Climate Risk and Vulnerability Assessment Framework for Caribbean Coastal Transport Infrastructure

Climate Change Impacts on Coastal Transport Infrastructure in the Caribbean: Enhancing the Adaptive Capacity of SIDS

6 December, 2017

United Nations Conference on Trade and Development

Regional Workshop - Barbados

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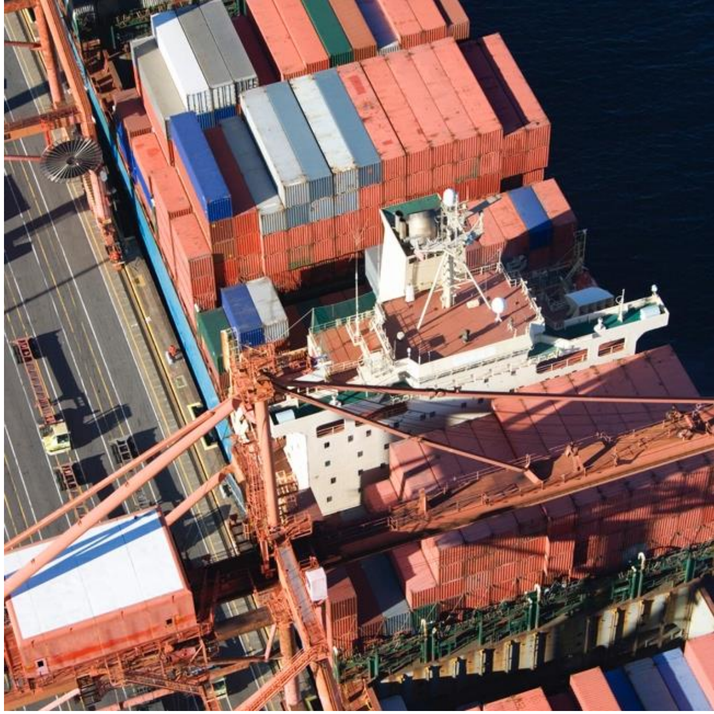
ICF

Agenda

Understanding and Addressing Coastal Transport Infrastructure Climate Change Vulnerability in Caribbean SIDS

- *Why is it important?*
- *Framework overview*
- *Key steps*



Climate Risk and Vulnerability Assessment Framework for Caribbean Coastal Transport Infrastructure

Final Report

Climate Change Impacts on Coastal Transport Infrastructure in the Caribbean: Enhancing the Adaptive Capacity of Small Island Developing States (SIDS)

November 2017

Submitted to:
United Nations Conference on Trade and Development (UNCTAD)
Geneva, Switzerland

Submitted by:
ICF
Washington, DC, USA

Why is it important?

Understanding and addressing coastal transport infrastructure climate change vulnerability in Caribbean SIDS

Caribbean SIDS Rely on Transport Infrastructure

Economy

Tourism

50%

of **GDP**

30%

of **employment**

Supplies

food

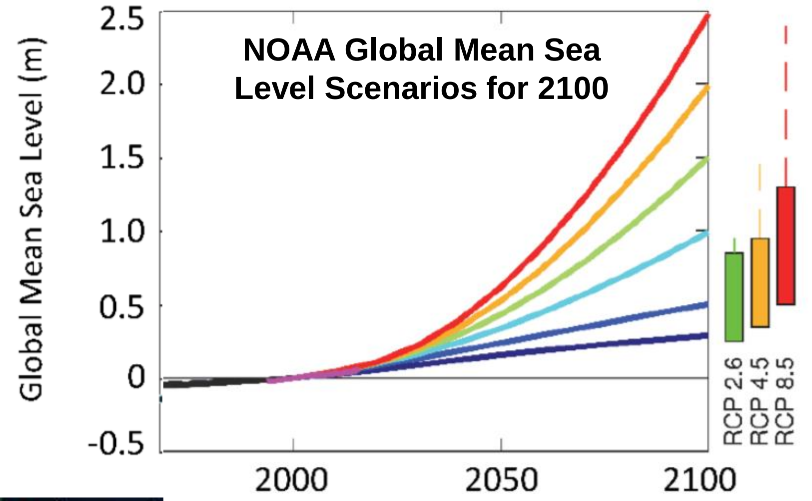
manufactured goods

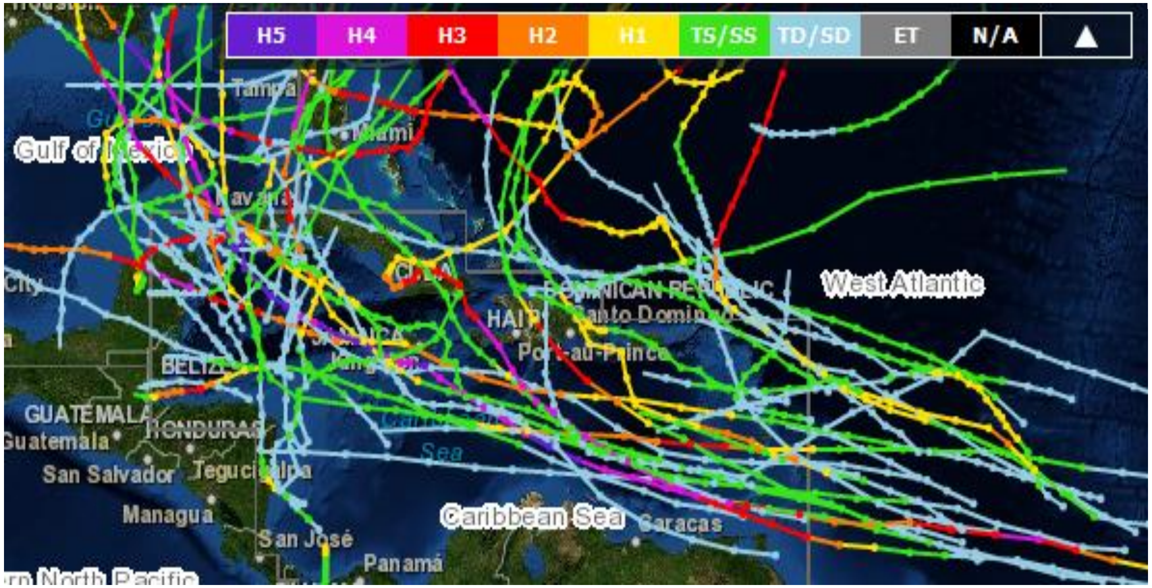
energy

UNCTAD (2014). Small island developing States: Challenges in transport and trade logistics. Trade and Development Board, Trade and Development Commission, Multi-Year Expert Meeting on Transport, Trade Logistics and Trade Facilitation, Third Session. 24-26 November 2014. Available at: http://unctad.org/meetings/en/SessionalDocuments/cimem7d8_en.pd

Coastal Transport Infrastructure Is Highly Exposed to Climate Variability and Change

- **Warmer temperatures**
- **Greater variability in precipitation**
- **Sea level rise**
- **Hurricanes and tropical storms**





Left: National Hurricane Center; Right: NOAA (2017). Global and Regional Sea Level Rise Scenarios for the United States. National Oceanic and Atmospheric Administration, National Ocean Service. Available at: https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf

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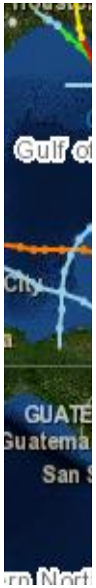

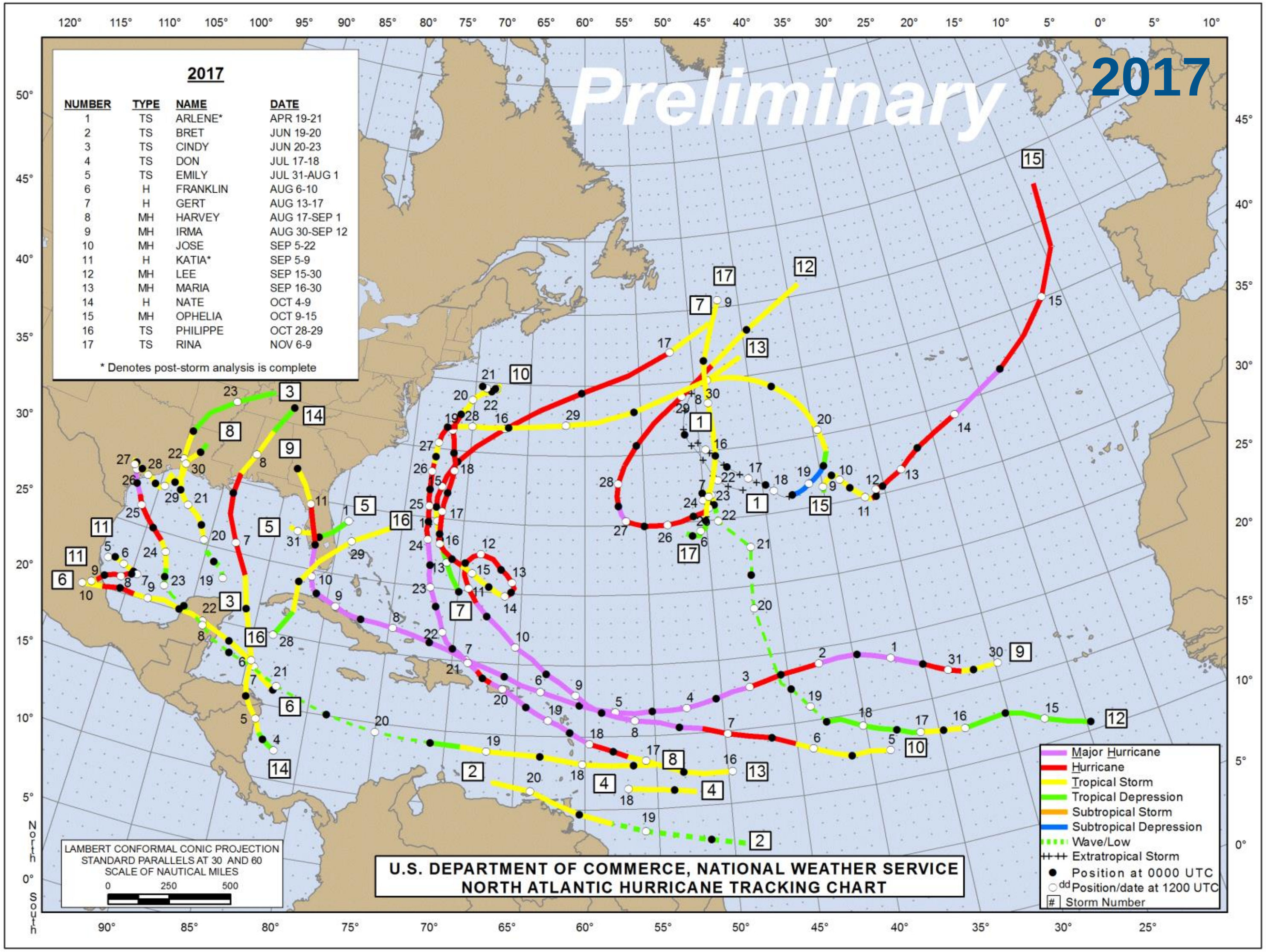

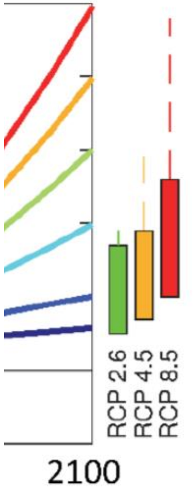

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Coastal Transport Infrastructure Is Highly Sensitive to Climate Variability and Change

Climate change and extreme weather affect transport infrastructure

Historical climate events show the costs to and implications for transport services

- In 2015, Tropical Storm Ericka triggered flash flooding, slope failure, and debris generation in the Commonwealth of Dominica:

Transport Impacts	Economic Impacts
• **60%** of damages were to the transport sector • Floods/landslides damaged **17%** of roads and **6%** of bridges • Both airports were flooded, damaging electrical equipment	• Roads and Bridges Damages: **US$288 million** • Airports Damages: **US$15 million** • Airport/Seaport Transport Sector Damages and Losses: **US$977,654** • Airport Operations Losses: **US$14.5 million** to airlines and **US$80,000** to airports • Airport shutdown impacted the tourism industry

Commonwealth of Dominica (2015). Rapid Damage and Impact Assessment: Tropical Storm Erika – August 27, 2015. Government of the Commonwealth of Dominica. ACP-EU Natural Disaster Risk Reduction Program. September.

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Not to mention Harvey, Matthew, Irma, Maria…

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Reducing Transport Sector Vulnerability in SIDS is Critical

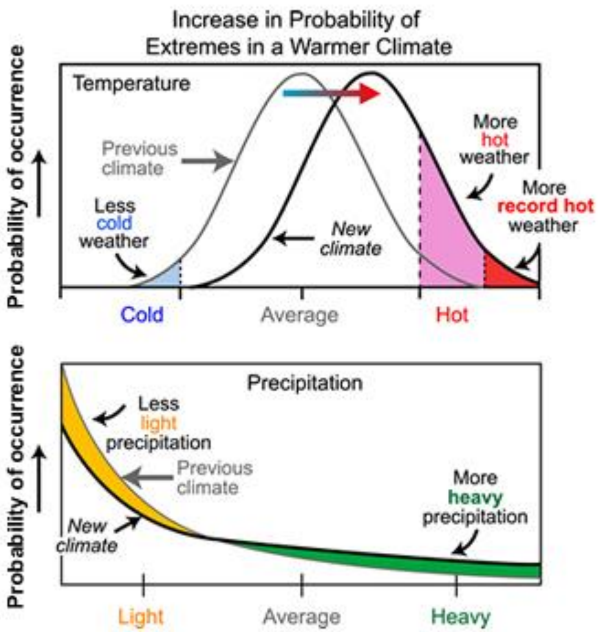
Disruptions to the transport network can have immediate and severe consequences on:

- Economy
- Development goals of the island
- Health and lifestyles of residents

The challenge of maintaining these critical services is already significant and will only increase as the climate changes

Considering Climate Information Can Increase Resilience of Coastal Transport Infrastructure

- **Historically, climate-sensitive investments and decisions assumed "stationarity"**
  - Stationarity = climate conditions remain the same when averaged over a sufficiently long time period
- **However, climate model projections and observations indicate *non-stationarity***



NOAA

Considering Climate Information Can Increase Resilience of Coastal Transport Infrastructure

- **Location and design of new infrastructure**
  - Location
  - Elevation
  - Drainage capacity
  - Material
- **Maintenance practices for existing infrastructure**
  - Pavement repair
  - Culvert maintenance
- **Capital and maintenance investment priorities**
- **Operational adjustments**
  - Construction timing
  - Aircraft takeoff weights
- **Emergency management scenarios**
- **Long-range planning**

Build the economic case for ***proactive*** and ***opportunistic*** resilience investments

Framework Overview

Understanding and addressing coastal transport infrastructure climate change vulnerability in Caribbean SIDS

Framework Goals

Provide a:

- **Structured way for organizations in SIDS to approach climate change adaptation**
- **Flexible, practical approach that uses available data to inform decision-making**
  - Framework outlines a continuum of approaches that can be used depending on data available

Audience: Port and Airport Managers in SIDS

By following the recommendations and steps in the methodology, transport managers can work towards identifying critical assets, current and future vulnerabilities, and potential adaptation strategies for the transport sector.

