CLIMATE RISK AND VULNERABILITY ASSESSMENT FRAMEWORK FOR CARIBBEAN COASTAL TRANSPORT INFRASTRUCTURE

OVERVIEW

As part of the project, a methodology[1] was developed to assist transport infrastructure managers and other relevant entities in SIDS in assessing climate-related impacts and adaptation options in relation to coastal transport infrastructure.

The *'Climate Risk and Vulnerability Assessment Framework for Caribbean Costal Transport Infrastructure'* provides a structured framework for the assessment of climate change impacts and vulnerability with a view to identifying priorities for adaptation and assisting in effective adaptation planning for critical coastal transport infrastructure; it allows for effective monitoring over time.

Climate change adaptation can be daunting, particularly when gaps in data create uncertainties regarding future conditions, the extent and costs of impacts, and the costs and effectiveness of responses.

The methodology is intended to help SIDS overcome these challenges by providing a practical approach that uses available data to inform decision-making at a facility, local, and national level. A technical aspect of the methodology involves the assessment of operational disruptions due to changing climatic factors.

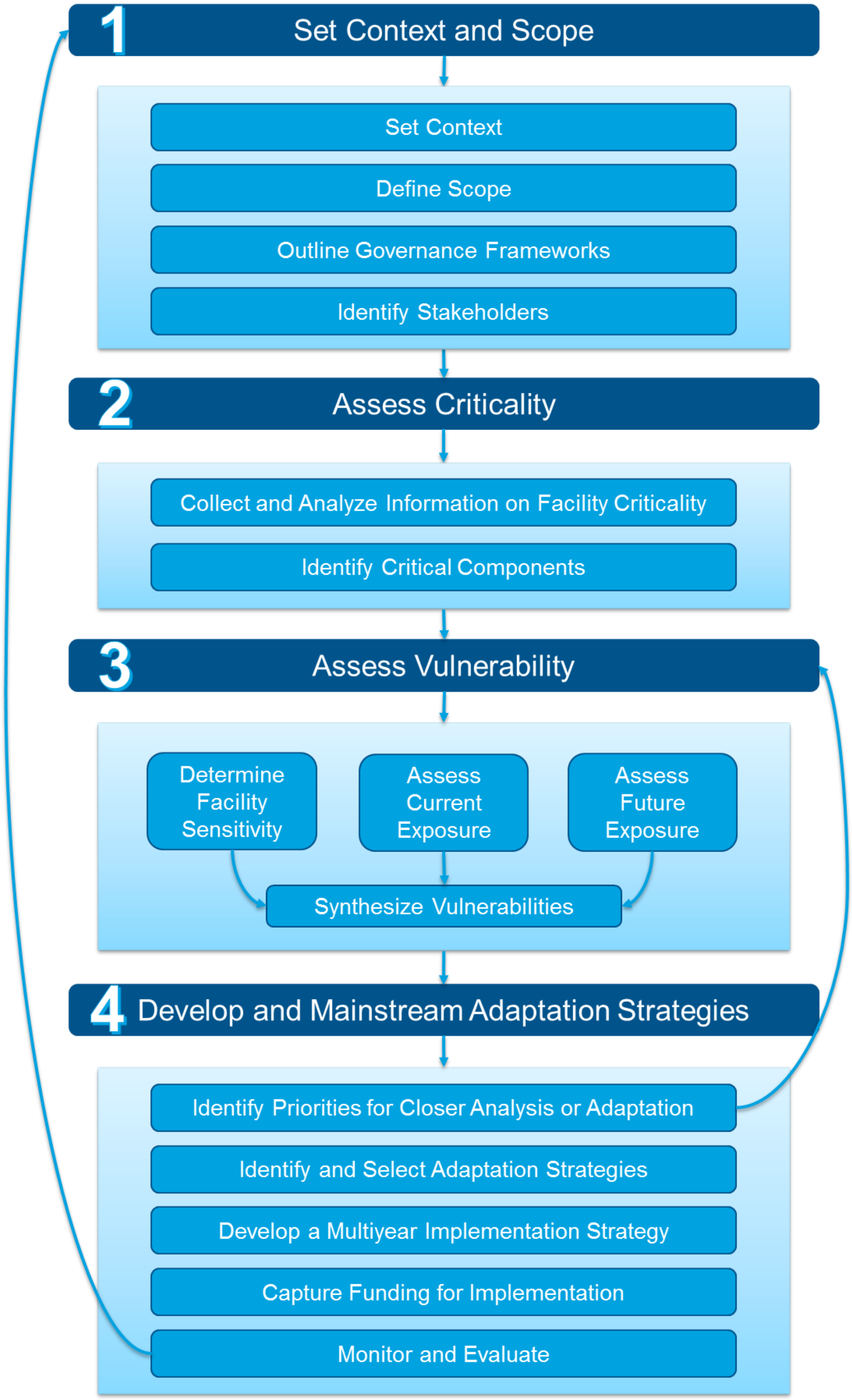
The methodology is transferable, subject to location specific modification, for use in other SIDS within the Caribbean and beyond.

