Climate change vulnerability and adaptation study for the port of Port-Louis in Mauritius

CTCN Technical Assistance Project – Ref Nb 2016000013

D4 – ACTION AND INVESTMENT PLAN REPORT

ARTELIA / JANUARY 2021 / 8714711

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VERSION	DESCRIPTION	WRITTEN BY:	REVIEWED BY:	APPROVED BY:	DATE
1.0	Concept	JFC / RSE	NZN	NZN	09/11/2020
2.0	Final	NZN			12/01/2021

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ACRONYMS

MPA	Mauritius Ports Authority
ICZM	Integrated coastal zone management
CCD	Climate Change Division
MMS	Mauritius Meteorological Services
MOI	Mauritius Oceanography Institute
CC	Climate change
JICA	Japan International Cooperation Agency
UNDP	United Nations Development Programme
UNFCC	United Nations Framework Convention on Climate Change
GEF	Global Environment Facility
MCT	Mauritius Container Terminal
GIS	Geographic Information System
MoESDDBM	Ministry of Environment, Sustainable Development, and Disaster and Beach Management
TEU	Twenty-foot equivalent unit
CD	Chart Datum
UNCTAD	United Nations Conference on Trade and Development
IFC	International Finance Corporation
MEXA	Mauritius Export Association
NOAA	National Oceanic and Atmospheric Administration
IOWAGA	Integrated Ocean Waves for Geophysical and Other Application

1. INTRODUCTION

Mauritius, as a small island developing state, is highly vulnerable to the adverse impacts of climate change. Port Louis harbor is exposed to a number of combined risks from sea level rise including storm surge, flooding and more powerful and frequent winds, thereby challenging the resilience of the port infrastructure whilst at the same time disrupting the supply chain.

The objective of the study is to conduct a climate change vulnerability and adaptation study for the port of Port Louis and assist with the identification of adaptation options and their monitoring.

The scope and nature of the technical assistance include:

- Review existing national plans and strategies related to the port sector in the context of climate change, to identify opportunities and options to address gaps and needs ;
- Undertake a climate risk assessment for the port of Port Louis, to identify current vulnerabilities and future risks, evaluate the risks, identify and prioritize adaptation options using a multi-criteria analysis and set a monitoring baseline ;
- Formulate an action plan for the implementation of adaptation options in relation to climate change for the port sector, with specific action targets and time frames ;
- Identify capacity building needs of engineers, marine personnel and other cadres of the port sector, on climate change, vulnerability assessment monitoring and evaluation and adaptation technologies.

This report, as Deliverable 4, is the action and investment plan report, presenting the capacity building plan, the action and investment plan and timeline, including costs of selected adaptation measures.

2. ACTION AND INVESTMENT PLAN

2.1. METHODOLOGY

Deliverable D2 has identified the port assets, the port operations, the climate impacts on assets and operations, and the level of vulnerability as illustrated by the port vulnerability matrix and flood modelling results.

Deliverable D3 has proposed various climate adaptation measures for the port, covering the full cycle of prevision, prevention, protection and mitigation of climate impacts, and ranked them according to a multi-criteria analysis (MCA).

The action and investment plan builds upon this foundation by:

- Selecting adaptation measures, according to the results of the MCA, the feedback from MPA including which measures are already being implemented, and avoiding mutually exclusive adaptation measures (such as hard protection measures) ;
- Defining the key objectives and prioritising adaptation measures according to the criticality of the impact addressed;
- Defining the implementation details and overall timeline of each adaptation measure.

2.2. ADAPTATION MEASURES DETAILED IN THE ACTION PLAN

Fourty-one (41) potential adaptation measures have been discussed in deliverable D3. This list is further shortened to sixteen (16) in the action plan because:

- Some measures are already in use:
    - #3 - Measure and account the carbon footprint of port activities (IAPH Guidance for Carbon Footprinting for Ports) ;
    - #6 - Refine knowledge of climate risks ;
    - #17 - Promote the use of renewable energies within the port (water, solar, wind) ;
    - #18 - Promote the use of electric equipment (e-RTG, hybrid straddle carriers etc) ;
    - #32 - Dry-proof construction of critical infrastructure ;
    - #33 - Wet-proof construction of non-critical infrastructure.
- Some measures are not applicable to the port of Port Louis:
    - #5 - Develop a flood risk management plan for Port Louis: flash floods such as the one of 2013 do not impact the port area;
    - #16 - Adapt storage procedures (height of exposed container and bulk stacks, above ground storage etc): not relevant if dry and wet-proofing is already in use (see #32 and #33 above);
    - #19 - Promote the use of clean fuels (LNG powered ships, low sulphur): positive for the environment, but does not directly address immediate climate concerns;
    - #29 - Build storm water retention basins against flash floods: flash floods such as the one of 2013 do not impact the port area;

- #34 - Relocate critical infrastructure: not relevant if dry and wet-proofing is already in use (see #32 and #33 above);
- #39 - Install waterproof electrical infrastructure: not relevant in view of the port configuration.

- Some measures are mutually exclusive:
  - #26 - Build coastal defence: reduced relevance with #25 – Build a breakwater, the preferred option;
  - #27 - Raise the working platform: reduced relevance with #25 – Build a breakwater, the preferred option;
  - #28 - Consider floating development: reduced relevance with #25 – Build a breakwater, the preferred option;
  - #30 - Increase capacity of drainage: reduced relevance with #25 – Build a breakwater, the preferred option;
  - #36 - Active motion damping system: reduced relevance with #25 – Build a breakwater, the preferred option;
- Some measures do not require implementation details or have a lower priority:
  - #7 - Monitor impacts of climate change on supply and demand for traded products: does not address immediate climate concerns;
  - #9 - Allow for increased downtime in financial predictions: does not require implementation details;
  - #10 - Climate adaptation funded as a specific item in the budget: does not require implementation details;
  - #12 - Include the pandemic risk in emergency management plans: does not address immediate climate concerns;
  - #21 - Diversify trade into climate-resilient commodities: does not address immediate climate concerns;
  - #31 - Install green roofs: positive for the environment, but does not directly address immediate climate concerns;
  - #38 - Install high efficiency refrigerated storage: positive for the environment, but does not directly address immediate climate concerns;
  - #42 - Install storm water collection tanks as renewable water source: positive for the environment, but does not directly address immediate climate concerns;

These measures are not shown in the action plan below. However many may still form an integral part of the climate adaptation policy, in particular the measures already in use, lower priority measures and measure #19 - Promote the use of clean fuels.

2.3. KEY OBJECTIVES AND PRIORITISING ADAPTATION MEASURES

The action plan proposed below organizes selected adaptation measures according to the following key objectives and priorities:

1. Increase knowledge on climate change (**immediate**)
2. Prevent damage on loading/unloading equipment of the MCT terminal and oil jetty (**medium term**)

3. Limit the increase of maintenance and repair costs due to climate change (**medium term**)
4. Allow continuous and safe berthing and quay operation at the MCT terminal (**immediate**)
5. Maintain continuous and safe operation within the port (**immediate**)
6. Maintain the regional attractivity of the port (**long term**)
7. Minimize the impact of the port on the environment (**long term**)

The PIANC methodology in annex illustrates how the priority of individual adaptation measures can be determined. This individual priority level is reflected in the timeline of the action plan below.

Measures in objective 2 also address other objectives (see annex). Objective 2 is hence not shown further. Objectives 6 and 7 concern long term measures which have bene excluded in the previous section. They are not shown further.

2.4. ACTION PLAN AND IMPLEMENTATION DETAILS

The action plan for the sixteen (16) remaining measures is detailed below over a 10 year time frame.

The total cost breakdown of about 320 M EUR includes:

- 1,679,000 EUR for preparatory activities, of which 1,000,000 EUR for the breakwater design and 400,000 EUR for environmental monitoring and an early warning system;
- 315,348,000 EUR for implementation, of which 300,000,000 EUR for the breakwater construction and 15,000,000 EUR for wind-resistant cranes;
- 1,767,000 EUR for monitoring, of which 1,500,000 EUR for breakwater maintenance costs.

As explained in report D3, a substantial uncertainty surrounds the cost of the breakwater which may be optimized in view of the local bathymetry.

