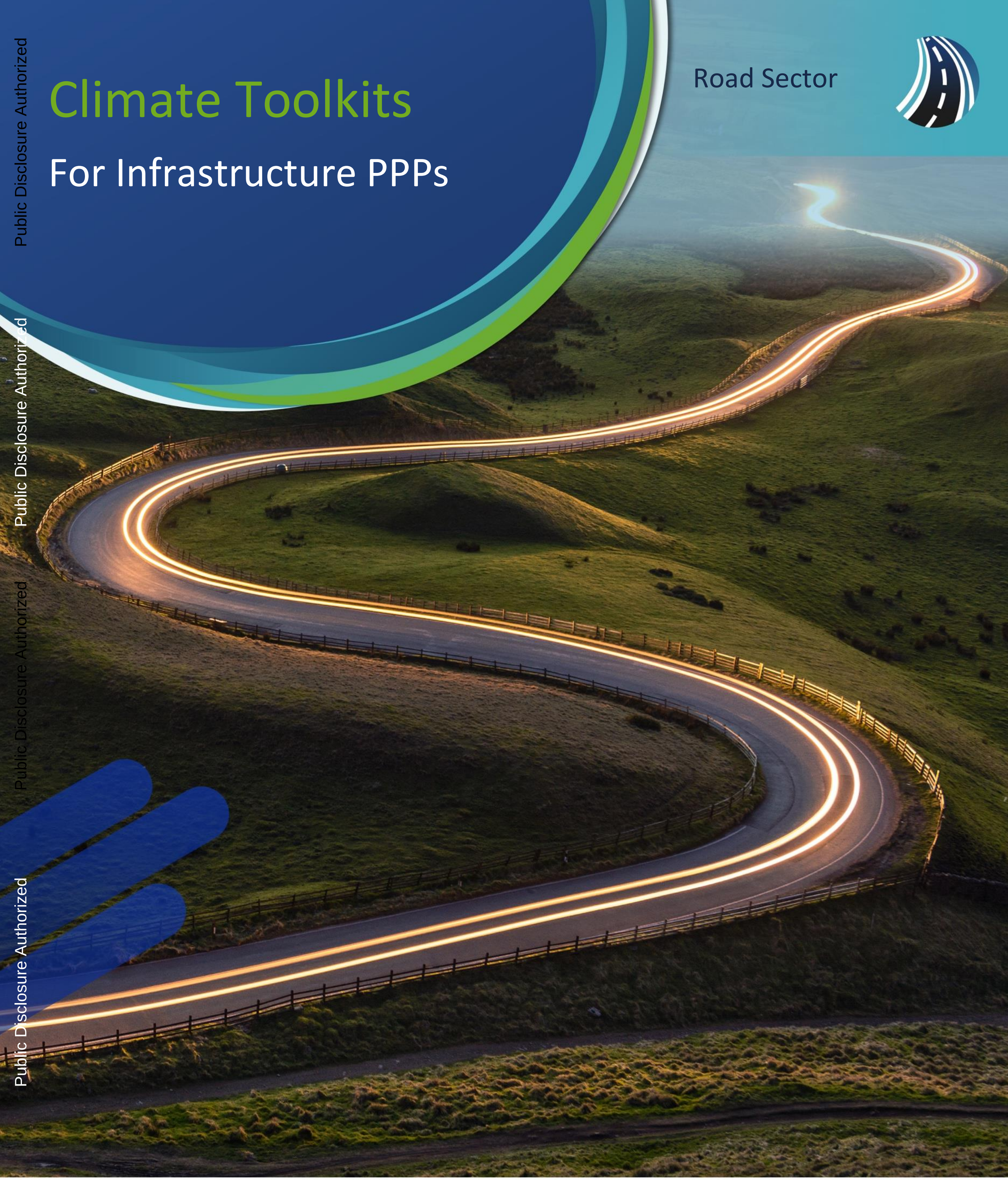
Climate Toolkits

For Infrastructure PPPs

Road Sector



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Global Infrastructure Facility A G20 INITIATIVE

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About PPIAF

PPIAF helps developing-country governments strengthen policy, regulations, and institutions that enable sustainable infrastructure with private-sector participation. As part of these efforts, PPIAF promotes knowledge-transfer by capturing lessons while funding research and tools; builds capacity to scale infrastructure delivery; and assists sub-national entities in accessing financing without sovereign guarantees. Donor-supported and housed within the World Bank, PPIAF's work helps generate hundreds of millions in infrastructure investment. While many initiatives focus on structuring and financing infrastructure projects with private participation, PPIAF sets the stage tomake this possible.

About the GIF

The Global Infrastructure Facility, a G20 initiative, has the overarching goals of increasing private investment in sustainable infrastructure across emerging markets and developing economies and improving services that contribute to poverty reduction and equitable growth aligned with the SDGs. The GIF provides funding and hands-ontechnical support to client governments and multilateral development bank partners to build pipelines of bankable sustainable infrastructure. The GIF enables collective action among a wide range of partners – including donors, development finance institutions, country governments, together with inputs of private sector investors and financiers – to leverage both resources and knowledge to find solutions to sustainable infrastructure financing challenges.

About CTA

IFC's PPP Transaction Advisory (CTA) advises governments on designing and implementing PPP projects that provide or expand much needed access to and/or improved delivery of high-quality infrastructure services – such as power, transportation, health, water and sanitation – to people while being affordable for governments. In doing so, CTA assists on both the technical, financial, contractual, and procurement aspects of PPP transactions. To date, CTA has signed over 400 projects in 87 countries, mobilizing over $30 billion of private investment in infrastructure, and demonstrating that well-structured PPPs can produce significant development gains even in challenging environments.

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List of Abbreviations and Acronyms

BRT	bus rapid transit
CAPEX	capital expenditures
CBA	cost-benefit analysis
CNG	compressed natural gas
CO2	carbon dioxide
CO2e	carbon dioxide equivalent
DBST	double bituminous surface treatment
EbA	ecosystem-based adaptation
EIRR	economic internal rate of return
EMAS	eco-management and audit scheme
GHG	greenhouse gas
GIB	Global Infrastructure Basel
GRI	Global Reporting Initiative
ICMA	International Capital Market Association
IPCC	Intergovernmental Panel on Climate Change
KPI	key performance indicator
LED	light-emitting diode
LPG	liquefied petroleum gas
LRT	light rail transit
LSE	London School of Economics
LTS	long-term strategy
MCA	multi-criteria analysis
MDBs	multilateral development banks
MoT	ministry of transportation
NAP	national adaptation plan
NbS	nature-based solutions
NDCs	Nationally Determined Contributions
NPV	net present value
n.a.	not applicable
OPEX	operating expenses
PPP	public-private partnership
RCP	Representative Concentration Pathway
SASB	Sustainable Accounting Standards Board
SRI	solar reflective index
SSL	Solid State Luminaires
TCFD	Task Force on Climate-Related Financial Disclosures
VfM	value for money

Foreword

The time for action to build a better future and green recovery has never been stronger as we navigate the uncertainty of a world dealing with multiple crisis on top of climate change. As governments across the globe face fiscal constraints, it has become imperative to crowd in private sector solutions, innovation, and finance to create new solutions and pathways to meet Paris Agreement goals on climate change and UN Sustainable Development Goal (SDG) commitments.

Participation of the private sector in Paris-Aligned infrastructure investments is critical and public-private partnerships (PPPs) are among the key solutions. PPPs are critical in supporting governments to bridge the infrastructure gap not only for the additional capital they bring but sector expertise and innovation as well. However, the PPP model is not without challenges, climate change creates uncertainty that can be difficult to account for in the framework of PPPs, which require a certain degree of predictability to attract investment and finance.

This sector-specific toolkit on the roads sector aims to address this challenge by embedding a climate approach into upstream PPP structuring. If structured correctly, PPPs in the transport sector can increase climate resilience offering market-based solutions to address both mitigation and adaptation challenges. PPPs are able to provide well-informed and well-balanced risk allocation between partners- offering long-term visibility and stability for the duration of a contract (typically 20 to 30 years)- compensating climate change uncertainty through contractual predictability.

The toolkit attempts to address questions like:

- In what ways-in terms of likelihood and impact-does climate change affect the roads sector, and what measures can be taken to alleviate these impacts through a PPP structure?
- How can decarbonization measures help to promote greener modes of transport and facilitate optimal risk allocation and contractual predictability in an environment marked by uncertainty and the need for resilience to unpredictable scenarios?

The Global Infrastructure Facility (GIF), The Public Private Infrastructure Advisory Facility (PPIAF) and International Finance Corporation, Transaction Advisory, Public-Private Partnership and Corporate Finance Advisory Services in collaboration with sector specialists across the World Bank Group (WBG)-have joined forces to build upon best practice on a topic at the cross-roads of climate change, infrastructure, and private sector participation. It is a field in evolution where there will be a great deal of innovation ahead of us.

Currently an insufficient focus is given to considering climate change in the framework of PPPs. For instance, the PPP tender selection criteria are currently ultimately based on the least cost approach, which may promote assets not resilient enough to withstand climate impacts. This may in turn result in total asset loss with devastating effects on the economy and society. This toolkit is indeed about providing solutions to public officials and their advisors on how to better align interests and incentives towards climate-smart investments and tap into private sector financing capacity.

The roads sector toolkit toolkit as part of the Climate Toolkits for Infrastructure PPPs (CTIP3) suite is ultimately a call for action for decision makers, to push for bold initiatives so that infrastructure investments become a critical and steady pathway to achieve Paris Agreement and SDG commitments.

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INTRODUCTION

The delivery of new transportation infrastructure has come to a critical crossroad

Sustainability, climate-change mitigation, adaptation, and resilience have become priorities for countries striving to meet their Paris Agreement commitments. These priorities impact planning, design, and operational decisions for new transportation assets, and transform the procurement and delivery of road infrastructure PPPs, adding a new set of considerations to the structuring phase. In line with global and national climate frameworks and policies, sustainable road infrastructure PPPs should support decarbonization of the transport sector by: promoting greener transportation modes; exhaust opportunities for energy/material conservation during construction and operation; incorporating design elements that create asset climate resilience; taking into consideration social inclusion aspects; and guaranteeing the safety of their users and the resilience of the communities they serve.

Road-climate interaction goes both ways

Road networks are already threatened by extreme weather events such as flooding, severe heat, and intense storms, experiencing costly climate-related impacts and leading to disruption and damage of roads, bridges, and other horizontal transport components. These impacts are projected to intensify in magnitude, duration, and frequency because of climate change. At the same time, road-based transportation systems are driving climate change with greenhouse gas (GHG) emissions that result primarily from motorized vehicles use and secondarily from construction, operation, and maintenance-related activities. To stop this vicious cycle, it is important to account for the effects of climate change early during decision-making, when options and investment priorities are discussed. For example, investments in actions contributing to GHG reduction and incorporating nature-based solutions (NbS) would positively impact the carbon footprints of roads, by encouraging a shift to low-carbon technologies and building resilience to climate change.

Interventions to develop more resilient road networks that are better prepared to face the stresses caused by the changing climate include increasing dimensions and capacities, using new materials, building protective works, incorporating nature-based solutions, and adding redundancies. Depending on the types of hazards and assets, these options come at an initial construction cost premium when compared to traditional approaches. Hence, it is essential to perform a systematic assessment of climate risks and GHG emissions reduction targets in order to design the optimum climate adaptation and mitigation strategies.

Climate considerations will impact project economics

The decision to invest upfront in climate change resilience, adaptation and mitigation will depend on many criteria, including the current and future exposure of the road, the consequences of failure compared with the risk level that is acceptable to users, the life-cycle cost of savings (e.g., due to the reduced need for repairs, disruptions, etc.), and the overall social benefits to the community. In some instances, PPPs can confer certain benefits (e.g., more effective use of new materials or low-emissions equipment, or innovatively designed adaptation and mitigation measures) compared to traditional procurement. On the other hand, parameters such as “green” construction requirements or climate-change induced risks could affect the availability of private financing, especially when risk reduction options are limited and, in many cases, untested. Therefore, the costs and benefits of climate considerations, as well as the value for money (VfM) of procuring a road project as a PPP, should be checked at the early stages of project selection, in order to identify any potential weaknesses and make the necessary adjustments.

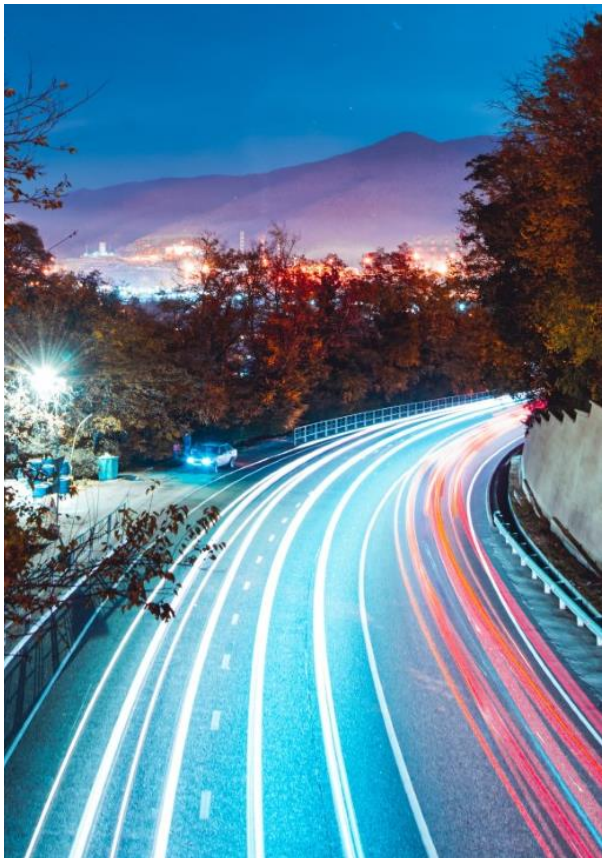
Well-defined, measurable indicators are essential

Climate change introduces a plethora of challenges in the delivery of new road infrastructure projects. Meeting climate mitigation and adaptation goals will involve such considerations as proper design and construction, adequate monitoring, sustainable operations, and efficient maintenance.

To ensure that climate considerations are fully embedded in such processes, it is recommended that agencies provide specifications and output requirements in the form of specific, measurable, attainable and action-oriented, relevant, and time-bound (SMART) indicators.

The road-sector toolkit and its intended users

In response to the needs identified above, this document is intended to be used by government agencies and their advisors in emerging market and developing economies (EMDEs), in order to assist them in incorporating climate-related risks and opportunities in the structuring phase of road infrastructure public-private partnership (PPP) projects. The toolkit complements the World Bank Group’s Climate Toolkits for Infrastructure PPPs (CTIP3)[1] by providing2 specific tools and step-by-step guidance on how to apply its provisions to road-sector specific PPPs. Note that the present toolkit it is not intended for design to structuring and tendering phases but should be consulted as a complementary tool to the Umbrella Toolkit.



[1] World Bank, IFC (International Finance Corporation), and MIGA (Multilateral Investment Guarantee Agency). 2022. Climate Toolkits for Infrastructure PPP*s*. Washington, DC: World Bank. Referred to as Umbrella Toolkit in this document.

EXECUTIVE SUMMARY

The toolkit contains three modules covering the major climate entry points (i.e., alignment with climate policies; incorporation of climate considerations in the project selection; and appraisal of climate effects in the project's economics and financing), followed by a fourth module that provides climate-related key performance indicators (KPIs) applicable to road projects.

Every module is divided into steps—outlining the logical order of the process—that are implemented using specific tools. The tools contained in this toolkit have different formats, depending on the task they serve, and many are accompanied by reference libraries. The toolkit also provides ready-to-use reporting templates to assist in the implementation of the process and the documentation of results.

Module 1 presents a two-step process, with tools to assist users with mapping climate policies, and screening projects' alignments with such policies, in order to identify areas where corrective actions may be needed.

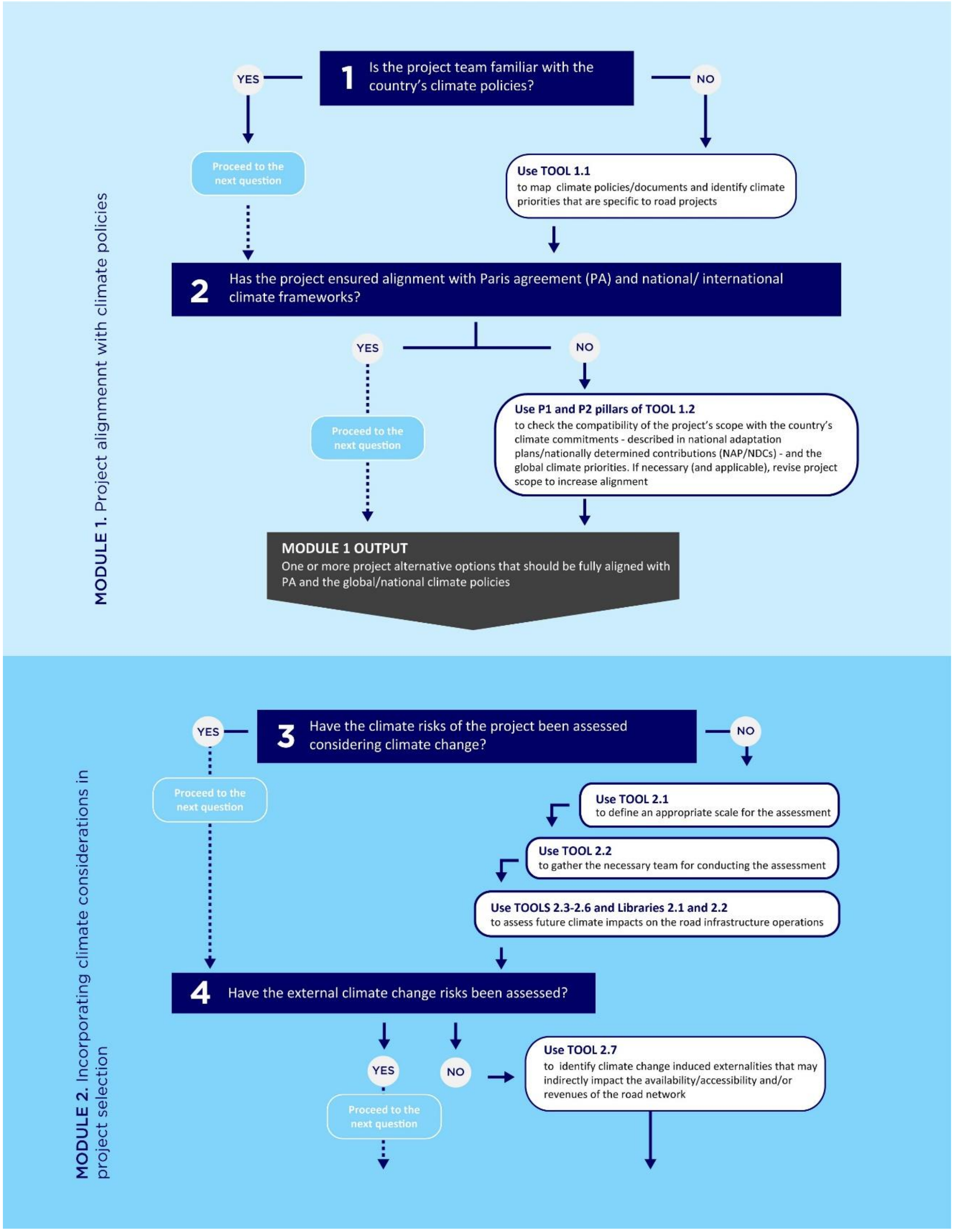
Module 2 contains five steps designed to assist users in assessing climate risks, defining strategies to reduce them, estimating the carbon footprints of projects at a preliminary stage, and designing strategies for climate mitigation actions

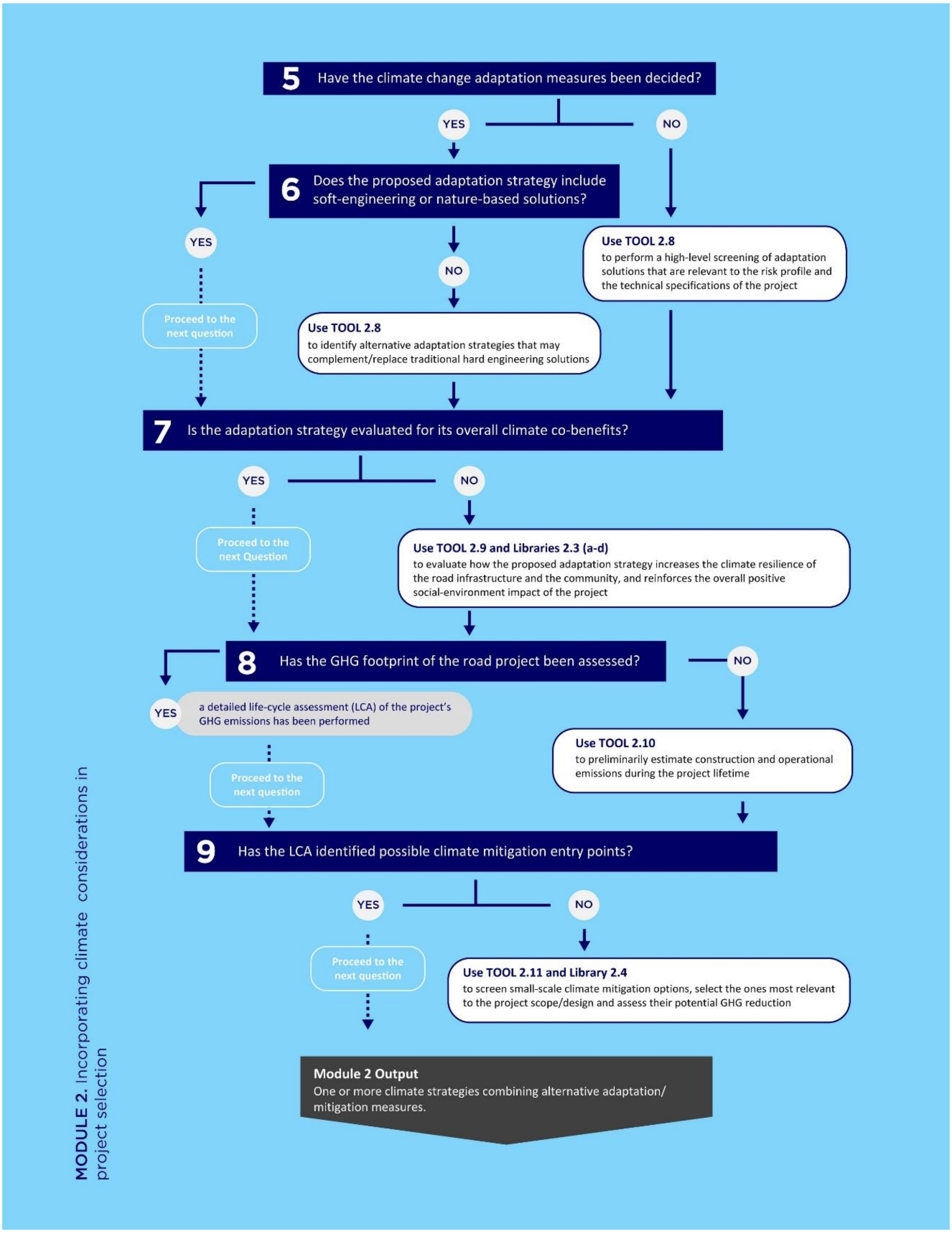
Module 3, which provides a two-step approach (comprising three tools) to guide users on how to prioritize climate strategies and check their economic soundness.