Major stages of the assessment framework

1. **Set Context and Scope** – at the outset, briefly set the parameters for the assessment
2. **Assess criticality** – understand the contributions of different elements of the transport system to the society and economy
3. **Assess vulnerability** – understand how critical elements of the transport system respond to climate stresses, and how risks of costly damages or disruptions may change in the future
4. **Develop adaptation strategies and mainstream in existing processes** – identify where further analysis is needed (and if so, circle back to stage 3), and where action can be taken without further analysis. Understand available options and strategies to reduce risks from climate variability and change. Monitor and evaluate to adaptively manage over time.

[1] The full report on the Climate Risk and Vulnerability Assessment Framework for Caribbean Costal Transport Infrastructure is available at SIDSport-ClimateAdapt.unctad.org.

Climate risk and vulnerability assessment framework for Caribbean coastal transport infrastructure



ASSESS CRITICALITY

1. Collect and Analyze Information on Facility Criticality – Examples

Facility Operations Data

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

Health/safety Implications of Facility

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

Interconnectivity Data

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

Economic Contributions Data

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

2. Identify Critical Components

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

Port components may include:	Airport components may include:
• Docks and berths • Cranes • Utilities • Buildings and warehouses • Access roads • Utilities	• Commercial passenger terminal facilities • Runways, taxiways, and holding areas • Gates • Aircraft parking aprons • Stormwater drainage • Water distribution systems • Communications systems • Aircraft fueling infrastructure • Navigational aids etc.

ASSESS VULNERABILITY

1. Choose Between Quantitative and Qualitative Vulnerability Assessment Methods

Choosing Between Quantitative and Qualitative 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 that would be helpful
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

One way to decide the correct approach is to decide based on the intended use of the vulnerability assessment, per the diagram below.

How will the assessment be used?

- 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

2. Determine Facility Sensitivity

Sensitivity – The extent to which the asset will be positively or negatively affected if it is exposed to a climate hazard

Port climate sensitivities

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 restricted port access. Heavy precipitation can	Flood waters can transport debris that must be removed before operations can resume. For example, this has occurred at Kingston Freeport Terminal,

Climate Hazard	Docks	Crane Operations	Access	Other
		operations and goods handling.	also cause increased sedimentation of the port basin, reducing drat clearance for vessels and terminal access.	requiring tugs and manpower to remove the debris before operations can resume (UNCTAD, 2017a).

