2
7	Competitiveness	2	1	0	-2
8	Climate resilience	2	2	-2	-2

Further, it was also acknowledged that different driving force categories may have varying influence on each of the selected sustainability indicators. This was addressed by weighting the influence of driving force categories across sustainability indicators:

INTERNAL DRIVING FORCE CATEGORY	WEIGHTING (EXPECTED RELATIVE INFLUENCE) OF DRIVING FORCE CATEGORY ON SPECIFIC INDICATORS							
	1	2	3	4	5	6	7	8
	GHG emissions	Status of Air Quality	Status of Port Environmental Quality	Status of Biodiversity & Habitat Intactness	Community relationship	Port-City collaboration	Climate resilience	Competitive-ness
1. Corporate culture and policy	0.20	0.30	0.30	0.30	0.40	0.30	0.40	0.20
2. Institutional arrangements	0.10	0.10	0.10	0.10	0.30	0.40	0.10	0.10
3. Technological development	0.40	0.30	0.30	0.30	0.10	0.10	0.40	0.30
4. Operational efficiency	0.30	0.30	0.30	0.30	0.20	0.20	0.10	0.40
DOMAIN	WEIGHTING		INDICATOR				WEIGHTING	
Environment	0.40		GHG emissions				0.25	

		Status of Air Quality	0.25
		Status of Port Environmental Quality	0.25
		Status of Biodiversity & Habitat Intactness	0.25
Social	0.30	Community relationship	0.50
		Port-City collaboration	0.50
Economic	0.30	Climate resilience	0.50
		Competitiveness	0.50

Step 6: Build anticipated scenarios and determine expected sustainability outcomes

Using a combination of driving force options (A to D) a variety of possible future scenario outcomes was defined:

NUMBER & DESCRIPTION		INTERNAL DRIVING FORCE TRAJECTORY COMBINATION	
1	'Doing nothing'	Corporate culture and policies	[D] 'Doing nothing'
		Institutional arrangements	
		Technological development	
		Operational efficiency	
2	'Fixing only institutions'	Corporate culture and policies	[D] 'Doing nothing'
		Institutional arrangements	[A] 'Supporting sustainable ports'
		Technological development	[D] 'Doing nothing'
		Operational efficiency	
3	'Fixing only policies & institutions'	Corporate culture and policies	[A] 'Supporting sustainable ports'
		Institutional arrangements	
		Technological development	[D] 'Doing nothing'
		Operational efficiency	
4	'Fixing only policies & technologies'	Corporate culture and policies	[A] 'Supporting sustainable ports'
		Institutional arrangements	[D] 'Doing nothing'
		Technological development	[A] 'Supporting sustainable ports'
		Operational efficiency	[D] 'Doing nothing'
5	'Greater sustainability focusing on climate change mitigation/ adaptation'	Corporate culture and policies	[B] 'Greater sustainability focusing on climate change mitigation/ adaptation'
		Institutional arrangements	
		Technological development	
		Operational efficiency	
6	'Greater sustainability focusing on improved pollution management'	Corporate culture and policies	[C] 'Greater sustainability focusing on improved pollution management'
		Institutional arrangements	
		Technological development	
		Operational efficiency	
7	'Fixing only policies, institutions & technologies'	Corporate culture and policies	[A] 'Supporting sustainable ports'
		Institutional arrangements	
		Technological development	
		Operational efficiency	[D] 'Doing nothing'
8	'Fixing only policies, technologies & operations'	Corporate culture and policies	[A] 'Supporting sustainable ports'
		Institutional arrangements	[D] 'Doing nothing'
		Technological development	[A] 'Supporting sustainable ports'
		Operational efficiency	
9	'Supporting sustainable ports'	Corporate culture and policies	[A] 'Supporting sustainable ports'
		Institutional arrangements	
		Technological development	
		Operational efficiency	

The above information was processed in a simple Excel spreadsheet model, to generate scores for each of the scenarios using the anticipated influence of internal driving force category trajectories on selected sustainability indicators, as well as the proposed weighting system. Results for each scenario can be compared across individual sustainability indicators, for each of the domains (i.e., environment, social and economic), as well as and overall sustainability score. For ease in interpretation, the sustainability indicator, domain and overall sustainability scores were normalized within a range from 0 to 100, where scores below 50 are indicative of a negative sustainability trajectory and score above 50 a positive sustainability trajectory.

Outcome of Generic Future Scenario Analysis

Figure 1 presents a comparison of the expected sustainability outcomes of the selected future scenarios for port development in the WIO region by 2050, where scores above 50 represent more sustainable positive trajectories and scores below 50 are indicative of less sustainable negative trajectories. Scenario 1 ('Doing nothing') and Scenario 9 ('Supporting sustainable ports') represent the two extreme situations in which port authorities either disregard any actions towards sustainable development (Scenario 1) or where port authorities diligently implement interventions to achieved sustainability (Scenario 9). While these extremes are unlikely to be realistic outcomes, they provide the relative end points against which to better calibrate intermediate interventions (Scenarios 2 to 8).

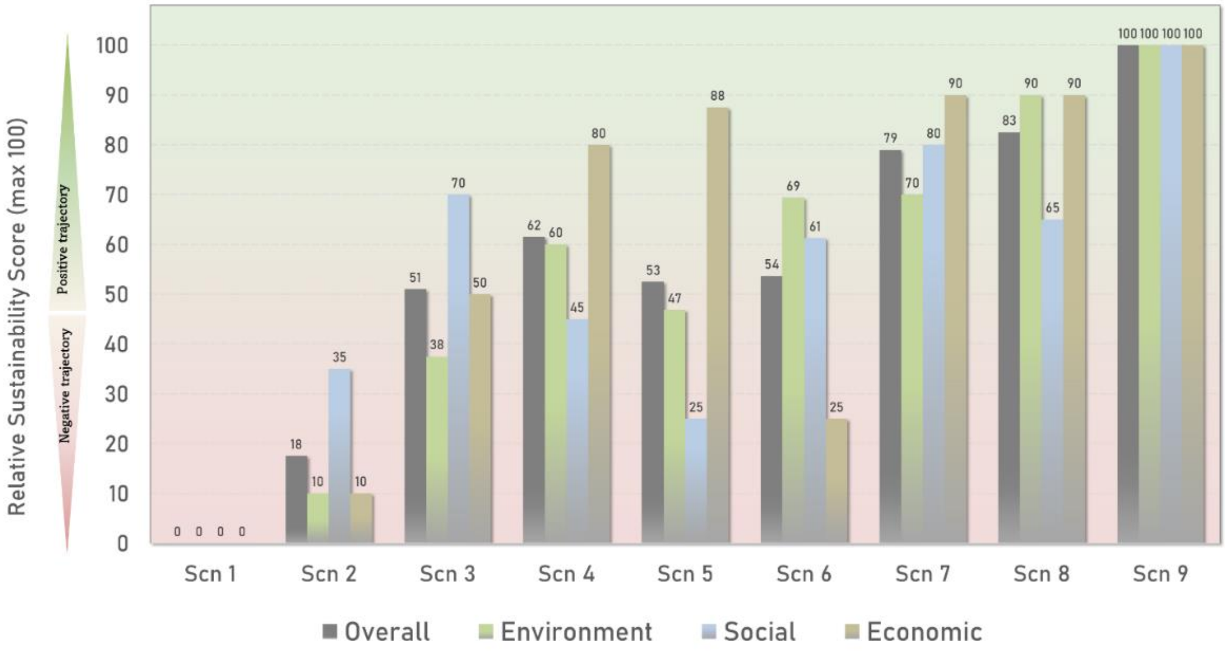

Figure 1 Comparison of overall (as well as environmental, social and economic) sustainability performance (as per selected sustainability indicators) across generic future scenarios for port development in the WIO region by 2050

Figure 2 schematises the outcomes per sustainability indicator for each of the future scenarios for port development in the WIO region by 2050.

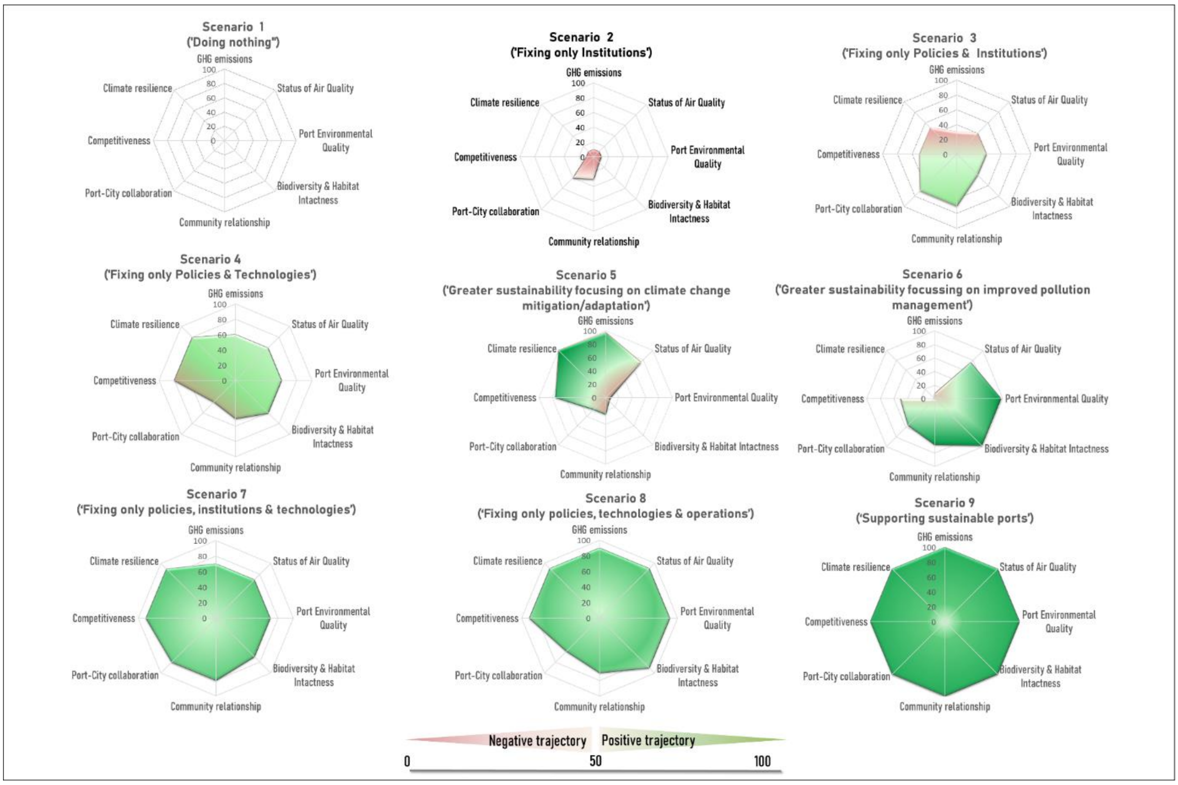

Figure 2 Comparison of expected overall influence of various future scenarios on selected sustainability indicators

As expected, the worst case ('Do nothing', Scenario 1) is unlikely to result in any sustainability. 'Supporting sustainable ports' (Scenario 9) is the ideal sustainability outcome. Scenario 2 ('Fixing only institutions') presents a situation where port authorities only address institutional matters, but do not implement important interventions in the other key driving forces (corporate culture and policies, technological development, or operational efficiencies). Evident from this outcome is that very little is likely to be achieved by 'only talking'. The method applied in the analysis of the generic scenarios for port development in the WIO region by 2050, can easily be adapted to develop and analyse site-specific scenarios within countries or for specific ports.

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ACRONYMS

AHP	Analytical Hierarchy Process
BAU	Business-as-usual
CSIR	Council for Scientific and Industrial Research
GDP	Gross domestic product
GEF	Global Environmental Facility
GHG	Green-house gas
GPP	Green Port Policy
KPA	Kenya Ports Authority
MTCC	Maritime Technologies Cooperation Centre
OPS	On-shore power supply
PMAESA	Port Management Association East and Southern Africa
PPP	'People', 'Planet', and 'Prosperity'
RSA	Republic of South Africa
SDG	Sustainable Development Goals
SES	Socio-ecological systems
SSPs	Shared socioeconomic 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

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1 INTRODUCTION

1.1 Background

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, with growing global trade, rapid coastal urbanization, depletion and degradation of natural resources, greater social awareness and empowerment, stakeholder expectations and demands for port sustainability have accelerated. Ports are increasingly pressurised to take actions, not merely focussing on economic generation, but also to implement resilient and sustainable strategies to consider the environment and society (Lu et al. 2016; Alamoush et al. 2021). The port industry therefore faces a growing challenge to address societal and environmental considerations while at the same time to improve their capacity to provide cost-effective services to traders (e.g., working towards 5th generation ports) (Kaliszewski, 2018; Lam and Van der Voorde, 2012; Roh et al., 2016). With increasing societal and regulatory pressures, port authorities around the world are compelled to pursue greater sustainability to safeguard their 'license to operate' and to grow their economic and environmental competitiveness (Lam and Van der Voorde, 2012; Roh et al., 2016). In response to these global challenges the concept of 'Green Ports' emerged, primarily focusing on balancing environmental challenges and economic demand (Bergqvist and Monios 2019; Lam and Notteboom 2014) and striving for sustainability through increasing both economic and environmental competitiveness (Maritz et al. 2014). The concept of 'Sustainable Port Development' builds on that of 'Green Ports' by also considering social sustainability, in essence advocating the need for a port development to create a balance between economic growth, environmental protection, and social progress to secure its long-term future (Hiranandani 2014; Taljaard et al. 2021).