Table 1: Action plan of priority adaptation measures

PREPARATION
REALISATION
MAINTENANCE / FOLLOW UP / MONITORING
ON GOING

Objectives and measures	Scoring	MCA	YEAR 1	2	3	4	5	6	7	8	9	10
1 - Increase knowledge on climate change												
Appoint an expert in charge of the overall coordination of climate adaptation (for instance the HSE expert)		4	Amend MPA organization structure; Appoint Climate Change officer									
Implement a climate adaptation capacity building program		1	Set up the program and participants; Secure financing		Carry out the program	Monitoring & evaluation						
Monitor climatic and environmental parameters		2	Existing monitoring; Liaise with meteorological public service; Define parameters to monitor									
Real time monitoring of waves and tides, Early Warning System		20	Equip with monitoring tool; Set up new monitoring; Set up Early warning system; Monitoring									
Keep track of all climate-related incidents and events affecting the port, and lessons learnt		2	Set up reporting system; Map incidents and related climate parameters; Improve understanding of climate related incidents									
Identify the exact cause of overtopping during South-West swell events and its recent increase (capital dredging works, strong local wind waves etc)		8	Identify exact cause of overtopping									
3 - Limit the increase of maintenance and repair costs due to climate change												
Increase inspection, repair and maintenance frequency		32							Adapt maintenance plan based on experience gained from climate-related incidents			
Strengthen functional requirements of future infrastructure		14									Adapt infrastructure based on improved knowledge of climate change impacts	

Objectives and measures	Scoring	YEAR 1	2	3	4	5	6	7	8	9	10
4 - Allow continous and safe berthing and quay operation at the MCT terminal											
Build a breakwater to reduce wave action at the MCT and oil jetties	22		Feasibility study; Preliminary deisgn; ESIA; Detailled design; Tenders	Bid Analysis; Construction		Maintenance					
Automate logistics procedures	14		Set up action plan with actors & set priorities	Implement automatisation projects according to plan; Central monitoring & coordination						X	
Install cranes that can safely operate under strong winds	34										Adapt infrastructure based on improved knowledge of climate change impacts
5 - Maintain continous & safe operation within the port											
Include climate adaptation in key policy and operational documents of the port, and Periodically review and update the climate component of key policy and operational documents of the port (continuous improvement process)	11		Include climate adaptation in key policies and operational documents	Review and update							
Adapt operational procedures (minimize disruption of supply chain, maximize operational wind and wave thresholds etc)	8		Update operational procedures according to climate change knowledge	Periodically check and review procedure. Continous improvement							
Promote the use of IAPH sustainabiliy standards (IAPH Lease Agreement Template, ESI clean ship incentive scheme, Toolbox for Port Clean Air Program etc)	11		Liaise with port actors and public authorities; Liaise with IAPH association	Perform training; Set up promotion action plan	Promote according to action plan						
Conduct regular emergency drills for climate events to minimize disruption	8			Set up new emergnecy drill process in line with climate knowledge and new operating procedures	Conduct emergenccy drills; Continuous improvement						

Implementation details of the selected adaptation measures are shown in the table below.

Table 2: Implementation details of selected adaptation measures

	Objectives & measures				Yeary Cost (USD)			Monitoring & evaluation indicator		
#		**Description**	**Implementing authority**	**Relevant stakeholders**	**Preparation**	**Execution**	**Maintenance / monitoring / OPEX costs**	**PREPARATION**	**EXECUTION**	**MAINTENANCE / MONITORING**
1 - Increase knowledge on climate change										
4	Appoint an expert in charge of the overall coordination of climate adaptation (for instance the HSE expert)	Appointing a Climate Change Offcier is the earliest step in the action plan. The person would be in charge of all climate and climate change related issues and would be involved in strategic committees.	MPA	- Port Operators - Ministry of Environment, Solid Waste Management and Climate Change	-	50,000	50,000	-	Climate Change Officer appointed	-
1	Implement a climate adaptation capacity building program	Implementing a capacity building program will instill participants with a climate change state of mind. Direct port users and some indirect port users must be included in the process.	MPA	- MPA - Direct port users - Ministry of Environment, Solid Waste Management and Climate Change	15,000	150,000	15,000	Set up capacity building program Secure financing sources	Capacity Building program on going	Capacity building program evaluation tools
2	Monitor climatic and environmental parameters	MPA shall gather climatic and environmental data from its own devices and complement them from national meteorological services already in place.	MPA	- MPA - The Mauritius Meteorological Services (MMS)	100,000	6,000	3,000	Climatic & environmental parameters selected	Climatic & environmental parameters monitored	Climatic & environmental parameters trends
20	Real time monitoring of waves and tides, Early Warning System	MPA shall gather climatic and environmental data from its own devices and complement them from national meteorological services already in place.	MPA	- MPA - The Mauritius Meteorological Services (MMS)	300,000	6,000	1,500	Early Warning system installed	Waves and tides monitoring. Early Warning System operational	Successfull early warning
8	Identify the exact cause of overtopping during South-West swell events and its recent increase (capital dredging works, strong local wind waves etc)	Understand the exact cause of overtopping based on monitoring and data analysis. This is a key step to properly design the protection measure identified (breakwater).	MPA	- MPA - Port operators	-	15,000	6,000	-	Causes identified	-
2	Keep track of all climate-related incidents and events affecting the port, and lessons learnt	Keeping track of incidents and climatic events allows: - to identify climatic trends and projections; - to measure the efficiency of the solution implemented ; - to forecast upcoming climatic event and get prepared.	MPA	- MPA - Port operators	-	6,000	3,000	-	Climate incident and events recorded.	Climate trends and projections
					415,000	233,000	78,500			

	Objectives & measures				Yeary Cost (USD)			Monitoring & evaluation indicator		
#		**Description**	**Implementing authorities**	**Relevant stakeholders**	**Préparation**	**Réalisation**	**Maintenance / monitoring / OPEX costs**	**PREPARATION**	**REALISATION**	**MAINTENANCE / MONITORIING**
3 - Limit the increase of maintenance and repair costs due to climate change										
32	Increase inspection, repair and maintenance frequency	Focus on infrastructure assets subject to the climate hazards identified, such as the MCT quay walls as well as the oil terminal equipment and jetty. For these infrastructure, increase prevention mesures.	MPA or port operators (concession contract terms)	- MPA - Port operators	-	-	-	Maintenance plan updated according to climate change data	Updated maintenance plan followed	Curative maintenance reduced
14	Strengthen functional requirements of future infrastructure	Design infrastructure based on climate projection data and identified impacts. Use climate projection data provided in deliverable D2 and associated hazards to design future infrastructure. Refer to adaptation measures such as wet/dry proofing or protection measures (dikes, barriers) if necessary.	MPA or port operators (concession contract terms)	- MPA - Port operators depending on responsbility / concession contractual terms	-	-	-	-	-	-
4 - Allow continous and safe berthing and quay operation at the MCT terminal										
22	Build a breakwater to reduce wave action at the MCT and oil jetties	Overtopping and MCT / Oil jetty operation downtime is the first cause of operation downtime and the most critical hazard identified over the 2020 - 2100 period. Breakwater will prevent the wave effect and overtopping and prevent flooding hazard.	MPA or port operators (concession contract terms)	- MPA - Port operators depending on responsbility / concession contractual terms	1,000,000	300,000,000	1500000 USD = 0.5% of the CAPEX	Feasibility and construction planning. Financing solution	Breakwater operational	MCT and Oil jetty operation downtime reduction
14	Automate logistics procedures	Port automation has five components that can be implemented individually : 1 – Automated equipment ; 2 – Equipment control system ; 3 – Terminal control tower ; 4 – Human machine interaction ; 5 – Interaction with the port community. Implementing authority depends on the components, but the systems shall be centralized around a common system to connect them all.	MPA Port operators Freight forwarders Shipping agents	- Port direct and indirect users	-	-	-	Port automation roadmap	Implementation according to schedule	Operation downtime reduction, productivity and safety monitoring
34	Install cranes that can safely operate under strong winds	Crane operation under strong wind shall not be implemented as a priority, as it is difficult to find a financial equilibrium based on climate change only. Instead, when crane have to be renewed, take into account climate change projection to dimension the cranes to be purchased.	Port operators	- MCT port operator	-	15,000,000	150,000	Cost Benefit Analysis to replace the cranes	Crane purchase	MCT quay operation downtime reduction
					1,000,000	315,000,000	1,650,000			

