Prioritizing Climate Resilient Transport Investments in a Data-Scarce Environment

A Practitioners' Guide

WORLD BANK GROUP

GFDRR

ACP-EU Natural Disaster Risk Reduction Program

An initiative of the African, Caribbean and Pacific Group, funded by the European Union and managed by GFDRR

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This Practitioners' Guide is one of several products of the technical assistance program aimed at supporting Belize is prioritizing climate-resilient infrastructure investment projects. Other products include the roads condition survey of Belize's primary and secondary roads, the National Climate Resilient Investment Plan, and the prioritization of climate-resilient investments in the road network. We are grateful to all who contributed to the creation of these documents.

Contents

Abbreviations

ACP	Africa Caribbean Pacific
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
CBA	Cost Benefit Analyses
CEO	Chief Executive Officer
CRIP	Climate Resilient Infrastructure Project
DEM	Digital Elevation Model
EU	European Union
GDP	Gross Domestic Product
GFDRR	Global Facility for Disaster Recovery and Reconstruction
IPCC	Intergovernmental Panel on Climate Change
MCE	Multi-Criteria Evaluation
MoF	Ministry of Finance
MoFED	Ministry of Finance and Economic Development
NGO	Non-Governmental Organization
NSDI	National Spatial Data Infrastructure
SMART	Specific, Measurable, Achievable, Realistic, and Time-bound
UNISDR	United Nations International Strategy for Disaster Reduction

Executive Summary

The planning and analysis of infrastructure investments is complex as it is both strategic and long-term in nature, involves large capital expenditures, and affects multiple stakeholders. The prioritization of investments in transport infrastructure investments, requires the explicit consideration of multiple and often conflicting and incommensurate perspectives and criteria. Compounding the challenges of prioritizing transport infrastructure investments is the present and future impact of climate. As a result, innovative and participatory tools are required to identify and prioritize key transport infrastructure investments that efficiently utilize available resources and engage multiple stakeholders with the goal of developing climate resilience.

Belize is exposed to a high level of risk from meteorological[1] hazards, which have significant negative impacts to economic and social development gains as well as to its infrastructure. As a result, the Government of Belize identified climate resilience as one of the key policy priorities in its national development agenda and approached the World Bank for support to develop a program that addresses the country's vulnerability to natural disasters and the impacts of climate change. Given the complexity associated with increasing the road network resilience and in the context of extensive financial needs and limited availability of funds, the Government wished to identify areas of the road network that combine highest risk with highest socioeconomic criticality to efficiently direct resources toward the highest climate resilience enhancing impact. In response to this request, the World Bank worked with the Government to carry out an assessment and prioritization process that resulted in identification of investments aimed at increasing the country's resilience to the impacts of natural hazards by improving key road segments in the road network.

The prioritization process and lessons learned from it are presented and discussed in this Practitioners' Guide, which aims to provide guidance for the prioritization of climate-resilient investments in road infrastructure by presenting a general methodology, a conceptual framework, and a case study of the process that was conducted in Belize. It specifically addresses environments where data is scarce, but there exists institutional memory that can be harnessed. It makes use of existing data, draws on expert knowledge,

and actively engages with key stakeholders, to identify and prioritize key national investments using a participatory and data-informed process.

The conceptual framework consists of six modules presented sequentially in practice; however, their implementation may be both in parallel and iterative:

(a) Definition of objectives and scope of the prioritization process

(b) Understanding of the governance context and establishing the institutional arrangements for the process

(c) Collation of data, focusing on identifying and bringing together existing data, and collection of data, focusing on the creation of new data to fill the data gaps

(d) Evaluation of criticality

(e) Assessment of risk/exposure from climate-related hazards

(f) Informed decision making

In each module, key concepts are presented followed by a description of the application in the Belize context. The process in Belize involved determining (a) socioeconomic importance of road sections and (b) flood susceptibility of the primary and secondary road network. Road stretches critical for access to public services such as hospitals and schools, movement of economic products and services, and use in evacuation routes as well as those that provide access to the socially vulnerable were assessed through the participatory Multi-Criteria Evaluation (MCE) process. Representatives from over 35 ministries, municipalities, private sector organizations, civil society, nongovernmental organizations (NGOs), and academic institutions determined the most important criteria for assessing the critical road stretches. Once these were established, the participants developed indicators to evaluate the criteria and scored each indicator, which enabled quantitative analysis of the road network. Flood susceptibility was analyzed using a combined approach of field inspections and collection of information on past events. Incorporating the outputs from these processes, a cutting-edge geospatial model was then developed based on network analysis.

Through this process, four key areas were identified that were the most critical and were highly susceptible to flooding:

(a) **Greater Belize City area.** Considered critical because of its importance for access of relief services to the communities and as an essential part of the evacuation network. Most road stretches are especially susceptible to flooding, ranking in the highest flood susceptibility range.

(b) **West of Belmopan.** Considered critical because it provides connectivity between production sites and raw material extraction areas and the (air) ports and border crossings, access of relief services, and access to socially vulnerable populations. Most road stretches were considered to be in the medium to high flood susceptibility range.

(c) **Northern area around Corozal.** Considered critical because several routes are used extensively as essential parts of the evacuation network and in providing access to socially vulnerable populations. In addition, the area is important for the connectivity between production sites and raw material extraction areas and the (air)ports and border crossings. Some road stretches were ranked in the high flood susceptibility range.

(d) **Southern area around Independence.** Considered critical because the dependency on these roads is very high. The majority of roads in this area, especially the highway, fall into the high flood susceptibility range.

The result was adopted by the Government as a strategic plan and used to coordinate investments that were implemented with various donors, including the World Bank. This process was successful in Belize because the ministry responsible for national development planning provided strong leadership throughout the process. This is essential if the results of prioritization processes are to be integrated into national processes.

Introduction

Transportation networks are a critical infrastructure for each country as they enable access and connectivity for economic activity; for access to services (for example, commerce, tourism, education, and health); and for emergency situations (for example, evacuation), among others. As such, the prioritization of transport infrastructure investments requires the explicit consideration of multiple and often conflicting and incommensurate perspectives and criteria as they have important social, economic, and environmental effects that affect stakeholders differently. Furthermore, the spatial distribution and network characteristics of transport infrastructure add another layer of complexity that needs to be taken into consideration.

Natural hazards can have a deleterious effect on transport infrastructure, particularly on road networks. For example, heavy rainfall may cause erosion and scouring of roads and bridges, flooding may result in road closures and limited use of roadways, and strong winds may bring debris that obstructs traffic flows. All of these have social impacts as they reduce the usability of the roadways, cut off access to communities and services in cases with limited redundancy, and increase travel times. Economic impacts may include increased time and costs to move people and goods to commercial areas and increased costs of road and vehicular maintenance. Due to the vulnerability of transport infrastructure to natural hazards and its importance in connecting communities, production sites and import/export nodes, transport infrastructure planning requires the integration of disaster risk management.

Compounding the challenges of infrastructure investment planning is the impact of climate change. As stated by the Intergovernmental Panel on Climate Change (IPCC), taken as a whole, the range of published evidence indicates that the "net damage costs of climate change are likely to be significant and to increase over time" (IPCC 2007).The global manifestation of climate change could include sea level rise, continued increase in temperatures, more frequent and intense hurricanes, increase in the frequency and magnitude of floods, and more severe droughts, among others. These effects are likely to continue to intensify through the current century. While the magnitude of such changes is still, in many cases, highly uncertain, they result in challenges in prioritizing, planning, and designing of infrastructure investments because those assets are usually built for many decades of service.

The Government of Belize had identified climate resilience as one of the key policy priorities in the national development agenda and approached the World Bank for support to develop a program that addresses the country's vulnerability to natural disasters and the impacts of climate change, focusing on the road network. In response to this request, the World Bank[2] worked with the Government to carry out an assessment and prioritization process that resulted in identification of investments aimed at increasing the country's resilience to the impacts of natural hazards by improving key road segments in the road network. Together, they developed a methodology to prioritize investments in segments of the road network based on the service they provide for socioeconomic activities, as well as their susceptibility to the impacts of natural hazards, which are expected to intensify in the future.

The state-of-the-art approach to prioritizing investments that build climate resilience among the people and within the economy drew on inputs from the U.S. Department of Transportation (Federal Highway Administration 2011). The approach involved integrating stakeholder evaluation of important road sections with technical hazard and risk assessments. It also included getting political buy-in to use the results of the quantitative analysis to inform a World Bank investment project. Given Belize's data

scarcity, the methodology provided a novel approach that integrated expert and local knowledge to develop quantitative tools for analysis. In addition to informing a World Bank investment project, the resulting priority list is being used to inform and guide road infrastructure investments throughout the country, including those by other multilateral development banks.

The process implemented in Belize and the guidance provided in this report reflect lessons learned by the World Bank teams that facilitated the development of climate-resilient strategies and investment programs in the Caribbean through the Pilot Program for Climate Resilience. The pilot program synthesized lessons learned from regional experiences with best practices around the globe as the World Bank team made concerted efforts to include state-of-the-art knowledge and expertise on the topic.

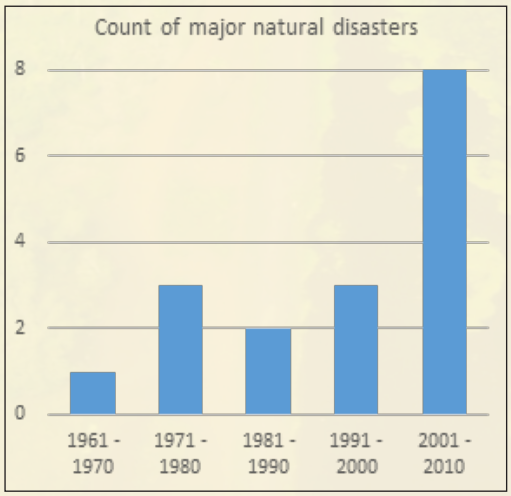
Three key factors underscored the engagement and led to the success of the prioritization effort documented herein: (a) the process had to be led by the Government; (b) the process had to be information based even when data was limited; and (c) the process had to be participatory. Key government ministries were involved in the entire process at both the technical and executive levels. There were timely submissions to the Cabinet as well as presentations to chief executive officers (CEOs) of the government ministries to keep the ministers and their CEOs apprised and engaged in the process. Technical officers from central and local governments, NGOs, and the private sector were encouraged and empowered to participate in the prioritization process. Though data was limited, the participants brought with them a body of knowledge and institutional memory that informed the discussions and scoring processes to build structured consensus on the priorities.

This work was conducted using financial support from the Africa Caribbean Pacific (ACP)–European Union (EU) Natural Disaster Risk Reduction Program, received through the Global Facility for Disaster Reduction and Recovery (GFDRR). It was meant to demonstrate that disaster risk resilience and broader climate resilience could be successfully integrated into national development goals.

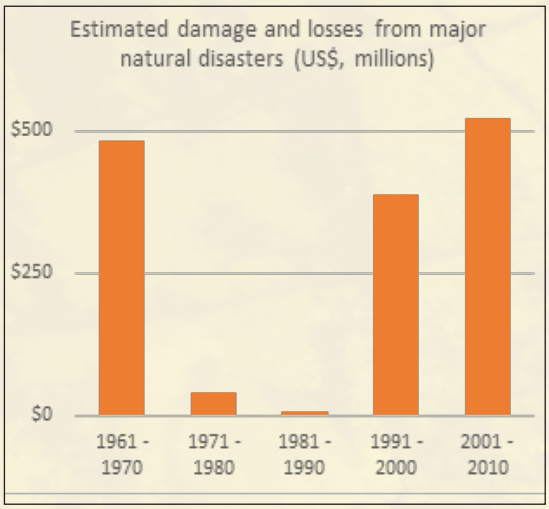
BOX 1. BELIZE CONTEXT

Belize is exposed to a high level of risk from meteorological and geophysical hazards, which have significant negative impacts on its economic stability and social development gains. Between 1995 and 2014, losses from hydrometeorological disasters were estimated at US$57 million, with an annual average loss of approximately 3 percent of gross domestic product (GDP) (Kreft et al. 2015). It is estimated that if current climatic trends continue, extreme events will become more frequent, resulting in greater fiscal impacts (Tompkins et al. 2004). Disasters could therefore have a direct and large impact on economic conditions through reduced productivity, unsustainable budgetary deficits, and increased national debt, due to reconstruction costs. Furthermore, resources appropriated to respond to natural disasters reduce the funding available for development projects. In recent years, the impact of natural disasters and the stagnating economy have contributed to the substantial increase in poverty. The charts in Figure 1 highlight the increasing frequency and severity of natural disasters in Belize.