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

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

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

- Kenya Ports Authority (KPA) has adopted a Green Port Policy (GPP) that is intended to address the negative impacts of port operations and is geared towards integration of environmental sustainability in port development/operations and significant reduction in greenhouse gas emissions. The policy focuses on initiatives on climate change mitigation/adaptation, use of renewable energy and recognizes the importance of stakeholders and partners towards achieving its sustainability objectives. Currently, the focus of the GPP is on the Port of Mombasa, but the KPA plans to expand its scope to include other ports managed by them, including the Ports of Lamu and Kisumu, and the dry ports.

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

1.2 Purpose

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

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

Specifically, the contribution to sustainable port development in the WIO region includes:

- Situation Assessment, providing the context and backdrop for greener port operations and development in the WIO region (UNEP et al. 2023a)

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

This document presents the Scenario Analysis which evaluates a series of generic port development pathways for the WIO region by 2050, ranging from 'Doing-nothing' to options incorporating 'Sustainable port' considerations. Given the diverse status of sustainable port development in countries of the WIO region, this Scenario Analysis adopted a range of generic port development futures or scenarios for the region. However, the method applied in the development and analysis of these generic scenarios can be applied within specific countries or ports to develop and analyse their own scenarios considering anticipated, site-specific conditions.

1.3 Structure of this Report

This introductory chapter (Chapter 1) is followed by an overview of international approaches in environmental scenario analysis, including methods to measure sustainable port performance (Chapter 2). Chapter 3 presents the approach adopted for this study, which largely following an anticipatory, qualitative (narrative) approach in the expression of a series of generic future scenarios for port development in the WIO region. These scenarios are informed by various anticipated options for pre-defined driving forces, which are rated according to pre-defined sustainability indicators. Finally, the outcome of the range of generic port development futures or scenarios is assessed, with further guidance on the site-specific application of the scenario analysis tool.

2 OVERVIEW OF INTERNATIONAL APPROACHES

2.1 Scenario Analysis Approaches

A Sustainable Port *adheres to the concept of resource saving and environmental-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)*

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

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

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

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

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

To inform the approach and the selection of scenarios towards a business case for sustainable port development in the WIO region, the typing of scenarios, the scenario development process, and a few related international case studies are investigated below.

2.1.1 Typing of scenarios

Alcamo (2001) and Alcamo and Henrichs (2008) define different types of scenarios that can be considered, namely:

- Qualitative versus Quantitative - Qualitative scenarios use words and symbols (narratives) rather than numerical estimates to depict a possible future. Advantages of well-written qualitative scenarios include the ability to represent or incorporate views of numerous role players and stakeholders and provide an easily understandable and interesting way of communicating futures. Their big disadvantage is their inability to provide numerical data to quantify trends. Quantitative scenarios address the latter, but in providing numerical data they create perceptions of certainty that may not always be true. Quantitative scenarios often draw on computer models that rely on assumptions that may implicitly be narrow in view. Complicated modelling outputs are also often difficult for non-modellers to understand (Alcamo 2001). That said, modellers usually record their assumptions, which provides greater transparency compared with the undeclared assumptions that often underpin qualitative scenarios. Decisions to use qualitative or quantitative approaches depend on the purpose of a scenario analysis. If the aim is to inform possible generic futures, then a qualitative approach may suffice. Where the aim is to inform specific actions, for example to mitigate climate change in specific operations (e.g., reduction of emissions) a quantitative approach may be more appropriate. Qualitative scenarios are well suited to stimulate policy ideas, for brainstorming, communication and education, where several views about the future need to be considered, or where modelling tools are not available for quantitative analysis. Quantitative scenarios are options for assessments that explicitly require data and numbers, or when a 'theory' (model) is required to back-up scenarios. A combination of approaches may also be a consideration.
- Exploratory versus Anticipatory - Exploratory scenarios typically commence in the present and then explore trends into the future. On the other hand, anticipatory scenarios (e.g., worst case, best case, and business-as-usual) prescribe a vision of the future (e.g., by 2030) and then visualise how each of these futures could be realised. Exploratory approaches are appropriate when the aim is to explore consequences of a specified future trend in driving forces, or to investigate the consequences of implementing a policy. Anticipatory approaches are appropriate when the aim is to assess steps that can lead to a specified end state (e.g., achieving environmental or social targets), or to inform policymakers how a 'desirable' end state could be achieved (e.g., how to achieve sustainable development).
- Baseline (reference) versus policy - In the context of environmental studies, baseline scenarios present future states of SESs without policy interventions, or where these may not yet have any marked influence. Policy scenarios, on the other hand, aim to depict the possible effects of various environmental policy interventions, for example when superimposed on baseline scenarios.

2.1.2 Scenario development

Methods to develop scenarios span both participatory and analytical approaches (Figure 2.1) (Alcamo 2001; Alcamo and Henrichs 2008). Participatory approaches typically involve consultation with experts and stakeholders to develop scenarios, while analytical approaches include expert systems, decision support systems and computer models.

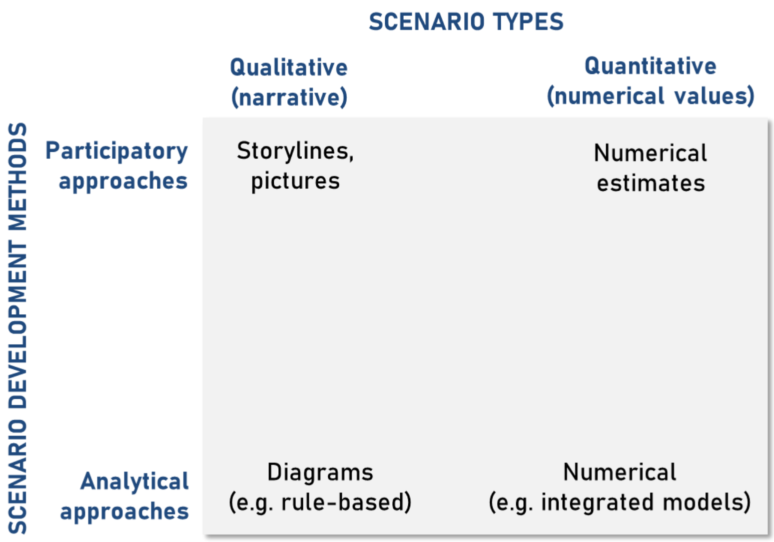

Figure 2.1 Classification of qualitative and quantitative scenarios versus participatory and analytical scenario development methods (Source: Alcamo and Henrichs 2008)

2.1.3 Examples: Environmental scenario analyses

Critical steps in a scenario analysis process include (Alcamo 2001; Alcamo and Henrichs 2008):

- Step 1: Define focal issue of the scenario exercise and aim of investigation
- Step 2: Identify key driving forces that are likely to shape future outcomes pertaining to the focal issue (e.g., population growth, policy status, technologies)
- Step 3: Build scenarios based on possible future developments of key driving forces
- Step 4: Identify key indicators (or elements) to measure future outcomes (e.g., state of pollution, livelihoods, profitability)
- Step 5: Define anticipated effect of driving forces (or combination of driving forces) on key indicators (either qualitatively [narrative] or quantitatively [numbers])
- Step 6: Determine expected outcomes, in terms of selected key indicators.

The following sections explore a few international case studies useful in informing scenario development and analysis options pertaining to sustainable port development in the WIO region.

2.1.3.1 Shared socioeconomic pathways (climate change)

The concept of shared socioeconomic pathways (SSPs) stems from a scenario framework specifically developed for climate change research (O'Neill et al. 2014). These pathways are combined in a dual axis matrix with possible climate change projections, using an array of simulation modelling techniques to derive likely future outcomes or scenarios (O'Neill et al. 2014. 2017; Riahi et al. 2017). In essence, the SSPs describe plausible alternative trends in the evolution of the global society and natural systems over the 21st century, without considering climate change. However, to be useful in the context of climate change outcomes, the SSPs are designed to span socioeconomic 'challenge spaces' in terms of climate change mitigation and adaptation (Figure 2.2).

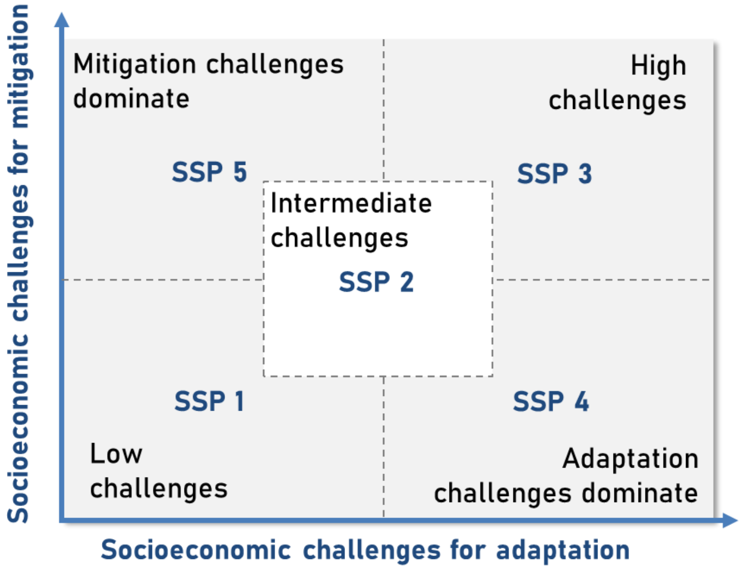

Figure 2.2 Conceptualisation of SSPs across climate change mitigation and adaptation challenge space (Source: O'Neill et al. 2014)

Although the SSPs are differentiated based on pre-specified outcomes, they are constructed from determinants of these outcomes, either expressed qualitatively or quantitatively (O'Neill et al. 2014). Table 2.1 illustrates examples of driving forces used in the characterization of the SSPs, focusing on determinants potentially influencing climate change mitigation and adaptation outcomes (O'Neill et al. 2014).

Table 2.1: Examples of key driving forces of SSPs potentially influencing climate change adaptation and mitigation outcomes (Source: O'Neill et al. 2014)

DRIVING FORCE	EXAMPLE
Demographics	• Population and age structure • Urban versus rural populations, and urban forms • Coastal versus inland populations
Economic development	• Gross Domestic Product (GDP) • Distribution of GDP, including economic catch-up by developing countries • Sectoral structure of economies, especially share of agriculture, and agriculture land productivity • Share of population in extreme poverty • Nature of international trade
Welfare	• Human development • Educational attainment • Health, including access to public health and health care facilities
Environmental and ecological factors	• Air, water, and soil quality • Fossil fuel resources and renewable energy potentials • Other key natural resources
Institutions and governance	• Existence, type, and effectiveness of institutions • Degree of participation • Rule of law
Technological development	• Type (slow, rapid, transformational) and direction (environmental efficiency, productivity improving) of technical progress
Broader societal factors	• Attitude to environment/sustainability/equity and world views • Lifestyles (including diets) • Societal tension and conflict levels
Policies	• Non-climate policies including development policies, technology policies, urban planning and transportation policies, energy security policies, and environmental policies to protect air, soil, and water quality. It is possible that SSPs could be specified partly in terms of policy objectives, such as strong welfare-improving goals, rather than specific policy targets or measures

Five SSPs for climate change research have been developed as summarised in Table 2.2 (Riahi et al. 2017). These were then described in terms of various elements that address aspects of the selected driving forces.