	Objectives & measures				Yeary Cost (USD)			Monitoring & evaluation indicator		
#		**Description**	**Implementing authorities**	**Relevant stakeholders**	**Préparation**	**Réalisation**	**Maintenance / monitoring / OPEX costs**	**PREPARATION**	**REALISATION**	**MAINTENANCE / MONITORIING**
5 - Maintain continous & safe operation within the port										
11 and 4	Include climate adaptation in key policy and operational documents of the port, and Periodically review and update the climate component of key policy and operational documents of the port (continuous improvement process)	Climate change and adaptation must be at the heart of port policy and drive strategical, financial and operational decisions. Including climate adaptation in key policy and operational document is the earliest step for maintaining continous and safe operation within the port	- MPA - Port operators	- Direct and indirect port users	15,000	7,500	3,000	-	Key policy and operation documents adapted	Key policy and operation documents updated
8	Adapt operational procedures (minimize disruption of supply chain, maximize operational wind and wave thresholds etc)	Adapting operational procedures is a response to climate hazards to maximize port productivity and performance while keeping the same level of security. It is best addressed by identifying operations which may continue despite certain climate hazards	- MPA - Port operators	- Direct and indirect port users	189,000	30,000	15,000	Operational procedure adaptation plan	Operational procedure adapted	Operation shutdown, productivity and safety monitoring
11	Promote the use of IAPH sustainabiliy standards (IAPH Lease Agreement Template, ESI clean ship incentive scheme, Toolbox for Port Clean Air Program etc)	The IAPH set up in 2017 the World Port Sustainability Program (WPSP). The goals are to enhance the sustainability of the ports and encourage the participation of supply chain members. The Program is based on the 17 UN Sustainable Development Goals and addresses five main topics: Climate and Energy, Community outreach and port-city dialogue, Governance and Ethics, Resilient Infrastructure, Safety and Security	- MPA	- Direct and indirect port users - Shippping lines - Ministry of Environment, Solid Waste Management and Climate Change - Ministry of Blue Economy, Marine Resources, Fisheries and Shipping	45,000	70,000	17,500	IAPH sustainability standards promotion plan. IAPH training performed	Promotion of IAPH sustainability standards	Continuous improvement
8	Conduct regular emergency drills for climate events to minimize disruption	Once operational procedures are adapted, emergency drill may be an efficient method to 1) audit the procedures, 2) train the team in charge 3) inform and train the people affected and 4) adapt the procedure in view of the drill outcomes.	- MPA - Port operators	- MPA - Direct and indirect port users	15,000	7,500	3,000	Emergency drills adapted	Emergency drill performed	Emergency drill outcomes enhanced (performance, safety, knowledge, management).
					264,000	115,000	38,500			

2.5. INVESTMENT PLAN

2.5.1. Proposed investment plan

Possible investment sources have been discussed with MPA and their rationale laid out in the concept note (report D5 of the present study).

A Financial Assessment has been conducted by MPA, which shows that the breakwater construction being very capital intensive with no direct return on investment cannot be financed solely with borrowed funding, and cannot be of interest to the private sector who would benefit from a more reliable and safer harbour. Hence, the Government of Mauritius and MPA would be responsible for funding the breakwater with the assistance of an accredited entity.

However, the government of Mauritius already has a large number of adaptation infrastructure projects to finance to adequately safeguard its coastline and territory to the increasing adverse effects of climate change. Mauritius has already financed adaptation projects including land drainage programs, coastal zone rehabilitation, Disaster Risk Reduction Operations for a total amount of USD 50 million (equivalent to Rs 2 billion) for the period 2018 to 2020. A second amount of USD 50 million has been committed in 2020 for the period July 2020 to July 2022. This may be compared to a Total Government Expenditure (TGE) of Rs 147.2 billion (USD 3.68 billion) for 2017-2018. As a result, to make this necessary additional infrastructure possible, some contribution funding in the form of a grant is unavoidable. At this stage a financial analysis of the investment has concluded that there is no alternative to having a grant covering a substantial part of the investment to make it viable.

The most plausible setup is hence shown in the table below, based on 50% GCF financing, 35% AfDB loan and 15% government and MPA funding.

Table 3 : Proposed investment plan

Component/Output	Indicative cost (USD)	GCF financing		Co-financing		
		Amount (USD)	Financial Instrument	Amount (USD)	Financial Instrument	Name of Institutions
Increase knowledge on climate change (immediate)	550,000	275,000	Grant	192,500	Loan	AfDB
				82,500	Subsidy	Mauritius government & MPA
Allow continuous and safe berthing and quay operation at the MCT terminal (medium term)	301,000,000	150,500,000	Grant	105,350,000	Loan	AfDB
				45,150,000	Subsidy	Mauritius government & MPA
Indicative total cost (USD)	301,550,000	150,775,000	Grant	105,542,500	Loan	AfDB
				45,232,500	Subsidy	Mauritius government & MPA

2.5.2. General considerations on financing sources

2.5.2.1. Sources of financing for large port infrastructure projects in Africa with significant adaptation component

Climate Change brings about considerable strain on infrastructure especially in the vicinity of coastal areas and more intensely within harbours. The impacts of more intense storms coupled with higher sea levels means that existing infrastructure need to be rebuilt factoring in additional cost in prevision to such impacts or specific additional infrastructure need to be installed to protect existing infrastructure from such additional impacts.

Climate change therefore implies extra infrastructure spending which can be substantial. These may be financed in various ways.

These additional infrastructures are often financed by sources such as:

- Specific mechanisms and funds put in place by the international community to finance adaptation efforts,
- Countries' development funding,
- Development banks.

As a general rule, such organisations, especially when large amounts are involved, favour:

- co-investments with other sources of finance. In addition to sharing costs, parties to such investment like to see that others have analysed the opportunity and have decided to invest also.
- When the owners of the infrastructure have a direct investment at stake in the project, some "skin in the game".

Investments vehicles typically available include grants, loans and guarantees. Also, various forms of technical assistance are usually financed or available for preparatory work to projects.

The most prominent sources of specific funding for climate change adaptation in an African context include, among others:

- **Multilateral funds**: the Green Climate Fund (GCF); the World Bank Global Environment Facility (GEF6); the Adaptation Fund; Africa Climate Change Fund (ACCF) – African Development Bank (AfDB); the Global Climate Partnership Fund (GCFP); the Public-Private Infrastructure Advisory (PPIAF) – World Bank; the Special Climate Change Fund (SCCF) – GEF; among others.
- **Bilateral sources**: the German GIZ-KFW including the International Climate Initiative (ICI) - German Federal Ministry for the Environment (BMU), the French Global Environment Facility (Fond Français pour l'Environnement Mondial – FFEM-AFD), the European commission, Japanese JICA, Chinese CIDCA (recent player), US AID, other EU countries (Danish, Dutch, Belgium, Italy, etc.); among others.
- **Development banks**: African Development Bank (AfDB), International Finance Corporation (IFC -WB), International Bank for Reconstruction and Development (IBRD), European Investment Bank (EIB), European Bank for Reconstruction and Development (EBRD); among others.

2.5.2.2. The GCF

The GCF is currently, by far, the largest source of climate change funding. Developed countries parties to the UN Framework Convention on Climate Change (UNFCCC) have agreed to jointly mobilise USD 100 billion per year by 2020, from a variety of sources. As of today, the amount pledge for the GCF1 is of the order of US$10 billion and a total of

US$23 billion have been approved including co-financing. Of the GCF projects currently approved, 13% are large projects exceeding US$250millions and very few at this stage are large adaptation infrastructure projects.

As illustration, in terms of financing harbour infrastructures, the GCF is currently financing port infrastructure in Nauru for a total investment of USD 65 million co-financed by Nauru 6%, GCF 41%, Asian Development Bank (ADB) 32%, and Australia 21%.

2.5.2.3. Examples of other sources

The AfDB offers a range of solutions to finance port facilities including PPP (Public Private Partnerships) throughout Africa as ports are seen as point of entry to the development of countries. Among many others, AfDB has financed port infrastructures in Senegal, Nigeria, Togo, Mozambique, Namibia, among others.

The WB is also very active, it has invested USD 13.5 billion in ports in Sub-Saharan Africa between 1990 and 2020.

2.5.2.4. Less conventional sources

However, the various financing vehicles that such organisations may offer, can be complemented by other means of financing such as:

- **the private sector**:

a number of the large climate finance sources (multilateral and bilateral) and especially the GCF have vehicles in place to stimulate and act as a catalyst so that the private sector is increasingly involved in the financing of climate change projects and ventures. This can be in terms of scaling up and replicating small and medium size ventures however such sources of financing very much welcome private organisation to commit resources and funding to climate change adaptation and mitigation contribution.

For large infrastructure projects, this is also in terms of supporting and facilitating PPP (Public Private Partnership). In our case, this could be the case of a private port operator with a concession who obtain support from the GCF to get access to favourable sources of finance in the form of favourable line of credit or access to guarantees which would limit potential financial losses of lenders, giving access to better loan rates.

- **specific green bonds (climate bonds)**:

Another source which may be explored for large infrastructure projects which include a sizable component of climate change is bond issuance, often called climate bonds or green bonds. Such bonds are better rated than their conventional counterpart (plain vanilla bonds) and meet a better subscription response and sometimes give access to favourable rates for the issuer. In particular banking organisation such as development banks (AfDB, EIB, …) may be very eager to issue such green bonds for infrastructure projects in Africa.