Figure 1. Frequency and Severity of Major Natural Disasters in Belize over the Past Two Decades



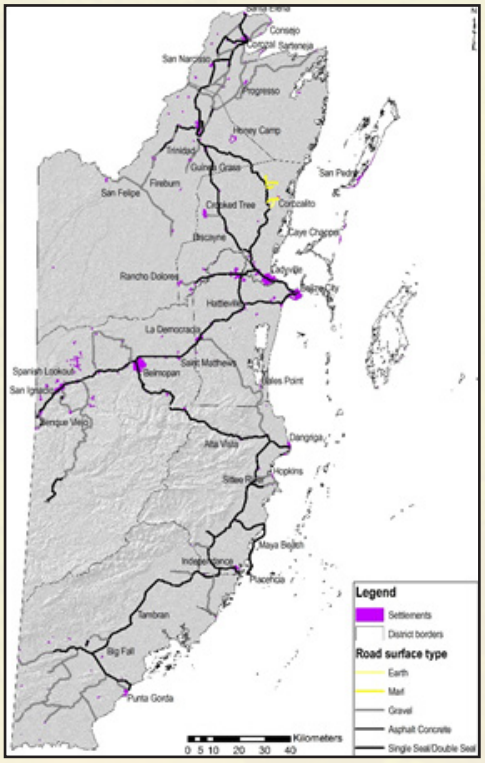
Source: D. Guha-Sapir et al. 2016.[3]



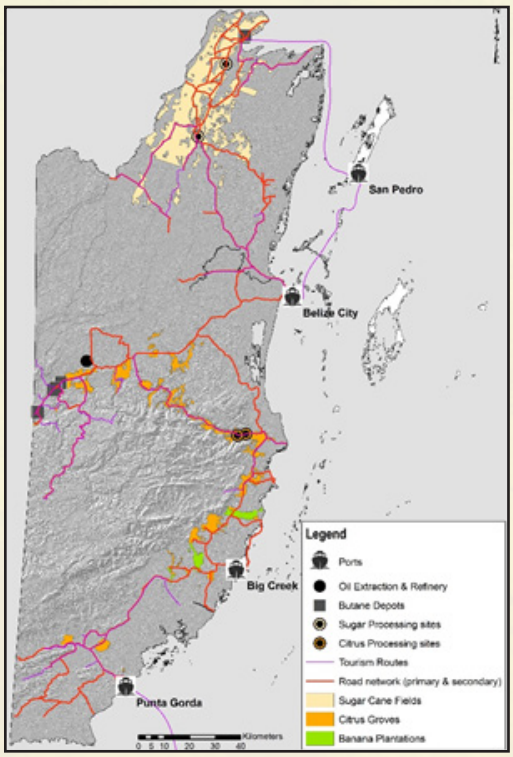
Source: D. Guha-Sapir et al. 2016 and own calculations.[4]

Underdeveloped and dilapidated infrastructure, particularly in the transport sector, is a key constraint to disaster vulnerability reduction and economic growth. The road network in Belize is particularly vulnerable due to the lack of redundancy and exposure to natural hazards. Dependency on the road network is further exacerbated as 70 percent of the population lives near primary and secondary road networks; thus, flooding of one section of a roadway can cut access and severely disrupt economic and social movement. The maps in Figure 2 show the relationship between the population and commerce centers and the road network.

Figure 2. Population and Road Networks (Left) and Economic Flows in Road Network (Right)



Source: Own elaboration using spatial data received from Government of Belize and analysis results.



Source: Own elaboration using spatial data received from Government of Belize and analysis results.

As a result, the Government of Belize has prioritized the transport sector in its medium-term investment planning, because of the socioeconomic importance and the need to reduce vulnerability. Given the complexity associated with increasing the road network resilience and in the context of extensive financial needs and limited availability of funds, the Government sought to identify areas of the road network that combine highest risk with highest socioeconomic criticality to efficiently direct resources toward the highest climate resilience enhancing impact.

Objective and Target Audience of the Practitioners' Guide

This report aims at providing guidance for the prioritization of climate-resilient investments in road infrastructure by presenting a general methodology and conceptual framework followed by showcasing the process that was carried out in Belize. It specifically addresses environments where data is scarce but where institutional memory that can be harnessed exists. It makes use of existing data, draws on expert knowledge, and actively engages with key stakeholders, to identify and prioritize key national investments using a participatory and data-informed process.

The Practitioners' Guide was primarily developed for

(a) transport specialists and planners who seek to prioritize and select investments;

(b) government officials who would like to use participatory processes to select investments;

(c) decision makers who operate in data-scarce environments;

(d) climate change specialists and disaster risk management specialists who provide advice and influence decision-making processes in governments, multilateral development banks, and other international development agencies; and

(e) private developers who want to engage in dialogue with governments about development and investment priorities.

Reader's Instructions

The methodology presented in this Practitioners' Guide consists of six modules and in each module, the conceptual approach is presented followed by the example from Belize. While the methodology is presented sequentially and in the best order for implementation, in practice, some of the activities for the various steps will overlap, take place in parallel, and go through several iterations. This is because the process involves developing a methodology based on the understanding of current data availability and conditions and then adapting the methodology once gaps in available data and other limitations are made known.

The modules are as follows:

- **Module 1: Definition of Objectives and Scope.** Good decisions need clear objectives and a well-defined scope. Therefore, immediate and ultimate objectives need to be distinguished. In addition, for the scope definition, aspects such as the spatial and temporal scale, the type of assets, and so on need to be considered.

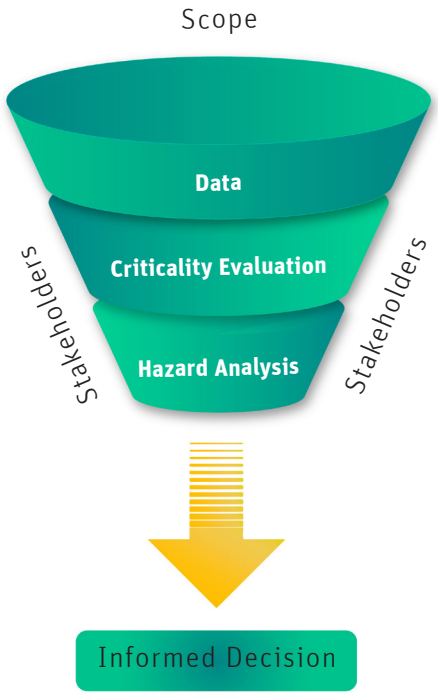
- **Module 2: Institutional Composition.** The composition of contributors and participants in the prioritization process is critical, particularly for getting the political buy-in, tapping into the technical expertise, and incorporating the concerns of road users. It is important to carefully identify key stakeholders and define the mechanisms and opportunities for participation.

- **Module 3: Data Collation and Collection.** The kind of data available and the resources to collect further data influence the choice of analysis approach and type of model to analyze the criticality and climate risks of the road networks. Consequently, once the objectives are clearly articulated, a quick list of the kinds of data that could support the assessment of options to achieve the objective should be prepared and a scan of the immediately available data sets, their scale, and their attributes, should be undertaken. Both, data collation and collection are iterative processes and are conducted in parallel to all of the other steps. While the scope and objectives of the prioritization process provide an initial indication of the data sets needed, ultimately, the criticality and hazard/risk model selection and setup determine the final list of required data sets and attributes.

- **Module 4: Criticality Evaluation.** Investments need to target areas that are strategic to reach the Government's development goals, including social, economic, and other considerations. An MCE is a flexible tool that enables the evaluation of the socioeconomic impacts arising from interruptions in the transportation network focusing on the importance of the road network and its various segments to the people and the economy (criticality).

- **Module 5: Assessment of Risk/Exposure from Climate-related Hazards.** The probability of physical impacts is evaluated, depending on the data availability, through an assessment of exposure or risk that the transport infrastructure is facing from the initially defined climate-related hazards.

- **Module 6: Informed Decision Making.** Based on the analysis of results from the criticality and the climate hazard assessment, the actual prioritization is carried out. This module provides insights on how the results were prepared for and used by decision makers.



Prioritization of Road Vulnerability Investments

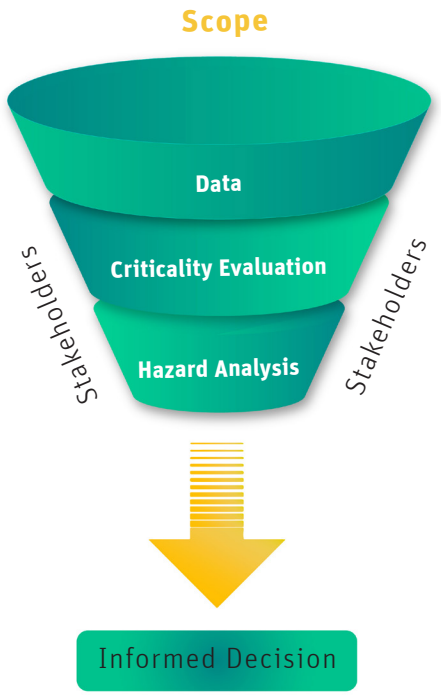
Module 1: Definition of Objectives and Scope

Good decisions need clear objectives, which should be specific, measurable, achievable, realistic, and time-bound (SMART) (Doran 2008). It is useful to distinguish between ultimate and immediate objectives, where ultimate objectives are framed in terms of strategic or high-level outcomes, such as the level of economic growth, social cohesion, or sustainable development, and immediate objectives are directly linked with the outputs of the project. Consideration of a proposed option needs to concentrate on those

criteria that contribute to the immediate objectives resulting in successful outputs and hence lead to accomplishing the ultimate objectives, that is, the outcomes.

Investment decisions and the associated budget allocation often require a prioritization process, as resources are often limited. To maximize returns, resources should be allocated to those investments that contribute to the achievement of the most important immediate and ultimate objectives.

An important step in the prioritization process is the determination of the objectives (immediate and ultimate) and the scope, including the following aspects:



- **Spatial scope/area under consideration:** This could be the entire country, a department, a district, a province, a state, a city, or some other geographically defined area.

- **Type of infrastructure and type of assets:** This could be road network, rail network, waterways, and so on.

- **The portion of the network that is being assessed:** This could be the entire network or a subset, such as the primary road network.

- **Climate-related natural hazards that are likely to affect the infrastructure:** This could be floods (flash, riverine, pluvial, and coastal floods); landslides; sea level rise; and so on.

- **Time horizon:** Infrastructure investments are planned for a certain lifespan. In the context of climate change, there is considerable change in conditions to be expected during the usually long lifespans of the assets that should be taken into account, if possible.

- **The prioritization methods:** Several prioritization tools exist and the team leading the process will need to assess the options and select those that will best help achieve the immediate and ultimate objectives. Cost-benefit analysis (CBA) and MCE are viable options. In the case of an MCE, it can involve a wide range of stakeholders or could be limited to those with expert knowledge about the relevant subject matter.

- **Data and information availability to support the prioritization process:** While ambitious objectives based on detailed analyses would be desirable, data and information availability are an important factor to consider when setting the scope. If initially there is not enough knowledge on the situation to factor this in, a second iteration to define the immediate objective and scope of the exercise may be needed.

BOX 2. SCOPE OF BELIZE PROJECT

Ultimate objective: Reduce climate vulnerability and increase climate resilience of the transport infrastructure in Belize.

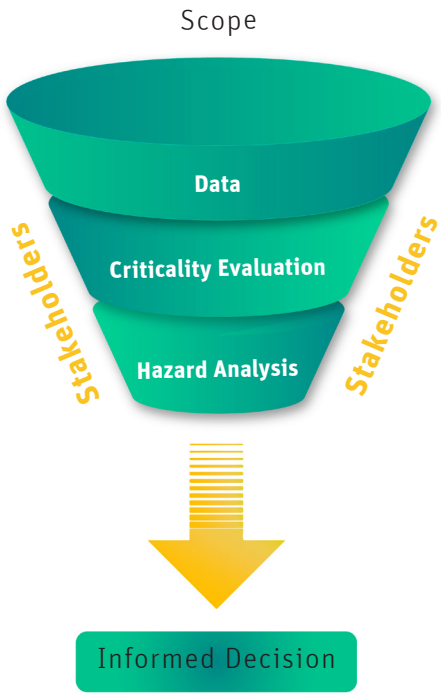
Immediate objective: Prioritize road investments in the primary and secondary road network to be able to strategically reduce climate risk.

Scope: Primary and secondary road network, consideration of riverine and flash flooding, no integration of climate scenarios.

Climate-related natural hazards likely to affect the infrastructure: The primary natural hazards to affect the roadways in Belize are riverine flooding, pluvial flooding, coastal flooding, and sea level rise. However, due to data limitations, coastal flooding and sea level rise could not be included in the analysis.

Temporal scope: While the optimal time horizon would be the approximate lifespan of the transport infrastructure assets that would be identified and addressed for retrofitting, there was not enough data available to estimate socioeconomic and climate-related changes. Thus, primarily, the current situation was evaluated for the prioritization process while changes over time would rather be considered when designing specific interventions.

Module 2: Institutional Composition



The composition of contributors and participants in the prioritization process is critical, particularly for getting the political buy-in, tapping into the technical expertise, and incorporating the concerns of road users. It is important to carefully identify key stakeholders and define the mechanisms and opportunities for participation.

First, transportation is a cross-cutting topic that concerns a multitude of government ministries and departments directly or indirectly, as well as the private sector and civil society. Roads enable access to services such as education and health care; facilitate social development; are critical in emergency situations for evacuation, response, and recovery; and are central to economic activities connecting production sites, markets, processing sites, and so on. Road construction is closely related to physical development opportunities and affects the natural environments. To ensure that the final prioritization adequately considers the country's strategic goals across all sectors involved, the representation of all those ministries and departments and key private sector and civil society partners is fundamental. Ministries and departments involved, range from Works/Transport through Education, Health and Local Government, Human Development/Social Transformation, National Emergency Management, and Economic Development and Tourism to Natural Resource Management and Physical Planning. In addition to governmental agencies, organizations from the private sector, academia, NGOs, and civil society have an important stake in the topic. As such, they need to be identified and included into the process. Finally, the Ministry of Finance (MoF) plays a critical role because the outcome of the prioritization of infrastructure investments shall inform and influence budget allocation.

Second, as this process is aimed at informing investment decision making, it naturally involves multiple levels of participants from institutions—ranging from the technical through the top administration to the political level. While mostly technical staff participate and engage fully (for example, in full-day workshops), policy and political actors at permanent secretary/CEO and minister levels need to be aware of the process, informed on the progress, and given the opportunity to discuss the findings and provide their endorsement at critical milestones to ensure that the results will be widely accepted, adopted, and used.