Table 2.2: Summary of the five SSPs developed for application in climate change research (Source Riahi et al. 2017)

SCENARIO	ELEMENT (DRIVING FORCE) DESCRIPTION
SSP 1 Sustainability – Taking Green Road	• World shifts gradually, but pervasively, toward more sustainable path, emphasizing more inclusive development respecting perceived environmental boundaries • Management of global commons slowly improves, educational and health investments accelerate demographic transition, and emphasis on economic growth shifts toward a broader emphasis on human well-being • Driven by an increasing commitment to achieving development goals, inequality is reduced both across and within countries • Consumption is oriented toward low material growth and lower resource and energy intensity.
SSP2 Middle of Road	• World follows a path in which social, economic, and technological trends do not shift markedly from historical patterns • Development and income growth proceeds unevenly, with some countries making relatively good progress while others fall short of expectations • Global and national institutions work toward but make slow progress in achieving sustainable development goals • Environmental systems experience degradation, although there are some improvements, but overall, intensity of resource and energy use declines • Global population growth is moderate and levels off in second half of century. Income inequality persists or improves only slowly and challenges to reducing vulnerability to societal and environmental changes remain
SSP3 Regional Rivalry – A Rocky Road	• A resurgent nationalism, concerns about competitiveness and security, and regional conflicts push countries to increasingly focus on domestic or, at most, regional issues • Policies shift over time to become increasingly oriented toward national and regional security issues • Countries focus on achieving energy and food security goals within their own regions at the expense of broader-based development. Investments in education and technological development decline • Economic development is slow, consumption is material-intensive, and inequalities persist or worsen over time • Population growth is low in industrialized and high in developing countries • Low international priority for addressing environmental concerns leads to strong environmental degradation in some regions
SSP4 Inequality – A Road Divided	• Highly unequal investments in human capital, combined with increasing disparities in economic opportunity and political power, lead to increasing inequalities and stratification both across and within countries • Over time, a gap widens between an internationally connected society that contributes to knowledge- and capital-intensive sectors of the global economy, and a fragmented collection of lower-income, poorly educated societies that work in a labour intensive, low-tech economy. • Social cohesion degrades and conflict and unrest become increasingly common • Technology development is high in the high-tech economy and sectors • Globally connected energy sector diversifies, with investments in both carbon-intensive fuels like coal and unconventional oil, but also low-carbon energy sources • Environmental policies focus on local issues around middle- and high-income areas.
SSP5 Fossil-fuelled Development – Taking Highway	• World places increasing faith in competitive markets, innovation, and participatory societies to produce rapid technological progress and development of human capital as the path to sustainable development • Global markets are increasingly integrated and strong investments in health, education, and institutions to enhance human and social capital • At same time, push for economic and social development is coupled with exploitation of abundant fossil fuel resources and the adoption of resource and energy intensive lifestyles • All factors lead to rapid growth of global economy, while global population peaks and declines in 21st century • Local environmental problems like air pollution are successfully managed • Faith in ability to effectively manage social and ecological systems, including by geo-engineering if necessary

Key indicators that were used to depict outcomes or implications of SSPs under different climate change projections, using a set of integrated assessment models, included:

- Energy supply and demand
- Land-use and land cover change
- Green-house gas emissions
- Air pollution and aerosol emissions
- Mitigations costs.

2.1.3.2 Land-use scenario analysis

Scenario analysis is also widely used to study probable outcomes in land-use change, specifically as it relates to sustainable agriculture and food demand (Alcamo et al. 2008). An array of scenarios has been developed within the context of a range of possible drivers (Table 2.3), typically benchmarked against 'business-as-usual' scenarios.

Table 2.3: Typical drivers and indicators (expression of outcome change) used in land-use scenario analysis (Alcamo et al. 2008)

DRIVING FORCE	INDICATOR
• Demographic - Population size including migration - Size of urban versus rural population • Economic - Average per capita income - Biofuel demand - Food demand - Food/crop prices - Food trade - Status of land tenure/farm size • Technological and Biophysical - Crop yield - Accessibility (infrastructure, travel distance) - Climate - Soil characteristics - Topography • Other Social Factors - Food preferences - Types of governance - Educational level	Land-cover (area change) in terms of: • Urban • Forest • Crop production • Biofuel production • Grassland

2.1.3.3 Port's Role in reducing green-house gas emissions from ships

A port specific example is provided by Winnes et al. (2015) who used scenario analysis to quantify potential reductions of ships' emissions of green-house gas (GHG) emissions in response to different measures adopted by ports. Their key driving forces included ship traffic and design, fuel options, power supply in ports, ship speeds and port operations (e.g., vessel turnaround times, ship manoeuvring) (Table 2.4).

Table 2.4: Driving forces and indicator (expression of outcome change) used in Port GHG emission reduction scenario analysis (Winnes et al. 2015)

DRIVING FORCE	INDICATOR
• Ship traffic and design • Fuel options • Power supply in ports • Ship speeds and operations in port (e.g., turn-over times, manoeuvring)	CO_2 emission reduction

The analysis defined three possible scenarios (Table 2.5).

Table 2.5: Summary of scenarios used in Port GHG emission analysis (Source: Winnes et al. 2015)

SCENARIO	DRIVING FORCE
Business-as-Usual	Current emissions based on: • Current ship ages • Current fuel practice
Scenario 1 'Fuel'	Reduction in emissions through potential fuel shifts: • Liquefied natural gas • Liquefied biogas • Methanol • Bio methanol • On-shore power supply (OPS)
Scenario 2 'Design'	Efforts to attract modern ships with more energy efficient designs: • Only modern ships • Ship design improvements (only small ships)

SCENARIO	DRIVING FORCE
Scenario 3 'Operations'	Improved operations in terms of: • Reduced speed • Reduced lay time at berth • Reduced lay time at anchor • Eco-driving during manoeuvring • Faster connection to OPS

In this instance the indicator by which outcomes were measured was CO_2 emission reduction (Table 2.4). Ultimately, the Business-as-usual (BAU) scenario projected a 40% increase in GHC emissions by 2030 from a 2010 baseline, while Scenario 3 ('Operations') projected the highest reduction in emissions at 10% lower than BAU levels.

2.2 Port Performance & Sustainability Indicators

Numerous studies have engaged in the establishment of performance and sustainability indicators for application in ports (e.g., Chiu et al. 2014; González Laxe et al. 2016; Lu et al. 2016; Schipper et al. 2017; Chen and Pak 2017; Stein and Acciaro 2020).

Chiu et al. (2014) reviewed academic studies and practical experience of several port authorities to identify a set of key factors (as indicators) constituting sustainability in relation to port operations. Focusing on in-port operation and development planning, specifically *energy conservation, environmental protection, and ecology care*, they categorised key factors into air pollution, water pollution, noise pollution, land and sediments pollution, materials selection, water consumption, energy usage, general waste handling, hazardous waste handling, habitat quality and greenery, community promotion, education and port staff training. They used a fuzzy Analytical Hierarchy Process (AHP) model to evaluate port performance. AHP is a popular technique used to model subjective decision-making processes based on multiple attributes. Twenty-six experts evaluated the performance of three major ports in Taiwan using fuzzy linguistic rules ('very poor', 'poor', 'normal', 'good', very good') in terms of the selected criteria (indicators). Their approach comprised the following steps:

- Step 1: Set up hierarchy system, decomposing issues into a hierarchy of interrelated decision elements (see Figure 2.3)
- Step 2: Generate input data consisting of a pairwise comparison matrix to find the comparative weight among decision elements
- Step 3: Synthesize judgment and estimate relative weight of decision elements
- Step 4: Aggregate decision elements as per allocated weighting to obtain rating for performance (e.g., rating effectiveness of various policies/strategies).

To establish links between the *economic and environmental* dimensions of sustainable development and port size and operations in Spanish ports, González Laxe et al. (2016) used cluster analysis to establish the influence of port size and operations on environmental and economic outcomes. Their indicators in the environmental dimension were organised into three categories, namely environmental management, eco-efficiency and environmental quality, while their economic indicators were organised into economic structure, and business and servicing. They provide useful metrics for measuring these indicators. A study by Lu et al. (2016) distilled and grouped a set of sustainability indicators into four sustainability assessment factors, namely *environmental* material (11), *economic* issues (6), environmental practices (6) and *social* concerns (6) without any detail on finer categorisation. The indicators were then applied to a selection of ports, in consultation with stakeholders, to prioritise importance in terms of the four sustainability assessment factors (implicitly across environmental, social and economic dimensions).

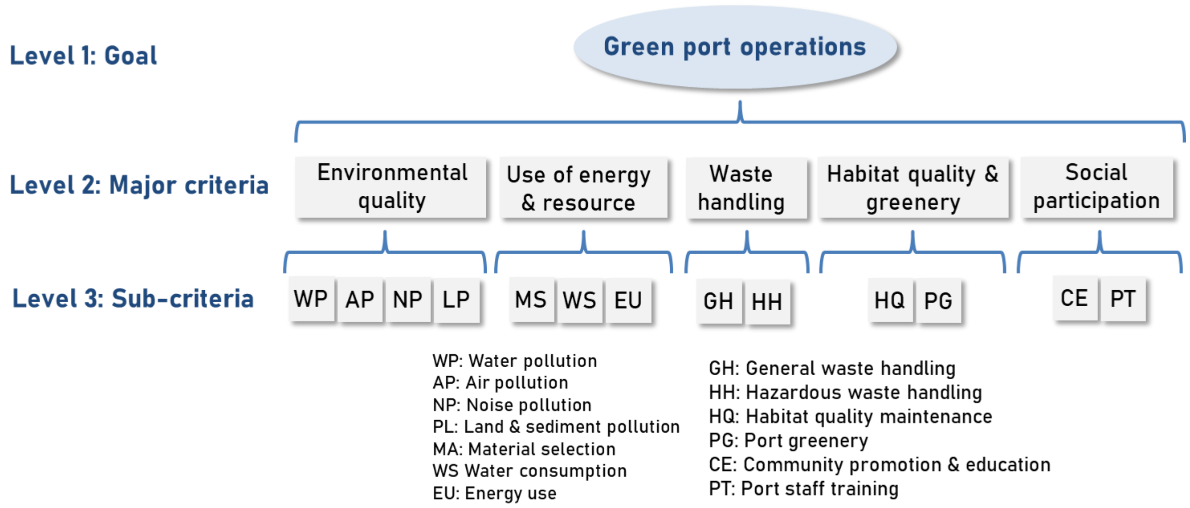

Figure 2.3 Hierarchical model for sustainable port performance assessment (Source: Chiu et al. 2014)

Schipper et al. (2017) distilled a set of *social, economic, and environmental* key performance indicators to evaluate and interpret future sustainable port-city development *plans* but did not focus on operational performance. Using evidence-based knowledge scoring, these indicators were organised and aggregated into sustainable social-, environmental-, and economic- sustainable measures which could be combined into an overall Sustainable Integrated Condition Index. Using this approach, they were able to compare future sustainability based on development planning in a selection of ports across the world. Focusing on sustainable performance, Chen and Pak (2017) identified a set of evaluation indicators for Chinese ports using the Delphi technique and covering mostly *environmental* aspects. Twenty-one sustainability performance indicators were prioritised and categorised in six dimensions, namely liquid pollution management, air pollution management, noise control, low carbon regulations and energy savings, marine biology preservation, and organization and management.

Following a comprehensive, systematic review of international literature covering sustainability assessments in the port sector, Stein and Acciaro (2020) proposed a set of measures (or indicators) to assist ports in assessing corporate sustainability. As in most other examples, their primary dimensions were *environmental, social* and *economic*. Focusing on indicators from the literature, they grouped indicators within each of these dimensions into several categories, that is environment: water pollution management (4), eco-efficiency (8) and air pollution management (8); social: community impact (5), employment quality (3), legal and political benefits (5); and economic: income and profitability (6), service quality (5) and macro-value (5). Their listing of measurement modes, such as answering a simple existing/non-existing question, is also useful. These are embedded into a corporate sustainability measurement framework for ports to empirically assess the effectiveness of corporate sustainability actions towards environmental, social, or economic value creation (Figure 2.4).

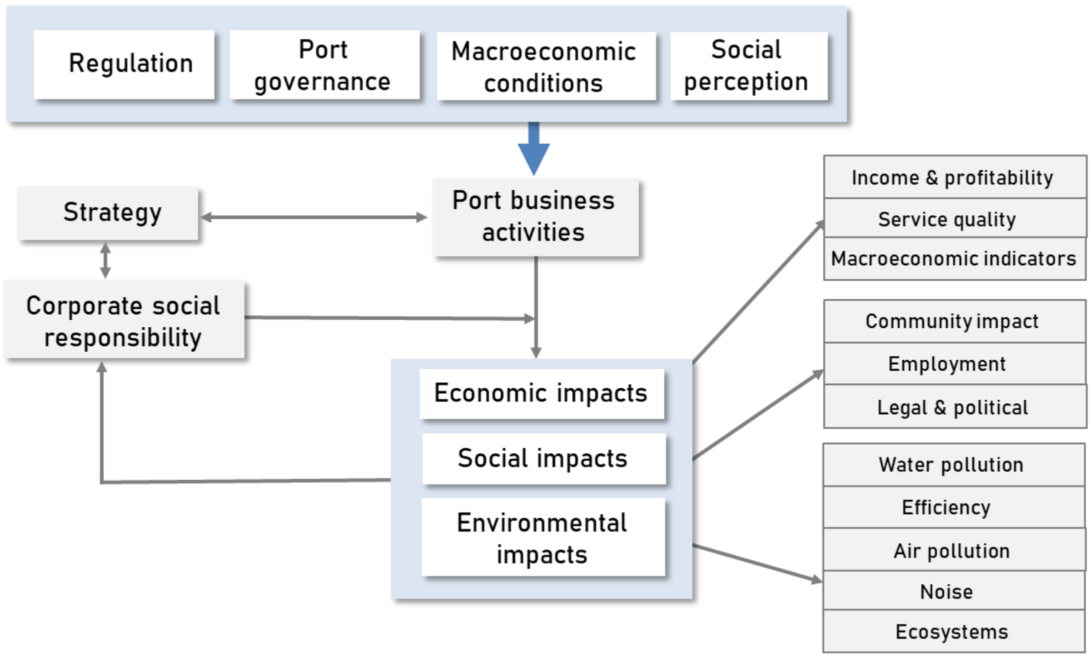

Figure 2.4 Conceptual framework for assessment of Corporate Sustainability in ports (Source: Stein and Acciaro 2020)

Based on these studies, significant commonalities emerge in the array of indicators previously used in port performance and sustainability assessment. Most studies organised indicators into the three interconnected sustainability dimensions: environment, social, and economic. Within each of these dimensions, frequent sustainability outcomes included *pollution management, biodiversity and habitat protection, eco-efficiency, community well-being, employee wellbeing*, and *sustainable economic growth and development.* Indicators linked to these outcomes focused on planning efforts, implementation of supporting programmes, and implementation of sustainable technologies. As a measure of the efficiency of plans, programmes and technologies, some studies also included status indicators to reflect the actual condition the environment, social cohesion and economic competitiveness.