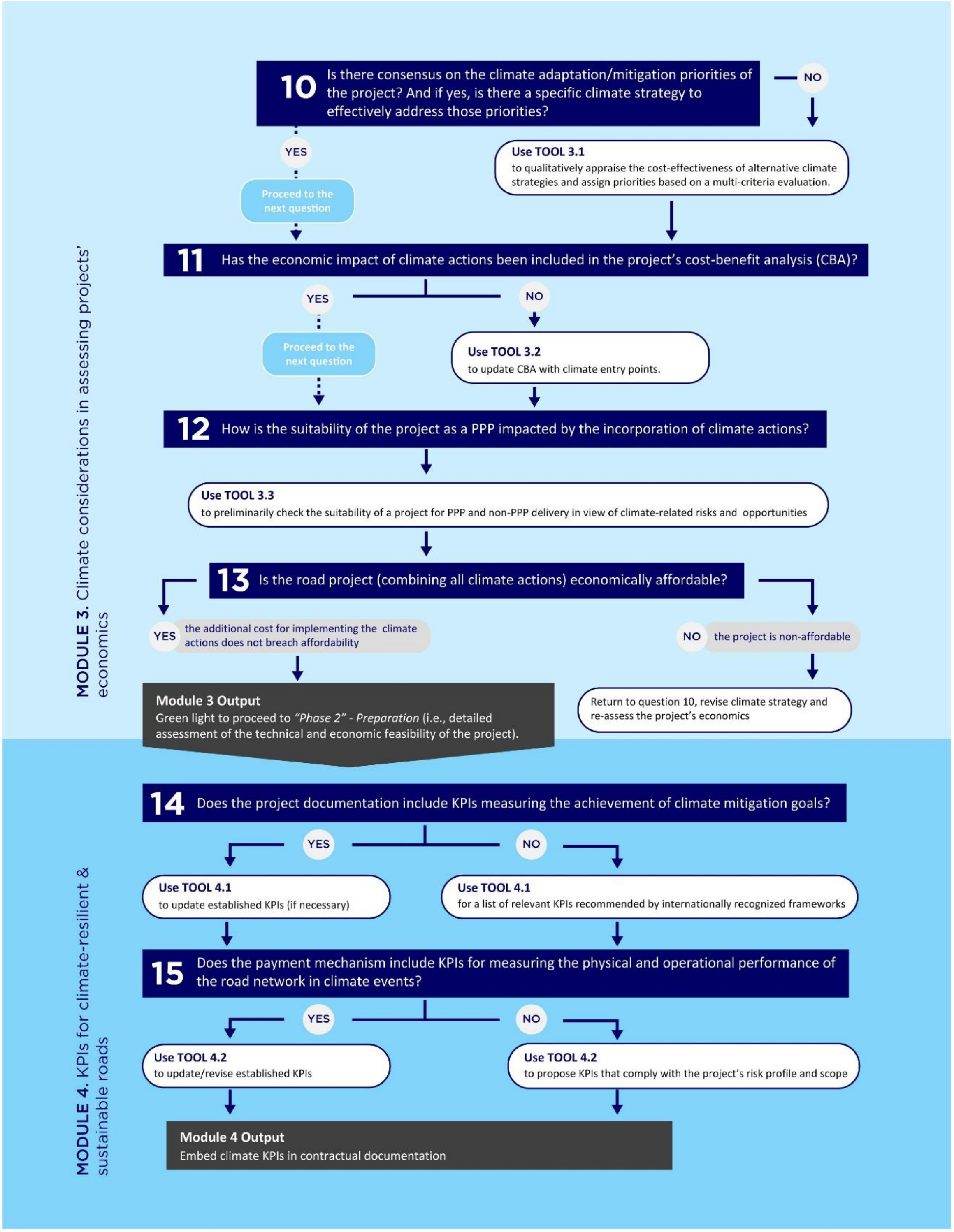
Module 4 presents a set of key performance indicators (KPIs) for all of the above processes that are specific to road projects and are meant to serve as entry points for the relevant activities.

The interconnections between the modules and the tools contained within each module are explained schematically in the **Toolkit Navigator** provided on the next page.

Toolkit Navigator



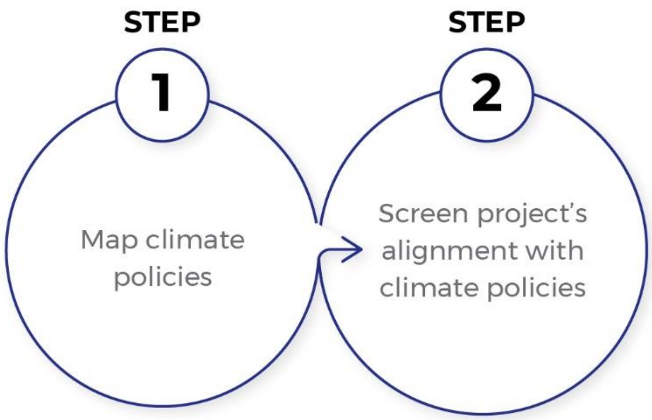

5 Have the climate change adaptation measures been decided?
YES
NO
6 Does the proposed adaptation strategy include soft-engineering or nature-based solutions?
YES
NO
Use TOOL 2.8
to perform a high-level screening of adaptation solutions that are relevant to the risk profile and the technical specifications of the project
Proceed to the next question
Use TOOL 2.8
to identify alternative adaptation strategies that may complement/replace traditional hard engineering solutions
7 Is the adaptation strategy evaluated for its overall climate co-benefits?
YES
NO
Proceed to the next Question
Use TOOL 2.9 and Libraries 2.3 (a-d)
to evaluate how the proposed adaptation strategy increases the climate resilience of the road infrastructure and the community, and reinforces the overall positive social-environment impact of the project
8 Has the GHG footprint of the road project been assessed?
NO
YES
a detailed life-cycle assessment (LCA) of the project's GHG emissions has been performed
Proceed to the next question
Use TOOL 2.10
to preliminarily estimate construction and operational emissions during the project lifetime
9 Has the LCA identified possible climate mitigation entry points?
YES
NO
Proceed to the next question
Use TOOL 2.11 and Library 2.4
to screen small-scale climate mitigation options, select the ones most relevant to the project scope/design and assess their potential GHG reduction
Module 2 Output
One or more climate strategies combining alternative adaptation/mitigation measures.
MODULE 2. Incorporating climate considerations in project selection


MODULE 3. Climate considerations in assessing projects' economics
10 Is there consensus on the climate adaptation/mitigation priorities of the project? And if yes, is there a specific climate strategy to effectively address those priorities?
YES
NO
Proceed to the next question
Use TOOL 3.1
to qualitatively appraise the cost-effectiveness of alternative climate strategies and assign priorities based on a multi-criteria evaluation.
11 Has the economic impact of climate actions been included in the project's cost-benefit analysis (CBA)?
YES
NO
Proceed to the next question
Use TOOL 3.2
to update CBA with climate entry points.
12 How is the suitability of the project as a PPP impacted by the incorporation of climate actions?
Use TOOL 3.3
to preliminarily check the suitability of a project for PPP and non-PPP delivery in view of climate-related risks and opportunities
13 Is the road project (combining all climate actions) economically affordable?
YES the additional cost for implementing the climate actions does not breach affordability
NO the project is non-affordable
Module 3 Output
Green light to proceed to "Phase 2" - Preparation (i.e., detailed assessment of the technical and economic feasibility of the project).
Return to question 10, revise climate strategy and re-assess the project's economics
MODULE 4. KPIs for climate-resilient & sustainable roads
14 Does the project documentation include KPIs measuring the achievement of climate mitigation goals?
YES
NO
Use TOOL 4.1
to update established KPIs (if necessary)
Use TOOL 4.1
for a list of relevant KPIs recommended by internationally recognized frameworks
15 Does the payment mechanism include KPIs for measuring the physical and operational performance of the road network in climate events?
YES
NO
Use TOOL 4.2
to update/revise established KPIs
Use TOOL 4.2
to propose KPIs that comply with the project's risk profile and scope
Module 4 Output
Embed climate KPIs in contractual documentation

MODULE 1

Module 1

PROJECT ALIGNMENT WITH CLIMATE POLICIES



The module is broken down into two steps. **Step 1** maps climate goals into specific climate attributes and considerations for new as well as brownfield road projects. **Step 2** provides a methodology for assessing the alignment of a project's description with these attributes. This mapping exercise will define the periphery of climate interventions, which will then be specified, detailed, and appraised in **Modules 2** and **3**.

Step 1

Map Climate Policies

SCOPE	This step supports the systematic documentation of global and national climate strategies, policies, and plans that constitute the framework for developing new road infrastructure. By understanding their underlying principles, targets, and commitments, the relevant agencies will be better prepared and equipped to design and deliver new sustainable road assets. These assets will align with the climate mitigation vision of the Paris Agreement (PA) and strengthen the capacity of communities to adapt to the adverse effects of climate change.
PROCESS	The process starts with a quick scan of the country's Nationally Determined Contributions (NDCs), national adaptation plans (NAPs), and long-term strategy (LTS), which are the main national guidance documents for achieving the goals of the PA and identifying climate opportunities in the road sector. It continues with a compilation of all the important documents that constitute the national climate policy landscape—whether climate laws or policies, or other official governance documents related to climate change.
TOOLS	**TOOL 1.1** Mapping climate policies and actors
OUTPUT	A country-specific inventory of the most important policy documents on climate change, with specific references to the delivery of new road assets.

TOOL 1.1

MAPPING CLIMATE POLICIES AND ACTORS

This tool is designed to facilitate a desk-study of the landscape of climate policies and frameworks governing the planning and delivery of new road assets, based on the mapping methodology presented in the Umbrella Toolkit (Introductory Phase and Module 1.1), while focusing on priorities and provisions that are specific to road projects.

For a more in-depth analysis of the country-specific policies and governance mechanisms, agencies are encouraged to seek support within the following agencies:

- The PPP unit (which is expected to have already completed a general mapping exercise for the country's PPP portfolio).
- Relevant ministries (e.g., Ministry of Public Works, Ministry of Infrastructure, Ministry of Finance, etc.) and their corresponding departments (e.g., Department of Urban Planning, Department of Transport and Main Roads, etc.).
- Municipalities and other subnational agencies, which are better informed about the climate adaptation activities that happen locally and may not necessarily be reflected in national policy documents (outlined below).

INPUT

This mapping exercise requires users to gather and consult the following sources of climate policy, including provisions and guidance on the climate mitigation and adaptation potential of road systems and their components. Each source is accompanied by a list of prompts meant to suggest focus areas.

1. National documents describing the country's strategic development vision

Focus areas:

- Is the development of new road infrastructure recognized as a strategic vision?
- How does it relate to the Paris Agreement, NDCs, and Sustainable Development Goals?
- Is a national transport plan available? What does it describe?
- Is a modal shift required?
- Does the country support more holistic urban transport policies and planning for decarbonization, such as "avoid, shift, improve"?

2. Road investment strategy or transport investment strategy (if available in the country-specific context)

Focus areas:

- What is the strategic role of road infrastructure investment, and how does it address the current and future needs of users, communities, and the environment?
- What is the definition of environmentally responsible road infrastructure?
- What is the definition of a resilient or climate-smart road network?
- What are the priorities for future transport investment decisions, and how do they relate directly or indirectly to climate change? (For example, a priority investment that foresees the improvement of the condition and performance of the existing road network will, among other things, reduce the exposure of road assets to extreme climate events that are exacerbated by climate change.)
- Are there descriptions of relevant investment plans or a projects pipeline (e.g., a dedicated budget to support an early transition to ultra-low emissions vehicles)?
- Are there specific environmental targets (e.g., a target to achieve no net loss of biodiversity, or to reduce carbon emissions to a specified target level; initiatives for

leveraging ecosystems and ecosystem services to protect or supplement road infrastructure, etc.)?

- Is decarbonization of road infrastructure considered a key transition area? Does it offer any guidance on decarbonization priorities and objectives in road projects?

3. **Nationally Determined Contributions** outlining short and mid-term climate action plans

Focus areas:

- What is the reduction emission target and which are the adaptation goals described in the NDC?
- What is the contribution of the transport sector in the national greenhouse gas (GHG) inventory?
- Does it mention the transportation sector? What are the exact priorities and measures covered in the NDCs for the sector?

4. **Long-term strategy** (if available), outlining a country's long-term vision on climate change

Focus areas:

- Does the LTS describe a long-term reduction emission goal? What is the time horizon?
- Does it specify measures to achieve this goal? How do these measures relate to the transportation sector? For example, is a modal change or implementation of sustainable transport policies prescribing fuel or vehicle technologies mentioned?

5. **National adaptation plans** (or National Adaptation Programmes of Action or national adaptation strategies) providing a clear framework of how climate-change adaptation actions can be integrated into the development planning of all economic sectors

Focus areas:

- Does the NAP address climate vulnerabilities that are specific to road assets? Which climate risks are considered most prominent?
- Does the NAP include an action plan to enhance climate adaptation and resilience? How is this related to road infrastructure?

Example

Brazil's NAP identifies climate adaptation as a pressing need for the transportation sector and calls for actions that: combine ecosystem-based adaptation (EbA) approaches in the design of new roads; promote climate mitigation and resilience; improve production and availability of information about extreme events; and increase the capacity of the transport sector to respond to extreme climate events by developing disaster response plans.

6. **Climate and environmental legislation** (enforced at either the national or sub-national or state level)

Focus areas:

- Does the legislation specify a "net zero" emissions target? Is this a cross-sectoral target, or does it include specific provisions for the transportation sector?
- Which ministries are responsible for the implementation of the law? Is it the responsibility of a single ministry, or are several ministries involved?
- What policy measures does the legislation entail, and how are these translated into national action plans and programs? For example, does the law promote the development of sustainable transportation, and what action plans have been developed toward that end?
- Is climate adaptation incorporated into climate legislation? What are the main areas of focus?
- Is there a national disaster risk management policy? Does it prescribe actions to enhance resilience against climate-induced impacts? Are there specific provisions for road assets?

7. **Transport development plans** (national or regional)

Focus areas:

- Is there a low carbon development plan for the transportation sector?
- Does it prescribe sustainable transportation policies? How may the described policies affect the delivery, operation, and maintenance of road assets? Are there specific requirements/specifications for new road assets (e.g., policies to prevent modal shifts to high-carbon modes, or to reduce the use of private cars, etc.)? How does it treat rehabilitation programs for existing roads?
- Which entities (i.e., ministries) are responsible for the implementation of the plans?

8. **Bilateral agreements** with neighboring or other countries, outlining the regime for transportation of passengers and for bilateral transit of goods (e.g., designated routes, border crossing permits)

Focus areas:

- Are there any agreements/commitments that promote sustainable practices for freight and passenger transport (e.g., bilateral trade agreements to promote sustainable biofuels)? How is this impacting traffic projections (volume and characteristics)?

9. **Good practices and climate-related guidelines** describing opportunities and entry points for integrating green attributes/practices in road projects (details for major climate taxonomies and the definition of eligible activities may be found in the Umbrella Toolkit (Insights 1.3 and 1.4)

OUTPUT

The results of the mapping need to be reported in a systematic and comprehensive way to support future steps. **Reporting Template A.1.1**[2] is provided in **Appendix A** to guide the reporting process.

IMPORTANT NOTE
Effort and resources

The more detailed the answers to the aforementioned prompts, the easier it will be to identify project-specific entry points and eventually achieve the highest alignment level with climate policies and targets. For further reading on the importance and benefits of alignment with climate policies, users are referred to the Umbrella Toolkit (Insight 1.5, Phase 0).

[2] Indicative reporting templates are provided only for guidance purposes throughout the document.

Step 2

Screen Projects' Alignment with Climate Policies

SCOPE	This step examines the project's scope and description relative to the mapped climate policies and the country's national development goals (outcome of **Tool 1.1**) and measures the project's alignment using a simple scoring system. In case of misalignment, specific actions are proposed to re-adjust the project scope towards a more sustainable and climate-resilient pathway.
PROCESS	The alignment process is performed in two stages, which are implemented during different phases of the project preparation. The **preliminary screening** may be performed **immediately after the project inception phase** (when the only available information is the outline of the project scope and the need it addresses). This first-level screening is meant to confirm that the overall project's scope aligns with (or at least does not deviate from) the national vision for climate mitigation and adaptation. The **second-level screening** may be performed **towards the end of the project selection, and prior to the appraisal of the projects' economic value**. At this stage, the project's risk profile has been qualitatively assessed, and a preliminary discussion on adaptation/mitigation measures is underway. This is the right time to re-evaluate the project's alignment with the national climate agenda (focusing now on specific project attributes) and re-adjust where necessary.
TOOLS	**TOOL 1.2** Screening project's alignment with climate policies
OUTPUT	• Climate alignment score (pre-screening and final result) • Actions to enhance the level of alignment (if deemed necessary)

TOOL 1.2

SCREENING PROJECT'S ALIGNMENT WITH CLIMATE POLICIES

The tool may be used to qualitatively assess the project's climate profile and its alignment with the vision, goals, and targets described in major climate policies. The tool is intended to complement the methodology described in the Umbrella Toolkit (Module 1.1). Therefore, it is structured in the form of a checklist comprising four pillars:

- Overall alignment of the project's scope with the Sustainable Development Goals and the Paris Agreement framework **(Pillar 1**, or **P1)**
- Overall alignment of the project's scope with the national climate agenda (primarily described in the NDCs, NAPs, LTS and other relevant documents) **(P2)**
- Specific interventions contributing to climate mitigation **(P3)**
- Specific interventions contributing to climate adaptation and resilience of the project, and of the broader community **(P4)**

The tool allows users to assign a qualitative score reflecting the performance of the project in each of the four pillars in order to identify areas where improvements may be possible.

In 2022, multilateral development banks (MDBs) developed the Joint MDB Assessment Framework for Paris Alignment for Direct Investment Operations,[3] which contains six building blocks (BBs): alignment with mitigation goals (BB1); adaptation and climate-resilient operations (BB2); accelerated contribution to the transition through climate finance (BB3); engagement and policy development support (BB4); reporting (BB5); and alignment of internal activities (BB6). It should be noted that the World Bank Group is committed to aligning financing flows with the objectives of the Paris Agreement. For the World Bank, the plan is to align all new operations by July 1, 2023. For International Finance Corporation (IFC) and MIGA, 85 percent of new operations will be aligned by July 1, 2023, and 100 percent will be aligned by July 1, 2025. It is expected that other MDBs will follow similar approaches. Hence, users are encouraged to ensure projects' compatibilities with the above framework when performing the screening process.

INSTRUCTIONS

1 **Define the type of screening**

For a **high-level screening** (performed during the very early stages of the project), users may focus on the first two pillars (P1) and (P2) only. During the **second-level screening** (implemented towards the end of the project selection), it is recommended to use the entire checklist (P1 to P4).

2 **Use the tool's input module to score the performance of the project according to each of the four pillars**.

3 **Use the tool's output module to calculate the project's alignment score.**

4 **Propose an action plan** for enhancing alignment and repeat scoring (ideally until full alignment is achieved).

[3] MDBs (2021). BB1 and BB2 Technical Note Joint MDB Assessment Framework for Paris Alignment for Direct Investment Operation (Working Draft as of November 2021). https://www.eib.org/attachments/documents/cop26-mdb-paris-alignment-note-en.pdf.

The action plan should be targeted to pillars that have received relatively low scores.

INPUT

The following checklist groups the criteria contributing to a project's alignment with national and international climate policies in relevant pillars (P1 to P4). Users are prompted to qualitatively assess the performance of the project in each of the four pillars, considering all the sub-criteria mentioned in the columns on the left. The goal is to be able to identify areas of poor alignment and seek improvements at an early stage—acknowledging that poor alignment may call into question the project's eligibility for funding by several sources, including MDBs.

Four Pillars for Appraising Alignment

P1 ALIGNMENT WITH THE SUSTAINABLE DEVELOPMENT GOALS AND THE PARIS AGREEMENT FRAMEWORK

Sub-criteria	Characteristics/actions enhancing project's alignment (non-exhaustive list of examples)
What is the project's primary purpose, and how does it support the country's Sustainable Development Goals (SDGs)?	• Ensuring the project can support goals such as SDG 1 (no poverty) and SDG 2 (no hunger)
Does the project support the country's efforts to reduce carbon dioxide (CO_2) emissions?	• Boosting public transport, easing border crossings, encouraging high-capacity trucks with harmonized standards, and promoting better driver training and certification • Solving congestion problems (which are responsible for increased CO_2 emissions)
Is climate adaptation an objective of the project?	• Improving the mobility of the population that is currently hampered by frequent climate-related interruptions
Does the project address greater overall inclusion and gender equality, and does it consider vulnerable groups?	• Increasing accessible public transport, especially for people who are unable to drive or do not own private means of transportation (thus contributing towards social cohesion and gender inclusivity)[4]

[4] WBG (2021). Green, Resilient and Inclusive Development (GRID) provides further guidance on gender aspects https://thedocs.worldbank.org/en/doc/9385bfef1c330ed6ed972dd9e70d0fb7-0200022021/green-resilient-and-inclusive-development-grid

P2 DOES THE PROJECT ALIGN WITH NATIONAL CLIMATE POLICIES?

Sub-criteria	Characteristics/actions enhancing project's alignment (non-exhaustive list of examples)
How does the project support the implementation of the country's NDCs and sustainable transportation agenda?	• Supporting the use of new fuel sources • Using the new road network as a platform to apply tax and financial incentives (e.g., for fuel consumption, ride sharing)
Does the project contribute to the GHG reduction target prescribed in the NDC for the transportation section (if applicable)?	• Reducing trip length and travel time, hence reducing total GHGs (compared to the do-nothing approach) • Setting and regularly monitoring specific GHG emission reduction targets • Considering the impact of the induced traffic
How does the project comply with the transportation-related climate mitigation and adaptation elements of the country's NDCs?	• Supporting the modal shift envisaged in the NDC (e.g., shift from road to bus rapid transit systems in urban areas) • Including lanes for non-motorized transport (bicycles and pedestrian mobility) and a more holistic approach to climate-smart mobility ("avoid, shift, improve" approach, such as non-motorized transport solutions, public transport tariff adjustments during the day to reduce peak hour traffic etc.)
Have the country's NDCs or NAP identified particular vulnerabilities for road assets? If yes, how is the project intended to address them?	• Yes, road systems are particularly vulnerable to climate risks, and their vulnerability is expected to intensify due to climate change; the road design will take into consideration climate change

P3 PROJECT'S POTENTIAL TO REDUCE GHG EMISSIONS. DOES THE PROJECT INCORPORATE SMALL-SCALE MITIGATION?

Sub-criteria	Characteristics/actions enhancing project's alignment (non-exhaustive list of examples)
Will the project include small-scale climate mitigation components?	• Provisions for solar roads,[5] roofs, and photovoltaic integrated noise barriers. • Use of solar powered toll booths.
Will the project include activities to avoid/reduce GHG emissions?	• Congestion charging or road pricing protocols, parking management, car-free city areas, low-emission zones. • Use of low-carbon marking material for pavements. • Use of low-maintenance bitumen or graphene-based surfacing.
Will the project include components that promote low-carbon and efficient transport?	• Charging stations and other infrastructure for electric vehicles, or hydrogen or dedicated biofuel fueling. • Digital solutions and programs dedicated to reducing GHG emissions.
Will the project adapt NbS for protection against climate risks?	• Use of NbS for road protection against flooding, coastal erosion, or other climate risks.
Will the road include energy efficiency provisions during construction and operation?	• Installation of energy-efficient appliances and equipment • Use of electric vehicles/machinery during construction • low-emission vehicles in the road operator's fleet • Segregated road section used for compressed natural gas (CNG) fueled or purely electric bus rapid transit (BRT) • Automated construction and use of pre-fabricated parts to reduce construction time (and related emissions)
Will road construction comply with the principles of a circular economy?	• Use of modified bitumen with recycled polyethylene and recycled tires • Use of warm mix asphalt[6] or recycled asphalt • Use of recycled aggregates as a road base material
Does the project promote the sustainable use and management of ecosystems?	• Replanting of removed trees • Installation of wildlife crossings

[5] A solar road is a road whose surface is covered by photovoltaic cells, in such a way that vehicles can travel over them and generate electricity or alternative energy.
[6] Warm mix asphalt (WMA) is a trial asphalt material that is produced at a temperature that is 40°C lower than the traditional 190°C used for hot mix asphalt, resulting in 15 percent less carbon emitted.