Africa is seeing increasing activities for such green bonds, issued by governments e.g. the Nigerian government was first for USD 29.7 million issuance aligned with their NDC in December 2017, also green bonds issued by cities such as in South Africa from Johannesburg for USD 84 million in 2014 or Cape Town for USD 136.9 million in 2017 and corporate bonds such as from the Moroccan solar company Masen in 2016 for USD 115.2 million. Nigeria and Kenya issued some guidelines for green bond issuances.

- **insurance sector**:

The insurance sector is indirectly involved in the adaptation measures that will be put in place as these will reduce significantly future claims.

In some cases, insurance companies are ready to participate financially in the adaptation measures as a prevention to higher claims. However, at this stage such cases are rare.

3. CAPACITY BUILDING PLAN

3.1. CAPACITY BUILDING NEEDS

Mauritius ranks high among countries that are most vulnerable to climate change. In the absence of adequate and timely adaptation measures to face the challenge posed by climate change, its socio-economic development will be adversely impacted. In order to mitigate the effects of climate change, adaptation measures are necessary. Capacity building is one such measure of prime importance.

According to the definition of United Nations Development Program (UNDP):

"*In the global context, capacity refers to the ability of individuals and institutions to make and implement decisions and perform functions in an effective, efficient and sustainable manner. At the individual level, capacity building refers to the process of changing attitudes and behaviours-imparting knowledge and developing skills while maximizing the benefits of participation, knowledge exchange and ownership. At the institutional level it focuses on the overall organizational performance and functioning capabilities, as well as the ability of an organization to adapt to change. At the systemic level it emphasizes the overall policy framework in which individuals and organizations operate and interact with the external environment*."

Capacity building (or capacity development) is the process by which individuals and organizations obtain, improve, and retain the skills, knowledge, tools, equipment and other resources needed to do their jobs competently. It also allows individuals and organizations perform at a greater capacity (larger scale, larger audience, larger impact, etc.).

Moreover, capacity building should be a continuous process, including but not limited to, the following:

- Training courses, seminars, webinars;
- Conferences, workshops;
- Specific training locally and abroad;
- Technical assistance from foreign agencies/experts.

At present, awareness of the effects of climate change in Mauritius is limited and the approach to tackle it at national level needs to be better coordinated among public and private stakeholders. Hence, raising awareness and developing know-how about expected influences of changing climatic conditions and the necessity to adapt to them will form part of capacity building. Forecasting future climatic events and reporting on various adaptation procedures will constitute the basis for empowering employees at various levels in acquiring new skills.

In the case of the MPA, it is expected that:

- capacity building needs for the port sector staff and its related cadres (Engineers, marine personnel and other cadres of the port sector) to enhance, implement and monitor the adaptive measures for the long-term resilience of the port of Port Louis against climate change, be identified and ;
- a clear assessment on how and where the necessary skills should be obtained and developed, be provided.

Through appropriate capacity building, the MPA will be able to sensitise all its employees to the potential risks they and their workplace will be exposed to due to climate change. Continuous training, exposure and networking will enable them to improve their overall competence to face the evolving situation.

In the short term, the MPA should decide on a well-thought strategy for coordinating the various initiatives it needs to take in order to adapt to the changing conditions and take appropriate corrective actions for minimising disruptions to

its operations while continuously improving the resilience of its services for in the long run, attaining its objective of becoming a green port.

3.2. CAPACITY BUILDING DURING THE PROJECT

During the project, introduction presentations on the following topics have been carried out at MPA:

- Scientific and technical aspects of Climate Change (CC);
- CC Vulnerability of the Ports sector;
- Adaptive Techniques and approaches to managing ports facing CC;
- Climate Finance: Ports adaptation project financing possibilities.

The course material has been made available to MPA.

3.3. CAPACITY BUILDING PLAN

3.3.1. Program

A capacity building program is one of the first steps to transform the philosophy of an organization such as the MPA into a climate change thinking body. This climate change awareness will go beyond the port for each participant and will most probably be put into practice on a daily basis.

Capacity building may appear very theoretical at first sight and be perceived as unproductive or inefficient for some members of the MPA. This hurdle must be overcome for a successful implementation. The support and commitment of MPA's management for building capacity for future climate change risk and climate awareness training if not already, will have to be secured, to provide training on climate adaptation actions. The capacity building program at the MPA will have as main advantage to gather personnel of the organization, including executive, senior and middle managers, around a climate adaptation reflection and foster communication between participants.

The MPA personnel will require continuous training for this process to be successful. In the initial stage, it is considered that it will need **Technical assistance** for putting a capacity building program in place. It is proposed that the MPA starts by enlisting the services of a foreign expert for that purpose. The latter could be a Health, Safety and Environment Expert with some 8-10 years of experience. The MPA may to that end, request Government to solicit its own local and foreign-based services and foreign Agencies represented locally (EU, UNDP, Consulates etc.) to assist in the recruitment of the expert. His tour of service would depend on MPA's specific needs but is expected to be not more than two short missions of two weeks.

Once appointed, the expert will be called upon to work in close collaboration with MPA Management for agreeing on a climate adaptation capacity building program, for eventual implementation. **Short-term training** and **visits to port(s)** having implemented such a program would benefit MPA senior cadres and policymakers (Ministry of Finance) for beefing up and fine tuning the program to suit MPA's specific needs.

Once the program is properly established at MPA's level, it will be in a position to start building adaptive capacity, covering **training for awareness raising** and **enhancement of competence, data collection and monitoring**.

Areas of interest for implementing the climate adaptation capacity building program will include:

- Understanding and monitoring climatic and environmental parameters;

- Training in and proposals for innovative early warning systems, real-time monitoring of waves and tides, new technology applicable to ports;
- Initiatives to gradually lower the port's carbon footprint;
- tracking all climate related events and incidents impacting the port and recording lessons learnt.

General climate risk awareness training will provide **basic climate awareness training** for management, administrative and frontline staff. This training will assist MPA to establish the concept of climate change in their own reality, thus helping the MPA to progress on adaptive capacity initiatives.

Training to **adapt organisational management systems** to incorporate climate issues is a necessity. Most responses to extreme weather events occur within the framework of a management system, such as risk or emergency management. Acquiring skills and knowledge to update and improve these systems to take climate considerations into account, is considered to be a key training requirement for MPA Management. **Technical assistance** by a foreign expert for a period of two to three weeks will enable the MPA to achieve this objective.

A scenario analysis is one of the tools the MPA can resort to as part of climate adaptation planning. This program will, by promoting an **in-house collaborative approach**, offer executive, senior and middle managers at the MPA the opportunity to improve their skills in the use of various scenarios for future planning for strategic investments.

Climate risk management training will enhance specific skills and knowledge of MPA cadres in this field, by improving their adaptive capacity to climate change. There are emerging processes and techniques for undertaking climate risk assessments at ports, requiring specific knowledge and further training for existing risk professionals. The MPA may seek Technical assistance, estimated at two weeks expert period, from international organisations such as the EU. The expert will guide the MPA in enabling it to adopt the processes and techniques it will consider best suited for its context.

The MPA may seek the **assistance of the national meteorological services** which can assist it personnel to identify and find appropriate climate information, interpret and analyse the data. Data collection and monitoring is an important strategy to build adaptive capacity to future climate change as it will enable it to gain a better understanding of its current vulnerability. The MPA will also have to **collaborate with other stakeholders** such as the Municipality of Port Louis, Ministry of Environment, the National Disaster Risk Reduction and Management Centre and partners in the port logistics business to further strengthen its adaptive capacity. This is considered to be a definite approach for identifying the current vulnerability to climate and building adaptive capacity for future climate change.

The MPA is a regular member of **International Association of Port Harbour (IAPH)** and can therefore actively benefit from its **expertise, network and regular conferences and meetings**. IAPH members have the opportunity to benefit from each other's experiences, tools and feedbacks. In 2017, the IAPH set up the World Port Sustainability Program (WPSP). The goals of the program are to enhance the sustainability of ports and encourage the participation of supply chain members. The Program is based on the 17 UN Sustainable Development Goals and addresses five main topics:

- Climate and Energy
- Community outreach and port-city dialogue
- Governance and Ethics
- Resilient Infrastructure
- Safety and Security.

WPSP works as a think tank and can provide various tools and share experience on port sustainability projects with the MPA as part of its capacity building strategies.

3.3.2. Cost estimation

The cost breakdown is detailed in the table below. Including some margin for contingencies, a budget of 6 M MUR or 150,000 EUR is suggested.

