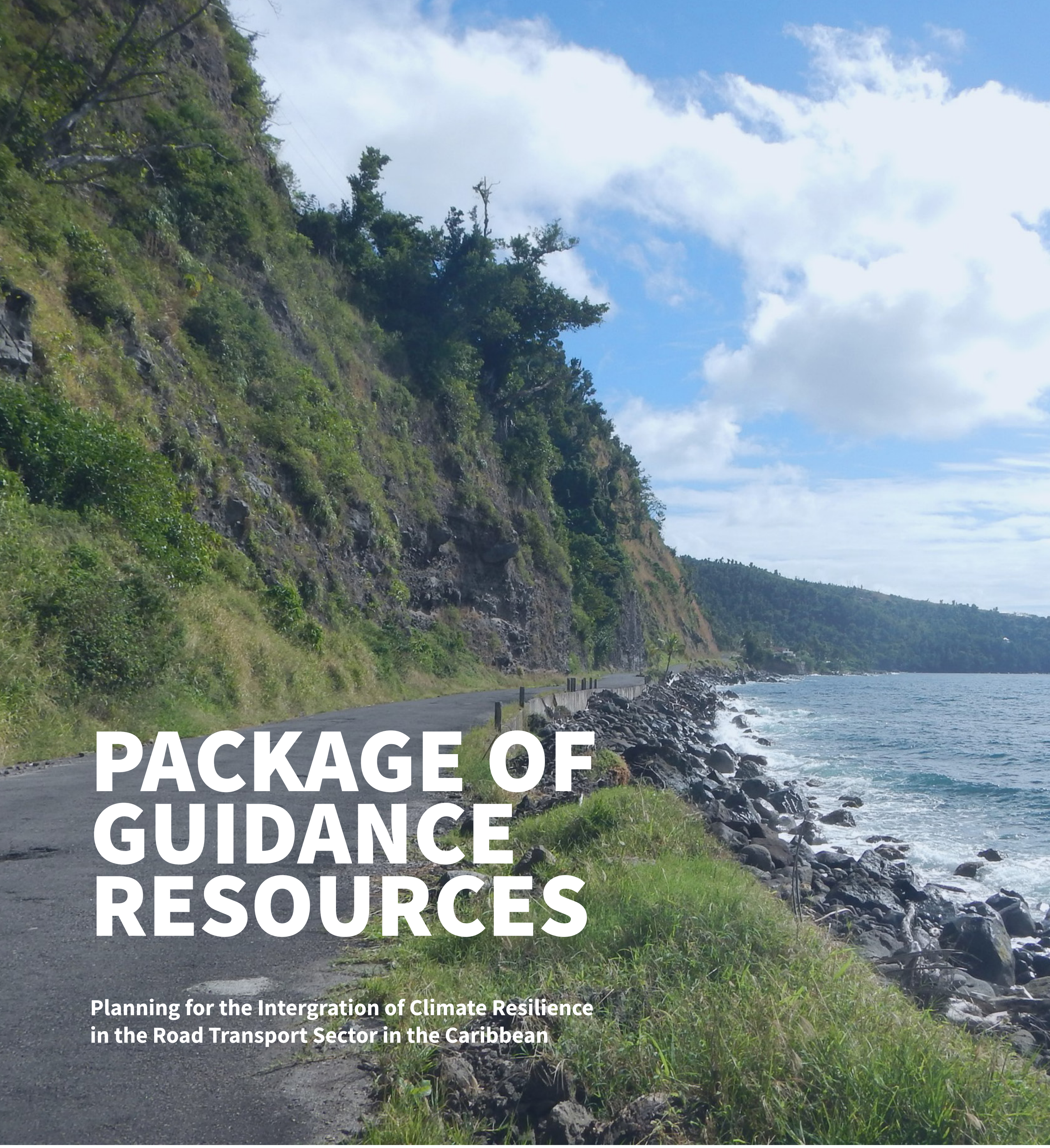

PACKAGE OF GUIDANCE RESOURCES

Planning for the Intergration of Climate Resilience in the Road Transport Sector in the Caribbean

An initiative of the African, Caribbean and Pacific Group, funded by the European Union, and implemented by:

Acronyms

AADT	Annual Average Daily Traffic
ADB	Asian Development Bank
AR5	The Fifth Assessment Report (Intergovernmental Panel on Climate Change)
ARIA	Adaptation: Rapid Institutional Analysis toolkit
BMC	Borrowing Member Country
CCRP	Climate Change Risk Profile
CBA	Cost-Benefit Analysis
CCA	Climate Change Adaptation
CCAP	Climate Change Adaptation Policy
CCCCC	Caribbean Community Climate Change Center
CCRA	Climate Change Risk Assessment
CCORAL	Caribbean Climate Online Risk and Adaptation Tool
CCRIF	Caribbean Catastrophe Risk Insurance Facility3
CDB	Caribbean Development Bank
CEA	Cost Effectiveness Analysis
CIMH	Caribbean Institute for Meteorology and Hydrology
CRIP	Climate Resilient Investment Plan
CRVA	Climate Risk Vulnerability Assessment
DEM	Digital Elevation Model
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
DRSRI	Domain-specific Road Sector Resilience Index
ESRI	Environmental Systems Research Institute
EVH	Exposure (E) - Vulnerability (V) - Hazard (H)
FWD	Falling Weight Deflectometer
GDP	Gross Domestic Product
GeoTIFF	Georeferenced Tagged Image File Format
GFDRR	Global Facility for Disaster Reduction and Recovery, World Bank
GCM	Global Circulation Models
GLC	Global Landslide Catalog
GIS	Geographical Information System
IPCC	Intergovernmental Panel on Climate Change
IRI	International Roughness Index
IRR	Internal Rate of Return
KNMI	Koninklijk Nederlands Meteorologisch Instituut
LCLIP	Local Climate Impact Profile
LIDAR	Light Detection and Ranging
MDD	Maximum Dry Density
MCA	Multi-Criteria Analysis
MCE	Multi-Criteria Evaluation
MIL	Matrox Imaging Library
mph	miles per hour
MRV	Measuring, Reporting and Verification
NASA	National Space Agency
NPV	Net Present Value
NSDI	National Spatial Data Infrastructure
ORSRI	Overall Road Sector Resilience Index
RAMS	Roads Asset Management System
RCP	Representative Concentration Pathway
RGB	Red - Green - Blue
RSRI	Roads Sector Resilience Index
SDI	Spatial Data Infrastructure
SLR	Sea Level Rise
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollars ($)
WGS	World Geodetic System

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Acknowledgements

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The authors would like to thank the Government of Saint Lucia together with Mr. Albert J Baptiste, Civil Engineer, and his staff; the Government of Guyana together with Mr. Geoffrey Vaughn, Project Coordinator/ Chief Works Officer, and his staff; and the Government of the Commonwealth of Dominica together with Mr. Howard Barret, Project Coordinator, and his staff. Valuable comments on the first drafts of this deliverable were received from Mr. William Ashby and Dr Yves Robert Personna, both from the Caribbean Development Bank.

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Glossary of terms

Note: the approach and terminology relating to vulnerability and risk assessment in relation to climate change can change depending on the sector, organization, and intended audience. Even basic definitions can vary significantly. This CRVA is generally based on IPCC AR5[1] definitions.

- **Adaptive capacity:** 'ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences'. It also includes resources for coping with impacts and minimizing damage. In the coastal road example, adaptive capacity could include the ability to close the road and reroute traffic with minimal delay; mobilization of resources to proactively maintain drainage and pavement; and planning to ensure that new infrastructure is not sited in exposed areas.

- **Adaptation measure:** Any discrete action or initiative which supports adaptation to current climate variability or future climate change. Adaptation options can enhance the resilience and/or reduce the vulnerability of systems to climate variability and change or enhance the capacity of the system to adapt to future climate change.

- **Climate:** The characteristics of the weather (temperature, precipitation, and wind patterns) which occur annually or seasonally, usually averaged over a 30-year time period for planning purposes.

- **Climate change:** This term refers to a statistically significant change in either the mean state of the climate or in its variability persisting for an extended period (typically decades or longer).

- **Criticality**: The importance of physical structures, facilities, networks, and other assets which provide services and access, that are essential to the social and economic functioning of a community or society.

- **Critical infrastructure:** The physical structures, facilities, networks, and other assets which provide services that are essential to the social and economic functioning of a community or society. This includes social infrastructure such as schools and health facilities, as well as other infrastructure systems (e.g., power station, water treatment plant).

- **Culvert:** A covered channel or large pipe to convey water below ground level, for instance under a road, railway or urban area, or beneath a building or other structure.

- **Exposure**: The presence of road transport infrastructure (e.g., roads, bridges and culverts) and/or the overall road corridor (including associated drainage, slope protection etc.) that could be adversely affected by climate variability and change, and other economically/socially important infrastructure and communities that are reliant on the road transport infrastructure.

- **Hazard**: The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts.

- **Hotspot:** A location on the road network which has greater exposure and/or vulnerability to the negative effects of climate change hazards.

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[1] Intergovernmental Panel on Climate Change (IPCC), 2013. Fifth Assessment Report, 2013. Glossary: https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_Glossary.pdf

- **Likelihood (of a hazard occurring):** A probabilistic estimate of the occurrence of a single event or of an outcome or of an observed trend or projected change lying in a given range. Likelihood may be based on statistical or modelling analyses, elicitation of expert views or other quantitative analyses.

- **Mitigation (of climate change):** Implementing policies to reduce greenhouse gas emissions and to enhance the capture and storage of greenhouse gasses.

- **Resilience**: Ability of the transportation system to withstand the impacts of climate change, both extreme weather and slow-onset impacts, to be able to maintain operations during such events and swiftly recover from any impacts.[2] In the case of climate change the degree to which we mitigate climate change in the short-term will affect resilience associated with a certain level of adaptation in the long-term. For this reason, climate resilience should be reviewed as a set of interventions that combines sufficient adaptation and mitigation. This is described as investing in Climate Resilient Development Pathways, defined as 'Trajectories that strengthen sustainable development at multiple scales and efforts to eradicate poverty through equitable societal and systems transitions and transformations while reducing the threat of climate change through ambitious mitigation, adaptation and climate resilience.'[3]

- **Return period:** Average interval of time between years in which events occur that equal or exceed a given magnitude.

- **Risk:** The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability or likelihood of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. In this report, the term risk is often used to refer to the potential, when the outcome is uncertain, for adverse consequences on lives, livelihoods, health, ecosystems and species, economic, social, and cultural assets, services (including environmental services) and infrastructure.

- **Risk assessment:** A risk assessment seeks to quantify the level of risk either quantitatively such as in monetary terms or qualitatively such as high, medium, or low.

- **Scour:** Erosion resulting from the shear forces associated with flowing water and wave action – in relation to road transport infrastructure it typically represents erosion associated with currents and the presence of bridges and other hydraulic structures.

- **Sensitivity**: This is the degree to which 'a system' is affected, either adversely or beneficially, by climate variability or change'. It is 'typically shaped by natural and/or physical attributes of the system' but also 'refers to human activities which affect the physical constitution of a system'[4].

- **Social inclusion**: The process of improving the terms on which individuals and groups take part in society - improving the ability, opportunity, and dignity of those disadvantaged on the basis of their identity[5].

- **Vulnerability**: The propensity of the individual road transport assets, the overall road corridor at a particular location, an overall road link or wider network, institutions, and users to be adversely affected by climate variability and change and their ability to respond. This is established by determining (i) the characteristics of the assets/institutions users that make them sensitive/susceptible to the adverse effects of a variable and changing climate, and (ii) their ability to respond to climate variability and change.

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[2] The resilience, in the context of transport, definition is adapted from DRM in the Transport Sector (World Bank) http://documents.worldbank.org/curated/en/524081468188378328/pdf/98202-WP-P126896-Box391506B-PUBLIC-DRM-Final.pdf and UNISDR terminology: https://www.unisdr.org/we/inform/terminology#letter-r

[3] Climate Resilient Development Pathways reflected in https://www.ipcc.ch/site/assets/uploads/sites/2/2018/07/SR15_SPM_High_Res.pdf and defined on page 26.

[4] GIZ. 2014. The Vulnerability Sourcebook. Concepts and guidelines for standardised vulnerability assessments. GIZ, Bonn and Eschborn, Germany.

[5] Adapted from World Bank's definition of social inclusion: https://www.worldbank.org/en/topic/social-inclusion

1

INTRODUCTION

A **Climate Risk and Vulnerability Assessment** (CRVA) has been carried out in Saint Lucia, Guyana and Dominica to pilot a new approach to identify and evaluate the effects of climate change on the road transport sector, which can then be utilized across the Borrowing Member Countries (BMCs) of the Caribbean Development Bank (CDB). This, together with an institutional assessment, have been combined into an investment plan for each country, to improve the resilience of the road transport sector. These three main deliverables are summarized as follows:

The **CRVA** comprises a quantitative analysis that is consistent with the Inter-Governmental Panel on Climate Change guidelines[6] and data collection on exposure, hazards, and vulnerability (EVH) of road transport. Data was received through stakeholder engagement in-country and through making use of publicly available information sources. The overall approach used was to generate 'hotspot' exposure-vulnerability-hazard maps through the CRVA that informed site investigations of the most critical and vulnerable locations.

The **Assessment of Policies** as well as the legal and regulatory framework governing transport was carried out across the three countries. This led to recommendations as to what is required in terms of institutional capacity, roles and responsibilities, and national policies, strategies and plans, alongside physical investments in the road network itself to enhance road sector resilience. This includes interface with other sectors.

These two outputs informed the preparation of a strategic **Climate Resilient Investment Plan** for each country, to enhance road sector resilience. This investment plan included physical investment in the road corridor itself as well as the wider physical investments (e.g., in related infrastructure) and institutional aspects. The importance of viewing the resilience of the road transport sector as coincident with wider built and natural environment resilience was highlighted – together with the fact that longer-term resilience is crucially dependent on a shift to low-carbon emissions in these countries and worldwide, which will transform the type of access and mobility required of the road transport network.

These principal outputs; Climate Risk and Vulnerability Assessment, Policies Assessment, and Investment Plan; are captured in two knowledge products. Firstly, a **Roads Sector Resilience Index** has been produced that sets out the methodology, including the detailed algorithm that underpins the generation of the hotspot maps in GIS. Secondly, this **Package of Guidance Resources** sets out the framework used as part of the CRVA studies for integrating climate resilience into the road transport sector.

The flow charts and the process presented in this document demonstrate how the user can follow the instructions of the 'Package of Guidance Resources' hereafter referred to as 'the guidelines'. The technical details underpinning these guidelines and its methodology are also presented and will need to be referenced by the engineers and other specialists employed by the user to undertake this analysis.

The guidelines present the overall process designed to assess the exposure, hazards, vulnerabilities, and risks of sections of the road network in Saint Lucia, Guyana and Dominica, the three case studies of this assignment. The framework provides detailed and practical instructions on how to conduct a climate change and natural hazard road network vulnerability and risk assessment, including GIS technical notes.

It also includes practical sections on screening of policies and prioritization for implementing a climate resilience investment plan. The process is structured into a series of steps which will guide users to apply a CRVA for all countries in the Caribbean region. The experience of the case studies, lessons learned and best practices in implementing the framework have been included in the first two sections of this report.

This document was presented at regional workshops to be organized by the CDB and amended to incorporate the feedback received from this workshop.

[6] Ibid.

2

LESSONS LEARNT FROM THE THREE PILOT STUDIES

The Climate Risk and Vulnerability Assessment (CRVA) is a useful analysis for countries and regions to get to know the extent of climate-related natural hazard risks and vulnerabilities in their road transport network. The approach taken can also be applied to all types of infrastructure, leading to prioritization of areas of future investment that need further improvement and maintenance, as well as wider institutional and systemic changes.

The CRVA also benefits the country of study in the following ways:

- Further understanding of the hazards that the region experiences, and how they will impact infrastructure systems;
- Overall awareness raising and targeted training and capacity building to local authorities and officials;
- Digitization of GIS data (and maps) that can be handed over to the government for ongoing use;
- Integration into asset management systems, which could lead to improvement of road network database if primary road and traffic data needs to be collected; and
- Adaptation measures and engineering recommendations are proposed to mitigate the effects of climate change in the hotspot locations identified.

Through the implementation of the CRVA framework in the three case study countries (Saint Lucia, Guyana, and Dominica), the Consultant has enhanced their own methodology and the following general lessons have been learned:

- It is important to undertake an exhaustive literature review of relevant research papers, reports and risk assessment methodologies. The desktop exercise also helps shortlist the most critical hazards which have a major impact on the selected infrastructure.
- An initial stakeholder consultation workshop before starting the process is important to inform the CRVA in terms of gathering information of historic disaster events and critical locations in the road network. The frequent occurrence of the same type of shocks in a specific location will inform the hotspot analysis and help validate the preliminary results. This will also inform as to the current data sets held and systems used that this process needs to integrate into in future.
- A continuous and regular communication with all the institutions and stakeholders involved is essential to understand their needs as well as obtaining first-hand data and information.
- The CRVA analysis requires a comprehensive GIS modelling exercise and data needs to be as much reliable and accurate as possible. This includes climate and hydro-meteorological data, topographic information and location of key assets/socio-economic data, and datasets relating to the inventory, condition, and traffic levels on the road network.
- Lack of data availability can be an issue across the Caribbean region. If data can't be obtained first-hand from national stakeholders, international and publicly sources can be used. Site surveys can be undertaken when localized CRVAs are required to collect vulnerability and criticality data. Reports and articles from neighbouring countries with similar characteristics can be consulted to counter and compare data.
- Where social data exists, it is often not disaggregated by communities nor digitized to facilitate integration into GIS for comparison with other spatial data, such as location of rivers and areas prone to land slippage. This makes difficult to allow for a more comprehensive analysis of the vulnerability of specific groups within the population.

- An inter-disciplinary team of climate resilient experts, risk modelers, civil engineers, social and gender specialists, economists and GIS experts is required to develop a CRVA. Team coordination and regular discussions among all the parties engaged are necessary to link the different activities with each other and ensure inter-disciplinary understanding. Integration of the assessment will need to be managed accordingly from the very beginning, and most likely involve a process of each discipline learning from and better understanding the others involved in the process.
- Engineering validation of the preliminary exposure - vulnerability - hazard (EVH) index results and hotspot locations is highly recommended through a visit to the most critical sites. This can improve the hotspot modelling by using more suitable indicators and data. On-site ground-truthing is crucial for the project to effectively link highly scientific climate and meteorological projections with clear recommendations of what needs to be done as a result.

3

SOURCES OF BEST PRACTICE

The CRVA framework has been developed by international and local experts working together, based upon extensive experience and a review of international best practice publications on climate resilience. The reading and analysis of a range of reports, papers and studies informed the methodology described in these guidelines. References to the main sources used are indicated in this section.

Best practise has been identified mainly from publicly available international sources, including the following:

- Intergovernmental Panel on Climate Change (IPCC), Fifth Assessment Report (unless superseded by later Assessment Report). Visit: https://ipcc.ch/report/ar5/ and Special Report: Global Warming of 1.5°C. Visit: http://www.ipcc.ch/report/sr15/.
- The Vulnerability Sourcebook, GIZ, 2014. Visit: https://www.adaptationcommunity.net/?wpfb_dl=203
- World Bank. 2015. Disaster Risk Management in the Transport Sector: A Review of Concepts and International Case Studies. Washington DC: World Bank. Visit: http://documents.worldbank.org/curated/en/524081468188378328/pdf/98202-WP-P126896-Box391506B-PUBLIC-DRM-Final.pdf
- Transport and ICT. 2015. Moving Toward Climate-Resilient Transport: The World Bank's Experience from Building Adaptation into Programs. Washington DC: World Bank, License: Creative Commons Attribution CC BY 3.0. Visit: http://documents.worldbank.org/curated/en/177051467994683721/Moving-toward-climate-resilient-transport-the-World-Bank-s-experience-from-building-adaptation-into-programs
- Highways England, 2016. Climate Change Risk Assessment Progress Report. Visit: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/596812/climate-adrep-highways-england.pdf
- Engineers Canada, 2016. PIEVC Engineering Protocol for Infrastructure Vulnerability Assessment and Adaptation to a Changing Climate: Principles and Guidelines. Visit: https://pievc.ca/sites/default/files/pievc-protocol-principles-guidelines-june-2016-part_1-e.pdf

The collection of data into GIS to run the modelling exercise is an essential task to start the CRVA process, a series of international sources have been used to either obtain or help develop a database of exposure, hazard, vulnerability and risk assessment datasets. Useful webpages include the following:

- Global Risk Data Platform. Visit: http://preview.grid.unep.ch
- Global Assessment Report Risk Data Platform. Visit: https://risk.preventionweb.net
- Centre for Research on the Epidemiology of Disasters (CRED) Emergency Events Database (EM-DAT). Visit: http://www.emdat.be
- National Space Agency (NASA) and Global Landslide Catalog (GLC). Visit: https://disasters.nasa.gov/floods; https://earthobservatory.nasa.gov; https://floodmap.modaps.eosdis.nasa.gov; and https://catalog.data.gov/dataset/global-landslide-catalog-export
- World Bank (WB), Climate Change Knowledge Portal. Visit: http://sdwebx.worldbank.org/climateportal
- Koninklijk Nederlands Meteorologisch Instituut (KNMI) Climate Change Atlas. Visit: https://climexp.knmi.nl/start.cgi

Table 3 in **Section 5.1** indicates other open sources relevant to the Caribbean region. When different sources which give the same data are available, it is recommended to compare and combine data where necessary and consider any gaps or discrepancies that are identified.

4

OVERVIEW OF THE CRVA METHODOLOGY

4.1. Development of the methodology

These guidelines will help users to assess climate-related natural hazard risks that impact upon the Caribbean region's road network. The methodology has been developed based upon extensive experience and a review of international best practice in climate resilience approaches, including that published by the IPCC, GiZ, and the World Bank, and national engineering organizations including Highways England and Engineers Canada (see **Section 3**).

Important factors that need to be considered through the process of putting these guidelines into practice are described in this Section.

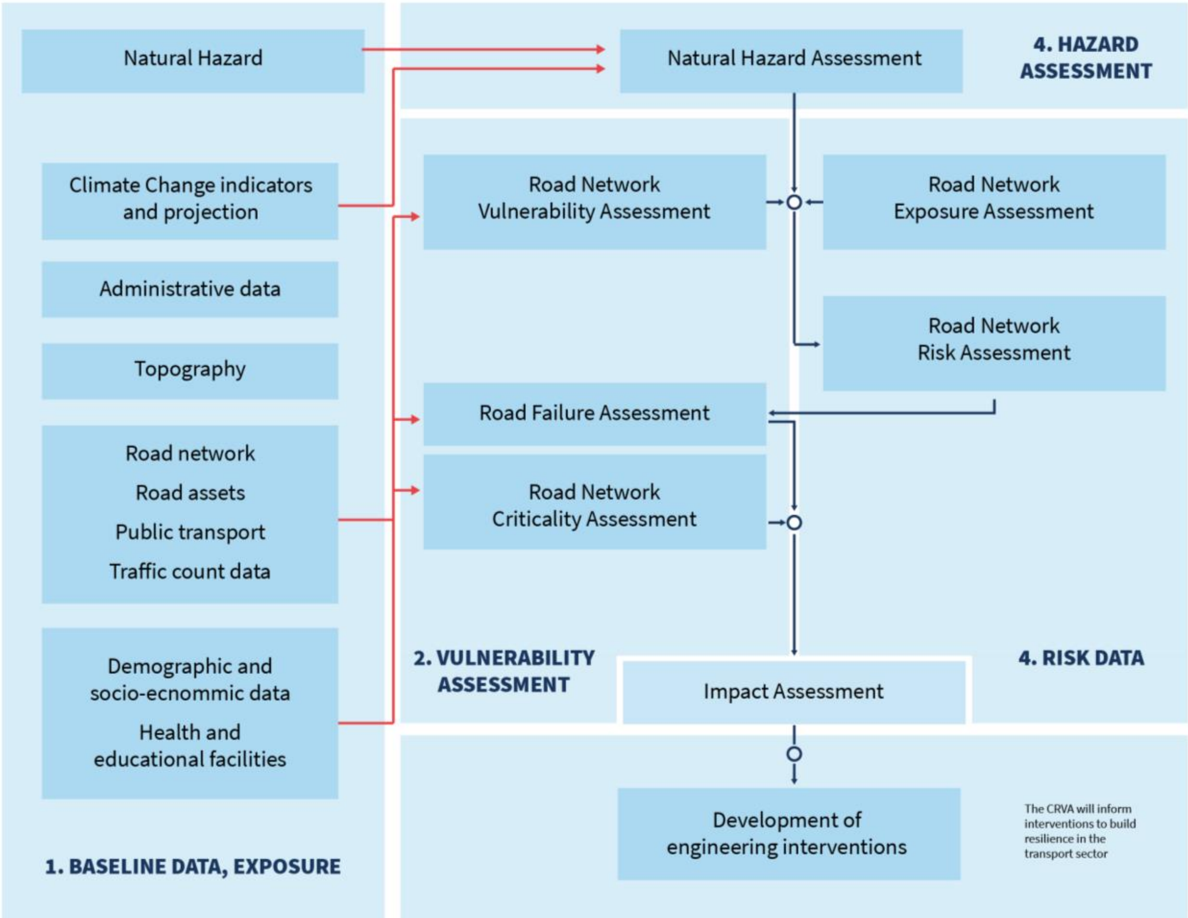
4.2. Key steps of the methodology

The following four steps were followed as part of the CRVA methodology to assess the data required for the individual components of Exposure-Vulnerability-Hazard (EVH) and develop a GIS database. The GIS data layers are subsequently used as an input to an index model (EVH index), allowing like-for-like comparisons of locational scores to be undertaken as an indicator of their overall vulnerability / resilience at different locations.

- Step 1: Exposure assessment
- Step 2: Vulnerability assessment
- Step 3: Hazards assessment
- Step 4: Exposure-Vulnerability-Hazard (EVH) mapping and Hotspots index

The long-term objective in the Caribbean is that road owners and managers are able to implement the framework developed as part of the CRVA for integrating climate resilience into the roads transport sector. The assessment will start with the review of the existing baseline data, check if the accuracy of the information is still applicable and will continue with the steps described in **Section 5** of these guidelines.

Figure 1: Key steps of CRVA framework



Once a complete road network database is established, it is important that it is kept up to date, so that it takes account of recent amendments and reflects changes to design standards and new technology. It is therefore recommended that the database is updated on an annual basis, as part of the normal asset management and budgeting process.

In addition, whenever a significant climate-related hazard (e.g., flash flood/landslide, storm surge/coastal flooding, hurricane/tropical storm) event occurs, it is important that appropriate surveys are completed after the event. These surveys should include:

- Analysis of the cause and extent of the event, including detailed rainfall records;
- Identification of the assets affected;
- Assessment of the damage experienced, in terms of whether assets were damaged, partially lost, or completely lost; and
- Assessment of the impact experienced, in terms of the length of time that connectivity was lost.

Based upon these surveys, the road network database should be updated, reflecting any amendments to assets, increases or decreases in vulnerability, and reflect the outcome of any remedial measures completed. At the same time, any unexpectedly large events (or events with unexpectedly large impacts) should be further investigated so that the hazard and vulnerability models used can be validated and updated accordingly.

4.3. Determine the geographic scope & scale of the assignment

The scope and scale of the assessment must be determined and agreed with the relevant government body and client. Studies can be undertaken at national, regional or local level, depending on the agreed government and beneficiaries' requirements and needs. If similar studies have been carried out before, it may be useful to consider using the same parameters studied in previous analysis.

Once the target area and scales have been agreed, it is important to define the road network to be studied. An analysis of the data available on all the different types of road classification is essential. For example, it could be that only the primary network is to be considered, or it may be decided to focus on long transport corridors instead of concentrating on specific road links. There is no fixed or universal rule about which factors should be considered, as these will depend on the location and asset being studied.

4.4. Agree timescale and identify future climate scenarios

The timescale to be used should be clearly defined. Generally, present and future climate change scenarios should be considered for the following three cases:

1. Baseline Case, covering the existing situation;
2. Medium-Term Projection, covering a 20-year period from the current time (e.g., up to 2040). This is chosen as it will inform risk and vulnerability for road carriageways and minor structures (e.g., culverts) over their usual design life; and
3. Longer-Term Projection, covering approximately a 50-year period from the current time (e.g., up to 2070). This is chosen as it will inform the risk and vulnerability for most major road structures (e.g., bridges and earthworks) over their usual design life.

Climate change trends will be determined from existing climate scenario modelling, localized (if needed) and then superimposed onto the baseline assessment for different types of natural hazards. Climate scenarios will inform both on 'slow onset' changes (e.g., sea level rise - increasing progressively with time) and changes to the frequency, severity and predictability of 'shock' extreme weather events (e.g. hurricanes and tropical storms).

4.5. Identify natural hazards to be assessed

These guidelines concentrate on the climate-related natural hazards that are the most significant in the Caribbean region. Local specialists may be able to advise on which are the most significant hazards in a particular location. After such an analysis, desk-review and/or stakeholder consultation of historical events, a list of the most significant hazards should define the scope of the study. The main hazards are set out as follows,

1. **Flooding** due to extreme and prolonged rainfall events. This could result in either surface water flooding (pluvial or flash flooding) or flooding of a river basin (fluvial flooding). This may be as a result of a tropical storm or hurricane. **Coastal flooding** is likely to be as a result of a combination of sea-level rise with a storm surge, which is likely to coincide with hurricane or tropical storm events;
2. **Landslide/geotechnical stability/soil erosion**, including due to flooding;
3. **Wind speed increase** (such as a result of a hurricane or tropical storm);
4. **Extreme heat event**, which could have an impact on material stability, such as for some tarmac road pavements; and
5. Others less relevant such as **wildfire** and **drought**.

The relationship between climate drivers and climate-related natural hazards is complex and reflects uncertainties in climate and hydro-meteorological models. The most significant hazards will reflect local conditions. For example, every region in the world has specific (explicit or implicit) models for the relationship between rainfall and landslides, all of which have different levels of uncertainty or confidence. This means that different rainfall levels or intensive short-term rainfall events tend to trigger different types of landslides in different regions of the world and within individual countries. The most significant climate-related hazards in the Caribbean context are presented in **Table 1**.

Table 1: Climate variables and parameters of interest in the Caribbean

Climate impact	Associated natural hazard (*and risk*[7]) for road transport sector	**Climate indicator (*and data available*)**
'Slow' onset effects of climate change		
Overall Changes in Precipitation	Riverine flooding (*Overtopping and wash away; Increase of seepage and infiltration into pavement and subgrade; Bridge and culvert scour*) High / low soil moisture levels (*Structural integrity of roads, bridges and culverts; Adverse impact of standing water on the road base*)	**Average conditions** Annual *(Average precipitation in mm or l/m ^{2})*
Sea Level Rise	Coastal flooding (*Structural integrity of coastal roads, pavement integrity)*	**Average conditions** Annual *(Average sea-level rise in m)*
Average Temperature Increase	High temperatures (*Exceedance of design / performance thresholds*)	**Average conditions** Annual *(Average temperature – annual)* Summer *(Mean maximum temperature – annual; Mean maximum temperature – month with the highest value)* Winter *(Mean minimum temperature – annual; Mean minimum temperature - month with the lowest value)*
Average Wind Conditions	Windstorms (*Stability of bridges; Damage to culverts, Wind-borne debris / tree fall; drifts*)	Average conditions (*Average wind speed - by direction annual*; *Wind direction (most frequent winds direction per station – annual)*

[7] Adapted from:

- NDF. (2016). Climate Resilient Roads- Cambodia Rural Roads Improvement Project: Results from Climate Change Adaptation. Nordic Development Fund. Helsinki, Finland.
- Dennis Consultants. (2008). First national engineering vulnerability assessment report; roads and associated infrastructure. The City of Greater Sudbury Infrastructure Services Department.
- US Department of Transport. (2012). Climate Change and Extreme Weather Vulnerability Assessment Framework. https://www.fhwa.dot.gov/environment/sustainability/resilience/publications/vulnerability_assessment_framework/fhwahep13005.pdf.