Key Principles

#1: Keep the end goal in mind

The purpose of assessing vulnerability is to improve decision-making with respect to climate variability and change. If possible, identify specific decisions to inform.

#2: Work within data limitations

Data limitations—be they gaps in data on current assets, historical weather, future climate, or others—need not curtail adaptation efforts.

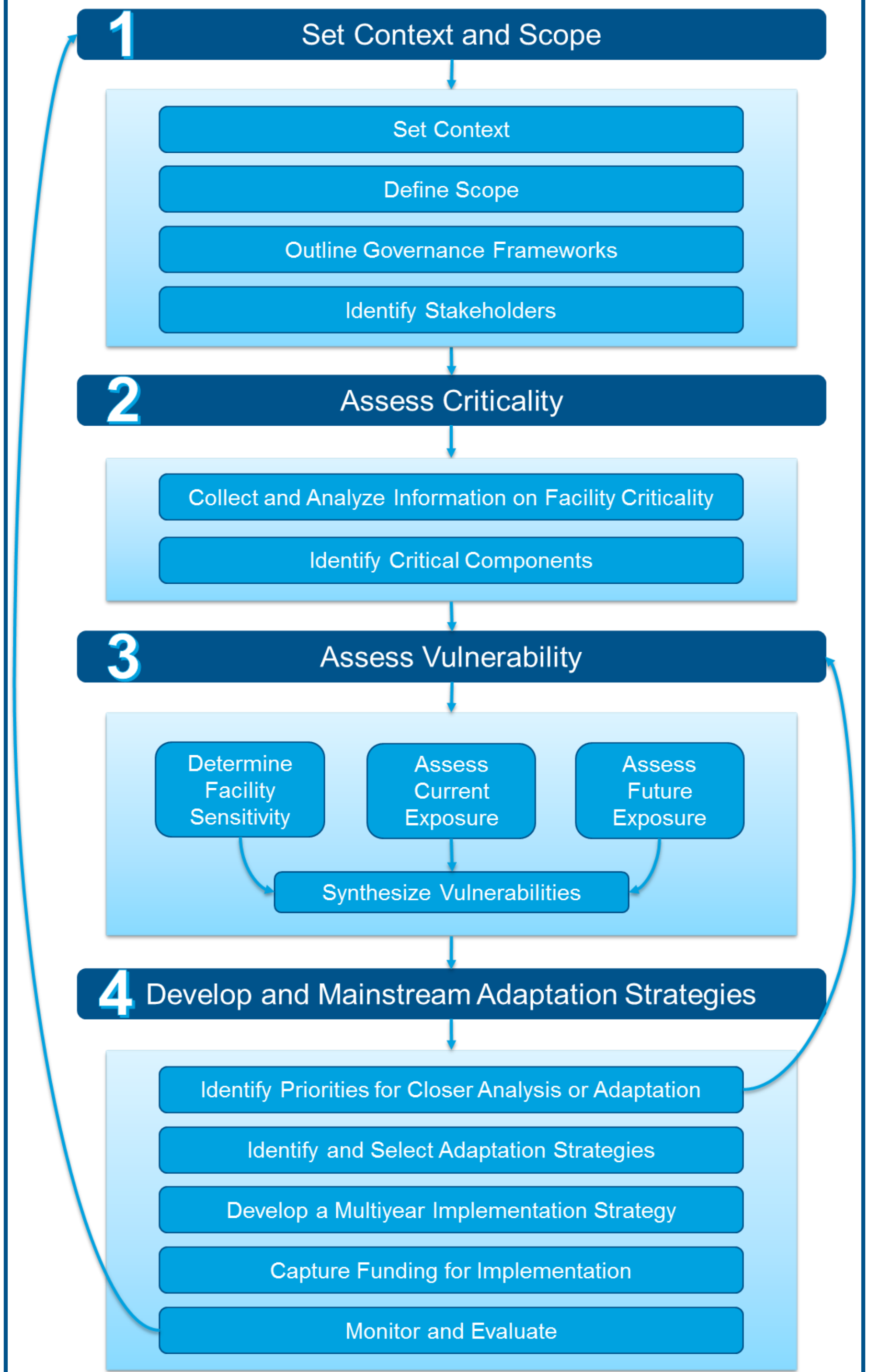
#3: Engage stakeholders

Stakeholder engagement is central to an effective climate change vulnerability assessment process and has multiple benefits, including:

- Help fill data gaps
- Build support for adaptation efforts
- Build capacity

Key Steps

Understanding and addressing coastal transport infrastructure climate change vulnerability in Caribbean SIDS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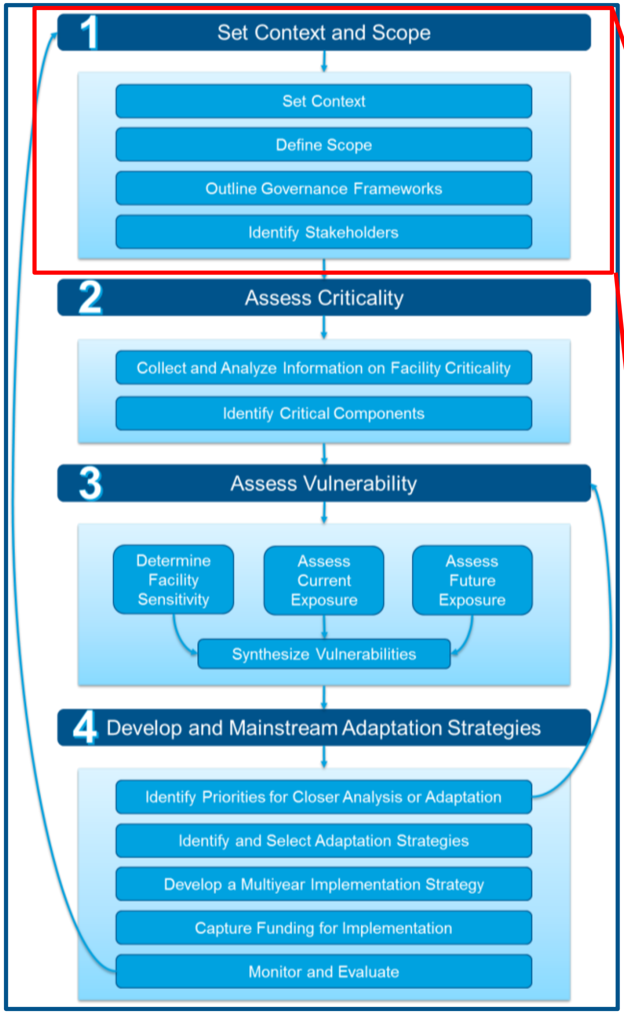
Assess Current Exposure
Assess Future Exposure
Synthesize Vulnerabilities
4 Develop and Mainstream Adaptation Strategies
Identify Priorities for Closer Analysis or Adaptation
Identify and Select Adaptation Strategies
Develop a Multiyear Implementation Strategy
Capture Funding for Implementation
Monitor and Evaluate

Stage 1: Set Context and Scope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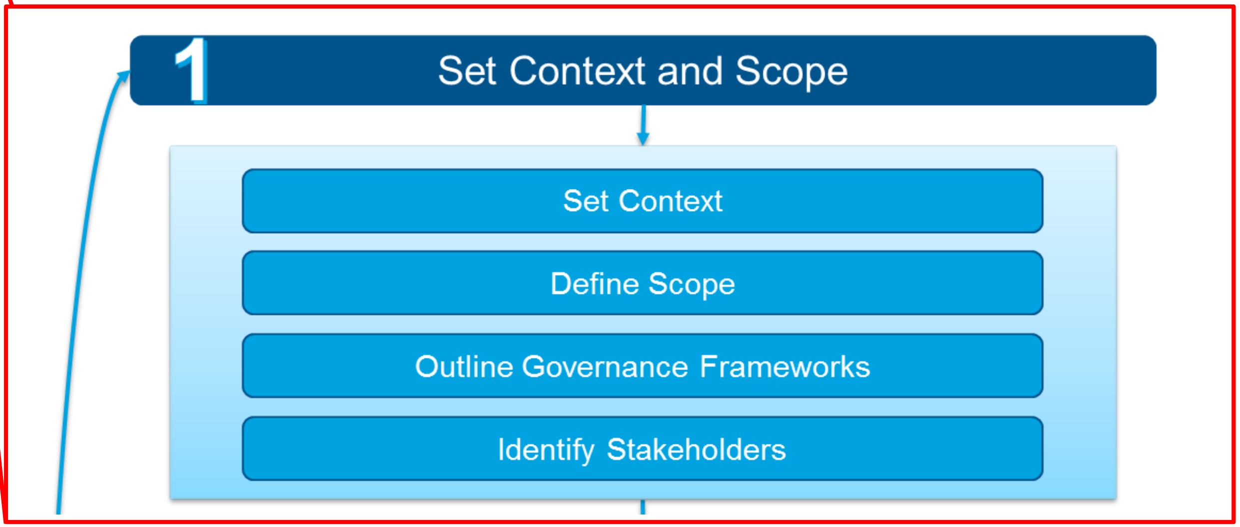
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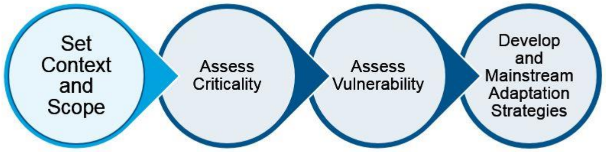
1.1 Set Context



- What are the pre-existing stressors to the transport system?
- How does your adaptation effort fit into the development needs of the country?
- Who are the main agencies and individuals responsible for adaptation?
- What related work has been done so far?
- What decisions are we trying to inform?

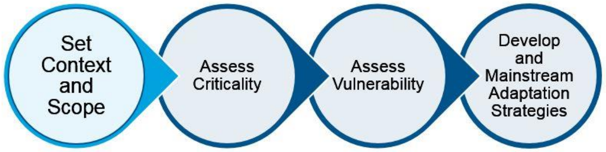
Quick early assessment

Saint Lucia Case Study Example

Existing studies or assessments completed prior to the case study include:

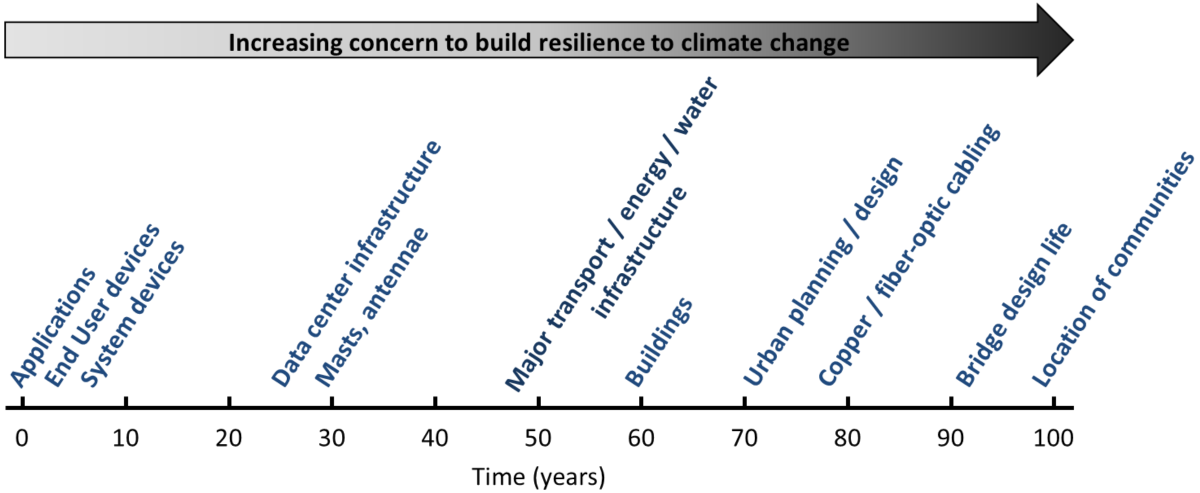
- CARIBSAVE Climate Change Risk Atlas, Climate Change Risk Profile for Saint Lucia
- World Bank Report: Climate Change Adaptation Panning in Latin America and Caribbean Cities, Final Report: Castries, Saint Lucia
- Second National Communication on Climate Change for Saint Lucia

1.2 Define Scope

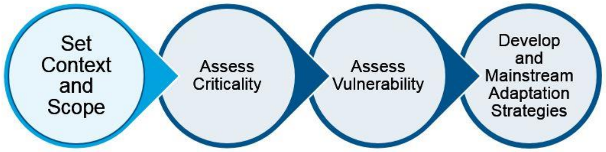


Define the scope of the vulnerability analysis. Decide on:

- **Physical Scope**
  - *What facilities to include? (e.g., focus on critical, likely to be vulnerable)*
- **Temporal Scope**
  - *What is the relevant time period for decision-making? What decisions are you trying to inform?*



- **Climate Scope**
  - *What climate hazards to include?*

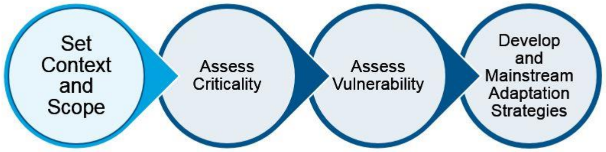


1.2 Define Scope

Jamaica and Saint Lucia Case Study Example

- **Physical scope** – Four specific assets in each country were selected on the basis of their economic and cultural importance to each nation.
- **Temporal Scope** – 2050s, to align with a 35-year long-term planning horizon, which corresponds with expected asset lifetimes and relevant long-term transport plans
- **Climate Scope** – Focused on coastal hazards of sea level rise and tropical storms; secondary emphasis on inland flooding and extreme heat

1.3 Outline Governance Frameworks



Outline the following for the selected transport facilities:

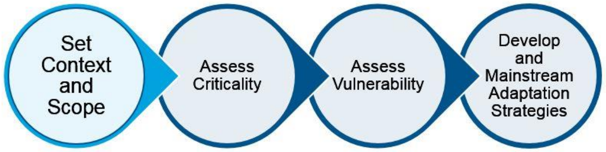
- **Ownership and Operational Framework**
  - What entities own and operate the facilities, and to whom are they responsible?
- **Legislative and Regulatory Framework**
  - What laws or statutes govern the behavior of the facilities?