Description	Personnel	Duration	Rate Euros	Rate USD	Rate MUR	Amount MUR	Remarks
Implement a climate adaptation capacity building program	1 Foreign Expert	2x2 weeks	25,000.00		1,180,000.00	1,180,000.00	
	2 MPA cadres	2 weeks		425/pax/day	17,127.50	411,060.00	Abroad
	1 Ministry of Finance Cadre	5 days		425/pax/day	17,127.50	85,637.50	Abroad
Adapt Operational Procedures	1 Foreign Expert	1 mth	25,000.00		1,180,000.00	1,180,000.00	FT local
	1 MPA Engineer/Cadre	2 weeks		425/pax/day	17,127.50	205,530.00	Abroad
Automate Logistics Procedures	1 Foreign Expert	1 mth	25,000.00		1,180,000.00	1,180,000.00	
	1 MPA Engineer/Cadre	2 weeks	25,000.00	425/pax/day	17,127.50	205,530.00	Abroad
Promote the Use of IAPH Sustainability Standards, Measure and Account the Carbon Footprint	Foreign Experts		-		-	-	MPA to obtain free Technical Assiatance
	2 MPA cadres	1 mth			17,127.50	856,375.00	Abroad
					Total	**5,304,133**	**MUR**

3.3.3. Outcome

It is expected that through the capacity building process, MPA Engineers, marine personnel and other cadres in the port sector will become fully aware of risks and challenges posed by climate change and prompt a befitting response accordingly, with a view to enhancing the port's resilience to mitigate its effects. The MPA may as a consequence make informed decisions with regard to various actions, notably as:

- Adapting operational procedures to maximize port productivity and performance while keeping the same level of security
- Promoting the Use of Electric Equipment to reduce air pollution and noise and considering powering electric equipment by producing renewable energy such as solar panel, wind turbine etc. as a viable green option
- Gradually replacing existing crane by modern cranes with automated or semi-automated operation system, which will also contribute to the MPA's automation of logistics processes and ultimately turn the port into a smart port
- Automating logistics processes to increase the competitivity and reliability of the port operations
- Building coastal defences such as dikes or retractable seawalls
- Diversifying trade into climate-resilient commodities
- Considering floating developments for future infrastructure
- Install active motion damping systems for moored ships to among others, increase ship accessibility and operability (mooring, loading/unloading) when the port is facing severe weather conditions
- Measure and Account the Carbon Footprint of Port Activities, for which the IAPH can provide a Carbon footprint calculator tool to the MPA to measure the port's carbon footprint.

4. GUIDELINES FOR CLIMATE CHANGE ADAPTATION

The present study, through deliverables D1 to D4, has illustrated one possible way to develop a climate adaptation strategy for the port.

Deliverable D1 has also illustrated case studies from around the world in its annex 2 and a literature review on climate change adaptation of ports in its annex 3.

Finally, as an exercise to help deriving the action plan, the methodology set out by PIANC EnviCom WG Report n° 178 has been applied to the present case of Port Louis, in annex of the present deliverable D4.

Each of these methods may help MPA derive the most appropriate framework to guide climate change adaptation.

5. CONCLUSION

This final report presents the practical details to adapt the port of Port Louis to climate change, through the capacity building plan, the action and investment plan, and through guidelines to include climate change adaptation into the long term policy of the port, based on best international practice.

A breakwater has been identified as the adaptation measure the most likely to have an immediate positive effect on the climate vulnerability of the port of Port Louis. Higher performance cranes (resistant to extreme wind) may further contribute to reducing this climate vulnerability.

While this study has strived to result in very concrete steps towards climate adaptation, it is important to bear in mind several aspects.

Climatic events should not be mistaken for climate change impacts. Many of the problems currently experienced by the port are not due to climate change, but to the infrastructure not being able to cope with the present climate. Of course, climate change is likely to amplify these issues as shown in this study, in particular because a small increase in extreme climatic parameters results in a large increase in associated downtime. Also, climate change is a very gradual process which is still not fully understood (see ongoing long term work of IPCC), while natural variability is at least an order of magnitude more important. It may never be possible to clearly state that a given event is due to climate change.

For this reason, we stress the importance of a global approach towards climate change adaptation. Measures should not limit themselves to those with the most visible impact on port activities (such as the breakwater or higher performance equipment). They should cover the entire adaptation cycle of prevision, prevention, protection and mitigation, as shown in deliverable D3. The strong added value of investing in the early phases of this cycle (prevision, prevention) is best illustrated by the present project, during which it was not possible to clearly identify the cause of operational downtime due to swell events, due to a lack of knowledge on the historical hazards. Knowing the hazards and associated asset vulnerability is the first step towards making informed decisions of which adaptation actions to implement.

Finally we firmly believe that climate change adaptation and GHG reduction in line with the 2015 Paris Agreement are a continuous improvement process, directly falling under the Health, Safety and Environment policy of the port. Dedicated funding, audits, and a Climate Change section in the Environmental and Social Monitoring System of the port and its associated operational documents, should ensure that climate change adaptation is given its due place. In turn, a strong policy framework may prove attractive to insurers willing to insure against climate risks.

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ANNEXES

ANNEX 1 – PIANC CLIMATE CHANGE ADAPTATION METHODOLOGY APPLIED TO PORT LOUIS

1. RISK ASSESSMENT AND OBJECTIVES

The present annex applies the PIANC (2020) climate change adaptation methodology to the port of Port Louis.

1.1. GENERAL METHODOLOGY

The opposite figure describes the main steps followed to define objectives for the action plan. Drawing on available outputs from previous deliverables, it is possible to get a clear view on the current and future situation of the port, on climate hazards and consequents impact as well as the cost of these impacts.

The risk assessment and objective formulation is necessary to refine the exact needs in terms of climate adaptation strategy.

The following chapters describe in detail the methodology and the results of the analysis.

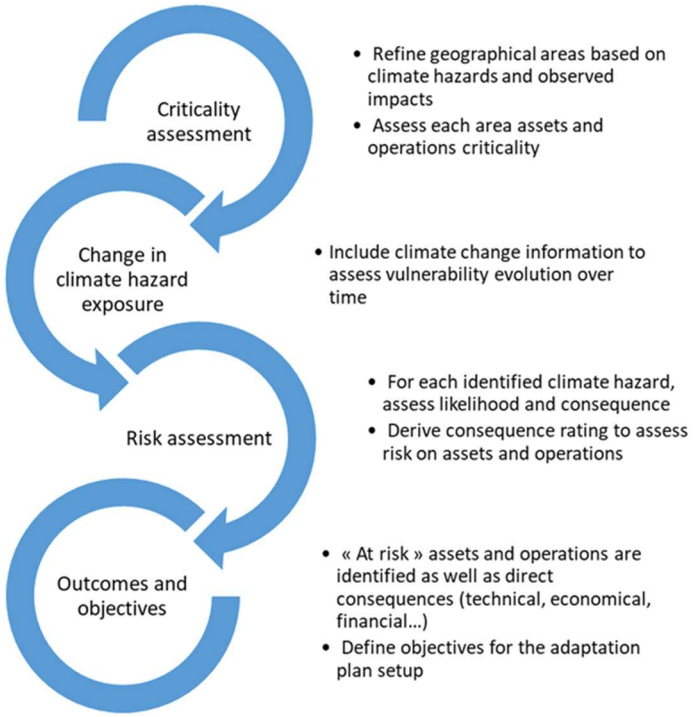

Figure 1 - Risk assessment and objective methodology

1.2. CRITICALITY ASSESSMENT

The initial process of identifying assets and operation vulnerability needs to be refined in view of projected changes in climate parameters, consecutives impacts on the port and cost of climate hazards on the port and more generally on the economy.

Flood modelling results showed heterogeneous impacts depending on the exact location of port assets and operations in the port. The MCT container terminal and the oil terminal directly facing the ocean are for instance more vulnerable to flooding and to the consequences of climate change than terminals located within the port basin. A criticality and risk assessment needs to be performed on geographical areas that present the same kind of exposure to the climate hazards and related impacts. In view of the conclusions of reports D2 and D3, the port is divided into four (4) distinct areas for the risk assessment:

- The MCT container terminal and oil jetty ;
- Terminals I&II, the coal terminal and shipyard ;
- The Caudan basin ;

- The ferry, fishing and sugar terminals.

A criticality assessment consists in looking at the relative importance of infrastructure and operation, and prioritising them depending on how their disruption or destruction would significantly impact the port activity itself, or the overall supply chain the port is being part of. This ranking follows the methodology set out in the PIANC EnviCom WG Report n° 178, illustrated below.

