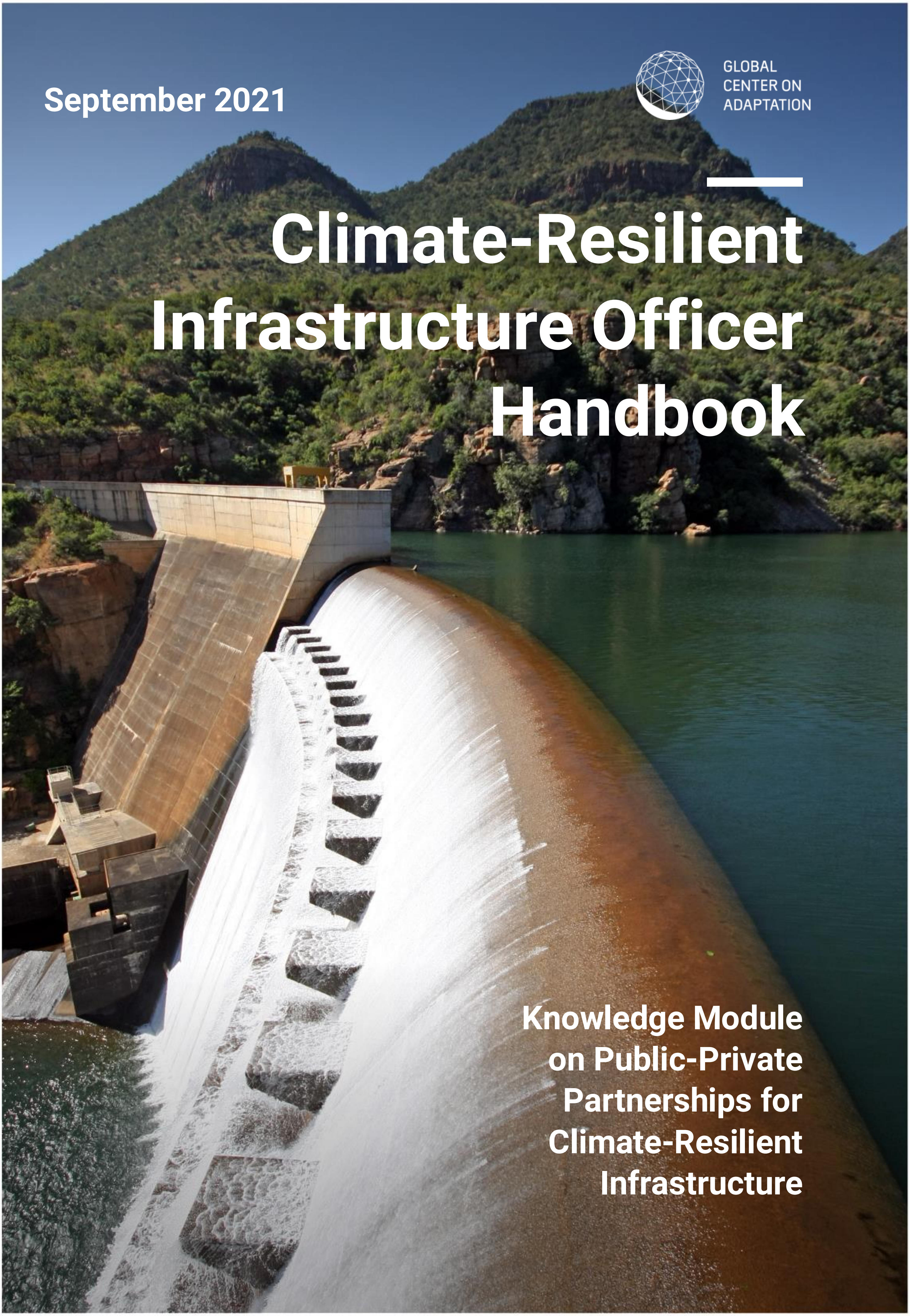

September 2021

GLOBAL CENTER ON ADAPTATION

# Climate-Resilient Infrastructure Officer Handbook

## Knowledge Module on Public-Private Partnerships for Climate-Resilient Infrastructure

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ADB

AFRICAN DEVELOPMENT BANK GROUP

European Bank for Reconstruction and Development

Global Infrastructure Facility A G20 INITIATIVE

IDB Inter-American Development Bank

IsDB البنك الإسلامي للتنمية Islamic Development Bank

PPIAF Enabling Infrastructure Investment

UNOPS

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# Acronyms

| Acronym | Full title |
|---|---|
| ADB | Asian Development Bank |
| AfDB | African Development Bank |
| BAFO | Best and Final Offer |
| BCR | Benefit-Cost Ratio |
| BRT | Bus-Rapid Transit |
| BVOCS | Biogenic Volatile Organic Compounds |
| CapEx | Capital Investment Costs |
| CBA | Cost Benefit Analysis |
| CBD | Convention on Biological Diversity |
| CRIDA | Climate Risk Informed Decision Analysis |
| CRIOs | Climate-Resilient Infrastructure Officers |
| CSOs | Civil Society Organizations |
| DBFOM | Design, Build, Finance, Operate, Maintain |
| DRR | Disaster Risk Reduction |
| EBRD | European Bank for Reconstruction and Development |
| EPC | Engineering, Procurement and Construction |
| ESIA | Environmental and Social Impact Assessment |
| ESG | Environmental, Social, and Governance |
| EU | European Union |
| GCA | Global Center on Adaptation |
| GCF | Green Climate Fund |
| GIHub | Global Infrastructure Hub |
| IDB | Inter-American Development Bank |
| IFC | International Finance Corporation |
| IISD | International Institute for Sustainable Development |
| ILO | International Labour Organisation |
| INDCs | Intended Nationally Determined Contributions |
| IPCC | Intergovernmental Panel on Climate Change |
| ITS | Intelligent Transport Systems |
| IUCN | International Union for Conservation of Nature |
| KPI | Key Performance Indicator |
| LDCs | Least Developed Countries |
| MCA | Multi-criteria analysis |
| MTRC | Hong Kong’s Mass Transit Railway Corporation |
| NAPs | National Adaptation Plan |
| NAPA | National Adaptation Programme of Action |
| NbS | Nature-based Solutions |
| NDCs | Nationally Determined Contributions |
| NGOs | Non-Governmental Organizations |
| NOAA | National Oceanic and Atmospheric Administration (USA) |

ACRONYMS

| Acronym | Full title |
|---|---|
| NPV | Net Present Value |
| OBC | Output Based Contracting |
| OpEx | Operation and Maintenance Costs |
| PPCR | Pilot Program for Climate Resilience in Nepal |
| PPIAF | World Bank's Public-Private Infrastructure Advisory Facility |
| PPPs | Public-Private Partnerships |
| R2R | Ridge to Reef |