Jamaica Case Study Example

The study team consulted with stakeholders to identify legislative or regulatory constraints on the airports, such as:

- **Civil Aviation Regulations of 2004:** requirements for operations of aerodromes
- **Protected Areas Policy of the Palisadoes Peninsula:** policy to protect the sensitive ecosystem

1.4 Identify Stakeholders



Develop a list of stakeholders to engage during the assessment process:

- Port and airport managers
- Port and airport authorities (e.g., Maritime Authority, Airport Authority)
- Private sector operators (e.g., ship owners, airline representatives)
- Asset owners and operators of interdependent infrastructure (e.g., energy, water)
- Government agencies overseeing transport, environment, natural development, and disaster preparedness
- Meteorological service
- Local or regional universities
- International or other organizations who have done related work

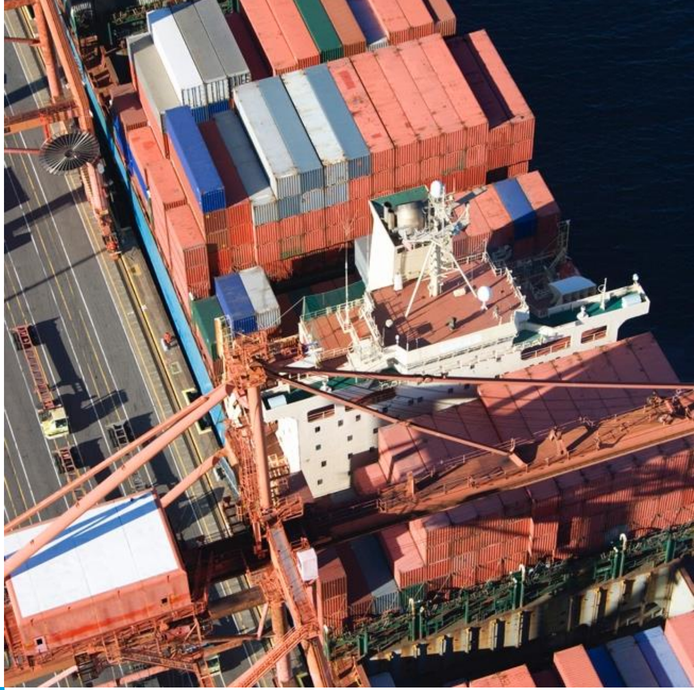
Benefits of engaging stakeholders include:

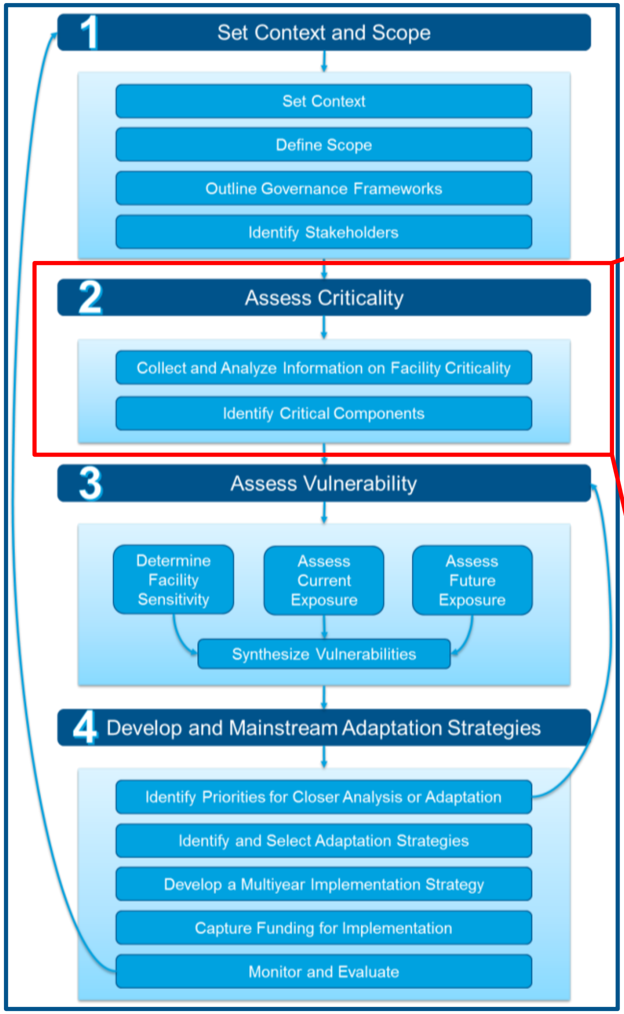
- Help fill data gaps
- Build support for adaptation efforts
- Build capacity to address risks

Tips for Engaging Stakeholders

- Establish regular communication protocols
- Establish clear requests for stakeholders

Stage 2: Assess Criticality

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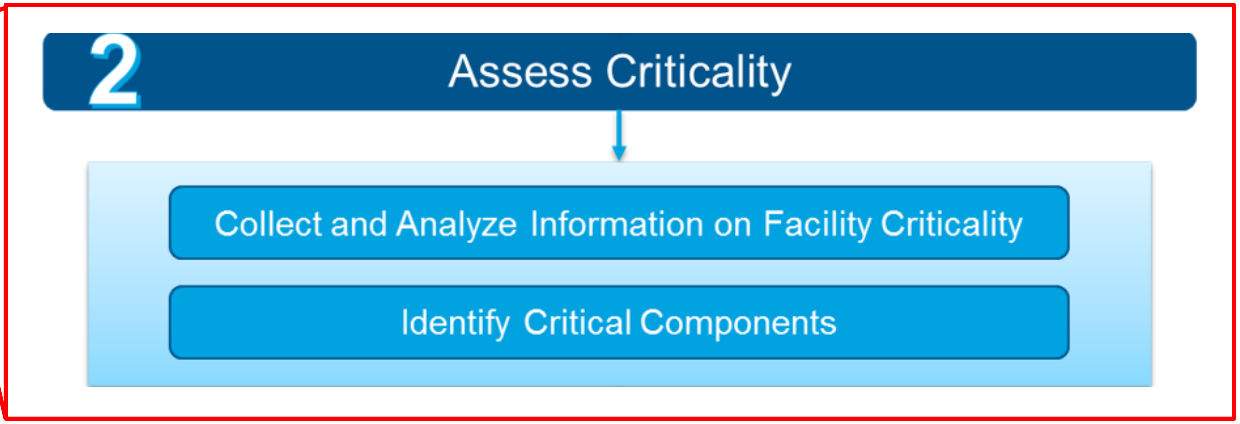
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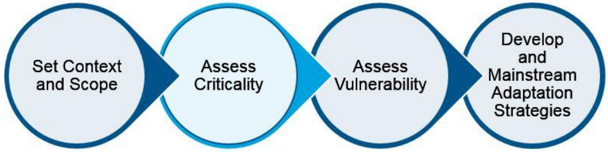
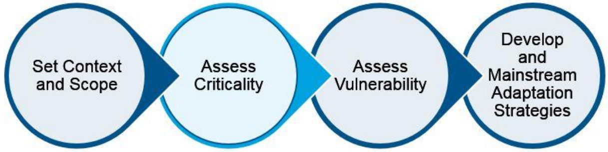


Defining Criticality

Criticality is the overall importance of a facility or component.



2.1 Collect and Analyze Information on Facility Criticality

Facility Operations Data

- Volume of passengers
- Value of cargo transported
- Cost to replace or repair the facility

Interconnectivity Data

- Whether facility provides access to economic centers
- Whether facility is necessary for power or communications systems to operate
- Whether facility is necessary to maintain access to water or food supplies

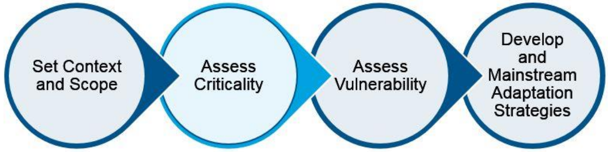
Health/Safety Implications of Facility

- Whether facility is necessary for hurricane evacuation
- Whether facility provides access to hospital or healthcare

Economic Contributions Data

- Contributions of facility to tourism
- Contribution of facility to GDP
- People employed at the facility

Not all data will be available within a reasonable timeframe or level of effort



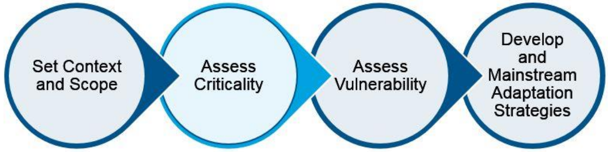
2.1 Collect and Analyze Information on Facility Criticality

Jamaica Case Study Example: Donald Sangster International Airport

The criticality assessment for Donald Sangster International Airport (DSIA) in Jamaica included the following information, which came from the noted sources:

- Of the approximately 1.7 million annual visitors to Jamaica, 72% use DSIA as their primary airport (Source: DSIA airport website and Airports Authority of Jamaica)
- The share of visitors using DSIA as their primary airport has been increasing since the 2008/2009 fiscal year (Source: Airports Authority of Jamaica)
- On average, 3.5 million persons traveled through the airport annually from 2010 to 2015 (Source: arrivals and departures data from DSIA)
- Nearly 65,000 kilos of cargo and mail came through DSIA in 2015 (Source: data from DSIA)
- Because of its location on the north coast, close to hotels and tourist attractions, the airport serves as a critical tourist gateway into the island, without which arriving passengers would have to travel long hours from NMIA to reach their north coast destinations (Source: stakeholder interviews)

Source: Smith Warner, 2017 (Case Study Report – Jamaica)



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Doesn't have to be comprehensive or exclusively quantitative

Goal is to gather available information, make the case for why ensuring operability of the facility is important

- Because of its location on the north coast, close to hotels and tourist attractions, the airport serves as a critical tourist gateway into the island, without which arriving passengers would have to travel long hours from NMIA to reach their north coast destinations (Source: stakeholder interviews)

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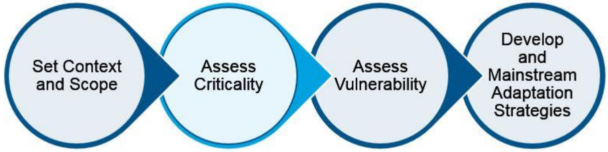
2.2 Identify Critical Components



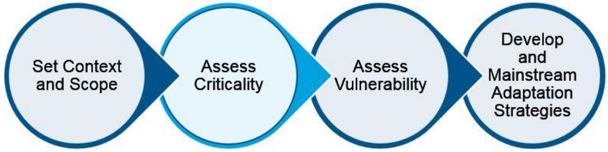
Define the relationship of different components to the functioning of the whole facility

Port components may include:

- Docks
- Navigation channel
- Cranes
- Utilities
- Generators
- Buildings and warehouses
- Access roads
- Personnel
- Drainage system

Airport components may include:

- Runways, taxiways, and aprons
- Terminals and other buildings
- Air traffic control
- Communication systems
- Access roads and parking lot
- Utilities
- Personnel
- Navigational aids
- Weather instrumentation
- Drainage system