The scenario analysis that is the subject of this study focused specifically on status indicators as these ultimately reflect the true outcome of sustainability efforts.

3 SCENARIO ANALYSIS FOR WIO PORTS

3.1 Approach and Method

A wide array of ports occurs in ten countries across the WIO region supports. They range from small fishing ports to large commercial ports (see Situation Assessment Report). Depending on their nature, and specific countries' legislation and policies, these ports are subject to a diversity of development and operational practices. This makes a detailed, quantitative scenario analysis approach, representative of specific ports in the region extremely difficult. Detailed information and numerical data on present and future port planning and operations, required for informed quantitative scenario analyses, are not readily available in the region. It was therefore proposed that a qualitative scenario analysis approach be adopted for this study, based on easily understandable narratives describing a range of generic future scenarios for port development in the WIO region, including the 'Do nothing' scenario and a selection of sustainable port development options. Further, it was proposed that scenarios be expressed as anticipatory scenarios, describing specific visions of the future (e.g., anticipated scenario outcomes port development in the WIO region by 2050 ranging from worst case to best case) rather than following an exploratory approach requiring an evaluation of outcome trends over time into the future.

The scenario development and analysis process adopted here, followed six steps (adapted from Alcamo 2001; Alcamo and Henrichs 2008):

Step 1: Define perspective and context of scenario exercise

For this study the context of the scenario analysis was to *conduct a scenario analysis on possible future port development outcomes, ranging from 'doing nothing' to 'supporting sustainable ports', to make a business case for environmentally sustainable port development in the WO region by 2050.*

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

Following consultation with stakeholders in the WIO region through in-person meetings (August 2022 and April 2023 in Dar es Salaam) it was acknowledged that driving forces comprise both external and internal categories. These were defined and verified with stakeholders in the WIO region at the in-person meetings.

Step 3: Identify key sustainability criteria (or indicators) by which to measure sustainability outcomes

For this study key sustainability criteria (or indicators) to measure outcomes were drawn from those applied in sustainable port performance and sustainability assessment indices (e.g., Chiu et al. 2014; González Laxe et al. 2016; Lu et al. 2016; Schipper et al. 2017; Chen and Pak 2017; Stein and Acciaro 2020). These were organized into the three *common* sustainability pillars: environmental, social and economic, to gauge sustainability 'patterns' across possible future scenarios. The list of key sustainability indicators was verified with stakeholders at the in-person meetings.

Step 4: Define possible trajectories for selected driving force categories

For each of the external and internal driving force categories, a range of potential trajectories, expressed as narratives, was defined within the context of key issues identified by stakeholders at the in-person meetings (see Appendix for details).

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

As input to the scenario analysis process, matrices were constructed to rate the anticipated influence of various driving force trajectories on each of the selected sustainability indicators. This was necessary to provide a transparent and common understanding of the expected influence assumed for various driving force trajectories on indicators, and ultimately the sustainability scores.

Step 6: Build scenarios and analyse anticipated sustainability outcomes

A set of generic future scenarios for port development in the WIO region by 2050 was then constructed using combinations of driving force trajectories, ranging from 'Doing nothing' to 'Supporting sustainable ports'. In this final step the results from Steps 3 to 5 were aggregated to obtain overall ratings for each of the future scenarios for port development in the WIO region by 2050, based on a combination of driving force trajectories and associated weighted influences on sustainability indicators, using a spreadsheet-based index.

3.2 Selection of Driving Forces and Indicators

3.2.1 Key driving forces

Driving forces likely to shape outcomes in port planning and operations in future comprise both external and internal force categories. External driving force categories relate to factors that are outside the control of port authorities, for example climate change and international market perspectives, growth and demand. Internal driving force categories primarily relate to aspects that are within the control of port authorities, such as future technology development and operations. The key envisaged external driving force categories to influence port development in the WIO region by 2050 were viewed as:

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

Drawing on international learning relevant to port environments, internal driving force categories for inclusion in this scenario analysis were presented and verified by stakeholders in the WIO region at in-person meetings in Dar es Salaam (August 2022 and April 2023). The driving force categories that were agreed upon for this study, together with motivations, are presented in Table 3.1.

Table 3.1: Summary of internal driving force categories included in this study, together with motivations

DRIVING FORCE CATEGORY	MOTIVATION
Corporate culture and policies	• Economic development direction chosen by ports might influence their ability to balance environmental and social sustainability • Extent to which ports incorporate environmental and social accountability in official policies influences the extent to which port officials can enforce sustainable practices
Institutional arrangements	• Establishment of dedicated and empowered institutions (e.g., environment departments in ports) provides a platform to enforce policies and coordinate activities • Extent to which ports communicate and consider wellbeing of local communities/city (in and around ports) will determine social sustainability, as well as level of potential conflict to be dealt with
Technological development	• Fuel and energy sources will determine efforts towards climate change mitigation • Technology development and adoption will influence a ports ability to address and mitigate impacts such as air, water and soil pollution, and destruction of coastal habitats and biota

DRIVING FORCE CATEGORY	MOTIVATION
Operational efficiency	• Skills, capacity and access to funding is directly correlated to effective implementation of sound environmental/social policies • Level of enforcement determines extent to which port authorities can ensure compliance with environmental/social policies

3.2.2 Key sustainability indicators

An array of performance and sustainability indicators have been developed for application in ports (see Section 2.2). For this analysis, we focus specifically on status indicators as these ultimately reflect the true outcomes of sustainability efforts. The key sustainability indicators chosen for this scenario analysis (as verified with stakeholders at the in-person meetings in Dar es Salaam) fell into the three key pillars of sustainability (environment, social and economic) (Table 3.2). Although this scenario analysis has a strong focus on environmental and social aspects, it includes economic indicators that could be driven by a port's level of environmental and social accountability.

Table 3.2: Summary of key sustainability indicators applied in this scenario analysis

INDICATOR	MOTIVATION
ENVIRONMENT	
GHG emissions	Commitment to climate change mitigation
Status of air quality	Commitment to manage and control atmospheric emissions
Status of port environmental quality	Commitment to manage and control wastewater, solid waste, and hazardous waste
Status of biodiversity & habitat intactness	Commitment to manage port infrastructure development and operations to protect biodiversity and habitat integrity (e.g., implementing biodiversity trade-off policies)
SOCIAL	
Community Well-being vs Conflict	Commitment to considering community needs, and their involvement in port matter that may affect their livelihoods
Port-City Collaboration vs Conflict	Commitment to consult and collaborate with adjacent urban centres
ECONOMIC	
Climate resilience	Commitment to consider climate change such as increased storminess, SLR etc.
Competitiveness (license-to-operate)	Level to which port environmental and social practices enable competitiveness (linked to international and client pressures re sustainability)

3.2.3 Potential trajectories for driving forces

For this study, anticipated trajectories for external driving force categories were assumed constant across all Scenarios as described in Table 3.3. Focus was rather given to potential variations in internal driving force trajectories that are within the control of port authorities.

Table 3.3: Summary of key external driving force trajectories anticipated to influence port development in the WIO region by 2050

EXTERNAL DRIVING FORCE CATEGORY	EXPECTED TRAJECTORY 2050
Climate Change	0.5 m SLR (from 2000 to 2050, assuming a ~1m rise by 2100 - Horton et al. 2020) together with a probable increase in occurrence and intensity of sea-storms
Shipping traffic in WIO Region	Shipping traffic to increase markedly, with an associated increase in port traffic
Societal pressure	Local societies, supported by international non-government organisations (NGOs), are increasingly empowered to challenge environmental and social decline
International market views	Increased international pressure for environmental/social accountability in ports, and therefore more effective competition in port market as 5th generation ports
Political stability	Political stability across WIO countries is expected to be variable, unstable at times

As insufficient qualitative data were available on ports in the WIO region to perform a detailed quantitative scenario analysis, it was decided to present future scenarios for port development in the WIO region by 2050, as narratives, comprising a combination of trajectories across the four internal driving force categories (Table 3.4). In turn, these internal driving force trajectories were contextualised in terms of the key issues workshopped by stakeholders at the in-person stakeholder meetings (see Appendix for details).

Table 3.4: Potential internal driving force trajectories considered in the construct of generic future scenarios port development in the WIO region by 2050

DRIVING FORCE		POTENTIAL TRAJECTORY
Corporate culture and policies	A	'Supporting sustainable ports': In response to global demand for environmental accountability to secure/grow their market share, port managers implement and enforce overarching policies for more sustainable ports. These are also reflected in lease agreements with private sector tenants. Lost revenue and rising infrastructure maintenance costs because of climate change impacts convince port authorities to act to increase climate resilience of port infrastructure and operations. Pressure from increasingly empowered communities/cities and resulting delays in development projects (with serious cost implications) necessitates port authorities to undertake joint, strategic, and integrated spatial planning of port development and expansion.
	B	'Greater sustainability focusing on climate change mitigation/adaptation': In response to global demand for environmental accountability to secure/grow market share, port managers implement and enforce overarching policies for more sustainable ports focusing on energy efficiency and renewable energy. These are also reflected in lease agreements with private sector tenants. Lost revenue and rising infrastructure maintenance costs because of climate change impacts convince port authorities to address greater climate resilience in port infrastructure development and operations. However, pollution, waste and wastewater management and control remain neglected. Ports still disregard societal responsibilities, reflected in uncoordinated spatial planning for port development and expansions impacting adjacent communities/cities.
	C	'Greater sustainability focusing on pollution management': In response to global demand for environmental accountability to secure/grow market share, port managers implement and enforce overarching policies for more sustainable ports focusing on pollution (waste and wastewater management and control). These are also reflected in lease agreements with private sector tenants. However, energy efficiencies and renewable energy issues remain neglected and port authorities fail to act on addressing climate resilience in port infrastructure development and operations. Ports also disregard societal responsibilities, reflected in uncoordinated spatial planning for port development and expansions impacting adjacent communities/cities.
	D	'Doing nothing': Management has a short-term economic focus, not acknowledging longer-term benefits of sustainable port policies or of strengthening climate resilience of port infrastructure and operations (e.g., associated with SLR and increased storminess). Sound lease agreements with private sector tenants, addressing their environmental and social responsibilities, are lacking. Uncoordinated spatial planning of port development and expansion impacts adjacent communities/cities.
Institutional arrangements	A	'Supporting sustainable ports': The financial and logistical value of functional, cross-sectoral institutional structures for environmental matters in cooperative port development is acknowledged. Dedicated port environmental departments are established and resourced. Increasing global pressure on ports (and port tenants) to account for their social and environmental responsibilities necessitates the establishment of dedicated institutional structures to communicate, coordinate and audit port user performance. Integrated climate change forums are established within port structures. These help drive increased climate resilience of port infrastructure development and operations. Pressure from increasingly empowered communities/cities (which otherwise object to and delay development projects with serious cost implications) necessitates port authorities to establish dedicated institutional structures to facilitate collaboration with society at large.
	B	'Greater sustainability focusing on climate change mitigation/adaptation': The financial and logistical value of functional, cross-sectoral institutional structures for environmental matters in cooperative port development is acknowledged. Dedicated port environmental departments are established and resourced, focusing on climate change mitigation/adaptation. These help drive increased climate resilience of port infrastructure and operations. Increasing global pressure on ports (and port tenants) to account for their social and environmental responsibilities necessitates the establishment of dedicated institutional structures to communicate, coordinate and audit port user performance. Integrated climate change forums are established within port structures. However, dedicated forums to facilitate collaboration/communication between port authorities and adjacent communities/cities are still lacking.
	C	'Greater sustainability focusing on improved pollution management': The financial and logistical value of functional, cross-sectoral institutional structures for environmental matters in cooperative port development is acknowledged. Dedicated port environmental departments are established and resourced, focusing on pollution management. However, integrated climate change forums are not established within port structures, and climate resilience of port infrastructure and operations is not increased. Increasing global pressure on ports (and port tenants) to account for their social and environmental responsibilities necessitates the establishment of dedicated institutional structures to communicate, coordinate and audit port user performance. Dedicated forums to facilitate collaboration/communication between port authorities and adjacent communities/cities are also still lacking.
	D	'Doing nothing': Silo-based management within authorities prevails, with no dedicated port environmental departments, resulting in uncoordinated planning and management, often with costly consequences (duplication of efforts, critical issues not addressed). No formal institutional structures are in place to coordinate activities across port users, risking potential detrimental environmental, social and economic consequences, especially during disasters and emergencies. No forums in place as platforms to facilitate communication and collaboration between port authorities and adjacent communities/cities.
Technological development	A	'Supporting sustainable ports': Pressured by global demand for environmental accountability and to secure/grow market share, ports focus on globally visible technological interventions linked to energy efficiency and renewable energy sources (this might also occur due to fossil fuel becoming increasingly expensive). Customer dissatisfaction (e.g., because of long vessel turnaround time) forces port authorities to invest in technologies for improved efficiencies. Pressure from empowered adjacent communities/cities (which otherwise result in increasingly costly legal conflicts) necessitate port authorities to implement innovative waste and wastewater management technologies to combat coastal water, air and land pollution.
	B	'Greater sustainability focusing on climate change mitigation/adaptation': In response to global demand for environmental accountability to secure/grow market share, port managers implement and enforce overarching policies for more sustainable ports focusing on energy efficiency and renewable energy. These are also reflected in lease agreements with private sector tenants. Lost revenue and rising infrastructure maintenance costs because of climate change impacts convince port authorities to act to increase climate resilience of port infrastructure and operations. However, pollution, waste and wastewater management and control remain neglected. Ports still disregard societal responsibilities, reflected in uncoordinated spatial planning for port development and expansions impacting adjacent communities/cities.
	C	'Greater sustainability focusing on improved pollution management': Pressure from empowered adjacent communities/cities necessitates port investment and implementation of innovative waste and wastewater management technologies to combat coastal water, air and land pollution. Port authorities fail to act to increase climate resilience of port infrastructure and operations and energy efficiencies and renewable energy issues remain neglected. Investment in renewable energy sources and technologies to improve port energy and logistical efficiencies is not made. Customer dissatisfaction remains high, and ports lose competitiveness.
	D	'Doing nothing': Energy efficient technologies (e.g., cold ironing) are not implemented and no investment is made in renewable energy. Ports remain strongly reliant on fossil fuels. Innovative waste and wastewater management technologies are also