Table 4: Criticality assessment table

Implications for: Scale of impact:	Safety	Economic effect, business continuity	Public effects and local community	Environment sustainability and compliance	Critical ?
Catastrophic	Risk of large numbers of serious injuries or loss of life	Loss or degradation would risk long-term viability of business including supply chains	Essential services lost, daily life becomes intolerable, unacceptable physical suffering	Irrecoverable damage, proven breach, prospect of corporate penalty Yes Major	Yes
Major	Risk of isolated instances of serious injuries or loss of life	Loss or degradation would have serious effects on business requiring significant remedial action	Severe disruption of essential services and hence daily life, high levels of physical suffering	Severe and continuing loss, significant management effort needed to deal with compliance failure Probably Moderate	Probably
Moderate	Risk of small numbers of injuries	Intervention needed to protect business continuity	Frequent disruption of essential services; daily life difficult, moderate levels of physical suffering	Minor, reversible damage, action needed on issues of compliance Unlikely Minor or insignificant	Unlikely
Minor or significant	Risk of near misses or minor injuries	Isolated difficulties (e.g. in supply chain, replacements or alternatives exist)	Intermittent disruption of essential services and daily life, low levels of physical suffering	Negligible damage, minor breaches, easily resolved Not critica	Not critical

Results of the criticality assessment for the port of Port Louis are presented below.

Being the only commercial port on the island and handling nearly all import/export activity, most assets and operations are considered critical. However, the Mauritius Container Terminal (MCT) and the oil terminal are the most critical area. The disruption of the container terminal would have the most severe impact on the port activity and on the economy of Mauritius in general.

Table 5: Port criticality assessment

		Criticality			
		not critical / not applicable	unlikely	probably	yes
MCT - Oil Jetty & Freeport					
Assets	Channel and basin				X
	Quay Wall				X
	Port equipment - Load / unload area				X
	Free port area		X		
	Hinterland connection		X		
Operations	Navigation and berthing				X
	Storage				X
	Processing				
	Free port Logistic operations		X		
Coal storage and shipyard					
Assets	Channel and basin				X
	Quay Wall				X
	Port equipment - Load / unload area				X
	Hinterland connection	X			
Operations	Navigation and berthing				X
	Storage				X
	Processing				
Terminal I & II					
Assets	Channel and basin				X
	Quay Wall				X
	Port equipment - Load / unload area				X
	Port equipment - Storage			X	
	Power plant		X		
	Industrial installation & products		X		
	Hinterland connection		X		
Operations	Navigation and berthing				X
	Loading / unloading				X
	Storage				X
	Processing				X
	Industries operations		X		
Caudan Bassin					
Assets	Channel and basin			X	
	Quay Wall			X	
	Parking area and buildings			X	
	Hinterland connection		X		
Operations	Navigation and berthing			X	
	Commercial activities			X	
Ferry / Fishing / Sugar Terminal					
Assets	Channel and basin				X
	Quay Wall & pier				X
	Port equipment - Load / unload area				X
	Storage area			X	
	Port equipment - Storage			X	
	Hinterland connection		X		
Operations	Navigation and berthing				X
	Loading / unloading				X
	Storage			X	
	Processing		X		

1.3. CHANGE IN CLIMATE HAZARD AND RISK ASSESSMENT

1.3.1. Change in climate hazard

The table below provides a general qualitative assessment of the evolution of climate hazards considered for this study (in line with report D2).

Table 6: Change in climate hazard qualitative assessment

	Flooding due to overtopping	Extreme wind	Sea level rise	Wet / dry spells	Fog / reduced visibility	Normal wind and wave	Air temperature	Sea temperature	Rain	CO2 concentration
Change in climate hazard	↗↗	↗	↗↗	↔	↘	↘	↗	↗	↗	↗

Change in climate hazard	
↗↗	Significant increase
↗	Increase
↔	No change
↘	Reduction
↘↘	Significant reduction

1.3.2. Risk rating methodology

The risk related to a climate hazard is the combination of the likelihood of the hazard and the consequence of the same hazard. By quantifying likelihood and consequences, it possible to assess the level of risk of a hazard on an asset or on a port operation. The tables below take inspiration from the PIANC EnviCom WG Report n° 178 and its methodology.

The table below provides a qualitative description of likelihood, quantified using a scale from 1 to 5.

Table 7: Likelihood assessment table

Qualitative description of likelihood	**Likelihood rating**	
It is expected that the climate hazard will occur, that the threshold will be exceeded or there will be another significant impact within the 2020 to 2100 period	Almost certain	5
It is likely that the climate hazard will occur, the threshold will be exceeded or there will be another significant impact within within the 2020 to 2100 period	Likely	4
The climate hazard may occur or the threshold may be exceeded or there may be another significant impact within within the 2020 to 2100 period	Possible	3
The climate hazard could occur, or the threshold could be exceeded or there could be another impact within within the 2020 to 2100 period	Unlikely	2
The climate hazard (or the exceedance of the threshold or the manifestation of an impact) is not expected to occur other than in exceptional circumstances within within the 2020 to 2100 period	Rare	1

The table below provides a qualitative description of consequences, quantified using a scale from 1 to 5.

Table 8: Consequence assessment table

If the occurrence of the hazard would cause impacts that…	… then an appropriate consequence rating is	
Irreplaceably or permanently affect critical assets, operations or systems and thus threaten the viability of the port with possible implications for the regional or national economy, potentially lead to loss of life, cause significant and irreversible contamination with hazardous substances	Catastrophic	5
Have a significant, negative long-term effect on critical assets, operations or systems and thus compromise the business continuity of the port, potentially lead to serious injury, result in significant or irreversible environmental impacts	Major	4
Have a negative, locally significant and/or short- to medium-term effect on critical assets, operations or systems with implications for business continuity in the affected parts of the port or waterway; potentially lead to minor injury, cause moderately significant environmental impacts	Moderate	3
Temporarily affect the efficiency or effectiveness of critical assets, operations or systems or aspects thereof but with no significant implications for business continuity overall, cause environmental impacts of minor significance	Minor	2
Have negligible implications for critical assets, operations or systems and hence business continuity, insignificantly affect the environment.	Insignificant	1

Based on the assessment of likelihood and consequences, it is possible to qualify the risk on assets and operations based on the following table.

Table 9 - Risk matrix

Likelihood → **Impact ↓**	Rare - 1	Unlikely - 2	Possible - 3	Likely -4	Almost Certain -5
Catastrophic - 5					
Major - 4					
Moderate - 3					
Minor - 2					
Insignificant - 1					

For each asset and operation considered, the risk score is presented using a colour code, providing a general and qualitative level of risk. Results of the risk assessment analysis provide a framework to define specific objectives to address in the action plan.

1.3.3. Risk assessment

The risk assessment on the port assets and operations builds upon the evolution of climate hazards and the risk rating methodology. The outcome of this risk assessment determines the priority of adaptation actions. Assets and operations which are not deemed critical are not rated.

The risk assessment for the port of Port Louis is presented in the table below:

Table 10: Port risk assessment

		Criticality				Flooding due to overtopping	Extreme wind	Sea level rise	Wet / dry spells	Fog / reduced visibility	Normal wind and wave	Air temperature	Sea temperature	Rain	CO2 concentration
		not critical / not applicable	unlikely	probably	yes	↗↗	↗	↗↗	↔	↘	↘	↗	↗	↗	↗
MCT - Oil Jetty & Freeport															
Assets	Channel and basin				X										
	Quay Wall				X										
	Port equipment - Load / unload area				X										
	Free port area		X												
	Hinterland connection		X												
Operations	Navigation and berthing				X										
	Storage				X										
	Processing														
	Free port Logistic operations		X												
Coal storage and shipyard															
Assets	Channel and basin				X										
	Quay Wall				X										
	Port equipment - Load / unload area				X										
	Hinterland connection	X													
Operations	Navigation and berthing				X										
	Storage				X										
	Processing														
Terminal I & II															
Assets	Channel and basin				X										
	Quay Wall				X										
	Port equipment - Load / unload area				X										
	Port equipment - Storage			X											
	Power plant		X												
	Industrial installation & products		X												
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Operations	Navigation and berthing				X										
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Assets	Channel and basin			X											
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	Parking area and buildings			X											
	Hinterland connection		X												
Operations	Navigation and berthing			X											
	Commercial activities			X											
Ferry / Fishing / Sugar Terminal															
Assets	Channel and basin				X										
	Quay Wall & pier				X										
	Port equipment - Load / unload area				X										
	Storage area			X											
	Port equipment - Storage			X											
	Hinterland connection		X												
Operations	Navigation and berthing				X										
	Loading / unloading				X										
	Storage			X											
	Processing		X												

Level of risk	Required adaptation action
Very high risk	Immediate adaptation action required
High risk	Adaptation action required as high priority
Moderate risk	Adaptation actions to be implemented via day-to-
Low risk	Risks to be managed and monitored via routine

1.3.4. Outcomes and objectives

General analysis

The analysis emphasises a combination of three hazards (overtopping, extreme waves, sea level increase) related to the sea with a high impact and high likelihood.