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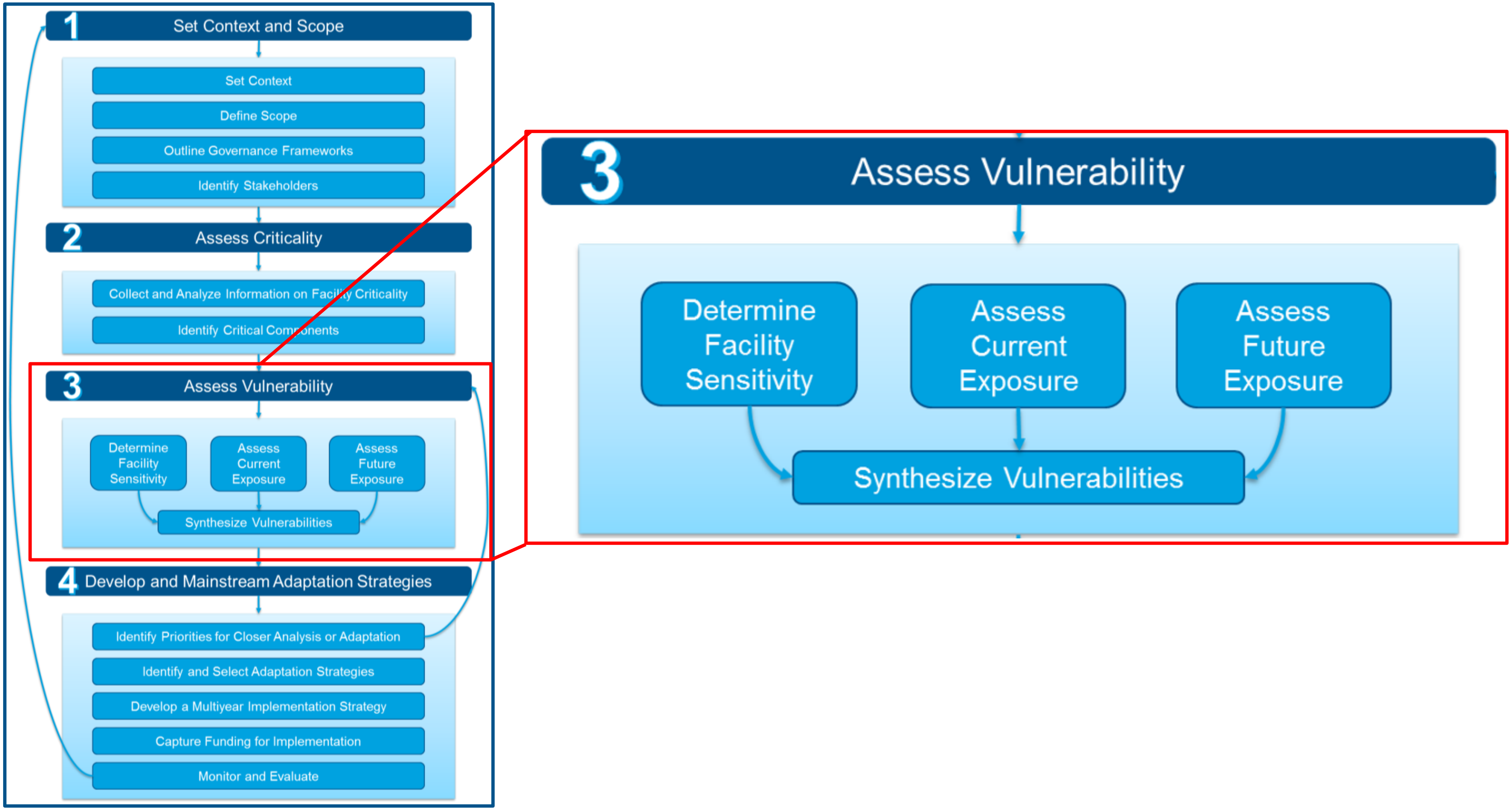
- Runways, taxiways, and aprons
- Terminals and other buildings
- Navigational aids
- Weather instrumentation
- Drainage system

Jamaica Case Study Example

Critical components at Donald Sangster International Airport:

- **Runway:** This is the sole runway, therefore its operability is directly connected to the operability of the airport
- **Access Road:** The airport's access road is the only way of accessing the airport

Stage 3: Assess Vulnerability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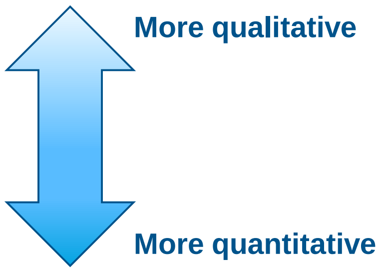
Choosing Between Vulnerability Assessment Methods

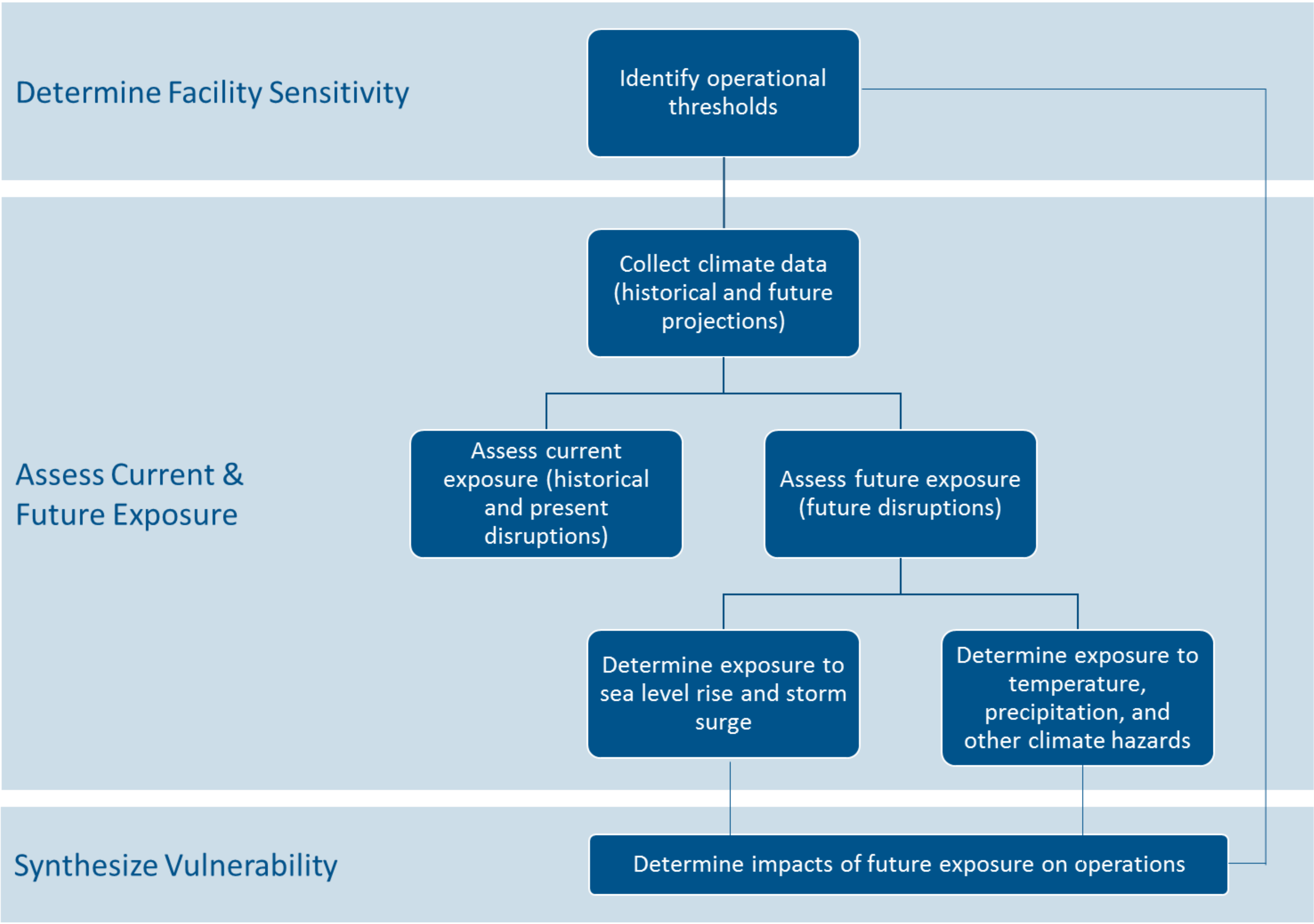
	Advantages	Disadvantages
Qualitative	• Easily understandable • Useful for prioritizing action • Relatively low cost to prepare	• Does not communicate complex or less obvious aspects of vulnerability well • May be open to interpretation and therefore contain uncertainties • Does not directly imply the nature of adaptations
Quantitative	• Helpful for informing cost-benefit analyses of adaptation options • Takes advantage of available data • Can communicate complex or less obvious aspects of vulnerability	• Can be time and resource intensive • Can be long, technical, hard to follow and thus not used effectively if sufficient outreach is not conducted • May not have all desired data

Determine the approach based on the intended use of the assessment:

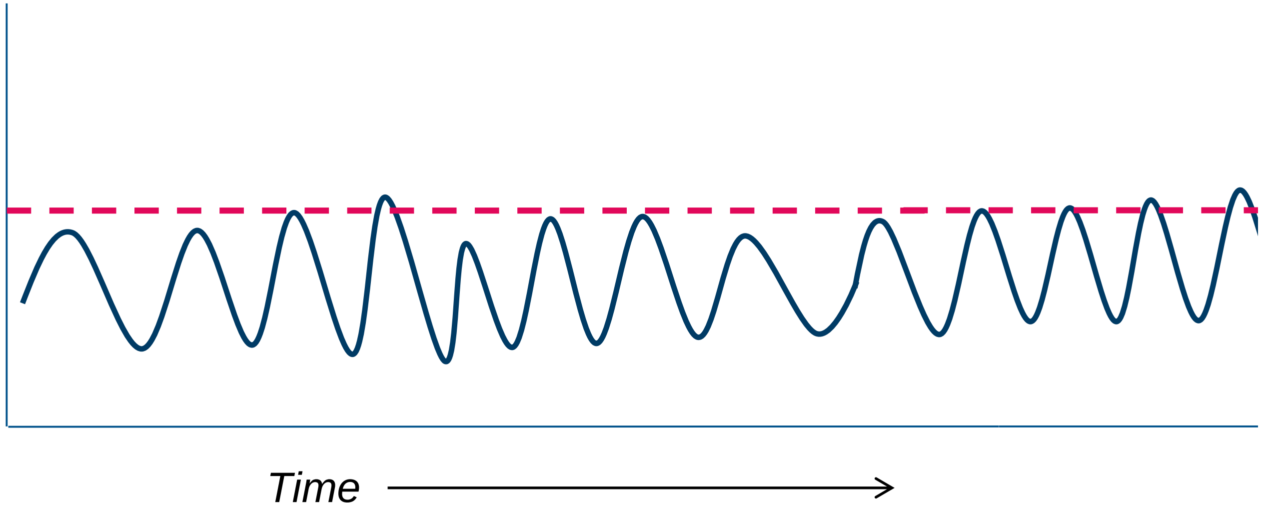
- To identify priorities for more detailed study
- To inform land use planning decisions
- To inform long-term facility plans
- To inform infrastructure investment decisions
- To build the economic case for adaptation
- To design adaptation strategies



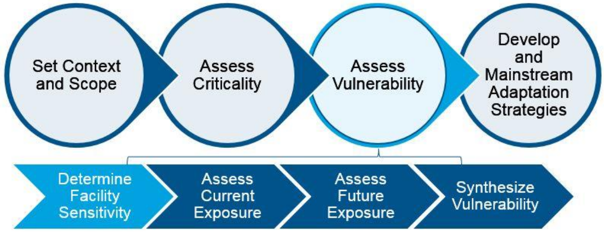
Overall Vulnerability Assessment Process



Conceptual Example – Climate Change Impacts Over Time



3.1 Determine Facility Sensitivity



Sensitivity is the degree to which the facility is likely to experience direct physical damage or operational disruptions

General Sensitivity Relationships

Facility Component

Climate Hazard

Climate Hazard	Docks	Crane Operations	Access	Other
Sea Level Rise	Higher sea levels can increase the risk of chronic flooding and lead to permanent inundation of dock facilities, making a port inoperable.	Not sensitive.	Sea level rise could affect port access routes.	Not applicable.
Tropical Storms/ Hurricanes/ Storm Surge	Storm surge can damage marine port facilities, causing delays in shipping and transport. For example, Hurricane Ivan in Grenada damaged the main port terminal and prevented normal operations for three weeks (OECS, 2004).	Not sensitive.	Tropical storms can cause roadway damage and debris movement, blocking access to the port for staff and ground transport.	Port operations may be halted for the duration of the storm. Floodwaters or winds can also transport debris that must be removed before operations can resume.
Wind	Not sensitive.	Cranes cannot be used above certain wind speeds. Inoperable cranes can cause delays in shipping.	Wind can blow over road signs and stir up dust from unpaved roads. Downed signs and swirling dust can create confusing and dangerous travel conditions.	High wind speeds could create hazardous working conditions for port staff. Winds can also transport debris that must be removed before operations can resume.
Extreme Heat	Not sensitive.	Not sensitive.	Extreme heat can result in asphalt pavement softening or rutting, or cracks in concrete pavement.	Extreme heat can create hazardous working conditions for port staff and could deteriorate paved terminal areas. Extreme heat can also raise energy costs for cooling.
Heavy Precipitation /Flooding	Heavy rain can reduce visibility and create flooding, causing damage to port structures and equipment and delaying shipping and transport.	Flooding can cause damage to crane equipment, making it inoperable and halting or slowing	Heavy rain can overwhelm existing draining systems and cause flooding, creating pavement and embankment failure, erosion, debris movement, and	Flood waters can transport debris that must be removed before operations can resume. For example, this has occurred at

Establish Operational Thresholds

What is an operational threshold?

Level of weather conditions at which a facility or piece of infrastructure experiences disruption or damage

- **In what conditions is the facility likely to experience damage or disruption?**
  - Does the facility have official operational manuals that specify thresholds?
  - What conditions is it designed to withstand?
  - In which conditions has it been unable to operate in the past?
  - In which conditions has it been damaged in the past?

Why establish thresholds?

- Helps focus search for and analysis of climate data (historical and projected)
- Process for sharing and documenting critical institutional knowledge
- Informs monitoring and evaluation over time
- Helps develop practical estimates of risks over time

Establish Operational Thresholds

Spectrum of Thresholds

- Heavy precipitation reduces visibility
- Waves overtop dock
- Very hot days threaten perishable goods
- Standing water on runway

- Cranes can’t operate at wind speeds > 25 m/s
- Pavement designed to tolerate maximum seven-day temperature of 41.4°C (106.4°F)

Examples

Identifying Thresholds: Aircraft Runway Length Requirements and Temperature

Individual aircraft manufacturers set minimum runway length requirements related to temperature:

- Identify the type of aircraft that use the airport or might use it in the future.
- For major aircraft categories, find airport specifications on the manufacturer's website.
- Read the tables for the elevation of your airport to determine how runway length requirements change with temperature.