'Shock' extreme weather events		
Precipitation	Flash flooding (*Overtopping and wash away; Increase of seepage and infiltration into pavement and subgrade; Standing water (aquaplaning)/safety; Lane closure/ traffic hindrance*) Riverine flooding (*risks as above*) Erosion/Landslides (*Loss of road section; Traffic hindrance and safety*)	**Precipitation extremes:** Frequency (*Average no. of days ≥ 10.0mm precipitation (mm or l/m ^{2}) – annual; Average no. of days ≥ 10.0mm precipitation (mm or l/m ^{2}) – month with the highest value)* Intensity *(Maximum daily sum precipitation (mm or l/m ^{2}) – annual;* *Maximum daily sum precipitation (mm or l/m ^{2})- for the month with the highest value)*
Storm Surge combined with Sea Level Rise	Coastal flooding (*Structural integrity of coastal roads, pavement integrity; Traffic hindrance and safety)*	**Storm surge extremes:** Change in extreme storm surge (height and return period). Likely to be different for different future time horizons (as it will be affected by sea level rise). Rise in sea level *(Average sea-level rise in meters – annual).*
Tropical cyclones/ hurricanes	Likely cause of storm surge and extreme precipitation *(see risks as above)* Extreme wind speed (Stability of infrastructure; impact of wind-borne debris on network/safety; Damage to signs, lighting fixtures and supports)	**Wind Speed extremes:** Change in extreme wind speed events
Extreme Temperature	Extreme heatwaves (*Pavement integrity, e.g. softening of asphalt layers, rutting, embrittlement (cracking), migration of liquid asphalt; Subsidence of structures and roads*) Wildfires (*Pavement integrity; Traffic hindrance and safety*) Dust storms (*Traffic hindrance and safety*)	**Temperature extremes:** High summer *(Average number of tropic days – annual)*

The CRVA will use observed data from historical records as the baseline conditions for aligning modelled future climate change projections for rainfall and temperature generated by global climate change models against existing weather patterns.

Although a similar process is required to assess the impacts due to each of these hazard types, it is recognized that data available for the future risk of some hazards may not be accurate enough in some countries/regions for a robust and meaningful analysis. In consultation with the Client and key stakeholders, the study of that particular hazard, which is not well documented, may not proceed. It is hoped all types of climate-related hazard data, including that derived from global modelling and that requiring local hydro-meteorological or other records, will improve over time.

Table 2 sets out the different categories of data required for different natural hazards. This reflects the availability of data and the implications of incorporating large amounts of data into analyses.
Global climate change models, including projections of climate indicators, are downscaled into regional or national models. The most suitable scale to use these models is usable to cover national assessments; however, it may not be suitable for localized or detailed analyses due to inherent uncertainties in downscaling the data. **Table 2** also recommends the scale of assessment to be used at national, regional and localized levels, considering the average size of the Caribbean countries.

Table 2: Recommended scale for different types of data set

Scale of assessment	Natural hazards	Road network	Climate indicators	Climate change
National 1: 300,000	All hazard types	Main trade roads	Baseline data from main meteorological stations	National scenarios
Regional 1: 25,000	All hazard types	Pre-defined road network	Baseline climate indicators from main meteorological stations and data from precipitation and hydrological stations	National scenarios (downscaled*)
Detail > 1: 5,000	Specific hazard	Road links, Road Assets	Baseline climate indicators from main meteorological stations and data from precipitation and hydrological stations - daily/hourly records	Numerical and spatial modelling based on historical records and future projections

5

DATA REQUIREMENTS

5.1. Data acquisition and management

The way data is acquired and managed is important, throughout the CRVA process. Three different types of data are required:

- **Primary Data**, which is acquired first-hand as part of field surveys, stakeholder consultations and data collection;
- **Secondary Data**, which is obtained from existing sources, such as those available from various government institutions, open and publicly sources, and private entities; and
- **Derived Data**, which is developed using the above types of data, from various analysis including in GIS, analytical processes, together with assumptions and estimates, to interpret where some data is missing.

Sufficient and consistent data quality is vital to any risk assessment and its outputs. Data acquisition can be time consuming and expensive so, before starting this analysis, it is necessary to identify the information available and their appropriate sources. Some data is easy to obtain as end-user products or through open access sources, whilst other data can be derived using different freely available datasets. Some data, however, may need to be collected through field investigations or surveys or be purchased, or may not exist (such as hydrological data on some Caribbean islands) so will need to be derived, with appropriate assumptions, from elsewhere.

As described in **Section 4.4**, the scale of the baseline hazard assessment (i.e., national, regional, local/detailed level), the extent of the area to be covered (because natural hazards have spatial distribution), as well as the outputs from assessment, are all crucial in determining the kinds of data needed. In terms of hazards assessed to underpin a national-level vulnerability analysis, the methodology requires either spatially distributed datasets for each hazard type or sufficient stakeholder consultation to identify where hazards are present and their significance. Indicative sources of data to be used in the Caribbean region are presented in **Table 3**.

Gaps in the required datasets are likely to be a recurring problem. This could include hydrological and meteorological datasets which may either be completely absent or may have missing time periods in the climate data. This may limit the ability for the modelling to accurately assess the resulting hazards, such as the increased flood risk due to rainfall. Or the converse, without an existing flood risk map, an estimation of how changes in rainfall predictions result in flood risk to the road network may be difficult or impossible. It is therefore important to apply numerical models that avoid any bias in interpolation, and also to improve these hydro-met datasets so that the CRVA process is able to be improved and strengthened in the future.

Some data from international and regional open-sources datasets may be usable. However, these tend to offer a lower resolution, which may limit results, particularly if required at a more local level. It is therefore recommended to use national and local sources of data wherever possible and use field surveys and historical records of disaster events to check that predictions from the CRVA are in line with that experienced on the ground (also referred to as ground truthing).

For data to be useable it also needs to be provided in a format suitable for processing, modelling and for spatial analysis in GIS. This may require some datasets with limited data points (e.g., locations of schools and hospitals, identification of roads which serve as bus routes) to be entered manually into GIS.

Table 3: Data required and potential international and regional sources for CRVA in the Caribbean

Basic Data Sets	Specific Data	Potential International Datasets
Climate indicators	Impact of climate change for different climate change scenarios, modelled in Global Climate Models and localised to see the impact in different parts of the	Koninklijk Nederlands Meteorologisch Instituut (KNMI) Climate Change Atlas: https://climexp.knmi.nl/start.cgi

	world. A combination of Global and/or Regional Climate Models might be used. The choice of scenario (Representative Concentration Pathways, RCPs) will inform the 'climate uplift'[8] that is considered. Impacts of climate change predicted on temperatures, precipitation, as well as predictions for sea level rise.	Sea levels to be obtain from Global Assessment Report Risk Data Platform: https://risk.preventionweb.net Additional information can be obtained from The CARIBSAVE Climate Change Risk Atlas (CCCRA): https://www.caribbeanclimate.bz/
Natural hazards data	Landslide data, including soils and vegetation	Nasa Open Portal, Global Landslide Catalog (GLC): https://catalog.data.gov/dataset/global-landslide-catalog-export
	Rainfall	Rainfall from relevant meteorological agency or similar from respective country, or utilising another national dataset where this is not available. For example, Caribbean Weather Impacts Group (CARIWIG): http://www.cariwig.org/ncl_portal/#info
	Floods and flash floods, including the locations of major rivers, streams and lakes.	National sources from the relevant land and survey department or similar from respective country. OasisHub Ltd: https://oasishub.co/ (at extra cost)
	Storm surge	Global Assessment Report Risk Data Platform: https://risk.preventionweb.net (again this should be aligned to the climate change scenario selected)
	Wildfire events, droughts and earthquakes	Global Risks Data Platform: http://preview.grid.unep.ch/ Caribbean Institute for Meteorology & Hydrology / Caribbean Regional Climate Centre: http://rcc.cimh.edu.bb/
Road network data	Trunk, regional and local roads, including road sections, names and classifications, and horizontal alignment	National sources from the respective government bodies, if available. If not or if partially available, (additional) primary data

[8] The 'climate uplift' will depend both on the future date range chosen (e.g., + 20 years, + 50 years) and climate scenario change (e.g. aligned to a 1.5°C, 2°C or 4+°C post-industrial temperature rise). Currently. climate mitigation efforts are in line with the latter, but international commitments aim to achieve the former. Predicting inputs based on pessimistic climate scenarios may require coastal assets to be abandoned in the Caribbean, whilst the former could result in under-design/provision of resilience measures. A realistic choice should align to the level of ambition to cut road transport carbon emissions, as part of Caribbean and global efforts to limit impacts, which will hit Small Island Developing States (SIDS) the first, and hardest.

	information for all of them, and vertical alignment information for local roads. Detailed information on road formation, pavement and condition. Detailed information on bridges, culverts, bottlenecks, break points and drainage systems. Location of bus routes.	may need to be collected through a road inventory and condition survey activities. Public transport routes can be obtained from the respective bodies. Regional source available: http://caribya.com/
Road Usage	Traffic count data	National sources from the respective government bodies, if available. If not, need to use Moving Observer Counts.
Topographic data	General and detailed contours Digital Elevation Model (DEM) at 30x30m resolution ideally	DEM can be obtained from USGS: https://earthexplorer.usgs.gov/ Contour lines can be generated from the DEM. The level of vertical accuracy of the DEM will affect the ability of flood risk to be modelled in the GIS environment if road elevation is also known (see above).
Socio-economic data	Population statistics and density including breakdown by gender and age, typically based on decennial census. Locations of primary and secondary schools; hospitals, health centres and dispensaries; village centres; markets centres; airports and seaports; tourism; major industrial infrastructure; and portable water facilities. Poverty levels by location.	National Bureau of Statistics of the respective country, normally available, supplemented with Labour Force Surveys if necessary. WorldPop: http://www.worldpopdata.org/
Administrative data	District divisions, wards and villages boundaries. Location and names of settlements.	National sources from the respective government bodies, if available. International free sources include: OSMaxx: https://osmaxx.hsr.ch/ Export Tool: https://export.hotosm.org/en/v3/ DIVA-GIS: http://www.diva-gis.org/ Global Risk Data Platform: http://preview.grid.unep.ch/

Data is normally provided in different formats, such as Excel files (e.g., for hydro-meteorological baseline data) or inconsistent GIS formats or even analogue data (maps). Different sources of spatial data may use different GIS coordinate systems and projections. This mismatch can present additional problems when working with data from different sources. In order to overcome this problem, it is recommended to use the UTM (Universal Transverse Mercator) reference system. The official and latest reference coordinate system in the Caribbean countries is the World Geodetic System 1984.

5.2. Overcoming data gaps

On some occasions, we may find the information available from the Government institutions is either ambiguous or incomplete, meaning that the datasets may not be reliable enough to ensure accurate GIS modelling results. Although it is sometimes not possible, it is recommended to allow in advance a data contingency budget which will cover any unexpected surveys that need to take place to verify and complete the datasets.

The road inventory database (exposure) may be the most economical and easiest data to collect first-hand. For instance, road pavement condition data can be collected by a visual assessment. This requires a suitable vehicle, a qualified engineering team, a good camera, and some days (and therefore per diems) travelling on the ground. A spreadsheet can be prepared with the list of primary and secondary roads to be assessed, excluding any tertiary or other roads if the budget does not allow for it. The engineers will need to judge the condition of each road segment using for example four grades: Poor, Fair, Good, Excellent.

Redundancy, information on alternative routes, can also be collected by a team formed by local users of the road network. International experts who do not know all the routes in detail, may struggle or miss some routes. It will be necessary to note potential roads that can be used if the main routes are blocked. This information will feed the hotspot (Exposure - Vulnerability - Hazard, EVH) modelling.

Any missing critical facilities or other road infrastructure assets, such as hospitals and schools or bridges and culverts, can also be collected first-hand. This will require a preliminary map which will be verified and completed during the field visit. GPS equipment will allow tagging the exact coordinates of the missing asset which will be transferred onto the GIS platform.

On the other hand, the lack of recent topographical information or Digital Elevation Model, may increase the funding needed to overcome data gaps. If the existing information is not sufficiently accurate or the resolution is poor, we may be experiencing difficulties when specific sites (small road sections) of the road network want to be modelled. The only solution would be to undertake a proper survey of the areas of study, bearing in mind this would be a costly option.

Social data may not always be digitized, or data may not represent variables that are desired, e.g., data on the number/percentage of females in households may be available but number/percentage of female headed households might not be accessible. The former still provides a useful proxy, even though it is not the preferred variable.

Finally, mention that it is worth checking in detail the outputs of other programs that may be running in parallel in the country. It could happen that other consultants are currently collecting relevant information which could help updating the ambiguous shapefiles with more recent data.

5.3. Data storage and metadata production

After the various datasets have been collected and checked for quality and usability, they need to be stored in a central database repository. This will avoid the risk of redundancy and data loss (see **Step 1.2** and **Step 1.3**). It is therefore necessary to convert different data formats into a raster data format for spatial analysis, utilising software-based export and transformation routines.

Documenting this metadata is an important element in data management and will provide clarity of what data is utilised in the modelling, and aid future updates. Metadata is data which describes and provides information about the datasets and describes the content and characteristics of the different files and how to interpret them. This includes where and when the data was obtained and analysed, the responsible institution, instructions for searching and other functions. Standardised metadata editors are included in GIS portals.

Metadata structure should follow acceptable standards whether adapted for the country's National Spatial Data Infrastructure (NSDI) protocols and standards or, in the absence of an NSDI, adapted for ease of establishment of appropriate records -management. The ISO Standard 19115 may be adopted for preparing the metadata for the datasets collected. Being cognizant of the data quality and data handling problems that are common in many Caribbean countries, certain metadata elements should be prioritized. Examples of prioritized metadata elements include title; detailed description; access constraints; use constraints; dataset credit; datum; and originator. A list of recommended metadata to be considered and included is set out in **Table 4**.

Table 4: Metadata elements list (Produced by the Consultant)

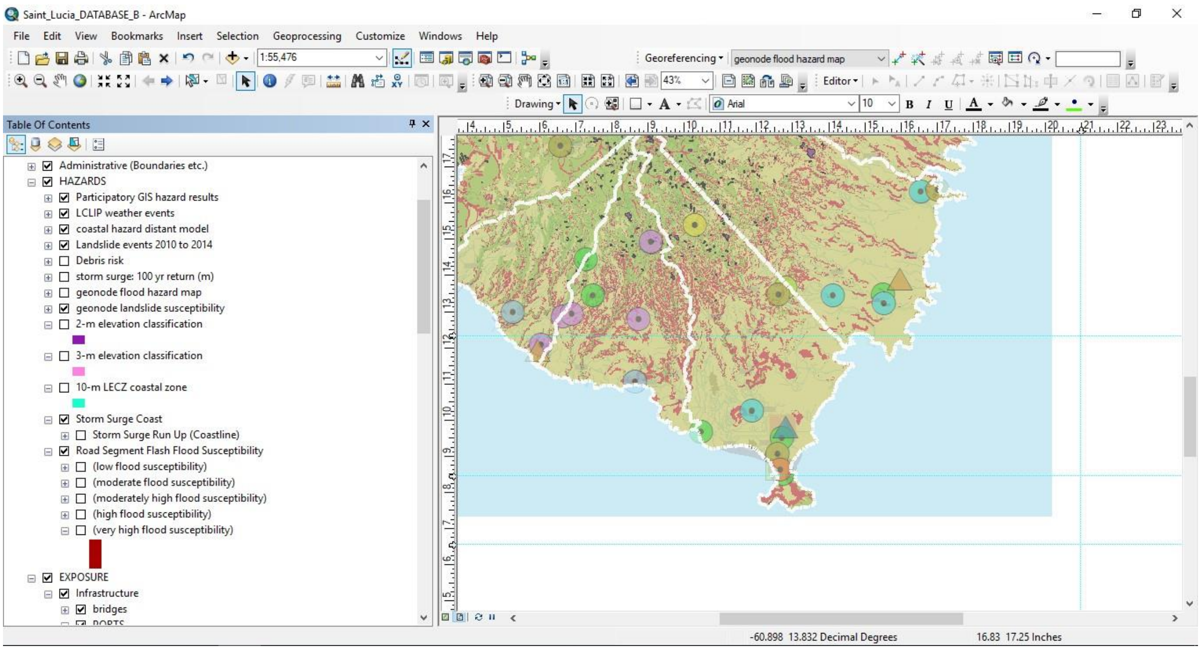
	Metadata Requirements and Mandatory Fields *Selected ISO 19115 and Federal Geographic Data Committee (FGDC) Metadata Content standards*	
FIELD	**CATEGORY**	**DEFINITION**
Title	**Identification**	This is the name by which the data set is known.
Detailed Description	**Entity and Attribute**	Description of the entities, attributes, attribute values, and related characteristics encoded in the data set.
Access constraints	**Identification**	These are the restrictions and legal prerequisites for accessing the data set.
Use Constraints	**Identification**	These are restrictions and legal prerequisites for using the data set after access is granted.
Dataset Credit	**Identification**	Recognition of those who contributed to the data set.
Contact	**Identification**	Contact information for an individual or organization that is knowledgeable about the data set.
Citation	**Identification**	Information to be used to reference the data set.
Publication Date	**Identification**	The date when the data set is published or otherwise made available for release.
Originator	**Identification**	This is the name of the organization or individual that developed the data set.
Time Period	**Identification**	Time period(s) for which the data set corresponds to the currency reference.

Datum	**Spatial Reference**	The description of the reference frame for, and the means to encode, coordinates in the data set
Status	**Identification**	This is the state of and maintenance information for the data set.
Security	**Identification**	This speaks to handling restrictions imposed on the data set because of national security, privacy, or other concerns.
Source Information	**Data Quality**	This speaks to the source data used in creating the data specified.
Standard Order Process	**Distribution**	These are the common ways in which the data set may be obtained or received and related instructions and fee information.
Metadata Reference	**Metadata Reference**	This is information on the currency of the metadata information, and the responsible party.

5.4. Database structure

In order to store and process the data collected, an integrated GIS database is required. For the Planning for the Integration of Climate Resilience in the Road Transport Sector in the BMCs of the CDB Project, the files are stored in an ESRI ArcCatalog, which is the database system of ESRI ArcInfo. **Figure 2** shows how the files (vectors and rasters) as they are organized and stored as different GIS database layers.

Figure 2: GIS Database screenshots (Produced by the Consultant)



6

CRVA METHODOLOGY STEPS AND TECHNICAL NOTES

This section details the steps to be followed to produce a Climate Risk and Vulnerability Assessment once the data has been collected, integrated and cleansed. The four steps set out below require the different datasets to be assessed using the GIS platform. Descriptions of key terminology used for the analysis complements that included in **Section 4.2**.

The following four steps are part of the CRVA methodology used to assess the data required for the individual components of Exposure-Vulnerability-Hazard (EVH), to develop a GIS database, and obtain a list of hotspot locations. The datasets, now structured into different GIS data layers, are used as an input. An additional layer analyses these different layers, which are in effect overlaid over each other, with the EVH 'Resilience Index' to calculate the locations of hotspots on the road network. These locations are then targeted through on-site assessment (ideally by an engineer, geotechnical specialist and hydrologist – depending on the hazard present) to recommend engineering solutions and resilience measures. These interventions may be just at the identified hotspot locations, or wider recommendations that are applied across the whole network or associated support. All of these recommendations should be combined into the investment plan[9]. See **Figure 1** for an illustration of the process.

- Step 1: Exposure assessment
- Step 2: Vulnerability assessment
- Step 3: Hazards assessment
- Step 4: Exposure-Vulnerability-Hazard (EVH) mapping and Hotspots

STEP 1: Exposure assessment

Introduction

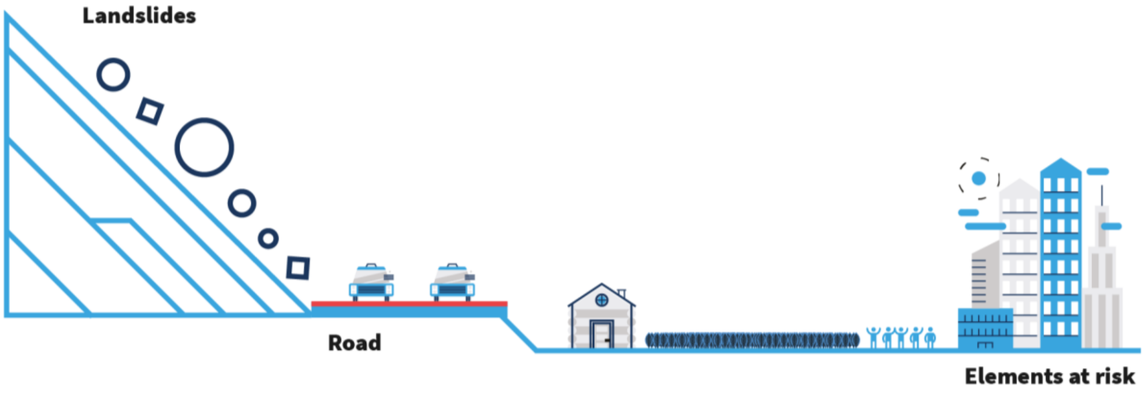
Exposure is defined by the IPCC AR5 report as '*the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected*'.

In this study, focused on the road transport sector, exposure is defined as the presence of road transport infrastructure (e.g., roads, bridges and culverts) that could be adversely affected by climate-related hazards, both directly as well as impacting other economically/socially important infrastructure and communities that are reliant on the road transport infrastructure.

Step 1 is focused on the physical assets 'at risk' in the road network itself. **Elements at risk** include population, properties, economic activities, including public services, or any other defined values exposed to hazards in each area. They can also be referred to as **assets**.

[9] Please note that the incorporation of resilience measures into the country's road investment program and prioritisation of the road infrastructure investments are not part of the CRVA process itself (but how it relates to wider road asset management) and are therefore not included in these guidelines.

Figure 3: Elements-at-risk in case of landslide hazard (Produced by the Consultant)



How exposure relates the road network, road infrastructure assets and elements at risk is set out in **Box 1**.

Box 1: Relating Exposure to the Road Transport Network as well as other Elements-at-Risk

This box explores sets out three questions that should be asked when exploring the exposure of the road transport network:

- *Firstly, **where*** is the Road Corridor exposed?
- *Secondly, **what*** road infrastructure assets are exposed?
- Thirdly, ***what else*** might be affected?

The *overall* exposure is whether there is a hazard that occurs at the same location as a point (or stretch) of the overall road corridor. However, the existence of some infrastructure aspects (e.g. retaining wall, drainage structure of sufficient capacity to cope with extreme flood events, slope protection, embankment to raise the overall road level) may reduce or eliminate exposure for the rest of the road transport infrastructure assets in all but the most extreme case. This means the overall exposure of the road corridor at a specific location and the exposure of different infrastructure assets may differ.

In some cases, actions to reduce the exposure of the road corridor will affect the level of exposure elsewhere. For example, an embankment might protect an elevated road from flooding, but also increase flood risk on one side of it, which might increase the flood risk in a community or for a school, for example. Similarly, actions to reduce the risk of landslide on a road might also reduce the landslide risk on other assets (see Figure 3).

Therefore, these guidelines recommends that exposure to be considered in three ways: firstly to assess the exposure of the overall road corridor to a specific, and then overall combination of hazards (through identification of a 'hot spot' location in GIS); secondly, through assessing (including through site visits and engaging with local road engineers) the extent to which different road infrastructure assets are exposed; and thirdly assessing the extent to which this impacts (positively or negatively) on other elements of risk beyond the road corridor, including through engaging with wider stakeholders.

Guideline

Step 1.1 Request and obtain base data

Base data that will form the background setting for the GIS maps needs to be collected from the different government institutions of the country of study. **Section 5.1** provides further guidance on data collection and management.

Typical base data that will be required to develop the EVH mapping is shown in **Table 5**Table 5: Summary of base data.

Table 5: Summary of base data

Main category	Sub-Category	Feature types
BASE	**Political/ Administrative/ Civic Boundaries**	Counties, parishes, settlements
	Topography	General and detailed contours, land-use data, spot heights, spot depths, peaks (volcanic, other),
		Local survey department topographic map series (1:10k, 1:50k) Digital Elevation Model (DEM) for terrain surface Major landmarks, general and detailed bathymetry
	Physical	Major and minor fault lines, coastline

Aerial or satellite imagery would also be considered part of the base maps and can be consulted, if available, to check the location of certain features. Google maps is the most popular free source available on the Internet. OpenStreetMap is free of copyright.

Step 1.2 Define exposure indicators and generate a data inventory

Exposure indicators relevant to road transport assets need to be identified and collected. It is recommended to keep updated a data inventory which includes the preferred resolution/scale of each of the GIS layers, as well as the desired geometry (polygons, polylines, points, raster, etc.) and the desired format (ESRI shapefile, ESRI raster). This is also applicable with other main category data be collected, such as hazards, sensitivity data, etc. An example of this is set out in **Figure 4**.

Figure 4: Base data inventory spreadsheet (Produced by the Consultant)

GIS DATA REQUIREMENTS FOR THE PROJECT: *Planning for the Integration of Climate Resilience in the Road Transport Sector in the Borrowing Member Countries of the Caribbean Development Bank*

PROJECT DATA SPECIFICATIONS - BASE DATA CATEGORY

1. No.	2a. Main Category	2b. Sub-Category	3. Feature Layer Name	4. Desired Specific Attribute	5. Priority Designation (High/absolutely necessary - H; Medium - M; Low - L)	6. Required Min Scale/ Resolution	7. Desired Geometry/ Data Model	8. Desired Format
1	A. BASE	A.1 POLITICAL/ ADMINISTRATIVE / CIVIC BOUNDARIES	counties	names	H	1 : 50,000	polygons	*.shp (ESRI shapefile)
2			parishes	names	H	1 : 50,000	polygons	*.shp (ESRI shapefile)
4			settlements	names	H	1 : 50,000	points	*.shp (ESRI shapefile)
7			bays	names	M	1 : 50,000	points	*.shp (ESRI shapefile)
10		A.2 TOPOGRAPHY	contours_general	100-m	H	1 : 50,000	polylines	*.shp (ESRI shapefile)
16			major landmarks	names	H	1 : 20,000	points	*.shp (ESRI shapefile)
18			digital elevation model	elevation value	H	6-m	raster	ESRI raster
26			coastline		H	1 : 20,000	polylines	*.shp (ESRI shapefile)

Table 6 summarizes the priority datasets that should be collected from the relevant government ministries and departments in the country of study in terms of exposure data.
It is essential to check the accuracy, resolution and quality of each exposure indicator. Some shapefiles may not be suitable to be used for the modelling exercise because they either lack sufficient accuracy or relevant attribute information. See **Step 1.3** for further guidance.

Table 6: Summary of exposure data

Main category	Sub-Category	Feature types (layer names)
EXPOSURE	**Infrastructure**	Bridges and culverts' locations (and levels if available). Major roads and junction locations. Centre line of the road network. Public transport routes (bus)
	Natural Resources	Major water courses (rivers), lakes
	Socio-Economic	Age, gender, employment, income/poverty, population numbers and density, GDP per capita, key economic activities
	Critical / Emergency Services	Location of fire stations, police stations and main office locations, hospitals and health centres/clinics, hotels and tourism centres, schools, community centres, places of worship, water supply and sewerage facilities, ports and airports, public buildings, electricity distribution network (including power stations and substations.

Map of existing Road Network

As an input to this sub-task, GIS maps should be prepared and validated for all the roads in the area under analysis. The road network should be broken down into identifiable road sections following the guidance of the local road engineers. Road sections and the associated data can be generated as a spreadsheet by the road's authorities for use in this analysis. The method for defining appropriate road sections is given in **Box 2**.

Box 2: Defining road sections, road links, infrastructure assets and road locations

In these guidelines, the term **road section** refers to a stretch of road that varies in length and may be many kilometres long. The sections should be defined to distinguish between different population or industrial centres. Sections will generally start or finish at major road intersections or infrastructure assets.

Generally, road sections will already be defined by the country's road institution, however it may be appropriate to sub-divide these sections to better represent variations in resilience or vulnerability. In defining road sections, the following principles should be adopted:

- Road sections should, as far as possible, be homogenous in terms of road standard, surface type and traffic levels;
- Road sections should always start or finish where there is a major settlement or traffic generator, e.g., a major town or industrial facility; and
- Where ownership of a road changes, for example between a state road and a local road, there should be a break between road sections.

For these guidelines, a **road link** is defined as a length of road between two defined points, but which may include a number of road sections.

A **road infrastructure asset** is a distinct structure within the road section. This could be a drainage structure, e.g., a culvert, a bridge. Each asset will typically be made up of several road elements.

A specific **road element** can be defined as a constituent part of the road infrastructure asset. For example, this could be a bridge abutment, embankment or road pavement.

Step 1.3 Analyse and generate a metadata elements list

Once the exposure indicators relevant to road transport assets are identified, data should be collected in accordance with the data collection methodology described in **Section 5**.

The quality of existing electronic data needs to be assessed, and formatting carried out prior to populating the database. Where information only exists in hardcopy/Microsoft Office/PDF format, these files should be converted appropriately (scanned and geo-referenced) and then digitized to enable further derivation of vector information. Digitization may also need to be employed to extract information from existing, state-owned Red-Green-Blue (RGB) composite satellite imagery at appropriate vintages and resolution. Transformations such as raster conversions may need to be carried out from vector data to derive important modelling datasets (such as digital elevation models from contour or spot height vector data sets).

The quality of the data and information sets collected should be assessed, both alone and in combination with other datasets. This may lead to the acquisition or development of additional data sets where data gaps are identified, to provide acceptable substitutes (proxies) to fill these data gaps. All data and information have to be of an acceptable quality for use in the GIS model.

The asset data inventory should be further developed in one of the following three formats:

(i) as an open source based Geo-node platform; or
(ii) as an ESRI-proprietary ArcMap geodatabase format; or
(iii) as the MIL's customizable-&-scalable proprietary web-based software.

Each of these options has its own advantages and disadvantages. However, the most important factor in determining which type of data inventory to use tends to be the capacity of the host agency to keep, update and maintain the GIS database in future. Stakeholder consultations can be used to assess these internal capacities and assess and determine the most suitable host agency. The relevant agency will need to be equipped with the necessary host requirements (hardware, software, networking). For instance, based on in-country assessment in Saint Lucia, the GIS Unit of the Ministry of Infrastructure, Ports, Energy and Labor, was identified as being the most suitable host candidate for an ArcMap GIS database.

The asset data inventory should also include metadata (see **Section 5.2**). This will include: the date published; where data was sourced from; the format of the data / information; whether data is geo-referenced / gridded / GIS compatible. The inventory also tags the available data against the indicator(s) it contributes to.