The MCT and oil jetty berthing and quay areas have the highest identified risks. These risks are mainly due to their geographical position, with quay walls directly facing the ocean and directly exposed to hazardous meteorological events coming from the sea.

To a lesser extent, Terminals I & II as well as the coal terminal and ship repair terminal are also identified as risky areas. Located at the entry of the basin, these terminals are still quite exposed to the ocean but can also benefit from their position within the basin which tends to reduce the impact of hazardous meteorological events.

The risk on infrastructure assets is moderate to low for most port areas. However **loading/unloading equipment** at the quay side are considered at risk when it comes to flooding from the sea and extreme wind.

The risk on operations increases with the proximity to the sea. Navigation and berthing as well as loading/unloading quay operations are highly risky.

> Navigation and berthing as well as quay operations on the MCT and oil jetty are the riskiest in terms of safety, damage and economic impacts.
>
> The main consequence of those climate hazards being operation shutdown and disruption, it is essential to ensure the continuity of the whole supply chain and reduce as much as possible the economic impact on port operation and to the Mauritius economy.

Objectives

Objectives follow five (5) themes namely, Management, Physical, Operational, Business and Environmental objectives. The table below summarizes the objectives for each theme based on observations resulting from the risk analysis. Among the ten (10) objectives, four (4) of them are considered primary objectives, meaning that the action plan has to provide an efficient answer to these objectives on a short time scale.

Table 11: Objectives & observations

Criterias for action plan	Category	Risk level	Cost of CC	Action plan
Management				
Objectives : **- Increase knowledge on climate change**				**Primary**
Observation				
Lack of knowledge on climate change	All	high	high	immediate
Physical				
Objectives : - Prevent damage on loading/unloading equipment, the MCT terminal and oil jetty - Limit the increase of maintenance and repair costs due to climate change				
Observation				
Damaging infrastructure facing the ocean or exposed to overtopping	Operational	low	low	long term
Damaging handling equipment on the quay	Operational	low	low	long term
Damaging goods during handling and/or storage operations	Financial	low	low	long term
Increase in maintenance cost and repair	Financial	medium	medium	middle term
Operational				
Objectives : **- Allow continous berthing and quay operations at the MCT terminal** **- Allow continous port operation when climate hazards occur**				**Primary** **Primary**
Observation				
Delays in vessel movements	Operational	high	high	immediate
Downtime for quay operations (loading/unloading)	Operational	high	high	immediate
Downtime during storage operation/delivery/collection	Operational	high	medium	immediate
Safety risk during operation in presence of climate hazards	Operational	high	low	immediate
Business				
Objectives : - Maintain the regional attractivity of the port				
Observation				
Investor and customer confidence loss	Financial	medium	medium	short term
Reduction in trade and revenues (on the long term)	Financial	high	low	long term
Spoilage of goods	Financial	low	low	middle term
Port performance and performance relative to other regional ports	Financial	high	high	short term
Environnmental				
Objectives : - Minimize the impact of the port on the environment				
Observation				
Pollution due to spoilage of goods	Environmental	low	low	long term

1.4. ADAPTIVE OPTIONS & ACTION PLAN

1.4.1. General methodology

The opposite figure describes the main steps followed to set up an action plan for the coming years. Each adaptation measure can be associated with one or more objectives and can be assessed in terms of benefit and priority.

Each measure is evaluated according to its capacity to address the objectives and to be part of a combination of measures.

The action plan must be seen as a general guideline for the port to adapt to climate change, with a clear idea of milestones interdependency and measures that set the timeline of the overall action plan.

The following sections describe in detail the methodology and the results of the analysis.

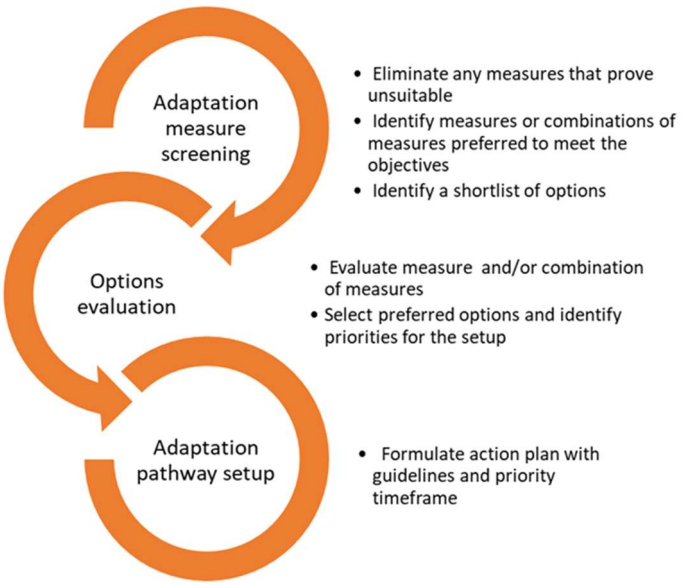

Figure 2 - Adaptive options & action plan methodology

1.4.2. Adaptation measure screening

Fourty-one (41) potential adaptation measures have been discussed in deliverable D3 and ranked according to a multi-criteria analysis. A new screening in light of the action plan shows that:

- Some measures are already in use:
    - #3 - Measure and account the carbon footprint of port activities (IAPH Guidance for Carbon Footprinting for Ports) ;
    - #6 - Refine knowledge of climate risks ;
    - #17 - Promote the use of renewable energies within the port (water, solar, wind) ;
    - #18 - Promote the use of electric equipment (e-RTG, hybrid straddle carriers etc) ;
    - #32 - Dry-proof construction of critical infrastructure ;
    - #33 - Wet-proof construction of non-critical infrastructure.
- Some measures are not applicable to the port of Port Louis:
    - #5 - Develop a flood risk management plan for Port Louis: flash floods such as the one of 2013 do not impact the port area;
    - #16 - Adapt storage procedures (height of exposed container and bulk stacks, above ground storage etc): not relevant if dry and wet-proofing is already in use (see #32 and #33 above);
    - #19 - Promote the use of clean fuels (LNG powered ships, low sulphur): positive for the environment, but does not directly address immediate climate concerns;

- #29 - Build storm water retention basins against flash floods: flash floods such as the one of 2013 do not impact the port area;
- #34 - Relocate critical infrastructure: not relevant if dry and wet-proofing is already in use (see #32 and #33 above);
- #39 - Install waterproof electrical infrastructure: not relevant in view of the port configuration.

1.4.3. Evaluation of shortlisted adaptation measures

The assessment of each remaining adaptation measure is made regarding its capacity to meet the objectives. The assessment is qualitative and binary (yes or no) in order not to complicate the methodology and the analysis.

The second step consists of evaluating each adaptation measure with a Cost Benefit Analysis (CBA) methodology. As cost is an essential criterion for such infrastructure and such project, it is important to take it into account for the final selection. The cost criterion is quantified from 0 to 4 (0 – highly expensive; 4 – reasonable cost). The benefit is also quantified from 0 to 4 depending on its potential to meet the objective. The benefit is the combination of three parameters answering the following question:

- Does the adaptation measure provide an interesting answer to a climate hazard? This question refers to the ranking presented in deliverable D3;
- Does the adaptation measure meet the previously identified objectives?
- Does the adaptation measure meet the primary objectives?

Results of the CBA analysis provides a quantitative measure by multiplying the “cost” criterion with the “benefit” criterion, with a result ranging from 0 to 16. The table below shows the results of the evaluation of shortlisted options.