P4 INCORPORATION OF A SPECIFIC STRATEGY FOR ADAPTING TO CLIMATE CHANGE

Sub-criteria	Characteristics/actions enhancing project's alignment (non-exhaustive list of examples)
Does the project incorporate methods to reduce the project's exposure/vulnerability to climate risks?	• Perform detailed risk studies for current and future climate conditions (e.g., flood risk mapping, geohazard mapping)
How will the project adapt to the adverse impact of climate change?	• Design and appraise adaptation strategies (e.g., road drainage system) for different climate scenarios
Does the project promote/facilitate the integration of activities that support adaptive management in a changing climate, through integrated observation/ monitoring and use of decision support tools?	• Design adaptation measures based on the principles of adaptive/robust planning (e.g., provisions to replace the rolling stock of a privately operated road to allow continuation of operations over water-flooded sections)
Does the project enhance climate resilience within the broader ecosystem?	• Design the road network with strict technical specifications to guarantee safety in the mobility of passengers even under extreme climatic conditions, thus contributing to community resilience. Is it possible to include some examples here?
Does the project incorporate NbS for climate adaptation?	• Assess potential environment impacts and propose contingency measures by conducting a thorough scoping exercise prior to the construction of bridges and culverts[7] • Include NbS in adaptation measures and explore options (e.g., plantation of mangroves at the coastal boundary of the road to prevent/mitigate coastal erosion)
Will the project include road transport emergency procedures/equipment for climate risks?	• Install smart information systems for disaster risk management during extreme events • Prepare/update disaster response plans
Does the project design consider aspects related to the protection of women and vulnerable populations from the impacts of climate change?	• Include gendered vulnerabilities in the climate risk analysis • Ensure adaptation measures are gender neutral or gender inclusive[8]
Does the project mainstream gender concerns in its programs and activities?	• Run project preparation in parallel with a gender action plan, to ensure that women have equal

[7] Bridge and culvert activities involve the construction of permanent engineering structures across watercourses and larger rivers, impacting the water environment (e.g., the groundwater hydrology and quality) and the river ecosystem (e.g., removal of native vegetation, disturbance, fragmentation or loss of terrestrial and aquatic habitats and ecology).
[8] WBG (2021). Green, Resilient and Inclusive Development (GRID) provides further guidance on gender aspects https://thedocs.worldbank.org/en/doc/9385bfef1c330ed6ed972dd9e70d0fb7-0200022021/green-resilient-and-inclusive-development-grid

Sub-criteria	Characteristics/actions enhancing project's alignment (non-exhaustive list of examples)
	opportunities with men to participate and receive the project benefits • Define (sex disaggregated) indicators, outcomes and/or output level results that will be relevant for proper monitoring to be carried out • Include terms of reference (TORs) that stipulate gender expertise and concrete deliverables during preparation and implementation

OUTPUT

Following the above process, users are expected to have identified the areas where the project is well aligned with the Paris Agreement goals, as well as the ones where further improvement is necessary. Users should keep in mind that MDBs will not be supporting projects that are not fully Paris aligned, according to the Joint MDB Assessment Framework for Paris Alignment for Direct Investment Operations.

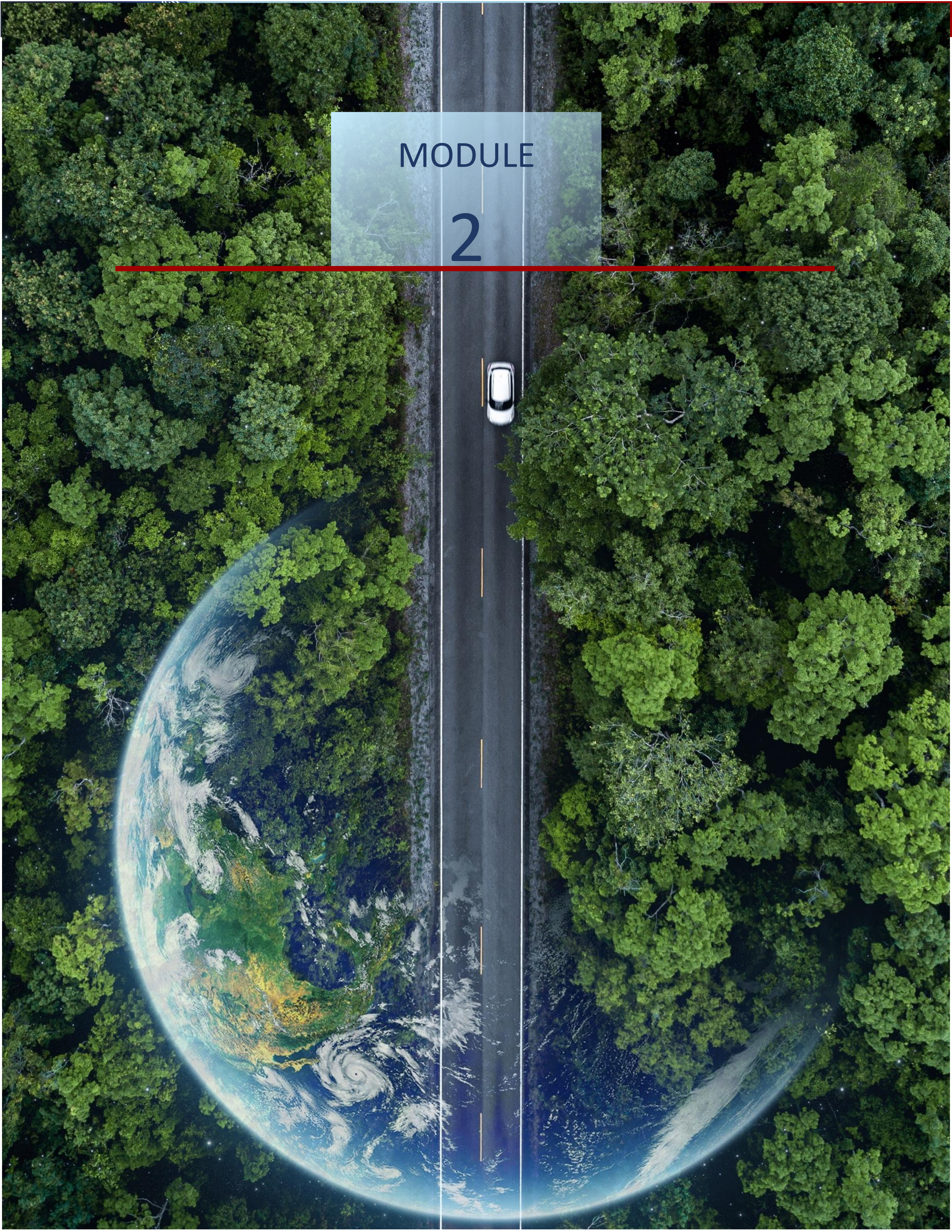
BOX 1.1 SMART ROADS ARE HARVESTING WATER IN SUB-SAHARAN AFRICA

Road infrastructure development across sub-Saharan Africa is a crucial ingredient to fostering growth and productivity. But new roads may often change the landscape, affect water flows to wetlands, cause landslides and flooding, and impact the livelihoods of rural populations. According to a recent survey, more than a third of households in Tigray, northern Ethiopia, reported flooding as a result of new roads, with negative effects on crop production for roughly one in 10 households.

A promising solution that has been increasingly applied in arid sub-Saharan areas is to exploit road infrastructure as a means to harvest water. The water intercepted by road bodies can then be guided to recharge areas or surface storage, or applied directly to the land. Roads can also be used to manage water catchments by controlling the speed of runoff, compartmentalizing and mitigating flood runoff, and influencing the sedimentation process in the catchments. A scoping study in Somaliland, a region facing low water availability for agriculture and livestock, found that the water harvest (from an annual average rainfall of 300 millimeters) has the potential to reach up to 300 cubic meters of water per kilometer of road per year.

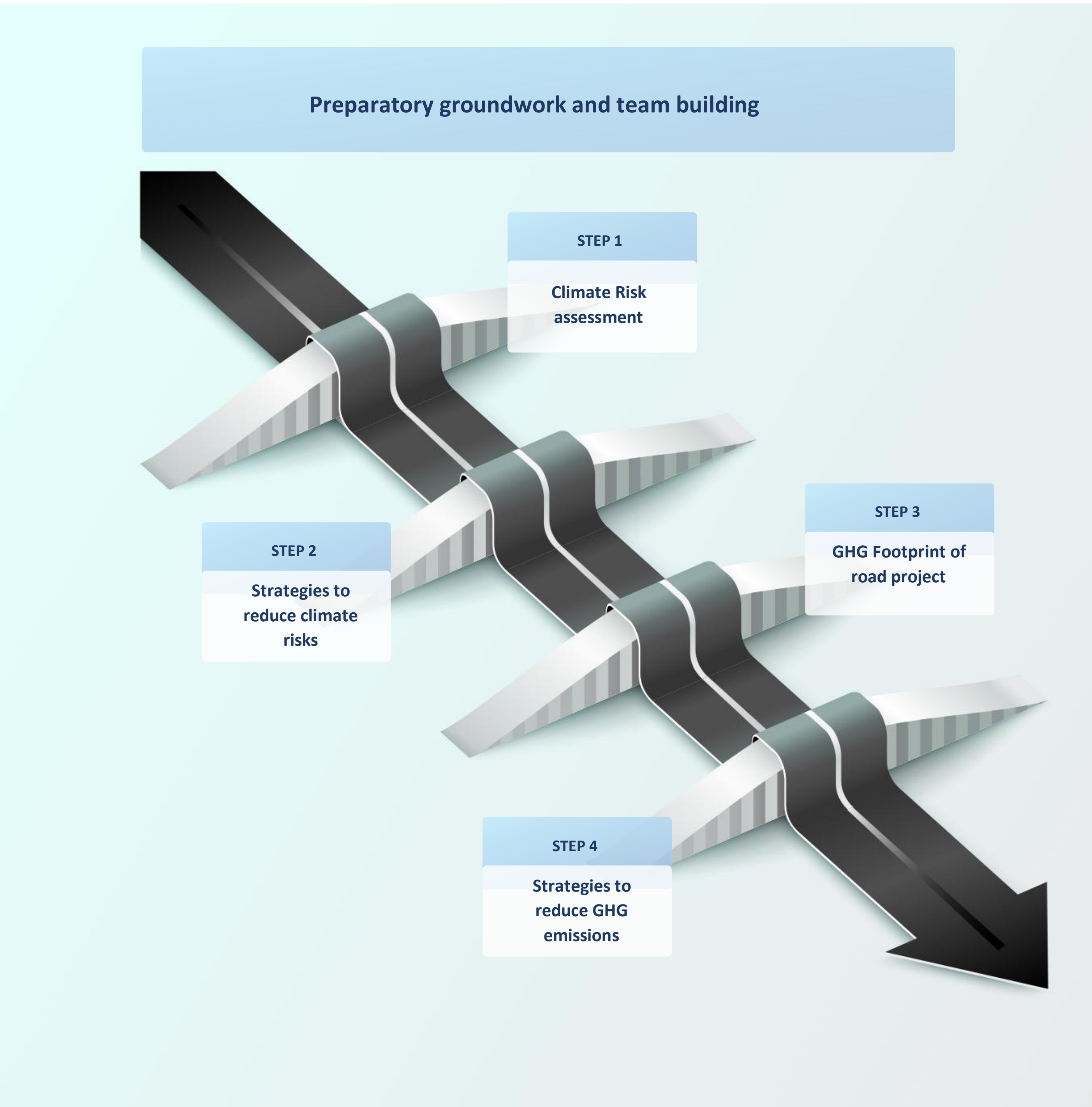
Source: Green Roads for Water (2022). *Integrating climate change adaptation and water management in the design and construction of roads: Somaliland – Scoping Study, and Awareness and Fundraising*.

MODULE 2



Module 2

INCORPORATING CLIMATE CONSIDERATIONS IN PROJECT SELECTION



This module comprises four steps (preceded by a preparatory **Step 0**), and each step includes different tools to perform certain actions, as described in the ensuing text.

This module provides tools and examples to support agencies in:

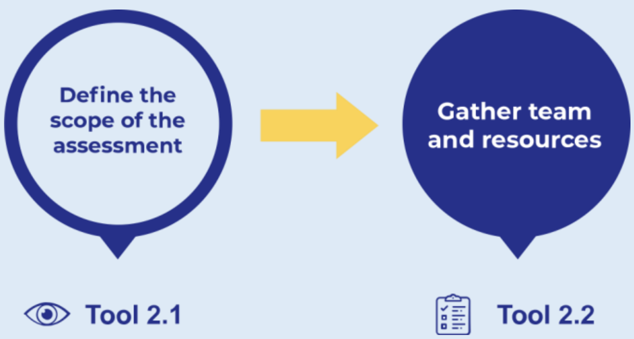
- Deciding whether it is safe to proceed with the project, or if it would be preferable to change the road alignment (to avoid locations that are safe now but may become risky as climatic conditions change) – **Step 1**.
- Identifying ways to protect, preserve, and improve road assets and services to withstand the stresses imposed by the changing climate, while building resilience for the broader community – **Step 2**.
- Diverting from traditional GHG-emitting adaptation strategies (i.e., building a dike to protect a road from flooding) and review soft-engineering solutions (e.g., monitoring) or nature-based solutions that may (either alone, or in combination with traditional grey infrastructure[9]) provide the necessary protection – **Step 3**.

Preliminarily assessing the GHG reduction that can be achieved by investing in e-mobility or small-scale mitigation (e.g., LED lighting in roads, use of electronic machinery in road construction) – **Step 4**.

[9] Grey infrastructure is a term adopted from the water management discipline to describe traditional interventions using man-made, constructed assets that are designed to avoid any type of ecosystem growing on them.

Step 0

Preparatory Groundwork

SCOPE	This is a preparatory step to help the entity in charge[10] formulate the scope of the assessment and decide what resources are needed and who (in terms of expertise) should be involved to effectively address the range of issues encountered.
PROCESS	The process begins with a decision-tree exercise (**Tool 2.1**) that engages users in formulating the specific objectives of the assessment, whether the assessment is a high-level screening of hazards in the project area (**typically performed prior to transaction structuring**), or a more in-depth assessment of the various components of the road network. Based on the decision-tree results, a list of minimum requirements (in terms of resources, personnel, and technical data) is proposed (**Tool 2.2**) that is necessary to accomplish the specific objectives of the assessment.
	
TOOLS	**TOOL 2.1** Climate assessment type decision tree **TOOL 2.2** Climate assessment checklist: resources and staff requirements
OUTPUT	• Decision on the type of assessment: system-level or asset-level • Required qualifications of the assessment team

[10] The implementing authority/agency may vary depending on country/state/county level. The term “entity in charge” is used throughout this document to refer to the responsible entity.

TOOL 2.1

CLIMATE ASSESSMENT TYPE DECISION TREE

This tool is in the form of a decision tree (see **Figure 2.1**) to find out the recommended level of climate assessment. Assessments may be categorized in two broad classes (although different combinations may also be valid):

- **System-level assessments** aiming at a bird's eye screening of the network can be performed internally with minimum external assistance. This type of assessment is **commonly performed in advance of a transaction structuring** when the road site (alignment) and modality have not yet been confirmed.
- **Asset-level assessments** are those that may require support from expert personnel. Asset-level assessments are **performed during the structuring phase**, when the road attributes (alignment, assets, modes of transportation) have been designed.

INPUT

In order to inform the decision tree, users are prompted to follow the questionnaire provided below.

1 **Has the project design been decided?**

Depending on the timing of the assessment in Phase 1 of the PPP cycle, the description of the project outline may vary substantially. Suppose the assessment is performed during the very early stages of the project. At that stage, the authority may have nothing specific in mind, apart from a very generic notion of the project underway (e.g., building a new peripheral highway to solve a city's congestion problem or improving rural mobility by converting key unpaved arteries to modern paved roads). It is also possible that the project alignment has not been permanently decided (e.g., the entity in charge is equally considering the possibility to proceed with a coastal road or an uphill highway project), let alone the specific technical aspects of the project. In that case, the objective would be to perform a high-level comparison of one or more alternatives, just to explore the potential risks or benefits that may tip the balance in favor of one solution over the other. This can be efficiently done by executing a system-level approach.

2 **Is the road alignment known?**

If, on the other hand, the location of the road network has been decided (and the specific alignment is known), the objective of the assessment would be to identify the locations with the highest climate exposure of the alignment and conceptualize an appropriate risk-reduction strategy, in parallel to the corresponding environmental, social and governance frameworks (e.g., the

Equator Principles, IFC Performance Standards). Depending on the resources available, either a system-level or an asset-level approach could be appropriate.

3

Is the technical solution of the project known?

Depending on whether the assessment is performed prior to or after the project's pre-feasibility study, the depth of the investigation of the analysis will also differ. If the preliminary technical design is available, it is more appropriate to proceed with an asset-level assessment that is more reliable for accounting for GHG emissions and identifying system criticalities.

OUTPUT

Depending on the answers given above, users should be able to decide on the right type of analysis following the decision tree of Figure 2.1.

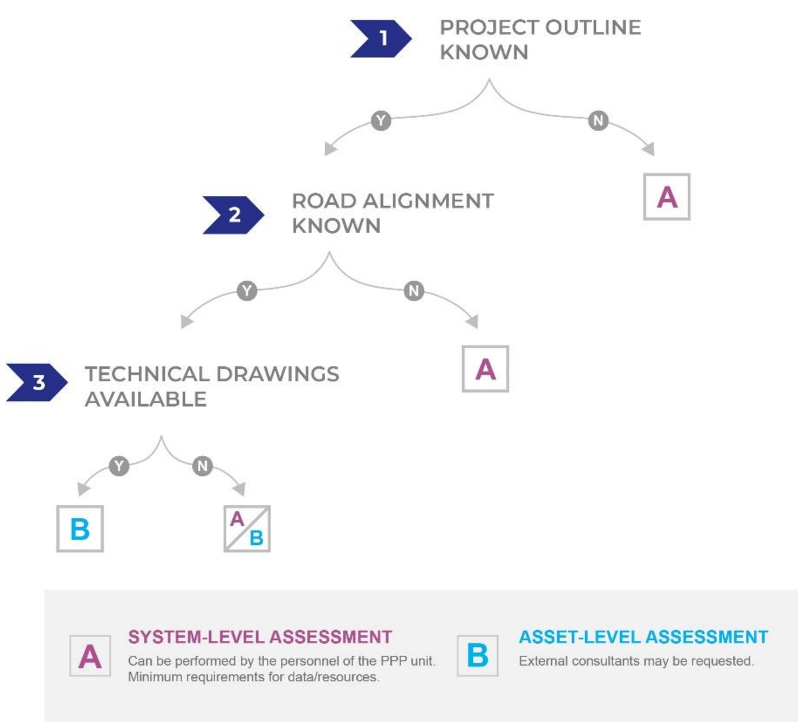


FIGURE 2.1 Decision tree for choosing the right type

TOOL 2.2

CLIMATE ASSESSMENT CHECKLIST: RESOURCES AND STAFF REQUIREMENTS

This tool helps agencies prepare to assess a road project's climate risk, by listing key data, resources, and team qualifications that are necessary to complete an adequate assessment. Specific descriptions of the tasks associated with each team member are provided alongside the respective tools in the subsequent sections (**Steps 1** and **2**). Depending on the output of **Tool 2.1**,the team's composition and the level of involvement of each team member may vary. It is at the discretion of the entity in charge whether an entire team/firm or individual consultants are to be invited. Not every team member mentioned below will be actively engaged in all four steps of the assessment; each one may be called upon at a particular milestone to provide relevant guidance and expertise.

REQUIRED DATA CHECKLIST

SYSTEM-LEVEL (PRE-TRANSACTIONAL) ASSESSMENTS

Project location
- ✓ Outline and main junctions

General road description
- ✓ Rural road, urban road, highway
- ✓ Traffic volume data
- ✓ Supported transportation modes (e-mobility, autonomous vehicles and buses, etc.)
- ✓ Particular construction features (e.g., tunnels, elevated highways, etc.)

Hazard data
- ✓ Online sources providing country-level data
- ✓ Climate projections included in NAPs (if available)

ASSET-LEVEL (STRUCTURING) ASSESSMENTS

Project location
- ✓ Road alignment: spatial and vertical
- ✓ Technical drawings provided by the pre-feasibility analysis

General road description
- ✓ Rural road, urban road, highway
- ✓ Road capacity (number of lanes)
- ✓ Supported transportation modes (e-mobility, autonomous vehicles and buses, etc.)
- ✓ Particular construction features (e.g. tunnels, elevated highways, etc.)
- ✓ Asset inventorying (broad classification and geographical coordinates)

Hazard data
- ✓ Online sources providing country-level data
- ✓ Regional hazards maps (e.g., inundation maps)
- ✓ Climate projections included in NAPs (if available)

TEAM QUALIFICATIONS CHECKLIST

SYSTEM-LEVEL (PRE-TRANSACTIONAL) ASSESSMENTS

- ✓ **Engineering consultants**
with experience in transportation projects (not necessarily transportation engineers).

- ✓ **Local contractors**
who have been actively engaged in the construction of road infrastructure in the broader area. They are expected to provide useful insights on regional risks, empirical data, and site-specific construction costs.

- ✓ **Government/municipal stakeholders**
who can provide insights on the priorities of the national strategy.

- ✓ **Local communities**
who can assist governments with data to assess risks.

- ✓ **Climate and environmental team**
that can help in the assessment of climatic hazards and their future projections on the region, and can provide insight into how the technical design might impact ecosystems and how natural ecosystems can be used for protection against climate change.

- ✓ **Gender experts**
who can identify key gender issues and assess if the project has the potential to promote gender equality and/or women's empowerment, or is likely to have an adverse gender impact or increase women's exposure to risks.

ASSET-LEVEL (STRUCTURING) ASSESSMENTS

- ✓ **Engineering consultants**
(structural, transportation, hydraulic, geotechnical) who can provide input on the vulnerability of road infrastructure assets as well as on their exposure to various climate-related hazards.

- ✓ **Geographic information system (GIS) specialists**
who can retrieve hazard data for online datasets and spatially analyze and display transportation assets and vulnerability information.

- ✓ **Climate risk analysts**
who can interpret hazard maps and can provide information and insight on historical climate data and future projections.

- ✓ **Asset management and cost consultants**
familiar with construction/replacement and maintenance costs.

- ✓ **Personnel with basic experience in GHG emissions accounting**

- ✓ **Government/municipal stakeholders**
(same as in the system-level approach)

- ✓ **Environmental staff**
(same as in the system-level approach)

- ✓ **Gender experts**
(same as in the system-level approach)

Step 1

Assess Climate Risks

SCOPE	The scope of this step is to help users recognize, and qualitatively assess, the climate risks affecting their road projects. The assessment will take into account both internal risks (i.e., the risk of damage affecting a road asset and its availability) and external risks (i.e., a serviceable road network with reduced traffic/ridership or accessibility). The identification of these risks, early in the planning stage, will inform resilience and adaptation priorities and guide the decisions of the next step.
PROCESS	The methodology for assessing climate risks is described in detail in the Umbrella Toolkit (Modules 1.2 and 2.1). The underlying assumption is that the risk of an infrastructure or a component may be defined as a function of the hazard intensity (which includes the likelihood of the event), its exposure (expressing the plausibility of the hazard affecting the infrastructure or the component), and its vulnerability (which expresses the sensitivity of the infrastructure to the specific type of threat), according to the fundamental risk equation: **RISK = HAZARD x [VULNERABILITY x EXPOSURE]** The risk estimation is performed by means of a qualitative risk-matrix synthesis. First, users are requested to identify the climate hazards that may potentially affect a road project and consider future projections to estimate the future hazard level (i.e., increase/decrease of the current trend). Then the project exposure and project vulnerability are investigated (either at a system level or by assessing the performance of different asset categories). Finally, the external risks are qualitatively assessed and added to the project's climate risk matrix.