Step 1.4 Production of exposure maps

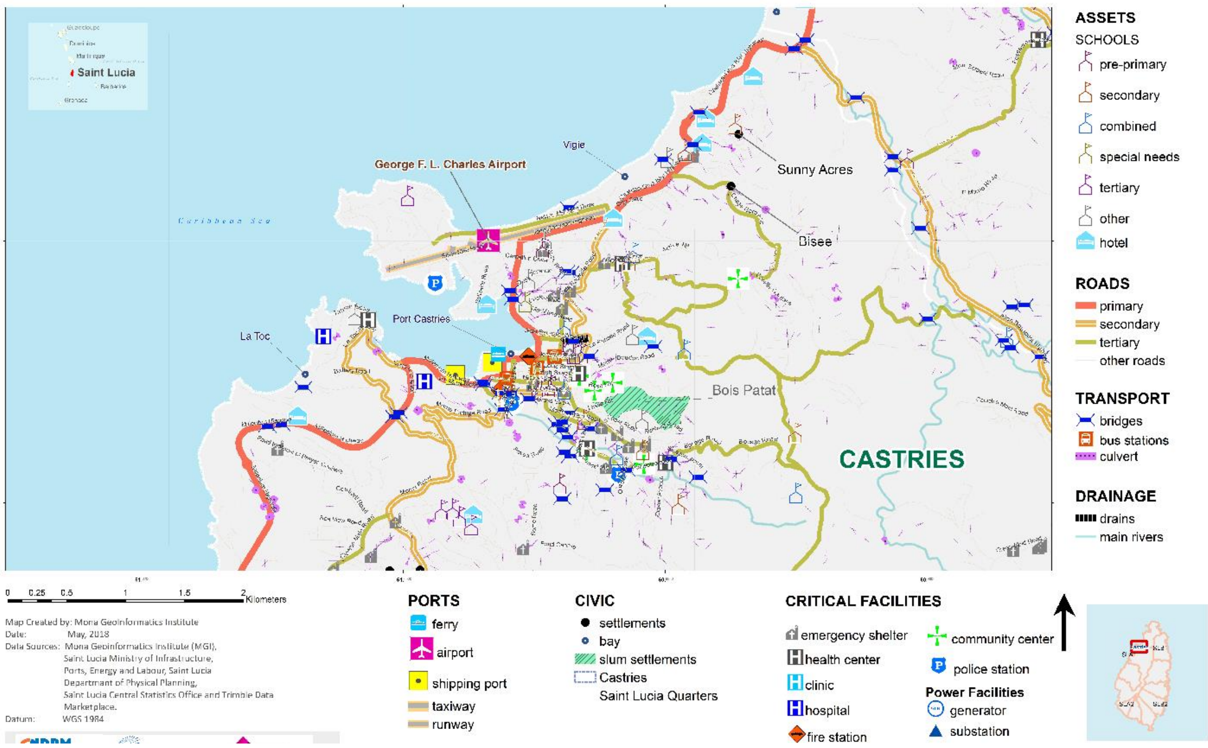
Once the road network location and the main facets of road transport infrastructure have been identified and stored in the GIS database, exposure maps can be produced.

In some cases, an engineering site assessment is required to identify or check the level of exposure of infrastructure assets at one or more locations. For example, a lack of elevation data for a road would mean that the vulnerability of the road asset modelled will not take into account where it is in a cutting or on an embankment, which will affect the level of exposure.

Similarly, a lack of data on the elevation of bridges (or capacity of culverts) would mean that the risk from inundation from river flooding is not able to be modelled. Therefore, at least to some extent, the aim of the CRVA produced will be to use the datasets that are available to best inform site assessments. It is important to mention that any vulnerability data missing, such as road level, will need to be collected through proper site surveys, which require additional funding and can't be done during the site assessment.

An example of an exposure map produced in Saint Lucia is included in **Figure 5.**

Figure 5: Exposure map of Castries, Saint Lucia (Produced by the Consultant)



STEP 2: Vulnerability assessment

Introduction

Vulnerability is defined by the IPCC AR5 report as '*the propensity or predisposition to be adversely affected*' and this encompasses '*a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt*.' This statement includes two related concepts, *sensitivity* and *adaptive capacity*, which are defined as follows:

- **Sensitivity** is defined by the IPCC as *'the degree to which a system or species is affected, either adversely or beneficially, by climate variability or change'*. It is *'typically shaped by natural and/or physical attributes of the system'* but also refers to *'human activities which affect the physical constitution of a*

system, such as tillage systems, water management, resource depletion and population pressure'. As most systems have been designed to and therefore adapted to historic climate (e.g. construction of bridges, road drainage systems), *'sensitivity already includes historic and recent adaptation'*.
- **Adaptive capacity** is defined by the IPCC as *'the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences'*.

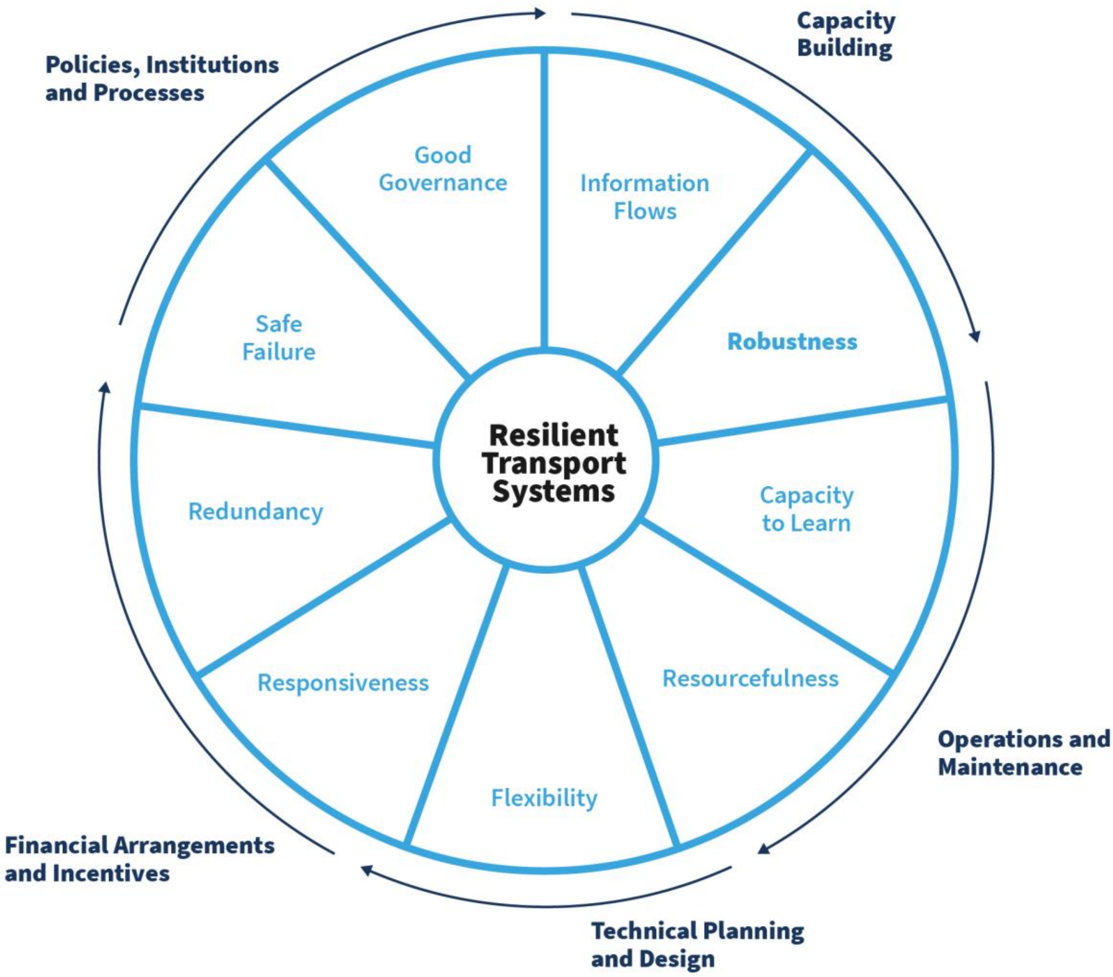
In this study, focused on the road transport sector, vulnerability is defined as the propensity of the road transport assets, network and institutions to be adversely affected by climate-related hazards and their ability to respond[10]. This is established by determining:

- The characteristics of the assets that make them **sensitive/susceptible** to the adverse effects of an increasingly variable and changing climate; and
- The **adaptive capacity**: the ability of the road network and institutions responsible for road transport to cope with climate variability and change.

As a result of how these aspects combine across the road asset management cycle (design, construction, operation and maintenance), the range of resilience measures varies widely at different levels. Interventions consider infrastructure assets, vulnerable locations, interface with wider infrastructure systems and elements at risk, institutional aspects, capacity building, policies' update and development, among others. These dimensions are represented in the following Resilience Wheel on disaster risk management in the transport sector, included in **Figure 6**.

[10] Although it is noted that the associated vulnerability of other 'elements-at-risk' close to or affected by changes to road infrastructure assets should also be considered.

Figure 6: The Resilience Wheel (different types of resilience in a transport system)



Source: Adapted from Disaster Risk Management in the Transport Sector, 2015, for the World Bank by IMC Worldwide

Guideline

Step 2.1 Define vulnerability indicators
The different vulnerabilities of road transport infrastructure assets to existing hazards need to be identified. The climate-related impacts need to be considered when there are high probabilities of occurrence and when the consequences to the road infrastructure asset are severe. Eventually, this exercise will allow to explore different ways of improving resilience in that particular asset.

Table 7 explores the range and nature of climate-related vulnerabilities of road transport infrastructure in the Caribbean. The availability of data on each of the features is critical to help analyse asset vulnerability.

Table 7: Climate-related vulnerabilities of road transport infrastructure

Asset	Climate-Related Impacts	How Does This Relate to Road infrastructure Assets
Roads	**Flooding.** This can either be due to river flooding, coastal flooding or flash-flooding. These can: * Make roads impassable to road users depending on the water depth (flooding).	▪ Paved surfaces are much less vulnerable to damage from flooding than unpaved surfaces. Impermeable road surfaces will divert surface water and protect road

Asset	Climate-Related Impacts	How Does This Relate to Road infrastructure Assets
	* Expose the road foundation to water and cause deterioration of road (saturation) * Cause erosion of road and/or breakup the road surface where flowrates are high (scour)	meaning the road should remain strong and passable when wet. ▪ Surface condition data (such as International Roughness Index, IRI) or structural assessments (deflectograph, Falling Weight Deflectometer, FWD) can be an indicator of road condition and life, respectively. ▪ The presence of drainage assets and an adequate maintenance regime will reduce a road's vulnerability, notably to saturation and scour. ▪ Changes in land use, such as deforestation and/or increased development, will affect permeability and/or size of a catchment area, which can affect overall run-off volumes and flow rates. This can change the flood and scour risk.
	Blockage and damage from landslides and rockfalls: Generally, the greater the slope, the greater vulnerability for landslides. However, the geology, pore water pressure (the 'wetness' of the slope), loadings on the slope/land use, can all have a significant effect on the level of risk.	▪ Roads cut into slopes (through changing slope angles and including 'made ground') increases vulnerability to landslips/landslides/flash floods. Embankments' vulnerability will change with time. Detailed quantified analysis is complex. ▪ The presence of robust and well-maintained retaining structures is a simple measure that can reduce vulnerability against landslides. Bioengineering measures (e.g., geotextiles and planting to stabilize slopes) may be more cost effective over longer lengths of road.
	Storm surges and coastal flooding: Coastal flooding can both flood the road and damage the road and associated infrastructure through wave action.	▪ Coastal defence structures can reduce coastal roads vulnerability (elevation can be useful where comparing against estimated surge heights etc.). These can range from hard-engineering structures (e.g., walls) or softer non-engineered solutions (e.g., mangrove planting).

Asset	Climate-Related Impacts	How Does This Relate to Road infrastructure Assets
	Temperature: Extreme temperatures can increase the softening of bitumen. Additionally, the underlying ground beneath a road (the sub-grade) can be vulnerable to drying out, affecting integrity and stability, due to long periods of drought.	▪ The vulnerability to extreme temperatures will depend on pavement construction and materials.
Drainage (pipe, culvert, channel, etc.)	**Flooding (drainage capacity exceeded)**, so flows surcharge and back up, can cause localized or widespread flooding, which can cause damage due to the diverted water. This is either from exceedance of the design parameters from rainfall intensity/duration and/or **drainage assets in poor condition** from debris build-up, accumulation of rubbish, vegetation growth etc. - often from a lack of maintenance - so that design flows capacities are reduced.	▪ The location and size of drainage - the larger and more frequent the drainage pipes/channels, the generally the lower the vulnerability of that section of road. ▪ The amount of maintenance on the road can act as a proxy for the condition of the drainage assets (although this does not mean they will not flood). ▪ Approximate Storm Return Periods: The basic return period for most highway drainage is 1 year, but systems should not surcharge into road in a 1 in 5-year event. Culverts carrying watercourses under main roads typically have a 1 in 10-year return period design. ▪ Check dams (Sabo dams11) can indicate vulnerable areas to flood or erosion from water flows
Bridges	**Wind:** High wind speed	▪ Windspeeds in excess of 80mph can be used as a general threshold at which bridges are likely to be closed to all traffic[12]. However, this applies primarily to major bridge structures. For example, current practice in Saint Lucia is not close to bridges due to high wind speeds, primarily because they are low level and short span.
	Flooding: Typically, river flooding, In addition to exceeding design flow levels, bridges are very vulnerable to debris blockage, especially during flood events when material carried by the flow can build up under the bridge deck or large culvert and the build-up of water pressure can cause	▪ Bridges under a significant depth of flood water can be considered unpassable to all traffic. ▪ Bridges will be affected by road access at the entry point to the bridge and beyond

[11] 'A study on debris flow outflow discharge at a series of sabo dams': https://www.jsnds.org/ssk/ssk_33_s_043.pdf
[12] High Wind Procedures in Operation at Tay Road Bridge, Scotland. Source: www.tayroadbridge.co.uk/traffic/high-wind-procedures

Asset	Climate-Related Impacts	How Does This Relate to Road infrastructure Assets
	overtopping, loss of the superstructure/deck, scour, divert water flow around a bridge to damage approach roads/abutments, or other significant damage.	- so even if a bridge is not vulnerable the roads used to access the bridge might be.
	Scour: Bridges and other structures which have foundations in a river are at risk from scour. The characteristics of the river and interaction with structure are fundamental to assessing scour risk (among many other factors). Scour risk needs to be assessed on a case-by-case basis and will very likely need detailed site surveys and details of the structure's foundation in the river.	▪ There is no meaningful way to assess a vulnerability of a bridge to scour using GIS datasets, except on zero scour flood risk basis – i.e., where water is not flowing, or bridge abutments are located far above predicted maximum flood levels). The scour risk needs to be assessed on a case-by-case basis and requires detailed site surveys and details of the structure's foundation in the river. It will also be affected by debris build up (and hence the maintenance regime) as noted above.
Signs, lighting, signals, gantries, power utility cables	**Access:** High winds can block access indirectly through fallen trees and debris, etc. Auxiliary infrastructure such as road signs and traffic signals being damaged by strong winds, trees felled by strong winds leading to closure of roads.	▪ Due to the slender nature of most road furniture, other than gantries, they do not suffer greatly in high winds. In that case even if the signals were damaged this does not close access to the road and road users can adapt provided the road is not physically blocked. ▪ Buried utilities and apparatus is vulnerable to water damage or erosion of the road from flash floods.
Coastal defence	Affected by storm surge flood/overtopping wind speed, structural damage - which has secondary effect of damaging or closing roads.	▪ Robust coastal defence structures will reduce the vulnerability of adjacent sections of road or other road transport infrastructure from erosion, wave action, storm surge etc. Coastal deference can be an integral part of the road structure.
Retaining structures	Affected by **flood** whereby excessive loading can cause structural damage - which has secondary effect of damaging or closing roads.	▪ Robust retaining structures - will reduce the vulnerability of the road to landslides.

In addition to assessing whether a road's specific infrastructure assets can be made more resilience, the overall adaptive capacity of the road network could be improved. For example, the existence of alternative routes can be considered to maintain access during extreme disaster events. Assessing whether it is best to improve a specific asset or divert traffic (or invest in) an alternative route (or mode of transport) should be based on a calculation of additional travel time when a road is disrupted. If a road is simply impassable during a disaster event this time may be relatively short. However, if a road asset is damaged such that is no longer safe and needs to be repaired this could be a far longer time. As repair and replacement of a major structure (e.g., bridge) can take far longer, the resilience of such major structures should be prioritized.

The adaptive capacity of a specific road section will also depend on its condition – as this will affect the extent to which a given exposure to a hazard results in failure that leads to significant time and cost to repair. Therefore, the maintenance history, overall information of road maintenance and repair strategies, and location of planned road rehabilitation, will affect a road's adaptive capacity. Other data sets on adaptive capacity are social indicators which are applied under **Step 4** of these guidelines.

Sensitivity indicators will be characteristics of the road section such as whether it is paved (e.g., flexible or rigid) or unpaved (e.g., earth, gravel) and the condition of the road surface (e.g., excellent, fair, good, poor).

The lack of some vulnerability data will affect the degree to which the hotspot modelling can identify the most vulnerable (as opposed to most hazard-prone and exposed) locations (see **Step 4**). Therefore, site-based engineering assessments are recommended to review the vulnerability factors as well as the vulnerability of the road corridor at the hotspot locations.

Step 2.2 Data quality assessments and normalization
The vulnerability data needs to undergo quality assessments and formatting to standardize data sets and to ensure compatibility. This is a desktop exercise undertaken by the GIS experts to ensure data and information is of an acceptable quality for use in the GIS model.

All the different data values need to be normalized into a range from 0 to 1. For example, considering than an earth road is more vulnerable than a gravel or paved road, the vulnerability of an earth road is given a value close to 1. The same applies to a road with poor drainage condition. Scoring the standard of the road is also based on its resilience, with higher specification roads tending to be more resilient with longer lifespans than lower specification roads.

Generally, there is an inverse correlation between resilience and vulnerability. Therefore, more vulnerable road sections would have resilience values closer to 0, with less vulnerable roads progressively increasing towards 1. **Technical note 1** describes how to calculate the average of all scored and numeric parameters for vulnerability.

Technical note 1: GIS normalization of vulnerability data

A road network consists of road links and nodes. It can be efficiently represented by a polyline vector, wherein each link is a separate vector feature. The vector format needs to be shapefile or another similar format, which can store an attribute table that is used to append all different kinds of additional spatial information. It is expected that a road network, as an element at risk, will contain some basic information per each link, such as road category, Average Annual Daily Traffic (AADT), link length, as well as other specific attributes.

In addition, it should also include its vulnerability to hazards representing the findings from either the data available (secondary data) or the road inventory and condition survey data collected in the field (primary data). All numerical values representing the vulnerability need to be normalized to a range or scale of 0-1. This further implies scoring of nominal data types, such as road surface type, and numeric ones such as road condition expressed as an International Roughness Index (IRI). This data is easily normalized and self-explanatory: the greater the IRI, greater the vulnerability and its value is closer to 1. Proposed normalization scores for quantifying the road category are set out in **Table 8**.

Table 8: Normalized scores for road engineering vulnerability

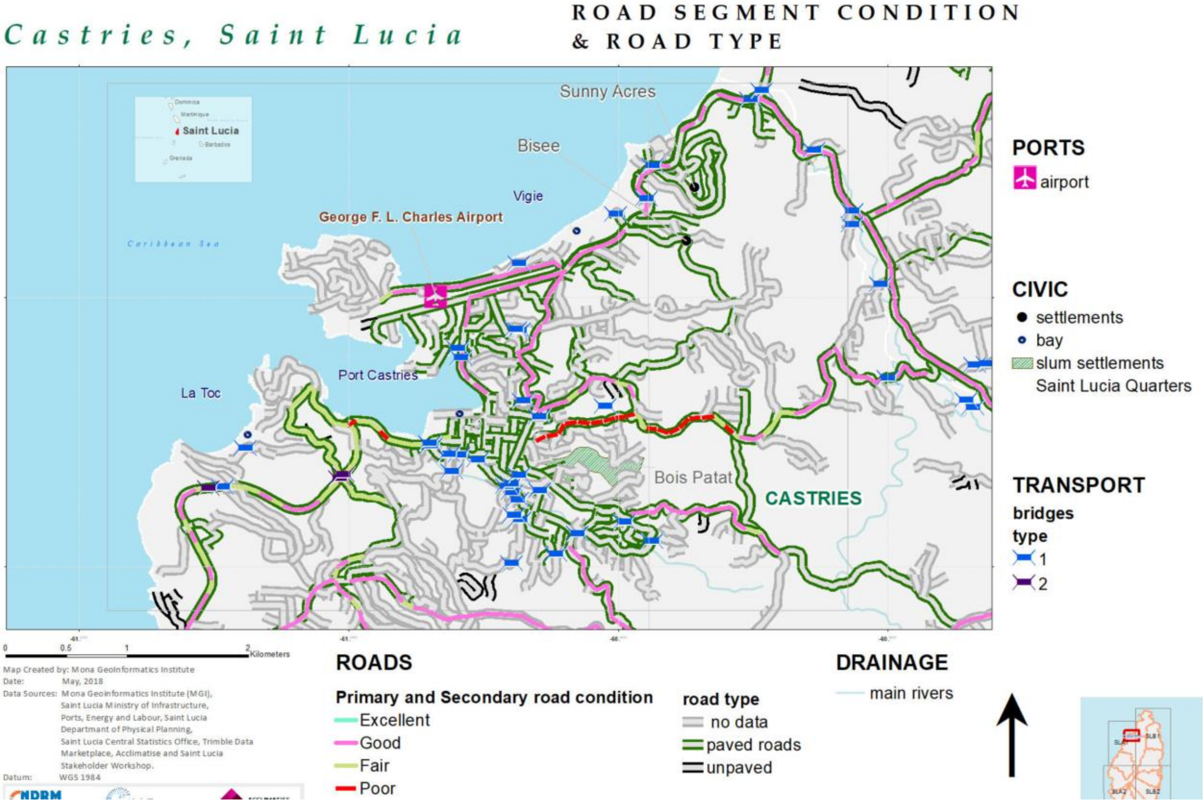
Road category (hierarchically ascending)	Vulnerability score
Very High Vulnerability	1 - 0.8
High Vulnerability	0.6 - 0.79
Moderate Vulnerability	0.4 - 0.59
Low Vulnerability	0.2 - 0.39
Very Low Vulnerability	0 - 0.19

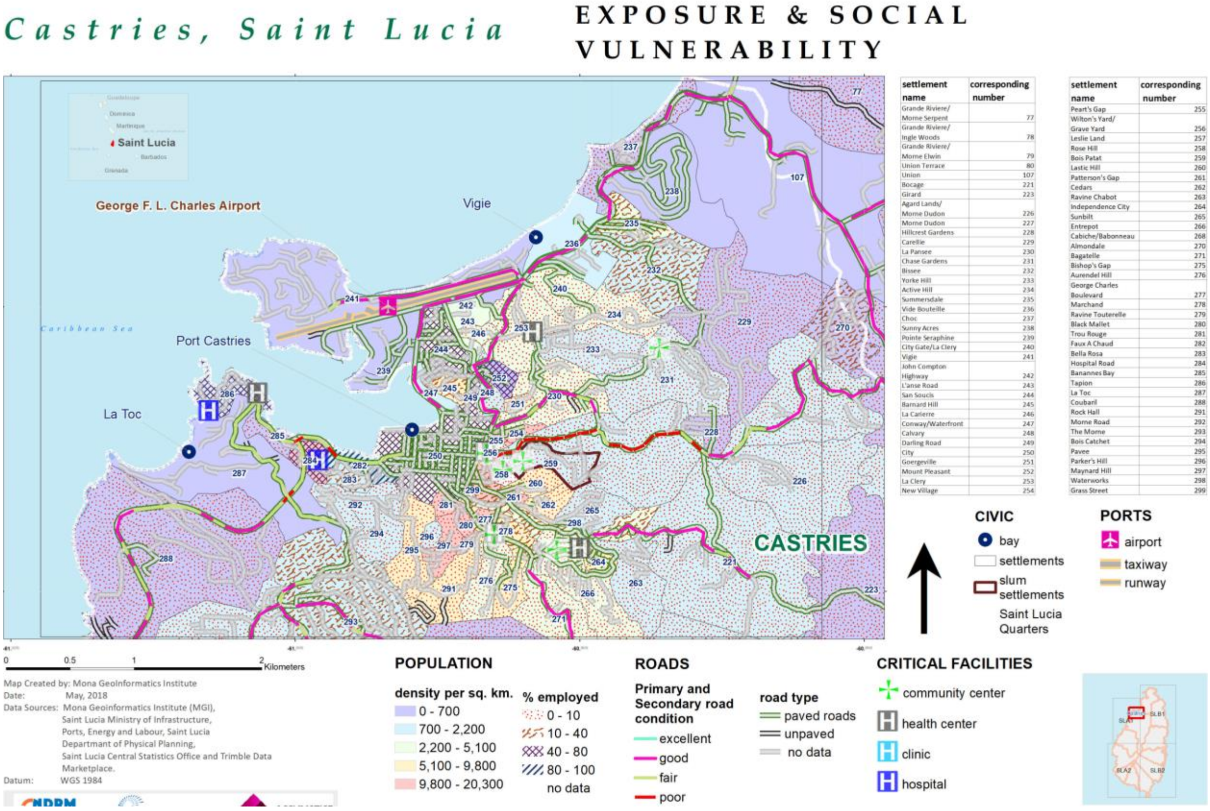
Scoring of the road category should follow a criterion based on the road's vulnerability. It is common that roads of a higher vulnerability have a less resilient structure, and their lifespans are lower compared to the lower vulnerability roads. Therefore, higher vulnerability areas should have values closer to 1, while lower vulnerability areas should have values decreasing towards 0. Vulnerability should represent the overall characteristics of each road link.

Step 2.3 Production of vulnerability maps

Once the vulnerability indicators have been identified, and data has been normalized and stored in the GIS database, vulnerability maps can be produced. The relevant GIS layers need to be activated depending on the type of vulnerability map to be produced. For example, a road condition vulnerability map will show road condition, type and main infrastructure features as well as critical infrastructure facilities, whereas a social vulnerability map will also show the location of social infrastructure indicators (e.g., location of schools and hospitals), and other socio-economic data available such as population density, employment and gender balance.

Figure 7: Vulnerability maps of Castries, Saint Lucia (Produced by the Consultant)





settlement name	corresponding number
Grande Riviere/ Morne Serpent	77
Grande Riviere/ Ingle Woods	78
Grande Riviere/ Morne Elwin	79
Union Terrace	80
Union	107
Bocage	221
Girard	223
Agard Lands/ Morne Dudon	226
Morne Dudon	227
Hillcrest Gardens	228
Carellie	229
La Pansee	230
Chase Gardens	231
Bissee	232
Yorke Hill	233
Active Hill	234
Summersdale	235
Vide Bouteille	236
Choc	237
Sunny Acres	238
Pointe Seraphine	239
City Gate/La Clery	240
Vigie	241
John Compton Highway	242
L'anse Road	243
San Soucis	244
Barnard Hill	245
La Carierre	246
Conway/Waterfront	247
Calvary	248
Darling Road	249
City	250
Goergeville	251
Mount Pleasant	252
La Clery	253
New Village	254

settlement name	corresponding number
Peart's Gap	255
Wilton's Yard/ Grave Yard	256
Leslie Land	257
Rose Hill	258
Bois Patat	259
Lastic Hill	260
Patterson's Gap	261
Cedars	262
Ravine Chabot	263
Independence City	264
Sunbilt	265
Entrepot	266
Cabiche/Babonneau	268
Almondale	270
Bagatelle	271
Bishop's Gap	275
Aurendel Hill	276
George Charles Boulevard	277
Marchand	278
Ravine Touterelle	279
Black Mallet	280
Trou Rouge	281
Faux A Chaud	282
Bella Rosa	283
Hospital Road	284
Banannes Bay	285
Tapion	286
La Toc	287
Coubaril	288
Rock Hall	291
Morne Road	292
The Morne	293
Bois Catchet	294
Pavee	295
Parker's Hill	296
Maynard Hill	297
Waterworks	298
Grass Street	299

STEP 3: Hazards assessment

Introduction

Hazard is defined by the IPCC AR5 report as '*climate-related physical events or trends, or their physical impacts'* that may cause *'loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources'*[13].

The geography, terrain, hydro-meteorological baseline conditions and climate change uplifts need to be studied for each specific country. The main types of hazards that the country experiences need to be identified and relevant data needs to be collected to undertake the hazard assessment. See **Step 3.1** for more information.

Each hazard is standardised into a sliding scale, typically ranging from 0 to 1 (see **Technical note 1** for classification into different categories). The standard assessment procedure for the natural hazards identified is to produce a map for each hazard of study. However, for further exposure, vulnerability and risk assessment, multi-hazard index layers can be used if required (see **Box 3**).

Hazard assessment uses climate change indicators to estimate how the levels of exposure are expected to change in the future. Using existing climate change projections, the output from this step could be a series of maps depending on the number of scenarios to be studied, e.g., medium-term hazards maps (such as for years 2035 and 2065) and long-term hazards maps (considering impacts in 2100 or a 100-year return period). See **Step 3.2** for more information.

Guideline

Step 3.1 Identification of hazards

The most common natural hazards identified in the Caribbean region are tropical storms, storm surge and hurricanes, earthquakes, landslides, floods, droughts and wildfires. An identification process of the type and range of natural disaster events and impacts that experience each country needs to be undertaken. Capturing articles and reports and stakeholder evidence on previous weather events that have had a material impact on transport assets and livelihoods are good methods to identify these hazards. Site engineering visits and consultations with local communities can also help to confirm the findings.

Once the hazards have been confirmed, data and information for these need to be collected. This will start by sourcing data held by government already and that held in open-source datasets. Datasets need to be sufficient to permit spatial analysis of hazard levels across the entire country, requiring datasets to be available at the national, rather than just regional or local scales. It is noted that some countries do not have a meteorological agency with good recent hydrological records, and it may be needed to look at publicly data online from the region, such as CHARIM GeoNode[14]. For data on landslides, it is recommended to use the Nasa Open Portal. Storm surge data is available from the Global Assessment Report Risk Data Platform. Details of wildfire events, droughts and earthquakes can be sourced from the Global Risks Data Platform. Reliable data on floods and flash floods is more difficult to obtain and, in some cases, relevant datasets may need to be purchased under a license from a private entity (for example, OasisHub Ltd). Some sources of natural hazards data for the Caribbean region are shown in **Table 3** in **Section 5.1.**

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[13] Oppenheimer, M., M. Campos, R. Warren, J. Birkmann, G. Luber, B. O'Neill, and K. Takahashi, 2014: Emergent risks and key vulnerabilities. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1039-1099.

[14] Extreme rainfall data can also be included within the flood susceptibility models that can be obtained from sources like CHARIM GeoNode, which is established to share data prepared as an outcome of the CHARIM project conducted for five Caribbean countries (Saint Lucia, Dominica, Belize, Saint Vincent, Grenada).