The first step is to determine which ministry or department will lead and coordinate the process. The MoF is well positioned to take on this function due to its convening power, ultimate decision-making role in budget allocation, and suitability for a moderator role for discussions among technical ministries. In the case of transport infrastructure, the ministries responsible for Works and Transport will be a key technical player because it is responsible for the management, maintenance, and upgrade of the asset. The ministry responsible for Natural Resources and Physical Planning is also a key partner because infrastructure improvement has implications for the natural environment and for planning. Other government ministries, the private sector, civil society, and academic representatives are also key determinants of the importance (criticality) of specific sections/segments of the road network and therefore need to participate in the prioritization process. Furthermore, the stakeholder group should involve all relevant agencies and actors that contribute to the evaluation and management of natural hazards and climate change effects. Additional stakeholders with specialized knowledge, such as researchers that have worked on relevant topics, should also be invited.

Once the stakeholders have been identified, the formalization of the participation of the technical representatives, particularly those from government ministries, should follow standard country procedures to appoint them to participate in the assessment process. This will ensure that they have the authority to engage in the discussions and bring useful data to support the assessment processes. Similarly, the engagement of permanent secretaries/CEOs and government ministers/Cabinet should make use of their standard operating procedures for deliberation on matters of national concern. This ensures that the prioritization discussions become part of the discussion agenda of the Government. Furthermore, it decreases the probability that critical steps or actors are left out.

BOX 3: BELIZE INSTITUTIONAL ARRANGEMENTS

In Belize, the Ministry of Finance and Economic Development (MoFED) led the prioritization process for the road network's climate resilience improvements investments with strong commitment and engagement from the CEO responsible for Economic Development. MoFED officially coordinated all related activities from the start of the process in May 2013 to the presentation of the final priority segments in December 2013. MoFED invited the Government, private sector, academia, and civil society representatives to the workshops and project meetings, organized presentations to the CEOs at strategic points, and ensured adequate communication of the process to the Cabinet of ministers using Cabinet papers and presentations.

For the criticality assessment, about 40 technical staff participated in the process, representing the government ministries, town and city councils, the private sector, academia, and civil society. Sessions were held to finalize the criteria for assessment of criticality, identification of indicators, scoring of the importance of the indicators, and discussion of the data to inform the indicators. The World Bank's team used the information to develop the criticality model and present the criticality scores for the various road segments.

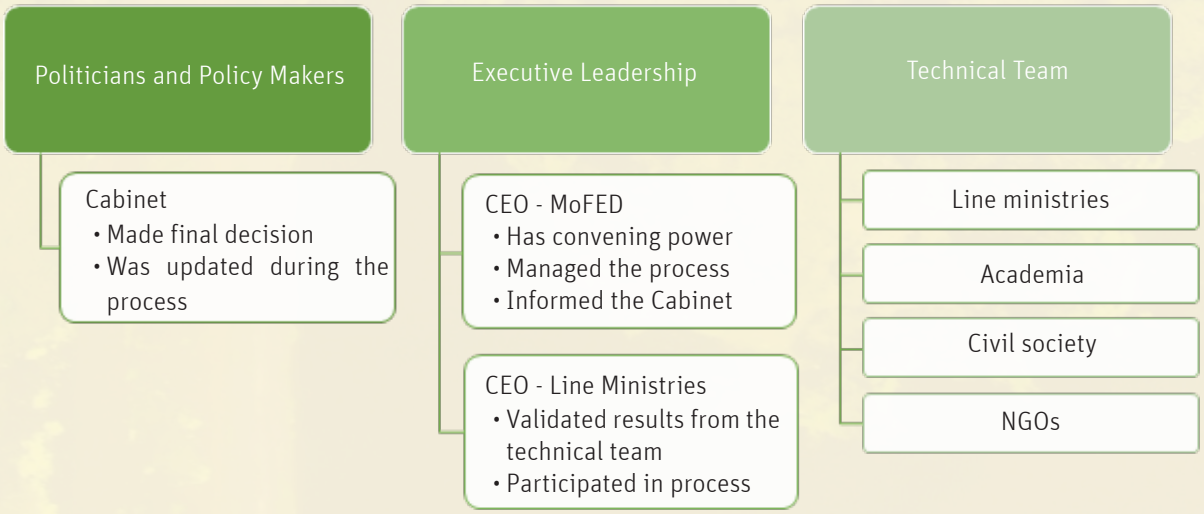
For the flood susceptibility assessment, the key contributors were primarily the district engineers from the Ministry of Works and Transport who have ample experience with flooding in their districts.

Throughout the prioritization process, four presentation and discussion sessions were held with the CEOs. This ensured that the CEOs were kept informed and that they could in turn update their respective ministers on the progress. That way, when Cabinet papers were submitted, there was familiarity with the topic. Three Cabinet papers on the process were submitted, providing updates together with the request for endorsement and concurrence to proceed:

- The first paper informed the Cabinet on the intention to carry out the prioritization process and gave an indication of the methodology.
- The second paper provided an update on the process and the criteria and indicators for scoring.
- The third paper presented the priorities for adoption.

In each case, there was a discussion among the Cabinet members followed by the decision to proceed. The decisions were communicated to the World Bank team through MoFED.

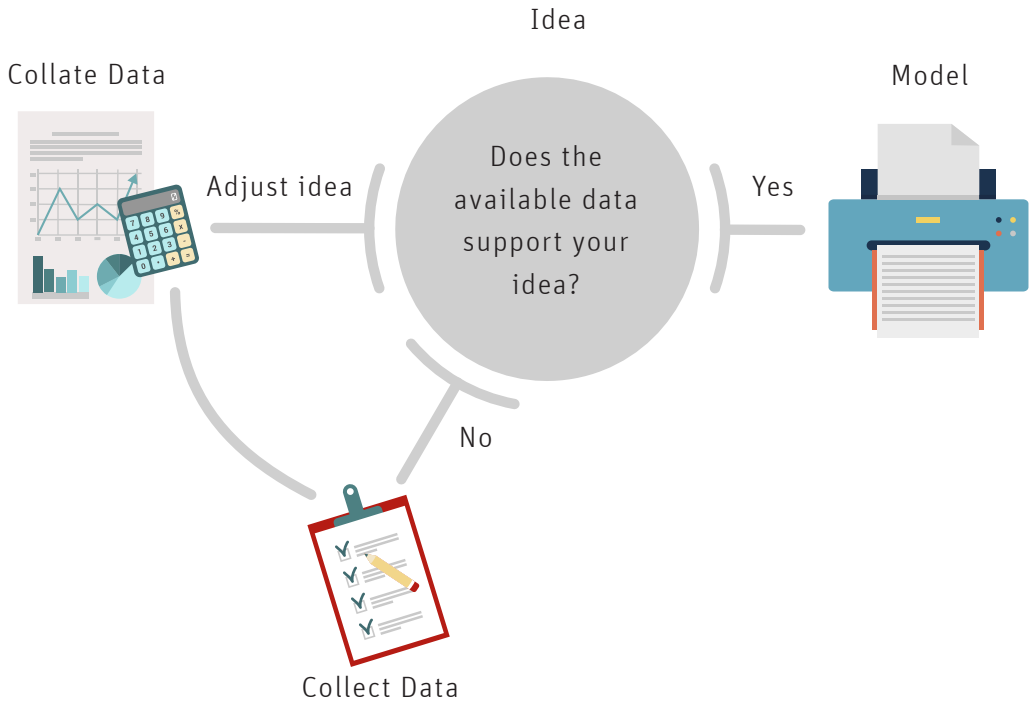
In summary, the process was successful because the CEOs were kept informed through presentations and discussions at Cabinet debriefing sessions as well as by their technical officers who participated in the technical sessions. The process enabled them to provide feedback at critical points in the process and develop a level of comfort with the approach that was being used.



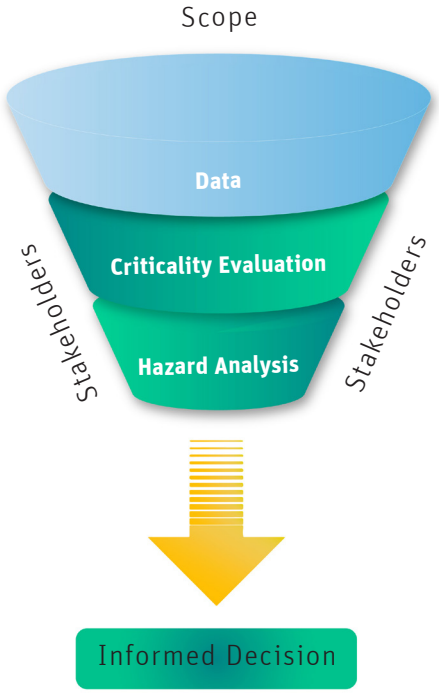
Module 3: Data Collation and Collection

Data collation and collection are complementary processes with the aim to be as efficient as possible in the use of existing data while strategically collecting data where needed and possible with the available resources to enhance the level of detail, quality, and so on of the modeling result (Figure 3).

Figure 3. Data Collation and Collection Process Leading to the Development of a Robust Model



Data Collation



The kind of data available influences the choice of analysis approach and model creation for the prioritization of road segments based on their criticality and flood susceptibility. Consequently, once the objectives are clearly articulated, a quick list of the kinds of data that could support the development of options to achieve the objective should be prepared and a scan for the immediately available data sets, their scale, and their attributes should be undertaken.

The first step is to generate a catalogue of the spatial and tabular data sets that are available, who the custodians are, the scale of the data, the associated attributes, the frequency of update, and the process for accessing the data. As the catalogue is being prepared, the accessible data should be collected and reviewed for accuracy, precision, and relevant attributes to support the analysis.

The data scan and review are vital steps as they provide the opportunity to undertake fitness for purpose evaluation. In addition, they result in the identification of immediately useable data; data that need augmentation or preprocessing before they can be used; data that are not immediately available/accessible; data that are available but do not exist in digital and immediately useable formats; and data that would need primary field collection effort. This knowledge helps with the quantification of the level of effort that will be required to preprocess, augment, and create relevant data sets for use in the assessment of options to achieve the immediate objectives.

For this process, a relationship of trust between the facilitating team and the actors involved in data management is critical since in many countries, there is not necessarily a culture of sharing data. The identification of existing spatial data management and sharing initiatives and key persons with a leading role in these processes, as well as the establishment of close collaboration, may significantly facilitate the access to data.

Most times, even data that have passed the fitness for purpose evaluation will need some preprocessing before use in an application or model. To the extent possible, that process should be undertaken for each data set as soon as it is selected for inclusion in the assessment model. This includes ensuring that the records have valid unique identifiers and that the relevant attributes are included in the right format.

One of the potential activities during preprocessing phase is to integrate records from multiple data sources with a similar/compatible scale and bring them together into one data set. Table 1 is a listing of some of the types of data that may be required when prioritizing to build resilience to natural hazards.

Table 1. Examples of Data Sets That May Be Required/Useful for Prioritization of Climate-resilient Investment Prioritization of Transport Infrastructure

Type of Data	Data Sets
Geospatial base data	Administrative and natural boundaries (for example, watersheds); cities, towns, and villages; roads; digital elevation model (DEM); bathymetric model for coastal areas; land use/land cover; waterways; wildlife distribution; archeological sites; and so on
Weather-/climate-related	Meteorological time series (rainfall, temperature, and so on), location of the rain gauges, climate predictions, and so on
Flood-related	Discharge time series, location of river gauges, information on flood events, flood inventories, and so on
Landslide-related	Landslide records; landslide inventory; existing landslide susceptibility, hazard, or risk analyses; soil maps; infiltration; geological/geomorphological maps; liquefaction potential; and so on
Disaster preparedness	Evacuation routes; hurricane shelter locations; critical assets; 911 services; and so on
Social	Population distribution, centers for social services (schools, hospitals, clinics, and so on), bus routes, and so on
Economic	Production centers, ports/airports, market centers, tourism facilities, banks, utilities, factories, natural resource distribution, and so on
Asset/infrastructure	Location, type (roads, public buildings, and so on), properties (size, materials, condition, and so on), and so on

In some cases, the data that are needed exist but not in an immediately useable digital format. They may be in PDF documents; scanned reports; paper copy of tables, reports, and maps; and so on. In these cases, the options for bringing the data into a useable digital format should be explored. Data may also be available through imagery that need to be interpreted. There has to be a balance between accuracy and precision on the one hand and cost of data generation on the other. Where the cost of data collation is reasonable, it is preferable to obtain the best quality of data possible from both a precision and accuracy perspective. Data should be ranked based on importance, relevance, and cost of collation with the highest ranked data being sourced and prepared first.

Data collation and collection is an iterative process. Existing data at the right scale and precision may be collated first and then appropriate attributes added over time as the importance and source become clearer. Through collation, data are continually improved before the actual analysis. In cases where the most suitable data are not available, appropriate proxies may be identified and take through the aforementioned iterative process. Therefore, proxies are understood as indirect measures that approximate a phenomenon in the absence of a direct measure.

Despite the best efforts at data collation, there could be data sets that do not currently exist and may need to be created using primary data collection methods. However,

as primary data collection may require significant time and resources, it should be targeted toward the required data with a clear definition of the level of detail and type of characteristics required. This step should only be carried in parallel to methodology selection and model creation as an iterative process.

BOX 4. BELIZE DATA COLLATION

Several data sets were collated for use in the prioritization model for the rehabilitation of Belize road segments. Examples of data sets that were used 'as is' include the Flood Extent of Tropical Depression 16 of 2008 and the Belize Land Use/Land Cover of 2011 by Meerman.

Data sets that were augmented included the Rivers of Belize and the Belize Land Systems Data initially prepared by King et al. as part of the Belize Natural Resources Assessment 1987 to 1992. In the case of the rivers data set, the rivers of Belize had been previously digitized from the 1:50,000 DOS (U.K. Directorate of Overseas Surveys) sheets for Belize. River names and river order were added as attributes to the records of the data set. In the case of the land systems data set from King et al., there was more information in the reports than in the shapefiles available. The reports were used to augment the shapefiles.