TOOLS	**TOOL 2.3** Climate hazard mapping considering future projections **TOOL 2.4** Assessment of project's exposure to hazard **TOOL 2.5** Vulnerability assessment of major asset categories **TOOL 2.6** Climate risk assessment **TOOL 2.7** Assessment of climate change-induced externalities and impacts on the road network
OUTPUT	• A qualitative risk matrix, per hazard, indicating the risk of physical damage and operational disruption of the road network • Prioritization/ranking of the most significant risks that will be passed onto **Step 2** to identify relevant adaptation measures

TOOL 2.3

CLIMATE HAZARDS MAPPING CONSIDERING FUTURE PROJECTIONS

This tool assists users in defining the climate hazards that could cause either physical damage or disruption and potentially affect the road network. It provides guidance on how to identify hazards and how to qualitatively assess their intensity at a preliminary level. For ease of reference, climate hazards are classified into four broad categories (temperature, precipitation, sea-level rise, and wind), each one representing a climate-related variable, the changes of which may directly impact the intensity and frequency of the hazards in the relevant category. For example, an increase in the average air temperature will increase the number of very hot days and heat waves, impact freeze-thaw cycles, and increase wildfires. A brief description of the four weather variables, their associated hazards, and the projected impacts on the road network is provided in **Figure 2.2**.

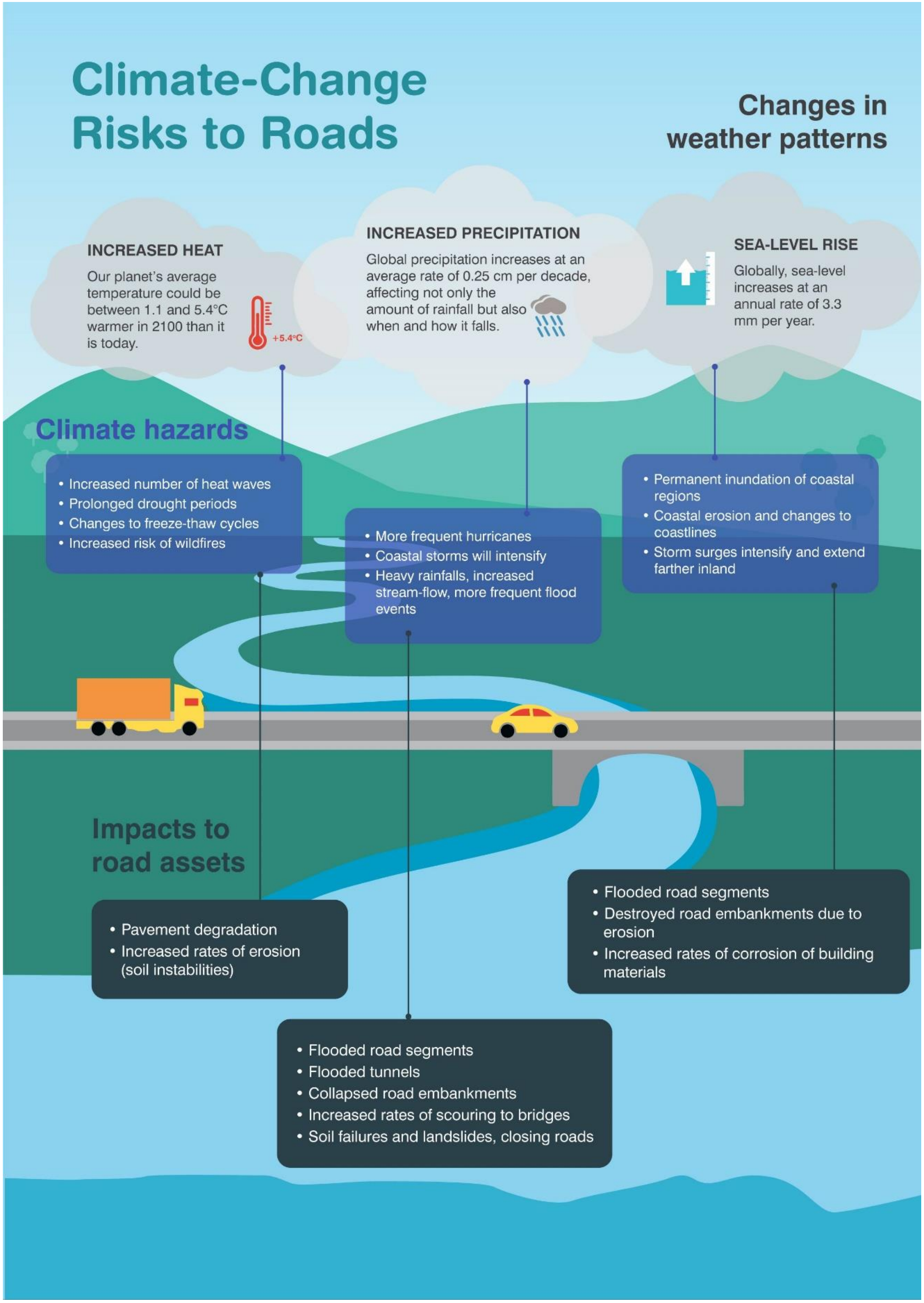


FIGURE 2.2 Climate-change risk to roads

INPUT

1 **Identify the country-specific climate-related hazards** relevant to the road project. Country/region-specific climate-related hazards can be found at the following (indicative) sources:

- Climate Change Knowledge Portal (World Bank Group)
- Think Hazard! (GFDRR - World Bank Group)
- Climate links (USAID)
- The Global Risk Data Platform (GRDP)
- Global Assessment Report on Disaster Risk Reduction
- Intergovernmental Panel on Climate Change (IPCC)

Users may also refer to **Library B.2.1** in **Appendix B** for a comprehensive list of climate hazards that may affect roads or road components.

2 **Exploit local knowledge and experience to confirm/revise hazard findings**

This may include already available regional impact maps (that illustrate sea level rise, temperature change, precipitation) and previous hazard studies. Past experiences in the area can also provide a foundation for identifying the most frequently encountered weather events or characterizing high-risk regions (e.g., a region known for unstable soils that has experienced frequent landslides due to precipitation in the past). Advice on regional risks may also be sought from local construction contractors or district engineers.

3 **Consider referring to climatologists and GIS specialists**

Agencies may seek for higher-precision hazard data and maps in case an asset-level assessment is performed.

4 **Decide on the timeframe of the assessment**

The minimum timeframe of assessing climate hazards shall be the PPP life cycle. However, the public party may wish to extend the timeframe for the study, given that the life cycle of the infrastructure may be longer than the duration of the PPP contract (e.g., infrastructure design life).

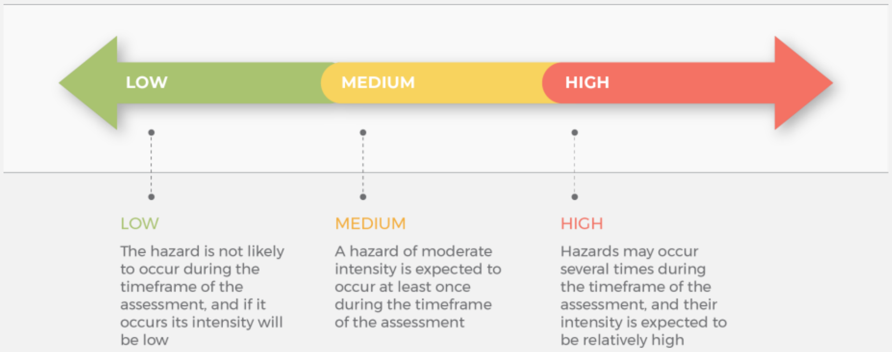
5 **Use the scoring system** provided in the graphic below to estimate the current hazard level as a function of the intensity (and duration) of the hazard and its likelihood of occurrence (or frequency of the event).

6 **Determine the future trend of hazards due to climate change (i.e., increasing, decreasing, or stable)**

At this point, it is considered sufficient to observe the global—and, if available, the regional—future projections of the corresponding weather variable and make reasonable guesses about the future trend of the hazard under consideration. For example, if the project region is showing an increasing trend (and if no other data are available), it is reasonable to anticipate that extreme rainfall events will also increase, and so will flood events. Country-level information on future climate trends may be retrieved from the Climate Change Knowledge Portal (World Bank Group).

7 **Estimate the future hazard level by combining current hazard intensity and future trend**

For example, for a "medium" current hazard level with an "increasing" trend, the future hazard level will be "high."



OUTPUT

The above process will result in a preliminary compilation of the profile of climate hazards affecting the project. Such hazard data need to be reported in order to be used as inputs in the subsequent risk estimates. **Reporting Template A.2.1** provided in **Appendix A** (or any similar template) may be used for listing the findings of the present tool.

IMPORTANT NOTE

Future Climate Projections Based on RCPs and SSPs

It is common practice to project future climate conditions based on the Representative Concentration Pathways (RCPs), to represent different trajectories of radiative forcing levels over time. Out of the four RCP scenarios, RCP 8.5 represents the highest emissions scenario, whereas RCP 2.6 represents the lowest emissions scenario. RCP 2.6 should generally be avoided when making projections, because it is overly optimistic compared to recent emissions trends.

In 2016, the Shared Socioeconomic Pathways (SSPs) were introduced as an update and a substantial expansion over the RCPs. Available through Phase 6 of the Coupled Model Intercomparison Project (CMIP6), the SSP framework contains a total of eight different multi-model climate trajectories based on alternative/plausible scenarios of future emissions and land-use changes, by which society and ecosystems will evolve in the 21st century. Global scale predictions of climate parameters for different SSPs are available in the WorldClim database.

TOOL 2.4

ASSESSMENT OF PROJECT'S EXPOSURE TO HAZARD

This tool may be used to assess the exposure of the road network to the hazards identified by **Tool 2.3**. Exposure provides information about which assets or locations are more likely to be affected by a hazard, based on certain characteristics (e.g., elevation, proximity to coastline). For example, an asset will be exposed to storm surge if located along the shoreline, but it may not be if it is located farther inland. This analysis will be important in determining site selection to the extent possible, and designing climate resilient options.

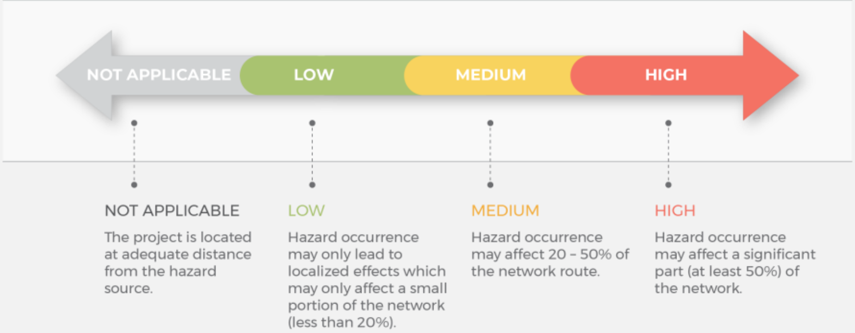
When regional impact maps are available and the road alignment is known, it is possible to estimate exposure by comparing the geographical spread of the hazard with the road alignment (i.e., assets within the impact zone will be affected, whereas those outside may not be). If such information is not available, past experiences and historic data can be used to identify hazard thresholds that are regularly impacting road networks. For example, experience may have shown that coastal floods do not impact assets above a certain elevation.

INPUT

1 **Retrieve the regional impact maps of the region**. If not available, continue to the next step.

2 **Review the road network[11] alignment and determine which portion of the network is outside the impact zone of the hazard.** If the information is not available, perform the assessment based on empirical thresholds (defined by the entity in charge or by local experts).

3 **Use the scoring system** provided below to assign exposure levels to asset categories or to the entire road network.



[11] The terms "road project" and "road network" are used interchangeably throughout the document to describe the entire road project, including all of its assets.

OUTPUT

The exposure information may be described using the exposure matrix provided in **Reporting Templates A.2.2a** (for system-level assessments) or **A.2.2b** (for asset-level assessments). Indicative templates for the reporting may be found in **Appendix A**. Note that the asset categories listed in the templates are indicative. Users are advised to modify the tables as appropriate.

TOOL 2.5

VULNERABILITY ASSESSMENT OF MAJOR ASSET CATEGORIES

The tool may be used to assess the vulnerability of the various road components to the hazards identified previously (**Tool 2.3**). Vulnerability measures the sensitivity of an asset to a climate hazard and reflects the level of the expected damage if the hazard were to occur. Hence, if the damage is expected to be high, the vulnerability of the asset to the specific hazard is considered to be high and if the damage is expected to be low, the vulnerability is considered low The vulnerability of an asset depends on the asset typology (i.e., different assets are sensitive to different hazards) and the specifics of the technical design (e.g., materials, dimensions, loads). For example, an unpaved road section is more vulnerable to flooding, as opposed to a paved road section with a properly designed drainage system.

For the purposes of this preliminary analysis, the vulnerability will be assessed empirically, based on engineering judgement. Less experienced users may wish to consult the supplemental material in **Library B.2.2** in **Appendix B**, which lists some key technical design features (called indicators) and how they affect vulnerability. For example, the existence of a clay subgrade will increase the vulnerability of a road pavement to flood, hence “clay subgrade” will be a vulnerability indicator for road pavements experiencing floods. *This tool is expected to support asset-based assessments. Users performing a system-level assessment may skip this step.*

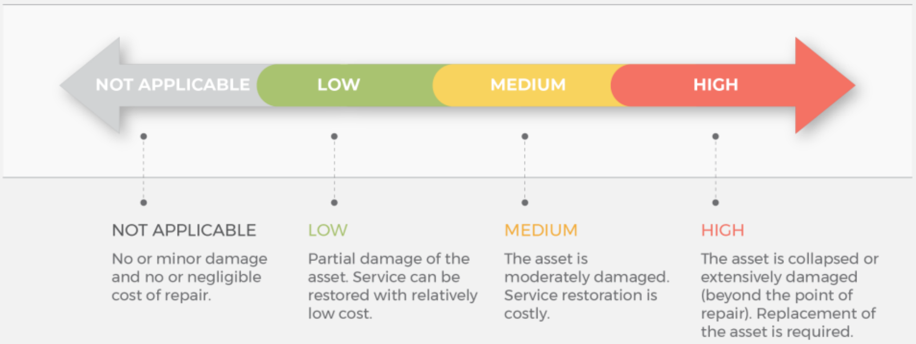
INPUT

1 **Asset inventorying:** List the asset categories that are relevant to the specific PPP project (e.g., bridges, earthworks, tunnels).

An indicative list of road asset categories is provided in **Reporting Template A.2.3b (Appendix A)**. Users may adjust or extend this list based on the specific features of each project alternative and available details.

2 **Find vulnerability indicators (involvement of experts required):** Use **Libraries B.2.2 (a-d)** to identify vulnerability indicators that are applicable to your project. Repeat the step for all asset categories and hazard types.

3 **Assess vulnerability:** Use the scoring system provided in the graphic below to assign vulnerability level(s) to asset categories.



OUTPUT

Vulnerability data may be summarized using **Reporting Template A.2.3b** in **Appendix A**. Note that the asset categories presented in the template are indicative. Users are advised to modify the table rows as appropriate.

IMPORTANT NOTE

INVOLVE STAKEHOLDERS THROUGHOUT THE PROCESS

An indicator-based approach will never perfectly capture local conditions or asset-specific details. Engaging consultants or local stakeholders, such as contractors, emergency managers, and engineers, can be insightful when refining indicators and scoring the vulnerability of assets.

TOOL 2.6

CLIMATE RISK ASSESSMENT

The tool may be used to assess the internal climate-induced risks of a road, considering the effects of the changing climate. Following the definitions provided in the Umbrella Toolkit (Modules 1.2 and 2.1), internal climate risks originate from hazards that are posed directly to the project and could damage the infrastructure itself and/or its availability. As such, they describe the likelihood of a road experiencing physical damage (e.g., flooded road sections, and destroyed bridges that require rehabilitation or replacement) and business interruption (e.g., loss of revenue generated by closed road links, and delays and increased travel time for users).

Tool 2.6 can be used in combination with **Tool 2.7**, to estimate external risks originating from hazards affecting not the road network per se, but its broader socioeconomic system, in order to estimate the total (internal and external) climate risk of the road project.

INPUT

1

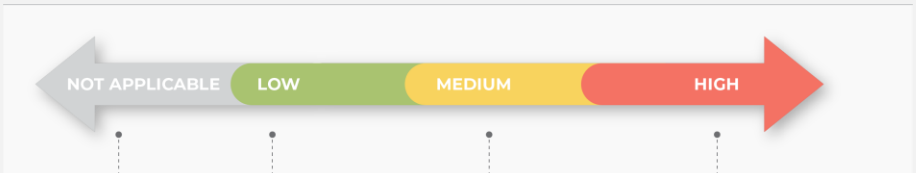
Calculate the climate risk level of each hazard using current (i.e., not future) values for the hazard intensity:

- Estimate the product of Hazard x (Exposure x Vulnerability), using the two-dimensional risk matrix provided below (where the color shading illustrates the different risk levels). First, combine Exposure (score appears in the first row) with Vulnerability (score appears in the first column) to estimate their product (i.e., EV). Repeat the process to calculate the risk as the product of Hazard x EV (i.e., read hazard intensity in the first column and combine with the EV score displayed in the first row).
- Example calculation: low x (medium x low) = low x low = low.
- For asset-based assessments, risk is calculated per asset category, before estimating the total risk of the road (by factoring in the contribution of individual assets and their criticality) – **Reporting Template A.2.4b**.
- For system-based assessments, the risk of the road is estimated as Hazard X (Exposure) – **Reporting Template A.2.4a**.

	Low	Medium	High
Low	Low	Low	Medium
Medium	Low	Medium	High
High	Medium	High	High

2 **Repeat** the **Step 1** process, using future hazard intensity indicators, to calculate the expected future climate risk level of the road (for each hazard).

3 **Describe** potential consequences for the road network (corresponding to future risk estimates) using the example consequence matrix provided below. Consequences should include the expected level of damage and disruption estimates.



NOT APPLICABLE	LOW	MEDIUM	HIGH
No consequences on the road assets and the network operations.	· Minor damage of road assets that can be recovered at low cost and time. · Small-scale disruption to community connectivity and transportation that can be rapidly recovered (e.g., within one day)	· Temporary loss of road assets that can be restored at a relatively moderate cost and within a reasonable timeframe. · Disruption to community connectivity and transportation that has measurable financial impacts. Full recovery of the network can be achieved within one week.	· Irreparable/severe damage across different infrastructure assets (or critical components) that may cause total loss of transportation service. · Major and potentially irrecoverable disruption to community connectivity and transportation. · Social outrage/distrust due to severe impacts on local communities.

4 **Roughly estimate** direct and indirect loss using the consequence score provided below as a reference.

- Direct loss may be calculated as: % damage x (Total Reconstruction Cost), where % damage is an average damage level of all road assets.
- Indirect loss (applicable to user-pays concessions) may be calculated as: Downtime (in days) x Daily Revenues (on the entire network or the affected portion of the network). It is noted that this is an upper-bound estimate that ignores the network topology and possible traffic re-adjustments (i.e., it assumes that the road network does not provide alternative routes for bypassing the damaged section).

5 **Repeat** the process for all hazards affecting the network.

OUTPUT

The overall climate risk of the road network may be assessed at this preliminary stage by aggregating the results of the above process. **Reporting Template A.2.5** in **Appendix A** may be used to assist this process.

TOOL 2.7

CLIMATE CHANGE-INDUCED EXTERNALITIES AND IMPACTS ON THE ROAD NETWORK

The tool may be used to perform a preliminary screening of the broader socioeconomic impacts of climate change and their interactions with the project underway. These interactions constitute external risks (or opportunities) to the operations and services of the road network that are beyond the project's control. Therefore, it is important to outline these risks early in the project selection process, estimate the severity of their impacts, and plan for contingencies when possible. It may even be advisable to abandon or restructure projects that experience high external risks that cannot be mitigated. Using the tool, users may identify potential roots of external risks and their consequences to road projects.

CONSULTANTS: The process would benefit from the involvement of infrastructure risk experts and PPP experts (see **Tool 2.2** for qualifications).

INPUT

Risk identification is performed using the table below. Users are advised to go through the table items that are most relevant to their project; evaluate the external risk level as low, Medium, or high (specifying risk sources that are particular to the project under consideration); and outline possible contingencies. It is noted that the provided entry points are only indicative and are not expected to be applicable to all road networks; hence, it is recommended that the list be extended as appropriate.

TABLE 2.1 External climate-induced risks and consequences for road projects

External Factors that can be Impacted by Climate Change	Example Consequences for Roads
Connecting infrastructure: Climate change may affect the performance of an external system (e.g., a terminal station, connector/feeder roads), thereby critically impacting the performance of the infrastructure itself.	Damage in a bus terminal station will affect the availability of bus service even if the road surface is available. Flooding of areas that feed the road network with drivers will negatively impact the revenues of the road (due to decreased toll/ticket collection).
Land use changes, whereby a specific area of land is converted from one use to another.	Change of land use from agricultural to residential can affect runoff generation. In combination with an expected increase in extreme precipitation events due to climate change, flooding may occur more frequently, and may cause operational disruption to the network.

External Factors that can be Impacted by Climate Change	Example Consequences for Roads
Geomorphological and environmental changes: Climate-related hazards may affect the surrounding environment, morphology and/or surrounding infrastructure, and, consequently, affect the operation and even the exposure and vulnerability of the project.	Wildfires may not directly cause physical damage to a road project, but they may completely alter its surrounding environment. As such, the road's exposure to flooding may increase because destroyed plants will no longer protect the infrastructure from threatening runoff.
Technological changes: Invention and practice of new technologies and innovative fields that may disrupt (in a positive or negative manner) the regular operation of the project when combined with climate risks.	Technological advancements may provide opportunities for the project to adopt innovative techniques that may positively impact the traffic capacity of the road network through real-time traffic control measures, Internet of Things, and integration of smart materials for road asset construction.
Demographic changes to the characteristics of human population and population segments. These may refer to population distribution, age, marital status, occupation, income, education level, and other statistical measures that may influence the project.	Different segments of the population make different use of the project's service, and these uses are associated with different vulnerabilities that can increase due to climate change. Changes in annual income, or population growth, might increase demand for the infrastructure (e.g., could increase traffic) and by extension the associated risk in case of a life-threatening event. On the other hand, increased traffic conditions will positively affect opportunities for investment.
Transport changes: Emerging technologies that will facilitate travelling and at the same time increase or decrease GHG emissions.	The introduction of electric/autonomous vehicles may affect the technical specifications of the network and the supporting infrastructure (e.g., provisions for electric chargers, reduced lane width and more space for green planting). Improper planning for the transport conditions of the future may incur increased rehabilitation costs.
Policy and regulation changes: Evolution of national and worldwide guidelines and regulations on sustainability and climate change.	Environmental, social, and governance (ESG) considerations and carbon taxes are likely to affect the demand or viability of certain economic activities.

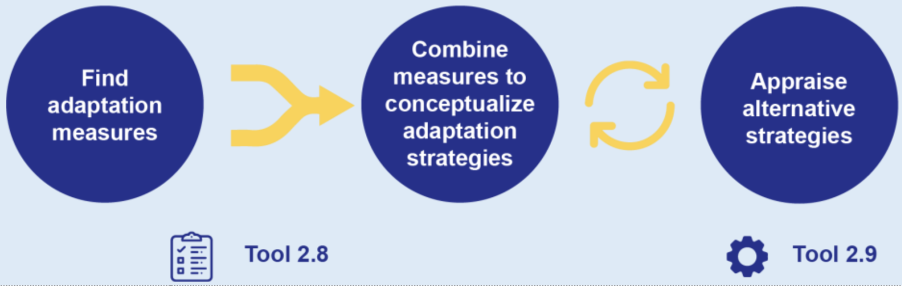
OUTPUT

Given that, in most cases, external risks are not mitigable by means of design, their timely identification is of paramount importance. Users are hence advised to carefully evaluate them and document the results in detail. **Reporting Template A.2.6** in **Appendix A** may be used for this purpose.

Step 2

Select Adaptation Strategies To Reduce Climate Risks

SCOPE	To pre-select among several adaptation options those that can most drastically reduce the project-specific climate risks while maximizing the positive socio-environmental impact of the project. The adaptation strategies are combined with the mitigation measures of **Step 3** to form the long-term climate plan for the road project under consideration, the economic value of which will be assessed as part of **Module 3.**
PROCESS	The process starts with a detailed mapping of all possible adaptation solutions relevant to the project's climate risks (**Tool 2.8**). Each option is associated with a risk reduction potential, a cost level, a GHG emission indicator, and a list of benefits. Users are then asked to conceptualize combinations of adaptation options—or adaptation strategies—that offer the requested protection level (i.e., comfortable level of risk). The alternative adaptation strategies are appraised, taking into consideration their overall socio-environmental impact, and adaptation priorities are identified (**Tool 2. 9**).