Step 3.2 Identification of climate indicators

After the types of climate-related hazards have been defined, the appropriate climate indicators[15] and future trends to assess each type of hazard need to be identified. These indicators should follow Caribbean design thresholds and acceptable return periods as defined in the design manuals of the corresponding country. For instance, if road drainage systems are designed for a 1 in 20-year flood event, the choice of indicators and datasets should match this standard wherever possible.

Climate change projections can predict impacts on annual rainfall; frequency of specific category hurricanes; average and extreme rainfall events; temperature patterns etc. Caribbean islands are vulnerable to the impacts of sea level rise. For instance, monitoring of beaches in Saint Lucia since 1995, shows that climate change has magnified loss of coastal areas and accelerated coastal erosion, with resorts and other infrastructure that lie less than 6m above sea level already being considered at risk.[16]

Once this desktop review of climate change variables and projections has been completed, data needs to be collected to inform the hazard assessment. It is recommended to use the KNMI Climate Change Atlas which provides a series of graphs that show baseline and future projections in terms of temperature and precipitation. Similar information may not be available from hydrometeorological services in some countries of the Caribbean region so there may be a need to use public data from the Internet. Some sources of climate indicators to study different future scenarios available for the Caribbean region are included in **Section 4.7** and **Table 3** in **Section 5.1**.

Where projections are not available for relevant hazards, a proxy type of modelling can be used. **Table 9** below shows, for some typical natural hazards, the optimum datasets and proposed proxy data which can be used where data is unavailable. The table also shows the outcomes expected from the different datasets.

Table 9: Hazard assessment sample

Natural hazard or climate-related secondary effects	Hazard Assessment			
	Optimal/ highly recommended	Outcomes	Proposed/proxies	Outcomes
Riverine floods	Numerical modelling within river basins (including flood defence constructions)	River basin flood hazard map	Flood modelling in GIS environment based on max. discharge/recorded water level (without flood defence constructions)	Fluvial flood susceptibility map (area prone to flooding)
Flash floods	Numerical modelling within catchment area	Flash flood hazard map	Flash flood modelling in GIS environment based on catchment area parameters	Flash flood susceptibility map (area prone to flash flooding)
Landslides	Quantitative models divided by landslide type	Landslide hazard map	Landslide susceptibility model in GIS environment	Landslide susceptibility map

[15] An ‘indicator’ is defined in these guidelines as a measurable variable used as a representation of an associated (but not measured or non-measurable) factor or quantity.

[16] CARIBSAVE Climate Change Risk Atlas (CCCRA). 2012. Ibid.

			based on AHP approach (hierarchy process)	(area prone to landslides)

Step 3.3 Data quality assessments and normalization
The hazard data also needs to undergo quality assessments and data formatting to ensure compatibility with the rest of the data. For example, qualitative scales (of low, medium and high) may need to be converted to a numerical scale and subsequently normalized on a 0 to 1 range. See **Step 2.2** for further details.

Where secondary data is not sufficiently complete or comprehensive for the requirements of this analysis, it may be necessary to assess whether the missing non-continuous data can be derived or interpreted from the secondary data that is available. Information may need to be estimated or extrapolated.

Table 10: Advantages and disadvantages of different spatial analysis

Spatial GIS methods	Advantages	Disadvantages
Interpolation	Interpolation creates a continuous surface from known sampled point values. It can be used to predict unknown values for any geographic point data, such as elevation and rainfall.	If the sampling of input points is sparse or uneven, the results may not sufficiently represent the desired surface.
Extrapolation	In the absence of data, extrapolation is a method for making predictions outside a sampled area.	Extrapolation cannot be supported on statistical grounds alone; it must be justified by physical considerations. Even if the assumed form of the relationship is correct, the extrapolation, though not biased, may be quite imprecise
Using gridded data for future projections	Full coverage of climate projection data.	High level gridded data showing one or two numbers for the whole of a country.

As the different sets of data are gathered, whether from secondary data or from interpreted/derived data, it is important that they are stored in a format that allows them to be analysed in a meaningful and consistent manner. Data collected from various sources can easily be produced in different timeframes, to different scales, and using different classification schemes. The information will require a detailed analysis, validation, harmonisation and description to be used adequately for CRVA purposes.

Section 5 provides further guidance data analysis and management, and **Technical note 2** below briefly describes the steps involved using GIS to undertake the proposed hazard assessment methodology.

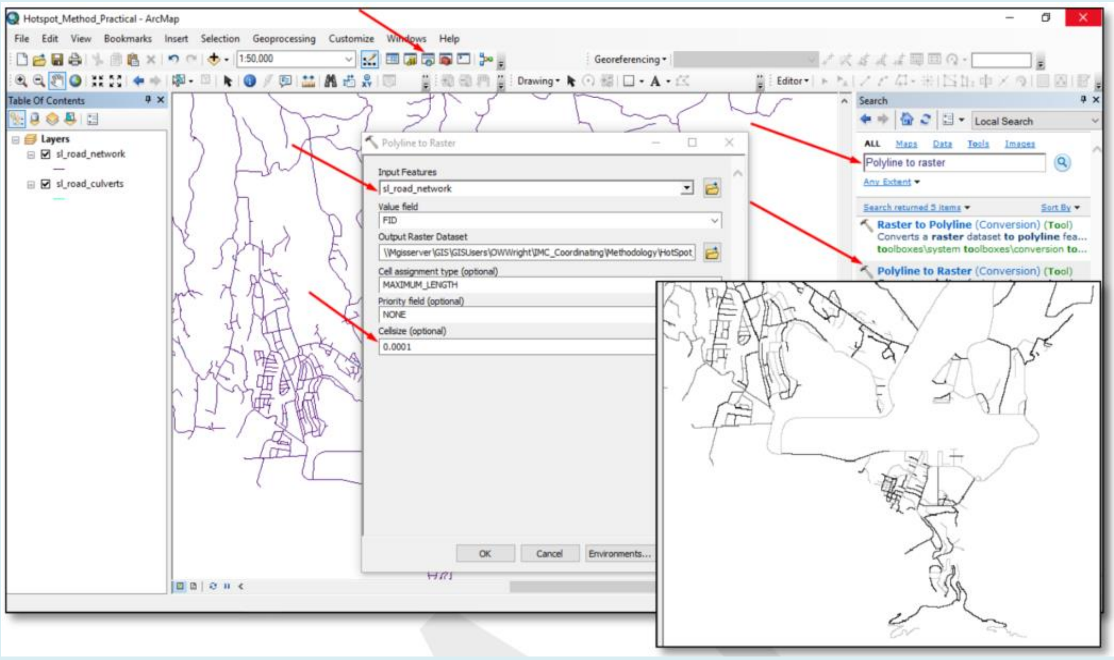
Technical note 2: Steps involved in the proposed hazard assessment using GIS

1. Keep consistent spatial reference for all source and derived data (WGS 84[17]), re-project if necessary (e.g., global open data such as land-use, soil maps, or local geological maps, etc.)
2. Interpolate source data (if necessary) to appropriate raster format, clip to the outline of the area of interest
3. Derive basic and advanced morphometric surface analysis using GIS modules (slope, aspect, hydrological parameters of the catchment area, etc.)
4. Convert vector to raster data, if necessary (polygons and metric polygon features)
5. Manipulate numerical rasters (if necessary, normalization, log-transformation, reclassification, etc.)
6. Manipulate categoric rasters (reclassify, assigning numerical value to categoric class, e.g., geological or land use unit)
7. Use raster calculator to compute weighted sums of rasters, according to susceptibility models
8. Overlap appropriate 0-1 normalized climate raster (e.g., precipitation) and recalculate the model from step 7 (of the technical note) to obtain hazard model
9. Reclassify the model obtained into different categories 'Very Low, Low, Moderate, High and Very High hazard'
10. Use an exposure factor around High and Very High hazard zones (expected radius of influence from the field or theoretical knowledge); or use some more appropriate exposure factor (e.g., inversed relative altitude above drainage channels for flash floods). Steps 8, 9 and 10 may not be needed, depending on the status of the data.

The screenshot below shows the GIS 'Polyline to raster' tool to convert a dataset to a raster dataset.

[17] The World Geodetic System (GDS) is a standard for use in cartography, geodesy, and satellite navigation including GPS. The latest revision is WGS 84, established in 1984 and last revised in 2004.

Figure 8: Screenshot polyline to raster tool (Produced by the Consultant)



Step 3.4 Production of hazard maps

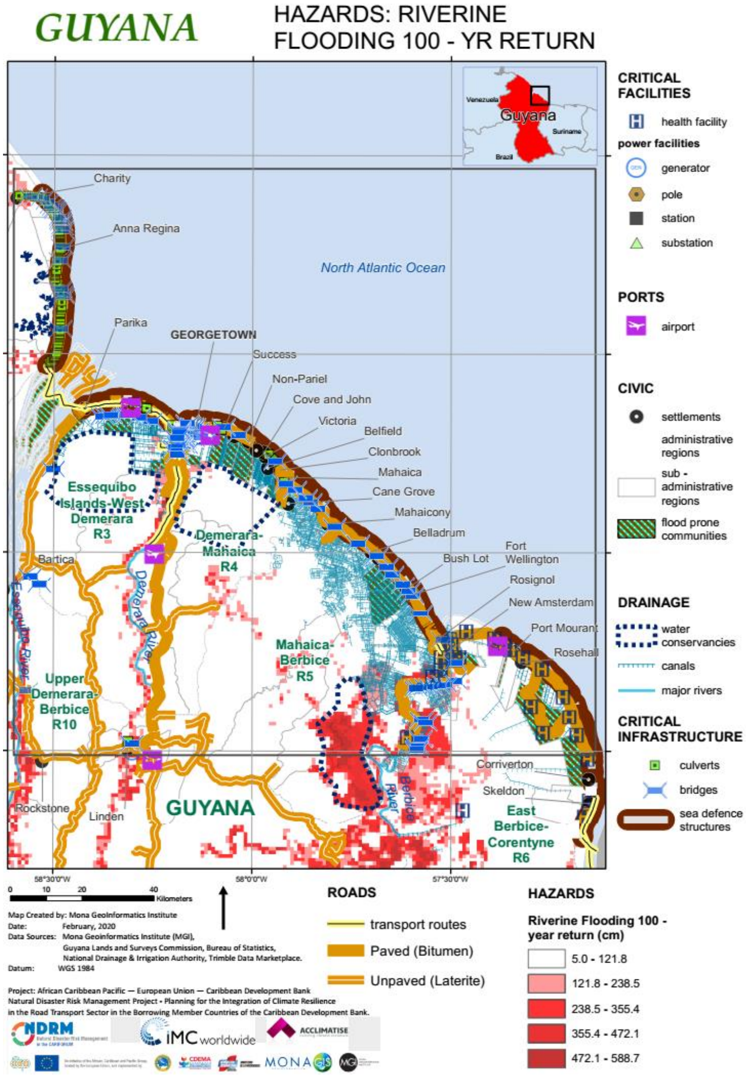
Once the types of hazards have been identified and the data has been collected, normalized and stored in the GIS database, hazard maps can be produced. **Figure 9** shows riverine flooding mapping results in Guyana for a 100-year return period and landslide susceptibility mapping results in Dominica.

For future climate maps, analysis can be undertaken for the required return periods, for the preferred greenhouse gas concentration trajectory (Representative Concentration Pathway, RCP) adopted by the IPCC for its Fifth Assessment Report (AR5) in 2014[18]. If data exists for several greenhouse gas emissions scenarios and sufficient project resources are available, it is recommended to analyse trends across several scenarios to determine the sensitivity to climate-related impacts. Typically, a more extreme scenario (e.g., RCP8.5[19]) should be supplemented by a mid-range scenario (e.g., RCP4.5/RCP6) to show the worst case and moderate case future trends, respectively. **Figure 10** shows storm surge hazard at long-term period (100-year return) and future trends of three scenarios of sea level rise in 2025, 2050 and 2100 for RCP8.5 in Saint Lucia.

[18] IPPC Scenario process for AR5: http://sedac.ipcc-data.org/ddc/ar5_scenario_process/RCPs.html

[19] This is a future concentration rather than a climate emissions trajectory. The RCP8.5 scenario corresponds to a radiative forcing of 8.5 W/m^2 at the end of the century.

Figure 9: Hazard maps of Guyana (above) and Dominica (below) (Produced by the Consultant)



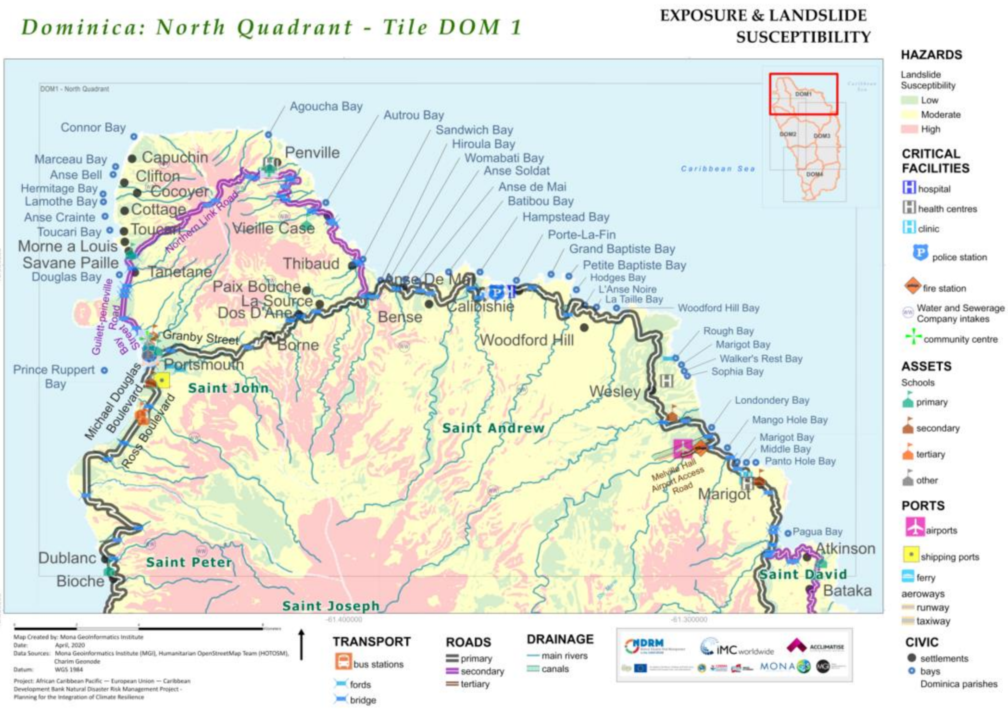
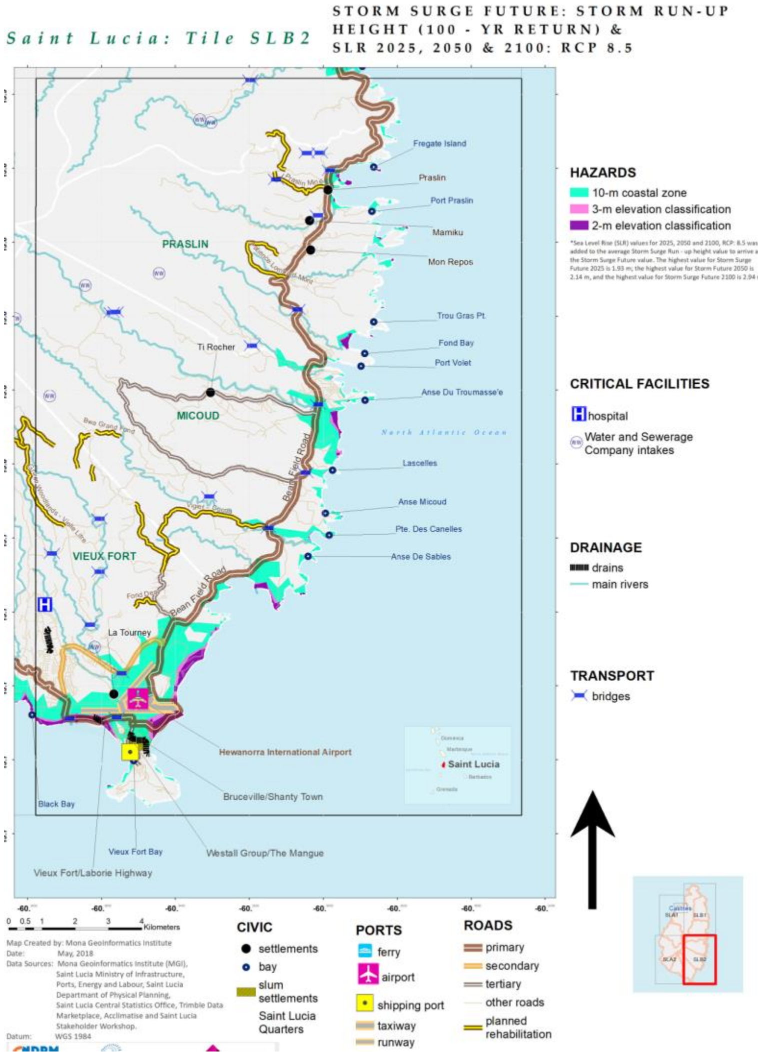


Figure 10: Sea Level Rise (SLR) values for 2025, 2050 and 2100, RCP: 8.5 of Castries, Saint Lucia (Produced by the Consultant)

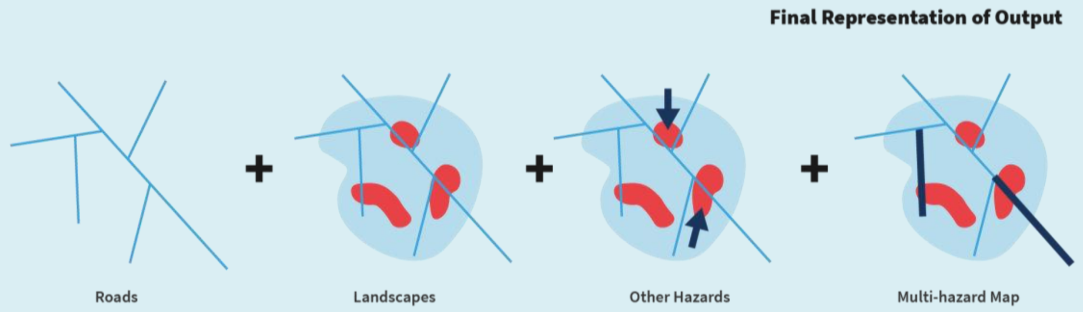


If required, a **multi-hazard risk** and **index** can be easily assessed once each of the hazards are ready to be mapped. Details of the analysis to produce a multi-hazard index are explained below.

Box 3: Multi-Hazard mapping

Multi-Hazard Risk is the sum of the probabilities of individual hazards multiplied by the elements at risk, their weight factors and probability of failure/damage to the element at risk due to the impact of hazards. This multi-hazard calculation is straightforward in the GIS environment and the activation of the relevant layers will produce the multi-hazard risk map. The process implies multiplying all the normalized individual hazard rasters and, if needed, readjust the 0-1 normalization of the resulting raster.

Figure 11: Representation of multi-hazard map (Produced by the Consultant)



Implications on using the Multi-Hazard Index

Once all the individual hazards are computed, and climate indicators determined, it is possible to combine them as illustrated in **Figure 11**. By combining the different hazard elements into a single index, based upon their perceived importance, a system that enables the identification of priority sections in terms of natural hazards can be developed. However, this is not a straightforward procedure, and it is not entirely recommended. It is suggested to observe each hazard and each of its risks and its impacts individually, rather than combining them for analysis.

The primary reason for this is the difference in hazard values (value distribution) after the 0-1 normalization procedures, which are recommended as the final stage of the susceptibility/hazard maps. Some of the resulting raster models skew away from the normal distribution, or some other regular distribution (e.g., log-normal). It means that they can have very different probability density along the 0-1 sliding interval.

For instance, we can have a flash flood model that has just a few values close to 1 and all other values generally converging towards 0 and, as a result, overlapping these two hazards would give a product that will not depict very well the flash flood. When the Very High multi-hazard would be spatially queried, for example values greater than a common 0.8 probability threshold, it might exclude most of the dangerous flash flood cases.

Furthermore, the normalized values are obtained from various approximations, some based on proxies, some on physical or hybrid models, which means that the final 0-1 estimates do not represent true probabilities, but their relative distributions.

STEP 4: Exposure-Vulnerability-Hazard mapping and hotspots

Introduction

As stated by the IPCC AR5 report, the interaction of climate-related hazards with an exposed and vulnerable system, leads to climate impacts. As such, '*vulnerability, exposure, and climate-related hazards (are) determinants of impacts*'. The **risk** of an impact happening is determined by the '***probability*** *[or* ***likelihood****] of occurrence of hazardous events or trends multiplied by [the severity of]* ***impacts*** *[or* ***consequence****] if these events or trends occur*'. A **hotspot** is an area which has greater exposure and/or vulnerability to the negative effects of climate change hazards.

The next and last step of the CRVA process after having mapped exposure (E) under Step 1, vulnerability (V) under Step 2 and hazards (H) under Step 3 in the study area, is to generate a map to highlight where the three parameters are significant, and therefore indicate which parts of the network (road sections or road links) are likely to impacted more significantly by the identified hazards.

To quantify a hotspot and allow a relative comparison to another hotspot (e.g., to target investment in the future) the datasets of differing units (e.g., social indicators such as population numbers, gender split, exposure indicators such as type of road, and climate hazards such as storm surge run up height) are required to be processed further into a common scale: the **EVH index**. The following steps are required in the mapping and index-driven hotspot assessment.

Guideline

Step 4.1. Data normalization for inclusion in EVH index
At this stage, all digitized data needs to be normalized to a standardized range of 0-1. Where the data are qualitative (e.g., High, Medium, Low), these data are first converted to a numeric scale. This allows different indicators with differing units and scales to be combined, e.g., quality of road surface (sensitivity/vulnerability) can be combined with flood risk (hazard). See **Step 2.2** for further information on data normalization.

In addition to normalizing, thresholds can also be applied to the data to ensure aspects such as minimum engineering design standards for a type of hazard are accounted for. Thresholds are the level above which a hazard begins to be a problem for an asset type. For example:

- For road melt, the temperature and sustained duration above which roads begin to melt;
- For wind speed, the speed above which bridges may be subject to closure; or
- Commonly adopted return periods for flood resilience design (e.g., 1 in 100-year return period rainfall events etc.).

Thresholds can commonly be obtained from design standards from the country/region or through the expert judgement of asset design and construction experts.

Step 4.2 Weightings and distances for inclusion in EVH index
The index is generated using as "equal weights" approach whereby all indicators are assigned a weighting of 1 for the purposes of computation. The weighting given to each indicator can be determined using multi-criteria analysis and/or project team discussions and provide a mechanism for sensitivity testing of the hotspot analysis depending on individual stakeholder concerns. For example, different parameters can be assigned different weights based on their influence on the overall assessment. These weights can also be based on expert opinions and judgements derived from existing literature, or other sources. This is a well-known approach, especially where it is not possible to undertake an assessment without proxies, as is the case where there are data gaps.

Exposure indicators are defined in the EVH index as a road asset (element at risk) at a distance from a particular hazard. Beforehand, it is necessary to estimate distances for which the road asset can be considered exposed to a particular hazard, including the effects of climate change. If the asset is within the exposure reach it further needs to be assigned a specific level of exposure - highest to lowest. For instance, in the case of landslide hazard, run-out distances of existing landslides, mapped on the field, are good indicators for defining the highest level of exposure, whereas for floods, furthest flooding footprints (flooding dirt marks on trees and objects) can be used. It is proposed to calculate spatial distances from the highest hazard zones and overlap these distances over the road asset. For this technique, it is necessary to follow the steps detailed in **Technical note 3**.

Technical note 3: Calculating distances for EVH index

The **first step** requires a classification of the hazard map into appropriate levels. It is proposed to use 5 class levels: Very Low (VL), Low (L), Medium (M), High (H) and Very High (VH), except for floods hazards, where 3 classes (H, M, L) are sufficient. It might be necessary to adjust class intervals manually, instead of using some typical automatic intervals (Quantile Classification, Natural Breaks, etc. used in GIS), and try to adjust the intervals so that the VH and H zones match with the historical hazard features. At the same time VL and L should enclose as few as possible of these features.

- After achieving optimal interval ranges, raster needs to be physically reclassified according to these ranges. This is repeated for all hazard types.
- The reclassified raster is then converted to polygon vectors. Editing is needed, and all polygons should be deleted, except for the polygons that outline VH hazard class. This is also repeated for all hazard types. In most cases, the VH will be a single feature polygon. However, landslides and flash floods for instance are expectedly going to have many VH features (not a single polygon). It is best to merge all these features into a single polygon artificially, by using standard polygon editing tool.

The **second step** is to calculate the spatial distance around the VH hazard zone (previously generated polygon vector file) by using the Euclidean Distance tool (or similar GIS buffer tools), so that the intermediate output is a distance raster. The final output is an inversion of the distance raster (the values decrease away from the VH zone), normalized to a 0-1 range. This should be repeated for each hazard type if necessary. It is worth considering the following:

- It is necessary to define the maximal reach for each hazard type, since this should be introduced as a boundary parameter during the calculation of the distance raster. This will differ for different hazard types, depending on the nature of the process. For instance, landslides are expected to have relatively small maximal reach, measured in tens of meters, whereas flash floods might reach up to hundreds of meters away from the VH zone.
- Numeric values of distance rasters increase away from the VH hazard zone, up to the estimated maximal reach, which has the highest value. However, the exposure implies that areas closer to the VH zone should have higher values than remote areas. This means that the distance (and elevation) rasters need to be inversed and normalized to a 0-1 range, to allow areas closer to VH zone to have values closer to 1 and remote areas close to 0. This should be repeated for each hazard type.

The **final step** includes overlapping the element at risk, for example the road network shapefile over the exposure raster and extracting exposure values for each road network link in a GIS

environment.
It is first necessary to perform zonal statistics over all hazard exposure rasters, using road link line vector as a reference, and choosing the SUM function as the zonal statistics operator. This will allow the pixel values of the underlaying raster to be summed up along each road link.

Afterwards, it is necessary to pick up these values back to the line vector. This can be done by temporarily converting road link line vector to a point vector. Values of all zonal statistics rasters can be picked up using the point extraction tool. Subsequently, it is necessary to relate the line vector of the road network with the point vector that now contains the exposure along the link. The match is achieved by simply relating the ID keys of point and line vectors.

Exposure values for each link in the line vector will be stored as an additional attribute in the attribute table. This will be a new vector that can be visualized by color-coding exposure values. This should be repeated for each hazard type.

Step 4.3 Create GIS model
Once all data are normalized onto a common scale of 0-1, and relevant thresholds applied if any, the different data layers are modelled following the EVH hotspot score formula:

EVH hotspot score = Exposure [Ei + Eii + Eiii + ..] + Sensitivity [Si + Sii + Siii + ..] - Adaptive Capacity [Ai + Aii + Aiii + ..] + Hazards [Hi + Hii + Hiii + ..]

Multiple indices can be developed by selecting all or some of the indicators. New indicators can be added at any time and the process of developing a ‘final’ index is an iterative process informed by available data and expert inputs from experts in road network operation and design, social science and hazards. Care is required to ensure the direction (positive/negative) of an indicator is accounted for. For example, high flood risk contributes to a high EVH score, whilst a well-drained highway would mitigate the impact and therefore lower the EVH score.

The impact of a hazard depends on:
- The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected (Exposure);
- Their propensity or predisposition to be adversely affected: Vulnerability (sensitivity and adaptive capacity); and
- The magnitude and duration of the Hazard(s).

The confluence of these three factors determines how the road network and the communities they serve will be affected. However, rather than simply generating discrete locational index-driven hotspots, the analysis uses the clustering technique Getis-Ord Gi (see **Technical note 4**).

Technical note 4: Getis-Ord Gi spatial statistic (ArcGIS tool)

Rather than simply generating discrete locational index-driven hotspots, the analysis can use the Getis-Ord Gi clustering technique of the final highest-scoring segments, which presents a more objective way of determining hotspots.

This type of analysis looks at statistically significant clustering rather than just where the higher scores are located. A single spot is analysed within the context of the scores of its neighbouring spots to generate a statistically significant clustered locational score. This considers other nearby EVH components which individually may be smaller, but could add up to a highly vulnerable, local multi-factor situation.

Step 4.4 Final EVH index

The EVH index is a live document that will be finalized once Step 4 is completed. The index will present the matrices adopted for specifying and implementing the indexing model within GIS and calculating location-specific hotspot scores. Normalization parameters including weighting and proximity distances (See **Step 4.1** and **Step 4.2**) are also indicated. Exposure and vulnerability are studied against each type of hazard, as shown in **Figure 12**. Further explanation on the production of this table is detailed in the Roads Sector Resilience Index report produced by the Consultant[20].

Figure 12: Sample of EVH index

									Hazards	
							Storm Surge height baseline: 100- year return	**Storm surge height Future (storm surge + sea level rise)**	**Flash Flood Susc. baseline**	**Landslide Susc. baseline**
									Scale / Normalising	
Dimension	**Data set**	**Scale / Normalising**	**Weight**	**Index +/-**		**Weight**	1	1	1	1
Exposure	Location of primary, secondary, tertiary and other roads	IF Proximity <= 100m = 1, Else = 0	1	+			Intersect with LECZ <=10m elevation and/or asset = 1, else 0	Inundation intersects with road / bridges	Normalise: V. High (=5) High (=4) Mod. high (=3) Mod (=2) Low (=1)	Normalise: High (=3) Mod (=2) Low (=1)
Exposure	Location of bridges	IF Proximity <= 100m = 1, Else = 0	1	+			Intersect with LECZ <=10m elevation and/or asset = 1, else 0	Inundation intersects with road / bridges	Normalise: V. High (=5) High (=4) Mod. high (=3) Mod (=2) Low (=1)	Normalise: High (=3) Mod (=2) Low (=1)
Exposure	Location of (land) drains	IF Proximity <=100m = 1, Else = 0	1	+						
Exposure	Location of culverts	IF Proximity <= 100m = 1, Else = 0	1	+						
Exposure	Location of bus stations	IF Proximity <= 100m = 1, Else = 0	1	+						

Step 4.5 Production of hotspots summary list and maps

Once the EVH index has been completed, hotspots maps can be produced. The hotspots on the map are ranked based on their score from the EVH index. This ranking will give a theoretical list of locations (hotspots), which could be some of the most vulnerable locations on the road transport network to climate-related natural hazards.