There was information such as the location of banks, production sites, and historical flooding among others for which digital data were not available but which were documented in reports. The information was used to create shapefiles to represent the information as data records with key attributes.

All of these are examples of data collation activities that occurred during the preparation for the prioritization of Road segments for rehabilitation. The list of features and phenomena for which data sets were collated for the Belize Transport Network Prioritization Model include the following:

(a) A DEM (Advanced Spaceborne Thermal Emission and Reflection Radiometer [ASTER], 30 m resolution)

(b) A stream network of the major rivers and streams

(c) A countrywide small-scale flood susceptibility from the land resources assessment (King et al. 1993)

(d) A flood extent mapped after Tropical Depression 16, which was derived using the automated classification of Landsat imagery

(e) A list of flood records from newscasts

(f) Flood hot spots identified by engineers of the Ministry of Works and Transport

(g) Location of production and processing centers for key products

(h) Location of (air)ports and border crossings

(i) Location of hurricane shelters, schools, hospitals, and health centers

(j) Evacuation routes

(k) Population centers

(l) Centers of economic activities

Data Collection

The data collection step complements data collation and is an iterative process that takes place in parallel with methodology development and model creation. While the scope and objectives of the prioritization process provide an initial indication of the data sets needed, ultimately, the criticality and hazard/risk model selection and setup determine the final list of datasets and attributes required for the analysis. It is useful to prepare a master data list with the specifications for each data set, in terms of features, attributes, and data type/properties for each attribute. This master data list and the specification of each data set can then be applied to guide the final preparation of data for the analysis. The data collated as described in the Data Collation subsection are compared to this list to determine if they need further preprocessing, complementing, or even new data collection.

In cases where the preferred data are not available or are too costly to produce in terms of time, human, and financial resources, the use of alternative data sets or proxies should be explored. A proxy data set would indirectly score an indicator and, in some cases, this may be sufficient to support the decision-making process. If suitable alternative data sets or proxies are identified, they should be prepared using the collation approaches discussed in the Data Collation subsection. If suitable proxies are not available, consideration should be given to primary data collection to create the data.

One of the data sets that is critical for prioritization of transport infrastructure investments is the transport network. If these data are not available, extensive field data collection may be required for which adequate planning should be undertaken. First, a comprehensive list of the features and attributes that will be collected should be prepared and the collection method should be documented. Then, the collection forms, which should enable the collection of all the features and attributes in the primary collection scheme, at the appropriate scale, accuracy, and precision, should be prepared and tested.

The final database that will store the data being collected should be designed using database development best practices. At present, relational or object relational databases provide the most versatile options for data storage and retrieval (including the storage of spatial data); this should be considered when developing the final database. Field collection should be organized in a way that facilitates the transfer of data to the final database.

Several options exist for primary data collection, but preference should be given to options that enable one-time entry of data. Serious consideration should be given to the use of software and mobile devices for the collection of field data. Tools, such as the Open Data Kit, that allow for the use of customizable data collections forms should be considered.

It is important to standardize data collection methods and practices across data collection teams. Quality control and quality assurance measures will need to be put in place to ensure that data collection teams follow standardized and tested protocols for data collection, transfer, review, and integration into the final database.

Once the primary data collection process has been developed, a field data collection and management guide should be prepared for all data collection and data integration teams to review and use. Resources should be allocated for testing of the data collection, data review, and data integration methods before they are finalized and adopted, as well as for the training of data collectors and data integrators.

Consideration should be given to the possible data uses besides the one that motivated the initial data collection. In addition, data update and maintenance processes that would enable the data, once collected, to be kept current while enabling historical views should be developed. It is recommended that data be maintained and updated as part of the normal workflows of those who are responsible for the data.

BOX 5. DATA COLLECTION FOR BELIZE PROJECT

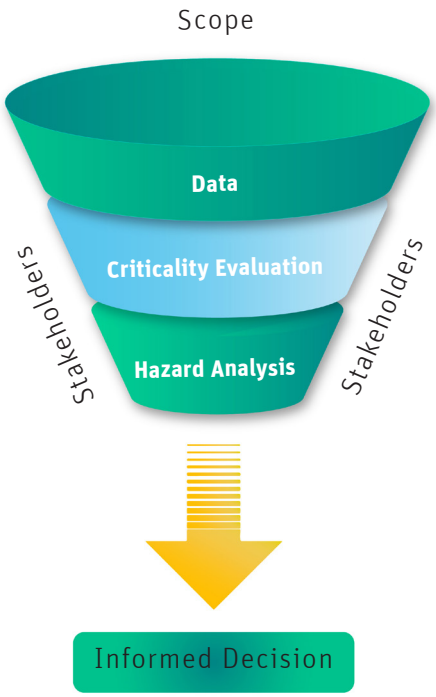
A data set that was not available before the prioritization of primary and secondary road segments for rehabilitation was the condition of the roadways and their appurtenances. Through field survey, the conditions of the road network at 2 km intervals, the road intersections, bridges, culverts, guardrails, signs, and other related appurtenances were collected using visual inspection techniques.

A list of features and attributes were agreed upon; a database to hold the data was designed; a data creation form was created and tested; and field data were collected, verified, and integrated into the database. Furthermore, a field data collection guide was prepared to train data collectors and data reviewers.

The resulting road network condition data for the primary and secondary road can, beyond supporting the prioritization of segments, be used for further purposes such as road asset management and maintenance. If these are considered from the beginning, data collection, guiding materials, and database setup can directly include such considerations—if resources permit—to make the effort as useful for the country as possible.

Module 4: Criticality Evaluation

Criticality: *As understood in this document, criticality is the importance of specific segment, or nodes in the transportation network (road segments, bridges, or culverts) in terms of their provision of access to various economically or socially significant locations.*



Infrastructure investments are designed for many years of service, involve large capital expenditures, and require the explicit consideration of multiple, sometimes conflicting and incommensurate, perspectives stemming from their important social, economic, and environmental effects that affect various stakeholders differently. A widely used approach to investment prioritization is traditional CBAs; however, CBAs often fail to consider many of the benefits of infrastructure investments because they rely wholly or very largely on monetary valuations. Thus, there is a need to extend the framework of CBA to adequately take into consideration not only economic and financial but also social, institutional, technical, and environmental factors that affect the selection and prioritization of infrastructure improvement interventions. MCE, sometimes also called Multi Criteria Analysis, is a decision-making tool for analysis of complex trade-offs between or among alternatives choices that can integrate quantitative and/or qualitative aspects in the process of prioritizing and ranking options. While there are a number of different MCE approaches, they all have in common that the "options and their contribution to the different criteria [are made explicit], and all require the exercise of judgment" (Communities and Local Government 2009). The judgment can either be made by a group of stakeholders through a consensus-building process, especially on cross-cutting and controversial topics (participatory MCE) or by one/few expert(s), based on knowledge, understanding, and expert judgment. Once the objective and scope have been defined (see module 1), the principal steps of an MCE process, as used for the assessment of the criticality of the road network, include the following:

(a) Identification of criteria

(b) Identification of indicators, data requirements, and scoring

(c) Weighting of the criteria

(d) Calculation of criticality

While the first three steps are highly participatory, the final step requires detailed analyses and calculations that should be performed by a small and qualified technical team, though intermediate and final results are validated throughout the process by specific sector representatives of the whole stakeholder group. In the following discourse, each step will be presented and explained, followed by the example from Belize:

Identification of Criteria

Criteria: *Principles or standards on which a judgment or decision may be based.*

As criteria form the core of an MCE, establishing a soundly based, operational set of criteria against which to judge/prioritize the options is a critical step. A measurement or a judgment needs to specify or indicate how well each option meets the objectives expressed by the criteria.

At a minimum, criteria should have the following characteristics: (a) internal consistency and logical soundness; (b) transparency; (c) ease of use; (d) measurable indicators, whose data requirements are not inconsistent with the importance of the issue being considered; (e) realistic time, level of effort, and cost requirements for the analysis process; (f) ability to provide an audit trail; and (g) software to carry out the assessment, where needed.

It is important to understand that while criteria may be abstract, the extent to which an asset or option meets a criterion or set of criteria should be measurable. To measure the extent to which the asset or option meets a criterion, one or more indicators are to be identified and assessed either quantitatively or qualitatively. Indicators will be discussed further.

Working sessions are a useful approach to obtain representative criteria reflecting the different perspectives of participating sectors and stakeholders. During those sessions, the stakeholders can be tasked with identifying and articulating criteria that reflect the importance of the asset/infrastructure that is being reviewed, while considering their respective sector strategies and perspectives. Depending on the number of participants, the entire group may be divided into smaller groups to carry out the assigned tasks. In addition to the identification of criteria, they should document their rationale for identifying each criterion and give an indication of how it could be measured/assessed.

To stimulate and inspire the criteria identification process, a number of criteria categories or topics can be determined before the stakeholder working sessions by the team coordinating the MCE process. The idea is to identify broad categories for which the asset is important; such thematic groups could include economic, health, social, and so on.

BOX 6. CRITERIA USED IN BELIZE PROJECT

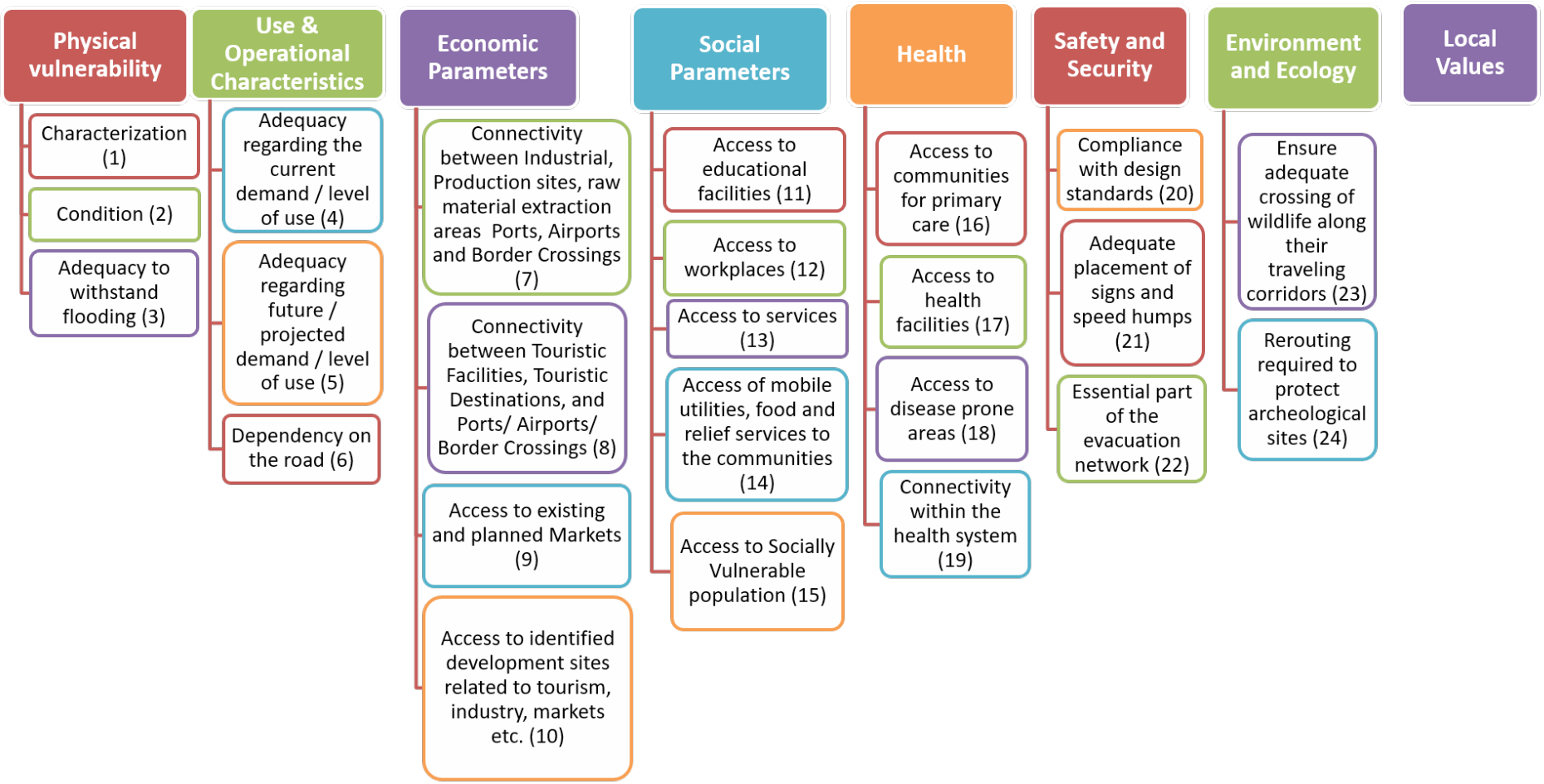
For the criticality assessment of the road network in Belize, the facilitating team provided eight categories under which workshop participants in groups of four to six persons were tasked with identifying criteria (see Figure 4).