DRIVING FORCE		POTENTIAL TRAJECTORY
		absent, resulting in coastal water and air pollution. Vessel turnover times are long due to poor vessel traffic management and inefficient traffic and cargo handling technologies.
Operational efficiency	A	'Supporting sustainable ports': Global pressure for greater environmental accountability and growing need to acquire port environmental certification (e.g., ISO14001) compel port authorities to implement and enforce environmental monitoring/auditing processes. Higher port traffic increases the risk of costly disasters, necessitating authorities to invest in improved disaster preparedness procedures. Improved pollution management enables port authorities to identify polluters and direct cost recoveries to their accounts (polluter pays principle) leading to improved compliance with waste regulations. Significantly improved environmental practices open lucrative funding opportunities with investors wanting to support sustainable port development (e.g., public-private partnerships). Port authorities acknowledge the value of more sustainable ports and the critical importance of adequately trained and motivated staff, to secure long-term (sustainable) economic growth.
	B	'Greater sustainability focusing on climate change mitigation/adaptation': Global pressure for greater environmental accountability necessitates port authorities to implement and enforce environmental monitoring/auditing processes (focusing on energy efficiency and renewable energy sources). Improved environmental practices open selected funding opportunities with investors interested in sustainable port development (e.g., public-private partnerships). Lost revenue and rising infrastructure maintenance costs because of climate change impacts convince port authorities to act to increase climate resilience of port infrastructure and operations. Investment is also made in training and capacity development to focus on energy efficiency and renewable energy, but not on pollution (waste and wastewater management and control).
	C	'Greater sustainability focusing on improved pollution management': Global pressure for greater environmental accountability and growing need to acquire port environmental certification (e.g., ISO14001) compel port authorities to implement and enforce environmental monitoring/auditing processes focusing on pollution (waste and wastewater management and control). Improved pollution management enables port authorities to identify polluters and direct cost recoveries to their accounts (polluter pays principle) leading to improved compliance with waste regulations. Improved environmental practices open selected funding opportunities with investors supporting sustainable port development (e.g., public-private partnerships). However, energy efficiencies and renewable energy issues remain neglected and port authorities fail to act to increase climate resilience of port infrastructure and operations. Investment in training and capacity development focusses on pollution (waste and wastewater management), but not energy efficiency and renewable energies.
	D	'Doing nothing': Effective environmental monitoring/auditing and disaster intervention preparedness (e.g., oil spills) are lacking due to inefficient funding, lack of training and capability development. Lack of management commitment to environmentally operational efficiency.

3.2.4 Anticipated influence of driving force trajectories on indicators

The anticipated influence of various driving force trajectories (Table 3.4) on selected sustainability indicators was estimated and scored using a 5-point scaling (-2 to +2) as follows (Table 3.5):

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

Table 3.5: Anticipated influence of driving force trajectories (see Table 3.4) on selected sustainability indicators (-2 = strong negative influence expected; -1 = some negative influence expected; 0 = no marked influence expected; 1 = some positive influence expected; 2 = strong positive influence expected)

INTERNAL DRIVING FORCE CATEGORY 1: CORPORATE CULTURE & POLICY

INDICATOR		EXPECTED INFLUENCE OF TRAJECTORY			
		A	B	C	D
1	GHG emissions	2	2	-2	-2
2	Status of Air Quality	2	1	1	-2
3	Status of Port Environmental Quality	2	-2	2	-2
4	Status of Biodiversity & Habitat Intactness	2	-2	2	-2
5	Community relationship	2	-1	1	-2
6	Port-City collaboration	2	-1	1	-2
7	Competitiveness	2	1	0	-2
8	Climate resilience	2	2	-2	-2

INTERNAL DRIVING FORCE CATEGORY 2: INSTITUTIONAL ARRANGEMENTS

INDICATOR		EXPECTED INFLUENCE OF TRAJECTORY			
		A	B	C	D
1	GHG emissions	2	1	1	-2
2	Status of Air Quality	2	1	1	-2
3	Status of Port Environmental Quality	2	1	1	-2
4	Status of Biodiversity & Habitat Intactness	2	1	1	-2
5	Community relationship	2	-1	-1	-2
6	Port-City collaboration	2	-1	-1	-2
7	Competitiveness	2	1	0	-2
8	Climate resilience	2	2	-2	-2

INTERNAL DRIVING FORCE CATEGORY 2: TECHNOLOGICAL DEVELOPMENT

INDICATOR	EXPECTED INFLUENCE OF TRAJECTORY

		A	B	C	D
1	GHG emissions	2	2	-2	-2
2	Status of Air Quality	2	1	1	-2
3	Status of Port Environmental Quality	2	-2	2	-2
4	Status of Biodiversity & Habitat Intactness	2	-2	2	-2
5	Community relationship	2	-1	2	-2
6	Port-City collaboration	2	-1	1	-2
7	Competitiveness	2	1	0	-2
8	Climate resilience	2	2	-2	-2

INTERNAL DRIVING FORCE CATEGORY 4: OPERATIONL EFFICIENCY

INDICATOR		EXPECTED INFLUENCE OF TRAJECTORY			
		A	B	C	D
1	GHG emissions	2	2	-2	-2
2	Status of Air Quality	2	1	1	-2
3	Status of Port Environmental Quality	2	-2	2	-2
4	Status of Biodiversity & Habitat Intactness	2	-2	2	-2
5	Community relationship	2	-1	2	-2
6	Port-City collaboration	2	-1	1	-2
7	Competitiveness	2	1	0	-2
8	Climate resilience	2	2	-2	-2

For the purposes of this analysis, the allocated scores in Table 3.5 were based on consensus, expert opinion. However, these scores can be adjusted in follow-up studies as and when more information becomes available for the WIO region, or when applied in specific countries or ports.

Further, it was also acknowledged that different driving force categories may have varying influence on each of the selected sustainability indicators. This was addressed by weighting the influence of driving force categories across sustainability indicators, as illustrated in Table 3.6.

Table 3.6: Weighting of relative influence of internal driving force categories across sustainability indicators, also including weighting of indicators within domains, and weighting of domains in overall sustainability score

INTERNAL DRIVING FORCE CATEGORY	WEIGHTING (EXPECTED RELATIVE INFLUENCE) OF DRIVING FORCE CATEGORY ON SPECIFIC INDICATORS							
	1	2	3	4	5	6	7	8
	GHG emissions	Status of Air Quality	Status of Port Environmental Quality	Status of Biodiversity & Habitat Intactness	Community relationship	Port-City collaboration	Climate resilience	Competitive-ness
1. Corporate culture and policy	0.20	0.30	0.30	0.30	0.40	0.30	0.40	0.20
2. Institutional arrangements	0.10	0.10	0.10	0.10	0.30	0.40	0.10	0.10
3. Technological development	0.40	0.30	0.30	0.30	0.10	0.10	0.40	0.30
4. Operational efficiency	0.30	0.30	0.30	0.30	0.20	0.20	0.10	0.40

DOMAIN	WEIGHTING	INDICATOR	WEIGHTING
Environment	0.40	GHG emissions	0.25
		Status of Air Quality	0.25
		Status of Port Environmental Quality	0.25
		Status of Biodiversity & Habitat Intactness	0.25
Social	0.30	Community relationship	0.50
		Port-City collaboration	0.50
Economic	0.30	Climate resilience	0.50
		Competitiveness	0.50

The method also allows for the weighting of sustainability indicators within each of the domains of environment, social and economic (Table 3.6). For the purposes of this analysis indicators within domains were given equal weighting. For the overall sustainability score, the method aggregates across the three individual domains, using a 0.4 for environment, and 0.3 each for the social and economic domains.

For the purposes of this analysis all weightings in Table 3.6 were based on consensus, expert opinion and presented to stakeholders at the in-person meeting in Dar es Salaam (April 2023). However, these weighting can be adjusted in follow-up studies as and when more information becomes available for the WIO region, or when applied in specific countries or ports.

3.3 Analysis of Generic Future Scenarios

3.3.1 Construct of generic future scenarios

For the purposes of this analysis external driving forces (Table 3.1) were assumed to remain constant in all future scenarios. Focus was rather given to trajectories for internal driving forces that will be under the control of port authorities. Using combinations of the potential driving forces (Table 3.4) nine generic future scenarios for port development in the WIO region by 2050 were constructed, representative of a range of anticipated generic outcomes ranging from 'Doing nothing' to 'Supporting sustainable ports' (Table 3.7).

Table 3.7: Construct of generic future scenarios for port development in the WIO region by 2050, based on combinations of potential internal driving force trajectories (see Table 3.4)

<table>
<tr><th colspan="2">NUMBER & DESCRIPTION</th><th colspan="2">INTERNAL DRIVING FORCE TRAJECTORY COMBINATION</th></tr>
<tr><td rowspan="4">1</td><td rowspan="4">'Doing nothing'</td><td>Corporate culture and policies</td><td rowspan="4">[D] 'Doing nothing'</td></tr>
<tr><td>Institutional arrangements</td></tr>
<tr><td>Technological development</td></tr>
<tr><td>Operational efficiency</td></tr>
<tr><td rowspan="4">2</td><td rowspan="4">'Fixing only institutions'</td><td>Corporate culture and policies</td><td>[D] 'Doing nothing'</td></tr>
<tr><td>Institutional arrangements</td><td>[A] 'Supporting sustainable ports'</td></tr>
<tr><td>Technological development</td><td rowspan="2">[D] 'Doing nothing'</td></tr>
<tr><td>Operational efficiency</td></tr>
<tr><td rowspan="4">3</td><td rowspan="4">'Fixing only policies & institutions'</td><td>Corporate culture and policies</td><td rowspan="2">[A] 'Supporting sustainable ports'</td></tr>
<tr><td>Institutional arrangements</td></tr>
<tr><td>Technological development</td><td rowspan="2">[D] 'Doing nothing'</td></tr>
<tr><td>Operational efficiency</td></tr>
<tr><td rowspan="4">4</td><td rowspan="4">'Fixing only policies & technologies'</td><td>Corporate culture and policies</td><td>[A] 'Supporting sustainable ports'</td></tr>
<tr><td>Institutional arrangements</td><td>[D] 'Doing nothing'</td></tr>
<tr><td>Technological development</td><td>[A] 'Supporting sustainable ports'</td></tr>
<tr><td>Operational efficiency</td><td>[D] 'Doing nothing'</td></tr>
<tr><td rowspan="4">5</td><td rowspan="4">'Greater sustainability focusing on climate change mitigation/ adaptation'</td><td>Corporate culture and policies</td><td rowspan="4">[B] 'Greater sustainability focusing on climate change mitigation/ adaptation'</td></tr>
<tr><td>Institutional arrangements</td></tr>
<tr><td>Technological development</td></tr>
<tr><td>Operational efficiency</td></tr>
<tr><td rowspan="4">6</td><td rowspan="4">'Greater sustainability focusing on improved pollution management'</td><td>Corporate culture and policies</td><td rowspan="4">[C] 'Greater sustainability focusing on improved pollution management'</td></tr>
<tr><td>Institutional arrangements</td></tr>
<tr><td>Technological development</td></tr>
<tr><td>Operational efficiency</td></tr>
<tr><td rowspan="4">7</td><td rowspan="4">'Fixing only policies, institutions & technologies'</td><td>Corporate culture and policies</td><td rowspan="3">[A] 'Supporting sustainable ports'</td></tr>
<tr><td>Institutional arrangements</td></tr>
<tr><td>Technological development</td></tr>
<tr><td>Operational efficiency</td><td>[D] 'Doing nothing'</td></tr>
<tr><td rowspan="4">8</td><td rowspan="4">'Fixing only policies, technologies & operations'</td><td>Corporate culture and policies</td><td>[A] 'Supporting sustainable ports'</td></tr>
<tr><td>Institutional arrangements</td><td>[D] 'Doing nothing'</td></tr>
<tr><td>Technological development</td><td rowspan="2">[A] 'Supporting sustainable ports'</td></tr>
<tr><td>Operational efficiency</td></tr>
<tr><td rowspan="4">9</td><td rowspan="4">'Supporting sustainable ports'</td><td>Corporate culture and policies</td><td rowspan="4">[A] 'Supporting sustainable ports'</td></tr>
<tr><td>Institutional arrangements</td></tr>
<tr><td>Technological development</td></tr>
<tr><td>Operational efficiency</td></tr>
</table>