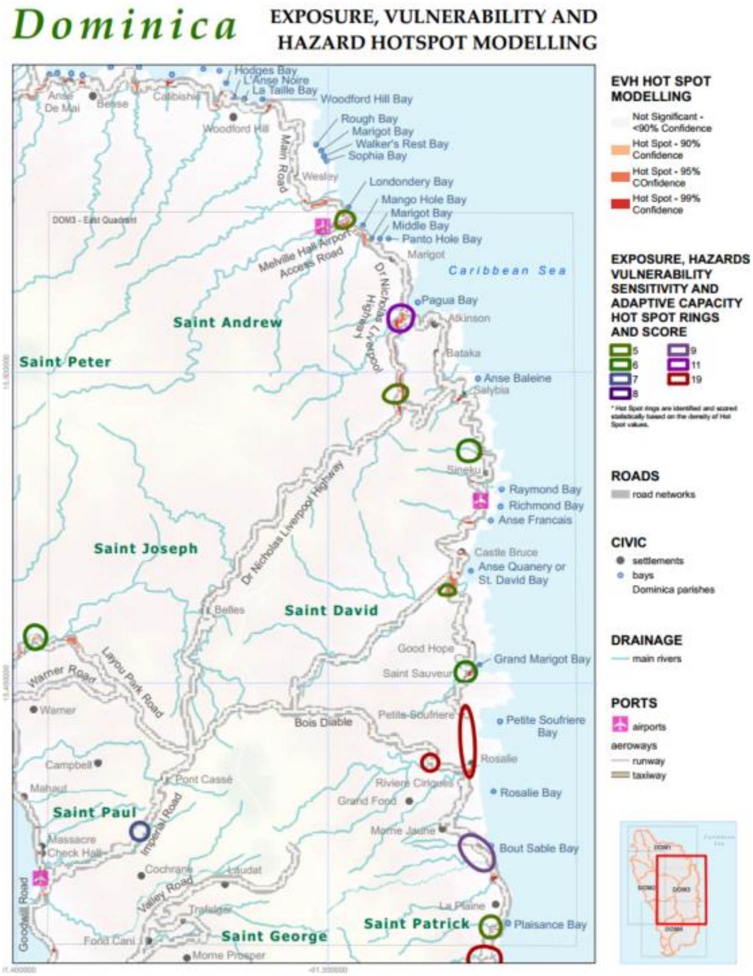
A list outlining the summary of the results can indicate the location (e.g., area, junction, km no. of road section, etc.) and the hotspot will be given a score. This will be useful for the last **Step 4.6**.

[20] The Resilience Index report (Task 3) correspond to the deliverable 'Roads Sector Resilience Report' produced by IMC Worldwide under the current assignment 'Planning for the Integration of Climate Resilience in the Road Transport Sector in the Borrowing Member Countries of the Caribbean Development Bank'.

As explained before, hotspot values are calculated using a combination of inputs from the different parameters of Exposure, Vulnerability, Hazards and Vulnerability subsets which are Adaptive Capacity and Sensitivity. Inputs are firstly rasterized and then reclassified and assigned a value of 1 per each pixel. Inputs need to be subsequently processed arithmetically using the raster calculator guided by the predetermined modelling algorithm (see **Step 4.3**).

The resulting output from this processing produces a score for each pixel based on the arithmetic calculation applied when inputs (pixels) overlapped. The range of hotspot values following this process will vary from 1 to 'undetermined number'. **Figure 13** shows the identification of hotspot rings with scores ranging from 5 to 19 on this quadrant[21] of Dominica.

Figure 13: Hotspots map, Dominica (Produced by the Consultant)



Step 4.6 Validation of hotspots during site visit
A discussion with the project team and Client needs to take place to decide the number of hotspots or values (e.g., hotspot rings and score 1 to 5 only which are the most critical) to be visited.

The relevant hotspots will be checked and discussed with relevant local stakeholders during the site visit. The validity of the most critical hotspots will be confirmed through site visits and local engineering knowledge.

[21] For the Dominica CRVA study, the range of hotspot values obtained following the EVH index modelling was from 1 to 19; for Saint Lucia it resulted to be from 1 to 12; and for Guyana it was from 1 to 11. The map only includes the relevant scores/ring colors of the results shown in a specific quadrant, merely for illustrative purposes and space limitations.

7

POLICIES, STRATEGIES AND PLANS

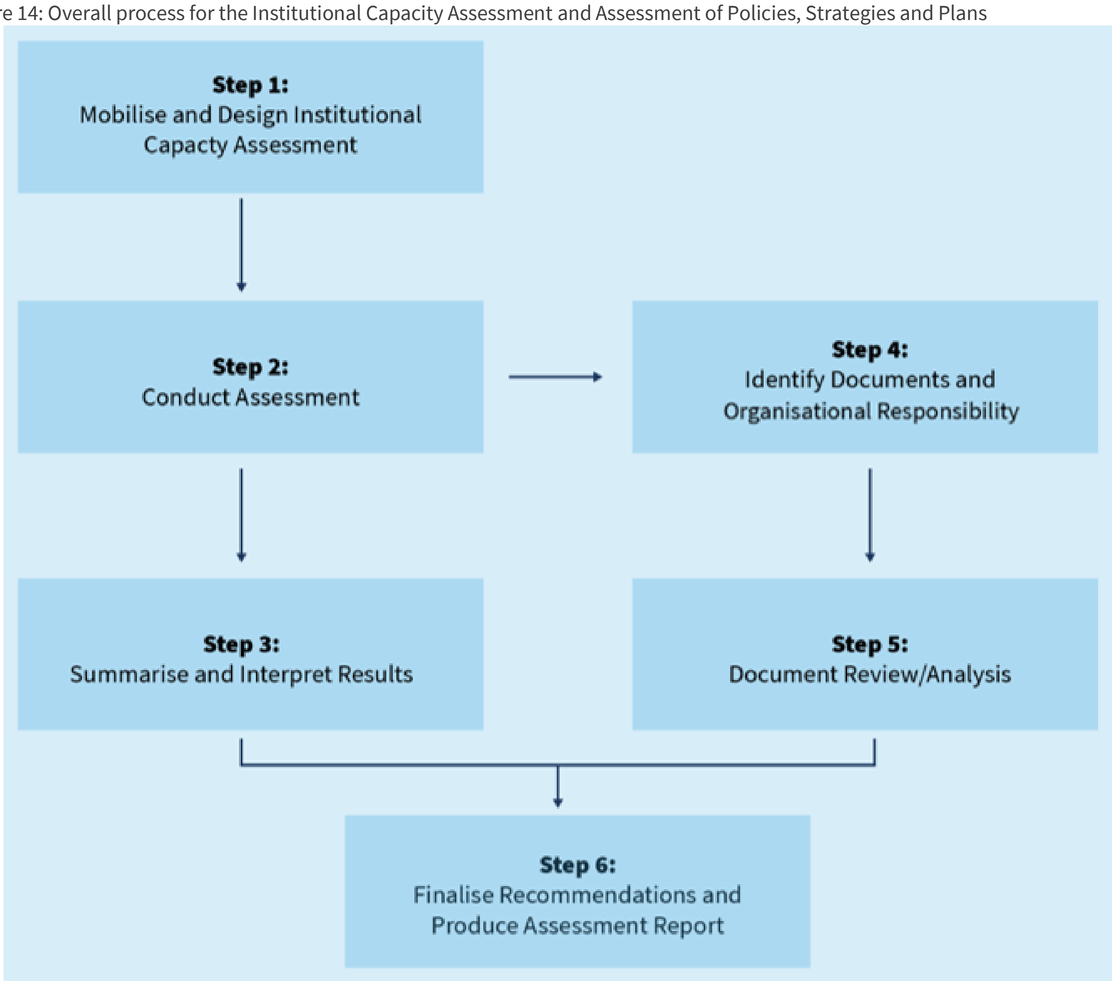
7.1. Introduction

This section of the Guidelines sets out the process to assess the institutional capacity and integration of climate resilience into the road transport sector's policies, strategies and plans. The objective is to address the following parameters.

- Assessment of the adaptive capacity of the works agencies, in terms of their ability to undertake risk and impact assessments, to plan and implement adaptation actions and to undertake adaptive management, and the agencies' requirements for additional support to enable them to implement adaptation measures.
- Assessment of relevant government agencies involved in the road transport sector in terms of their institutional mandate and their level of awareness of climate change and incorporation of climate risks into (their) organisation's work.
- Identification of what can constrain the ability of relevant organizations to adapt.
- Assessment of strategies and plans for exposure of the road transport sector to climate risks.
- Assessment of relevant laws and regulatory framework.
- Review of recent and current programmes in the country and potential linkages with the study to share information and fill any gaps.
- Analysis of how gender and social inclusion is promoted and considered in all the existing policies.

The results of the stakeholder engagement process and assessment of relevant legal and regulatory frameworks, policies, strategies and plans are integrated into a finalized set of recommendations for the road transport sector for the country of study. The overall methodology is summarized in **Figure 14**.

Figure 14: Overall process for the Institutional Capacity Assessment and Assessment of Policies, Strategies and Plans



The individual activities outlined in **Figure 14** combine to produce an institutional capacity assessment of the road transport sector, with respect to climate resilience and considering all the existing plans and policies. This should be complemented by a range of expert knowledge relating to the different professional areas explored, including climate science and climate resilience, disaster risk management, GIS, road asset management, hydrology and geotechnical/geological understanding of landslide risks, transport planning and highway engineering. The six steps are described as follows.

STEP 1: Mobilise and design institutional capacity assessment

Before designing a bespoke capacity assessment, the first activity undertaken is the identification of any publicly available documentation on capacity for climate risk management in the country. This should aim to engage stakeholders, clarify objectives, determine data and information collection and analysis approach, and determine how to conduct the assessment.

In the case that an assessment of capacity within the road transport sector does not already exist, the first stage is to identify a list of key government/works institutions that should be engaged in the institutional capacity assessment. An overall guide to these institutions and their link to the road transport sector are presented in **Table 11**. This should be adapted for each Borrowing Member Country, as appropriate. The lead Ministry engaged can use the following list as a guidance to identify stakeholders to invite to the workshop.

Table 11: Key government institutions for engagement in the institutional capacity assessment, and their link to the road transport sector

Institution	Involvement in road transport sector
Ministry/department/agency with responsibility for roads and bridges	Responsibility for capital works and maintenance
Ministry/department/agency with responsibility for drainage	Responsibility for capital works and maintenance
Ministry/department/agency with responsibility for land use planning	Planning development, which includes where roads are required
Ministry of Finance	Financing capital works and maintenance
Ministry/department/agency with responsibility for public transport	Roads utilized for primary activity
Disaster risk management agency	Emergency response, including with respect to climatic damage to roads
First responders (military, ambulance, fire, police services)	Roads utilized for primary activity
Ministry/department/agency with responsibility for airport/ports	Roads utilized for primary activity – transport of persons and goods

A half-day institutional capacity assessment workshop is proposed. This can take the form of a self-assessment workshop, based on the use of a facilitated and adapted questionnaire. The recommended agenda for the workshop is presented in **Table 12**. The sample questionnaire is presented in **Annex A** (see **Section 7.2**), drawing on the summary of the questionnaire components set out in **Annex B** (see **Section 7.2**).

Table 12: Institutional Capacity Assessment workshop agenda

Timing	Session
0 – 70 minutes	Introduction to assessment and questionnaire
70 – 180 minutes	Assessment via facilitated questionnaire
180 – 225 minutes	Participants report back to plenary and each present one capacity building suggestion for consideration

The questionnaire is organized according to five areas of institutional/organizational capacity, as cited by the 'USAID Global Climate Change Institutional Capacity Assessment' to address climate change. The rationale for applying these five areas is that they provide a clear, bounded framework (achievable within a short workshop) for the assessment and align with both the Inter-Governmental Panel on Climate Change's (IPCC's) indicators of adaptive capacity[22] and the GIZ seven success factors for national adaptation planning presented in the Stocktaking for National Adaptation Planning (SNAP) tool[23]. **Table 13** structures the assessment according to these five areas of institutional capacity. Weakness in the capacity areas is considered as constraints to adaptation.

Table 13: Five areas of institutional capacity included in USAID's 2016 Global Climate Change Institutional Capacity Assessment[24]

Area of capacity	Factors
Governance	• Mandate or mission to address climate change impacts • Climate change adaptation is explicitly incorporated in the organizational structure • Commitment of leadership or organizational ownership to address climate change impacts (e.g., senior person is assigned/empowered, unit charged with addressing climate change, coordinating bodies in place)
Information, data and analysis	• Access to information, data and analysis • Quality of information, data and analysis • Capacity to monitor, generate and use • Routine monitoring, generation and use
Policy and planning	• Processes, procedures, tools in place to integrate climate change impacts/adaptation into planning • Processes, procedures, tools in place to integrate gender equity and social inclusion into planning • Relevant stakeholders (internal and external) involved with integrating climate change into planning process. Gender balance is relevant here. • Current plans and strategies integrate climate change adaptation

[22] Adger, W.N., S. Agrawala, M.M.Q. Mirza, C. Conde, K. O'Brien, J. Pulhin, R. Pulwarty, B. Smit and K. Takahashi, 2007: Assessment of adaptation practices, options, constraints and capacity. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 717-743.
[23] See GIZ. 2016. SNAP. Stocktaking for National Adaptation Planning. Assessing capacity for implementing NDCs.
[24] Based on the methodology set out by USAID. 2016. Global Climate Change (GCC) institutional capacity assessment. Facilitator's guide. Version 1.

Area of capacity	Factors
Resources	• Budget for addressing climate change impacts • Human resources – adequate numbers of trained staff assigned to address climate impacts • Infrastructure and equipment (hardware, software, etc.)
Implementation, M&E, knowledge management	• Planned climate change actions implemented • Climate change services/goods provided • Targeted stakeholders/constituents benefitting • Climate change actions monitored, feedback from stakeholders solicited, open reporting on results of implementation • Performance of services and programs is evaluated • System in place disseminating information on and improving strategies, implementation, services and programmes

STEP 2: Conduct the assessment

The first activity in conducting the institutional assessment is an initial literature review on institutional capacity and relevant policies and documents available. It is recommended to take brief notes on findings to help understand the background of the exercise and highlight potential matters of future discussion with stakeholders. This initial literature review will be completed in detail in Step 4.

The half-day workshop should then be conducted. The participants' names who attend should be recorded, together with their position and institution. The participants can be split up into different groups, each with a facilitator to work through the questionnaire, answer any clarification questions and stimulate discussion on the various points raised.

After the facilitated questionnaire is completed, one spokesman from each of the working groups should provide feedback, including any initial recommendations on interventions needed to strengthen the capacity of their organization to enable them to deal with the impact of climate change with respect to their organization's involvement in the road transport sector. Follow up emails and phone calls can be made, as required, to obtain additional required information, including to feed into the document review and recommendations (Step 4 and Step 5). In addition, for each key institutional stakeholder, the vision, mission statement/objectives, organization chart should be obtained and presented.

STEP 3: Summarize and interpret results

Results from the questionnaire should be entered into a formatted Excel spreadsheet, analysed and summarised in tables. The results of the institutional capacity assessment can then be discussed, with quantitative scores assessed, and presented using a radar chart and range bar chart for both the current situation and strategic goals (see examples in **Figure 15** and **Figure 16**).

Figure 15: Example of presentation of the range of scores for the five institutional capacity areas

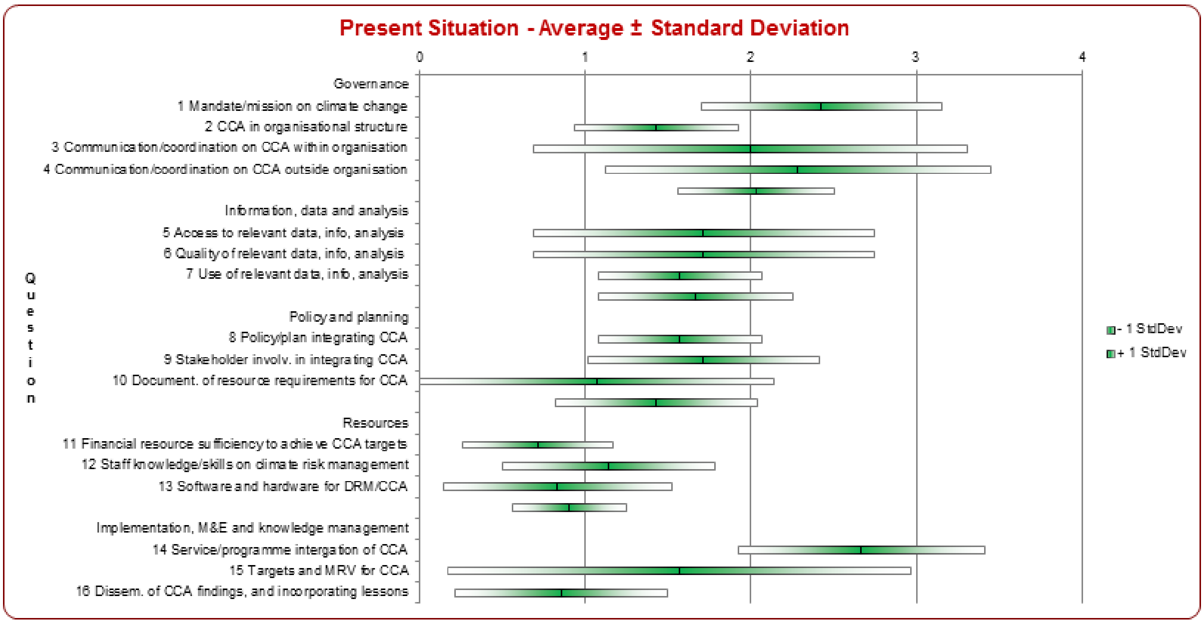
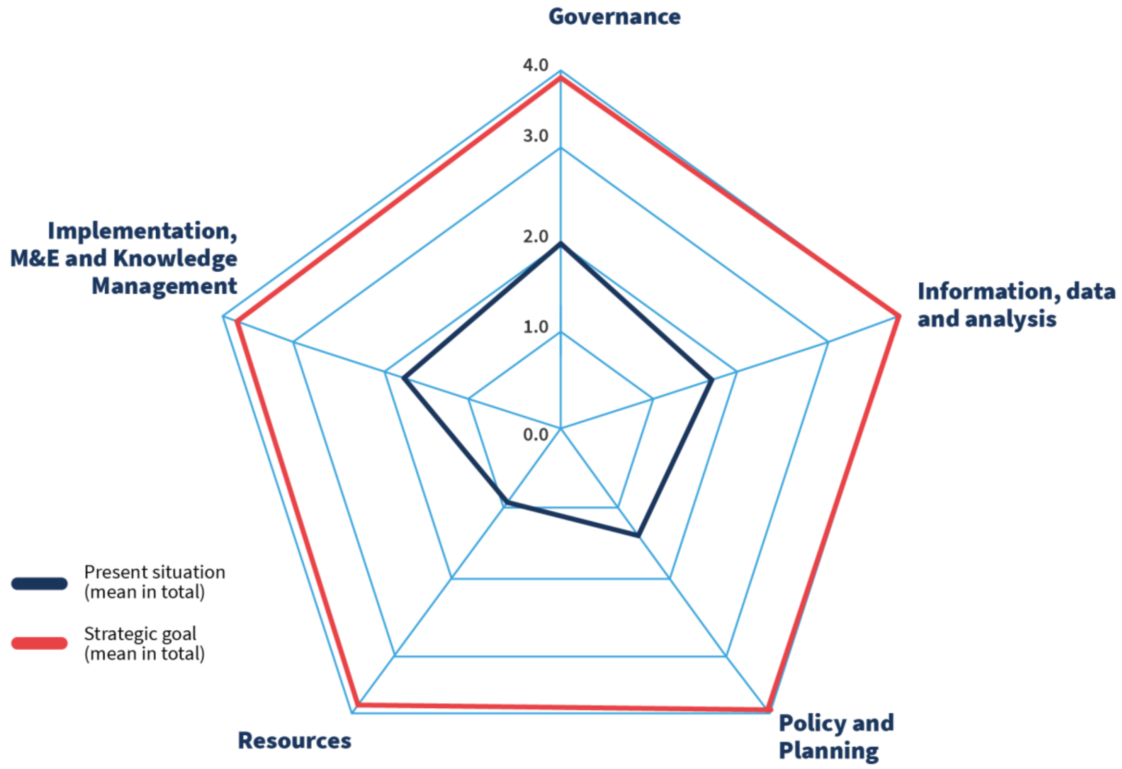


Figure 16: Example of Radar chart presenting the mean institutional capacity score for the present situation, and strategic goal, for the five institutional capacity areas



An analysis of the results of the assessment carried out for each stakeholder are presented and then collated as an overall table of recommendations (see template in **Table 14**). These recommendations draw on the questionnaire responses, the workshop feedback session, and expert judgement, and are organized according to the five capacity areas around which this assessment is structured. Options that are highlighted by questionnaire participants as priorities during the workshop feedback session can be emboldened and presented in another font (e.g., green font).

Table 14: Feedback on institutional capacity of each stakeholder in turn

Area of capacity	Feedback
1. Governance	1.1 Mandate/mission on climate change 1.2 CCA in organizational structure 1.3 Communication/coordination on CCA within organization 1.4 Communication/coordination on CCA outside organization
2. Information, data and analysis	2.1 Access to climate change information, data and analysis that is relevant to the road transport sector 2.2 Quality of climate change information, data and analysis that is relevant to the road transport sector 2.3 Use of climate change impacts/adaptation information, data and analysis to address road transport
3. Policy and planning	3.1 Policy/ plan addressing climate change risks, challenges and opportunities, including gender equity and social inclusion 3.2 Stakeholder (counterparts, beneficiaries) involvement in integrating climate change into policy/planning/projects 3.3 Documentation of resource requirements for addressing climate change impacts
4. Resources	4.1 Sufficiency of financial resources to achieve climate change adaptation priorities and objectives 4.2 Staff knowledge and skills on climate risk management 4.3 Software (e.g., GIS programmes) and equipment (e.g., appropriate vehicles) for implementing disaster risk management/climate change adaptation
5. Implementation, monitoring and evaluation, and knowledge management	5.1 Services and programmes addressing climate change impacts, vulnerabilities and risks 5.2 Organizational targets (qualitative/quantitative) for adaptation; monitoring, reporting and evaluation 5.3 Dissemination of information on climate impacts/adaptation; using lessons learnt to improve interventions

STEP 4: Identify documents and organizational responsibility for each document

The first step is to make a list of and collate all laws, regulations, policies, strategies, plans and budgets that relate to the following.

- Road transport sector. For example, infrastructure policy, national development plan referring to road transport, existing and proposed master plans, budgets for implementing transport sector plans and their sensitivity to climate change;
- Disaster risk management and climate change adaptation. For example, disaster risk management law, policy; sector specific disaster/climate change management plan;
- National and sector specific climate change policies and action plans, including those required to comply with international agreements; and
- All the above should consider the extent to which documents and policies are inclusive and promote gender equality.

Documents can be collated through downloads from the internet according to availability and through telecoms/ face-to-face meetings. Direct contact with stakeholders allows confirmation of a comprehensive list. These documents should be listed in the accompanying Excel spreadsheet, along with the author / institution with responsibility for each document. Documents can be organized according to sector for ease of reading, noting in the spreadsheet key pages or sections.

STEP 5: Document review/analysis

The next step is to review each document using the questions set out in the literature review template provided in **Annex C** (see **Section 7.5**). The questions have been developed based on the Caribbean Climate Online Risk and Adaptation TooL (CCORAL) Workbook; based on questions relating to how climate variability and climate change might be relevant to Caribbean Legislation, Policies/Strategies, Planning and Budgets[25]; and based on the and Asian Development Bank (ADB) (2011) guidance on 'Building Adaptation Strategies into (Road-related) Policy and Sector Planning'[26]. The series of questions is designed to represent the main aspects of climate risk management, from understanding context, identifying climate vulnerabilities/risks, identifying and considering appropriate adaptation options for implementation, and monitoring and evaluating them.

It is intended that questions are answered by non-climate/gender experts, and as such, reference documents are quoted to provide support where needed. Responses to questions can be provided using this template, with direct quotations and page number references included wherever possible.

Once all documents have been reviewed, it will be possible to answer the question about whether documents 'enable, constrain or overlap' with others in the list. This may inform final recommendations on amendments.

STEP 6: Finalize recommendations and produce report

This final step combines the conclusions from the institutional assessment and the results of the findings from the assessment of relevant legal and regulatory frameworks, policies, strategies and plans. Both are integrated into a finalized set of recommendations, which are supported by the views of the key stakeholders engaged and the various documents assessed.

It is important that the development of the assessment report also considers the findings and recommendations resulting from the CRVA (see **Section 6**) and the workbook used to develop the RSRI (see **Section 8**). All these tasks need to be complemented with each other, ensuring results are consistent and resolving any confusions or contradictions encountered.

In order to make easier the identification of the stakeholders that are required to act to implement each recommendation, the list of suggestions can be supported by the template shown in **Table 15** below.

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[25] Available at: http://ccoral.caribbeanclimate.bz/stage3/non-expert. Last accessed: 24.11.17.

[26] Asian Development Bank (ADB). 2011. Guidelines for Climate Proofing Investment in the Transport Sector Road Infrastructure Projects

Table 15: Institutional capacity building options organized by capacity area

		Principal (Government) Stakeholders		
Area of capacity	**Options**	**Stakeholder 1**	**Stakeholder 2**	**Stakeholder 3**
1.Governance	*1.1 Mandate/mission on climate change* *1.2 CCA in organizational structure* *1.3 Communication/coordination on CCA within organization* *1.4 Communication/coordination on CCA outside organization*			
2.Information, data and analysis	*2.1 Access to climate change information, data and analysis that is relevant to the road transport sector* *2.2 Quality of climate change information, data and analysis that is relevant to the road transport sector* *2.3 Use of climate change impacts/adaptation information, data and analysis to address road transport*			
3.Policy and planning	*3.1 Policy/ plan addressing climate change risks, challenges and opportunities, including gender equity and social inclusion* *3.2 Stakeholder (counterparts, beneficiaries, including vulnerable groups) involvement in integrating climate change into policy/planning/projects* *3.3 Documentation of resource requirements for addressing climate change impacts*			
4.Resources	*4.1 Sufficiency of financial resources to achieve climate change adaptation priorities and objectives* *4.2 Staff knowledge and skills on climate risk management* *4.3 Software (e.g., GIS programmes) and equipment/hardware (e.g., appropriate vehicles) for implementing disaster risk management/climate change adaptation*			
5. Implementation, M&E & knowledge management	*5.1 Services and programmes addressing climate change impacts, vulnerabilities and risks* *5.2 Organizational targets (qualitative/quantitative) for adaptation; monitoring, reporting and evaluation*			

	5.3 Dissemination of information on climate impacts/adaptation; using lessons learnt to improve interventions			

7.2. Annexes

Annex A: Institutional capacity assessment questionnaire template

Name	
Position	
Institution	
Date	
Email/phone	

How to fill in the questionnaire

- Please answer the questionnaire based on your knowledge of your organization.
- Please tick the appropriate box to provide your answer.
- Please provide as much detail as possible in the 'information' section for your answer.
- Strategic aim = the strategic objective(s) that your organization should be aiming to achieve within five years.

<u>Capacity area #1: Governance</u>

1. **How strong is your organization's mandate or mission to address climate change?**

	0=weak	1=rather weak	2=neither weak nor strong	3=rather strong	4=strong	n.a.
Current state						
Strategic aim						

Information – describe mandate/mission as relates to climate change:

2. **To what extent does the organizational structure support climate change adaptation (CCA)?** (i.e. to what degree are climate change- related responsibilities and lines of authority clear and appropriate?)

	0=weak	1=rather weak	2=neither weak nor strong	3=rather strong	4=strong	n.a.
Current state						
Strategic aim						

Information – describe roles/resp. for CCA:

3. **How strong are mechanisms, if any, for communicating/ coordinating on climate change adaptation across relevant parts of your organization and with external organizations?**

	0=weak	1=rather weak	2=neither weak nor strong	3=rather strong	4=strong	n.a.
Current state (internal)						
(external)						
Strategic aim (internal)						
(external)						

Information – give examples of mechanisms:

Capacity area #2: Information, data and analysis

4. **What is your organization's level of access to climate change information, data and analysis that is relevant to the road transport sector?**

	0=weak	1=rather weak	2=neither weak nor strong	3=rather strong	4=strong	n.a.
Current state						
Strategic aim						

Information – sources of info, any barriers to access:

5. **What is the quality of climate change information, data and analysis that is relevant to the road transport sector?**

	0=weak	1=rather weak	2=neither weak nor strong	3=rather strong	4=strong	n.a.
Current state						
Strategic aim						

Information – e.g., what info/quality do you want that you don't have?

6. **How comprehensive is the use of climate change impacts/adaptation information, data and analysis to address road transport?**

	0=weak	1=rather weak	2=neither weak nor strong	3=rather strong	4=strong	n.a.
Current state						
Strategic aim						

Information – how do you use it (e.g., planning, altering hydrological modelling)? What aspirations do you have for use of this info?

Capacity area #3: Policy and planning

7. **How well does your organizational policy/ plan address climate change risks, challenges and opportunities to respond, including gender equity and social inclusion?**

	0=weak	1=rather weak	2=neither weak nor strong	3=rather strong	4=strong	n.a.
Current state						
Strategic aim						

Information – give examples:

8. **To what extent are stakeholders (counterparts, beneficiaries, including vulnerable groups) involved in integrating climate change into policy/planning/projects?** Please consider gender balance.

	0=weak	1=rather weak	2=neither weak nor strong	3=rather strong	4=strong	n.a.
Current state						
Strategic aim						

Information – give examples of who is involved, and who else you would like to involve in future:

9. **To what extent has your organization documented resource requirements for addressing climate change impacts?**

	0=not at all	1=rather weak	2=neither weak nor strong	3=rather strong	4=strong	n.a.
Current state						
Strategic aim						

Information – If documented, how? Separate budget line?

Capacity area #4: Resources

10. To what extent are your organization's financial resources sufficient to achieve your climate change adaptation priorities and objectives?

	0=weak	1=rather weak	2=neither weak nor strong	3=rather strong	4=strong	n.a.
Current state						
Strategic aim						

Information/ justification:

11. How adequate is the level of staff knowledge and skills on climate risk management?

	0=weak	1=rather weak	2=neither weak nor strong	3=rather strong	4=strong	n.a.
Current state						
Strategic aim						

Information/ justification:

Please indicate where there is staff knowledge/skills in the following (ü) and # of staff with this capacity:

ü	*#*	*Knowledge and skills on climate risk management*[27]
		Assessment of climate change hazards, vulnerabilities, risks, appropriate adaptation responses
		Prioritization of climate change risks and appropriate adaptation responses
		Coordination of adaptation activities with multiple stakeholders, including vulnerable groups
		Information management (collecting, analysing, and disseminating information in support of adaptive activities)
		Overarching climate risk management
		GIS specialists/technicians

12. How adequate is your software (e.g., GIS programmes) and hardware (e.g. appropriate vehicles) for implementing disaster risk management/climate change adaptation?

	0=weak	1=rather weak	2=neither weak nor strong	3=rather strong	4=strong	n.a.
Current state						
Strategic aim						

Information – what software/hardware do you have access to?

[27] Capacities informed by WRI National Capacity Assessment 'institutional functions for adaptation'

Capacity area #5: Implementation, M&E and knowledge management

13. **To what extent do the services and programmes that your organization implements address climate change impacts, vulnerabilities and risks?**

	0=weak	1=rather weak	2=neither weak nor strong	3=rather strong	4=strong	n.a.
Current state						
Strategic aim						

Information – give examples of services/programmes:

14. **To what degree does your organization set realistic targets (qualitative/quantitative) for adaptation, and then monitor, report and evaluate them?**

	0=weak	1=rather weak	2=neither weak nor strong	3=rather strong	4=strong	n.a.
Current state						
Strategic aim						

Information – examples?

15. **How strong is your system for disseminating information on climate impacts/adaptation, and using lessons learnt to improve strategies, implementation, services and programmes?**

	0=weak	1=rather weak	2=neither weak nor strong	3=rather strong	4=strong	n.a.
Current state						
Strategic aim						

Information - describe:

Finally, having answered all the questions, would you like to add any general comments or suggestions?
Also, are there other government agencies responsible for road infrastructure not present today? Please write below/ on the reverse.