Takeoff Runway Length Requirements by Temperature and Aircraft[1]

	Mean maximum daily temperature of the warmest month				
Boeing:	Standard Day: 15°C	30°C	37.2°C	40°C	50°C
737-600	2,134 m	2,316 m	3,048 m	n/a	3,505 m
737-700/-700W	2,804 m	3,048	3,810 m	n/a	4,572 m
737-800/-800W/BBJ2	2,377 m	2,469 m	n/a	3,078 m	4,572 m

Identifying Thresholds: Sea Level Rise

To obtain an indication of how much "room" the facility has to accommodate sea level rise:

- Measure the vertical distance between immediate coastal infrastructure (such as docks) and mean higher-high water levels

[1]Boeing (2013). 737 Airplane Characteristics for Airport Planning. Boeing Commercial Airplanes. D6-58325-6, September 2013. Available at: http://www.boeing.com/assets/pdf/commercial/airports/acaps/737.pdf

Examples

Identifying Thresholds: Aircraft Runway Length Requirements and Temperature

Individual aircraft manufacturer … ated to temperature:

- Identify the type of aircraft th…
- For major aircraft categories, … 's website.
- Read the tables for the eleva… ngth requirements change with temperature.

Takeoff Runwa… Aircraft[1]

			warmest month	
Boeing:	Sta…		40°C	50°C
737-600			n/a	3,505 m
737-700/-700W			n/a	4,572 m
737-800/-800W/BBJ2			3,078 m	4,572 m

This afternoon's activity will focus on identifying thresholds

To obtain an indication of … date sea level rise:

- Measure the vertical distance between immediate coastal infrastructure (such as docks) and mean higher-high water levels

[1]Boeing (2013). 737 Airplane Characteristics for Airport Planning. Boeing Commercial Airplanes. D6-58325-6, September 2013. Available at: http://www.boeing.com/assets/pdf/commercial/airports/acaps/737.pdf

Determine Impact of Crossing Thresholds

- **Direct impacts to facilities**
  - Duration of disruption
  - Cost of operational shutdown
  - Cost of repairs
- **Indirect impacts and Losses**
  - Lost economic activity
  - Disrupted industries (e.g., agriculture, energy, tourism)
  - Lost ecosystem services

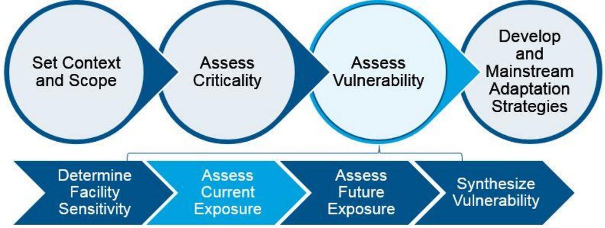
Quantify what's possible, and also list what's not possible to quantify (e.g., indirect losses)

Spectrum of Impacts

- Insignificant
- Minor
- Moderate
- Major
- Extreme

- Rainfall > 200 mm in 24 hours causes closure for 3 days
- Each hour of closure costs $10,000
- Water elevations > 1 m would cause $2,000,000 in damage

3.2 Assess Current Exposure



How frequently the relevant sensitivity thresholds have been exceeded in the past?

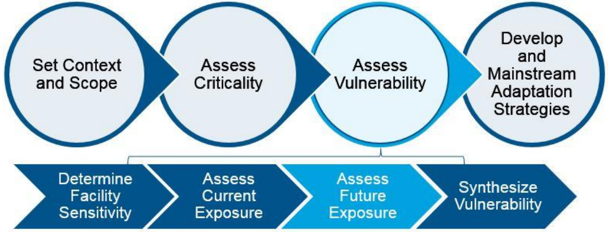
- Meteorological data
- Anecdotal evidence/qualitative ratings
- Climate model hindcasts

Saint Lucia Case Study Example

The study team used climate model hindcasts to estimate how frequently the following thresholds were exceeded from 1970-1999:

- **Heat Index over 30.8°C with relative humidity of 80%**: 0.6 days per year
- **Days with temperature > 31°C**: 0.33 days per year
- **Rainfall > 20 mm**: 45.9 days per year

3.3 Assess Future Exposure



Estimate how climate change could affect facilities in the future

Two main types of climate data:

- Temperature, precipitation, and other hazards
- Sea level rise and storm surge

Presentation this afternoon will elaborate on gathering climate data to determine exposure to temperature and precipitation using a variety of methods

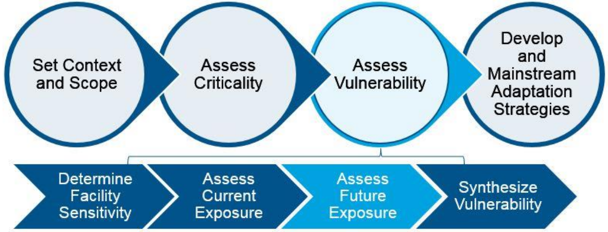
Determine Exposure to Sea Level Rise and Storm Surge

Determine how much sea level rise may be expected

Determine which locations might be affected using one of the following approaches:

- **Review of pre-existing inundation maps and data**
- **Inundation mapping**
- **Qualitative assessment**

3.3 Assess Future Exposure



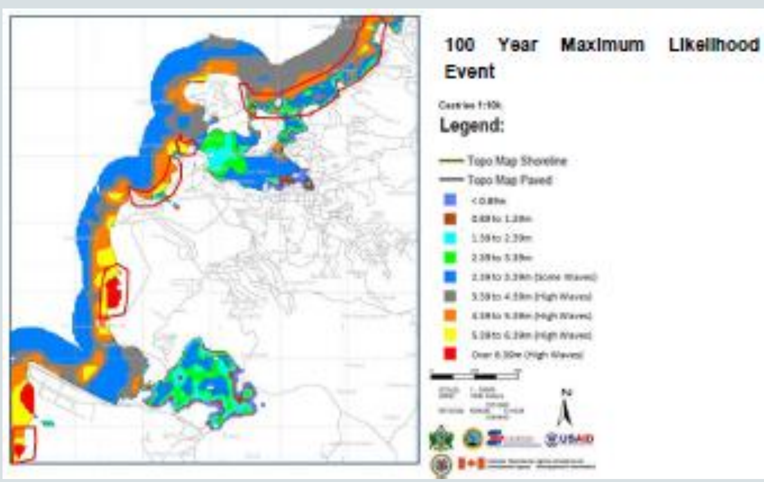
Determine which locations might be affected by sea level rise:

Option 1

Pre-existing Inundation Maps and Data

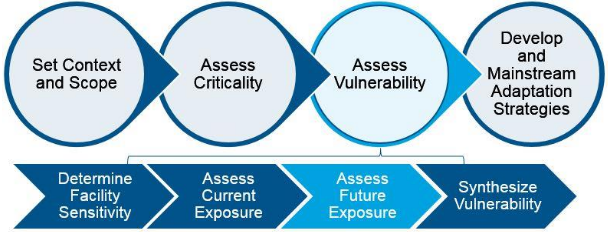
Geospatial data and models can help identify the locations most likely to be inundated under different sea level rise or storm surge scenarios

For example, see below map of Castries 100-year coastal flooding event with sea level rise[1]



[1]ICF GHK (2014). Climate Change Adaptation Planning in Latin American and Caribbean Cities. Final Report: Castries, Saint Lucia.

3.3 Assess Future Exposure



Determine which locations might be affected by sea level rise:

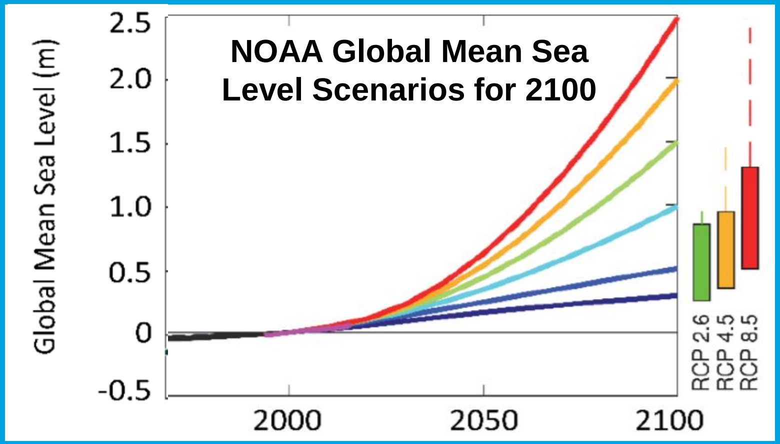
Option 2

Develop Inundation Maps

Use the following to do your own mapping of potential inundation:

- **Sea level rise scenarios**
- **Current tidal surface elevation**
- **Digital elevation model** of the study locations – higher resolution the better
    - LiDAR data limited in the Caribbean

How much SLR to plan for?

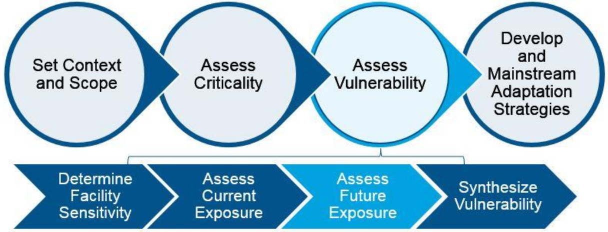


May vary based on **risk tolerance** for the decision and **lifetime of project**.

Lower risk tolerance and higher lifetime = higher SLR scenario

Map literature-supported levels of sea level rise on top of mean higher high water

3.3 Assess Future Exposure



Determine which locations might be affected by sea level rise:

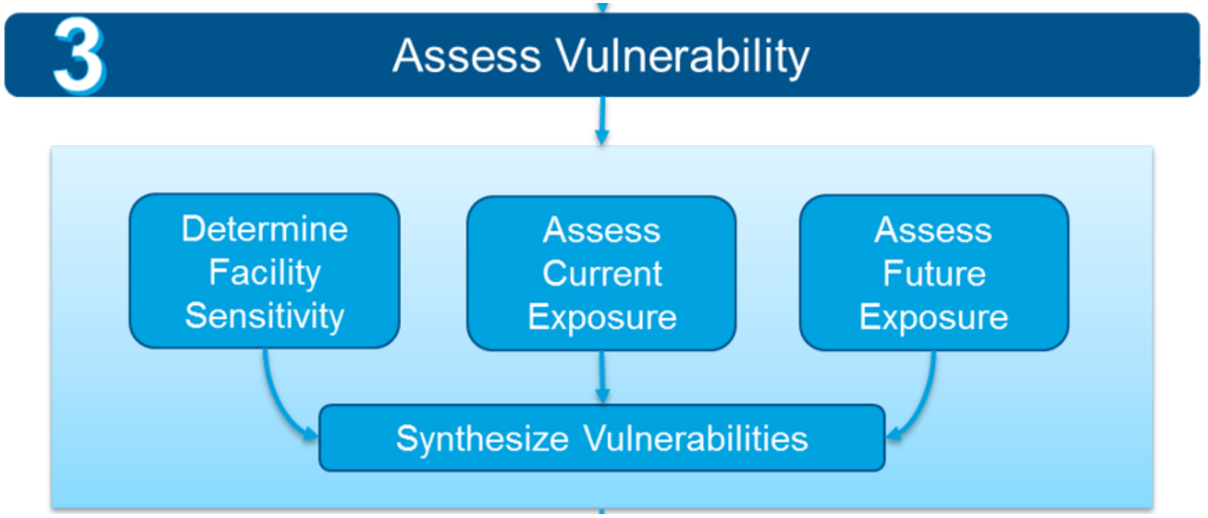
Option 3

Qualitative Assessment

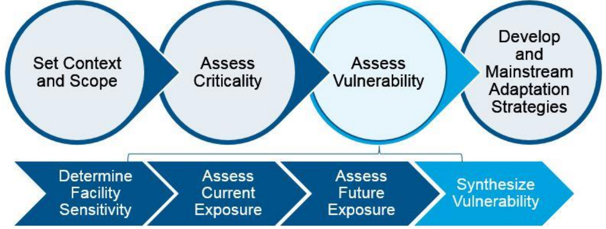
Estimate potential flood risk areas using **best available information** and **professional judgment**.

For example, meet with stakeholders to identify low-lying areas and places that historically flood during high tide events.

Photo credit: Cassandra Bhat, ICF


3
Assess Vulnerability
Determine Facility Sensitivity
Assess Current Exposure
Assess Future Exposure
Synthesize Vulnerabilities

3.4 Synthesize Vulnerabilities



Quantitative Example

Identify how often operational thresholds are expected to be exceeded in the future and quantify impacts

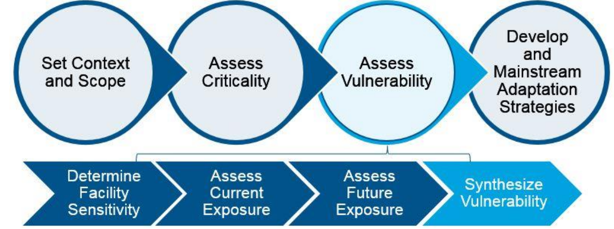
Operational Threshold	Precipitation > 20 mm per day
Impact Description	Cranes at the port are unable to operate
Quantified Impacts	6 hours / $60,000
Current Frequency	2 days/year
Future Frequency	4 days/year
Current Risk	12 hours / $120,000
Future Risk	24 hours / $240,000

Qualitative Example

Combine the information on criticality, sensitivity, current vulnerability, and exposure to identify the potential vulnerabilities using a vulnerability matrix, risk matrix (below), qualitative ranking, or vulnerability profile

		Consequence of Hazard				
		Insignificant	**Minor**	**Moderate**	**Major**	**Extreme**
Likelihood of Hazard	**Almost Certain**	Medium	High	Very High	Very High	Very High
	Likely	Medium	Medium	High	Very High	Very High
	Possible	Low	Medium	Medium	High	Very High
	Unlikely	Low	Low	Medium	Medium	High
	Rare	Low	Low	Low	Medium	Medium