Airport climate sensitivities

Climate Hazard	Airport Runways/Tarmac	Airport Buildings	Access	Other
Sea Level Rise	Standing water on runways can prevent flight operations. Disruptions are dependent on duration of potential inundation, and are driven by elevation and other conditions. Severity may range from occasional (e.g., during extreme high tides), to twice daily, to permanent.	Sea level rise could inundate low-lying coastal buildings. Impacts may range from nuisance to permanent loss of facility operations.	Sea level rise could also affect airport access routes.	Not applicable.
Storm Surge	Tropical storms and storm surge may deposit large amounts of debris onto runways (e.g., vegetative debris, sand). Operations cannot resume until debris is cleared.	Tropical storms can damage airport buildings through roof damage or thrown debris. Documents and equipment on the ground flood could be destroyed.	Tropical storms can cause roadway damage and debris movement, preventing airport access.	Airport operations may be halted for the duration of the storm.
Wind	Strong winds can prevent aircraft takeoff and landing. Winds can also deposit debris onto runways that requires cleanup before operations can resume.	Very strong winds can damage buildings through roof damage or flying debris.	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.	Strong winds and debris movement could create dangerous working conditions for airport staff.
Extreme Heat	High temperatures can increase required takeoff lengths. They can also cause pavement softening or cracking, which can increase maintenance costs.	High temperatures can increase building energy costs.	Extreme heat can result in asphalt pavement softening or rutting, or cracks in concrete pavement. Airport access is unlikely to	Extreme heat can create hazardous working conditions for airport staff. Extreme heat can also raise

Climate Hazard	Airport Runways/Tarmac	Airport Buildings	Access	Other
			be affected, however.	energy costs for cooling.
Heavy Precipitation/ Flooding	Heavy rain can overwhelm existing drainage systems, causing standing water on pavements and inhibiting operations. Water on the runways can prevent planes from landing. Flood waters can also deposit debris onto runways that requires cleanup before operations can resume.	Heavy rain can overwhelm existing drainage systems, causing flooding in buildings. Impacts may range from nuisance to permanent loss of facility operations.	Heavy rain can overwhelm existing roadway drainage systems and cause flooding, creating pavement and embankment failure, debris movement and erosion and restricting airport access.	Heavy rain can reduce visibility and create hazardous working conditions for airport staff.

3. Establish Operational Thresholds

What is an operational threshold?

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

Why establish thresholds?

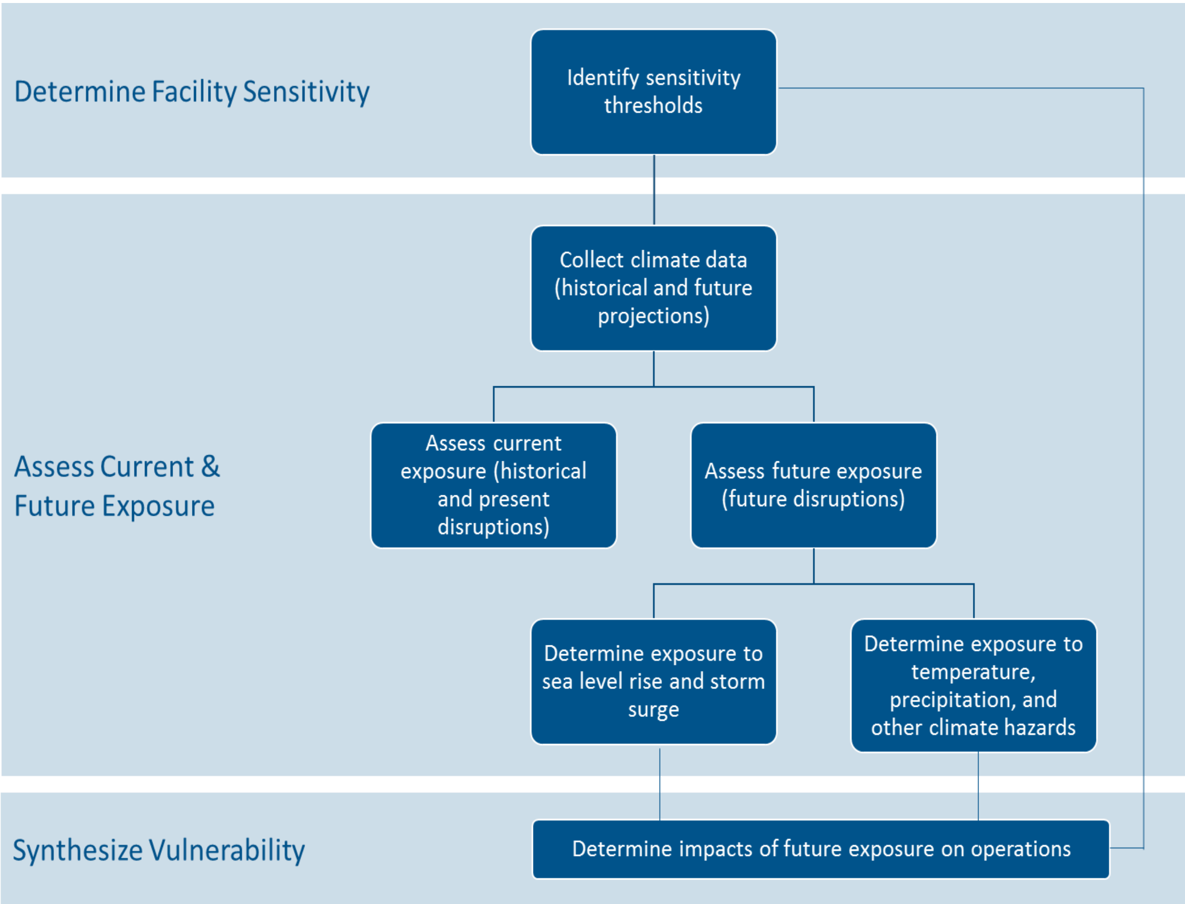
Help focus search for and analysis of climate data (historical and projected)