Annex B: Summary of institutional capacity assessment questionnaire components

Governance	1	How strong is your organization's mandate or mission to address climate change?	Mandate/mission on climate change
	2	To what extent does the organizational structure support climate change adaptation? (i.e., to what degree are climate change- related responsibilities and lines of authority clear and appropriate?)	CCA in organizational structure
	3	How strong are mechanisms, if any, for communicating/ coordinating on climate change adaptation across relevant parts of your organization?	Communicate/coordination on CCA within organization
	4	How strong are mechanisms, if any, for communicating/ coordinating on climate change adaptation with external organizations?	Communicate/coordination on CCA outside organization
Information, data and analysis	5	What is your organization's level of access to climate change information, data and analysis that is relevant to the road transport sector?	Access to relevant data, info, analysis
	6	What is the quality of climate change information, data and analysis that is relevant to the road transport sector?	Quality of relevant data, info, analysis
	7	How comprehensive is the use of climate change impacts/adaptation information, data and analysis to address road transport?	Use of relevant data, info, analysis
Policy and planning	8	How well does your organizational policy/ plan address climate change risks, challenges and opportunities to respond, including gender equity and social inclusion?	Policy/plan integrating CCA
	9	To what extent are stakeholders (counterparts, beneficiaries) involved in integrating climate change into policy/planning/projects? Please consider gender balance	Stakeholder involvement in integrating CCA
	10	To what extent has your organization documented resource requirements for addressing climate change impacts?	Document. of resource requirements for CCA
Resources	11	To what extent are your organization's financial resources sufficient to achieve your climate change adaptation priorities and objectives?	Financial resource sufficiency to achieve CCA targets
	12	How adequate is the level of staff knowledge and skills on climate risk management?	Staff knowledge/skills on climate risk management
	13	How adequate is your software (e.g., GIS programmes) and hardware (e.g., appropriate vehicles) for implementing disaster risk management/climate change adaptation?	Software and hardware for DRM/CCA
Implementation, M&E and knowledge management	14	To what extent do the services and programmes that your organization implements address climate change impacts, vulnerabilities and risks?	Service/programme integration of CCA
	15	To what degree does your organization set realistic targets (qualitative/quantitative) for adaptation, and then monitor, report and evaluate them?	Targets and MRV for CCA
	16	How strong is your system for disseminating information on climate impacts/adaptation, and using lessons learnt to improve strategies, implementation, services and programmes?	Dissemination of CCA findings, and incorporating lessons

Annex C: Literature Review Template

C.1 Template Used for Assessment

Author, Publication Date, Title	
Document Type - Law, Regulation, Policy, Strategy, Plan + Period (where noted)	
Objectives. Also, does monitoring and evaluation integrate indicators of climate resilience, including for roads?	
How does this relate to the road transport sector and climate change? How are the objectives, and activities set out in relation to impact of weather/ climate hazards? **Are activities promoted that could increase vulnerability, maladaptation or miss opportunities arising from climate change** (including for the road transport sector)?	
What road transport sector adaptation options are recognized?	
Is the document gender-responsive and inclusive of other vulnerable groups? If so, how does this relate to climate adaptation and/or the transport sector?	
Does this enable, constrain or link to other documents? Could amendments/additions improve climate resilience of (road) infrastructure? (Complete after review)	

C.2 Example of Table Completed for 1 document for one of the case study countries

Author, Publication Date, Title	Department of Sustainable Development (2018) **Saint Lucia's National Adaptation Plan (NAP) 2018-2028**
Document Type - Law, Regulation, Policy, Strategy, Plan + Period (where noted)	Strategy/Plan, 2018-2028
Objectives. Also, does monitoring and evaluation integrate indicators of climate resilience, including for roads?	Delivery and coordination of adaptation measures across eight sectors including 'infrastructure and spatial planning'. The overarching aims are to enhance climate-related adaptation and risk reduction actions, including for infrastructure.
How does this relate to the road transport sector and climate change? How are the objectives, and activities set out in relation to impact of weather/ climate hazards? **Are activities promoted that could increase vulnerability, maladaptation or miss opportunities arising from climate change** (including for the road transport sector)?	Table 5 – climate impacts including damage/ reduced capacity to coastal roads/bridges, interruption of road access due to disasters, infrastructure risk of inundation from sea-level rise, Reduced effectiveness of drainage infrastructure. Recognition of challenge of rapid urbanisation (to coastal areas) and need to relocate settlements and infrastructure. Recognises need to integrate climate change into infrastructure planning and operations. Not clear link between adaptation and mitigation within transport sector, as the NAP does not focus on transport sector.

What road transport sector adaptation options are recognized?	Develop national land use plans – but not mention links to road transport policy/strategy. Suggests developing a national Climate Vulnerability Assessment, linked to social impact. This could link to the CRVA delivered for this project.
Is the document gender-responsive and inclusive of other vulnerable groups? If so, how does this relate to climate adaptation and/or the transport sector?	Does not explicitly focus on transport sector so no focus on gender/vulnerable groups in relation to transport sector. Highlights (Annex 1) the need for improved knowledge base, including in mapping socioeconomic as well as climate and environmental data.
Does this enable, constrain or link to other documents? Could amendments/additions improve climate resilience of (road) infrastructure? (Complete after review)	Notes that sector CRVAs completed but does not specifically refer to transport sector. Proposes a national climate vulnerability assessment is conducted and linked to emergency planning. This could build on the GIS-based CRVA completed through this project.

8

ROADS SECTOR RESILIENCE INDEX

8.1. Introduction

The Roads Sector Resilience Index (RSRI) has been developed to assess and measure the level of resilience of the road transport sector and could be applied in different countries and contexts. The index also considers a measure of the level of vulnerability of the sector (infrastructure and transport assets) and the existence of capacity (policies, plans, strategies, awareness, trained staff) to prepare for and implement adaptation options.

The RSRI is a decision support tool that can be used not only to evaluate the resilience performance of the road transport sector, but also to identify and prioritize resilience interventions for climate resilience planning and programming. In addition, the index can also be used to track the progress of resilience development and risk reduction of the road sectors in BMCs; and it serves as a Risk-informed Decision Support (RiDS) for strategic public investment planning in road asset risk reduction and system resilience building.

This section presents a summary of the theoretical methodology used to develop the toolkit components based on the World Bank Resilience Wheel concept prepared by IMC Worldwide[28] in 2015 (see **Figure 6**).

8.2. Resilience Wheel domains and indicators system

As indicated in the previous section, the RSRI adopts the Resilience Wheel conceptual model of transport sector resilience proposed by the World Bank[27] to help create an indicators system (see **Section 8.2**) with a weighing mechanism assigned (see **Section 8.3**), the RSRI index equations (see **Section 8.4**), together with a comprehensive questionnaire to be discussed with stakeholders (see **Section 8.5** and **Annex A** in **Section 8.6**).

The five domains of a resilient transport system defined by the Resilience Wheel are used to further develop a list of 20 indicators which represent 20 key components of a road transport system. The five domains considered including the proposed resilience indicators system is outlined in **Table 16**.

Table 16: Proposed indicators system for measuring the road sector resilience

Domains	Core indicators
Domain 1: Policies, Institutions, and Processes	Indicator 1.1 National and sectoral policies for mainstreaming Climate Resilience and Disaster Risk Management
	Indicator 1.2 Legal and regulatory framework
	Indicator 1.3 Sectoral leadership, institutional arrangement and coordination mechanisms
	Indicator 1.4 Horizontal and vertical information flow
Domain 2: Technical Planning and Design	Indicator 2.1 Public investment planning framework and process
	Indicator 2.2 Engineering design standards and norms
	Indicator 2.3 Project identification, preparation and appraisal standards and process

[28] World Bank and IMC Worldwide Ltd, 2015: Disaster Risk Management in the Transport Sector – A review of Concepts and International Case Studies, available for download from https://openknowledge.worldbank.org/handle/10986/22365.

Domains	Core indicators
	Indicator 2.4 Access to Climate Change and Disaster Risk Information
Domain 3: Operation and Maintenance	Indicator 3.1 Standard operational procedures for Operation and Maintenance
	Indicator 3.2 Road Asset Management System (RAMS) on infrastructure performance
	Indicator 3.3 Real-time Monitoring, Early Warning and Response
	Indicator 3.4 Communication systems
Domain 4: Technical Expertise	Indicator 4.1 Capacity building for officials and civil servants
	Indicator 4.2 Dedicated staff assigned to address Climate Resilience and Disaster Risk Management issues
	Indicator 4.3 Technical Skills Base
	Indicator 4.4 Knowledge management, risk awareness, and community engagement
	Indicator 5.1 Budget allocation and financial resources
	Indicator 5.2 Financial incentives and cost-sharing mechanisms
	Indicator 5.3 Monitoring and evaluation mechanisms
	Indicator 5.4 Post-investment auditing and portfolio management

8.3. Rating and weighting of resilience indicators

The indicators selected are all very critical to contribute to the overall resilience performance of the road sector system. In this regard, equal weight is assigned to all the domains and their associated core indicators.

A four-class scale, which reflects the four levels of the indicator performance, i.e., Low, Fair, Moderate and Sufficient, is adopted to rate the 20 resilience indicators. Each indicator is scored with a value varying from 0 to 4 against a set of pre-defined criteria[29]. **Table 17** presents a summary of the metrics of the resilience indicators, including performance classification, score, colour code, and implications.

Table 17: Scale and score matrix for rating the resilience indicators

Performance Class	Score	Colour Code	Implications
Level 4: Sufficient	3-4		*The indicator has* ***sufficient capabilities*** *to address Climate Resilience and Disaster Risk Management issues* ***effectively and efficiently****.*

[29]The pre-defined criteria for rating the resilience indicators is based on a long list of specific requirements. Further details of the criteria defined for each of the 20 indicators can be consulted in the Road Sector Resilience Index Reports, Task 3, of the Planning for the Integration of Climate Resilience in the Road Transport Sector in the BMCs of the CDB project, implemented by IMC Worldwide.

Level 3: Moderate	2-3		*The indicator has **moderate capabilities** to address Climate Resilience and Disaster Risk Management issues **adequately**.*
Level 2: Fair	1-2		*The indicator has **fair capabilities** to address Climate Resilience and Disaster Risk Management issues, **to some degree**.*
Level 1: Low	0-1		*The indicator has **low capabilities** to address Climate Resilience and Disaster Risk Management issues, with **certain difficulties.***

8.4. Calculation and presentation of RSRI value

Based on the scores resulting from each indicator, two Road Sector Resilience Indexes can be built: 1) Overall Road Sector Resilience Index (ORSRI); and 2) Domain-specific Road Sector Resilience Index (DRSRI), by using the equations indicated in **Figure 17**.

Figure 17: RSRI equations

$$ORSRI = \sum_{i=1}^{5}(DS_i \cdot W_i)/80$$

$$DRSRI_i = \sum_{j=1}^{4} IS_{ij}/16$$

Where DS_i is the subtotal score of the i^{th} domain; Wi is the weight of the i^{th} domain (in this study, Wi = 1); IS_{ij} is the score of the j^{th} indicator of the i^{th} domain.

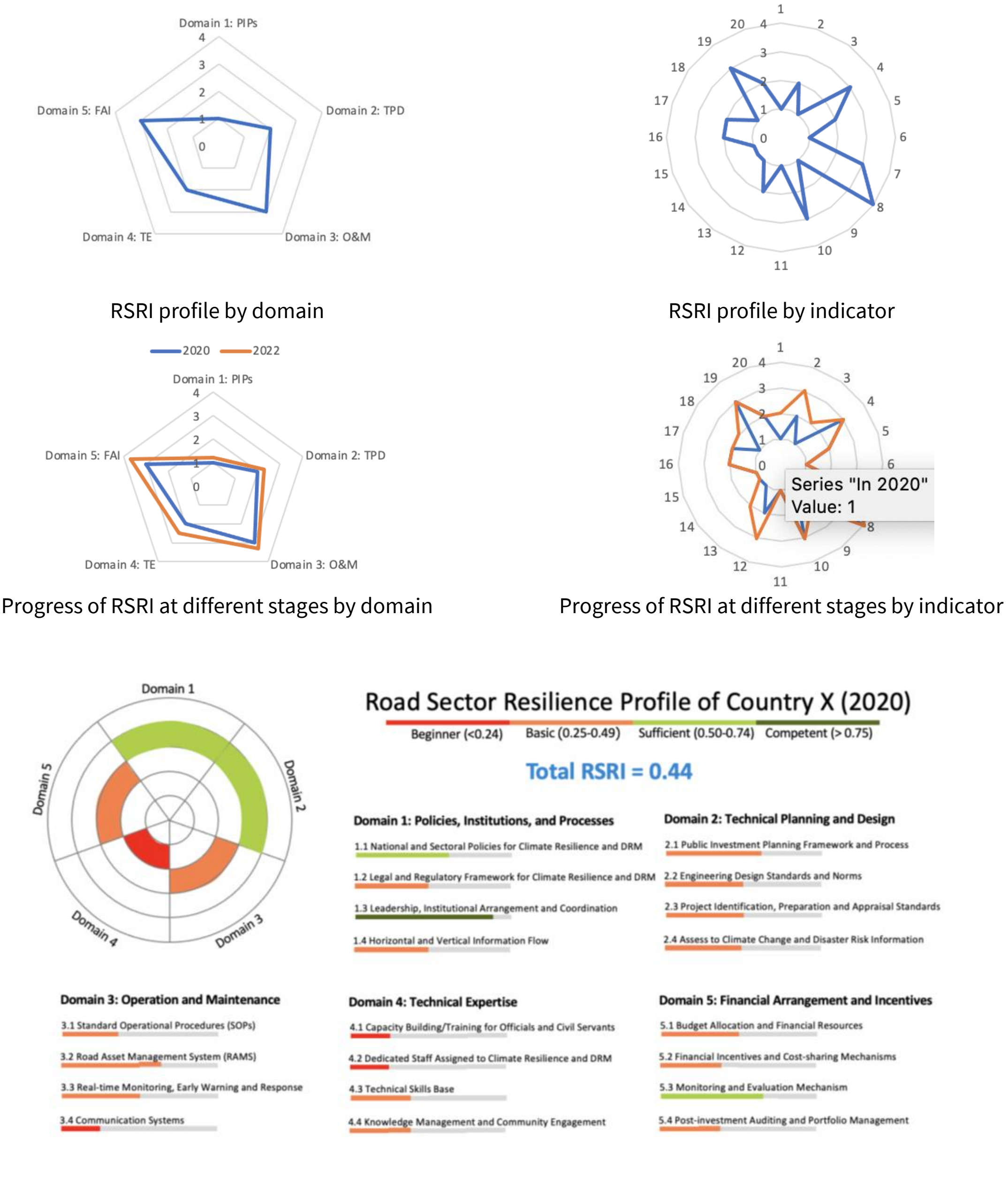
The value of both resilience indexes varies from 0 to 1; and the resilience performance of a road sector system is classified into four levels: Level 1 - Beginner; Level 2 - Basic; Level 3 - Sufficient; and Level 4 - Competent. Their implications are illustrated **Table 18**.

Table 18: Classification of system resilience performance and implications of the RSRI

Performance Class	Colour Code	RSRI Value	Implications
Level 4: Sufficient		0.75-1.00	The sector and its domains have **sufficient capabilities** to address Climate Resilience and Disaster Risk Management issues **effectively and efficiently.**
Level 3: Moderate		0.50-0.74	The sector and its domains have **moderate capabilities** to address Climate Resilience and Disaster Risk Management issues **adequately**.
Level 2: Fair		0.25-0.49	The sector and its domains have **fair capabilities** to address Climate Resilience and Disaster Risk Management issues, **to some degree.**
Level 1: Low		0.00-0.24	The sector and its domains have **low capabilities** to address Climate Resilience and Disaster Risk Management issues, with **certain difficulties.**

The resulting RSRI value can be presented using different diagrams to visualise the road sector resilience profiles. **Figure 18** shows different options that can be used to represent the results.

Figure 18: Visualization of RSRI values



RSRI profile by domain

RSRI profile by indicator

Progress of RSRI at different stages by domain

Progress of RSRI at different stages by indicator

Visualization of road sector resilience profile in a snapshot

8.5. Workbook for Road Sector Resilience Assessment

A workbook for conducting the road sector resilience assessment has been designed to identify evidence to support the indicator rating against the pre-defined criteria for each indicator. The workbook consists of three integral parts:

1. A close-end questionnaire organized in a checklist format to easily provide answers. Further evidence and comments are encouraged to support the responses. A full copy of the workbook has been included in **Annex A** of **Section 8.6**.
2. A checklist for collecting supporting documentation, as shown in **Annex B** of **Section 8.6**.
3. A score sheet to document the scores of each indicator and associated supporting evidence. This has been included in **Annex C** of **Section 8.6**.

Key informant interviews and stakeholder consultations are undertaken to complete the questionnaire, collect relevant evidence and/or documents from stakeholders, and complete the score sheet. The assessment can be conducted either with the form of a group discussion or organising separate interviews with the different stakeholders.

It is important that the results of the scoring sheets inform the rating given to each of the resilience indicators, supporting the justification of the score values assigned.

8.6. Annexes

Annex A: RSRI Workbook

Domain 1: Policies, Institutions, and processes

Indicator 1.1 National and Sectoral Policies for Mainstreaming Climate Resilience and Disaster Risk Management (CR/DRM)		
Questions	**Answers**	**Notes/Sources of Evidence**
(1) ***Are there any national policies or strategies in place in your country to address Climate Resilience and Disaster Risk Management (CR/DRM) issues in the development processes?*** • How does the National Strategic Development Plan (NSDP) identify climate change and disaster risks and relevant CR/DRM activities? • How have the national CR/DRM policies been integrated into the sectoral development policies and plans? • How do national CR/DRM policies and procedures facilitate the incorporation of new scientific information into project design? • Do the national policies and strategies take account of gender equity and social inclusion?	○ **Yes** ○ **No**	
(2) ***Has the road sector developed sector-specific policies or strategies addressing CR/DRM issues***?	○ **Yes** ○ **No**	
(3) ***Are national CR/DRM strategies/plans and sector specific CR/DRM strategy (Road Sector Strategy) coherent***?	○ **Yes** ○ **No**	
(4) ***Is there collaboration across multiple Jurisdictions, modes, infrastructure systems, and actors to develop sectoral CR/DRM strategy***?	○ **Yes** ○ **No**	
(5) ***Are there sector-specific guidelines in place for addressing CR/DRM and infrastructure resilience at all levels and ensure resilient investment***?	○ **Yes** ○ **No**	
(6) ***Are there any lessons learned to address CR/DRM issues in the road sector***? • If so, please give examples.	○ **Yes** ○ **No**	

Indicator 1.2 Legal and Regulatory Framework		
Questions	**Answers**	**Notes/Sources of Evidence**

(1) ***Is a legal and regulatory framework required to clarify the role and responsibilities of the road sector to address Climate Resilience and Disaster Risk Management (CR/DRM) issues in the public investment planning***?	○ **Yes** ○ **No**	
(2) ***Are the current regulatory frameworks and incentives and penalty structures often reviewed to reflect the costs more accurately from service failures due to extreme weather events***?	○ **Yes** ○ **No**	
(3) ***Do regulations and procedures facilitate the exchange of information between scientific experts and decision makers***?	○ **Yes** ○ **No**	
(4) ***Is the protection of consumer interest and quality of service reflected in the regulatory framework, which can be negatively impacted when transport infrastructure fails due to exposure and vulnerability to natural hazards***?	○ **Yes** ○ **No**	
(5) ***Is there a permanent mandate of the sectoral agency (laws, by-laws) regarding Climate Resilience and Disaster Risk Management (CR/DRM) issues?*** • Is there any temporary mandate (political/board leadership priority)? • Is there a written mission or policy statement on addressing Climate Resilience and Disaster Risk Management (CR/DRM)? • Is there an articulated vision or leadership statement on addressing Climate Resilience and Disaster Risk Management (CR/DRM)? • Were vulnerable groups such as involvement of women, youth, elderly, and persons with disabilities included in defining the mandate, mission, or policy?	○ **Yes** ○ **No**	
(6) ***Is the Climate Resilience and Disaster Risk Management (CR/DRM) mandate/mission known to and respected by relevant external stakeholders (e.g., other relevant organizations, beneficiaries)?*** • Which external stakeholders were involved in defining the mandate, mission, or policy? • How were these stakeholders identified? • How did these external stakeholders participate in defining it? • Has their support—or lack thereof—benefitted or hurt the organization's work on Climate Resilience and Disaster Risk Management (CR/DRM)?	○ **Yes** ○ **No**	
(7) ***Are Climate Resilience and Disaster Risk Management (CR/DRM) challenges fully addressed in the investment and maintenance plans of regulated utilities?***	○ **Yes** ○ **No**	

Indicator 1.3 Sectoral Leadership, Institutional Arrangement, and Coordination Mechanisms		
Questions	**Answers**	**Notes/Sources of Evidence**
(1) ***Is there a single point of authority to coordinate work across different agencies (energy, communications, water, transport, environment etc.) and examine the risks and potential cascading failures across the whole***	○ **Yes** ○ **No**	

infrastructure system, such as an infrastructure resilience council? • What are the mandates and responsibilities related to Climate Resilience and Disaster Risk Management (CR/DRM)? • Is there sufficient CR/DRM expertise at a leadership level? • Is there a champion in place responsible for promoting CR/DRM within the sector? • Is there capacity for gender mainstreaming within the Authority?		
(2) ***Are there any specific units or positions established to deal with Climate Resilience and Disaster Risk Management (CR/DRM) issues?*** • What are their name and key responsibilities? • To what extent are CR/DRM-related departmental or functional responsibilities and lines of authority clear and appropriate? • To what extent is the organizational structure conducive for exercising leadership on the CR/DRM goals and objectives? • What works well? What encourages decisive leadership on CR/DRM?	○ **Yes** ○ **No**	
(3) ***Are there transportation management centres in place to act as the nerve centres for monitoring traffic, emergency response, coordination, and travel advisories, and as the clearinghouses for all information during a disaster and an overview of all emergency preparedness issues, which can usefully feed back into planning***?	○ **Yes** ○ **No**	
(4) ***Are there national disaster risk management councils and oblige public bodies and legal bodies that are involved in electricity, transport, finance etc. to participate and draft CR/DRM operations and bear responsibilities for CR/DRM activities***?	○ **Yes** ○ **No**	
(5) ***Are there mechanisms in place for communication and coordination across relevant parts of the sector for CR/DRM***? • How well do these mechanisms work? In what ways has the organization collaborated internally across units on setting CR/DRM goals and priorities? • Does the Ministry of Finance (MOF) involve in coordinating CR/DRM and resilience projects since they have direct access to and are the accounting office for all ministries?	○ **Yes** ○ **No**	
(6) ***Is there any coordination in place across infrastructure systems and share disaster contingency manuals between operators of different modes and infrastructure systems?*** • What transportation routes convey and are co-located with utilities that are essential for recovery and maintaining emergency power systems? • Are disaster contingency manuals critically assessed and revised with other infrastructure operators if necessary?	○ **Yes** ○ **No**	
(7) ***Are cross-agency reconstruction agencies involved in the coordination of data sharing,***	○ **Yes** ○ **No**	

speed assistance, the efficient use of funds, and the reconstruction process? • Is a new coordinating and monitoring function required to be integrated into an existing ministerial system? • Should a special agency with specific authorities and responsibilities be established for coordinating response to large and remote disasters?		

Indicator 1.4 Horizontal and Vertical Information Flow		
Questions	**Answers**	**Notes/Sources of Evidence**
(1) ***Is there an information system in place for cross-agency information sharing and data storing?*** • Which consist of a data menu that contains a list of all datasets that are requested during a disaster, a data steward acting as a point of contact for data requests after and in advance of disasters, and an interagency data portal[30] to allow agencies to access and store one another's data? • Is the legal framework required for a multi-agency data portal?	○ **Yes** ○ **No**	
(2) ***Are there any channels in place for information to be exchanged and transmitted quickly between transportation system managers, staff, and users (across different modes of transport), as well as across multiple agencies and infrastructure systems?***	○ **Yes** ○ **No**	
(3) ***How efficient are information flows to transmit back lessons after disasters and emergencies***?	○ **Yes** ○ **No**	
(4) ***Are agents (engineers, operators, government officials etc.) able to access reliable information derived from rigorous data collection and risk assessment processes to make strategic decisions regarding transport infrastructure***?	○ **Yes** ○ **No**	
(5) ***Are agents receptive to local knowledge and new techniques, including those focused on the needs of vulnerable groups***?	○ **Yes** ○ **No**	
(6) ***Are they trained in how to collect and use this information***?	○ **Yes** ○ **No**	
(7) ***Do flexible, forward-looking, progressive plans implement change iteratively as more information is learnt about the climate change or local context***?	○ **Yes** ○ **No**	

Domain 2: Technical Planning and Design

[30] Geospatial information to allow teams to visually assess the condition of all assets, if they are being assessed and their prioritization in the work program. It helps manage interdependencies between systems and service providers and reduces the number of times roads are dug up and construction teams can better coordinate, reducing costs considerably.

Indicator 2.1 Public Investment Planning Framework and Process		
Questions	**Answers**	**Notes/Sources of Evidence**
(1) ***Is there a procedure or guidelines in place for local authorities to integrate the goals and objectives of Climate Resilience and Disaster Risk Management (CR/DRM) into sectoral planning?*** • Are the objectives, such as public safety, economic competitiveness, a healthy environment, tackling climate change, and providing equal opportunities to all citizens, included into resilient road projects? • Are these objectives included in the department's high-level strategic goals? • To what extent are the CR/DRM objectives congruent with the sector's broader mission/mandate?	○ **Yes** ○ **No**	
(2) ***Does the strategic plan address climate change/disaster risks, challenges, and opportunities?*** • To what extent are these informed by the challenges and opportunities? • By what method were the CR/DRM goals and objectives prioritized?	○ **Yes** ○ **No**	
(3) ***Is the sectoral CR/DRM plan informed by quality climate change/disaster risk information (CCDRI), data, and analysis?*** • To what extent is it based on best practice? • What sources of evidence were used? • Is there a mechanism to update the plan based on the latest knowledge and information? • How well is the mechanism followed?	○ **Yes** ○ **No**	
(4) ***Does the sectoral CR/DRM plan include resource requirements?*** • How realistic are these requirements given available resources and other constraints? • To what extent will identified resources be sufficient to accomplish stated CR/DRM goals and objectives?	○ **Yes** ○ **No**	
(5) ***Are the sectoral stakeholders involved in the development of the sectoral CR/DRM plan?*** • How were they selected? • How were stakeholders (counterparts, beneficiaries) consulted as this plan was written? • How are their CR/DRM priorities documented and incorporated? How well are gender and cultural considerations related to CR/DRM incorporated? • Were vulnerable groups such as women, youth, elderly, and persons with disabilities involved in the development of the sectoral plan?	○ **Yes** ○ **No**	
(6) Has the sectoral CR/DRM plan—and its objectives - used in guiding management decisions and operational planning?	○ **Yes** ○ **No**	

Indicator 2.2 Engineering Design Standards and Norms		
Questions	**Answers**	**Notes/Sources of Evidence**
(1) ***Are there any hazard-specific (e.g., sea level rise, floods, strong winds, fires, earthquakes) design and construction codes?***	○ **Yes** ○ **No**	

• Are there any sector-specific performance-based design and construction codes (e.g., elevated codes for mass occupancy buildings or for critical infrastructure)? • Are there any sector-specific guidelines for how to apply these codes and standards?		
(2) ***Have the current design standards and norms been updated to be performance-based[31] to set the degree of functionality that infrastructure should reach within a defined recovery time, thus capturing the temporal dimension of resilience***?	○ **Yes** ○ **No**	
(3) ***Are any design standards reconsidered for the following subsurface conditions***? • Materials specifications, cross-sections and standard dimensions, vertical clearance, drainage and erosion, structure, and siting standards and guidelines?	○ **Yes** ○ **No**	
(4) ***Has any infrastructure protection been enhanced by stabilizing slopes and scour protection, or risks mitigated through upstream river training works, reforestation, Sustainable Urban Drainage Systems (SUDS) or the introduction of buffers in the system (floodplains)?***	○ **Yes** ○ **No**	
(5) ***Are any worse-case scenarios explored to evaluate whether certain pieces of critical infrastructure should be designed for more severe weather events?***	○ **Yes** ○ **No**	
(6) ***Do designers/engineers push for new information based on their first-hand experience designing and constructing infrastructure?***	○ **Yes** ○ **No**	
(7) ***Are there any barriers to incorporate resilient design standards into new projects?*** • Do national policies and procedures hinder the incorporation of new scientific information into project design?	○ **Yes** ○ **No**	
(8) ***Are there any infrastructure guidelines to guide repair and replacement decisions during the reconstruction process?*** • Does a mechanism need to be in place to challenge and consider alternatives to the prescribed design standards?	○ **Yes** ○ **No**	

Indicator 2.3 Project Identification, Preparation and Appraisal Standards		
Questions	**Answers**	**Notes/Sources of Evidence**
(1) ***Are there the standards and guidance on project identification and preparation procedures been updated by addressing Climate Resilience and Disaster Risk Management (CR/DRM) issues and adequate resilience measures?*** • Is there high-level strategic priority in place to ensure the adoption of the principles of resilience in project appraisal, infrastructure design and construction?	○ **Yes** ○ **No**	

[31] Setting performance-based standards involves adopting a system approach and assessing the criticality of infrastructure links within the network as well as understanding what the purpose of the assets/links are within the system (i.e., evacuation routes, links to hospitals, ports etc.).