Table 3.8: Calculation of sustainability scores (outcomes) for generic future scenarios for port development in WIO region by 2050 (see Table 3.7 for description of scenarios 1 to 9)

INDICATOR	WEIGHT	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
ENVIRONMENT	0.40	-2.00	-1.60	-0.50	0.40	-0.13	0.78	0.80	1.60	2.00
1 GHG Emissions	0.25	-2.0	-1.6	-0.8	0.4	1.9	-1.7	0.8	1.6	2.0
Corporate culture and policy	0.20	-2	-2	2	2	2	-2	2	2	2
Institutional arrangements	0.10	-2	2	2	-2	1	1	2	-2	2
Technological development	0.40	-2	-2	-2	2	2	-2	2	2	2
Operational efficiency	0.30	-2	-2	-2	-2	2	-2	-2	2	2
2 Status of Air Quality	0.25	-2.0	-1.6	-0.4	0.4	1.0	1.0	0.8	1.6	2.0
Corporate culture and policy	0.30	-2	-2	2	2	1	1	2	2	2
Institutional arrangements	0.10	-2	2	2	-2	1	1	2	-2	2
Technological development	0.30	-2	-2	-2	2	1	1	2	2	2
Operational efficiency	0.30	-2	-2	-2	-2	1	1	-2	2	2
3 Status of Port Environmental Quality	0.25	-2.0	-1.6	-0.4	0.4	-1.7	1.9	0.8	1.6	2.0
Corporate culture and policy	0.30	-2	-2	2	2	-2	2	2	2	2
Institutional arrangements	0.10	-2	2	2	-2	1	1	2	-2	2
Technological development	0.30	-2	-2	-2	2	-2	2	2	2	2
Operational efficiency	0.30	-2	-2	-2	-2	-2	2	-2	2	2
4 Status of Biodiversity & Habitat Intactness	0.25	-2.0	-1.6	-0.4	0.4	-1.7	1.9	0.8	1.6	2.0
Corporate culture and policy	0.30	-2	-2	2	2	-2	2	2	2	2
Institutional arrangements	0.10	-2	2	2	-2	1	1	2	-2	2
Technological development	0.30	-2	-2	-2	2	-2	2	2	2	2
Operational efficiency	0.30	-2	-2	-2	-2	-2	2	-2	2	2
SOCIAL	0.30	-2.00	-0.60	0.80	-0.20	-1.00	0.45	1.20	0.60	2.00
5 Community relationship	0.50	-2.0	-0.8	0.8	0.0	-1.0	0.7	1.2	0.8	2.0
Corporate culture and policy	0.40	-2	-2	2	2	-1	1	2	2	2
Institutional arrangements	0.30	-2	2	2	-2	-1	-1	2	-2	2
Technological development	0.10	-2	-2	-2	2	-1	2	2	2	2
Operational efficiency	0.20	-2	-2	-2	-2	-1	2	-2	2	2
6 Port-City collaboration	0.50	-2.0	-0.4	0.8	-0.4	-1.0	0.2	1.2	0.4	2.0
Corporate culture and policy	0.30	-2	-2	2	2	-1	1	2	2	2
Institutional arrangements	0.40	-2	2	2	-2	-1	-1	2	-2	2
Technological development	0.10	-2	-2	-2	2	-1	1	2	2	2
Operational efficiency	0.20	-2	-2	-2	-2	-1	1	-2	2	2
ECONOMIC	0.30	-2.00	-1.60	0.00	1.20	1.50	-1.00	1.60	1.60	2.00
7 Competitiveness	0.50	-2.0	-1.6	0.0	1.2	1.0	0.0	1.6	1.6	2.0
Corporate culture and policy	0.40	-2	-2	2	2	1	0	2	2	2

	INDICATOR	WEIGHT	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
	Institutional arrangements	0.10	-2	2	2	-2	1	0	2	-2	2
	Technological development	0.40	-2	-2	-2	2	1	0	2	2	2
	Operational efficiency	0.10	-2	-2	-2	-2	1	0	-2	2	2
8	Climate resilience	0.50	-2.0	-1.6	0.0	1.2	2.0	-2.0	1.6	1.6	2.0
	Corporate culture and policy	0.40	-2	-2	2	2	2	-2	2	2	2
	Institutional arrangements	0.10	-2	2	2	-2	2	-2	2	-2	2
	Technological development	0.40	-2	-2	-2	2	2	-2	2	2	2
	Operational efficiency	0.10	-2	-2	-2	-2	2	-2	-2	2	2

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
GHG emissions	0	10	30	60	98	8	70	90	100
Status of Air Quality	0	10	40	60	75	75	70	90	100
Port Environmental Quality	0	10	40	60	8	98	70	90	100
Biodiversity & Habitat Intactness	0	10	40	60	8	98	70	90	100
Community relationship	0	30	70	50	25	68	80	70	100
Port-City collaboration	0	40	70	40	25	55	80	60	100
Competitiveness	0	10	50	80	75	50	90	90	100
Climate resilience	0	10	50	80	100	0	90	90	100
Environment	0	10	38	60	47	69	70	90	100
Social	0	35	70	45	25	61	80	65	100
Economic	0	10	50	80	88	25	90	90	100
OVERALL SCORE (100 max)	0	18	51	62	53	54	79	83	100

3.3.2 Outcomes of generic future scenarios

Table 3.8 presents the results from analysis of each of the nine scenarios, using the anticipated influence of internal driving force category trajectories on selected sustainability indicators (Table 3.4) and the scoring system presented in Table 3.5. Results for each scenario can be compared across individual sustainability indicators, for each of the domains (i.e., environment, social and economic) and as an overall sustainability score. For easier interpretation the sustainability indicator, domain and overall sustainability scores were normalized within a range of 0 to 100. Scores below 50 are indicative of a negative sustainability trajectory and scores above 50 a positive sustainability trajectory.

Figure 3.1 presents a comparison of the expected sustainability outcomes of the selected future scenarios for port development in the WIO region by 2050, where scores above 50 represent more sustainable positive trajectories and scores below 50 are indicative of less sustainable negative trajectories. Scenario 1 ('Doing nothing') and Scenario 9 ('Supporting sustainable ports') represent the two extreme situations where port authorities either disregard any actions towards sustainable development (Scenario 1) or where port authorities diligently implement interventions to achieved sustainability (Scenario 9). While these extremes are unlikely to be realistic outcomes, they provide the relative end points against which to better calibrate intermediate interventions (i.e., Scenarios 2 to 8).

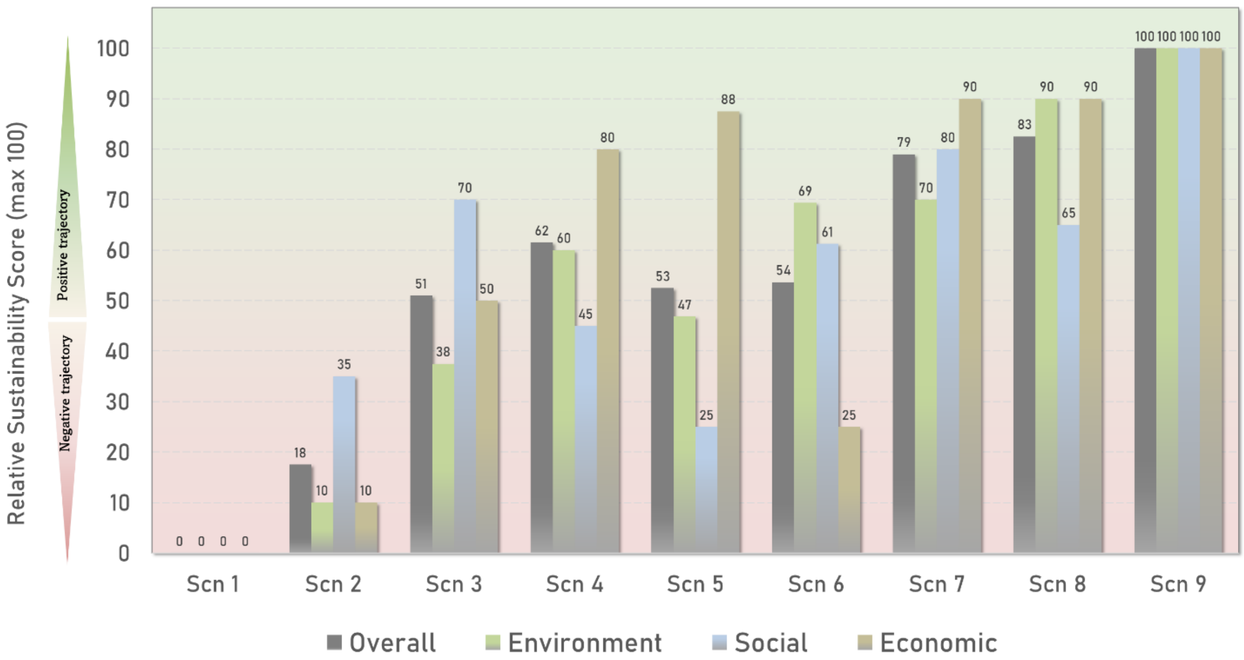

Figure 3.1 Comparison of overall (as well as environmental, social and economic) sustainability performance (as per selected sustainability indicators) across generic future scenarios for port development in the WIO region by 2050

Figure 3.2 schematises the outcomes per sustainability indicator for each of the future scenarios for port development in the WIO region by 2050. As expected, the worst case ('Do nothing', Scenario 1) is unlikely to result in any sustainability. 'Supporting sustainable ports' (Scenario 9) is the ideal sustainability outcome. Scenario 2 ('Fixing only institutions') presents a situation where port authorities only address institutional matters, but do not implement interventions in the other key driving forces (corporate culture and policies, technological development, or operational efficiencies). Evident from this outcome is that very little is likely to be achieved with 'only talking'.

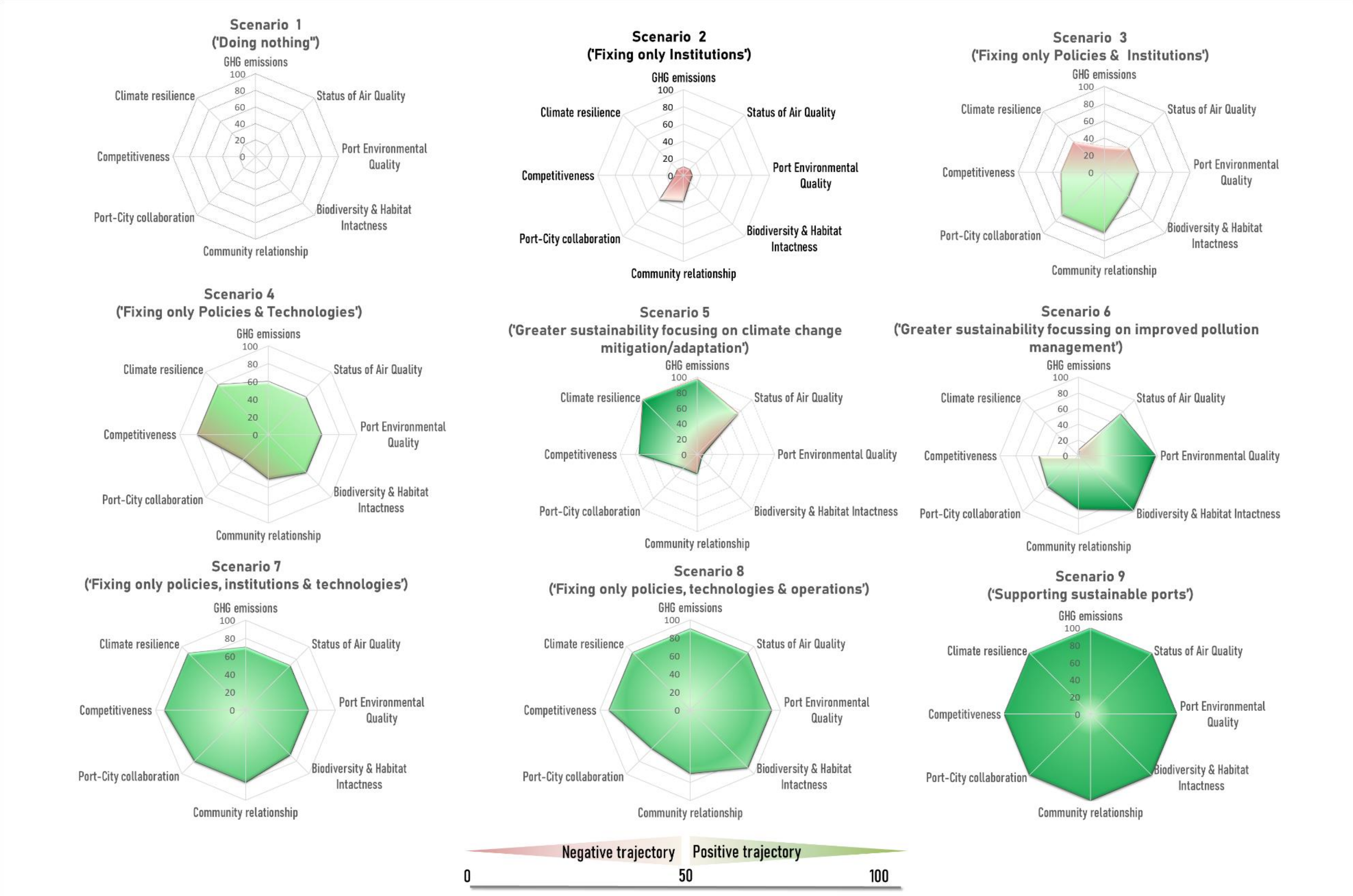

Figure 3.2 Comparison of expected overall influence of various future scenarios on selected sustainability indicators

Scenario 3 ('Fixing only institutions and policies') introduces the establishment of policies supporting sustainability, but again 'only talking' and having 'legislation on paper' is unlikely to achieve significant progress towards sustainability. Practical implementation is needed through, for example, technological developments and operational efficiency. In Scenario 4 ('Fixing only policies and technologies') the influence of such practical implementation measures becomes apparent, although in this scenario the lack of institutional progress in terms of community and port-city relationships is clear.