TOOLS	**TOOL 2.8** High-level screening of climate adaptation strategies **TOOL 2.9** A participatory decision-support tool for appraising climate adaption strategies
OUTPUT	A ranking of adaptation strategies and their associated costs, savings, and benefits.

TOOL 2.8

HIGH-LEVEL SCREENING OF CLIMATE ADAPTATION STRATEGIES

This tool will guide users through the process of structuring climate adaptation strategies that are appropriate for the level of anticipated climate risk. Adaptation strategies may include:

- Structural interventions (i.e., hard-engineering solutions) aimed at increasing the robustness of the design
- Soft-engineering solutions (e.g., Internet of Things or systems for disaster warning and management) that cannot prevent the damage from taking place but may alleviate its consequences
- Changes in the design/alignment of a road or a road segment/component aimed at reducing the exposure of the project
- Nature-based solutions that protect the infrastructure while offering additional climate mitigation and environmental benefits to the project.

A detailed description of adaptation categories and relevant examples are provided in the Umbrella Toolkit (Module 2.2).

INPUT

The tool is meant to be used in combination with **Libraries B.2.3 (a-d)** in **Appendix 2**, which include a non-exhaustive list of adaptation measures for the most prominent climate hazards and road asset categories.

1. **Start the process** with the climate hazard that is associated with the highest risk.

2. **Consult the risk report** of **Tool 2.6** to find out which asset categories contribute the most to the risk (asset categories with no/low risk may be disregarded). *This step is only applicable to an asset-level assessment; if a system-level assessment is performed, this step may be skipped.*

3. **Identify adaptation measures**. Refer to **Libraries B.2.3 (a-d)** in **Appendix 2**, and look for applicable adaptation measures (i.e., appropriate for the specific hazard and the asset under consideration). If a system-level assessment is performed, check adaptation solutions generally applicable to road sections or pavements.

4. **Combine adaptation measures**. Define a comfortable level of risk, and combine adaptation options that can reduce the risk below the maximum acceptable level. This step may include combinations of more than one adaptation option. For example, suppose a road is expected to experience increased flood risk, and the

intention is to reduce the risk to the minimum feasible. In that case, the team should search for adaptation measures that separately or collectively achieve a high level of risk reduction. These may include interventions to increase the drainage capacity of road sections, in combination with the installation of a runoff water management system to reduce the level of water that eventually reaches the road.

5 **Conceptualize alternative adaptation strategies**. Review adaptation strategies and generate alternatives by replacing (where possible) hard engineering solutions with nature-based or soft engineering solutions.

6 **Repeat the process** for other climate hazards.

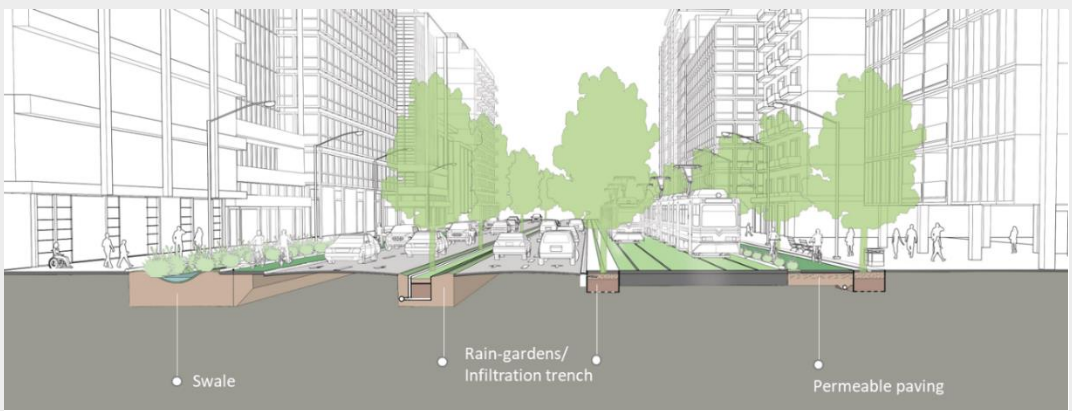
OUTPUT

Results may be summarized using **Reporting Template A.2.7** in **Appendix A**. It is generally considered good practice to come up with two to five alternative strategies; these will be further evaluated in **Tool 2.9**.

BOX 2.1 GREEN INFRASTRUCTURE IN URBAN STREETS TO SUPPORT TRADITIONAL WATER DRAINAGE SYSTEMS

Green infrastructure can help reduce flooding and water pollution by capturing, storing, conveying, attenuating, filtrating, infiltrating, or soaking stormwater in natural ways. It simultaneously provides a form of natural relief to the road infrastructure, improves the street aesthetic, and benefits the community. Although the components and processes involved in green infrastructure are vast, some representative examples are listed below and schematically illustrated in **Figure B2.1.1**.

FIGURE B2.1.1 Adding green water management solutions in urban road sections (adapted from Global Designing Cities Initiative | Global Designing Cities Initiative)



Infiltration components (e.g., soakways, infiltration trenches/basins, rain gardens), capture surface water runoff and allow it to soak and filter through to the subsoil layer, before returning it to the water table. Although the specific components of an infiltration component may vary, they generally consist of an organic top layer with vegetation overlaying a filter media. The area is normally planted with native species that are tolerant to elevated contaminant levels and fluctuations in soil moisture.

Permeable paving allows rainfall to move through the pavement to the soil beneath and provides water to nearby landscaped areas. Applications of permeable paving may be in the form of block pavers with infiltration gaps between pavers, or porous material with infiltration gaps within the material.

Swales are shallow and wide vegetated channels designed to store and/or convey runoff and remove pollutants. They are an alternative to a piped drainage system, where space and grade are available.

Example application: In order to mitigate the flood risk in the Sangdo-dong area in Seoul, an optimized low-impact development (LID) technology for an urban flood adaptation has been proposed.[12] The technical solution foresees the extensive use of green roofs and permeable pavements with vegetated swales in city roads with sufficient widths.

Retention basins are man-made ponds with vegetation around their perimeters. They are used to support stormwater drainage systems during extreme flood events and improve urban landscape and micro-climate conditions.

Example application:[13] The stormwater and flooding alleviation plan of Beira City in Mozambique features a system of deep drainage channels that flow into a new 150-hectare retention basin connected to outlying wetlands and the ocean.

TOOL 2.9

A PARTICIPATORY DECISION-SUPPORT TOOL FOR APPRAISING CLIMATE ADAPTATION STRATEGIES

This tool is designed to help PPP planners to develop adaptation strategies that increase the climate resilience of the road network itself and that of the broader community, while minimizing negative impacts and risks to the population, and reinforcing the project's overall positive social-environment impact.

INPUT

1 **Organize** assessment team (AT)

[12] Kim, Jaekyoung, Jihoon Lee, Soonho Hwang, and Junsuk Kang. 2022. "Urban flood adaptation and optimization for net-zero: Case study of Dongjak-gu, Seoul. *Journal of Hydrology: Regional Studies* 41.

[13] Beira Master Plan 2035 – SDUBeira.

It is advised that the assessment team include a variety of stakeholders, e.g., government/municipal authorities' representatives, members of environmental agencies, gender and social inclusion experts, and public representatives.

2 **Brief** local authorities on the results of the climate risk assessment, and present the selected adaptation strategies.

3 **Agree** on the assessment criteria and identify pertinent indicators to measure performance.

4 **Evaluate** the performance of each strategy based on the list of criteria considered. For now, performance may be measured using qualitative scoring (e.g., high, Medium, low).

OUTPUT

Summarize evaluation results and rank the preferred adaptation strategies using **Reporting Template A.2.8** in **Appendix A**.

Step 3

Estimate the GHG footprint of the project

SCOPE	This step will assist users in qualitatively estimating the GHG emissions of the project (or the project alternatives). The scope of this analysis is twofold: (i) to compare alternative project options as per their GHG footprint during the construction phase (e.g., a shorter road alignment implemented via a tunnel might be more GHG intensive than a longer rural road for which typical road sections are implemented); (ii) to compare emissions due to different usage of the road network (e.g., an intercity road may reduce congestion problems but may encourage the passage of trucks, resulting in a heavier GHG footprint).
PROCESS	The process follows the outline for GHG emissions accounting described in the Umbrella Toolkit (Module 2.1), starting with the estimation of the GHG footprint of the "do nothing option"—the theoretical upper-bound emissions of a road project assuming zero mitigation measures. Intermediate steps include the estimation of construction emissions and operational emissions (primarily generated by the traffic of vehicles and projected over the investment timeframe).

TOOLS	**TOOL 2.10** A high-level procedure for the preliminary life cycle assessment (LCA) of GHG emissions
OUTPUT	A pre-assessment of the project's GHG emissions for different alternatives and time horizons.

TOOL 2.10

A HIGH-LEVEL PROCEDURE FOR THE PRELIMINARY LIFE CYCLE ASSESSMENT (LCA) OF GHG EMISSIONS

The tool may be used to assess the GHG emissions of the baseline project (i.e., assuming complete absence of mitigation measures). The tool will be used in combination with **Tool 2.11** to estimate the GHG reduction that can be achieved using different mitigation solutions. It is important that emissions are calculated over the life cycle of the project. It is possible that more economical solutions that have a low GHG construction footprint today may produce increased GHG emissions over a longer timeframe, owing to highly emissive operating conditions (e.g., an unpaved road is producing lower GHG emissions during construction, but may be responsible for increased GHG production during its operation, attributed to lower travel speeds, higher congestion potential, and increased operations and maintenance (O&M) costs).

INPUT

1. **Review GHG emissions targets** for new transportation projects in the country of origin.
   Users may glean relevant information from taxonomy frameworks, national climate targets (see **Module 1**), and/or minimum requirements imposed by international organizations (if a specific funding/ financing pathway will be pursued).

2. **Set a GHG reduction goal** in alignment with the above frameworks.

3. **Review available tools/methodologies for the estimation of GHG emissions in road projects**. Recommended tools and guidelines may include:
   - World Bank, 2011: Transport Greenhouse Gas Emissions Mitigation in Road Construction and Rehabilitation: A Toolkit for Developing Countries
   - World Bank, 2011: ROADEO: A Toolkit for Greenhouse Gas Emissions Mitigation in Road Construction and Rehabilitation
   - Royal Institution of Chartered Surveyors (RICS), 2012: Methodology to calculate embodied carbon of materials
   - Institution of Structural Engineers (IStructE), 2020: A brief guide to calculating embodied carbon
   - International Financial Institutes (IFI) joint approach to GHG assessment in the transport sector, (2015)

- Asian Development Bank (ADB), 2016: Guidelines for Estimating Greenhouse Gas Emissions of Asian Development Bank Projects: Additional Guidance For Transport Projects
- European Investment Bank (EIB), 2020: Methodologies for the Assessment of Project GHG Emissions and Emission Variations

4 **Calculate construction emissions**. For each project option (if more than one is considered), perform a preliminary estimate of the construction GHG emissions, calculating the contribution of key emitting sources (**Figure 2.3**). For preliminary rough estimates, users may refer to the emission values provided in **Table 2.2**.

5 **Calculate operational emissions.** For each project alternative (if more than one) perform a life cycle assessment of the operational emissions, using simple calculations that correlate type of vehicle, type of engine, speed and traffic flow with fuel usage and equivalent GHG emissions. Relevant tools and guidelines include:

- World Bank Guidance Manual on GHG Accounting and SPC for Transport Investment Operations
- World Bank's newly developed Urban Transport GHG Estimation Tool

Depending on the required level of detail (and the availability of resources), fuel-based or distance-based methods may be utilized. For very preliminary rough estimates, users may also refer to **Table 2.3.**[14]

TABLE 2.2 Indicative GHG emissions per road asset (t CO2e/km[15]) for various road categories

Emissions (t CO2e/km)	Expressway	National Road	Provincial Road	Rural Road (gravel)	Rural Road (DBST[16])
Earthworks	161	16	12	3	3
Pavements[17]	1,334	425	157	72	86
Culverts	238	51	17	12	12
Structures (e.g., bridges)	1,068	119	21	3	3
Road furniture[18]	432	182	0	0	0
Total	**3,234**	**794**	**207**	**90**	**103**

Source: World Bank. 2011. Transport Greenhouse Gas Emissions Mitigation in Road Construction and Rehabilitation: A Toolkit for Developing Countries.

[14] Distance-based emissions are recommended only for high-level assessments because they ignore the effects of road surface roughness, fuel type, and engine technology.
[15] t CO2e/km: tonnes of carbon dioxide equivalent per kilometer
[16] Double bituminous surface treatment.
[17] Pavements include the construction of the surface, the base, and the sub-base.
[18] Road furniture refers to all road fixtures, such as steel covers, traffic domes (silent cops), lane markers, and lights.

TABLE 2.3 Indicative emissions per vehicle type

Vehicle Type	Carbon Dioxide: CO_2 Factor (kg/unit)	Methane: CH_4 Factor (g/unit)	Nitrous Oxide: N_2O Factor (g/unit)	Unit
Medium- or heavy-duty truck	1.407	0.013	0.033	Vehicle-mile
Passenger car	0.341	0.009	0.008	Vehicle-mile
Light-duty car	0.464	0.012	0.010	Vehicle-mile

Source: US Environmental Protection Agency

FIGURE 2.3 Main sources of GHG emissions during road construction

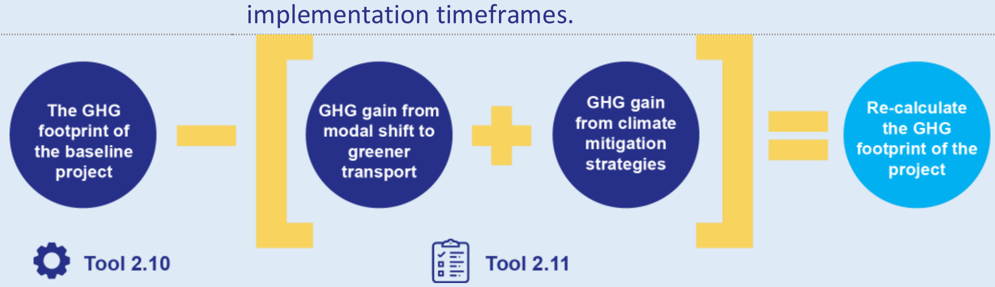
OUTPUT

The total emissions of the "do nothing" case may be summarized using **Reporting Template A.2.9** (**Appendix A**). This will serve as the basis for the evaluation of GHG reduction targets to be performed in **Step 4**.

Step 4

Select Mitigation Measures

SCOPE	To identify entry points for mitigation measures, and highlight their corresponding benefits and trade-offs. The cost effectiveness of alternative mitigation strategies (including carbon emissions / shadow pricing calculations[19]) will be assessed in **Module 3,** considering the overall project economics and financial plan.
PROCESS	The output of **Tool 2.10** can be used to identify entry points for possible GHG emissions reductions in road projects. Reduction of emissions can be achieved in several ways, including a modal shift towards greener forms of transportation (e.g., replacing car lanes with bicycle lanes), integration of small-scale mitigation solutions in the design/operation of the road (see examples in **Figure 2.4**), incentivizing lower carbon footprint transportation, provisioning of dedicated high-occupancy vehicle (HOV) lanes, etc. Users are advised to explore alternatives and qualitatively appraise their socioeconomic impacts and other potential benefits (using the supporting material of **Library B.2.4** in **Appendix B**). Then using **Tool 2.9** (described previously), climate mitigation strategies may be prioritized based on their cost/benefit potential and their implementation timeframes.



TOOLS	**TOOL 2.11** High-level screening of GHG reduction strategies applicable to roads
OUTPUT	• Alternative climate mitigation strategies for each project and their associated costs and benefits. • (Optional) A ranking/prioritization of the different climate mitigation strategies.

[19] These reflect current and future changes in market conditions, which will increase the cost of carbon emissions and fossil fuels, thereby changing the use and need for current products and services.

TOOL 2.11

HIGH-LEVEL SCREENING OF GHG REDUCTION STRATEGIES APPLICABLE TO ROADS

This tool describes measures/procedures that may be implemented during the construction and O&M phase of road projects to increase energy efficiency, reduce GHG emissions, and promote sustainability and the green economy.

INPUT

1. **Retrieve the GHG emissions reduction goal** (if there is one) from **Tool 2.10.**

2. **Consult the checklist on Figure 2.4** to identify entry points for small-scale mitigation. A more detailed list of mitigation options is provided in **Library B.2.4,** although users are encouraged to further expand such lists on the basis of new/updated data and practices.

3. **Consider the possibility of a modal shift to greener forms of transportation** (e.g., dedicated lanes for electric buses and bicycles on urban roads) and estimate GHG net emission benefits. Intermediate steps include: (i) assumption of a percentage diversion from other transport modes (e.g., from private cars to buses); (ii) estimation of average annual mileage for transport mode categories; (iii) combination of (i) and (ii) to estimate project GHG emissions per transport mode category, with and without the project; and (iv) estimation of GHG net emission reduction (i.e., GHG emissions *with* the project minus GHG emissions *without* the project).

4. **Select a climate mitigation strategy** by combining (2) and (3) measures that are consistent with the specifics of the project under consideration (i.e., they are feasible from a technical perspective, and there is some experience with their implementation).

5. **Provide a rough estimate for the cost of climate mitigation.** If necessary, consult local construction contractors and/or engineers with experience in sustainable construction. Include land acquisition and resettlement costs if the envisaged mitigation strategies have additional space requirements (e.g., segregated lanes for e-traffic may require widening the road sections).

6. **Pre-assess the GHG emissions** of the project after the implementation of the climate mitigation strategy.

7 **Check goal.** By comparing the achieved reduction with the GHG goal, the effectiveness of the mitigation strategy is assessed. If the reduction is lower than desirable, the mitigation strategy is revised until a minimum acceptable performance is achieved.

OUTPUT

The proposed climate mitigation actions that are contributing to the GHG emissions reduction target in the optimal way should be reported and properly justified based on the analysis above. **Reporting Template A.2.10** in **Appendix A** may be used for this purpose.

Climate Mitigation Checklist

- ✓ Implementation of NbS[20] (e.g., natural flood management [NFM] approaches, green retaining solutions).
- ✓ Entry points for blue-green infrastructure, sustainable alternatives, and good practices.
- ✓ Entry points for engaging with circular economy approaches (e.g., recycled concrete aggregate or reclaimed asphalt pavement).
- ✓ Road infrastructure to support and promote the usage of electric vehicles (charging stations, toll discounts for electric vehicles, availing dedicated lanes, etc.).
- ✓ Installation of street-lighting systems powered by renewable energy (e.g., self-solar-powered lights).
- ✓ Energy-efficient lighting systems (e.g., LED lighting).
- ✓ Green plantation.?? NBS or??
- ✓ Usage of low-carbon construction materials (e.g., gabions versus concrete walls).
- ✓ Usage of high-efficiency asphalt (e.g., low rolling resistance material for the asphalt).

FIGURE 2.4 Checklist of climate mitigation strategies to eliminate, sequester, or reduce GHG emissions in road projects

[20] A thorough introduction to NbS is provided in *Nature-based Solutions: a Cost-effective Approach for Disaster Risk and Water Resource Management*, published in 2019 by the World Bank.

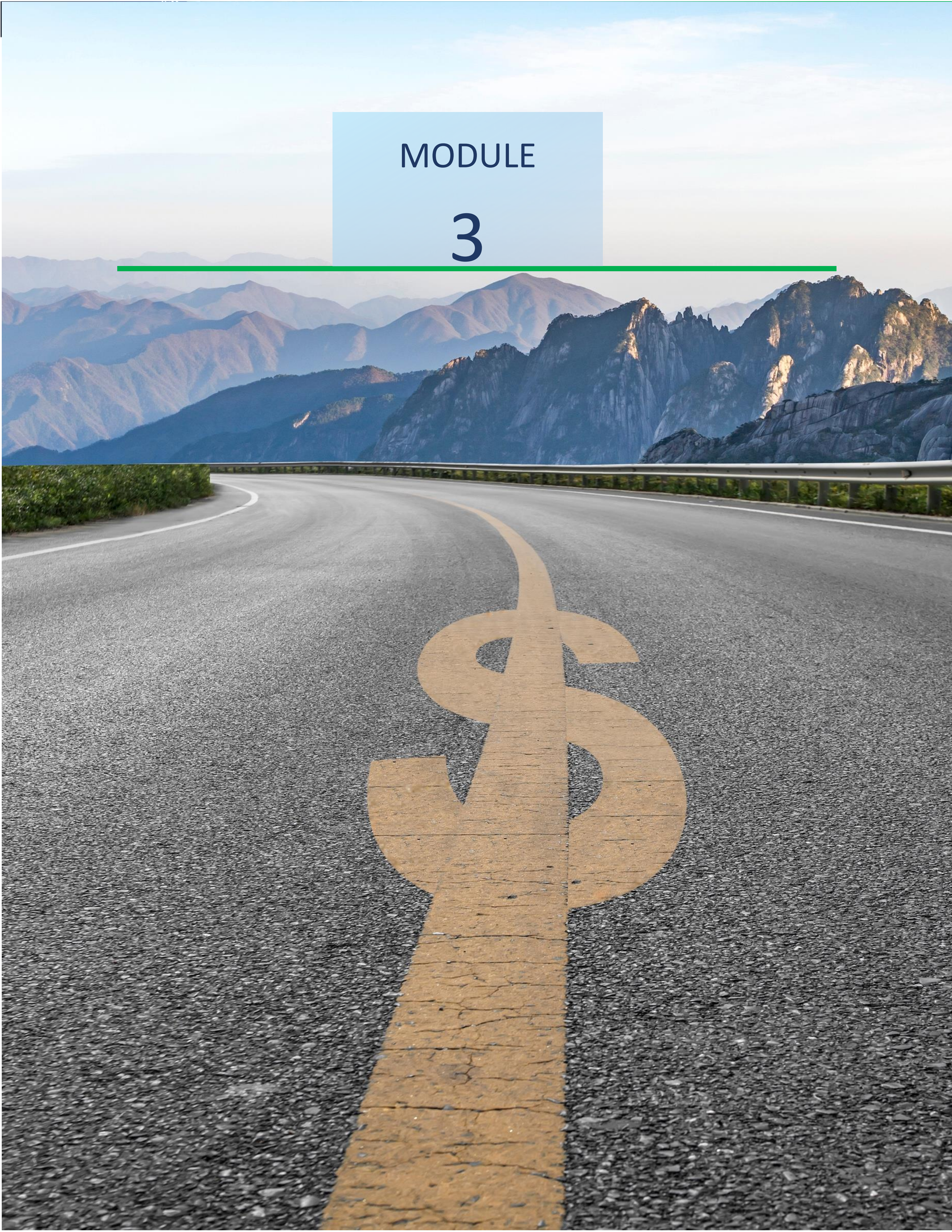
BOX 2.2 INNOVATIVE SUSTAINABLE PRACTICES USED FOR UK HIGHWAYS

- The upgrade of the A14 highway between Cambridge and Huntingdon trialed the low carbon cement Cemfree for curbs, drainages, and fills. Cemfree is a cement produced by the Cambridgeshire-based DB Group (Holdings) Ltd. DB Group claims Cemfree can achieve embodied carbon savings of up to 80 percent when used to replace ordinary Portland cement (OPC) in concrete production.
- The recently completed A590 road resurfacing project in Cumbria was the United Kingdom's first carbon neutral minor works scheme. A key initiative was the use of ex-situ foam-mix recycling of existing road surface plannings that reduced the need to import and export materials to and from the site, and erased approximately 6,000 heavy goods vehicle (HGV) movements from the operation, saving 230 tonnes of carbon dioxide equivalent (CO_2e). Furthermore, the recycled road surface has greater porosity than hot-rolled asphalt or concrete, helping to reduce rolling noise from vehicles. In addition to the associated carbon benefits, significant carbon reductions were also realized as a result of energy efficiency measures. The use of solar-powered generators, lighting, signage, closed-circuit television (CCTV), and catering facilities, along with the use of electric vehicles, saved approximately 70 tonnes of CO_2e.
- The National Highways of England and the Department for Transport have invested £8.1 million to lead the first real-world operational trial of platooning vehicles/trucks on UK roads. Platooning vehicles may travel at closer distances, increasing the fuel economy gains through increased aerodynamic efficiency.