• Is there a standard methodology and published guidelines on feasibility studies? • Is there a standard methodology and published guidelines on environmental/ social impact assessments?		
(2) ***Are there any standards, published criteria, and appraisal models for evaluating and prioritizing the costs and benefits of various options?*** • Could these standards and models measure the cost of infrastructure damage, failure and service delays from multiple natural hazards, and the benefits of long-term resilience? • How is data (on the project's merits and key characteristics) presented and structured to facilitate decision making?	○ **Yes** ○ **No**	
(3) ***Have the project feasibility reports included an assessment of the impact of disasters on road infrastructure?*** • Is there (central/ decentralized) capacity to support feasibility studies?	○ **Yes** ○ **No**	
(4) ***Has the project considered the neighbouring land-use practices and upper catchment land management in the scope of transport projects***?	○ **Yes** ○ **No**	
(5) ***Has Environmental and Social Impact Assessment (ESIA) been conducted to explicitly addressing the impacts of natural hazards on infrastructure, and by taking climate change into consideration and how a project will respond to an evolving environmental baseline?*** • What are the rules governing environmental/ social impact assessments? • How are results of assessments used to inform decision making on investments? • Is there (central/ decentralized) capacity to support and monitor environmental/ social impact assessments?	○ **Yes** ○ **No**	
(6) ***Are there any project evaluation and reporting requirements in place to share all information about the project's capabilities and limitations with key decision makers and emergency responders?***	○ **Yes** ○ **No**	
(7) ***Are the project stakeholders and beneficiaries, including communities, vulnerable groups, and emergency responders, engaged in the identification, planning and design of all transport projects in order to ensure that the impact of natural hazards is taken into account and the CR/DRM interventions are context-specific?***	○ **Yes** ○ **No**	

Indicator 2.4 Access to Climate Change and Disaster Risk Information (CCDRI)		
Questions	**Answers**	**Notes/Sources of Evidence**
(1) ***Is there a system (including procedures, infrastructure, resources) in place to collect and monitor appropriate climate change and disaster risk data, information, and analysis?*** • Are there any national GIS systems to record past weather events and create harmonized data-sharing mechanisms? • Are there standard formats and reporting standards in place for monitoring and collecting climate change/disaster risk and damage data?	○ **Yes** ○ **No**	

• Are the data disaggregated and are social data digitized for integration into GIS for comparison with other spatial data to allow for a more comprehensive analysis of the vulnerability of specific groups within the population? • Are standardized datasets used as a default standard for designers, such as rainfall intensity charts, the Intensity-Duration-Frequency (IDF) curves, as a quality control mechanism?		
(2) ***Has the collection of data on natural hazards and the modelling and analysis of this data[32] been improved and revisited on a regular basis?*** • Is there a timetable of regular risk assessments and audits for infrastructure assets that can provide information on their condition and reliability? • Are the data disaggregated and are social data digitized for integration into GIS for comparison with other spatial data to allow for a more comprehensive analysis of the vulnerability of specific groups within the population?	○ **Yes** ○ **No**	
(3) ***Have infrastructure sectors been engaging in weather information collection[33] specific to their sector as weather has specific and varied local impacts on transport infrastructure?***	○ **Yes** ○ **No**	
(4) ***Does relevant staff understand climate change/disaster risk information, data and analysis***? • Who are the relevant staff? • How well does leadership understand climate change/disaster risk data, information, and analysis?	○ **Yes** ○ **No**	
(5) ***Are there any open sharing mechanisms of climate change/disaster risk information among transportation agencies, climatologists, scientists, insurance companies, and those professionals and volunteers on the frontline of emergencies?*** • Are infrastructure companies encouraged to disclose information[34] on how they have taken the risks from natural hazards into account? • Is there any information and knowledge sharing among transportation agencies, climatologists, scientists, insurance companies, and those professionals and volunteers on the frontline of emergencies?	○ **Yes** ○ **No**	

Domain 3: Operation and Maintenance

Indicator 3.1 Standard Operational Procedures (SOPs) for Operation and Maintenance		
Questions	**Answers**	**Notes/Sources of Evidence**

[32] For flooding this can include reducing the time lag between data collection and analysis to the receipt of data daily; improved flood modelling and analysis; rehabilitation of radar and improvement of the meteorological systems to allow for better utilization of upstream hydrological information; and to provide predictions of flood levels, flows, peak travelling speed, and potential inundated areas. It is also particularly important to continually revisit flood maps as climate change has resulted in higher-than-expected flooding levels.

[33] Information generated by the central meteorological centre is often too generic for specific types of infrastructure or sectors. Infrastructure sectors should deepen their understanding of weather impacts and collaborate on information gathering.

[34] Information disclosure is a useful tool for generating market pressure and incentivizing behaviour change. Stakeholders can scrutinize this information, identify cross-sectoral adaptation measures, and create pressure for infrastructure owners/operators to adopt best practice (PricewaterhouseCoopers, 2010).

(1) ***Are there standards and regulations regarding ensuring safe operation and maintenance of public investments and outlays***?	○ **Yes** ○ **No**	
(2) ***Is there a regular and detailed inspection required to underpin maintenance and assess whether specific repair works are needed?***	○ **Yes** ○ **No**	
(3) **Are maintenance works needed for culverts, canals, removal of sedimentation, control of vegetation, slopes, repair of edge, shoulders, potholes, and cracks?** • What are the costs of maintenance[35]? • How much percent of the cost has been spent on consistent, regular, and routine maintenance whilst How much is spent on emergency unplanned repairs and reconstruction activities? • How can the costs of regular maintenance can be optimized?	○ **Yes** ○ **No**	.
(4) ***Are there any disaster contingency manuals in place for all transport operators which will immediately activate emergency procedures and establish a disaster response headquarters?***	○ **Yes** ○ **No**	
(5) ***Is redundancy introduced into emergency operating systems so that if a disaster hits the main operating system there are procedures in place for a secondary unit to temporarily take over?***	○ **Yes** ○ **No**	

Indicator 3.2 Road Asset Management System on Infrastructure Performance		
Questions	**Answers**	**Notes/Sources of Evidence**
(1) ***Is there a road asset management system for keeping a record of infrastructure damage and helping government agencies understand where to prioritize investment across the transport network as it tracks an asset's entire lifecycle?*** • Does this system detail the specific causes of failure, such as extreme weather?	○ **Yes** ○ **No**	
(2) ***Are the inventories of critical infrastructure assets cross-referenced with hazard maps to identify the threat from system failure?*** • Are transit assets, such as buses, vans, fuel supplies, communications equipment, and repair facilities and key aspects of the assets listed (construction type, year built, footprint etc.), also inventoried?	○ **Yes** ○ **No**	
(3) ***Are the impacts of hazards on the condition, performance, and life of the asset and its ability to provide a reliable and safe service used to inform the development of objectives, performance metrics, and data-collection efforts to help manage extreme risk as well as influence the timing of rehabilitation and replacement***?	○ **Yes** ○ **No**	
(4) ***Are the road assets that are repeatedly affected by weather events flagged (the flag could come from***	○ **Yes** ○ **No**	

[35] The economic case for maintenance is significant and is only a small fraction of the construction cost—5 percent to 6 percent per annum for an unpaved rural road (Neal 2012).

maintenance asset performance logs, maintenance work orders, road condition) and the costs of those events tracked? • Are risk ratings or vulnerability indicators included in the asset management database to enable agencies to quickly see where to target Climate Resilience and Disaster Risk Management (CR/DRM) actions? • What is further information gathered by on-site investigations, historical records, topographical surveys, and interviews with local people living nearby?		
(5) ***Does the information management system on infrastructure performance provide the capacity to learn from past failures and to possibly detect early deteriorations?***	○ **Yes** ○ **No**	
(6) ***Are regular inspections carried out for critical facilities such as airports and seaports to see if they are accessible in the event of a disaster or increased demand for their services?*** • What are the landing conditions for international flights Post-disaster, these conditions heavily contributed to the crisis as poor transport infrastructure became a barrier to emergency aid and recovery? • Is there ferry vessel/terminal compatibility by compiling and maintaining a register of existing and potential emergency ferry terminals, and their characteristics and requirements in the event of an emergency?	○ **Yes** ○ **No**	
(7) ***Are transportation lifeline networks/routes, which are essential to regional and national mobility, aid in evacuations and maintaining basic transportation services, identified, categorized, and prioritized?*** • Is this lifeline network identified and categorized through a risk assessment process based on criteria determined by stakeholders and a consideration of economic, environmental, and social impacts? • Is the categorization of networks and the approximate timeframe for services to be restored set through performance-based standards? • Are lifeline audits conducted to assess performance during both expected and extreme disaster scenarios to help with response planning? • Is critical infrastructure identified, such as power and water, which particularly need to be well networked and accessible for the emergency services and more generally for the public, during and immediately after a disaster? • Are the interdependencies between transport modes considered and categorized? • Does this categorization communicate in advance to the general public, agencies, utilities and emergency service providers for improving mobility after a disaster and ensure transportation agencies identify what investments are needed to maintain these transportation lifeline networks?	○ **Yes** ○ **No**	

Indicator 3.3 Real-time Monitoring, Early Warning and Response		
Questions	**Answers**	**Notes/Sources of Evidence**
(1) ***Are there any real-time monitoring systems in place to monitor critical assets and hazard sites through the systematic collection of "live data" of structures[36]?*** • Are local communities also involved in monitoring potential hazards? • Are vulnerable groups or their advocates involved in the monitoring process?	○ **Yes** ○ **No**	
(2) ***Are there any Early Warning Systems (EWSs) of any forms from technologically advanced to relatively simpler community-based systems*** in place, as an important operational part of Climate Resilience and Disaster Risk Management (CR/DRM) within transport systems? • Do the EWS consider the needs of vulnerable groups?	○ **Yes** ○ **No**	
(3) ***Are there any highly visible contingency plans and transitional traffic measures in place to identify alternative routes*** in the case of an emergency, particularly to major logistics facilities vulnerable to closure such as arterial roads, ports, and airports?	○ **Yes** ○ **No**	
(4) ***Are there any of the following transitional traffic measures in place***? ○ Exploiting redundant capacity in the system by adding extra ferry or bus services and maximizing the capacity and flexibility of other vehicles. ○ Introducing temporary transit services such as bus bridges, bus lanes, and ferry services on routes with the highest priority. ○ Assessing whether transport routes can be adapted in case of an emergency. ○ Establish contraflow bus systems and emergency reserve bus fleets effective during an emergency ○ Introduce mutual aid agreements between operators in advance, for example, between bus agencies and ferry operators to ensure there is spare capacity in the event of a disaster. ○ Implement high-occupancy vehicle requirements. ○ Locate emergency park-and-ride location in advance and draft websites and maps for circulation.	○ **Yes** ○ **No**	

[36] Data is generally collected through pre-placed sensors, which feed into a remote monitoring system that can be used to analyze and report data. Monitoring of data allows real-time decisions to be made affecting the operation, maintenance, and safety of bridges.

○ Provide for bikes and pedestrians during an emergency to increase the transport system's resilience. ○ Provide indicators (in a similar way as "snow pole markers" are used to delineate the edge of the road) for road users to notice where the sides of the road are, and to indicate the flood depth, during inundation events.		
(5) ***Are existing Business Continuity Plans (BCPs) incorporated with an understanding of the resilience of the operation and management of the infrastructure***? • Are BCPs developed and reviewed with supply chain partners, service users, and emergency responders? • Are there any forums created for the private sector to share experiences, exchange knowledge and information, prepare business continuity plans, and provide training?	○ **Yes** ○ **No**	
(6) ***Are emergency processes regularly reviewed through a multi-stakeholder team so that any problems and inefficiencies can be identified, and event, impact, and response scenarios can be modelled***? • Are there any forums in which vulnerable groups can share experiences and exchange knowledge and information?	○ **Yes** ○ **No**	
(7) ***Is Disaster Waste Recovery (DWR)[37] in place to*** fill holes/soft spots and "lower-grade" road construction? Are there any regulatory frameworks, controls, and standards in place to institutionalize DWR?	○ **Yes** ○ **No**	
(8) ***Are emergency repair works*** to get the right balance between taking immediate action and choosing the correct solutions with the longer-term recovery process and future resilience in mind?	○ **Yes** ○ **No**	
(9) ***Does operations and recovery planning*** integrate private and non-profit sectors into their planning?	○ **Yes** ○ **No**	

[37] In the immediate period following a disaster, waste can be used for filling of holes/soft spots and "lower-grade" road construction. Concrete is often the most widely available waste material, but other materials that can also be effectively used are brick, stone, and gravel. A blended mix of virgin material/recycled material can be used as a solution to meet certain engineering specifications, or where DWR is limited. DWR can be applied to many construction projects, including roads, bridges, embankments, flood protection, kerbs, bedding for footways/paving, gabions, ballast for railway sleepers, airport runways, ports, and harbours. There are technical challenges to get the right quality material for DWR. Consideration should be given to working with local crushing plants (usually associated with quarries), where the plant (crusher, screens) can be adapted to produce materials to the right specification. A challenge is to obtain "good quality" rubble that is free from non-construction material (household material, hazardous material, waste etc.). The logistics of the supply chain is important in relation to the waste DWR point. There are many factors to consider, including the trucking/transport available, clearance needs, storage, material available, production volume etc. materials, techniques, and specifications. Testing and certification of products and materials should also be incorporated into the process. Local/in-country training is also needed to establish the techniques and specifications of crushed material etc. before a disaster. It can also be a challenge to gain widespread acceptance of DWR and overcome people's perceptions of DWR material, both socially and culturally, as rubble could have been someone's home once. Demonstrations and example specifications may help overcome negative perceptions of DWR and build capacity in this area. Furthermore, DWR can be linked to livelihood/income-generation schemes, as in Haiti where it has generated more than 100,000 hours of work for local men and women.

Indicator 3.4 Communication Systems		
Questions	**Answers**	**Notes/Sources of Evidence**
(1) ***Are there any compatible and reliable communication systems between service providers and road users in place for emergency response?*** • Are these compatible with each other, able to resist power cuts, and scalable? • Do the systems accommodate vulnerable groups, e.g., persons with disabilities?	○ **Yes** ○ **No**	
(2) ***Are resilience targets communicated on the level of usability and the time it takes to restore ICT systems to manage user expectations?*** • For example, targets could be set for a minimal level of service (for emergency responders)—functional (for the economy to begin moving again) and operational (near capacity).	○ **Yes** ○ **No**	
(3) ***Are there Intelligent Traffic Systems (ITS) in place*** that can provide information for commuters and freight on alternative routes to be used—variable signs on roads, dedicated radio channels, mobile phone, as well as "**vulnerable hotspots**" to road users to prevent traffic jams and accidents, as well as prevent further damage to the road? • Are the systems designed for used by persons with disabilities?	○ **Yes** ○ **No**	
(4) ***Are there any communication protocols procedures in place***: 1) Communication protocols between the environment agency and transport operators as well as between weather forecasters and transport operators are important so that they can take adequate precautions to minimize disruption and ensure the safety of users; and 2) to mobilize and move staff from other locations that have not been impacted by the disaster?	○ **Yes** ○ **No**	.
(5) ***Are there any contingency plans*** that clearly specify staff availability in times of extreme weather, including the full contact information of critical personnel who is and is not likely to respond in an emergency, as well as channels for transferring accurate and real-time information, such as Facebook and Twitter?	○ **Yes** ○ **No**	
(6) ***Is there coordination with other critical infrastructure departments*** that have upstream/downstream interdependencies with transport infrastructure to ensure that there are emergency plans for their staff (particularly those operating pumps/levees, for example)?	○ **Yes** ○ **No**	
(7) ***Are there exercises planned on a regular basis and the relevant tools and evaluation guidelines provided to conduct these exercises***?	○ **Yes** ○ **No**	

Domain 4: Technical Expertise

Indicator 4.1 Capacity Building for Officials and Civil Servants

Questions	Answers	Notes/Sources of Evidence
(1) ***Are there any training programmes in place for government officials and civil servants to understand the principles of resilience***, covering *Spatial planning, gender-sensitive risk analysis, knowledge of mitigation strategies and protective measures, partnership building and networking; collecting, storing, and sharing information; program evaluation, management, and design Expertise; as well as the first-responder, operations-level training for emergency response*?	○ **Yes** ○ **No**	
(2) ***Are the training sessions often organized?*** • What are the key modalities of delivering trainings, such as training sessions and workshops, one-on-one technical assistance, and peer-learning opportunities?	○ **Yes** ○ **No**	
(3) ***Are these training events effective?*** • What are the outcome and impacts?	○ **Yes** ○ **No**	
(4) ***Are there any specific online portals*** offering tools, best practices, links to funding opportunities, a calendar all training and technical assistance offerings in the region, blogs and discussion boards, updates on regional activities, and forums to request assistance from technical experts?	○ **Yes** ○ **No**	
(5) ***Are there any technical guidance, capacity building and details delivered to the sub-national level?***	○ **Yes** ○ **No**	

Indicator 4.2 Dedicated Staff Assigned to Address Climate Resilience and Disaster Risk Management (CR/DRM) Issues		
Questions	**Answers**	**Notes/Sources of Evidence**
(1) ***Are there any positions established specifically to responsible for addressing CR/DRM) issues***?	○ **Yes** ○ **No**	
(2) ***Is there any staffing plan within the sector aligned to CR/DRM objectives and priorities***?	○ **Yes** ○ **No**	
(3) ***Do the persons to fill these positions have appropriate technical competency to fulfil their responsibilities***?	○ **Yes** ○ **No**	
(4) ***Are there any issues and challenges for staffing and keeping the staff on the positions?***	○ **Yes** ○ **No**	
(5) ***Do you have any recommendations for improving the staffing for CR/DRM issues?***	○ **Yes** ○ **No**	

Indicator 4.3 Technical Skills Base		
Questions	**Answers**	**Notes/Sources of Evidence**
(1) ***Is the current technical skillset aligned with the CR/DRM objectives and priorities?***	○ **Yes** ○ **No**	
(2) ***Are key management and technical positions related to CR/DRM filled with people with the appropriate qualifications and skills?*** • Are there positions that have yet to be established or filled?	○ **Yes** ○ **No**	
(3) ***Are well-qualified experts selected for engineering design studies and work supervision?***	○ **Yes** ○ **No**	

(4) ***Has the development skills base been improved among engineering consultants, as well as management supervision skills?***	○ **Yes** ○ **No**	
(5) ***Are engineers trained to adopt a systems perspective during the design and planning of infrastructure?***	○ **Yes** ○ **No**	

Indicator 4.4 Knowledge Management, Risk Awareness, and Community Engagement

Questions	Answers	Notes/Sources of Evidence
(1) ***Is there a system for documenting, storing, and disseminating Climate Resilience and Disaster Risk Management (CR/DRM) knowledge within the road sector?*** • Is knowledge accessible internally and externally? • Who are the users of this information?	○ **Yes** ○ **No**	
(2) ***Is there a regular internal process within the road sector for sharing and thinking about good practices and lessons learned regarding CR/DRM?*** • How often is this done?	○ **Yes** ○ **No**	
(3) ***Is there a systematic or formal process in place to systematically identify good practices?*** • What are the most important sources of learning?	○ **Yes** ○ **No**	
(4) ***Does the road sector participate in discussions with counterparts and beneficiaries on CR/DRM approaches, lessons learned, and good practices?*** • If so, how often? • Have these discussions been mutually beneficial? • Why or why not?	○ **Yes** ○ **No**	
(5) ***Are local approaches used to mitigate the effect of disasters on transport networks given the differential impact of disasters across a country and the presence of different microclimates across one stretch of a transportation network?*** • Do local authorities interact and share information on a regular basis so that a similar level of resilience is met across regions? • Do local authorities and communities understand the risks affecting their infrastructure and what infrastructure is critical in their community, including their vulnerable groups? • Can workshops between local critical infrastructure representatives and asset owners provide invaluable information on access to critical assets, interdependencies, service restoration time frames, and the impact of hazards on the local system? • Is this information stored and used for future local planning assumptions and shared with emergency responders, so they understand where the **priority infrastructure** lies and how much time they have to respond before the infrastructure collapses?	○ **Yes** ○ **No**	
(6) ***Can increasing awareness and learning in communities around hazard-affected areas help provide early detection of problems and inefficiencies, as well as increase their ownership of the operations and maintenance of the infrastructure?*** • Can communities be taught early warning signs, such as tension cracks opening in the ground high above the	○ **Yes** ○ **No**	

road bench, minor rock falls, and slips at the foot or edges of the potential slip areas? • Are community labour-based methods used to ensure infrastructure development more successful and sustainable when roads are maintained and built; to builds the skills of local communities and the capacity for replication, operation, and maintenance of works; and to provide more opportunities for salvaging and reusing existing materials after a disaster? • Can vulnerable groups be involved in these initiatives?		

Domain 5: Financial Arrangement and Incentives

Indicator 5.1 Budget Allocation and Financial Resources for Achieving Climate Resilience and Disaster Risk Management (CR/DRM) Objectives and Priorities		
Questions	**Answer**	**Notes/Sources of Evidence**
(1) ***Are there any types of financial resources are available for addressing CR/DRM issues pre-disaster, during disaster, and post-disaster phases?*** • Is transparent gender-sensitive criteria applied when allocating CR/DRM resources? • Have financial resources been sufficient to achieve CR/DRM objectives and priorities? • To what extent are the financial resources to address CR/DRM stable and reliable?	○ **Yes** ○ **No**	
(2) ***Have any of the following funding instruments been used in your country for recovery, reconstruction, and rehabilitation of road assets and related infrastructure?*** • **Budget-sharing mechanisms between local and central governments**: Budget-sharing mechanisms between local and central governments allow local authorities to apply for additional funding for reconstruction works. The procedures should be negotiated in advance and cover the following: procedures for applying for a subsidy to the central government; the cost-sharing ratio of rehabilitation works; criteria for the types and severity of disasters, which require these mechanisms; establishment of a body of experts and organizations to the central government level and team formulation and procedures for damage assessment. • **Special additional budget allocation**: Where regional budgets are insufficient, there may be options for requesting additional funding from national or international bodies. • **Public-private partnerships**: Policy incentives can be used to promote private sector investment to share reconstruction costs. Public-private partnerships are often used to procure funds for infrastructure improvement, as it is seen as relatively low risk and suitable for long-term fund operation by pension and insurance institutions. • **Regular budget**: Allowance for diversion of funding for existing projects to urgent repair work in the case of disasters.	○ **Yes** ○ **No**	

	• **Existing programs with international partners**: There may be options for negotiating for additional funds or diverting existing funds from international partners into post-disaster activities. • **Loans**: If allowed by law, it may be possible to obtain emergency loans, though this may impact on the future fiscal position of the country/province. • **New taxes**: This is unlikely to be an attractive option, though theoretically possible. Levies, taxes, or surcharges can be used to raise additional funds for reconstruction. • **Policy incentives for boosting domestic trade and commerce**: Adopting changes to policy for commerce can promote investment and help to inject liquidity into affected areas. • **Disaster insurance**: Initiatives such as the Pacific Catastrophe Risk Insurance pilot are insurance programs aimed at helping to reduce the financial vulnerability of small island nations in the Pacific to natural disasters. • **Recovery of private sector**: Promoting private sector recovery can promote collaboration in repair and operation of transport infrastructure, devolving responsibility and releasing resources. Infrastructure repair may rely on the private sector resources and providing support to these private enterprises can facilitate recovery. • **Direct assistance**: Housing assistance with materials; livelihood restoration with free seeds, tools etc.; temporary income sources (i.e., cash-for-work); alternative employment opportunities with retraining or referrals for rapid repairs or clearance of transport route; and targeted assistance for vulnerable groups. • **Indirect assistance**: Temporary tax breaks; credit schemes to businesses with soft terms; and injecting equity to support recovery; and targeted assistance for vulnerable groups.		
(3)	***Are emergency funds or transferring risk to sovereign insurance pools included into Pre-disaster planning?*** • Is this arrangement able to ensure *strategic leadership and take proactive measures to increase the resilience?* • Are Emergency Budgets flexible for meeting rapid response demands?	○ **Yes** ○ **No**	
(4)	***Have Catastrophe Bonds (CAT Bond)[38] provide an immediate pay-out after the disaster has occurred?***	○ **Yes** ○ **No**	

[38] Catastrophe Bond (CAT Bond) allows risks to be transferred from an insurer or reinsurer into the capital markets thus increasing the amount of insurance that can be written. Furthermore, they are attractive to investors as a means of diversifying their investment portfolios as natural catastrophes are not correlated to existing economic conditions. Catastrophe bonds are index-based insurance mechanisms, where the indemnity is based on a specific weather parameter measure over a prespecified period. Pay-out occurs when the index exceeds a pre-specified value. Index-based insurance is used when there is a strong quantifiable relationship between weather risk and losses. the potential mismatch between contract pay-outs and the actual loss experienced. Few of the 200 odd cat bonds that have been sold have generated a pay-out following a disaster (Keohane, G. L., 2014). For example, four storms in Haiti created considerable damage in 2008, but because most of this was due to flooding and not wind (the triggering parameter of the index-based coverage) a pay-out was not triggered by CCRIF.

• Can they be linked to emergency response plans, as well as to the level of adaptation built into the infrastructure by returning the savings from reduced damage or service interruption to investors?		
(5) ***Is multi-stakeholder coordination required to deal with the complications arising from multiple actors using different budget mechanisms to channel funds?*** • How are existing programs diverted and tendering processes shortened to provide more rapid support to emergency works required?	○ **Yes** ○ **No**	

Indicator 5.2 Financial incentives and Cost-sharing Mechanisms		
Questions	**Answer**	**Notes/Sources of Evidence**
(1) ***Are there any types of financial incentives and cost-sharing mechanism measures have been used in dealing with Climate Resilience and Disaster Risk Management (CR/DRM) issues in your county?*** • Such as Emergency funding arrangement, performance-based funding, betterment funds, gender-sensitive resilient selection criteria and resilience auditing, flexible procurement policies, Public-Private Partnership cost-sharing mechanism	○ **Yes** ○ **No**	
(2) ***Are emergency funding arrangements used to incentivize resilience to be mainstreamed within reconstruction projects and encourage pre-disaster planning[39], which will aid effective recovery and reconstruction***?	○ **Yes** ○ **No**	
(3) ***Is performance-based funding [40]used to disaster repair and reconstruction, with resilient assessment criteria being applied in the selection and prioritization of transport infrastructure investments***?	○ **Yes** ○ **No**	
(4) ***Are betterment funds [41]established to restore or replace hazards to a more disaster-resilient standard than before?***	○ **Yes** ○ **No**	
(5) ***Are there any gender-sensitive resilient selection criteria and resilience auditing that has been adopted to encourage decision makers to incorporate gender-sensitive resilient investment criteria into transport infrastructure?***	○ **Yes** ○ **No**	
(6) ***Do procurement policies[42] include filtering criteria to select infrastructure projects that have considered the risks from natural hazards, the longer-term risks from climate change, and those that have considered cross-sectoral adaptation?***	○ **Yes** ○ **No**	

[39] Pre-disaster contracting frameworks involve establishing long-term framework agreements between the client and contractors, consultants and suppliers, which enables rapid mobilization, effective risk sharing and collaborative working. Ultimately, this saves time, cost, and resources and lays the foundation for more resilient infrastructure.

[40] Alliance contracting is an arrangement where parties enter into an agreement to work cooperatively and share risk and rewards measured against predetermined performance indicators. The contractor's profit is earned through performance, reducing claims. It also promotes collaboration within a commercial framework between experts from different companies acting in the project's interest.

[41] Betterment costs are the difference between restoring or replacing an asset to its pre-disaster standard and the cost of restoring or replacing it to a more disaster resilient standard.

[42] For large disasters, flexible approaches to procurement are introduced to understand the capacity of the construction industry and the availability of materials, as well as ensure that in releasing work out into the market this will not have the effect of overstretching construction companies or artificially driving up prices.

(7) ***Has the private sector been engaged in improving the quality of construction, through the Public-Private-Partnerships (PPPs) cost-sharing mechanisms?*** If yes, what challenges, such as complex, time-consuming, legal and regulatory arrangement, capacity to deal with PPS, etc. are there associated with such as an approach?	○ **Yes** ○ **No**	

Indicator 5.3 Monitoring and Evaluation Mechanisms		
Questions	**Answers**	**Notes/Sources of Evidence**
(1) ***Does the Project Results Framework include appropriate performance indicators to measure CR/DRM and resilience results against the overall sectoral CR/DRM and resilience goals and objectives?*** • How are these performance indicators selected?	○ **Yes** ○ **No**	
(2) ***Is there sufficient expertise in monitoring and evaluating CR/DRM and resilience performance?*** • Are there performance evaluation task forces established after a disaster to assess why infrastructure failed and to ensure lessons are learnt during the reconstruction process?	○ **Yes** ○ **No**	
(3) ***Is gender and social inclusion incorporated into CR/DRM and resilience performance monitoring and evaluation?*** • What are some examples of how this is done?	○ **Yes** ○ **No**	
(4) ***Does data for monitoring CR/DRM performance clearly and accurately represent intended results?*** • Does it have sufficient precision and timeliness to inform management decisions? • Are there safeguards to prevent transcription errors and data manipulation?	○ **Yes** ○ **No**	
(5) ***Has data for monitoring and evaluating CR/DRM and lessons learned informed current and future strategies and programming?***	○ **Yes** ○ **No**	

Indicator 5.4 Post-investment Evaluation and Portfolio Management		
Questions	**Answers**	**Notes/Sources of Evidence**
(1) ***Is there a unified format and guidelines for post-investment evaluations, covering the key aspects e.g., costs, timeliness, quality of deliverables, outputs, outcomes, and impacts?***	○ **Yes** ○ **No**	
(2) ***Are these post-investment evaluations often conducted?***	○ **Yes** ○ **No**	
(3) ***Are end users (e.g., local governments) involved in post-investment evaluations?*** • Who/ what level of government has relevant responsibilities?	○ **Yes** ○ **No**	
(4) **Are there any issues, such as expertise, with undertaking post-investment evaluations?**	○ **Yes** ○ **No**	
(5) ***Has the results of the post-investment evaluations been applied to new strategy and programming?***	○ **Yes** ○ **No**	

Annex B: Checklist of relevant documents required

This annex presents an indicative list of supporting documents required for evaluating each RSRI domain and associated indicators.

Domains	Indicators	Required Documents	✓
Domain 1: Policies, institutions, and processes	Indicator 1.1 National and sectoral policies for mainstreaming Climate Resilience and Disaster Risk Management (CRDRM)	• National and sectoral policies, strategies, and action plans on CCA and DRM • Sectoral development strategies and plans	
	Indicator 1.2 Legal and regulatory framework	• Institutional provision of the Ministry of Public Works (MPW)	
	Indicator 1.3 Sectoral leadership, institutional arrangement and coordination mechanisms	• Vision and mission statement of MPW • Documentation on the roles and responsibilities • Documentation on various coordination mechanisms	
	Indicator 1.4 Horizontal and vertical information flow	• Documentation of organizational chart, business models, reporting protocols	
Domain 2: Technical Planning and Design	Indicator 2.1 Public investment planning framework and process	• Policies, procedures, guidelines for sectoral planning. • Sample sectoral development plans	
	Indicator 2.2 Engineering design standards and norms	• Design standards and norms • Guidelines for climate-resilient design	
	Indicator 2.3 Project identification, preparation and appraisal standards and process	• Guidelines for project planning, design, appraisal	
	Indicator 2.4 Access to Climate Change and Disaster Risk Information (CCDRI)	• Technical specification of institutional GIS information system • Metadata, data dictionary	
Domain 3: Operation and Maintenance	Indicator 3.1 Standard operational procedures (SOPs) for Operation and Maintenance	• Guidelines or procedures for O&M • Special policy for CRDRM	
	Indicator 3.2 Road Asset management system on infrastructure performance	• Technical specification of the system	
	Indicator 3.3 Real-time Monitoring, Early Warning and Response	• Technical specification on EWS system • Contingency plans and business continuity plans • Procedures for emergency response	
	Indicator 3.4 Communication systems	• Technical specification on communication systems	
Domain 4: Technical Expertise	Indicator 4.1 Capability building for officials and civil servants (training)	• Project document of training programmes • Concept notes and agendas • Workshop reports	
	Indicator 4.2 Dedicated staff assigned to address CRDRM issues	• TORs of positions	
	Indicator 4.3 Engineering Skills Base	• Functional description of units and departments • Position profiles	
	Indicator 4.4 Knowledge management, risk awareness, and community engagement	• Web sites • Knowledge portals	
	Indicator 5.1 Budget allocation and financial resources	• National policies for international cooperation	

Domain 5: Financial Arrangement and Incentives	Indicator 5.2 Financial incentives and cost-sharing mechanisms	• Policies for cost-sharing	
	Indicator 5.3 Monitoring and Evaluation Mechanisms	• Guidelines for M&E • Projects' Results framework	
	Indicator 5.4 Post-investment Auditing and Portfolio Management	• Project Mid-term and Terminal Evaluation reports	

Annex C: Scoring sheet for rating Road Sector Resilience Indicators

Resilience Indicators	Resilience Score (0-4)	Supporting Evidence
Domain 1: Policies, institutions, and processes		
Indicator 1.1 National and sectoral policies for mainstreaming Climate Resilience and Disaster Risk Management (CRDRM)		
Indicator 1.2 Legal and regulatory framework		
Indicator 1.3 Sectoral leadership, institutional arrangement and coordination mechanisms		
Indicator 1.4 Horizontal and vertical information flow		
Subtotal		
Domain 2: Technical Planning and Design		
Indicator 2.1 Public investment planning framework and process		
Indicator 2.2 Engineering design standards and norms		
Indicator 2.3 Project identification, preparation and appraisal standards and process		
Indicator 2.4 Access to Climate Change and Disaster Risk Information (CCDRI)		
Subtotal		
Domain 3: Operation and Maintenance		
Indicator 3.1 Standard operational procedures (SOPs) for operation and maintenance		
Indicator 3.2 Road asset management system on infrastructure performance		
Indicator 3.3 Real-time monitoring, early warning and response		
Indicator 3.4 Communication systems		
Subtotal		
Domain 4: Technical Expertise		
Indicator 4.1 Capacity building for officials and civil servants (training)		

Indicator 4.2 Dedicated staff assigned to address CRDRM issues		
Indicator 4.3 Technical skills base		
Indicator 4.4 Knowledge management, risk awareness, and community engagement		
Subtotal		
Domain 5: Financial Arrangement and Incentives		
Indicator 5.1 Budget allocation and financial resources		
Indicator 5.2 Financial incentives and cost-sharing mechanisms		
Indicator 5.3 Monitoring and evaluation mechanisms		
Indicator 5.4 Post-investment auditing and portfolio management		
Subtotal		
TOTAL		

9

PRIORITIZATION AND INVESTMENT PLANS

9.1. Introduction

Project appraisal is an economic analysis process that involves assessing the project viability. Project viability assesses whether a project will be sustainable in terms of generating revenue for self-sustenance over time. For socio-economic development, project appraisal is also undertaken to determine whether the project will have significant positive impacts on socio-economic development.