3.4 Synthesize Vulnerabilities



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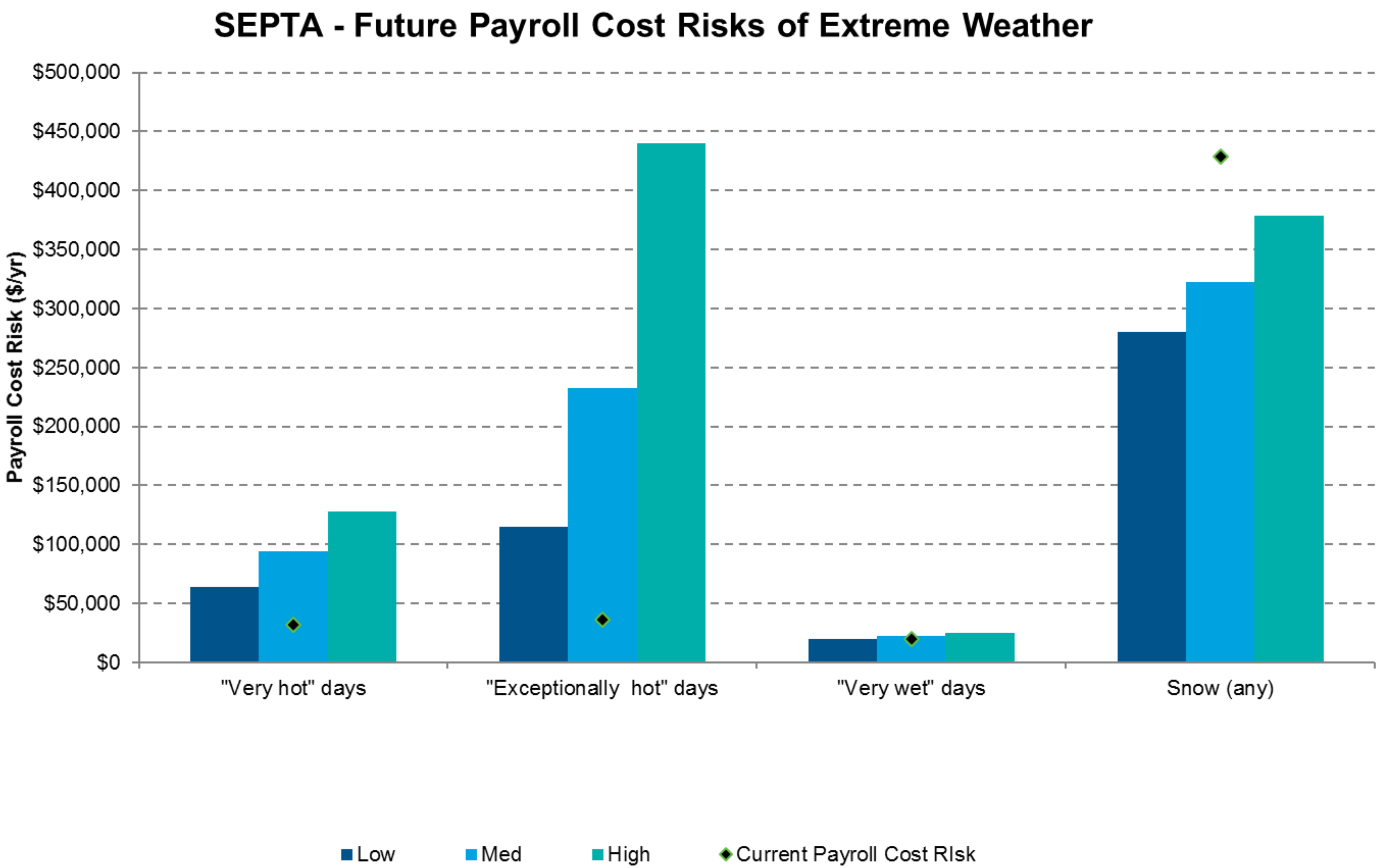
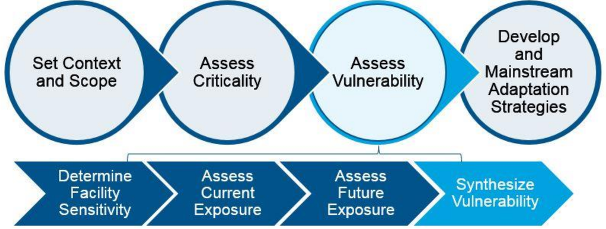
	Unlikely	Low	Low	Medium	Medium	High
	Rare	Low	Low	Low	Medium	Medium

Quantitative Example in Practice



3.4 Synthesize Vulnerabilities



Quantitative Example

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Qualitative Example

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Likelihood of Hazard	**Almost Certain**	Medium	High	Very High	Very High	Very High
	Likely	Medium	Medium	High	Very High	Very High
	Possible	Low	Medium	Medium	High	Very High
	Unlikely	Low	Low	Medium	Medium	High
	Rare	Low	Low	Low	Medium	Medium

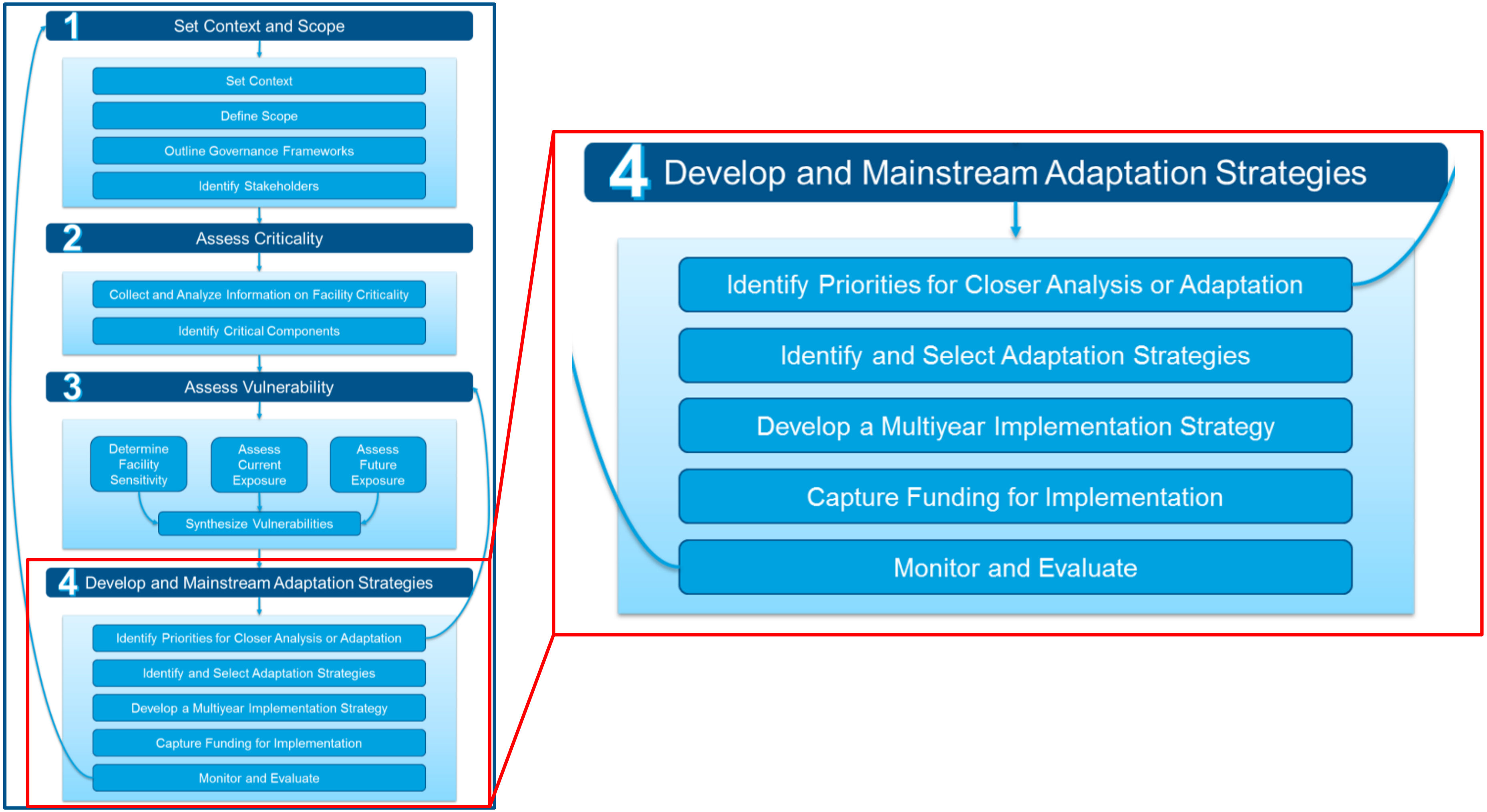
Qualitative Example in Practice

Avatiu Port, Rarotonga, Cook Islands

CLIMATE EVENT	EXISTING RISK[*1]			YOUR UNDERSTANDING OF FUTURE CLIMATE RISK		
	Consequence (Impact)	Likelihood	Risk	Consequence (Impact)	Likelihood	
				Higher *Lower* *No Change*	*More* *Less* *No Change*	*Comments*
High Wind (e.g crane safety, navigability)	Moderate	Likely	High	Higher	More	Tug boat most vulnerable. High wind - just shut down services/stay in port.
High Rainfall (e.g flash flooding in surrounding districts or site drainage issues)	Minor	Possible	Medium	Same	More	
High Waves (e.g navigability, sea supply chain, breakwaters etc.)	Moderate	Likely	High	Higher	More	
Temperature	Minor	Almost Certain	High	Higher	More	
Sea Level Rise	Moderate	Almost Certain	Very High	Higher	More	
Tropical Cyclone (e.g combination of high winds, waves and storm surge)	Possible	Extreme	Very High	Higher	More	Years of cyclones. Lines boat and crane can be done within a day if conditions are ok. Tug can be brought in later if a bigger boat required. Once tug back in water takes about 4 hours to ballast the tug. NB in regards to 2005 cyclone- opened straight away and mess had to be cleaned up. Roofing was an issue that needed to be cleaned up and rocks removed. 1987 cyclone - was like a 100 year cyclone, wiped everything on seaward part of wharf pushed into the harbour (none of it had been removed). Previous failings - all cargo needs to be taken off-site.

Adapted from Cox R, Panayotou K, Cornwel R, and Blacka M (2013). Climate Risk Assessment for Ports and Connected Infrastructure: Case Study Avatiu Port, Rarotonga, Cook Islands. Water Research Laboratory (WRL) Technical Report 2013/15. October 2013. Available at: http://www.mfem.gov.ck/images/documents/DCD_Docs/Climate_Change/Coastal_Adaptation/WRL_TR2013_15_Final.pdf

Stage 4: Develop and Mainstream Adaptation Strategies


1 Set Context and Scope
Set Context
Define Scope
Outline Governance Frameworks
Identify Stakeholders
2 Assess Criticality
Collect and Analyze Information on Facility Criticality
Identify Critical Components
3 Assess Vulnerability
Determine Facility Sensitivity
Assess Current Exposure
Assess Future Exposure
Synthesize Vulnerabilities
4 Develop and Mainstream Adaptation Strategies
Identify Priorities for Closer Analysis or Adaptation
Identify and Select Adaptation Strategies
Develop a Multiyear Implementation Strategy
Capture Funding for Implementation
Monitor and Evaluate
4 Develop and Mainstream Adaptation Strategies
Identify Priorities for Closer Analysis or Adaptation
Identify and Select Adaptation Strategies
Develop a Multiyear Implementation Strategy
Capture Funding for Implementation
Monitor and Evaluate

What is Adaptation?

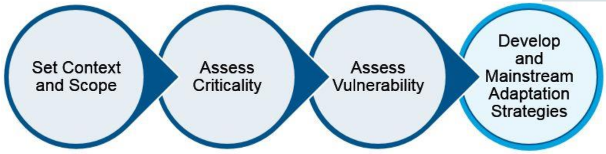
***Adaptation*:**

Process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities (IPCC)

Adaptation enhances resilience:

Capability to anticipate, prepare for, respond to, and recover from significant stressors with minimum damage

After a major flood, a pumping station in Santo Domingo was raised by the height of a person to avoid future impacts. (Source: ICF)

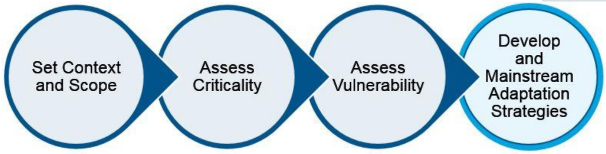


4.1 Identify Priorities for Closer Analysis or Adaptation

What are the adaptation priorities? (from vulnerability assessment)

Where do you need further information in order to act?

- Further analysis is useful where the costs of adaptation could be high
- Some adaptation measures can be justified from economic, social, and environmental perspectives regardless of the future changes in climate



4.2 Identify and Select Adaptation Strategies

Strategic planning & policy

- Airport/port strategic plan
- Airport/port master plan
- Land-use planning
- Utility planning

Infrastructure development

- Infrastructure siting, design specifications
- Construction budget and schedule

Program management

- Staff training

Operations & maintenance

- Maintenance schedules
- Annual maintenance budget

Emergency management & disaster risk reduction

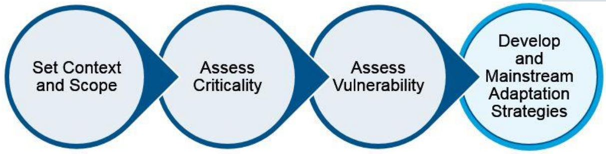
- Worst case scenarios
- Proactive mitigation

Adaptation can apply to all levels of decision-making

Adaptation options may not be technologically innovative or climate change-specific; many will involve well-established technologies and management approaches applied wisely to address climate risks.