| RCP | Representative Concentration Pathways |
| RDM | Robust Decision Making |
| RFP | Request for Proposal |
| RFQ | Request for Quotation |
| RRS | Resilience Rating System |
| SDGs | Sustainable Development Goals |
| SEP | Stakeholder Engagement Plan |
| SIA | Social Impact Assessment |
| SIDS | Small Island Developing Nations |
| SPV | Special Purpose Vehicle |
| TCFD | Task Force on Climate-related Financial Disclosures |
| TOR | Terms of Reference |
| UNAM | National Autonomous University of Mexico |
| UNDP | United Nations Development Programme |
| UNDRR | United Nations Office for Disaster Risk Reduction |
| UNEP | United Nations Environment Programme |
| UNFCCC | United Nations Framework Convention on Climate Change |
| UNOPS | United Nations Office for Project Services |
| VfM | Value for Money |
| WACC | Weighted Average Cost of Capital |
| WWTP | Wastewater Treatment Plant |

WELCOME

**Welcome to the Climate-Resilient Infrastructure Officer (CRIO) Handbook.** This Handbook is part of the Knowledge Module on Public-Private Partnerships (PPPs) for Climate-Resilient Infrastructure, which has been developed by the Global Center on Adaptation (GCA) and its partners to provide PPP practitioners with the tools and knowledge required to structure investment programs that incorporate climate resilience into infrastructure PPPs. The goal of this Handbook is to promote climate-resilient infrastructure to PPP practitioners, ensuring that new and existing projects account for physical climate risks, are able to adapt to future climate, socio-economic and technological change scenarios, and harness the potential of Nature-based Solutions (NbS) across the infrastructure lifecycle. This Handbook is composed of five modules:

**Module 1** – Introduction

**Module 2** – Overview of resilient infrastructure

**Module 3** – Key tools and capacities to integrate climate resilience into PPPs

**Module 4** – Furthering the enabling environment for climate-resilient PPPs

**Module 5** – Embedding resilience in the framework of a PPP

**The main audience for this Handbook are practitioners from:**

- Practitioners from the public and private sector, including infrastructure operators, asset managers, investors and financiers, NGOs and International Organizations, directly working with infrastructure PPP projects at country, regional and/or city-level;
- Decision makers working at national, regional and local level, from ministries and governmental agencies, as well as PPP Units, that hold responsibility to make decisions to structuring, implementing and advising PPP programs; and
- Technical staff of multilateral banks from both infrastructure and climate programs that work with infrastructure projects and development of country programs.