Figure 4. Categories of Criteria Identified as a Starting Point for Discussions among Stakeholders

Physical Vulnerability	Description of the current condition, the related need of repair/ reconstruction, and how that affects the asset's utility
Use and Operational Characteristics	Factors that indicate the level/extent of use within the transport network, its capacity and importance in supporting the economy, social services, evacuation, and so on
Economic Parameters	Asset's role in supporting commerce and providing access to major employment destinations: contribution to economic functions
Social Parameters	Importance of transport assets to the community with regard to providing access to facilities that allow the community to function: contribution to social functions
Health	The extent to which segments of the network provided access to health facilities
Safety and Security	The extent to which segments of the network are designated evacuation routes or components of the national defense system
Environment and Ecology	Environmental or ecological aspects that may influence the prioritization or avoidance of interventions in a certain area
Local Values	This category is able to include any criteria that may not fit into the above outlined categories

During a large group (plenary) work session, the criteria identified by the various small groups were presented and integrated into a common framework. Similar criteria were combined and concise names for each criterion were determined for ease of analysis. The criteria were reviewed to ensure that they had the relevant characteristics (for example, consistency and logical soundness, transparency, ease of use). The final category, 'Local Values' was a category aimed at capturing criteria that did not belong to the other categories; however, since none of the groups identified criteria for this category, it was eliminated from the analysis. This preliminary framework was further refined and adjusted as part of the MCE process. For example, some criteria were later removed due to lack of data, discovery of further redundancies, and so on. The preliminary set of criteria used is presented in Figure 5.

Figure 5. Preliminary Set of Criteria



Weighting of the Criteria

As initially mentioned, MCEs can integrate qualitative and quantitative criteria. The first step in the integration process is the weighting of the criteria; This step essentially assigns relative importance to each criterion.

Weighting: *Numerical weights are assigned to define the relative importance for each criterion compared with the other criteria.*

Typically, the weighting is done through a consensus-building process. There are numerous approaches with different levels of complexity, ranging from simple discussions followed by an agreement on weights to consensus-building exercises and weighting in groups or individually followed by calculations of average weights. The selection of method may depend on the size of the group, the difference in perspective, and the time available. Box 7 discusses the approach used in Belize to weight the criteria used in the criticality assessment of the road network.

BOX 7. WEIGHTS FOR THE BELIZE PROJECT

For the weighting process, the workshop participants were split up into groups of four to six persons and carried out the following five-step process:

(a) Each group, after being informed of the strategic development objectives[5] and sector strategies, classified all criteria into 'high priority', 'medium priority', and 'low priority' criteria classes. First, the group identified five to nine high-priority criteria; then, it selected five to nine criteria for the medium priority class. The remaining criteria were checked to ensure that they were suitably classified as part of the low-priority class. Any criteria without priority were eliminated.

(b) The group discussed and decided upon a weight for each class with a total weight of 100 percent among all three classes.

(c) Once the priority classes were weighted, each person was given 24 stickers and was tasked with distributing 8 stickers among the criteria of each of the three classes.

(d) The weight for each criterion was calculated as a product of the weight of the class and the proportion of the stickers that it received within the class.

(e) Each group presented its weighting result to the entire workshop and explained the rationale behind its approach. The overall weight for each criterion was calculated by averaging the weights it received from the different groups.

During a session following the same workshop, the results were presented and discussed with the entire group. The session focused on criteria that had received the most similar or the most dissimilar weights between groups, the overall highest weights, the overall lowest weights, criteria proposed for elimination, and finally the top seven criteria that totaled up to 50 percent of the overall weight (see table 2). The groups discussed whether the results represented the discussions within and between groups.

Table 2. Criteria Weights of the Primary Criteria Totaling up to 50 Percent of the Overall Weight

Criterion	Weights Resulting from the Workshop (%)	Weights from the Workshop Adjusted by the CEOs (%)
Essential part of the evacuation network	17.03	17.90
Condition	17.78	16.52
Dependency on the road	15.23	16.50
Adequacy regarding the current demand/level of use	12.07	14.57
Access of mobile utilities, food, and relief services to the communities	14.26	13.79
Connectivity between industrial, production sites, raw material extraction areas, ports, airports, and border crossings	10.00	11.35
Access to socially vulnerable populations	13.64	9.37

Subsequently, the weights were presented to the CEOs, and each CEO individually had the opportunity to adjust the weights. By averaging the weights among all CEOs, a second set of weights was created (see table 2). This set of weights was used for developing the criticality model.

Identification of Indicators, Data Requirements, and Scoring

Criteria, defined as principles or standards on which a judgment or decision may be based, are generally abstract and therefore not directly measurable. To operationalize/measure each criterion, one or more indicators need to be determined bearing in mind that the aggregate score of the indicators of a criterion should convey a 'single meaningful message' regarding the extent to which the criterion is met. The score of each indicator is derived using one or more data sets that indicate/measure aspects of the performance of the criterion.

Indicator: *Variable or component of a system used to provide specific information on the state or condition of a particular criterion. It is a measurable variable used as a representation of an associated (but nonmeasured or nonmeasurable) factor or quantity.*

If more than one indicator is used to measure a criterion, the weight (contribution) of each indicator to the final measure needs to be determined. This could vary from a simple average, where each indicator's contribution is equal, to a weighted average, where each indicator's contribution varies. Expert judgment was used to determine the relative weights of indicators in the calculation of indicator scores for each criterion.

The indicator selection is influenced by the availability or collectability of data that covers the entire area under consideration, at sufficient resolution and detail. Indicator identification is an iterative process, which starts with initial data screening followed by more in-depth data search, data collation, and exploration of new data collection. The more data available to measure a criterion, the more options there are for selection of appropriate indicators. If the data to measure a particular indicator are not available and cannot be collected or created, they will need to be replaced by an alternative indicator for which data can be found or created.

As indicators are being finalized, a common scoring system needs to be established to enable the joining of indicators into one criterion and criteria into the overall criticality. This is necessary as indicators could be assessed using very different units such as distance, time, monetary value, or qualitative measure, all of which would need to be converted into one standard scoring system.

Common scoring systems include three or five levels and could be either numerical or nominal. Consequently, a five-level scoring standard would be 'very high', 'high', 'moderate', 'low', 'very low', or '1', '2', '3', '4', '5', while a three-level scoring standard will be 'high', 'moderate', 'low', or '1', '2', '3'. In reality, any number of scoring schemes is possible as long as it is consistently applied across all criteria, and there is a significant difference between the score levels, which enables each score level to add value. Subsequently, the threshold values for the score levels are defined for each indicator.

While a large group of stakeholders can identify criteria and their indicators, the definition of the threshold values for the scores applied to each indicator and the calculation of aggregate scores for each criterion should be carried out by a smaller group, with verification of the outputs by subject-matter experts. For example, indicators for health-related criteria should be identified and/or verified with representatives from the Ministry of Health, health professionals, and community development practitioners.

BOX 8. INDICATOR IDENTIFICATION FOR BELIZE PROJECT

The indicator identification and finalization exercise was carried out in a small technical team that included a transport engineer with experience in network analyses and a GIS expert familiar with the Belizean context. Preliminary indicators were identified, data required to inform those indicators were determined, and their availability or the possibility of using proxies was evaluated. Depending on the feasibility of the indicators, alternatives were studied and, through an iterative process, a first set of indicators was created. Those indicators were discussed with the respective sectors in the Government to obtain feedback and to make adjustments as required.

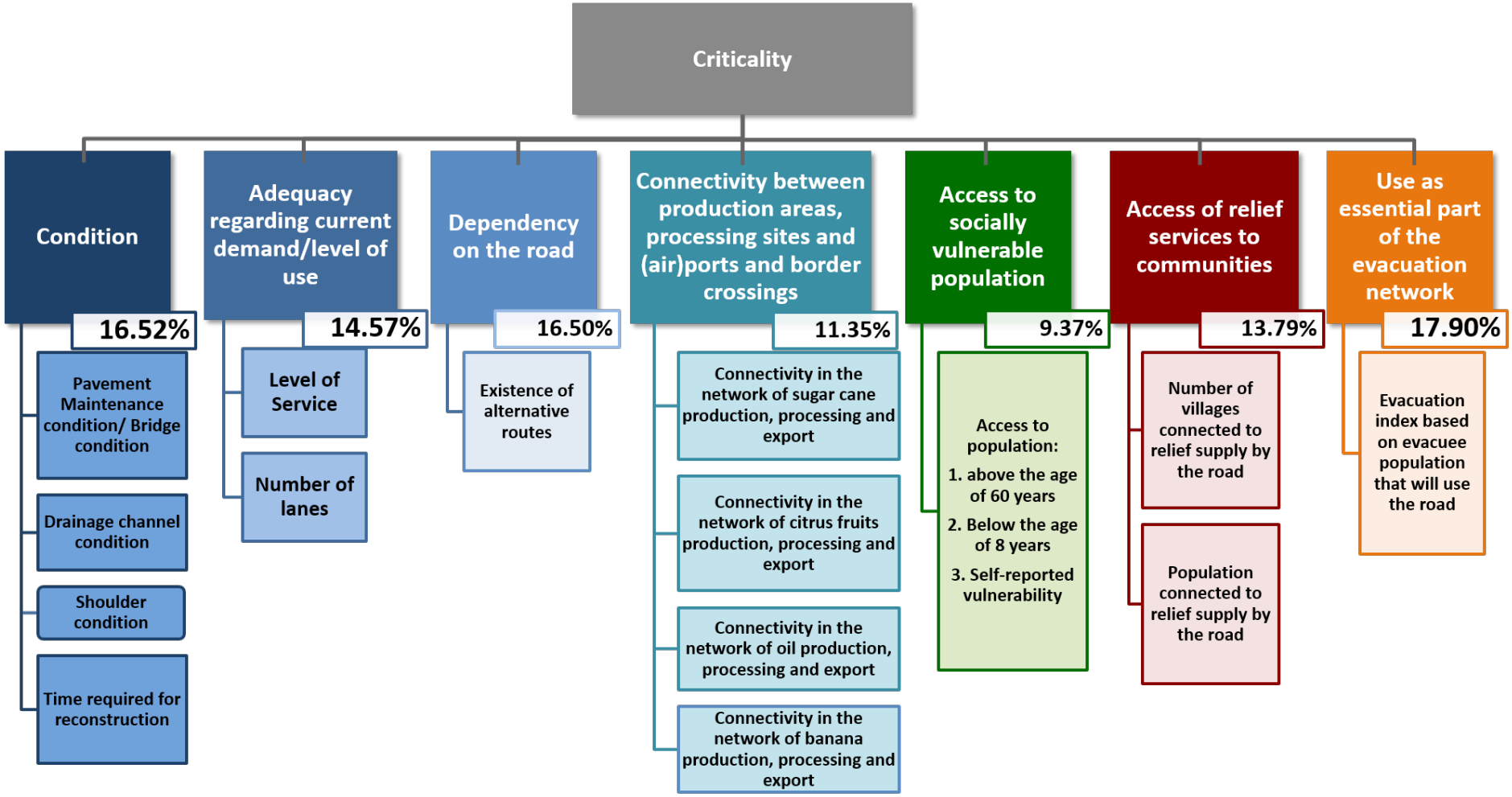
The scoring system applied in Belize consisted of six levels. For indicators with less differentiation in the data, only four out of the six levels were applied.

Table 3. Scoring System

Score	Level of Criticality (Detailed)	Level of Criticality (Simple)
0	Unknown	Unknown
1	Low	Low
2	Marginal	
3	Moderate	Moderate
4	Considerable	
5	High	High

The final set of seven criteria were assessed using 15 indicators. For example, the criterion Dependency on the road was measured using the Existence of alternative routes indicator. Once the number and quality of alternative routes had been measured, their contribution to criticality was evaluated using the scoring system by attributing a higher value (score) to roads for which no alternative routes were available or the alternative routes were of a lower category and poorer condition. Conversely, roads for which alternative routes could be identified received a lower score. For details on the indicators and their scoring, refer to the report on the 'MCE criteria and indicator framework – Belize' (Schreiner et al. 2013).

Figure 6. Framework of Indicators Used to Measure Criticality Criteria



The Modeling Environment for the Criticality Analysis

Once all the data are organized and the scoring system and process are finalized, a score for each indicator will need to be assigned to each segment. Adding the scores as attributes to the segments of the road network and the MCE is typically carried out within a software environment. Several software options are available for the kind of evaluation needed in an MCE.

BOX 9. MODELING ENVIRONMENT FOR BELIZE PROJECT

In the case of Belize, ArcGIS was used to prepare data for the analysis, VISUM was used for the criticality analysis, and ArcGIS was used for the flood susceptibility analysis. ArcGIS was also used for the overlay of the results of the criticality analysis and flood susceptibility assessment and finalization of the areas where road rehabilitation could have the biggest resilience-building effects.

VISUM, developed by PTV Group of Germany, was selected for the criticality analysis. VISUM is a transportation demand forecasting platform that allows for detailed management of GIS data and offers a wide range of transportation analyses tools and configurable traffic assignment functions. Its models take into consideration all road users and their interactions, and its capabilities are recognized by professionals involved in transport planning. Transportation experts use VISUM to model transport networks and travel demand, to analyze expected traffic flows, to plan public transport services, and to develop advanced transport strategies and solutions.

Most of the data collated or collected for the Belize MCE analysis was in the ESRI Shapefile format, so, in addition to providing an array of transport analysis functions, the criticality analysis environment needed to be able to read data in this format. The data model used by VISUM is compatible with ESRI's Shapefile format; it permits each vector data type (point, line, and polygon) to be classified, and several types of attributes (string, integer, real, date, time, Boolean, and so on) can be assigned to them directly or as related tables. Additionally, the attributes can be used as an object for filtering, mathematical procedures, and graphical display. In explaining the merits of VISUM, the transport engineer leading the model analysis reflected:

> "VISUM offers a wide range of predefined functions; from a simple GIS intersect operation to complex heuristics to optimization models used in traditional travel demand forecasting models. Those functions can be structured into calculation procedures, which execute each selected function according to predefined parameters. The procedures work in a similar way to scripts, with the advantage that programming is not required."