A project is deemed to be viable if it generates benefits which exceed its socio-economic costs (including externalities). By determining the project economic or financial viability, this enables the decision makers (individuals and/or authorities) to compare the options of solving the problem and selecting an option(s) that will maximize socio-economic and environmental benefits. As climate resilient interventions are projects and require financial investment, they should ideally be subjected to economic analysis to determine their economic feasibility and viability to enable prioritization. This is in line with the United Nations Framework Convention on Climate Change (UNFCCC)[43] notion of maximising co-benefits from climate change adaptation and mitigation projects.

One of the widely used appraisal technique that has gained popularity is Cost-Benefit Analysis (CBA). It is an economic appraisal technique that uses money as a yardstick to determine a proposed investment's viability. CBA is a relatively old process first proposed in 1848 by the French engineer Jules Dupuit and formalized by the British economist Alfred Marshall as a project appraisal technique. Since then, the technique has gained popularity and has been applied to a wide range on projects such as dams and highways and, over the years, CBA has gained a lot of popularity in climate change adaptation and mitigation related projects (UNFCCC, 2011).

There are two types of CBA: the economic CBA and the financial CBA. The economic CBA is undertaken at a larger level and takes into account all externalities, both positive and negative, that are likely going to arise from the intervention. The financial CBA is concerned about the project profitability and disregard the externalities that will be incurred by the external parties. The decision criteria for a proposed or implemented project are based on the Net Present Value (NPV) and Internal Rate of Return (IRR).

CBA has seven steps which are followed to prepare the Climate Resilient Investment Plan (CRIP). They are:

1. Identification of the alternatives or options
2. Identification of the impacts of the alternatives
3. Quantification of the impacts of the alternatives
4. Valuation of the impacts of the alternatives
5. Discounting the valued impacts
6. Deriving net present value, internal rate of return and benefit cost ratio
7. Sensitivity analysis

The steps are discussed in detail in this section using illustrations from the Dominica case study country, which was subjected to CBA for road section prioritization.

STEP 1: Identify alternatives or options

This is the first stage of the CBA, and it involves the identification of the alternatives or options that can be implemented to solve the society problem. It is important to note that there can be one option which will still be subjected to CBA to determine whether it is economically viable to undertake. In the case of road climate resilient interventions, the alternatives are the road sections which are identified to be vulnerable to climate

[43] UNFCCC (2011) Assessing the costs and benefits of adaptation options an overview of approaches- the Nairobi work programme on impacts, vulnerability and adaptation to climate change. https://unfccc.int/resource/docs/publications/pub_nwp_costs_benefits_adaptation.pdf

change impacts, and hence require to be climate proofed. The road segments across the country of study that are selected for CBA are determined by the hotspot modelling undertaken as part of the CRVA (see **Section 6**).

Once the list of road sections is confirmed, adaptation measures are proposed for each of them. They technically become the projects that are recommended for implementation to build resiliency of the road transport network.

It is important that the measures proposed are discussed and agreed with the relevant stakeholders, ensuring they can be applied successfully to the local context. Under Step 3 of the CBA, the interventions are assessed based on the costs and benefits to be incurred and generated under each road section, hence specific details are required for the analysis. This information includes the spatial scale of the road (length), construction materials to be used, and road elevation levels proposed (i.e., higher levels may mitigate the impact of flooding).

Table 19 presents a summary of the road sections (hotspots) identified through the CRVA with their proposed interventions for the Dominica case study country.

Table 19: Proposed climate resilient interventions for each road section/area (Dominica)

Road section	Proposed interventions
Bout Sable Bay area	▪ Slope stabilisation ▪ Retaining structures ▪ Road rehabilitation to include drainage
Boetica area	▪ Construction of 20 m span bridge
Pointe Mulatre Bay area	▪ Road rehabilitation including drainage
Imperial Road Antrim Sylvania	▪ Slope stabilisation
Soufriere to Scotts Head	▪ Seawall reconstruction
Point Michel to Soufriere road	▪ Slope stabilisation ▪ Retaining existing structures ▪ Road rehabilitation including drainage
Tarreau (Hillsborough Bridge to Warner)	▪ By-pass road construction including drainage
Rosalie (Petite Soufriere to Rosalie)	▪ Road construction and rehabilitation including drainage ▪ Reconstruction of 60 m bridge at Rosalie
Au Delices	▪ Slope stabilisation ▪ Riverbank protection ▪ Retaining wall ▪ Riprap protection ▪ Road reconstruction including drainage

STEP 2: Identify the interventions' impacts

Step 2 refers to the impacts of the climate resilient interventions proposed, which are classified as costs (negative impacts) and benefits (positive impacts). All the direct, indirect and intangible costs and benefits are identified and described in detail. It is important to consider socio-economic and environmental/ecological impacts, understanding the rational for their occurrence.

All the impacts' timescales should be defined, and two scenarios can be considered: Without-the-intervention and With-the-intervention.

- **Without-the-intervention**: this scenario assumes business as usual where no intervention is implemented and the impacts of climate change on the road infrastructure and road operations services are uncontrolled.
- **With-the-intervention**: this scenario assumes implementing the proposed adaptation measures, which reduce the impacts of climate change on road infrastructure and road service operations. The reduced impacts considered avoided costs are categorised as benefits.

The avoided costs or benefits of implemented measures are estimated as the difference between the impacts of climate change under the Without-the-intervention and With-the-intervention scenarios. The following are costs and benefits that can be considered for the interventions of study on the road transport sector.

Implementation costs

These are the fixed total costs that will be incurred in the implementation of adaptation measures for each road section.

Maintenance costs of interventions

Maintenance costs are the operational costs that are incurred annually to maintain the implemented interventions. They need to be calculated in terms of occurrence during the project lifespan, considering whether they will be incurred annually and assuming the maintenance percentage per year. The road engineers can provide further information on these costs.

Benefits of interventions

The benefits of the proposed interventions are identified for each road section and categorised into direct, indirect and intangible benefits. The immediate benefits are easier to quantify and value while the indirect benefits require a more detailed assessment. The intangible benefits are those that can only be described, hence are mainly qualitative and difficult to measure.

The premises for the identification of the benefits for the interventions is based on the fact that the roads are built to enable economic growth and development as they facilitate movements of goods, services, and labour. They provide access to basic services such as education and health facilities and employment centres. In addition, they enable income generation through agriculture investment and productive employment. Thus, the main benefits that can be considered to climate-proofing road infrastructure are the following.

- **Avoided costs of road repairs and maintenance**: this is the cost that would have been incurred if the roads segments are not climate proofed. Climate variables, mainly temperature and rainfall, affect the road physically through wear and tear (Chinowsky et al., 2011[44]; Miradi, 2004[45]).
- **Increase of operational road days**: the impact of natural disasters can result in road closure and delays which increases the days that the roads are operated without being used.
- **Reduced vehicle maintenance costs**: there is a direct relationship between the vehicle operational costs and the state of the road. Poor maintained roads result in incremental operational costs in terms of tyre replacements, shock absorbers and vehicle components (Alaniz, 2013[46]; Ingraham, 2015[47]). Therefore, since there is an association between climatic variables and status of the road, the vehicle operational costs are likely to increase over time if the roads are not climate proofed.
- **Timesaving for users**: either a partial or a total closure of the roads for maintenance tasks after extreme climatic events result in delays, and this is a cost for the road users increasing their travel

[44] Chinowsky, P., Hayles, C., Schweikert, A.m Strzepe, N., Strzepek, K., Schlosser, A.C (2011). Climate Change comparative impact on developing and developed countries. The engineering Project Organisational Journal (March 2011) 1, 67-80

[45] Miradi M. (2004) Artificial neural network (ANN) models for prediction and analysis of ravelling severity and material composition properties, in Mohammadian M. (ed.) CIMCA 2004, Gold Coast, Australia, pp. 892–903.

[46] Alaniz (2013) The Cost of Bad Asphalt and Concrete Roads. https://alanizpaving.com/2013/05/the-cost-of-bad-asphalt-and-concrete-road/

[47] Ingraham, C (2015) Where America's worst roads are - and how much they're costing us.

time. The benefits for avoiding road closure and delays are estimated, based on the two scenarios of without-the-intervention and with-the-intervention.

- **Reduced accidents and mortality**: poor maintained roads cause road accidents due to the bad condition of the surface and the existence of potholes. Climate proofing the roads will reduce road deterioration resulting in less accidents and mortality.
- **Users' enjoyment of the journey**: driving on well-maintained roads increases the users' enjoyment and hence their well-being. Climate proofing the roads will therefore be beneficial for the users' health.

STEP 3: Quantify costs and benefits

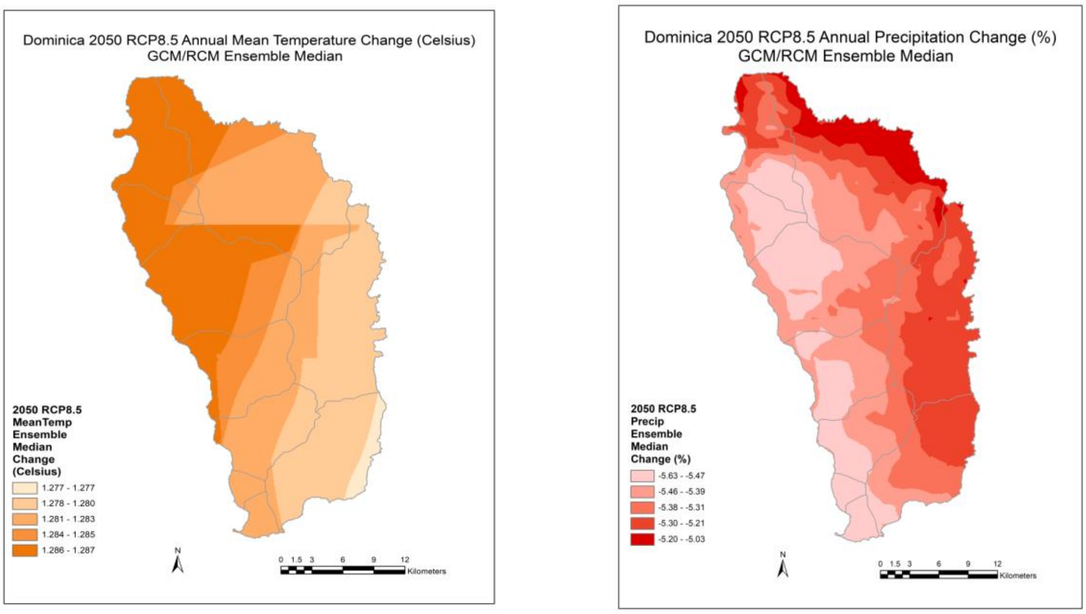
This is an important and technical aspect of the CBA, and it involves converting the identified benefits to numerical values. Quantification of the costs is not necessary in this case since the estimates of the interventions proposed are already provided in a numerical value. For the benefits, quantification is undertaken based on the two scenarios of without-the-intervention and with-the-intervention. For the Dominica case study country, the parameters studied for quantification of the benefits are climate scenarios and traffic counts.

Climate scenarios

For quantification to be possible, it is necessary to study the future climate outlook of the country collecting information for different climate scenarios. They can be developed based on ensemble of 50 Global Circulation Models (GCMs) for temperature and precipitation for the year 2050. This is necessary to estimate the avoided costs of road repairs as well as road closure and delays. The approach is in line with recommendations made by Chinowsky et al., (2011) and the World Bank (undated), which note the importance of understanding the temperature range and the rate of either annual or decadal changes in a region.

A dose-response technique is applied, which translates the impacts identified into stressor–response values based on engineering data and previous impact studies. For the Dominica case study, the climate scenarios used are depicted in **Figure 19**.

Figure 19: Climate scenarios for annual temperature (left) and annual precipitation (right) (Dominica)



Based on engineering parameters, it is estimated that precipitation contributes to 80% of the deterioration of unpaved roads, attributing the remaining 20% to traffic density (Chinowsky et al., 2011; Miradi, 2004). For paved roads, Miradi (2004) estimates that rainfall and temperature account for 4% and 36% respectively of the maintenance costs.

Road traffic volume density

Road traffic volume is required to be able to quantify the benefits of time saved, avoided maintenance costs and any other indirect benefits associated with the measures proposed. Road traffic volume defines the road users, this being a variable that determines the extent of the benefits.

Traffic volume needs to be estimated based on traffic counts and the number of passengers per vehicle. The road users' population also needs to be categorised into students, workers, etc. enabling estimating the costs of time wasted for missing economic activities (e.g., university lessons which promote the economy in the long term, work-related activities) due to road closure or delay.

Traffic data can be obtained from the relevant Ministries and assumptions are made based on similar reports if information for the roads of study is not available. For the Dominica case study, road traffic volumes were not available and were therefore obtained from the traffic survey undertaken for the Loubiere to Bagatelle Road study[48] (see **Table 20**). They were then projected for a 20-year period in line with the interventions' lifespan, and were also used to estimate the avoided costs of vehicle maintenance.

Table 20: Sample of observed traffic volume daily data (Dominica)

Day	From Bagatelle (East to West)												Total
	Non-motorized		Motorized										
	Bicycles	Carts	M/C	Cars	Light Goods	Mini-buses	Medium Buses	Large Buses	Light trucks	Medium Trucks	Large Trucks	Semi-trailers	
Tuesday	**0**	**1**	**26**	**44**	**166**	**40**	**0**	**0**	**6**	**16**	**0**	**0**	**299**
Friday	0	0	30	45	133	24	1	0	7	13	1	1	255
Saturday	0	0	27	43	149	32	0	0	9	8	0	0	268
Average weekdays	0	0.5	28	44.5	149.5	32	0.5	0	6.5	14.5	0.5	0.5	277
Average weekends	0	0	27	43	149	32	0	0	9	8	0	0	268
Average totals	0.00	0.36	27.71	44.07	149.36	32.00	0.36	0.00	7.21	12.64	0.36	0.36	274

The benefits of climate resilient interventions are also a function of the number of road users (passengers) using the road daily to access work. Estimating the number of users can be based on the assumption that mini cars and cars transport an average of two passengers, minibuses carry 12 passengers, buses carry 50 passengers, while the rest of vehicular traffic do not carry any passengers. The projected number of road users is calculated annually.

After estimating the traffic volume and the number of passengers per vehicle, the delays that would occur under the with-the-intervention and without-the-intervention scenarios are calculated. Estimating the delays of road closures of one road lane should build up from past observed road closures and the probability of extreme events that result in travel disruption.

[48] Road Network Safety Assessment Post Tropical Storm Erika, Dominica, Final Report, February 2020, International Road Assessment Programme (iRAP) and Loubiere to Bagatelle Road Feasibility Study, Economic Appraisal including traffic surveys, 2017, assignment undertaken in Dominica by an international Consortium formed by IMC Worldwide.

These calculations are estimated based on the probability of storm in any given year (see **Table 21**), estimated duration of road closure needed to repair the damage (see **Table 22**), and the impacts' likelihood under the without-the-intervention (see **Table 23**) and with-the-intervention (see **Table 24**) scenarios. Under without-the-intervention, it is estimated that road closure will be of 3.7 hours in any year (see **Table 25**) while with-the-intervention, it is estimated it will be of 1.5 hours (see **Table 26**). The avoided delay due to the intervention is the difference between both scenarios, which in this example would be of approximately two hours.

Table 21: Annual probability of tropical storms of different intensity[49]

Intensity[48]	Likelihood in Given Year
TD	20%
TS	35%
H1	8%
H2	3%
H3	3%
H4	3%
H5	1%

Table 22: Estimated road closure times by tropical storm category[47]

Storm type intensity[48]	Road closure (h)
H2	12
H3	**24**
H4	36
H5	**48**

The extreme event considered were the impacts of different tropical storm categories based on probability of occurrence. They were estimated using the Do Nothing and Do Everything scenarios as presented in **Table 23** and **Table 24**.

Table 23: Impact likelihood – Do Nothing[47]

Scale[50]	Replacement	Major repair	Minor repair	Clean
TD	0%	5%	20%	100%
TS	5%	10%	25%	100%
H1	10%	15%	25%	100%
H2	15%	25%	30%	100%
H3	20%	30%	50%	100%
H4	30%	50%	75%	100%
H5	50%	75%	100%	100%

[49] Source of Table 21, Table 22, Table 23, Table 24, Table 25 and Table 26: Loubiere to Bagatelle Road Feasibility Study, Economic Appraisal including traffic surveys, 2017, assignment undertaken in Dominica by an international Consortium formed by IMC Worldwide.
[50] TD stands for Tropical Depression; TS stands for Tropical Storm; H1-H5 stands for Hurricanes of category 1-5 on the Saffir-Simpson Hurricane Wind Scale (see further information on https://www.nhc.noaa.gov/aboutsshws.php).

Table 24: Impact likelihood – Do Everything[47]

Scale[48]	Replacement	Major repair	Minor repair	Clean
TD	0%	0%	10%	100%
TS	0%	0%	15%	100%
H1	0%	5%	20%	100%
H2	5%	10%	25%	100%
H3	5%	15%	30%	100%
H4	10%	20%	30%	100%
H5	10%	20%	35%	100%

Resulting from **Table 21**, **Table 22** and **Table 23**, the delays due to road closure are calculated in **Table 25**.

Table 25: Hours of road closure without-the-intervention

Storm Type	Road Closure	Replacement	Major Repair	Minor Repair	Probability of Occurrence	Road closure hours in a year by storm category
H2	12	0.15	0.25	0.3	0.03	0.3
H3	24	0.2	0.3	0.5	0.03	0.7
H4	36	0.3	0.5	0.75	0.03	1.7
H5	48	0.5	0.75	1	0.01	1.1
					Total road closure in any year	**3.7**

Resulting from **Table 21**, **Table 22** and **Table 24**, the delays due to road closure are calculated in **Table 26**.

Table 26: Hours of road closure with-the-intervention

Storm Type	Road Closure	Replacement	Major Repair	Minor Repair	Probability of Occurrence	Road closure hours in a year by storm category
H2	12	0.05	0.1	0.25	0.03	0.1
H3	24	0.05	0.15	0.3	0.03	0.4
H4	36	0.1	0.2	0.3	0.03	0.6
H5	48	0.1	0.2	0.35	0.01	0.3
					Total road closure in any year	**1.5**

As indicated above, the difference between both scenarios (3.7 hours minus 1.5 hours), result in an avoided delay of approximately two (2.2) hours.

STEP 4: Derive economic values

CBA uses money as a yardstick; therefore, all costs and benefits are converted into US$ values. The costs are estimated based on market prices for road construction and interventions, as explained in Step 3, and assuming that the market prices are without distortion and hence reflective of the economic values. It may be useful to cross-check the costs gathered in previous stages of the CBA with similar national or regional studies.

The benefits are estimated based on market prices for labour, minimum wage and regional vehicle maintenance costs for using based roads. For the Dominica case study, the constant price was derived based on the long term observed consumer price index for the country estimated at 1.01 annually.

STEP 5: Calculate discount rate

Costs and benefits occur at different intervention timescales; hence it is necessary to determine the present value to ensure comparison. The discounting process consists of finding the present value of future costs and benefits, using the formula depicted below.

$$\mathrm{PV} = \frac{\mathrm{b_t}}{(1+\mathrm{r})^{\mathrm{t}}}$$

Where: PV is the present value of either a benefit or a cost
b is the benefit or the cost occurring in time
t is the time when the benefit or cost is occurring
r is the discount rate (12% for similar projects)

STEP 6: Estimate NPV and IRR for each intervention

Based on the derived total economic benefits and costs of the proposed climate resilient interventions, the net benefits are estimated over a 20-year period. Using a discount rate of 12%, the NPV and the IRR are calculated using the two equations depicted below.

$$NPV = \sum \frac{b_t - c_t}{(1+r)^t}$$

Where: NPV is Net Present Value
b_t is benefit occurring in year t
c_t is the cost occurring in year t
t is the time
r is the discount rate

$$IRR = \sum \frac{b_t}{(1+r)^t} - \sum \frac{c_t}{(1+r)^t} = 0$$

Where: IRR is the Internal Rate of Return
b_t is benefit occurring in year t
c_t is the cost occurring in year t
t is the time
r is the discount rate

The decision criteria is:

- If NPV>0, the intervention is economically viable and hence should be accepted as the benefits outweigh the costs. If there are more than one competing alternatives, then the role is to select the one with the highest NPV.
- If NPV< 0, the intervention is not economically viable and should be rejected as it will be a burden to economic development,
- If NPV=0, the intervention breaks-even as discounted benefits equal discounted costs. Therefore, the project can be either accepted or rejected.

For the IRR, the decision criteria is to select the alternative which gives a higher IRR than the discount rate. For the Dominica case study, the derive NPV and IRR are depicted in **Table 27**.

Table 27: NPV and IRR for the road sections of study (Dominica)

Year	Bout Sable bay area	Boetica area	Pointe Mulatre bay	imperial road	Pointe Michel to Soufriere	Tarreau	Rosalie	Soufrier to Scotts	Au Delicies
2021	(2,250,000.00)	(5,800,000.00)	(1,300,000.00)	(23,900,800.00)	(37,500,000.00)	(8,200,000.00)	(16,600,000.00)	(1,500,000.00)	(8,450,000.00)
2022	368,325.56	525,043.48	299,739.78	3,519,734.82	2,654,352.65	2,419,978.52	4,037,737.44	376,246.74	2,516,574.30
2023	350,731.24	547,603.69	314,101.12	3,524,509.67	2,757,285.42	2,512,398.74	4,215,782.15	393,421.53	2,525,984.39
2024	368,013.78	573,149.40	329,675.86	3,658,608.11	2,883,097.76	2,623,692.94	4,374,170.24	412,443.47	2,622,485.00
2025	385,272.33	597,775.88	345,470.69	3,821,637.32	2,994,520.42	2,960,795.14	4,382,071.47	431,271.13	2,831,968.90
2026	403,345.75	623,474.68	362,027.07	3,966,595.88	3,110,144.22	3,071,393.17	4,546,782.52	450,967.83	2,939,626.83
2027	422,273.00	650,293.58	379,382.09	4,116,928.64	3,230,126.55	2,855,461.98	4,717,548.54	471,574.35	3,051,311.63
2028	447,597.79	678,282.53	397,574.62	4,272,833.49	3,354,630.73	2,964,185.36	4,894,590.46	493,133.44	3,167,173.89
2029	520,888.33	707,493.78	416,645.48	4,434,515.61	3,483,826.27	3,076,990.44	5,078,137.32	515,689.88	3,287,369.94
2030	552,571.13	737,981.96	436,637.49	4,602,187.81	3,617,889.09	3,282,456.59	5,268,426.57	539,290.59	3,412,062.00
2031	577,780.19	769,804.20	457,595.57	4,776,070.81	3,757,001.76	3,407,096.23	5,465,704.38	570,448.20	3,541,418.47
2032	604,153.16	805,559.22	480,227.21	4,956,393.50	3,925,412.70	3,555,925.33	5,703,193.38	584,619.16	3,695,984.28
2033	622,814.78	840,307.83	503,280.95	5,173,734.58	4,075,922.52	3,690,671.90	5,916,212.35	618,238.67	3,835,811.76
2034	651,369.30	876,580.47	527,449.81	5,368,567.97	4,232,094.16	3,830,467.05	6,137,043.71	646,573.64	3,980,866.61
2035	681,248.98	914,445.60	552,788.28	5,570,607.43	4,506,204.26	4,118,264.37	6,607,129.11	695,830.92	4,280,352.11
2036	712,516.36	953,974.86	579,353.49	5,780,118.68	4,678,382.12	4,273,876.46	6,853,138.73	735,939.60	4,441,825.09
2037	745,236.96	995,243.19	607,205.41	5,997,377.37	4,857,025.37	4,435,309.15	7,108,152.82	760,770.36	4,609,324.43
2038	779,479.47	1,038,328.98	636,406.97	6,222,669.41	5,042,376.62	4,729,211.05	7,372,499.86	795,511.54	4,783,076.04
2039	813,576.68	1,083,314.25	667,024.19	6,456,291.39	5,234,687.67	4,907,490.92	7,646,520.45	831,862.56	4,830,597.15
2040	849,238.89	1,127,068.58	698,289.82	6,698,550.97	5,402,983.20	5,065,970.55	7,887,170.96	868,073.34	4,986,769.97
NPV	1,298,081.67	(722,167.78)	1,689,394.39	8,023,033.92	(12,380,622.90)	14,875,955.31	20,470,853.57	2,222,199.55	15,124,403.01
IRR	19.11%	10.19%	27%	17%	7%	34%	27%	29%	33%
NPV_{STA}	(63,630.35)	(3,210,830.00)	714,749.11	(5,288,669.96)	(28,272,759.69)	7,884,237.76	8,245,665.82	1,043,029.19	7,960,540.85
IRR_{STA}	12%	5%	18%	9%	1%	22%	17%	19%	22%

The results indicate that it is not economically worthwhile to implement the proposed interventions on Pointe Michel to Soufriere and Boetica area as the Net Present values are negative and IRR is lower than the discount rate. For the remaining road sections, it is economically viable to implement the proposed measures and therefore they should be accepted as they have positive NPV and high IRR. In terms of prioritisation, Rosalie is the most preferred road section as depicted in **Table 28**.

Table 28: Prioritization of the road sections based on NPV (Dominica)

Road section	NPV	IRR	Rank
Rosalie	20,470,853.57	27%	1
Au Delicies	15,124,403.01	33%	2
Tarreau	14,875,955.31	34%	3
Imperial road	8,023,033.92	17%	4
Soufrier to Scotts	2,222,199.55	29%	5
Pointe Mulatre Bay	1,689,394.39	27%	6
Bout Sable bay area	1,98,081.67	19%	7
Boetica Area	-722,167.78	10%	8

Pointe Michel to Soufriere	-12,380,622.90	7%	9

STEP 7: Sensitivity analysis and prioritisation

Sensitivity analysis is an important component of CBA since it deals with uncertainty. It is performed for the proposed road sections by changing the values of the parameters and assessing the responsiveness of the estimated NPV and IRR. It is defined as a worst-case scenario and attempts to answer the question of 'what if?'. In the case of Dominica, sensitivity analysis was performed by escalating the costs by 25% and reducing the economic benefits by 20%. Sensitivity analysis can also be undertaken by changing the discount rate. For the worst-case scenarios, it is not recommended to do sensitivity analysis for alternatives that have yielded negative NPV under the best-case scenario since, under worst-case scenario, it will further decrease their NPV and IRR.

Table 29 depicts the results for the sensitivity analysis of the Dominica case study which indicates that Pointe Mulatre Bay, Tarreau, Rosalie, Soufrier to Scotts and Au Delicies are economically viable under the worst-case scenario.

Table 29: Sensitivity analysis for the road sections of study (Dominica)

Year	Bout Sable bay area	Boetica area	Pointe Mulatre bay	imperial road	Pointe Michel to Soufriere	Tarreau	Rosalie	Soufrier to Scotts	Au Delicies
NPV_{STA}	(63,630.35)	(3,210,830.00)	714,749.11	(5,288,669.96)	(28,272,759.69)	7,884,237.76	8,245,665.82	1,043,029.19	7,960,540.85
IRR_{STA}	12%	5%	18%	9%	1%	22%	17%	19%	22%

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SUMMARY

This guidance manual details the steps to complete a Climate Risk and Vulnerability Assessment, as an evidence-based approach to integrate climate adaptation (as part of wider climate resilience) into the roads transport sector in the Caribbean. It draws on the experience of the case studies undertaken in carrying out the Climate Risk and Vulnerability Assessment in Guyana, Saint Lucia and Dominica.

The document includes technical notes on the collection and use of data, analysis of these in the GIS environment using a Road Sector Resilience Index (see separate report for details[51]), together with lessons learned and best practices identified through the three case studies countries.

These guidelines intend to be user-friendly, both providing an overall introduction to what an evidence-based, GIS-driven climate vulnerability and risk assessment entails, and providing further detail of each of the steps required to be followed to obtain the CRVA results. Following this approach will enable the establishment of a GIS-tool which informs as to the level of risk and vulnerability across a country's road transport network.

The results of the GIS mapping can be used to identify the most critical road sections or links exposed and most vulnerable to climate-related natural hazards across a country. This in turn could inform the development of an investment plan so resilience measures are prioritized as part of wider road asset management systems.

Looking wider, this study could also be useful to aid understanding and investment planning to make all parts of a country's infrastructure assets resilient, as most if not all are located on the road network. Finally, the wider institutional aspects of how this can be embedded in government systems is set out in the Task 2 reports[52] completed for the three case study countries.

This draft final version of the guidance manual has been prepared for use at an online regional workshop to be organized by CDB in April 2021 as the final package to be delivered through this project. Following the workshop feedback will be incorporated and a final document prepared in an improved format suitable for publication by the Caribbean Development Bank.

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[51] The Resilience Index report (Task 3) correspond to the deliverable 'Roads Sector Resilience Report' produced by IMC Worldwide under the current assignment 'Planning for the Integration of Climate Resilience in the Road Transport Sector in the Borrowing Member Countries of the Caribbean Development Bank'.

[52] The Task 2 reports correspond to the deliverable 'Assessment of Relevant Policies, Plans, Strategies, Legal and Regulatory Framework Governing Road Transport' produced by IMC Worldwide under the current assignment 'Planning for the Integration of Climate Resilience in the Road Transport Sector in the Borrowing Member Countries of the Caribbean Development Bank'.

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