Table 12: Evaluation of adaptation measures

			RANK	Managment	Physical		Operation		Business	Environnmental	Cost benefit analysis		
				1 - Increase knowledge on climate change	2 - Prevent damage on loading/unloading equipment, the MCT terminal and oil jetty	3 - Limit the increase of maintenance and repair costs due to climate change	4 - Allow continous and safe berthing and quay operation at the MCT terminal	5 - Maintain continous & safe operation within the port	6 - Maintain the regional attractivity of the port	7 - Minimize the impact of the port on the environment	Benefit	Cost	Result
				Immediate	medium term	medium term	Immediate	Immediate	long term	long term			
Monitor hazards											Monitor hazards		
1	Prevision	Monitor climatic and environmental parameters	2								4	4	16
2	Prevision	Real time monitoring of waves and tides, Early Warning System	20								3	4	12
Quantify climate impacts											Quantify climate impacts		
4	Prevision	Identify the exact cause of overtopping during South-West swell events and its recent increase (capital dredging works, strong local wind waves etc)	8								4	4	16
7	Prevision	Monitor impacts of climate change on supply and demand for traded products	36								1	4	4
Plan with climate change in mind											Plan with climate change in mind		
8	Prevision	Appoint an expert in charge of the overall coordination of climate adaptation (for instance the HSE expert)	4								4	4	16
9	Prevision	Allow for increased downtime in financial predictions	39	Does not address objectives							1	4	4
10	Prevision	Climate adaptation funded as a specific item in the budget	39	Does not address objectives							1	4	4
Adapt operations to climate hazards											Adapt operations to climate hazards		
11	Prevention	Include climate adaptation in key policy and operational documents of the port.	4								4	4	16
12	Prevention	Include the pandemic risk in emergency management plans	34	Does not address objectives							1	4	4
13	Prevention	Periodically review and update the climate component of key policy and operational documents of the port (continuous improvement process)	4								4	4	16
14	Prevention	Increase inspection, repair and maintenance frequency	32								2	3	6
15	Prevention	Adapt operational procedures (minimize disruption of supply chain, maximize operational wind and wave thresholds etc)	8								4	4	16

			RANK	Managment	Physical		Operation		Business	Environnmental	Cost benefit analysis		
				1 - Increase knowledge on climate change	2 - Prevent damage on loading/unloading equipment, the MCT terminal and oil jetty	3 - Limit the increase of maintenance and repair costs due to climate change	4 - Allow continous and safe berthing and quay operation at the MCT terminal	5 - Maintain continous & safe operation within the port	6 - Maintain the regional attractivity of the port	7 - Minimize the impact of the port on the environment	**Benefit**	**Cost**	**Result**
				Immediate	medium term	medium term	Immediate	Immediate	long term	long term			
Capitalize on opportunities linked to climate adaptation											Capitalize on opportunities linked to climate a		
20	Prevention	Promote the use of IAPH sustainabiliy standards (IAPH Lease Agreement Template, ESI clean ship incentive scheme, Toolbox for Port Clean Air Program etc)	11								4	4	16
42	Prevention	Install storm water collection tanks as renewable water source	24								2	3	6
21	Prevention	Diversify trade into climate-resilient commodities	25								1	4	4
Strengthen climate preparedness											Strengthen climate preparedness		
22	Prevention	Implement a climate adaptation capacity building program	1								4	4	16
23	Prevention	Conduct regular emergency drills for climate events to minimize disruption	8								3	4	12
24	Prevention	Strengthen functional requirements of future infrastructure	14								4	1	4
Hard protection measures											Hard protection measures		
25	Protection	Build a breakwater to reduce wave action at the MCT and oil jetties	22								**4**	**2**	**8**
26	Protection	Build coastal defenses such as dikes or sea walls (potentially of retractable or temporary nature)	31								1	3	3
27	Protection	Raise the working platform, critical transport links and equipment (or any combination thereof)	36								4	0	0
28	Protection	Consider floating developments for future infratructure	32								4	0	0
31	Mitigation	Install green roofs	23								1	3	3
Increase equipment efficiency and operability				Increase equipment efficiency and operability							Increase equipment efficiency and operability		
35	Protection	Automate logistics procedures	14								4	1	4
36	Protection	Install active motion damping systems for moored ships	29								2	2	4
37	Protection	Install cranes that can safely operate under strong winds	34								3	1	3
38	Protection	Install high efficiency refrigerated storage	27								1	3	3
Mitigate future impacts				Mitigate future impacts							Mitigate future impacts		
40	Mitigation	Keep track of all climate-related incidents and events affecting the port, and lessons learnt	2								4	4	16
41	Mitigation	Manage the costs of climate change risks through insurance contracts (a proactive climate change adaptation policy may decrease insurance costs)	7								1	4	4

Analysis and preferred options

Out of the 30 adaptation measures shortlisted, 9 of them have the maximum notation of 16, and all of the objectives are covered by adaptation measures.

Some of the measures are mutually exclusive, meaning that the selection of one adaptation measure automatically eliminates other measures. This is the case for hard protection measures where measure #25 – Build a breakwater reduces the relevance of measures #26 – Build coastal defence, #27 – Raise the working platform, #28 – Consider floating development, #30 – Increase capacity of drainage and #36 – Active motion damping system. The CBA analysis ranked adaptation measure #25 – Build a breakwater as the preferred measure with a score of 8 out of 16. This score is relatively low compared to some other measures because hard protection measures suffer from a high implementation cost.

1.4.4. Pathway setup

Each adaptation measure is affected to one or more objective depending on its capacity to address the objective. In order to define the action plan and pathway, the implementation priority is estimated based on the previous scoring. The higher the score, the earlier the implementation.

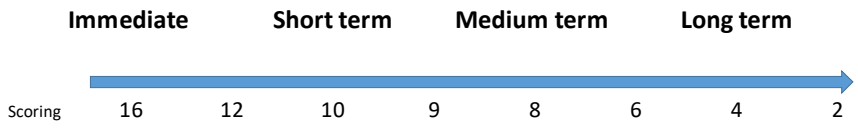

Table 13: Priority level of adaptation measures

Priority	Objectives and measures	MCA scoring	ADAPTATION PLAN							
			Immediate		Short term		Medium term		Long term	
			Scoring							
			16	12	10	9	8	6	4	2
Immediate	1 - Increase knowledge on climate change									
	Appoint an expert in charge of the overall coordination of climate adaptation (for instance the HSE expert)	4	X							
	Implement a climate adaptation capacity building program	1	X							
	Monitor climatic and environmental parameters	2	X							
	Real time monitoring of waves and tides, Early Warning System	20		X						
	Identify the exact cause of overtopping during South-West swell events and its recent increase (capital dredging works, strong local wind waves etc)	8	X							
	Keep track of all climate-related incidents and events affecting the port, and lessons learnt	2	X							
Medium Term	2 - Prevent damage on loading/unloading equipment, the MCT terminal and oil jetty									
	Build a breakwater to reduce wave action at the MCT and oil jetties	22					X			
Medium Term	3 - Limit the increase of maintenance and repair costs due to climate change									
	Build a breakwater to reduce wave action at the MCT and oil jetties	22					X			
	Increase inspection, repair and maintenance frequency	32						X		
	Strengthen functional requirements of future infrastructure	14							X	
Immediate	4 - Allow continous and safe berthing and quay operation at the MCT terminal									
	Build a breakwater to reduce wave action at the MCT and oil jetties	22					X			
	Automate logistics procedures	14							X	
	Install cranes that can safely operate under strong winds	34							X	
Immediate	5 - Maintain continous & safe operation within the port									
	Include climate adaptation in key policy and operational documents of the port,	11	X							
	Adapt operational procedures (minimize disruption of supply chain, maximize operational wind and wave thresholds etc)	8	X							
	Periodically review and update the climate component of key policy and operational documents of the port (continuous improvement process)	4	X							
	Promote the use of IAPH sustainabiliy standards (IAPH Lease Agreement Template, ESI clean ship incentive scheme, Toolbox for Port Clean Air Program etc)	11	X							
	Conduct regular emergency drills for climate events to minimize disruption	8		X						
Long Term	6 - Maintain the regional attractivity of the port									
	Include the pandemic risk in emergency management plans	34							X	
	Monitor impacts of climate change on supply and demand for traded products	36							X	
Long Term	7 - Minimize the impact of the port on the environment									
	Install storm water collection tanks as renewable water source	24						X		
	Install green roofs	23							X	
	Install high efficiency refrigerated storage	27							X	
	Others									
	Allow for increased downtime in financial predictions	39							X	
	Climate adaptation funded as a specific item in the budget	39							X	
	Diversify trade into climate-resilient commodities	25							X	

This first analysis provides a general understanding on how to achieve the objectives with adaptation measures prioritized over time. Adaptation measure #22 – Build a breakwater addresses three objectives:

- “2 - Prevent quay loading/unloading equipment potential damage on MCT terminal and Oil Jetty”.
- “3 - Limitate the increase of maintenance and repair costs due to climate change”
- “4 - Allow continous and safe berthing and quay operation for MCT terminal”

In the action plan, this measure is affected to the objective with the highest priority, 3 - “Allow continuous and safe berthing and quay operation for MCT terminal”. Objective number 2 - “Prevent damage on loading/unloading equipment of the MCT terminal and oil jetty” is removed to avoid duplicates.

The action plan is presented in the main report.