Source: Highways England. "Net Zero Highways: Our 2030/2040/2050 Plan"; Amey PLC. https://www.amey.co.uk/.

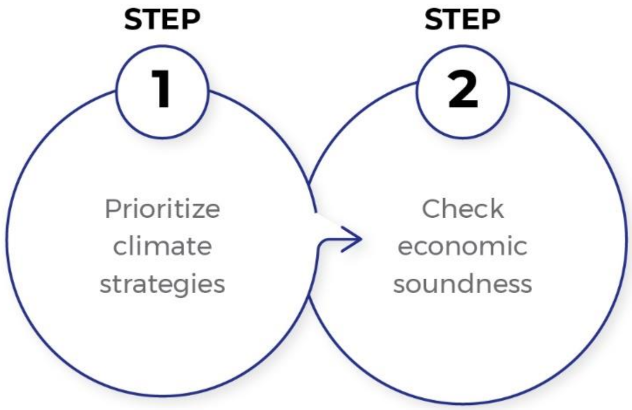
MODULE

3



Module 3

CLIMATE CONSIDERATIONS IN ASSESSING PROJECTS' ECONOMICS AND FINANCES

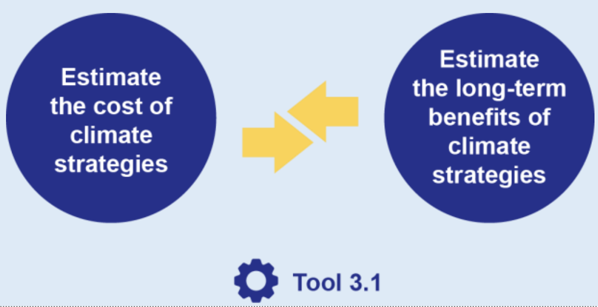


This module is meant to support agencies (i.e., the line ministry) in conducting their traditional Phase 1 economic assessments, in view of the above climate considerations. In particular, the module provides tools and examples for:

- Prioritizing different climate adaptation/mitigation options using a stakeholder approach (**Step 1**)
- Estimating the maximum additional cost at which the project is deemed unaffordable (**Step 2**)
- Identifying all climate-related costs/benefits that should be integrated with an enhanced cost-benefit analysis (CBA) (**Step 2**).

Step 1

Prioritize climate adaptation and mitigation strategies using multi-criteria analysis (mca)[21]

SCOPE	This step compares different climate adaptation/mitigation strategies (including a "do nothing" option), using a range of qualitative criteria. Shortlisted alternatives will move forward for a preliminary economic analysis (conducted in **Step 2**).
PROCESS	The process begins after the completion of **Tools 2.9** and **2.11**, which should have indicated a set of measures that may be added to the "do nothing" alternative to reduce climate risks and increase the overall environmental benefit of the project. The measures examined at this stage may substantially differ from a technical, economic, social, and strategic standpoint. In order to identify the preferred solution (or set of preferred solutions), the different climate strategies are analyzed using an MCA (**Tool 3.1**), within a participatory decision-making framework. By performing this type of qualitative analysis, aspects that cannot easily be quantified or put into monetary terms (e.g., impacts to the environment or communities) will be included in the decision-making process.
	
TOOLS	**TOOL 3.1** MCA assessment of climate strategies
OUTPUT	Preferred project alternative(s) (including climate measures) and a "do nothing" solution (where no climate measures are included).

[21] MCA: multi-criteria analysis.

TOOL 3.1

MCA ASSESSMENT OF CLIMATE STRATEGIES

This tool describes the process of conducting an MCA for the appraisal of the costs and benefits of alternative climate strategies (i.e., combinations of climate measures[22]). To see how climate decisions may benefit from an MCA (or equivalent approaches), users are referred to the Umbrella Toolkit (Module 2.1).

INPUT

1 **Define/refine the criteria of the assessment that best reflect national priorities**

Potential criteria to consider in the analysis include:

- Capital and life-cycle costs
- Estimated GHG emissions reductions over the project life cycle
- The risk-reduction potential of the strategy or its contribution to the resilience of the project (users may refer to the Umbrella Toolkit for a definition of the "resilience of" notion)
- Effectiveness in responding to the uncertainty of a changing climate (i.e., the adaptiveness of the strategy)
- The potential of a strategy to enhance the overall resilience of the impacted community (or certain disadvantaged groups within the community)
- Other factors (e.g., technical feasibility, protection of biodiversity, social acceptance, the optionality of green financing/funding).

Users may update/modify the above list of criteria to best reflect the priorities of the ministry in charge. Good practice favors a limited list of criteria to make the assessment effort realistic and to keep the selection process as simple as possible.

2 **Rank criteria based on their importance or criticality**

Apply a general "rule of thumb"; ranking of criteria should be compatible with national priorities.

[22] By climate measures, we refer to both adaptation and mitigation measures.

3 **Measure the impact of each climate strategy against the criteria considered**

By this point, a preliminary assessment has been conducted as part of **Tools 2.9** and **2.11**. Here the assessment may be revised and complemented by the input provided by the MCA team. The scoring system may be qualitative (e.g., high, medium, or low) or arithmetic (1 to 5). Users are prompted to use **Reporting Template A.3.1** to compare the overall benefits of the envisioned strategies.

4 **Start the analysis by abandoning strategies that do not contribute to high-ranked criteria,** and continue the process in an iterative manner until a manageable list of alternative climate strategies is obtained. Guidance on evaluation methods that are compatible with the MCA framework is provided in the Umbrella Toolkit (Module 2.1).

5 **Aggregate the results**

Rank finalists based on their overall acceptance by the MCA team. Users should make sure that the "do nothing" option is also included in the list of alternatives.

OUTPUT

A ranked list of climate strategies to be forwarded to **Step 2**.

Step 2
Check economic soundness of alternative climate strategies

SCOPE	This step compares the highly ranked climate strategies of the previous step (output of **Tool 3.1**) in terms of cost effectiveness, affordability, and suitability for a PPP. The output will be a project that has been successfully screened from an economic perspective and can therefore be considered suitable for proceeding to a full technical and economic appraisal.
PROCESS	Following the screening process presented in the Umbrella Toolkit, the economic analysis is performed in stages, starting with a preliminary CBA (**Tool 3.2**) to identify the project that maximizes the benefit-cost ratio. For best results, all important climate-related costs (e.g., additional climate capital expenditures (CAPEX), and costs of disruptions caused by extreme weather events) and benefits (e.g., risk reduction benefits, and protection of human settlements and biodiversity) should be synthesized and compared after monetary evaluation. Alternatively, a standard CBA with respective parameters should be performed to identify the solution with the maximum benefit/cost ratio. Once the project has been identified, the affordability of the project is tested in view of the budgetary limits, constraints, and other concurrent investment plans of the public authority, following the general considerations described in the Umbrella Toolkit. The final check is to assess how climate-induced risks, costs, and opportunities may affect the suitability of a project as a PPP (**Tool 3.3**). The project that successfully passes all tests receives the green light to proceed to the appraisal phase.
TOOLS	**TOOL 3.2** Climate entry points for CBA for road networks **TOOL 3.3** Climate value-drivers for VfM analysis
OUTPUT	A road project with climate adaptation and mitigation measures that can be moved forward for appraisal

TOOL 3.2

CLIMATE ENTRY POINTS FOR CBA FOR ROAD NETWORKS

This tool describes entry points for climate-related CBA considerations that are relevant to road projects. Prior to applying the tool, users are advised to review methodologies for estimating the monetary value of social-environmental benefits and the CBA Primer (2017)[23] and consult the Umbrella Toolkit (Modules 1.3 and 2.3), where climate-related considerations for CBA (applicable to all sectors) are described in greater detail.

INPUT

TABLE 3.1 Road-specific climate entry points for CBA

CBA Process Outline (per **APMG PPP Certification Guide**)	CBA Sub-steps (per **APMG PPP Certification Guide**)	Climate Entry Point
Projecting financial data with conversion/ adjustment	Tax adjustment	• If applicable in the country, include tax incentives that promote "green" behavior (e.g., use of environmentally friendly vehicles, tax-credits[24]) • If applicable, include levies and environmental taxes for the "do nothing" option
	Shadow prices and opportunity cost adjustment	• Adjust costs and benefits as would otherwise be done following the 2017 World Bank Guidance Note on the shadow price of carbon[25]
	Construction of the model	• Include the cost of constructing/implementing adaptation measures (e.g., cost of larger pipes and trenches, cost of constructing flood protection measures for the road, and cost of higher quality pavement material) • For nature-based solutions, the total cost should also include the cost of maintenance (which may be a significant portion of the initial investment) • Consider the cost of sustainable construction (e.g., cost of recycling demolition materials, investment in electrical construction machinery) • Include the cost of investments in small-scale mitigation (e.g., CAPEX of LED lights or photovoltaic cells) • Include auxiliary cost introduced by green requirements (e.g., cost of charging stations for electric vehicles)
	Operational and maintenance costs	• Consider the increase in the cost of repairs due to increased incidence of storms, flood events, and higher temperatures (e.g., cost of repairing potholes, maintenance of gullies) • Consider the effect of reduced electricity cost (e.g., road signage, lights using electricity from photovoltaics)

[23] Guzman, A., and F. Estrázulas. 2012. "Full Speed Ahead: Economic Cost-Benefit Analyses Pave the Way for Decision-Making." *Handshake* 7, October 2012.
[24] An example is the Road Infrastructure Development and Refurbishment Investment Tax Credit Scheme in Nigeria.
[25] World Bank. 2017. "Shadow Price of Carbon in Economic Analysis." World Bank Guidance Note, November 12, 2017. https://thedocs.worldbank.org/en/doc/911381516303509498-0020022018/original/2017ShadowPriceofCarbonGuidanceNoteFINALCLEARED.pdf.

CBA Process Outline (per **APMG PPP Certification Guide**)	CBA Sub-steps (per **APMG PPP Certification Guide**)	Climate Entry Point
	Defining term and residual value	Residual value estimates should be adjusted to include climate change impacts, for example: • Reductions[26] related to unrepaired damages (e.g., collapsed road sections) • Reductions caused by the increasing rate of material deterioration due to climate change (e.g., corroded metal bridges, road surface damage due to water salination)
Adding externalities	Defining list of externalities	The cost of externalities may include: • Cost of indirect damage caused by broken supply chains, increased travel times, increased road accidents (due to absence of early warning systems for extreme weather conditions) • Cost of emergency services (e.g., destruction of a bridge may require the use of helicopters to provide supplies to households). Emergency response costs can be estimated using data from past events. • Permanent or temporary changes in traffic patterns caused by: - Changes in the population or economic activity of the coverage area of the road network (e.g., increased risk of desertification) - Loss of connectivity with the regional network (in the aftermath of extreme weather events) • Disruption during construction (caused by unfavorable weather conditions, e.g., extreme heat, frequent and intense rainfalls, cyclones) • Long-term effects on air, water quality, and noise • External benefits comprise increased user safety, the certainty of traffic and associated revenues, etc.
Adding (other) socioeconomic benefits	Monetizing/inferring value for relevant benefits	• Include an increase in private investment confidence (business, entrepreneurship, property)
	Considering/qualifying other unvalued benefits	• Include resilience benefits such as: - Avoided loss to the network adjusted over the probability of the event - Avoided disaster to the broader ecosystem (e.g., if the road can be used as an evacuation route for nearby settlements) • Environmental benefits of nature-based solutions (e.g., quality of air, better aesthetics) • Alignment with strategic climate objectives
Relative price adjustments and bias/ risk adjustments	Market imperfection	• Apply as would otherwise have been done
	Other opportunity cost adjustments	• Consider alternative uses of the land and space that climate measures cover, if any, and apply such costs
	Taxes	• Same as above, apply only to the extent that tax advantages are applicable when a project exceeds its purpose in social benefits, and/or • Consider the tax income gained from steady, uninterrupted operations.

[26] The calculated reduction should be adjusted to account for the probability of failure.

CBA Process Outline (per **APMG PPP Certification Guide**)	CBA Sub-steps (per **APMG PPP Certification Guide**)	Climate Entry Point
Defining base case, and defining and calculating economic internal rate of return (EIRR)	Discount rate definition and calculation of net present value (NPV) and EIRR	• Consider adjusting discount rate for valuation depending on levels of certainty of cash flows (applies to projects that include climate measures) and uncertainty of cash flows (applies to "do nothing" alternatives). This needs to be aligned with the probabilistic analysis of events occurring to avoid "hurting" a project with uncertainty twice (once with high probability of costs occurring and once with high discount rate because of uncertainty of cash flows).
Incorporating uncertainty: sensitivities	Test the strength of the proposed business plan and present the effect of variations	• As would otherwise be conducted

OUTPUT

The results of the analysis of climate entry points in the project's CBA may be summarized in a screening report highlighting which climate mitigation and adaptation aspects have been considered, and ensuring these have been adequately evaluated.

IMPORTANT NOTE

CHOOSING DISCOUNT RATE

The discount rate used in the economic analysis is particularly important when evaluating and comparing adaptation options, because the associated benefits (or avoided costs) are unlikely to be realized for many decades. There is no consensus on the appropriate discount rate to use for resilience strategies. As a good practice, study teams may choose to explore the sensitivity of economic analysis findings to different discount rates, or the possibility of applying a non-constant discount rate over the horizon of the assessment.

TOOL 3.3

CLIMATE VALUE DRIVERS FOR VFM ANALYSIS

A VfM analysis is performed to identify whether (and to what extent) climate-related risks, opportunities, and uncertainties may affect the suitability of a project for PPP and non-PPP delivery. This tool describes entry points for climate-related considerations for VfM analysis that are relevant to road projects. It explains the rationale of these considerations, identifies conditions of positive, negative or (conditional) performance, and, where applicable, provides specific references and examples from road projects.

INPUT

TABLE 3.2 Impacts of climate change on PPP suitability for road projects

VfM Driver	PPP Suitability: Climate Considerations	Conditions	Impact on PPP Suitability
Project size	Is the project too big for the market? Or is the project too complex to be delivered as a PPP?	Introduction of climate considerations in a road project may—in certain circumstances—result in increasing its size due to the required adaptation works. Such a condition may be particularly problematic when the construction of the adaptation measures requires the cooperation of different PPP units or other government units outside the PPP unit. E.g., a road with flood protection measures will require the co-operation of the transportation and water management units, which may be practically unfeasible. Such conditions could impact the appetite of potential bidders or hinder the project's financing.	**Negative**
		The transportation sector is generally missing standardization on how to design adaptation measures while considering changing climate conditions. Hence, the potential requirement to account for climate change would demand significant expertise and could result in increased preparation time (and perhaps budget).	**Negative**
Market appetite	Would there be private investor appetite?	The identification of previously unknown climate risks (e.g., the locations of a road section on a projected flood plain) could hamper an investor's appetite to invest.	**Negative**
		Proper design and cost estimates of climate adaptation/mitigation works would provide visibility and hence increase private sector appetite.	**Positive**
Precedent projects	Are precedent transactions already developed as PPPs for this type of project in the country/region or in similar countries?	If the road project is part of a greater urban mobility project, or project pipeline for which detailed risk assessment studies have already been performed, it will be easier to incorporate climate risks in the transaction.	**Positive**

VfM Driver	PPP Suitability: Climate Considerations	Conditions	Impact on PPP Suitability
Risk allocation	Are there any significant climate risks within the project that are not manageable by a private partner?	In some circumstances, climate related events may cause extended losses to road networks. The risk of sustaining such losses may be reduced by proper design of climate adaptation works and insurance against any excess risks. In case costs for climate adaptation works are high or insurance is unavailable, the risk may not be manageable by the private partner (e.g., risk of inundation of road sections due to unprecedented sea-level rise, or frequent flooding of rivers that will require extensive replacement/rehabilitation cost during the project timeframe).	**Negative**
		Uncertainty in estimating risks (i.e., CAPEX and/or O&M costs) will also impact PPP suitability of roads. Plausible climate risk reduction measures: incorporate uncertainty in the financial assessments, or use more flexible contract structures, to allow for adjustment in tariff level that can partially compensate for the climate-induced loss.	**Mostly negative** (unless specific measures to increase certainty are taken)
	Are there circumstances where climate risks can be better assumed by the private party?	The private sector's capital and innovation brings higher efficiency in disaster preparedness, response, and recovery. Also, insurance coverage increases the capability of the private party to assume a certain level of climate risk. Road concessions have a better track record than roads operated by public entities (e.g., municipalities) in combating extreme weather events, due to better O&M practices (e.g., lower possibilities of disruption, and implementation of operational innovations such as early warning systems).	**Positive**
	Is there a risk of non-availability of the land or right of way, and land acquisition cost overrun?	Geophysical hazards (e.g., landslide, subsidence) may be intensified by climate change; hence roads passing through landslide-prone areas, thawing permafrost zones, areas impacted by coastal erosion, etc., could experience higher risks.	**Mostly negative** (unless recognized and proper measures are taken)

VfM Driver	PPP Suitability: Climate Considerations	Conditions	Impact on PPP Suitability
Certainty of offtake/ supply	Is it possible that the project will experience a change in demand due to climate change?	Interdependencies of the road network with vulnerable external infrastructure that is not under the control of the PPP may have a negative impact on the demand (e.g., non-accessibility of the road network from flood-prone locations), thus compromising investment certainty.	**Mostly negative**
		Increased growth of a region (partially affected by milder climate conditions) may positively impact the road demand.	**Mostly positive**
Project quality	Will the project quality increase if the project is developed through a PPP scheme?	In some cases, the private party may bring innovation and high standards. Examples of such innovation applicable to roads could indicatively include contractors with experience in NbS; expertise in automated construction using pre-fabricated sections to reduce construction time and increase project quality, thus positively impacting the climate resilience of the project; recycling construction materials; low-emissions equipment; new materials; etc.	**Mostly positive** (provided that the methods used are tested)
		As commercial lenders become more informed about climate change risk, they will demand higher climate resilience standards to stimulate high performance in order to ensure repayment/returns.	**Positive**
Output-based contracting	Is it possible to define clear output requirements for road performance in climate events?	There are examples of road PPPs that have incorporated climate and sustainability clauses in output-based contracting (e.g., relating the intensity of rainfall with the duration of road closure for repairs). Output-based contracting in roads could easily be linked to financial incentives or penalties, thereby enhancing climate risk mitigation and resulting in faster as well as better responses to climate-related disruptions.	**Mostly positive**
Finance availability	Are there any significant climate risks that may harm the availability of financing?	In general, technologies for reduction of climate risks in road projects are mature and have been tested both technically and commercially. However, climate-related events may be responsible for external risks (e.g., loss of accessibility of feeder roads networks, reduced traffic), which could be non-mitigable. Such risks may test the	**Negative** (unless recognized and proper measures are structured)

VfM Driver	PPP Suitability: Climate Considerations	Conditions	Impact on PPP Suitability
		willingness of financiers to participate or could result in requests for higher guarantees.	
Legal or regulatory framework	Has the country adopted national legislation on climate change?	Prior existence of a national framework promoting green investments, defining other subsidies and incentives for private sector participation, would definitely boost the project. For example, existing legislation describing beneficial provisions for electric vehicles and eco-mobility would positively impact the implementation of low-carbon public transport plans.	**Mostly positive**

OUTPUT

The results of the VfM may be summarized in a screening report highlighting which climate mitigation and resilience aspects have been considered, and how they are impacting the suitability of the project as a PPP.

MODULE 4

Module 4

KPIs FOR CLIMATE-RESILIENT AND SUSTAINABLE ROADS

KPIs are customarily used in PPP road projects to assess and evaluate the project's performance during design, construction, and operation. KPIs are developed around specific government objectives, and the private partner will either be entitled to additional payments for good performance or reduced payments for poor performance. Expanding this general notion to road PPPs containing climate actions, the relevant KPIs can be used to measure: (i) the road project's alignment to specific climate mitigation objectives, and (ii) the ability of the road project to prepare, respond to, and quickly recover from climatic hazards.

The tools described in the ensuing section provide indicative high-level examples of climate KPIs soliciting forward-looking information to be included in performance-based contracts.

Based on the understanding that there is no one-size-fits-all for KPIs, the tools describe climate indicators that may be applicable to a broad range of road projects. It is then the obligation of the entity in charge, with the assistance of experienced consultants, to formulate project-specific KPIs that best describe the technical/operational challenges of the project, and to take advantage of the expertise and innovation skills of the private sector.

TOOL 4.1

KPIs MEASURING CLIMATE MITIGATION OBJECTIVES

This tool is designed to help public authorities and their advisors when structuring and preparing performance-based contracts for roads. **Table 4.1** provides a non-exhaustive list of climate mitigation KPIs that can be widely adaptable to road projects and have been recommended by internationally recognized frameworks.

The KPIs are structured around four thematic areas representing core elements of a PPP contract: design, construction, O&M, and investments. KPIs are described by a performance objective and an example measurement (i.e., how to measure compliance with the objective). Where applicable, the (recommending) organization is also stated. Depending on the performance objective, one or more example measurements may apply (that can be used complementarily or interchangeably with each other). It should be noted that the tool does not provide threshold values for the suggested KPIs. This is country- and project-specific information that the public authority should provide based on good-practice examples and applicable norms/rules.

Overall, it is considered good practice to define two levels of achievement: a *conserving level* having no negative impacts and an *improved level* that will overall benefit the project performance. Performance below the conserving level signifies the application of penalties, whereas performance above the improved level may be tied to specific rewards/incentives for the private sector.