Key Principles

- “Mainstream” adaptation activities
- Define “success”
- Promote adaptive management
- Select low-regret options
- Select “win-win” options
- Favor reversible and flexible options
- Add “safety margins”
- Promote soft adaptation strategies
- Pre-plan for disaster response
- Increase system flexibility
- Use existing disaster risk reduction efforts to support adaptation



4.2 Identify and Select Adaptation Strategies

- **Types of adaptation strategies**

Process Enhancements

- Provide warnings of extreme temperatures to minimize heat stress risks for workers
- Plan for increased debris removal operations
- Adopt a post-disaster reconstruction plan
- Improve transition planning to ensure staff with more experience transfer their institutional knowledge to new staff
- Track data on impacts over time

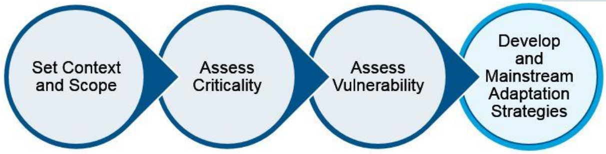
Ecosystem Enhancements

- Support sustainable land use and development to avoid slope destabilization and landslides
- Plant vegetation around airport buildings to lower surface/air temperatures, and manage stormwater runoff
- Support beach nourishment, coral reef protection, and nearshore seagrasses to reduce coastal flood risk

Engineering Enhancements

- Improve cranes’ braking systems and wind speed prediction systems
- Elevate structures
- Harden shorelines
- Protect exposed utilities
- Increase drainage capacity
- Install building energy efficiency improvements

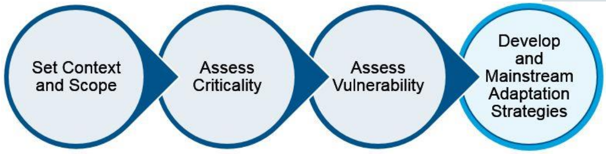
Consider a range of adaptation options – one measure will rarely do it all



4.2 Identify and Select Adaptation Strategies

Identify adaptation strategies through:

- Collective brainstorming with system and asset managers as well as relevant stakeholders to collaboratively brainstorm adaptation strategies
- Exploring relevant adaptation strategies proposed for or implemented locally or elsewhere
- Seeking guidance from relevant experts from both inside and outside of the refuge

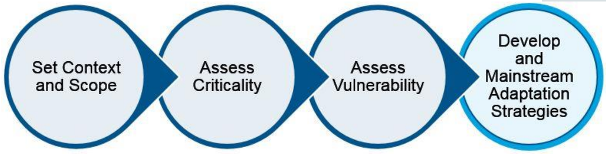


4.2 Identify and Select Adaptation Strategies: Example

Port of Manzanillo[1]

- A recent study analyzed the climate risks and provided an adaptation plan for the port.
- The recommended actions work within the context of planning at the Federal, State, and Municipal levels and provide a range of strategy types.
- The plan includes:
  - **Measures that build adaptive capacity** (Update plans for evacuation/business continuity during extreme events)
  - **Operational Measures** (Improve procedures for handling materials under adverse conditions)
  - **Engineered/hard structural solutions** (Upgrade sediment traps)
  - **Ecosystem based measures** (Continue efforts to preserve mangrove areas for natural flood defenses)
  - **Hybrid measures** (Adjust port facilities in response to changing customer demands and trade flows)

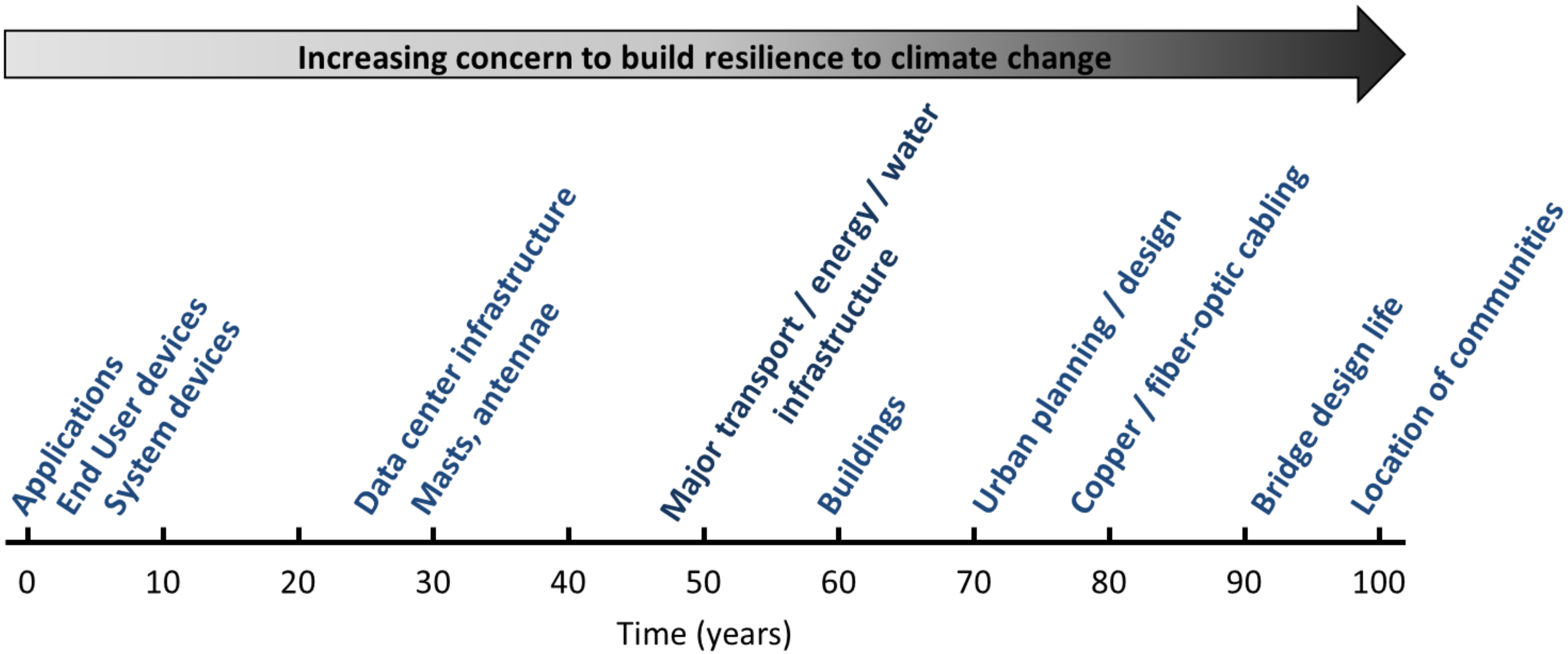
[1] IDB (2015). Port of Manzanillo: Climate Risk Management (Final Report). September, 2015. Available at: https://publications.iadb.org/handle/11319/7649



4.3 Develop a Multiyear Implementation Strategy

Consider Timing

- Near-term adaptation measures should
  - Effectively address immediate vulnerabilities,
  - Address highest priority impacts
  - Be feasible and affordable to implement quickly



Example of Phased Adaptation

Incorporate SLR and other climate changes into design of new infrastructure opportunistically

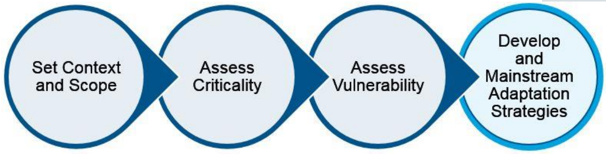
Identify data and research needs

Track frequency of weather-related disruptions over time

Incorporate CV&C considerations into long-range plans, establish policy to adapt

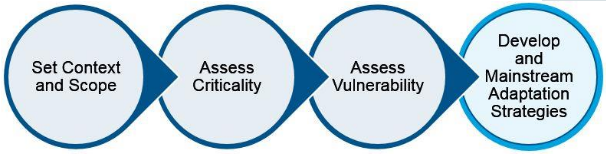
Establish a pre-disaster plan to facilitate climate-resilient recovery

Implement asset-specific adaptation strategies (e.g., protection, retrofits)



Example Process

- **Identify adaptation options**
- **Check that you've identified a wide range of options**
  - Include a variety of types of adaptation measures?
  - Include some that can be implemented quickly and some that will take time?
- **Sort the adaptation measures into:**
  - Near-term / simple to implement
  - Long-term / complex to implement
- **Simplify complex measures**
  - Split into multiple measures or scale back?
  - Phase through incremental steps?
- **Identify near-term adaptation strategies**
- **Develop phase adaptation plan**



4.4 Capture Funding for Implementation

A variety of entities provide funding for climate change adaptation efforts

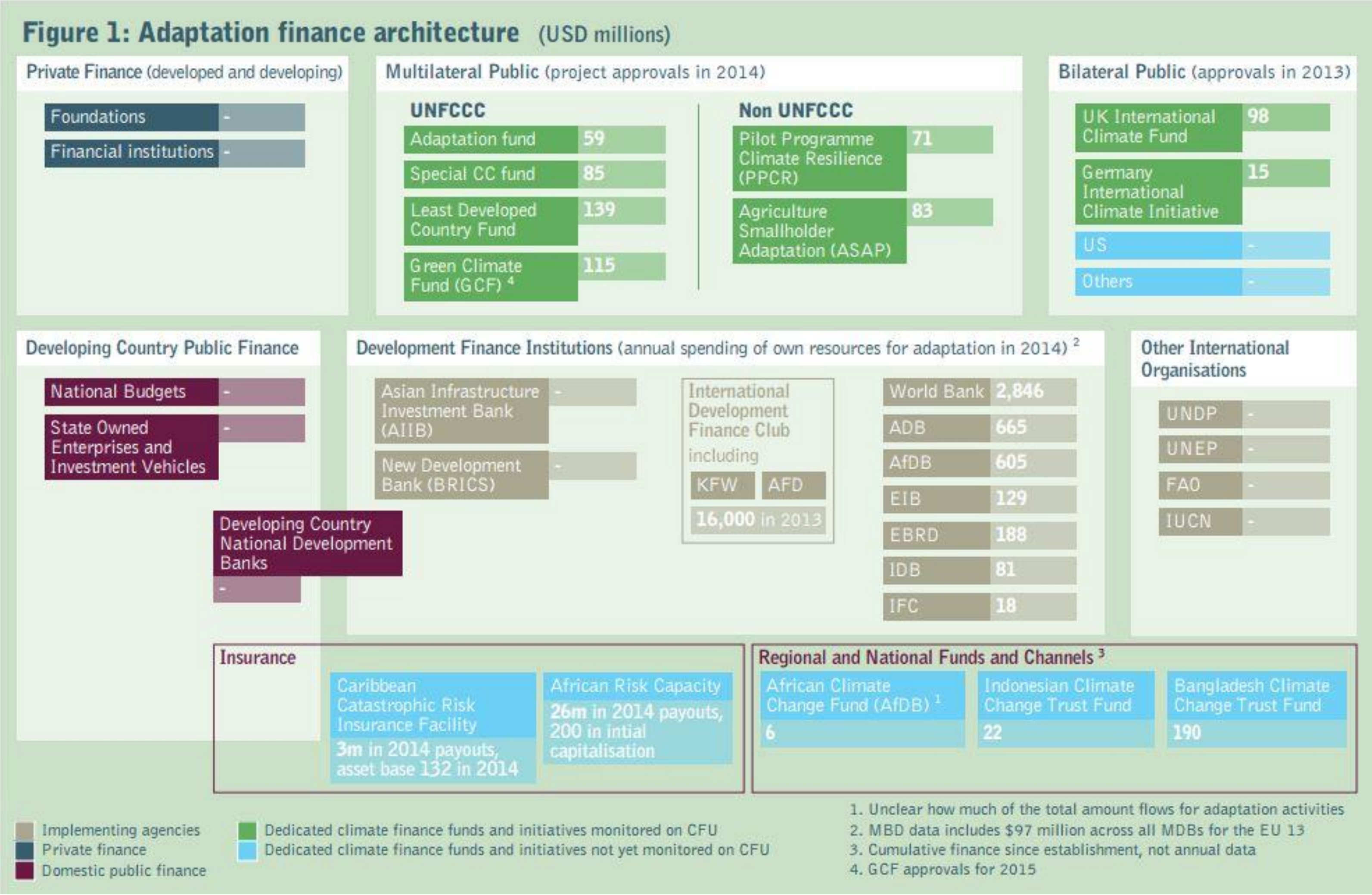
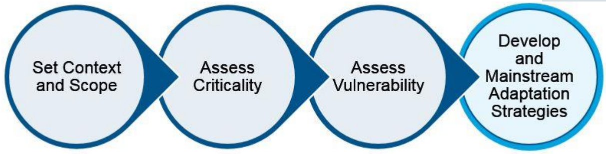


Figure source: Trujillo NC, Watson C, Caravani A, Barnard S, Nakhooda S, and Schalatek L (2015). Climate Finance Thematic Briefing: Adaptation Finance. Climate Finance Fundamentals. December 2015.