Calculation of Criticality

First, each indicator is calculated separately for the entire road network. Subsequently, using the indicator weights, indicators are linked to criteria. Finally, the overall criticality is computed as the sum of products of criteria and their respective weights.

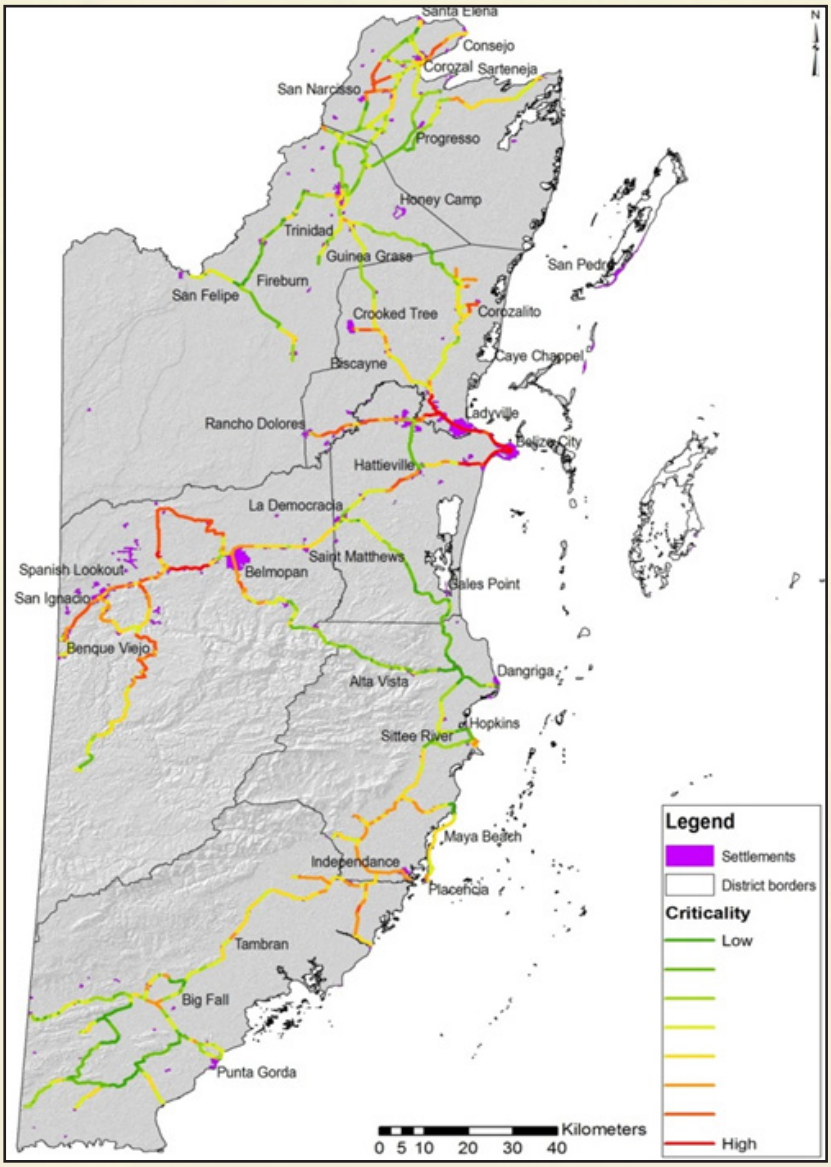
BOX 10. CALCULATION OF CRITICALITY IN THE BELIZE PROJECT

The final criticality of the primary and secondary road network of Belize is presented in figure 7.

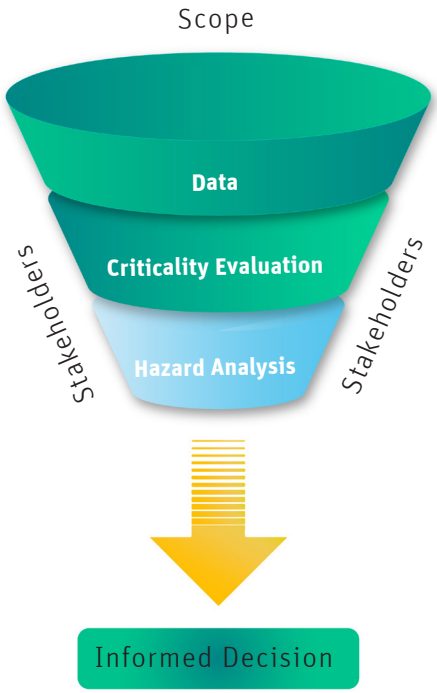
After the model was developed and run, the results went through a series of validation exercises, the first round of which was conducted by the team that led the prioritization process. Their main task was to ensure that the model was complete and that there were no major errors in the results at a technical level. Based on knowledge of the area under assessment, it was checked whether the results were reasonable.

The next round of validation was held with key stakeholders. Their task was to determine if the modelled results identify key areas that need to be addressed based on the criteria that had been defined.

Figure 7. Criticality of the Primary and Secondary Road Network



Module 5: Assessment of Risk/ Exposure from Climate-related Hazards



Risk is defined as the probability of a hazard event and its negative consequences. In a technical context, it is often described as a function of **hazard, exposure**, and vulnerability. A natural hazard refers to the "likelihood and intensity of a potentially destructive natural phenomenon, such as ground shaking induced by an earthquake or wind speed associated with a tropical cyclone" (GFDRR 2014). This guide focuses on natural hazards and, more specifically, hydrometeorological hazards that may affect the road infrastructure. **Exposure** refers to the location, attributes, and value of assets that are important to communities, such as people, buildings, factories, farmland, and infrastructure. In this guide, the focus is the road network, including roads, bridges, drainage, and so on. Finally, **vulnerability** refers to the reaction of an element when exposed to a hazard impact. For example, vulnerability of a road to flooding increases with worsening road conditions and may lead to damage of the surface and possibly even destruction of the road.

Risk assessment is "a methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods, and the environment on which they depend" (UNISDR 2009). The Guidelines for Mainstreaming Disaster Risk Assessment in Development define disaster risk assessment as "the process of collecting and analyzing information about the nature, likelihood, and severity of disaster risks." The process includes deciding whether to prevent or reduce disaster risks, determining which risks to address, and developing a plan to manage those risks. The assessment process emphasizes proactive management of disaster risks through reduction of both prospective and accumulated risks. It covers assessment of risks from future hazards as well as those that have already occurred. It is important to note that risk assessment is the first step in effective disaster risk management and should be undertaken as part of a comprehensive risk management strategy.

There is not one standard approach to risk assessment. The method used in a specific situation is dependent on a number of factors, including the purpose, area of interest, scale or level of detail, and the time frame to be assessed. Furthermore, very practical factors include time and resources to complete the task and availability of data.

Usually, the relation is that the more detailed an analysis and the larger the area under consideration, the higher the cost due to the need for a more sophisticated model with higher data requirements.

In the context of prioritization of climate-resilient investments of road infrastructure, three principal levels of detail with respect to risk/exposure assessment can be distinguished: (a) susceptibility assessment; (b) hazard assessment; and (c) risk assessment. It is important to note that the approaches are additive, that is, the hazard assessment builds on the susceptibility assessment and the full risk assessment builds upon the hazard assessment.

(a) Susceptibility assessment. This approach aims at identifying the geographic likelihood of a certain hazard, that is, the probability that one area will be affected in the future versus another area, also referred to as 'susceptibility'. It does not provide information on the temporal probability of the hazard, meaning that although it could determine that one area will be affected with a higher probability than another, no information is provided when or how often an event may occur. Subsequently, the susceptibility information is overlaid with the road network to identify the areas that are located in areas susceptible to the hazard under consideration and therefore exposed to a potential impact. This approach does not consider vulnerability; this means, it is not required to understand how assets will behave when affected by a certain event—information that is often not easy to obtain. This approach is especially useful if detailed rainfall records, discharge information for floods, landslide inventories, bathymetry data, and so on are missing and the principal source of information are experts.

(b) Hazard assessment. In a hazard assessment, the spatial and temporal probability of an event occurring in an area is analyzed. Subsequently, the hazard information is overlaid with the road network to identify the areas that are exposed to high, medium, and low hazard levels. In comparison to the susceptibility assessment, the hazard assessment provides information on the frequency and intensity with which a certain type of event could be expected. However, in this case, the vulnerability of the assets, that is, the reaction of the assets to the impact of an event, is not taken into account. This approach is useful if ample data on the natural system is available (rainfall, discharge, topography, bathymetry, infiltration, and so on) and the natural hazard phenomena are well understood, but there is a lack of understanding on the reaction of assets to the impact.

(c) Risk assessment. In a full, quantitative risk assessment, the probability of a certain level of damages is described in financial terms. This requires an in-depth understanding of the processes contributing to the hazard; the elements that are exposed to the hazard; and the vulnerability of the assets, that is, their behavior when affected at different hazard levels. This approach requires availability of numerous high-quality data sets. A challenge with this type of approach is the availability of models because there is a limited amount of vulnerability models and curves available for roads, bridges, and culverts, especially as it relates to climate-related hazards such as floods and landslides.

Table 4. Comparison of Three Levels (Depth) of Risk Assessments

	Susceptibility Assessment	Hazard Assessment	Risk Assessment
Input data requirements	Expert knowledge on the natural hazards and assets, information on past events, and other geospatial data as available. Location of the assets under consideration	Additionally, good quality digital terrain model, bathymetry hydrometeorological time-series, soil distribution and characteristics, land cover, and so on	Additionally, asset data, including location, extent/shape, and characteristics and damage data as basis for vulnerability models/functions
Data scale/level of detail	Small/low	Medium/moderate	Large/high
Advantages	Simple, with low data and time requirements	Good trade-off between level of effort and obtained information. While the costs of impacts are not quantified, the combination of hazard intensity and exposed assets provides a good first idea of possible effects.	Full quantification of risk provides a good understanding of the probability of impacts and related costs. It can serve as a starting point for cost-benefit considerations.
Disadvantages	Due to the qualitative or semiquantitative nature of the susceptibility assessment, no information on the absolute level of hazard in different areas or future cost implications is provided. The approach is purely based on the experience from past events and can therefore not integrate projections under future conditions.	No information is provided on the effect of a hazard event on the asset.	High cost, time, and data requirements

Please note that it is beyond the scope of this guide to provide details on susceptibility, hazard, and risk assessments but to rather provide an overview of their characteristics (Table 4). There are many models, and an expert in the respective field should do the selection and implementation of the assessment.

BOX 11. FLOOD SUSCEPTIBILITY ANALYSIS IN BELIZE

Due to its generally flat topography and multitude of rivers and perennial streams, pluvial and riverine flooding are among the principal hazards in Belize. Another major hazard is coastal flooding given the long and low-lying coastline. For this road infrastructure prioritization process, a flood susceptibility assessment focusing on riverine flooding was carried out, given (a) the lack of sufficient hydrometeorological data at a fine-enough resolution and the lack of suitable resolution topography and bathymetry data; (b) the countrywide scope of the analysis; and (c) the limited time and financial resources available. Coastal flooding was not taken into consideration because there was no existing analysis for the entire country at the required scale and an analysis could not be conducted given the low quality and resolution of the DEM. Landslides are not a major risk along the primary and secondary road networks due to Belize's generally flat topography.

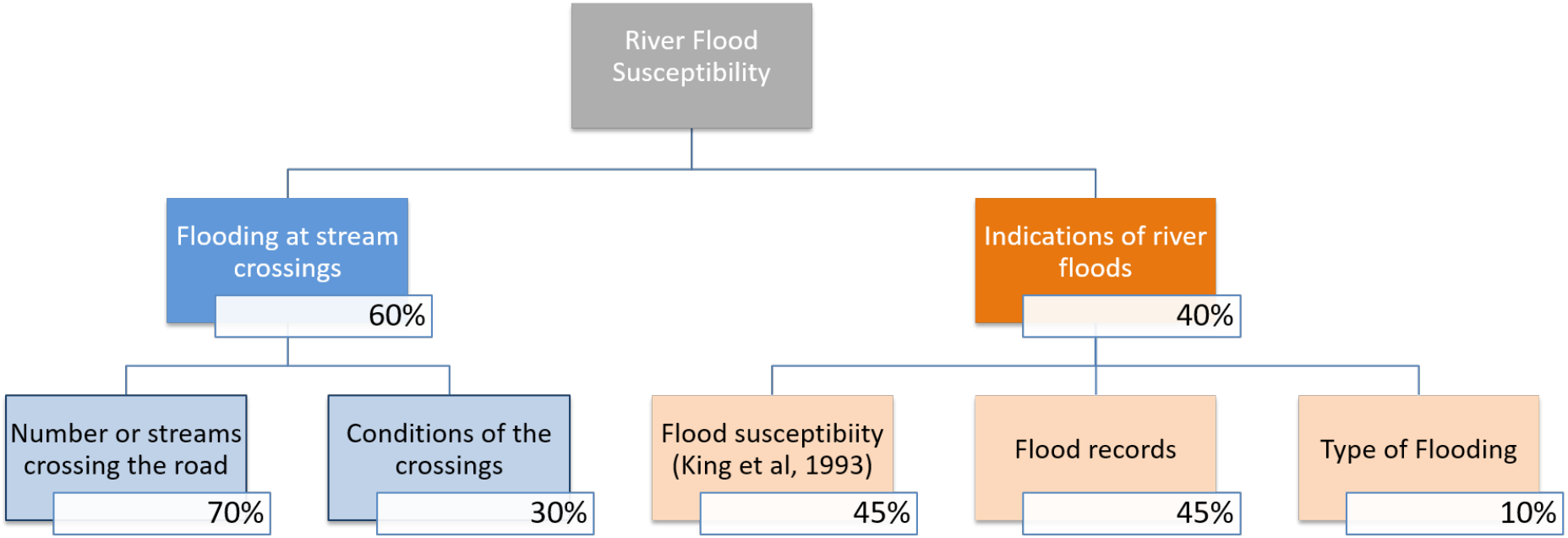
The flood susceptibility analysis carried out in Belize was based on combining expert knowledge with field observations, data on past flood events, and existing literature into a qualitative approach. The MCE tool was used; however, this time, expert judgment determined the criteria, weights, and indicators. In the following section, the criteria and indicators are presented and described (Figure 8 and Figure 9).