TABLE 4.1 Indicative climate mitigation KPIs

DESIGN-RELATED KPIs

Performance Objective	Example Indicators	Framework/ Organization
Support of sustainable modes of transportation	Electric vehicle charging stations and infrastructure: *number (charging capacity) per kilometer (km)*	• ICMA[27]
	Bicycle lanes and bicycle parking stations: *km*	• ICMA
	New or improved train lines, and dedicated bus, BRT, LRT[28] corridors, bicycle lanes: *kms or percentage of the road network coverage*	• ICMA
Improvement of energy efficiency	Efficiency of road lighting equipment for traffic areas: *e.g., power density (watt/area unit); annual energy* consumption *(kWh); number of LED or solid-state lighting (SSL) fixtures with lumen/watt (Lm/W); active power/energy losses in lighting installations*	• ICMA • EN 13201 [1–5] standards[29]

[27] International Capital Market Association
[28] BRT: bus rapid transit; LRT: light rail transit
[29] BS EN 13201 Parts 1-5 Road Lighting Standards

Performance Objective	Example Indicators	Framework/ Organization
Reduction of the heat island effect	Road area that meets solar reflective index (SRI[30]) criteria: *percentage of road network*	• Envision Framework/ Institute for Sustainable Infrastructure[31] • ICMA
	Approximate excess heat produced and not captured by the road: *kW*	• SuRe by GIB

CONSTRUCTION-RELATED KPIs

Performance Objective	Example Indicators	Framework/ Organization
Increase of energy efficiency	Consumption of electricity, gas and water for construction works: *e.g., kW/day, gallons/day*	• TCFD (Task Force on Climate-Related Financial Disclosures) • GRI:[32] 103, 302 • SASB[33] • EMAS[34] by European Commission
Reduction of emissions in construction	Total amount of embodied tons of CO2 and other GHG emissions of the construction materials: *CO2e*	• TCFD • GRI:[35] 103, 302
	Net CO2 equivalent emissions of road construction equipment per usage: MT (metric tonne) *of CO2e per km (or m3).*	
Reduction of the heat island effect	Annual temperature increase/decrease in the surrounding areas after road construction: *degrees Celsius or percentage change*	• SuRe Standard by (GIB)[36]
Promoting sustainable resource management and circular economy	Materials used for construction/ maintenance works that come from local and/or recycled or reclaimed sources (e.g., earthworks using local soil, embankment material from demolition waste, gabions instead of concrete retaining walls, pavement rehabilitation using recycled materials): *percentage of total materials used*	• SuRe by GIB

[30] SRI is an index used to measure the part of solar radiation that is reflected back by a surface
[31] Use Envision/Institute For Sustainable Infrastructure
[32] Global Reporting Initiative
[33] Sustainability Accounting Standards Board
[34] Eco-Management and Audit Scheme
[35] Global Reporting Initiative
[36] SuRe Standard: Sustainable and Resilient Infrastructure - Infrastructure Tool Navigator (sustainable-infrastructure-tools.org)

Performance Objective	Example Indicators	Framework/ Organization
	Primary and secondary suppliers of road machinery/equipment that have sustainability sourcing/procurement/management certification: *percentage or number*	• SuRe by GIB
Promoting the use of renewables	CNG[37] and/or renewable fuel consumption for construction works over total fuel consumption: *percentage share of renewable fuel consumption*	• TCFD • SASB
Leverage biodiversity	Native, non-invasive species before and after the road construction and the associated infrastructure: *number of such species as percentage of all species*	

OPERATIONS AND MAINTENANCE-RELATED KPIs

Performance Objective	Example Indicators	Framework/ Organization
Modal shifts increase to more sustainable and less polluting means of transportation	Ridership of alternative means of transportation: *e.g., number of passengers per vehicle-trip kilometer (PVK); passengers per route kilometer (PRK); passengers per hour per direction (PPHPD)*	• ICMA
	Estimated reduction in car/truck use: *number of kilometers driven, share of total transport ridership*	• ICMA
Increase of energy efficiency	Consumption of electricity, gas and water for operations: *e.g., kW/day, gallons/day*	• TCFD Metrics • SASB • Envision Framework
	Energy input per desired output of operation equipment (e.g., traffic patrol vehicles): *e.g., fuel consumption in litters/km*	• TCFD • GRI: 103, 302 • SASB • EMAS by European Commission
Reduction of GHG emissions	Life-cycle net CO2 equivalent emissions of the road network: *MT (metric tonne) of CO2e, percent reduction (over a baseline)*	▪ TCFD ▪ SASB ▪ Envision Framework
	Net CO2 equivalent emissions of operation equipment (e.g., patrol cars) per usage: *tn of CO2e per km*	▪ TCFD ▪ SASB ▪ Envision Framework
Promoting the use of renewables	Renewable energy produced within the road project (e.g., solar panels on stations, canopies, and	• TCFD • GRI: 103, 302 • SASB

[37] CNG: compressed natural gas.

Performance Objective	Example Indicators	Framework/ Organization
	administrative buildings): *percentage increase from baseline year; percentage of total energy demand*	• EMAS by European Commission
	Renewable fuel consumption (of the rolling stock) over total fuel consumption: *percentage share of renewable fuels*	• TCFD • SASB
	Clean vehicles (e.g., gas vehicles, battery electric vehicles, plug-in hybrid electric vehicles) or alternative-powered vehicles (LPG,[38] CNG, fuel cells, compressed air) in the operating fleet*: total amount, percentage share of green fleet*	• TCFD • SASB
Reduction of air pollutant emissions	Air quality measurements in characteristic locations of the network (i.e., stations, passengers crossings): *mg/m3 of carbon monoxide, ground-level ozone, nitrogen oxides; percentage reduction in measurements performed at specified distance and height from the road edge*	• Envision
Reduce human exposure to traffic-related pollution	Roadside vegetation (i.e., the vegetative barrier between road and adjacent land) in urban environments: *percentage share*	

INVESTMENT-RELATED KPIs

Performance Objective	Example Indicators	Framework/Organization
Increase of CAPEX (capital expenditures) on climate mitigation	Investments (CAPEX) in low-carbon fleet and equipment: *total cost or percentage of total CAPEX*	• TCFD • SASB
Reduction of OPEX (operating expenses) (while investing in sustainability)	Energy savings from using low-carbon alternatives (e.g., microgrids) to cover operational energy demands: *percentage increase (over a baseline case)*	• TCFD • CDP[39] • SASB
Increase of green sources of financing	Green bond ratio: *total amount of green bonds outstanding (at year-end) divided by (a five-year rolling average of) total amount of bonds outstanding*	European Commission (2019/C 209/01): ISO/CD 14030-1
	Green debt ratio*: total amount of all green debt instruments (including sustainability-linked loans) outstanding (at year-end) divided by (a five-year*	European Commission (2019/C 209/01): ISO/CD 14030-1

[38] LPG: liquefied petroleum gas.
[39] Climate Disclosure Standards (CDP).

Performance Objective	Example Indicators	Framework/Organization
	rolling average of) total amount of all debt outstanding	

TOOL 4.2

KPIs MEASURING CLIMATE ADAPTATION OBJECTIVES

Climate-adaptation KPIs measure either the **physical** (e.g., percentage of damaged road sections, information technology failures) **and/or operational performance** of a road network (e.g., time out of service, time to full functionality) related to specific climate hazards. Contrary to the customary practice, climate-adaptation KPIs:

- Correlate the road performance with specific intensity thresholds of the climate event
- Have different intensity thresholds for normal and extreme weather conditions
- Assess the capacity of the operator to manage a climate event based on functional recovery times (and to a lesser extent on available resources)
- Can be updated to absorb any abrupt changes in the climatic patterns of the region due to climate change (provided that there is the necessary justification).

Table 4.2 provides a **non-exhaustive list of climate-adaptation KPIs** that can help the public authorities and their advisors when structuring and preparing performance-based contracts for roads. Two broad classes of KPIs are recognized—physical and operational. Example indicators for measuring the achievement or not of the KPI are also provided. However, the tool does not recommend specific threshold values for either the event intensity or the performance level of the road. These should be derived in consultation with the technical advisor, in due consideration of the project's risk profile, the frequency of the event, and the importance of the road project. For example, a road that is used as an emergency route, and should therefore remain always operational, will have more stringent thresholds than an ordinary road.

IMPORTANT NOTE

Climate thresholds and performance levels

One KPI may be related to one or more hazards. However, the climate thresholds that apply to different hazards will differ. Moreover, depending on the severity of the event, different performance levels will apply for the same hazard (e.g., longer response times will be tolerated for extreme rather than normal-intensity events)

TABLE 4.2 Indicative climate-adaptation KPIs

PHYSICAL KPIs

Performance Objective	Example Indicators	Relevant Hazards[40]
Roughness of the road surface	▪ Cracks of specific dimensions: *number per unit area of road* ▪ Potholes: *number per unit area*	• (Urban, river, coastal) flooding • Snowfall/hail • Excessive heat • Ice melt / permafrost thaw • Landslides
Percentage of road closed to traffic	▪ Road inundated, covered by snow, or covered by debris: *percentage of roadway that is affected, as a function of the intensity of the climate-related phenomenon and the criticality of affected road sections, out of the full network or the PPP project*	All hazards
Maintenance of assets to meet specific performance standards	▪ Periodic condition assessments: *number/year* ▪ Minimum asset condition score above a minimum threshold: score depends on asset type e.g., for pavement the International Roughness Index (m/km) may be used for the ride quality ▪ Frequency of preventive maintenance actions: *number*	All hazards
Visibility/operability of traffic signs	▪ Distance from which signs are clearly visible: *meters* ▪ Power/IT failures affecting digital signs: *number/event*	• Extreme rain/fog • Dust storms

OPERATIONAL KPIs

KPI /Target	Example Indicators	Relevant Hazards[41]
Functional recovery time with respect to the intensity of the event and the criticality of the road section	▪ Time required to reach a certain percentage of road capacity: *days* ▪ Time required to reach 100 percent capacity: *days*	All acute hazards
Road safety	▪ Accidents due to climate hazards: *number*	All hazards
Availability of emergency resources	▪ Emergency water supply points for firefighting: *number per km* ▪ Pumping stations: *number per km* ▪ Fleet and maintenance plan of emergency vehicles: *number of emergency vehicles per km, frequency of maintenance activities*	• Fire • (Urban, river, coastal) flooding • Snowfall/hail • Landslides • Tornadoes/twisters/ cyclones
Emergency response time	▪ Time elapsed between a predicted event and a warning announcement to drivers: *minutes*	• Fire • (Urban, river, coastal) flooding

40 **Table 4.2** maintains the climate hazard description of **Module 1** – (**Library B.2.1**).
41 **Table 4.2** maintains the climate hazard description of **Module 1** – (**Library B.2.1**).

KPI /Target	Example Indicators	Relevant Hazards[41]
	▪ Time elapsed between a climate-related warning and the completion of all relevant emergency response procedures: *minutes*	• Snowfall/hail • Tornadoes/twisters/cyclones
Response time of emergency vehicles	▪ Time to access affected area: *minutes* ▪ Time required for first aid to arrive: *minutes*	• All hazards
Time to clear road	▪ Time required to de-ice road surface in case of extreme cold: *minutes/km* ▪ Time required to clean road surface of debris, rockfalls, material transported by flood water, etc.: *hours (counting from the moment the road closed to traffic)*	• Snowfall/hail • Dust storms • Landslides • Tornadoes/twisters/cyclones
Time to resume construction	▪ Time to resume a certain percentage of operability of construction sites following disruptive climate events as a function of their intensity: *days*	• (Urban, river, coastal) flooding • Landslide • Tornadoes/twisters/cyclones
Increased preparedness for climate events	▪ Frequency of emergency drills: *number of evacuation/emergency response exercises per year* ▪ Existence of procedures for post-event assessments: *yes/no*	• All acute hazards
User satisfaction	▪ Complaints received (after climate-related events): number/event ▪ Canceled or affected bus services (due to climate events): *number*	• All hazards

Summary and Conclusions

CLIMATE ENTRY POINTS IN THE EARLY STAGES OF ROAD PPP PROJECT PREPARATION

After completion of all the steps described in this toolkit, users are expected to have a clear view of how to incorporate climate considerations into the early stages of a road PPP project preparation, using a set of practical tools that allow:

- **Identification and mapping of national and international climate-related frameworks** and commitments relevant to the road project under consideration. To this end, the tool navigates users through the main documents defining such policies, while guiding them as to the specific focus areas that are of importance for a road PPP project.

- **Screening of the alignment of the road PPP project with the Paris Agreement** and the regulations stemming from it. Screening is performed by means of four sets of questionnaires—each referring to one pillar of the relevant considerations—through which users are able to identify areas where improvements may be necessary, recalling that all World Bank Group-supported projects must be fully aligned with the Paris Agreement by 2025.

- **Appraisal of the climate-related risks that the specific project is exposed to,** which are identified as the potential losses that could be either internal to the project (in the form of physical damage and loss of revenues due to a climate event immediately impacting the operability of the infrastructure) or external (in the form of economic losses due to an event impacting access to the road project that may remain physically intact). To this end, a set of readily available online resources are provided that allow users to understand which hazards may affect the project, given its location and geometric data. Based on such data, a set of libraries provides guidance as to the potential effects of each hazard on specific assets of the road network. Hence, users will be able to form a preliminary opinion as to the vulnerability of each asset type, its appropriateness for the project/region, and the associated needs for risk reduction measures.

- **Preliminary exploration of climate adaptation and resilience strategies** to reduce the risks identified above and enhance project bankability. The relevant tools help users identify adaptation measures specific to each road asset, while at the same time providing a high-level indication as to the costs and benefits of each alternative option, so that users are able to design different resilience strategies—each with distinct costs and benefits—including the potential for the project to access additional resilience-linked liquidity pools.

- **Estimation of the carbon footprint of the road project** by performing a preliminary assessment of the GHG emissions associated with the construction and operation of the road network. The relevant tools provide step-by-step instructions on how to conduct a preliminary life cycle analysis (LCA) of such emissions, supported by libraries providing indicative emissions values associated with each (construction- or operation-related) activity.

- **Selection of appropriate climate mitigation measures** aiming to reduce the carbon footprint of the project. Given that the road transportation sector is a driver of economic development on the one hand, but is generally associated with high GHG emissions on the other, it is important to explore options—applicable to both the construction and operation phases—to mitigate them, because that would be necessary to enhance the project's alignment with climate-related frameworks and ensure eligibility for funding or for accessing green financing. To support the preliminary selection of mitigation options, the relevant tools provide specific examples applicable to road assets, accompanied by a simplified methodology to assess the effect of such measures in reducing GHG emissions.

Preliminary identification of climate entry points in the cost-benefit analysis of the project, using a step-by-step approach that supports users in understanding how climate risks, as well as adaptation and resilience plans, may be reflected in the project economics, by presenting the tradeoffs between climate-related risks and investments.

Preliminary appraisal of the project's VfM and suitability as a PPP using a set of tabulated instructions explaining the effects of the various potential climate actions identified above, on parameters such as project bankability, investor appetite, and project risk profile. It is also shown how failure to act—or invest—may result in a negative impact on the project, if investor risks remain unmitigated, or if insufficient measures hamper the eligibility of the project to receive funding from multiple sources.

Preliminary identification of climate (mitigation or adaptation related) KPIs that could be used to trigger climate-related clauses of the payment mechanism in PPP contracts. It is shown that climate considerations are meant to be present in all phases of the PPP project—from project selection, design, and construction, throughout project implementation. To this end, a non-exhaustive set of essential climate-related KPs are presented as part of the relevant tools that describe road-specific actions and quantifiers to allow them to be monitored.

The present road-specific toolkit, when used in conjunction with the World Bank Group's Umbrella Toolkit document, is meant to support PPP agencies operating in EMDE countries to incorporate climate risks and opportunities in road PPP projects, by providing detailed guidance applicable to the early stages of such projects' preparation. Given the importance and complexity of incorporating climate change considerations into PPP projects, all appraisals performed at the preliminary stages with the help of this toolkit will need to be re-assessed in detail with the help of expert consultants on the basis of project-specific data that will become available in subsequent stages of the project.

Appendix

Appendix A

REPORTING TEMPLATES

Reporting Template A.1.1 Climate entry points in transportation policies

Policy Document	Document Type	Coverage	Entity in Charge	Climate Provisions
Name (year)	Strategy, law, policy, action plan, taxonomy, etc.	National/ subnational/ regional	Intra-governmental entity (ministry, municipality, etc.)	Summarize key points
Complete as appropriate				

Reporting Template A.2.1 Hazard matrix for road network assets

Hazard Type	Current Level	Future Trend	Future Level
	Low/Medium/High	Increasing/Decreasing/ Stable	Low/Medium/High
Flood			
Landslides			
Extreme rainfall			
Tornadoes			
Complete as appropriate			

Reporting Template A.2.2a System-level exposure matrix (can be used to compare different project alternatives at a high level)

	Flood	Coastal Erosion	Add Hazard Types from Tool 2.3
	n.a./Low/Medium/ High	n.a./Low/Medium/ High	n.a./Low/Medium/ High
Road alternative 1			
Road alternative 2			

Reporting Template A.2.2b Asset-level' exposure matrix for a project alternative

Asset Categories	Flood	Coastal Erosion	Add Hazard types from Tool 2.3
	n.a./Low/Medium/ High	n.a./Low/Medium/ High	n.a./Low/Medium/ High
River bridges			
Coastal bridges			
Coastal roads (elevation < 1 meter)			
Roads (elevation > 1 meter)			
Drainage systems			
Natural slopes/cuts			
Add more asset types as appropriate			
TOTAL exposure			

Reporting Template A.2.3 Asset-level' vulnerability matrix of a project alternative

Asset Categories	Flood	Coastal Erosion	Add Hazard Types from Tool 2.3
River bridges	n.a./Low/Medium/ High	n.a./Low/Medium/ High	n.a./Low/Medium/ High
Coastal bridges			
Coastal roads (elevation < 1 meter)			
Roads (elevation > 1 meter)			
Drainage systems			
Natural slopes/cuts			
Add more asset types as appropriate			

Reporting Template A.2.4a Current and future climate risk of the road project

Asset Categories	Flood		Coastal Erosion		Add Hazard Types from Tool 2.3	
	Current	Future	Current	Future	Current	Future
Road alternative 1						
Road alternative 2						

Reporting Template A.2.4b Current and future climate risk estimates of road asset categories

Asset Categories	Flood		Coastal Erosion		Add Hazard Types from Tool 2.3	
	Current	Future	Current	Future	Current	Future
River bridges						
Coastal bridges						
Coastal roads (elevation < 1 meter)						
Roads (elevation > 1 meter)						
Drainage systems						
Natural slopes/cuts						
Add more asset types as appropriate						

Reporting Template A.2.5 Internal risks synopsis and preliminary loss estimates

Hazard Type	Current Risk Level	Future Risk Level	Projected Consequences	Direct Loss (due to physical damage)	Indirect Loss
	Low/Medium/High	Low/Medium/High	Fill cell based on consequence score	Provide a rough estimate in US$	Provide a rough estimate in US$
Flood					
Coastal erosion					
Add rows with other hazards (from Tool 2.3)					

Reporting Template A.2.6 External climate-induced risks and contingencies

External Factors impacted by **Climate Change**	**Consequences for Roads**	**External Risk Level**	**Contingencies**
Include only factors that are relevant to the project	Describe how the external factor will impact the project	Low/Medium/High	Can the risk be mitigated? If yes, describe contingencies
Connecting infrastructure			
Land-use changes			
Geomorphological and environmental changes			
Technological changes			
Demographic changes			
Transport changes			
Policy and regulation changes			
Other (complete as appropriate)			

Reporting Template A.2.7 Climate adaptation strategies synopsis

Climate Adaptation Strategy		**Risk Level (prior to adaptation)**	**Risk Level (after adaptation)**
HAZARD #1 (e.g., flood)			
#1.1	Brief description of the adaptation strategy	Low/Medium/High	Low/Medium/High
#1.2	Description of an alternative adaptation strategy (if applicable)		
#1.3	Description of an alternative adaptation strategy (if applicable)		
HAZARD #2 (e.g., prolonged heat waves)			
#2.1	Complete as appropriate		

Reporting Template A.2.8 Appraisal of adaptation strategies for hazard protection (example refers to flood protection)

Risk Level			Climate Adaptation Strategy	Benefits							Cost (US$)
(Prior adaptation) Low/Medium/High			(Combination of different adaptation measures) Number and description	Resilience of Low/Medium/High	Resilience through Low/Medium/High	GHG emissions Low/Medium/High	Adaptive capacity Low/Medium/High	Biodiversity protection Low/Medium/High	Social acceptance Low/Medium/High	Green funding Low/Medium/High	
L	M	H	**#1.1** e.g., elevated road alignment + caisson breakwaters + vegetation (mangroves)								
			# 1.2 e.g., beach nourishment + elevated flood protection								
			Complete as appropriate								

Reporting Template A.2.9 Estimation of GHG emissions of the "do nothing" option

Project Alternative	Construction Emissions	O&M Emissions	Overall Project Emissions
Alternative 1			
Alternative 2			
Complete as appropriate			

Reporting Template A.2.10 Costs and benefits of climate mitigation strategies

Climate Mitigation Strategy	Benefits						Cost (US$)
(Combination of different mitigation measures)	GHG reduction	Health benefits	O&M cost savings	Biodiversity protection	Social acceptance	Green funding	(preliminary cost)
Number and description	Low/Medium/ High	Low/Medium/ High	Low/Medium/ High	Low/Medium/ High	Low/Medium/ High	Low/Medium/ High	
#1 e.g., LED lighting system + solar-powered lighting + NbS for erosion protection							
# 2 e.g., green retaining wall s+ optimized pavement bituminous mixture + inclusion of e-mobility lane							
Complete as appropriate							

Reporting Template A.3.1 Comparing climate strategies via arithmetic MCA

No	Climate Action	MCA Criteria									Total weighted score
		CAPEX	Life-cycle cost	GHG emissions reduction	Project's resilience	Community resilience	Environmental benefits	Social benefits	Alignment with policies	Define other criteria as appropriate	
Weights (should add to 1)				W_1	W_2	W_3	W_4	W_5	W_6	W_n	
1	"Do nothing" solution (i.e., no climate strategy is implemented)										
2	Strategy (specify climate adaptation and mitigation measures)										
3	Alternative strategy (if applicable)										
4	Complete as appropriate										

Appendix B

LIBRARIES

Library B.2.1 Indicative climate-related hazards to roads

		Hazard Name	Hazard Description	Impacts on Road Assets	Intensity Measures (IMs)/ Indicators Relevant to Road Assets
SEA LEVEL RISE	CHRONIC HAZARDS	Inland Inundation	Coverage of inland due to chronic sea level rise.	Coverage of road assets (e.g., road pavement) located at low altitude, in close proximity to the seaside.	- Change of sea level as a global average - Change of sea level locally - Measurement of potential sea-level anomalies
		Coastal Erosion	Coastal erosion is the process by which local sea-level rise, strong wave action, and coastal flooding wear down or carry away rocks, soils, and/or sands along the coast.	Gradual deterioration of coastal road assets, such as bridge foundations, earthworks, etc. Damage could lead to malfunction or even to subsequent collapse.	- Measurement of local sea-level rise - Soil type/stiffness and strength - Wave energy, etc.
	ACUTE HAZARDS	Tidal Waves/ Storm Surge	The temporary increase, at a particular locality, in the height of the sea due to tidal conditions affecting the coastal environment.	Temporary coverage of road assets (e.g., road pavement) located at low altitude, in close proximity to the seaside. Damage of coastal road infrastructure (bridges, road furniture, etc.). Potential accidents, injuries/deaths.	- Measurement of potential sea-level anomalies - Duration of tidal sea-level rise, etc.
		Landslides/Rockfalls (as a result of coastal erosion)	A mass of material that has moved downhill because of gravity, often assisted by water when the material is saturated. Sea-level rise may cause landslides due to coastal erosion.	Displacement/instability or even collapse of road assets (e.g., bridges, retaining structures, etc.) located within an area that is prone to landslides.	- Water level and wave energy - Soil type - Slope angle, etc.
PRECIPITATION	ACUTE HAZARDS	River Flood	The overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas that are not normally submerged.	- Operational disruption due to coverage of the road pavement with water. - Scouring of bridge foundations and subsequent failure.	- Measurement of flood height - Peak water velocity - Maximum 24-hour flood volume - Total flood volume per month/year - Frequency of flood events per month/year, etc.
		Urban Flooding	Accumulation of water in urban areas due to extreme precipitation and failure of the drainage system.	- Operational disruption due to coverage of the road pavement with water - Damage of the road furniture - Potential accidents	- Measurement of flood height - Peak water velocity - Maximum 24-hour flood volume - Total flood volume per month/year - Frequency of flood events per month/year, etc.
		Coastal Flood/Storm Surge	The temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions (precipitation, low atmospheric pressure and/or strong winds).	Periodic increase of sea level may affect low-altitude road assets; water could cover the pavement and cause operational disruptions and/or car accidents.	- Measurement of potential sea-level anomalies - Duration of sea-level rise, etc.
		Landslides/Debris Flow	A mass of material that has moved downhill because of gravity, often assisted by water when the material is saturated.	Displacement/instability or even collapse of road assets (e.g., bridges, retaining structures, etc.) located within an area that is prone to landslides.	- Soil type - Soil permeability - Slope angle - Groundwater level - Pore - water pressure, etc.
		Snowfall/Hail	A form of precipitation consisting of individual ice crystals (snow) or solid ice (hail).	Operational disruption and damage of road furniture. Accidents may occur due to ice/snow on the pavement.	- Amount of snow per month/year and seasonal change of precipitation patterns - Maximum hail size - Duration of the event - Frequency of hail events or extreme snowfall per year - Speed of ice, etc.
TEMPERATURE	CHRONIC HAZARDS	Excessive Heat	Temperature that is rare (unusually high) in a particular place and at a particular time of year (i.e., higher than the 10th or 90th percentile of a probability density function estimated from observations).	- Asphalt rutting, flushing, and bleeding of bituminous surfaces and/or cracking. - Loss of bitumen stiffness and subsequent permanent deformations due to traffic loading. - Decrease of productivity during construction, operation and maintenance due to unhealthy working conditions.	- Maximum temperature per month/year - Number of summer days (e.g., days with maximum temperature >25°C) per year, etc.
		Excessive Cold	Temperature that is rare (unusually low) in a particular place and at a particular time of year (i.e., lower than the 10th or 90th percentile of a probability density function estimated from observations).	- Asphalt rutting, flushing and bleeding of bituminous surfaces and/or cracking. - Loss of bitumen stiffness and subsequent permanent deformations due to traffic loading. - Decrease of productivity during construction, operation and maintenance due to unhealthy working conditions.	- Minimum temperature per month/year - Number of cold days (e.g., days with maximum temperature < 20°C), etc.
	ACUTE HAZARDS	Drought	A period of abnormally dry weather lasting long enough to cause a serious hydrological imbalance. Drought is a relative term and must refer to the particular precipitation-related activity that is under discussion.	- Increased mortality of plants along road alignments (planted slopes, embankments, etc.). This may subsequently increase risk of flooding, landslides, etc. - In combination with temperature rise, drought may cause asphalt deterioration.	- Standardized precipitation index (SPI) - Soil moisture, - Groundwater and reservoir storage - Length of the longest period of consecutive days without rain, etc.
		Ice Melt/Permafrost Thaw	Progressive loss of sea ice, glacier, or ground (soil or rock, including ice and organic material) that remains at or below 0°C for at least two consecutive years.	Displacement/instability or even collapse of road assets located within a permafrost area prone to melting and ice displacement.	- Sub-surface temperatures - Near permafrost surface air temperature - Melting ratio - Ice displacement per year, etc.
		Wildfires	Uncontrolled fires that burn in wildland vegetation, often in rural areas.	- Partial operational disruption of road network. - Destruction of plantation along road alignments.	- Total number of fires per month/year (frequency) - Total land area burned (magnitude) - Age of forest and plantation - Humidity of the area, etc.
WIND	ACUTE HAZARDS	Tornadoes/Twisters/ Hurricanes/Tropical Cyclones	A violently rotating column of air touching the ground, usually attached to the base of a thunderstorm. In the case of tropical cyclones, the term refers to a strong, cyclonic-scale disturbance that originates over tropical oceans.	Tree falls, signpost failures, difficulty in driving, and consequent operational disruptions and accidents.	- Maximum wind speeds - Frequency of tornadoes per month/year - Maximum wind gust speeds per month/year - Number of consecutive days with extreme wind (i.e., speed > 70 mph) per month/year, etc.
		Dust Storms	The result of terminal winds raising large quantities of dust into the air and reducing visibility at eye level (1.8 meters) to less than 1,000 meters.	Coverage of network assets with dust and consequent operational disruption and/or car accidents.	- Dust particle concentrations, - Dust storm average duration, etc.