4.5 Monitor and Evaluate

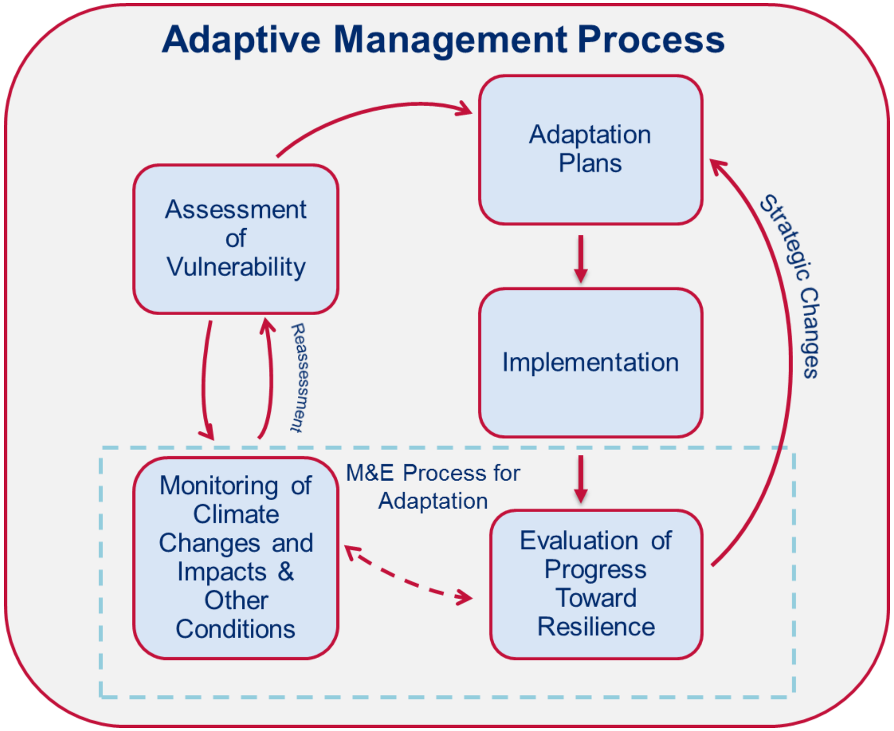
Establish a monitoring and evaluation implementation plan

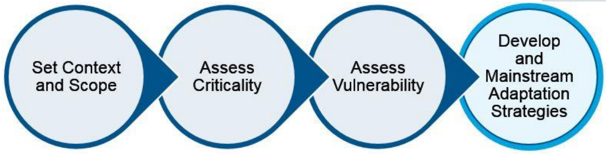
Adaptive Management

- Iterative process for revisiting adaptation practices to adjust to changing conditions and increase resilience over time

Monitoring and Evaluation

- Considers unique factors related to climate-resilient development:
  - Changes in climate information / impacts
  - Unexpected observations in climate and non-climate stressors / impacts
  - New technologies / approaches that may be more effective





Example Information to Track

Climate Changes

- **Water levels**
- **Frequency of threshold exceedance**

Climate Impacts

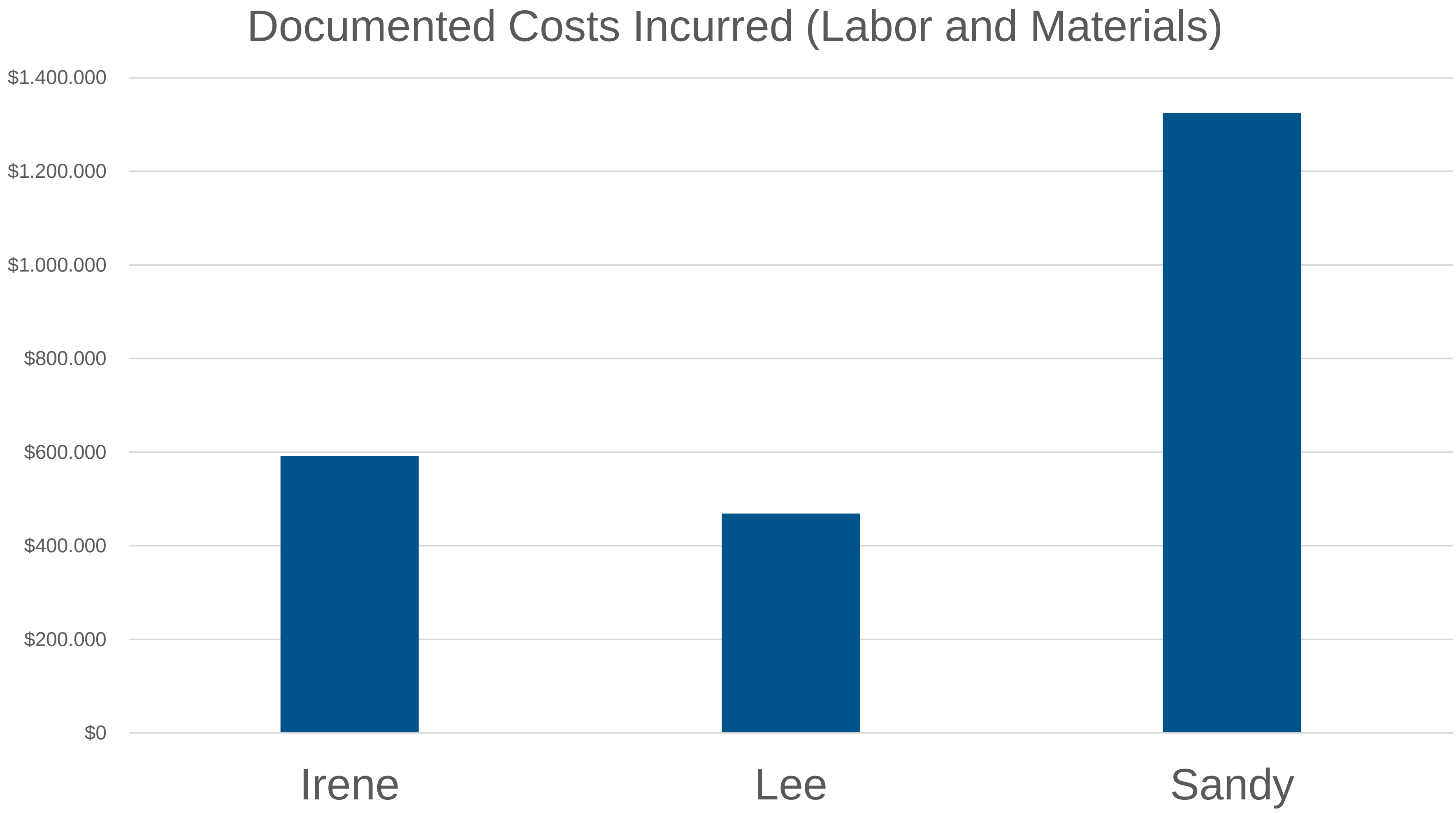
- **Frequency of disruptions**
- **Duration of disruptions**
- **Cause of disruptions (e.g., heavy rain, heat, tidal flooding, storm surge)**

Performance of Adaptation Strategies*

- **How do climate impacts differ before/after interventions?**

*To the extent possible (though this will likely be limited)

Effects of Monitoring Actual Costs (SEPTA)



FTA, 2013, A Vulnerability and Risk Assessment of SEPTA's Regional Rail

Sandy Damage

Photo source: SEPTA

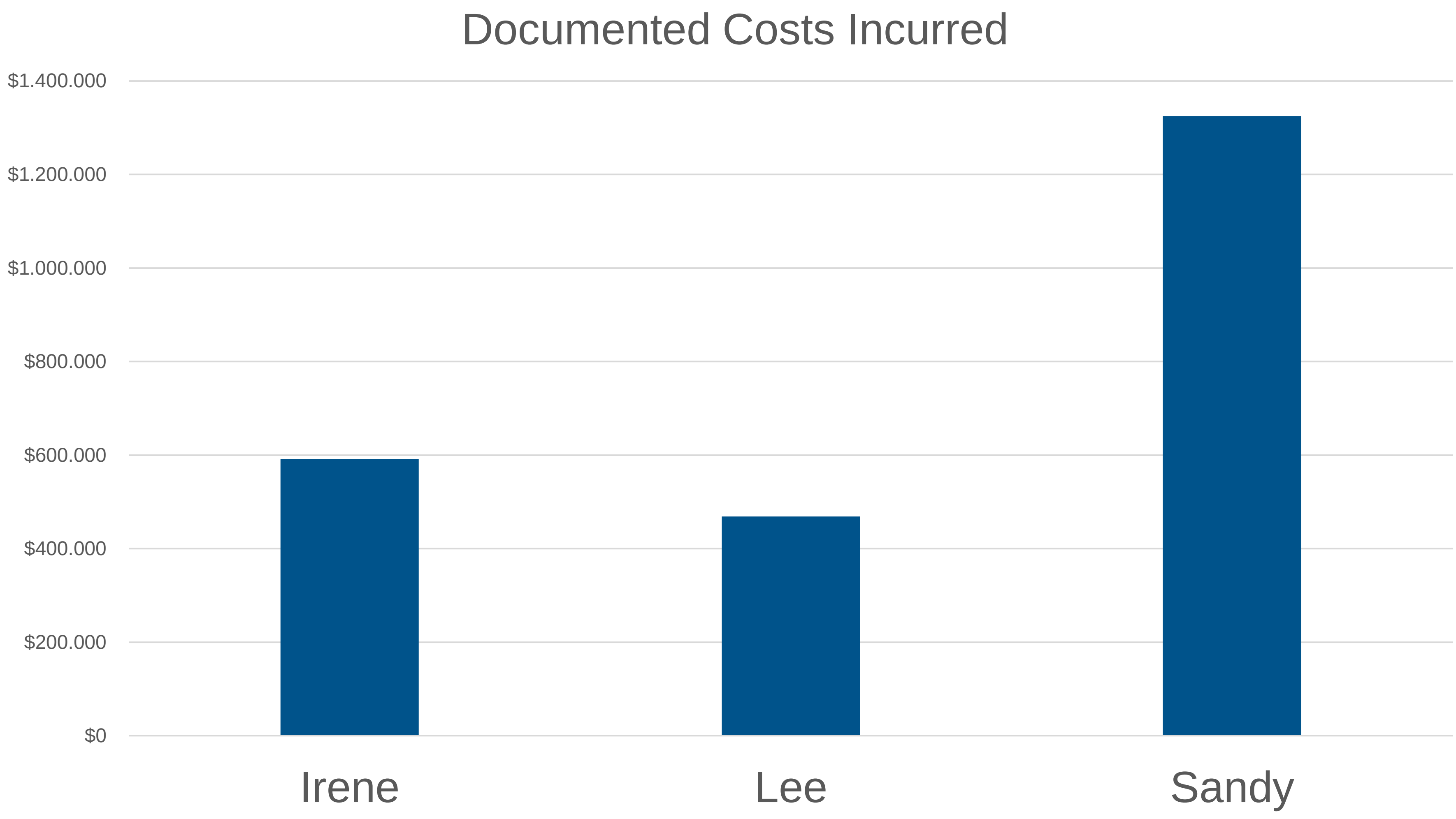
Lee Damage

Photo: SEPTA

Irene Damage

Photo: SEPTA

Effects of Monitoring Actual Costs (SEPTA)



FTA, 2013, A Vulnerability and Risk Assessment of SEPTA's Regional Rail

Example: Using climate information in adaptive management

Adaptation strategy: Incorporate climate change data and trends into an airport's master plan. Integrating climate change at a high-level will influence other sectors of the airport as trends are realized.

Monitoring climate trends:

1. Trends indicate that a runway is increasingly more vulnerable to flooding
2. Trends indicate increasing intensity and frequency of heat waves which threaten employee safety

→

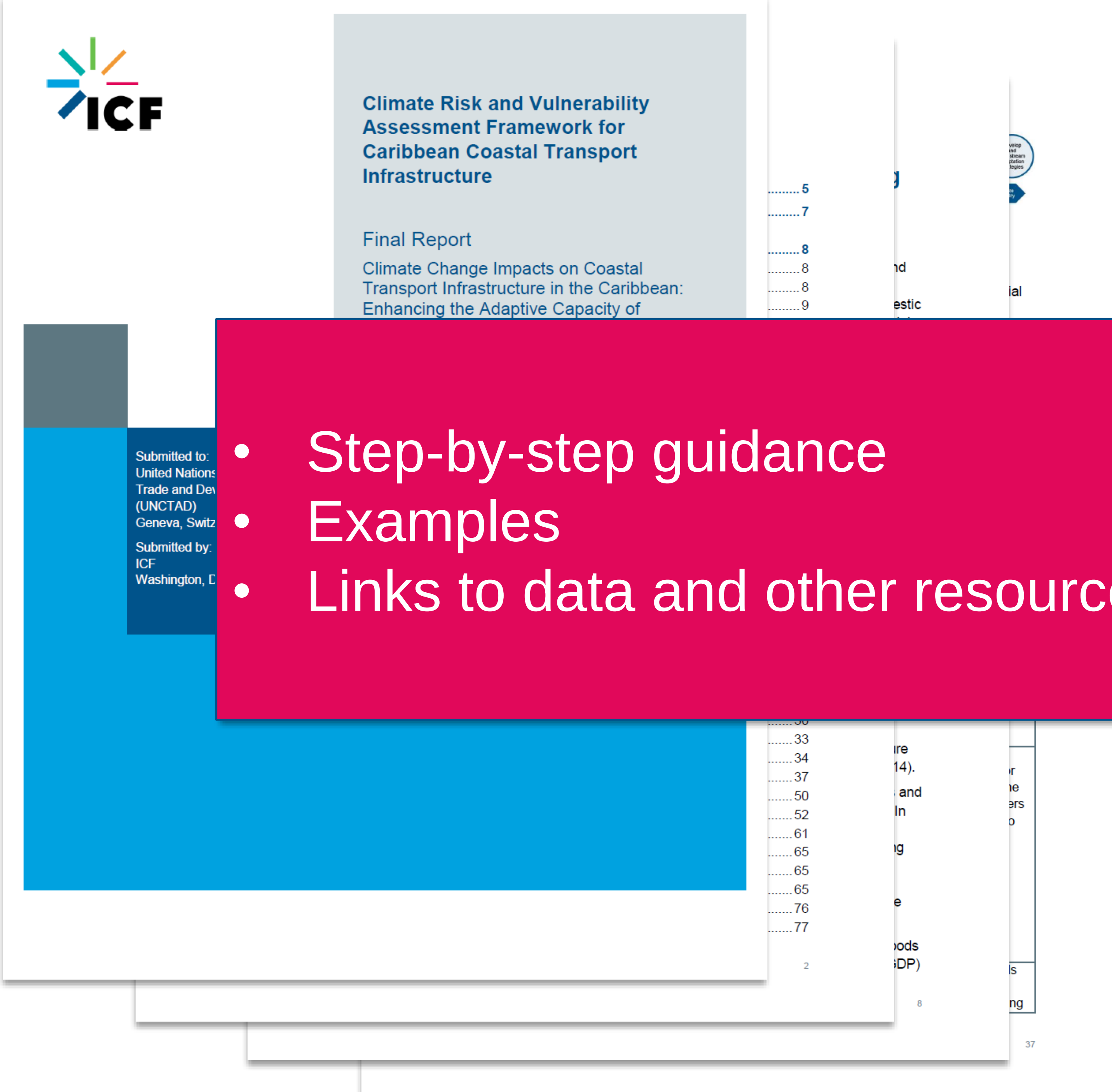
Adaptive Management:

1. Re-evaluate lifespan of runway and consider adaptation options such as elevating the runway
2. Adjust protocol for employee safety such as changing work hours during high heat conditions

ICF

Final Thoughts

- **Resilience is a good business practice**
- **Decisions may not be straightforward**
- **You are not in this alone**
- **Be flexible**



- Step-by-step guidance
- Examples
- Links to data and other resources

Questions?