Scenario 5 ('Greater sustainable focussing on climate change mitigation/adaptation') present a situation where port authorities focus strongly on addressing issues pertaining to climate mitigation and adaptation. The anticipated effect of this in reducing *GHG emissions* and increasing *Climate resilience* is clear. However, the lack of attention to the management and control of emissions, waste and wastewater, has a clear influence on pollution (environmental quality). By way of contrast, in Scenario 6 ('More sustainable focusing on improved pollution management') authorities tend to focus on emission, waste and wastewater management and control, with clear impact in reducing pollution and improving environmental quality). However, in this scenario, the lack of effort to address climate mitigation and resilience remains an issue.

The value of combining technological developments or operational efficiencies with supporting policies and sound institutional arrangements is evident in Scenario 7 ('Fixing only policies, institutions, and technologies'). Even greater value for sustainable port development is achieved if technological developments and operational efficiencies are combined with supporting policies (Scenario 8, 'Fixing policies, technologies, and operations'). The overall ratings in Figure 3.1 illustrate the positive progress that can be made towards sustainability through practical implementation and intervention to adopt advanced technologies and increase operational efficiencies in ports (e.g., Scenarios 7 and 8) rather than focusing on policy development and institutional interventions alone (e.g., Scenarios 2 and 3).

3.3.3 Development of site-specific port development scenarios

The scenario analysis method applied in this project involved development of generic scenarios for port development at the regional (WIO) scale. However, there are clear benefits to conducting scenario analysis at smaller scales, either nationally (within countries) or even for specific ports. This was recognised by stakeholder representatives at the in-person meeting held in Dar es Salaam in April 2023, who expressed interest applying the approach in their national- or port specific situations.

To guide this a generic approach is presented in this section. It follows the method applied for the purposes of the regional assessment but is expressed more generally with the intention of being explanatory so that it can be customised for specific use. It follows six steps adapted from Alcamo (2001) and Alcamo and Henrichs (2008).

<u>Step 1: Define perspective and context of scenario exercise</u>

E.g.: *Conduct a scenario analysis on possible future port development outcomes, ranging from 'doing nothing' to 'supporting sustainable ports', to make a business case for environmentally sustainable port development in 'country' or 'port' by 2050.*

<u>Step 2: Identify key driving forces likely to shape future outcomes</u>

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

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

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

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

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

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

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

Step 4: Define possible trajectories for selected driving force categories

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

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

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

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

INTERNAL DRIVING FORCE CATEGORY	POTENTIAL TRAJECTORY	
	D	....
Operational efficiency	A	....
	B	....
	C	....
	D	....

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

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

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

The ratings can be decided in a participatory manner among a group of experts with knowledge on such matters:

INTERNAL DRIVING FORCE CATEGORY X

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

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

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

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

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

DOMAIN	WEIGHTING	INDICATOR	WEIGHTING
Economic	…	Climate resilience	…
		Competitiveness	…

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

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

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

Step 6: Build scenarios and analyse anticipated sustainability outcomes

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

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

The above input can then be populated in the spreadsheet model to calculate sustainability scores for each scenario for individual sustainability indicators, for each domain and an overall sustainability score, using the spreadsheet-based index, similar to that provided for the generic scenarios (e.g., Figures 3.1 and 3.2).

4 REFERENCES

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.

Alcamo J and Henrichs T. 2008. Chapter Two. Towards Guidelines for Environmental Scenario Analysis. In: Developments in Integrated Environmental Assessment Volume 2. Alcamo J (ed.). pp 13-35. Elsevier.

Alcamo J, Kok K, Busch G and Priess J. 2008. Chapter Four. Searching for the future of land: scenarios from the local to global scale. In: Developments in Integrated Environmental Assessment, Volume 2. Alcamo J (ed.). pp.67-103. Elsevier

Alcamo J. 2001. Scenarios as tools for international environmental assessments. European Environment Agency. Environmental issue report No 24. https://op.europa.eu/en/publication-detail/-/publication/f806ee7c-3898-40ee-a5fe-ea7173d42a32

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

African Union (AU) 2019. Africa Blue Economy Strategy https://www.au-ibar.org/sites/default/files/2020-10/sd_20200313_africa_blue_economy_strategy_en.pdf

Ares Moreno A. 2018. A methodology for developing a Green Port. Master Thesis. Delft University of Technology, Faculty of Civil Engineering and Geosciences, Department of Hydraulic Engineering. https://repository.tudelft.nl/islandora/object/uuid:2debc917-e389-4944-a794-342d35788769/datastream/OBJ/download

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

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.

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, (DOI:10.1080/03088839.2017.1327726).

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

Darbra RM, Ronza A, Casal J, Stojanovic TA and Wooldridge C. 2004. The Self Diagnosis Method A new methodology to assess environmental management in seaports. 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 seaports. Marine Pollution Bulletin 50 (8): 866-874. https://doi.org/10.1016/j.marpolbul.2005.04.037

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

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

Dublin Port Company. 2012b. Dublin Port Masterplan Strategic Environmental Assessment Environmental Report: Post Adoption Statement. Dublin, Ireland. http://www.dublinport.ie/wp-content/uploads/2018/04/06.-DPC_MP_SEA_-POST-ADOPTION-STATEMENT-Feb-2012.pdf

Elsawah S, Hamilton SH, Jakeman AJ, Rothman D, Schweizer V et al. 2020. Scenario processes for socio-environmental systems analysis of futures: A review of recent efforts and a salient research agenda for supporting decision making. Science of The Total Environment 729: 138393. https://doi.org/10.1016/j.scitotenv.2020.138393

González Laxe F, Bermúdez FM, Palmero FM 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.

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

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

Horton BP, Khan NS, Cahill N. et al. 2020. Estimating global mean sea-level rise and its uncertainties by 2100 and 2300 from an expert survey. Clim Atmos Sci 3: 18. https://doi.org/10.1038/s41612-020-0121-5

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

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.

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 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.

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): 0957-4093.

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.

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.

Moomaw WR 1996. A sustainability postscript. Environmental Impact Assessment Review 16: 425-427.

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

Nations Environment Programme, Nairobi Convention Secretariat and Council for Scientific and Industrial Research. 2022. Western Indian Ocean: Strategic Framework for Coastal & Marine Water Quality Management UNEP, Nairobi, Kenya. XXIV + 89 pp + Appendices.

O'Neill BC, Kriegler E, Ebi KL, Kemp-Benedict E, Riahi K et al. 2017. The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. Global Environmental Change 42: 169-180. https://doi.org/10.1016/j.gloenvcha.2015.01.004

O'Neill BC, Kriegler E, Riahi K. et al. 2014. A new scenario framework for climate change research: the concept of shared socioeconomic pathways. Climatic Change 122: 387–400. https://doi.org/10.1007/s10584-013-0905-2

Pavlic B, Cepak, F, Sucic B, Peckaj M and Kandus B. 2014. Sustainable port infrastructure, practical implementation of the green port concept. Thermal Science 18(3): 935-948. DOI:10.2298/TSCI1403935P

Pintér L, Hardi P, Martinuzzi A and Hall J. 2012. Bellagio STAMP: principles for sustainability assessment and measurement. Ecol. Indicat. 17: 20–28.

Riahi K, van Vuuren DP, Kriegler E, Edmonds J, O'Neill BC, Fujimori S, Bauer N et al. 2017. The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. Global Environmental Change 42: 153-168. https://doi.org/10.1016/j.gloenvcha.2016.05.009

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.

Saaty TL. 1980. The Analytic Hierarchy Process, McGraw-Hill International Book, New York, NY, USA.

Sala S, Ciuffo B and Nijkamp P. 2015. A systemic framework for sustainability assessment. Ecological Economics 119: 314–325.

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.

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

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

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

Taljaard S, Van Niekerk L, Huizinga P and Slinger JH. 2012. How scientists learnt about their role in governance: The case of Great Brak. International Conference Littoral 2012: Coasts of Tomorrow, Oostende, Belgium, 27-29 November.

Taljaard S. 2011. An implementation model for integrated coastal management in South Africa – from legislation to practice. PhD Dissertation, Department of Geography and Environmental Studies, University of Stellenbosch, South Africa.

Ugboma C, Ugboma O and Ogwude I. An Analytic Hierarchy Process (AHP) Approach to Port Selection Decisions – Empirical Evidence from Nigerian Ports. Maritime Economics & Logistics 8: 251–266. https://doi.org/10.1057/palgrave.mel.9100160

United Nations Environment Programme, Nairobi Convention Secretariat and Council for Scientific and Industrial Research. 2022 (in press). Western Indian Ocean: Strategic Framework for Coastal & Marine Water Quality Management UNEP, Nairobi, Kenya.

United Nations Environment Programme, Nairobi Convention Secretariat and Council for Scientific & Industrial Research. 2023a (n prep). Towards Sustainable Port Development in the Western Indian Ocean. Situation Assessment. UNEP, Nairobi, Kenya, ….. pp.

United Nations Environment Programme, Nairobi Convention Secretariat and Council for Scientific & Industrial Research. 2023b (in prep). Towards Sustainable Port Development in the Western Indian Ocean. Toolkit for Sustainable Port Development in a Blue Economy. UNEP, Nairobi, Kenya, ….. pp

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.

Walker C. 2019. How to Use Scenario Analysis to Manage in Uncertain Times. https://www.asisonline.org/security-management-magazine/articles/2019/10/how-to-use-scenario-analysis-to-manage-in-uncertain-times/

Winnes H, Styhre L and Fridell E. 2015. Reducing GHG emissions from ships in port areas. Research in Transportation Business & Management 1: 73-82. https://doi.org/10.1016/j.rtbm.2015.10.008

World Bank. 2017. What is the Blue Economy? https://www.worldbank.org/en/news/infographic/2017/06/06/blue-economy

Zahedi F. 1986: The Analytic Process: survey of the method and its applications. Interfaces 16: 96–108.