Library B.2.2a Indicative vulnerability indicators of road assets exposed to **sea-level rise**

Asset Category	Vulnerability Indicators	Measures	Rationale
Coastal roads	Road elevation	- Relative elevation to sea level (mean, highest tidal, etc.)	Road segments with higher elevation are less vulnerable to inundation.
Coastal roads	Existence/ condition of sea-side protection	- Structural condition - Maintenance (e.g., visual signs of corrosion) - Previous incidents of overflows	Retaining walls, dikes, sea walls or other flood defense infrastructure will protect the road from sea-level rise hazards and reduce road vulnerability.
Coastal roads	Historic coastal erosion development	- Distance from road - Progressive rate of erosion (e.g., annual erosion rate) - Exposed tree roots, rocks, stream-like indentations	Roads at locations where coastal erosion has already occurred and is already progressing are likely to be impacted first.
Coastal roads	Exposed adjacent areas	- Distance from road - Inundated area during past events	Even if the road is protected against sea-level rise, road inundation may occur by inflowing water from adjacent flooded areas.
Coastal roads/ bridges	Foundation soil	- Lithological classes - Permeability - Strength properties	Different types of soil have different strength, deformability, and drainage characteristics, and thus can be less or more susceptible to erosion and subsidence.
Natural slopes or cuts	Bedrock material	- Geology - Historic landslides (e.g., signs of displaced soil, inclined trees, etc.) - Stream hydrography and erosion	- Different geological units have different susceptibility to landslides. - Areas that have historically experienced landslides are more generally vulnerable. - The existence of springs and high ground-water level increases the risk of landslide.
Natural slopes or cuts	Slope	Inclination	Increasing inclination increases the risk of landslides.

Library B.2.2b Indicative vulnerability indicators of road assets exposed to **extreme precipitation events**

Asset Category	Vulnerability Indicators	Measures	Rationale
Road section	Elevation	- Relative elevation	Road segments with low elevation in relation to the adjacent areas are more prone to inundation.
Road section	Proximity to waters (rivers, streams, lakes, shoreline, coastline, etc.)	- Distance	Road segments closer to inland waters are more likely to flood in case of an extreme event.
Road section	Land use/cover	- Type of use/cover (e.g., dense/coarse vegetation, dense/coarse built areas, etc.)	Road segments that are located near different types of land use/cover have different susceptibility to floods (e.g., a densely vegetated area is less likely to flood in comparison to a parking area with asphalt).

Asset Category	Vulnerability Indicators	Measures	Rationale
Road section	Status of existing drainage network on which the road drainage system depends	- Frequency of maintenance - Drainage capacity	The sufficiency and efficiency of the overall drainage network on which the road is dependent is important to avoid flooding.
Road section	Pavement type	- Porosity of the pavement material	The type and material of the pavement plays an important role in the capacity of the road to be infiltrated by, or retain water. Impermeable surfaces are more likely to experience issues with flooding or runoff water.
Road section	Road subgrade	- Strength and permeability of the subgrade material - Groundwater level	- Clay strata are more susceptible to subsidence and permanent settlements. - A high groundwater level further increases the above risk.
Road section	Road cleaning system	- Frequency of waste removal and sedimentation/debris clearing from rivers, streams, trenches, outlets, and other drainage infrastructure elements	Inefficient cleaning/maintenance can reduce the drainage capacity of the road and increase the likelihood of flooding or debris flows. Road segments with increased waste, sedimentation, or debris are more likely to experience issues first.
Road section	Water flow accumulation	- Size of contributing area	Roads that accumulate water from larger areas are more likely to flood.
Road section	Sliding risk	- Steep road gradients	Roads with increased gradients (e.g., exits/entrances of highways) are more prone to closures during intense snowfalls.
Road section	Proximity of trees	- Trimming maintenance frequency	During heavy snowfalls, trees may fall.
Drainage system	Drainage capacity of pipes/culverts/trenches or other drainage infrastructure	- Sizes, shapes, capacity	Road segments that have higher drainage capacity (overcapacity) with respect to their drainage demand (i.e., beyond design codes) present increased redundancy to flooding.
Bridges	- Structural type and foundation	- Bridge height - Bridge deck (continuous or non-continuous) - Bridge foundation (footings or piles) - Foundation soil	- Bridges with high clearance experience reduced flood stressing/impacts and thus are less vulnerable. - Bridges that are built over streams on a bed of gravel/sand are prone to scouring as the racing floodwater “scours away” the bed downstream from its piers, weakening their ability to hold up the structure. - Bridges on piled foundations are less vulnerable to scouring,
Embankments	Slope (and height)	- Inclination - Slope height	- Road embankments or cuts with very steep slopes are more likely to fail during extreme precipitation events.

Asset Category	Vulnerability Indicators	Measures	Rationale
			- High embankments are more vulnerable to displacements.
Embankments / natural slopes / cuts	Bedrock material	- Geology - Historic landslides (e.g., signs of displaced soil, inclined trees, etc.) - Stream hydrography and erosion	- Different geological units have different susceptibility to landslides. - Areas that have historically experienced landslides are generally more vulnerable to them. - The existence of springs and high groundwater levels increases the risk of landslides.
Tunnels/underground structures	Tunnel stability	- Structure weight (including the weight of the overlying soil layers) - Anchoring systems	- In extreme flood events, underground structures may experience uplift.
Tunnel/subways	Openings	- Stairways, vent bays, elevators within the surge zone	- In extreme precipitation events, storm-water may spill into the underground structure through openings, impeding operations and causing physical damage to assets and equipment. - Installation of flood gates and barriers can reduce vulnerability.

Library B.2.2c Vulnerability Indicators of road assets exposed **to heat-waves and wildfires**

Asset Category	Vulnerability Indicators	Measures	Rationale
Road pavement	Truck load/traffic	- Volume of heavy vehicle traffic - Average daily truck traffic	Road segments with higher volume of truck traffic are more likely to experience issues due to temperature rise because pavements experience heavier stress on those segments.
Road pavement	Temperature threshold in pavement binder	Threshold value	- Pavement binders are designed to withstand specific temperature thresholds. Asphalt may experience rutting if pavement temperatures exceed the high-temperature thresholds. - Polymer-modified binders are less sensitive to damage from high temperatures.
Road pavement	Past experience with temperature damage	Length of damaged road in the past	- Road segments that already experience rutting may experience worsening problems as the temperature increases.
Concrete assets (e.g., concrete pavements, bridges)	- Thermal susceptibility of concrete - Existence/ condition of concrete pavement joints	Thermal expansion coefficient of concrete	- Different types of concrete have different embedded heat tolerance, expressed as the thermal expansion coefficient. - In jointed, plain concrete pavement, the traverse contraction joints allow for load transfer without damage to the pavement, as long as the joints are functioning properly. Therefore, the condition of joints is an indicator of how likely concrete assets

			are to be damaged during high temperatures.
Embankments	Properties of the subgrade soil	Permeability, strength, deformability, thermal state, freezing-thawing cycles	- Abrupt melting of the permafrost layer is leading to frost heaving of pavements and permanent subsidence. – Clayey peat-silt strata are generally more susceptible to degradation.

Library B.2.2d Indicative vulnerability indicators of road assets exposed to **extreme wind**

Asset Category	Vulnerability Indicators	Measures	Rationale
Signals	Structural integrity	Signal height and supporting system (e.g., single pole support, frame support, etc.)	Lightweight road infrastructure that is not safely anchored may fall when subjected to extreme wind gusts.
Road	Proximity to trees	- Proximity of trees to power lines and the road - Trimming maintenance frequency	Although not a road asset, the existence of trees along the road increases the likelihood of damage during extreme wind events.
Road	Proximity to non-windproofed structures and trees	- Number of structures (e.g., large sun shade shelters, flat-style roofs, etc.) that are prone to wind damage	Road segments very close to vulnerable-to-wind structures are more likely to experience issues during extreme wind events.
Road	Proximity to power utilities	- Density of power utilities - Underground or over-ground power lines - Age of infrastructure utilities	Road segments with more power utilities and power lines above ground are more likely to experience issues during extreme wind events.
Road	Proximity to dust deposits	Density and height of wind-break walls	Wind-borne debris may cause significant disruption to the road network. The presence of wind-break walls decreases vulnerability.

Library B.2.3a List of indicative adaptation measures for road projects subjected to **sea-level rise**

	Adaptation Measures	Sea-Level Rise: Inland inundation	Sea-Level Rise: Coastal erosion	Sea-Level Rise: Tidal waves / storm surge	Sea-Level Rise: Landslides/ rockfalls	Applicable to	Risk Reduction	Preliminary Cost Considerations	Multiple Benefits: GHG emissions	Multiple Benefits: Adaptive capacity	Multiple Benefits: Biodiversity protection	Multiple Benefits: Social acceptance	Multiple Benefits: Green funding
Planning	Change road alignment	•	•	•	•	Coastal roads	High	**High cost**. Retreat from the shoreline can be expensive, unnecessary, and sometimes impossible, especially in highly modified environments.	High	Low	Low	Complete as appropriate	No
Structural (Hard Solutions)	Elevate road alignment	•		•		Causeways, bridges	High	**High cost.** Depends on the size of the road, the elevation and the availability of fill materials.	High	Low	Low	Complete as appropriate	No
	Elevate flood protection (bulkheads, seawalls, dikes)	•		•		Coastal roads, causeways, bridges	High	**Medium/High cost.** Cost largely depends on the size of the intervention, the materials and the construction method.	High	Medium	Low	Complete as appropriate	No
	Revetment/shoreline hardening (rock armoring, stone gabions)		•	•	•	Coastal roads, causeways, flood barriers	Medium	**Low cost**	Medium	High	Medium	Medium	No
	Caisson breakwaters; artificial reefs; groynes		•	•		Coastal roads, bridges; causeways	High	**Medium/High cost**	Medium/ High	Medium	Low	Medium	No
	Slope stabilization measures (landforming, littoral strip reloading, benches)				•	Coastal cliffs	Medium	**Medium cost**	Medium	High	Medium	Medium	No
	Slope protection measures (rockfall-containing system, littoral strip reloading, mesh, bolted/anchoring/shotcreted faces)				•	Coastal cliffs	High	**Medium/High cost**	Medium/ High	Low	Low	Low	No
NbS	Planting vegetation (trees, marshes/mangroves)		•	•	•	Coastal cliffs, causeways, clayey bank coast	Low/Medium	**Low cost** (installation and maintenance)	Low	High	High	High	Yes
	Beach nourishment		•			Sandy coast	Medium	**Medium cost** (installation and maintenance)	Medium	High	Medium	High	Yes
	Berms and dunes	•		•		Any coast	Low	**Low cost**	Low	High	High	High	Yes
	Natural reef breakwaters (e.g., oyster reefs)		•	•		Offshore (to all coastlines)	Low/Medium	**Low cost**	Low	High	High	High	Yes
Soft Solutions	Early warning for extreme surge conditions	•		•		Coastal roads	Medium	**Low/Medium cost**	Low	High	N/A	High	Yes
	Field monitoring of precarious slopes		•		•	Coastal Cliffs	Medium/ High	**Low/Medium cost**	Low	High	N/A	High	Yes

Library B.2.3b List of indicative adaptation measures for road projects subjected to **extreme precipitation events**

	Adaptation Measures	Increased Precipitation					Applicable to	Risk Reduction	Preliminary Cost Considerations	Multiple Benefits				
		River flood	Hurricane/ urban flooding	Coastal food/ storm surge	Landslide/ debris flow	Snowfall				GHG emissions	Adaptive capacity	Biodiversity protection	Social acceptance	Green funding
Structural (Hard Solutions)	Increase surface drainage (e.g., side drains, larger culverts, sustainable urban drainage)	•	•	•			Roads on level/rolling (mountainous) terrain	Medium	Low/Medium	Low	Low	N/A	N/A	Yes (applicable for Sustainable Drainage Systems)
Structural (Hard Solutions)	Increase subsurface drainage (e.g., drainage pipes, subgrade drainage, internal drains of retaining soil structures, etc.)	•	•		•	•	Roads on level/rolling (mountainous) terrain	Medium	Medium/High	Low/ Medium	Low	N/A	N/A	
Structural (Hard Solutions)	Fixed barriers (levees, dykes, earth mounds, solid concrete walls)	•		•			Road segments within flood plains	High	High	High	Low	N/A	Low/ Medium	
Structural (Hard Solutions)	Increased road/bridge elevation (e.g., deep bridge pillars)	•		•			River bridge, road segments within flood plains		High	High	Medium	N/A	Low/ Medium	
Structural (Hard Solutions)	Embankment/scour protection (e.g., rock riprap, subsoil protection)	•	•	•			Road segments within flood plains, causeways, bridges	Medium	Medium	Medium	Medium	N/A	N/A	
Structural (Hard Solutions)	Elevate entrances/install floodgates in underground facilities		•				Underwater road tunnels	High	High	High	Low	N/A	N/A	
Structural (Hard Solutions)	Surface treatment on roadway (anti-skid surface, permeable/reservoir pavements, ice fencing)					•	All roads, bridges	Medium	Low/Medium	Medium	Medium	N/A	N/A	
Structural (Hard Solutions)	Slope protection measures (retaining structures, surface-protection measures)				•		Roads on rolling (mountainous) terrain	High	Medium/High	Medium/ High	Medium	N/A	N/A	
NbS	River/lake restoration	•	•				Rural roads	Low/Medium	High	Low	High	High	High	Yes
NbS	Nature-based hydraulic measures to infiltrate and store rainwater	•	•	•			All roads	Low	Low	Low	High	Medium	N/A	
NbS	Restore/maintain urban greenery	•	•	•	•		All road	Low	Low	Low	High	High	High	
Soft Sol.	Monitoring options for drainage, maintenance/repair	•	•	•			All roads	Low/Medium	Medium/High	Low	High	N/A	High	
Soft Sol.	Early warning for extreme weather	•	•	•		•	All roads	Low/Medium	Low	Low	High	N/A	High	
Soft Sol.	Field monitoring of precarious slopes				•		Roads on rolling (mountainous) terrain	High	Low	Low	High	N/A	N/A	

Library B.2.3c List of indicative adaptation measures for road projects subjected to **extreme heat waves** and **wildfires**

	Adaptation Measures	Temperature					Applicable to	Risk Reduction	Preliminary Cost Considerations	Multiple Benefits				
		Excessive heat	Excessive cold	Drought	Permafrost thaw	Wildfires				GHG emissions	Adaptive capacity	Biodiversity protection	Social acceptance	Green funding
Structural (Hard Solutions)	Surface treatment of roadways (e.g., anti-skid surface, porous coating, reflective coatings, adjustment of bituminous mixture)	•	•	•			All roads, bridges	Medium	Medium	High	High	N/A	N/A	
	Road subgrade treatment (e.g., remove moisture-sensitive soils)	•		•			Roads on level terrain	High	High	High	Low	N/A	N/A	
	High-albedo surfacing materials for paved surfaces				•		All roads, bridges	Low/ Medium	Medium	High	High	N/A	N/A	
	Sun sheds to protect permafrost slopes				•		Natural slopes & road cuts (roads in rolling terrain)	Low/ Medium	Medium	Medium	Medium	N/A	N/A	
	Increase thermal resistance of embankment structure (e.g., polystyrene insulation) or heat-extraction methods (e.g., heat drains)				•		All roads	High	High	High	Low	N/A	N/A	
	Restore/maintain urban greenery	•					Urban roads	Low/ Medium	Low	Low	High	High	High	
Planning	Create wildfire buffers					•	Roads close to forests	Medium	Medium	Medium	Low	Low	Low/ Medium	
Soft Sol.	Emergency-response plans (evacuation routes in case of wildfire)					•	Roads crossing forests	Medium	Medium	Low	High	N/A	High	Yes
	Fire-hazard monitoring in areas of risk					•	Roads close to forests	High	Medium	Low	High	High	High	Yes

Library B.2.3d List of indicative adaptation measures for road projects subjected to extreme winds

	Adaptation Measures	Wind		Applicable to	Risk Reduction	Preliminary Cost Considerations	Multiple Benefits				
		Tornadoes/ Twisters	Dust Storms				GHG emissions	Adaptive capacity	Biodiversity protection	Social acceptance	Green funding
Structural (Hard Solutions)	Wind-proofing of hanging signals, lights, and lightweight equipment	•	•	All roads	High	Low	Low	High	N/A	N/A	
	Installation of wind breaks	•	•	All roads	Medium	Low	Low	High	Low	Low	
	Bridge rehabilitation	•		Suspension bridges	High	Low	High	Low	N/A	N/A	
	Installation of impact protection structures	•		All bridges	Medium	Medium	Medium	Low	N/A	N/A	
Soft Solutions	Early warning (for extreme winds and low visibility conditions)	•	•	All roads	Medium	Low/Medium	Low	High	N/A	High	

Library B.2.4 List of indicative climate mitigation measures specific to road projects

	Mitigation Measures	Applicable to	GHG Reduction	Preliminary Cost Considerations	Multiple Benefits: Health benefits	Multiple Benefits: O&M cost savings	Multiple Benefits: Biodiversity protection	Multiple Benefits: Social acceptance/ aesthetic improvements	Multiple Benefits: Green funding
Construction	Efficient road vehicle fleets with a lower unit emissions ratio for material transportation	Material transportation	**Medium**: approximately 50 percent decrease in unit emissions and savings of more than 20 percent in total transport emissions	Medium	Low	N/A	N/A	N/A	N/A
Construction	GHG efficient methodologies for excavation of hard soil (such as explosives)	Earthworks	**Low:** explosives seem to produce less emissions than other excavation methodologies for hard soil	Low	N/A	N/A	Low	Low	N/A
Construction	Reduction in the use of lime as a means to stabilize soil	Earthworks	**Low**	Low	High	N/A	Medium	N/A	N/A
Construction	Optimized pavement structures (high-performance bituminous mixtures and continuously reinforced concrete pavement [CRCP] on bituminous base)	Pavements	**High:** depending on the level of efficiency, construction method may reduce significantly the total GHG of the road construction	Medium	N/A	High	N/A	Low	N/A
Construction	Cold pavement mixtures as well as recycled/reclaimed aggregates and materials	Pavements	**Medium**	Medium	N/A	Low	Medium	Medium/High	N/A
Construction	Use of alternative barriers (such as wood or plantation)	Barriers	**Medium**	Low/Medium	Medium	Low	High	High	N/A
Construction	Usage of renewable energy during construction—installation of photovoltaic systems	Road network	**Medium**	High	Medium	N/A	Medium	Medium/High	Yes
Construction	Optimization of construction to reduce transportation of materials	Road network	**High:** depending on the level of efficiency, the construction method may reduce significantly the total GHG emissions of the road construction	Medium	Medium	Low	Low	N/A	No
Construction	Usage of eco-friendly textiles (instead of plastic or steel) for mechanically stabilized walls	Retaining structures	**Medium**	Medium	N/A	N/A	Medium	Medium	No

	Mitigation Measures	Applicable to	GHG Reduction	Preliminary Cost Considerations	Multiple Benefits				
					Health benefits	O&M cost savings	Biodiversity protection	Social acceptance/ aesthetic improvements	Green funding
O&M	Limiting rolling resistance caused by pavement texture (considering safety regulations and specifications)	Pavements	**Medium:** limiting asphalt resistance may significantly reduce traffic emissions. However, safety issues should be considered in the implementation of such solutions	Low	N/A	N/A	N/A	N/A	No
O&M	Installation of street-lighting systems powered by renewable energy (e.g., solar panels)	Lighting	**Low**	Low	N/A	Medium	N/A	High	Yes/ No
O&M	Energy-efficient lighting systems (e.g., LED lighting)	Lighting	**Low**	Low	N/A	Medium	N/A	Medium	Yes/ No
O&M	Installation of electric vehicle charging stations	Road network	**High:** electric vehicles could be among the most efficient solutions for GHG reductions in road operation	Medium	High	N/A	N/A	Medium/High	Yes
O&M	Inclusion of e-mobility lane	Road network	**Medium:** inclusion of e-mobility lane would promote the use of electric vehicles	Low	High	N/A	N/A	Medium	Yes
O&M	Introduction of speed limits to mitigate GHG emissions	Road network	**Low / Medium**	N/A	Medium	Medium	N/A	Low	No
O&M	Maintain asphalt in good condition (no breaks and cracks), aiming to reduce vehicle GHG emissions	Pavements	**Medium / High:** maintaining the pavements in good condition significantly reduces traffic emissions	Low/Medium	Medium	Low	N/A	High	No
NbS (affecting Construction and O&M)	Planting vegetation (across the road network)	Slopes, retaining structures, barriers, embankments	**Medium / High**	Low	Medium/High	N/A	High	High	Yes
NbS (affecting Construction and O&M)	Nature-based hydraulic measures to infiltrate and store rainwater	Drainage	**Medium**	Medium	Medium/High	N/A	Medium/High	Medium/High	Yes
NbS (affecting Construction and O&M)	Blue-green solutions (limiting the amount of concrete structures, e.g., gabion walls instead of concrete walls)	Road network	**Medium**	Low	Medium / High	N/A	High	High	Yes
NbS (affecting Construction and O&M)	Restore/maintain greenery in urban and rural areas	Road network	**Low / Medium**	Low	High	N/A	High	High	Yes
NbS (affecting Construction and O&M)	NbS for erosion protection (e.g., use of plantation for protection of coastal embankments)	Retaining structures, bridges, embankments	**Low**	Low/Medium	Medium/High	Medium	High	High	Yes

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