Process for sharing and documenting critical institutional knowledge

Informs monitoring and evaluation over time

Helps develop practical estimates of risks over time

Sensitivity threshold methodology for vulnerability assessment



Compilation of available port and airport climatic sensitivity thresholds

Climate Hazard	Component	Impact	Example Threshold	Source
Ports				
Extreme Heat	Operations	Energy costs	1°C warming = 5% increase in energy costs (in one illustrative terminal)	IDB, 2015b
	Paved surfaces	Asphalt pavement softening	Depends on asphalt pavement grade (**see box below for how to determine thresholds based on pavement grade and location**)	U.S. DOT, 2014
Heavy Rain	Cranes	Low visibility inhibits crane operation	In Manzanillo, intense rainfall > 20 mm within 24 hours reduces visibility enough to impair operations	IDB, 2015b
	Goods handling	Inability to handle water-sensitive goods	Precipitation > 1 mm within 24 hours	IDB, 2015b
Flooding	Operations	Flooding in some locations of the port could impair operations.	Conditions that cause flooding will vary by facility.	

Climate Hazard	Component	Impact	Example Threshold	Source
Tidal Flooding	Docks	Flooding	Dock elevation/quay height (**see box below for more information**)	IDB, 2015b
Wind Speeds	Cranes	Ability to operate	Varies by crane type. For example, 25 m/s (56 mph, 48.6 knots) for a CONTECON SSA	IDB, 2015b
	Navigational channel	Ability to berth ships (due to waves)	Varies by facility. For example, at Kingston Container Terminals (KCT) in Jamaica: • Winds ≥ 18 m/s (40.3 mph, 35 knots) force operational shutdown • With winds of 12.8-18 m/s (28.8-40.3 mph, 25-35 knots), discretion is applied At Falmouth Cruise Port: • Winds > 12.8 m/s (28.8 mph, 25 knots) create unmanageable docking trajectories	UNCTAD, 2017a
Airports				
Extreme Heat	Runways	Ability of aircraft to take off	Runway length requirement varies based on plane type, weight, and runway length. **See box for how to determine thresholds for any aircraft and location**. Rule of thumb: Runway length requirements increase by 1% for every 1°C by which the mean daily maximum temperature of the hottest month exceeds 15°C (assuming runway is at sea level) (ICAO, 2006)	ICAO, 2006, Chapter 3
	Flight operations	Aircraft maximum take-off operational temperature	47.7°C (118°F)	ACRP, 2016
	Personnel	Reduced employee ability to work safely outdoors (need for more breaks)	Heat Index* over 39.4°C (103°F) is "high" risk Heat Index* over 46°C (115°F) is "very high" risk	ACRP, 2016
Heavy rain	Flight operations	May decrease runway friction to aircraft cannot take off	Varies by airport	ICAO, 2002, Chapters 6-7
Flooding	Flight operations	Inability of aircraft to land or take off	Any flooding on the runway can impair operations. Conditions that cause flooding will vary by airport.	ICAO, 2002, Chapter 2
Sea Level Rise	Flight operations	Flooding on the runway	Runway elevation	U.S. DOT, 2014