APPENDIX: KEY ISSUES WITHIN INTERNAL DRIVING FORCES (as identified by Stakeholders)

INTERNAL DRIVING FORCE	THEME	ISSUE	COMMENT
1: Commitment & policy	Legislation & policies	Environmental processes	Environmental Impact Assessment: (1) EIAs can be done for new ports to be constructed (feasibility study); (2) Environmental audits for existing ports - check compliance
1: Commitment & policy	Legislation & policies	Environmental processes	Present: SEA and EIA community of .....
1: Commitment & policy	Legislation & policies	Environmental processes	Future: SEA and EIA
1: Commitment & policy	Legislation & policies	Environmental processes	Commonalities: EIA/SEA ES&IA
1: Commitment & policy	Legislation & policies	International conventions	Regulations/ratification and domestication of conventions
1: Commitment & policy	Legislation & policies	International conventions	Commonalities: Conventions (international)
1: Commitment & policy	Legislation & policies	Port Policy: Climate change	Threat: Climate change
1: Commitment & policy	Legislation & policies	Port policy: General	Future: Operational policies greener
1: Commitment & policy	Legislation & policies	Port policy: General	Mozambique: Policy and management borrowed from SA policy and legislation
1: Commitment & policy	Legislation & policies	Port policy: General	Mozambique: Policy = JV ?
1: Commitment & policy	Legislation & policies	Port policy: General	Policies and regulations
1: Commitment & policy	Legislation & policies	Port policy: General	Current causes: Lack of policy
1: Commitment & policy	Legislation & policies	Port policy: General	Future: Clear integrated policies and systems
1: Commitment & policy	Legislation & policies	Port policy: General	Lack of alignment between regulations and port policies
1: Commitment & policy	Legislation & policies	Port policy: General	Future: National strategy
1: Commitment & policy	Legislation & policies	Port policy: General	Commonalities: Policies - local
1: Commitment & policy	Legislation & policies	Port policy: General	Challenges: .... Maritime national policies not adopted
1: Commitment & policy	Legislation & policies	Private sector involvement	Future: PPP Authorisation
1: Corporate culture & policy	Legislation & policies	Private sector involvement	Kenya: Management is hybrid and involves private sector
1: Corporate culture & policy	Legislation & policies	Private sector involvement	Kenya: Consider management hybrid between governance and private sectors
1: Corporate culture & policy	Legislation & policies	Private sector involvement	Mozambique: Concession to private
1: Corporate culture & policy	Legislation & policies	Private sector involvement	Mozambique: Ownership risks
1: Corporate culture & policy	Legislation & policies	Spatial planning	Lack of planning (e.g. land use)
1: Corporate culture & policy	Legislation & policies	Spatial planning	Marine spatial planning
1: Corporate culture & policy	Legislation & policies	Spatial planning	Future: Will have more ports closer together
1: Corporate culture & policy	Legislation & policies	Spatial planning	Future: Improved planning and design
1: Corporate culture & policy	Legislation & policies	Spatial planning	Threats: social trade-offs competition for space
1: Corporate culture & policy	Legislation & policies	Spatial planning	Threats: Understanding influence zone around ports by managers (e.g., dredging)
1: Corporate culture & policy	Legislation & policies	Spatial planning	Threats: Lack of planning (both existing and new), costly
1: Corporate culture & policy	Legislation & policies	Spatial planning	Threats: Lack of land-use planning
1: Corporate culture & policy	Legislation & policies	Spatial planning	Lack of understanding of broader influence zone of port
1: Corporate culture & policy	Legislation & policies	Spatial planning	Challenges: Land-based/urban problems
1: Corporate culture & policy	Legislation & policies	Spatial planning	Challenges: Ports are sensitive areas (pollution, contamination)
1: Corporate culture & policy	Legislation & policies	Spatial planning	Future: Management of biodiversity areas
1: Corporate culture & policy	Legislation & policies	Spatial planning	Limited area for development
1: Corporate culture & policy	Management commitment	Buy-in: General	Current causes: Commitment of management
1: Corporate culture & policy	Management commitment	Buy-in: General	Future: Improve perception on sustainability for critical stakeholders
1: Corporate culture & policy	Management commitment	Buy-in: Modernisation	Culture: Ports in Mombasa and region are old and over 100 yrs. This is an old culture that needs to be broken. Most still use old systems of thinking, thus change is required quick for a green transition
1: Corporate culture & policy	Management commitment	Buy-in: Social	Culture wise
1: Corporate culture & policy	Management commitment	Buy-in: Social	Future: Social vision
1: Corporate culture & policy	Political	Political will & support	Lack of political will and bilateral ......
1: Corporate culture & policy	Political	Political will & support	Current causes: Political interference
1: Corporate culture & policy	Political	Political will & support	Commonalities: Port infrastructure and politics
2: Institutional	Environmental department	Environmental department	Need to have dedicated departments wrt environmental issues in port authorities/institutions
2: Institutional	Environmental department	Environmental department	Institutional structure
2: Institutional	Multi-stakeholder collaboration	Cross-sectoral authorities	Conflict between regulatory body and enforcement body (overlapping mandates of institutions)
2: Institutional	Multi-stakeholder collaboration	Cross-sectoral authorities	Oil spill contingency plan (how effective it is): (1) Lack of coordination among relevant stakeholders; (2) effectiveness of regional collaboration (MoUs); (3) lack of equipment/finance

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2: Institutional	Multi-stakeholder collaboration	Cross-sectoral authorities	Kenya: Administration… government
2: Institutional	Multi-stakeholder collaboration	Cross-sectoral authorities	Kenya: Change port management, currently under port authority
2: Institutional	Multi-stakeholder collaboration	Cross-sectoral authorities	Kenya: Development is an institutional - national
2: Institutional	Multi-stakeholder collaboration	Cross-sectoral authorities	Threats: Multi stakeholder planning/governance needed
2: Institutional	Multi-stakeholder collaboration	Cross-sectoral authorities	Multi stakeholder planning/governance/coordination
2: Institutional	Multi-stakeholder collaboration	Cross-sectoral authorities	Future: Enforcement, need capacity as well as multi-institutional/stakeholder involvement
2: Institutional	Multi-stakeholder collaboration	Cross-sectoral authorities	Challenges: Point of social and economic conflict
2: Institutional	Multi-stakeholder collaboration	Cross-sectoral authorities	Current causes: Lack of coordination (silo mentality)
2: Institutional	Multi-stakeholder collaboration	Cross-sectoral authorities	Current causes: Stakeholder participation in port development (continuous)
2: Institutional	Multi-stakeholder collaboration	Cross-sectoral authorities	Challenges: City-port interface …. In several countries
2: Institutional	Multi-stakeholder collaboration	Cross-sectoral authorities	Challenges: Some…. Entities have different management within port infrastructure
2: Institutional	Multi-stakeholder collaboration	Cross-sectoral authorities	Challenges: Available… Committees …. Not efficient
2: Institutional	Multi-stakeholder collaboration	Local communities	Madagascar: National interest and local interest port management
2: Institutional	Multi-stakeholder collaboration	Local communities	Involvement of all stakeholders (proposed)
3: Technological	Energy	Energy efficiency	Mozambique: Equipment used depends on fuel to operator implemented share power
3: Technological	Energy	Energy efficiency	Mozambique: Technology - Fuel energy (power); share-power at dock (Mozambique perspective)
3: Technological	Energy	Energy efficiency	Lack of energy efficiency
3: Technological	Energy	Energy efficiency	Future: More consideration on efficiency of ports (cost/benefit analysis)
3: Technological	Energy	Energy efficiency	Commonalities: Recent technology - port efficiency
3: Technological	Energy	Renewable energy	Use of renewable energy in ports
3: Technological	Energy	Renewable energy	Present: Little renewable energy being used
3: Technological	Energy	Renewable energy	No renewable energy
3: Technological	Energy	Renewable energy	Reliability on fossil energy
3: Technological	Energy	Renewable energy	Planning for alternative energy more environmentally friendly
3: Technological	Energy	Renewable energy	Future: Green energy resources policy
3: Technological	Vessel operations	Vessel logistics	Smart Ports - TOS, VTS, ERP, single window less waiting time/less emission
3: Technological	Vessel operations	Vessel logistics	Future: Tech - track booking and scanning from arrival to exit and info sharing
3: Technological	Vessel operations	Vessel logistics	Mozambique: Future - "tag track" one-gate (in/out) ……… (Mozambique perspective)
3: Technological	Vessel operations	Vessel logistics	Mozambique: Control room - digitalisation of process single window system; track booking system - traffic management (Mozambique perspective)
3: Technological	Vessel operations	Vessel logistics	Future: Embrace technology - cope with bigger ships, monitoring, waste management
3: Technological	Vessel operations	Vessel logistics	Automation of systems
3: Technological	Waste management	Waste management	Addressing waste (integrated waste management)
3: Technological	Waste management	Waste management	Inadequate facilities, e.g., waste management, and monitoring
3: Technological	Waste management	Waste management	Future: Embrace technology - cope with bigger ships, monitoring, waste management
3: Technological	Waste management	Waste management	Commonalities: Recent technology - port efficiency
3: Technological	Waste management	Waste management	Commonalities: Waste management plans
3: Technological	Waste management	Waste management	Challenges: Waste management especially dumping - wastewater, dredged material
4: Operational	Compliance & enforcement	Environmental audits	Challenges: Challenges with port certification
4: Operational	Compliance & enforcement	Environmental audits	Lack of energy audits
4: Operational	Compliance & enforcement	Environmental audits	Mozambique: Environment - compliance with the … (best practice) (Mozambique perspective)
4: Operational	Compliance & enforcement	Environmental audits	Threats: Pollution and oil spills
4: Operational	Compliance & enforcement	Environmental audits	Threats: Waste disposal
4: Operational	Compliance & enforcement	Environmental audits	Threats: Invasive species
4: Operational	Compliance & enforcement	Environmental audits	Threats: Dredging/sedimentation
4: Operational	Compliance & enforcement	Environmental audits	Threats: Weak law enforcement
4: Operational	Compliance & enforcement	Environmental audits	Lack of environmental and social safeguards, including expertise investigating oil spills
4: Operational	Compliance & enforcement	Environmental audits	Weak enforcement
4: Operational	Compliance & enforcement	Environmental audits	Future: Enforcement, need capacity as well as multi-institutional/stakeholder involvement
4: Operational	Compliance & enforcement	Environmental audits	Poor performance

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4: Operational	Compliance & enforcement	Environmental audits	Commonalities: ISO certification
4: Operational	Financial	Funding	Mozambique: Culture – port built on loans from China etc. who has a say in terms of operations
4: Operational	Financial	Funding	Mozambique: Financially shareholders involved
4: Operational	Financial	Funding	Present: Loans to expand ports or mega development: ownership versus paying loan
4: Operational	Financial	Funding	Mozambique: Financial support
4: Operational	Financial	Funding	Mozambique: Financial funds – no …. (Willingness of stakeholders) (Mozambique perspective)
4: Operational	Financial	Funding	Financial matters
4: Operational	Financial	Funding	Sustainability versus finances
4: Operational	Financial	Funding	Lack of resources
4: Operational	Financial	Funding	Lack of private sector investment and engagement
4: Operational	Financial	Funding	Current causes: Economic factors
4: Operational	Financial	Funding	High costs of infrastructure and technology
4: Operational	Financial	Funding	Limited financial resources
4: Operational	Monitoring	Environmental monitoring	Lack of air and water quality monitoring (sediments)
4: Operational	Monitoring	Environmental monitoring	Challenges: … parameters for port monitoring (environment and waste management)
4: Operational	Monitoring	Environmental monitoring	Future: Embrace technology – cope with bigger ships, monitoring, waste management
4: Operational	Monitoring	Environmental monitoring	Inadequate monitoring tools and systems
4: Operational	Monitoring	Environmental monitoring	Challenges: … parameters for port monitoring (environment and waste management)
4: Operational	Safety & security	Safety & security	Kenya: Upgrade port safety and security
4: Operational	Safety & security	Safety & security	Risk assessment
4: Operational	Safety & security	Safety & security	Commonalities: Health and safety
4: Operational	Training & capacity building	General	Current causes: Knowledge (level of expertise)
4: Operational	Training & capacity building	General	Limited expertise
4: Operational	Training & capacity building	General	Capacity building
4: Operational	Training & capacity building	General	Problem: Training on sustainability; Question of ownership (loans)
4: Operational	Training & capacity building	General	Inadequate capacity, e.g., for monitoring
4: Operational	Training & capacity building	New technology	Role of IMO help developing nations Ito capacity building for green ports, training, facilities/technologies, research
4: Operational	Training & capacity building	New technology	Present: Too many older people working in ports, less capacity of new tech use
4: Operational	Training & capacity building	New technology	Future: Employing younger people who are open to new/greener technologies
4: Operational	Training & capacity building	New technology	Future: Training including sustainability
4: Operational	Training & capacity building	New technology	Mozambique: Capacity building – employ younger people and trained in SA and locally, especially simulation as a means of training
4: Operational	Training & capacity building	New technology	Mozambique: Knowledge – capacity building (training for young); training center (simulation facilities) (Mozambique perspective)
4: Operational	Training & capacity building	Oil spill contingency	Commonalities: Contingency planning – training
4: Operational	Training & capacity building	Oil spill contingency	Challenges: Capacity and …. Oil spills ….

Key Issues in WIO ports as identified by Stakeholders (summary of the above):

CATEGORY 1: CORPORATE CULTURE & POLICY	Management commitment to adopt policies (environmental assessments, greener ports)
	Climate resilience response
	Private sector involvement (port ownership & terminal operators)
	Strategic spatial planning (e.g., link to zone of influence)
	Political will and support (not sure that this would markedly change over scenario period - 2030-50? Change in port behaviour most likely to be driven by external driving forces e.g., climate change, societal pressure, global demand for social/environmental accountability to secure market share)
CATEGORY 2: INSTITUTIONAL ARRANGEMENTS	Dedicated environment department (execution/enforcement)
	Cross-sectoral collaboration/coordination of authorities
	Multi-stakeholder involvement/participation from role-players (port users)
	Local community acknowledgement/conflict
3: TECHNOLOGICAL DEVELOPMENT	Energy efficiency
	Renewable energy
	Waste management
	Vessel logistics (turnover time)
CATEGORY 4: OPERATIONAL EFFICIENCY	Environmental auditing/monitoring (enforcement of policies)
	Securing Funding
	Operational training & capacity development towards greener ports
	Disaster preparedness training & capacity development
	Safety & security (while this certainly relates to well-being of employees and port users, this is not considered central to the focus this project, i.e., environmentally sustainable (greener) ports