Identification of Criteria

To carry out a simplified susceptibility analysis, criteria were chosen considering the available data and according to the causes of flooding of the road network, which include undersized stream-crossing structures and insufficient hydraulic capacity of culverts and bridges. The underlying cause is that often design and construction of culverts and bridges is carried out without sufficient hydrologic and hydraulic information, which results in undersized structures in most cases. In addition, a significant number of stream crossings is in bad condition (obstructed or damaged), which leads to further reduced hydraulic capacity and increased vulnerability. Susceptibility to river floods, which relates to the flooding caused directly by the water bodies, seems to be less frequent than the flooding at crossings; however, for high-severity events, it can significantly affect the road network. Based on these observations, the flood susceptibility analysis was developed using the following two criteria: (a) Flooding at stream crossings and (b) Indications of past river flooding.

Weighting of the Criteria

Figure 8. Flood Susceptibility Flow Chart - Concept of the Flood Susceptibility Analysis Approach



Note: The river flood susceptibility consists of two criteria (dark blue and dark orange boxes), which are composed of multiple indicators (in the light blue and the light orange boxes). In the rectangles on the lower right side of each criterion/indicator, the weights are presented.

To obtain the overall flood susceptibility, the criteria need to be combined using weights based on their respective relevance. Because flooding at crossings appears to be the most frequent issue and results in the need for constant repairs of the road infrastructure, it was assigned a higher weight (60 percent) than the indication of past river flooding (40 percent).

Identification of Indicators, Data Requirements, and Scoring

Once the criteria were established, indicators were developed based on experience from past events, field observations, and expert knowledge. In the case of flooding at stream crossings, based on the assumption that most stream crossings, especially culverts, are undersized and mostly in insufficient condition, the following two indicators were chosen: (a) number of streams crossing the road and (b) condition of the crossings (see the light blue boxes in Figure 8). The second criterion, indications of past river floods, integrates all available information on past events, indications from experts, and existing studies as well as flood characteristics. Two types of information sources were considered: the flood susceptibility information from the study of King et al. (1993) and the flood records from newspapers, expert information, and mapping of the flood extent after Tropical Depression 16. In addition, the type of flooding was taken into account due to the varying effects that different types of flooding may cause on the road network. For example, floods in sloped areas have a quick onset and recede quickly after the rainfall events, whereas floods in plain areas rise more slowly but may stay longer and thereby impede traffic for a longer time.

To estimate the indicators, the road network was divided into 5 km stretches, and information collected based on visual inspection and existing data was attached. Each indicator was 'normalized' from its original unit and assigned a score between 1 and 100, which was chosen based on expert judgment with the aim to capture increasingly worse flood susceptibility conditions. The following section describes the indicators in more detail.

Number of stream crossings. Any crossing of a river or small stream along a road has the potential for flooding, especially considering that according to the Ministry of Works and Transport, no design standards currently exist. Consequently, the assumption underlying this analysis was that stream-crossing structures were undersized for the whole network. On that basis, the number of streams crossing the road was an indicator of possible flooding, whereby for every stream crossing a 5 km stretch of the primary and secondary roadway, a score of 10 was applied. This value was obtained from a linear normalization procedure, where the road stretch with the maximum number of crossings (10) was given a score of 100.

Condition of crossings. Crossing structures in poor condition enhance the flood hazard potential because they reduce the hydraulic capacity. The condition of crossings within each 5 km stretch was determined by the culverts, bridges, or streams in the worst condition given a score of 100, partially damaged or partially clogged given a score of 50, and in good condition given a score of 0.

Flood susceptibility (King et al. 1993). When King et al. (1993) did the assessment of renewable resources in Belize, they ranked the potential for flooding across Belize. Each 5 km stretch of road within areas that they identified as flood prone was given a score of 100, and 5 km stretches within areas not judged as flood prone were given a score of 0.

Flood records. The 5 km stretches located in areas where flooding was identified in recorded events were considered to be in a confirmed susceptibility area and given a score of 100. Other areas were given a score of 0.

Type of flood. The type of flood expected can greatly influence the hazard conditions; for example, the floods that occur in the mountainous areas are more likely to be flash floods while floods in flat areas tend to remain much longer. Flash floods cause short-term interruption of traffic while floods in the flat areas last longer and cause more significant traffic disruption. Therefore,

flat areas, where there would more likely be slow onset floods, were given a score of 100 and mountainous areas, where there would more likely be flash floods, were given a score of 50 and areas not prone to flooding or where no floods were recorded were given a score of 0.

A weight was then assigned to each indicator so indicator scores could be combined into a final score for each criterion per 5 km stretch of road.

Indicator weights for the criterion flooding at crossings. Given the assumption that road drainage structures were inadequate, the number of stream crossings across the road stretches would affect the likelihood of flooding more than the condition of crossings. As such, more weight was given to the number of stream crossings (70 percent) and less weight to the condition of crossings (30 percent).

Indicator weights for the criterion indication of past river flooding. The flood susceptibility study by King et al. (1993) was used to identify stretches of road that could be flooded according to geomorphological conditions. The recorded events were considered as a complement of the study by King et al. (1993); therefore, equal weight (45 percent) was given to the flood susceptibility (King et al. 1993) and the flood records indicator. While the type of flood plays a role in the resulting impact, it is comparatively less relevant and therefore weighted lower (10 percent).

Calculation of Flood Susceptibility

First, the indicators were calculated for the entire road network; then, using the weights, the criteria values were derived and the flood susceptibility values were computed.

After the model was developed and run, the results went through a series of validation exercises the first round of which was conducted by the team that led the prioritization process. Its main task was to ensure that the model was complete and that there were no major errors in the results at a technical level. Based on knowledge of the area under assessment, it was checked whether the results were reasonable.

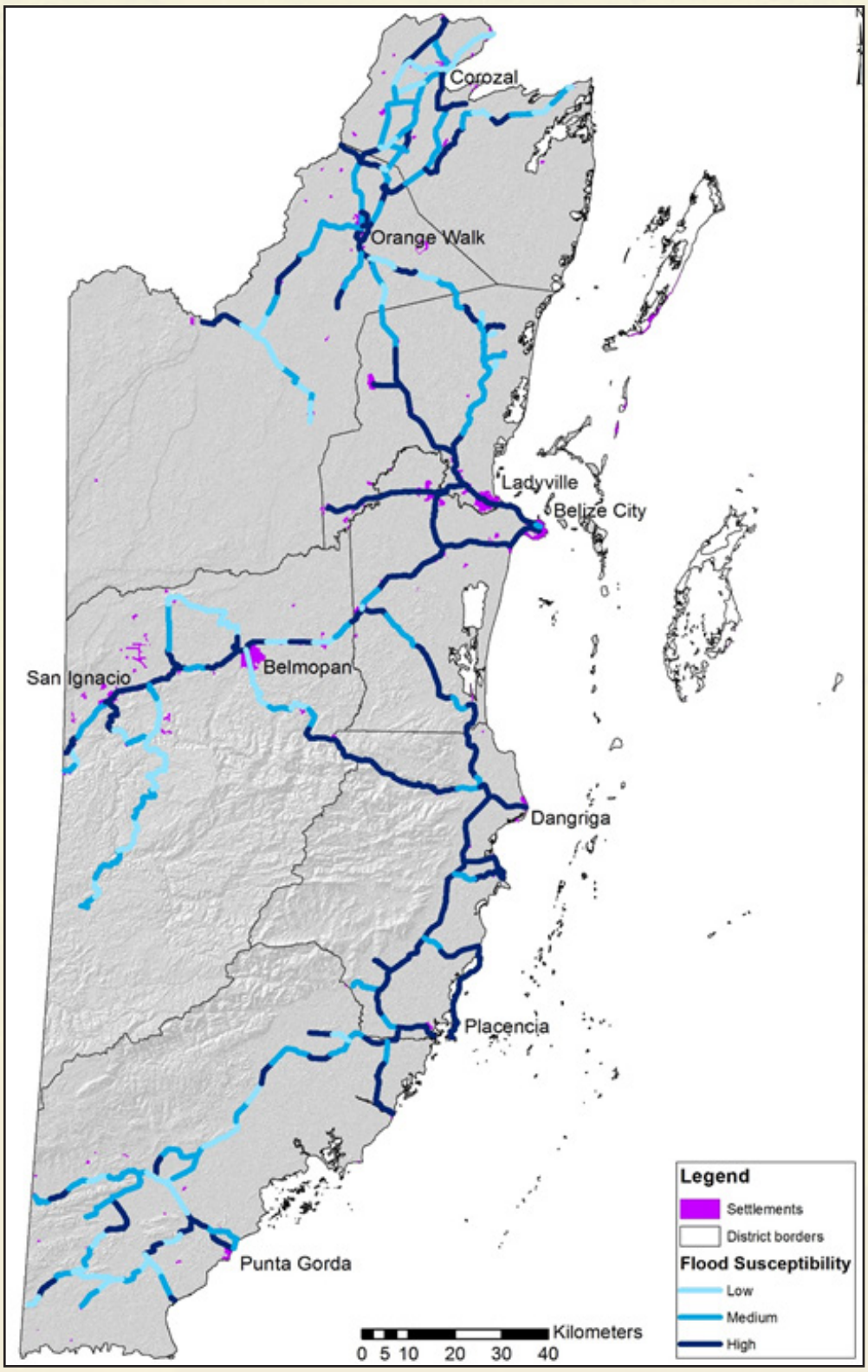
The next round of validation was held with key stakeholders. Their task was to determine whether the modelled results identify key areas that need to be addressed based on the criteria that had been defined.

Subsequent to the validation, three susceptibility classes were established: (a) high susceptibility—areas with a final score between 50 and 100; (b) medium susceptibility—areas with a final score of 0–49; and (c) low susceptibility—areas with a final score of 0. The results were compared with data of critical sites collected in the field to validate the results and then combined with these data. The final ranking were estimated as follows:

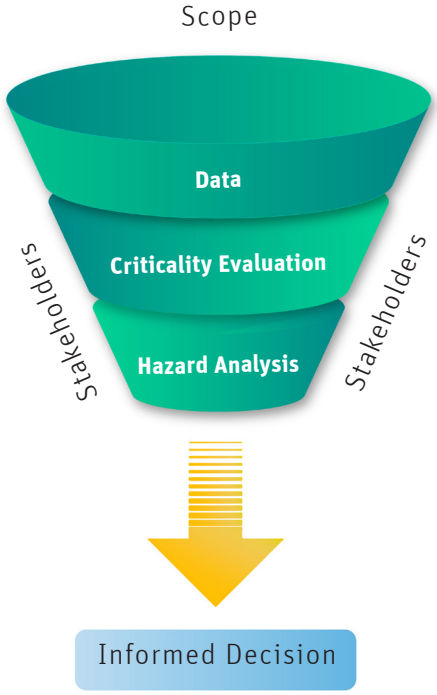
- High priority: A 5 km stretch identified as Priority 1 stretches AND critical from the field analysis
- Medium priority: A 5 km stretch identified as Priority 1 stretches OR critical from the field analysis
- Low Priority: A 5 km stretch identified as neither Priority 1 NOR critical from the field analysis

The final outcome of the analysis, the flood susceptibility evaluation of the entire primary and secondary road network of Belize, is presented in Figure 9.

Figure 9. Flood Susceptibility of the Primary and Secondary Road Network



Module 6: Informed Decision Making



While creating models, calculating numbers, and preparing maps is critical, it is equally important to involve the decision makers from the beginning of the process so that they buy into the process and are prepared for the final results. Thus, it is advisable to involve the Cabinet, or the highest decision-making authority, at strategic points throughout the process. Upper management, such as the CEOs of line ministries, should also be engaged, so that there are frequent points at which incremental approval is given for intermediate outputs and proposed methodologies. Ultimately, the decision to allocate funds to projects rests with the Cabinet and is executed through the MoF, which is responsible for budget preparation. Key stakeholders of the process such as the MoF can provide guidance on how to best present the final results and discuss their use.

The information provided should enable decision making about the most effective use of scarce resources to make the people and economy more resilient to the impacts of natural hazards. As such, additional information about already ongoing infrastructure investments and cost implications should be included in communication to decision makers.