Climate Hazard	Component	Impact	Example Threshold	Source
Wind Speeds	Flight operations	Inability of aircraft to land or take off	Commercial airports: sustained winds of 20 m/s (45 mph, 39 knots) or frequent gusts of 26 m/s (58 mph, 50.4 knots) General Aviation airports: 11.2 m/s (25 mph, 21.7 knots)	ACRP Report 160

Example: 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. For example, the table below shows the takeoff runway length requirements for two models of Boeing 737 aircraft under multiple temperature conditions, assuming the airport is at sea level.

Takeoff Runway Length Requirements by Temperature and Aircraft

	Mean maximum daily temperature of the warmest month				
	STD* 15°C (59°F)	STD+15°C 30°C (86°F)	STD+22.2°C 37.2°C (99°F)	STD+25°C 40°C (104°F)	STD+35°C 50°C (122°F)
Boeing 737-600	7,000 ft. (2,134 m)	7,600 ft. (2,316 m)	10,000 ft. (3,048 m)	n/a	11,500 ft. (3,505 m)
Boeing 737-700/-700W	9,200 ft. (2,804 m)	10,000 ft. (3,048)	12,500 ft. (3,810 m)	n/a	15,000 ft. (4,572 m)
Boeing 737-800/-800W/BBJ2	7,800 ft. (2,377 m)	8,100 ft. (2,469 m)	n/a	10,100 ft. (3,078 m)	15,000 ft. (4,572 m)

Source: Boeing, 2013

All values assume the following conditions: maximum aircraft takeoff weight, sea level, dry runway, zero wind, zero runway gradient, air conditioning off, and optimum flap setting.

*STD = Standard Day

4. Synthetize Vulnerabilities

Quantitative example

Identify how often sensitivity thresholds are expected to be exceeded in the future and, quantify the impacts of exceeding that threshold.

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

Qualitative example

Combine the information on criticality, sensitivity, current vulnerability, and exposure to identify the potential climate change vulnerabilities, using for example a vulnerability matrix, risk matrix (example on the right), 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

5. Potential Adaptation Measures - Examples

Process Enhancements

- Provide warnings of extreme temperatures to minimize heat stress risks for workers
- Review all planned capital investments with lifetimes > 20 years to ensure they are designed with future climate in mind
- Enhance emergency evacuation plans
- Improve transition planning to ensure staff with more experience transfer their institutional knowledge to new staff
- Review flood early warning systems

Ecosystem Enhancements

- Support beach nourishment, coral reef protection, sea grass buffers, and other ecosystem restoration efforts
- Implement mangrove management programmes
- Support sustainable land use and development to avoid slope destabilization and landslides
- Consider catchment-level landscape planning and ecosystem based adaptation options for reducing risk of drainage overflow.

Engineering Enhancements

- Improve cranes' braking systems and wind speed prediction systems
- Build new coastal defenses
- Raise quay height
- Install pavement sensors to monitor runway degradation from the sun or from standing water
- Relocate high-value, high vulnerability infrastructure to reduce risk
- Elevate runways or buildings at risk from sea level rise