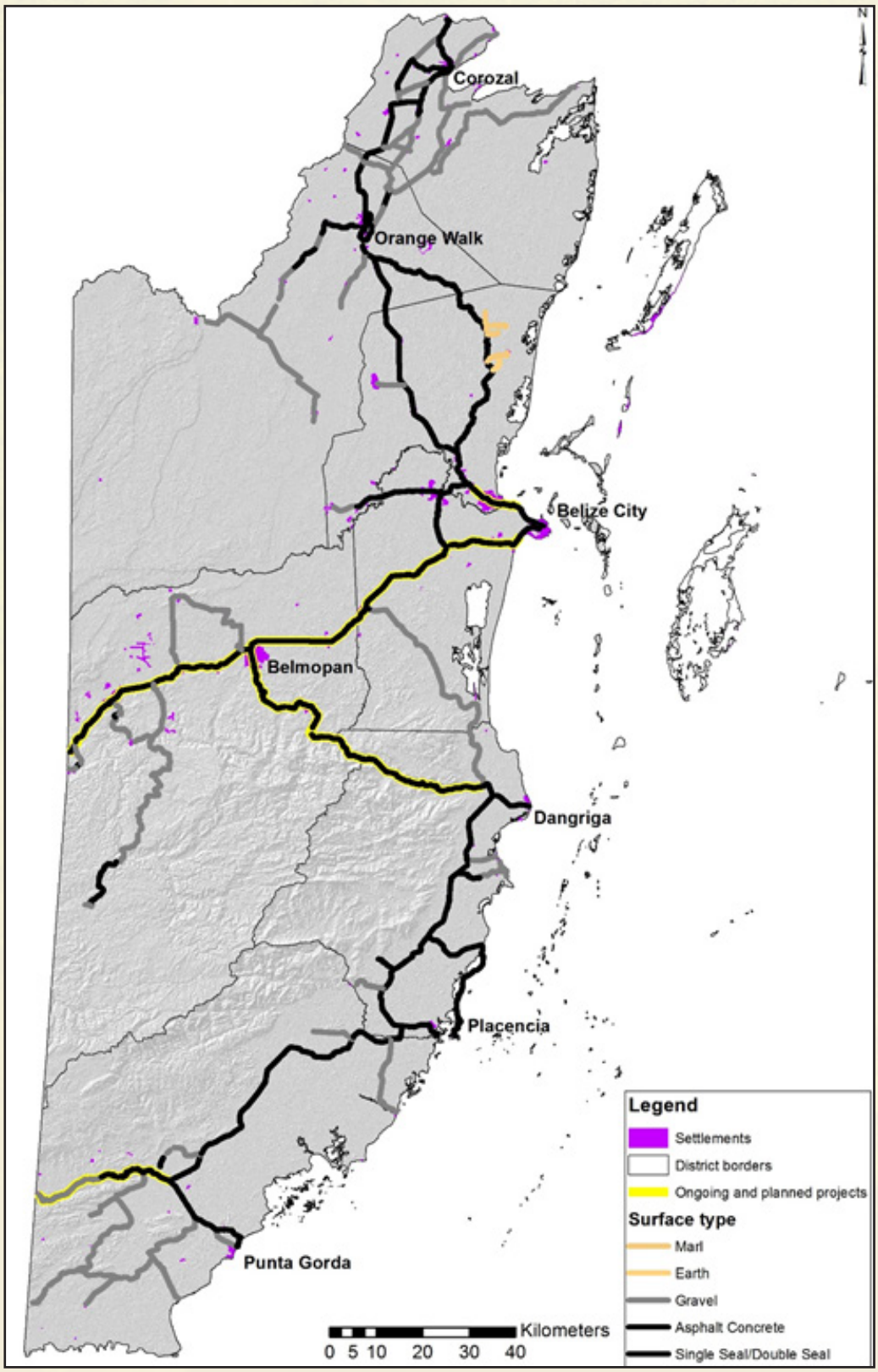
BOX 12. USING THE RESULTS TO INFORM INVESTMENTS IN BELIZE

Three Cabinet papers were submitted when there was an intermediate product or proposed methodology for the Cabinet to approve throughout the process. The Cabinet papers were short and focused on presenting the most important information required for decision making. In addition, there were frequent discussions with CEOs during their Cabinet debriefing session as well as further discussions with the CEO directly responsible for managing the process and relationship with the Cabinet.

When presenting the final results, additional information that was considered useful for prioritizing investments was integrated into the presentation; for example, information on planned or already ongoing infrastructure projects were included.

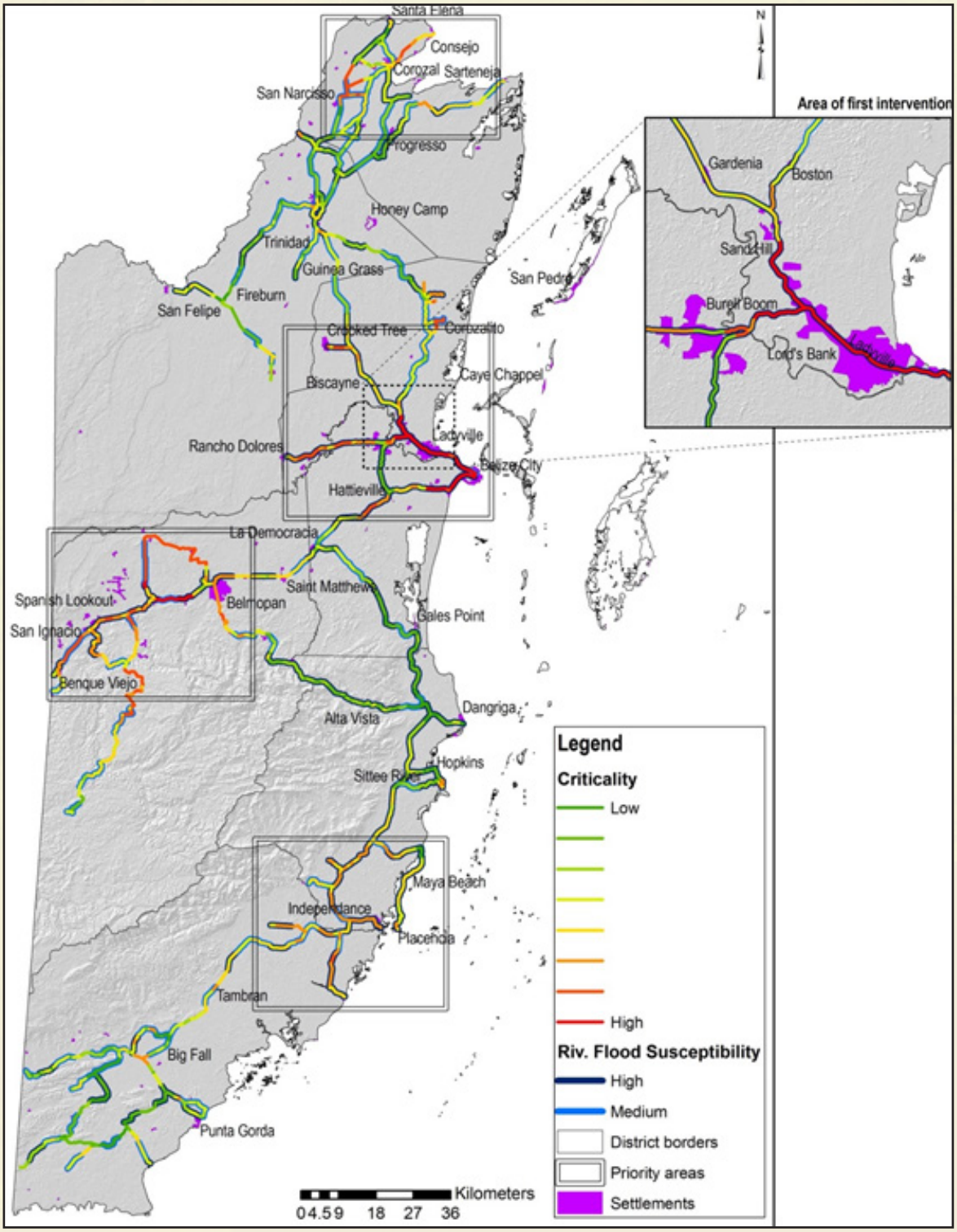
In the selection of intervention for the World Bank project, the scope and cost of investments were considered as interventions that required major capital investments, for example, paving of unpaved roads or the construction of new roads were not considered, given the limited funds available. The map showing road type and condition (see Figure 10) reveals that all highways stretching between (a) the Western Border (to Guatemala) and Belize City, (b) the Hummingbird highway from Belmopan to Dangriga, (c) the Southern highway from Dangriga to Punta Gorda, and (d) the Northern highways are paved while most other roads of the primary and secondary network have a gravel surface.

Figure 10. Road Surface Type Including Information on Ongoing and Planned Projects



The prioritization of flood risk reduction was carried out based on the identification of areas with high flood susceptibility in combination with high socioeconomic criticality. Thereby, not a single road stretch was identified rather than areas with significant criticality and flood susceptibility to account for the network character of the transport infrastructure.

Figure 12. Priority Areas for Flood Vulnerability Reduction Investments under the Climate Resilient Infrastructure Project



The four areas that have been identified and prioritized for road investments are the following:

(a) **Greater Belize City area.** This area was considered critical because it got a high criticality rating in the 'access of relief services to the communities' and 'essential part of the evacuation network' criteria and a medium criticality rating in all the other criteria. Flood susceptibility of road stretches in this area ranked in the highest susceptibility class.

(b) **West of Belmopan.** This area was considered critical because it got a high criticality ratings in the 'connectivity between production sites and raw material extraction areas and (air) ports and border crossings', 'access of relief services to the communities', and 'access to socially vulnerable populations' criteria and a medium criticality rating in most of the other criteria. Flood susceptibility of road stretches in this area ranked from low to high, with most stretches in the medium to high susceptibility class.

(c) **Northern area around Corozal.** This area was characterized by a mix of high to low criticality. Several routes are ranked as highly critical in the 'essential part of the evacuation network' and their importance in providing 'access to socially vulnerable populations' criteria. In addition, the area had high criticality for the 'connectivity between production sites and raw material extraction areas and (air)ports and border crossings' criterion. Flood susceptibility of road stretches in this area ranged from low to high.

(d) **Southern area around Independence.** This area was characterized by medium criticality. While the 'dependency on the road' criteria was ranked very high, the 'condition of the roads' is comparatively good, so the criteria was ranked low. Flood susceptibility for the majority of road stretches in this area, especially the highway, fell into the high flood susceptibility class.

The Government of Belize used this information for the selection of sites for intervention under the World Bank–supported', Climate Resilient Infrastructure Project (CRIP).

Discussion and Lessons Learned

The participatory prioritization of investments in the road infrastructure in Belize combined the results of two MCE processes: criticality and susceptibility assessments of the primary and secondary network. The final output was the identification of priority

areas in the network toward which resilience improvement investments should be targeted. The process was successfully completed, and the final product is being used to identify or inform investments in road infrastructure in Belize. This section presents some factors that led to the success of the prioritization process and some lessons learned to consider during future implementation of similar processes.

(a) **A good understanding of the decision-making processes in a jurisdiction where a prioritization process is to be implemented is useful.** Time spent discussing who the key decision makers are, how they make their decisions, and the deliberation processes for resource allocation options should inform the way information is shared and discussed during the prioritization process. In the case of Belize, the interactions among technical officers, the CEOs, and the Cabinet was managed by the CEO in the MoFED. Her experience in facilitating discussions between the Government, at its various levels, and multilateral banks about project selection enabled the facilitating team to work with technical representatives and CEOs at key junctures in the process.

At the technical level, the CEO for Economic Development worked with her colleagues to appoint representatives from their respective ministries to participate in the criticality assessment of the road network and collaborated with the Ministry of Works and Transport in the implementation of the susceptibility assessment. She worked with the facilitating team to package the findings, at strategic points in the process, for submission to the executive for consideration, discussion, and endorsement. The priority list was not submitted simply as a final product, but rather the process, intermediate product, and final list were sequentially submitted and incrementally adopted.

(b) **As much as possible, get the organization that facilitates the decision-making process to participate in the technical discussions and to take ownership of the process and results.** This could improve the prospects for use of the results and the adoption of the methods and principles of evidence-based decisions in resource allocation processes.

In the case of Belize, the MoFED successfully led the prioritization process through the Government's decision-making mechanisms.

The Ministry of Works and Transport, which is responsible for road infrastructure, participated in both the criticality and flood susceptibility components of the evaluation. As a result, it is now integrating disaster resilience into the design and construction of roadways, as well as including resilience considerations in its maintenance planning.

(c) **Evidence-based prioritization could improve resource allocation and lead to higher levels of human development.** The information for evidence-based prioritization comes from institutional and operational knowledge, as well as data collected and assessed. Good data development and data-sharing capabilities better enable evidence-based resource allocation. If at all possible use the process to help to develop and or strengthen the data collection and data management and sharing culture.

(d) **Data created or compiled for use in evidence-based prioritization for resource allocation in a particular thematic area will often be useful in other thematic areas.** Bearing this in mind could help ensure that collected data are appropriately disaggregated.

In the case of Belize, a series of data sets were collated and created for use in the model to prioritize road segments for investments. An important data set that was created was the road database, which can also be used as input for the management of the primary and secondary public roads. Other data created included the location of public buildings such as banks, production centers, and historic floods, among others. Some existing data such as the Belize Rivers and the land systems from the King et al. (1993) study were upgraded to improve usability in the MCE models, and others such as the 30 m ASTER DEM, Belize Land Use/Land Cover, and Belize settlements were collated for use. In total, about 30 data sets were utilized in some way in the preparation of the prioritization model. The data collated and collected have been shared through the national spatial data infrastructure (NSDI). It is expected that the Government will adopt and update the data sets as well as use them in its national development planning.

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1. Meteorological: High wind/excess rainfall/hurricanes and drought.
2. Latin America and Caribbean Urban and Disaster Risk Management team in the Social, Urban, Rural and Resilience Global Practice
3. Guha-Sapir, D., R. Below, and Ph. Hoyois - EM-DAT: International Disaster Database - www.emdat.be - Université Catholique de Louvain - Brussels - Belgium.
4. Guha-Sapir, D., R. Below, and Ph. Hoyois - EM-DAT: International Disaster Database - www.emdat.be - Université Catholique de Louvain - Brussels - Belgium.
5. Adjusted for inflation to 2016 using the U.S. Bureau of Labor Statistics inflation calculator: http://www.bls.gov/data/inflation_calculator.htm.
6. In the beginning of the workshop, a presentation was given by MoFED on the strategic development objectives of the Government.
7. http://www.preventionweb.net/files/4040_africaguidelinesmainstreamingdrassessmentdevelopment1.pdf.