These practitioners should be able to advocate for and integrate climate resilience into infrastructure PPPs within their organization and with clients. Ultimately, the Knowledge Module on PPPs for Climate-Resilient Infrastructure, will provide the capacity for Climate-Resilient Infrastructure Officers (CRIOs) to apply the concepts of this Handbook upstream to transform policies, plans and strategies, and downstream to develop climate-resilient infrastructure PPPs.

# Executive Summary

Climate-related shocks and stresses are increasing in frequency and magnitude, causing damages to infrastructure systems and disruptions in the provision of services. Yet there is not sufficient investment needed to infrastructure systems' climate resilience. The global urban infrastructure investment gap alone is estimated to be over US$4.5 trillion per year, with a premium of 9-27% is required to make infrastructure low carbon and climate- resilient[1]. Public-Private Partnerships (PPPs) are a key entry-point to mobilise private sector finance to bridge this gap and must be resilient to climate change and work to build the resilience of the communities they serve. The Climate-Resilient Infrastructure Officer (CRIO) Handbook provides tools and guidance on how PPP practitioners can best integrate and advocate for climate-resilient infrastructure.

## Leveraging Nature-based Solutions for climate-resilient PPPs

Nature-based Solutions (NbS) are cost-effective solutions that provide benefits to the environment, economies and communities, and therefore are critical to enhance resilience through infrastructure. They can reduce the impact of disasters and increase the resilience of people, assets and ecosystems while supporting communities to adapt to a changing climate - for example, by the use of mangroves to buffer against sea-level rise and associated storm surges. PPPs can provide a vehicle to finance and scale up the implementation of NbS and promote the integration of NbS to enhance resilience of infrastructure from project identification. NbS should also be mainstreamed into the resilience options appraisal to adapt to and mitigate identified climate risks of an infrastructure project when adequate.

## Making decisions about climate risk and uncertainty

Addressing climate risk in a PPP project requires having a keen understanding of what uncertainty is in the context of climate change, how to manage it. Even under uncertain conditions, decisions still need to be made and practitioners must develop ability to model climate scenarios to better design and cost robust and flexible solutions that account for climate risks. The public and private partners need to accept uncertainty of climate risks, account for future climate scenarios in the decision-making, and prioritize solutions that have positive benefits and reduce vulnerability.

## Improving the enabling environment for climate-resilient PPPs

The public partner can proactively mainstream climate resilience into infrastructure planning by identifying and prioritising projects that relate to their climate commitments (e.g. Paris Agreement, Nationally Determined Contributions or National Adaptation Plans). The public partner needs to better understand and communicate current and future climate risks, including through data collection and monitoring, modelling climate impacts to identify costs and benefits, and integrating climate risks into design and resilience options. This will facilitate the mobilization of private capital and incentivize better investment in climate resilience. It is also necessary for the public partner to proactive invest in adaptation, mainstream climate-resilient standards, and integrate participatory process.

The private partner should integrate best practices of climate resilience into infrastructure investment, design, operations, and maintenance. This includes embedding climate resilience into PPP contracts through resilient design and Key Performance Indicators (KPIs), as well as setting higher resilience benchmarks into O&M standards and leveraging data to monitor resilience options and maximize benefits of current and future projects. Building in resilience will be key to make PPPs bankable and allow them to tap into a growing market of green finance.

Lenders should consider innovative financing and funding mechanisms to support resilience, including concessional and blended finance, with Multilateral Development Banks (MDBs) playing a key role, and aligning their investments with green finance principles. The end user, citizens and communities directly affect by the project, should play a key role in designing and delivering climate-resilient PPPs as they have knowledge on-the-ground, will be the first to be affect by climate hazards and are the beneficiaries of the services provided by infrastructure.

## Integrating climate resilience into the PPP project cycle

**Project Identification Phase:** Infrastructure needs to be resilient to climate impacts (resilience *of* infrastructure) and to help build the resilience of the communities it services (resilience *through* infrastructure). The project identification phase is the critical point in which the public partner can prioritise projects that build resilience *through* infrastructure. The public partner should already understand the key climate hazards relevant to the project by conducting a high-level climate risk screening.

**Project Appraisal Phase:** The project appraisal phase is where the public partner can integrate principles around decision-making under uncertainty. In this phase, practitioners will assess the key climate hazards, exposure, and vulnerabilities of infrastructure assets and systems. Resilience options to mitigate and adapt to the climate risks, including Nature-based Solutions, will then be identified and appraised to assess their robustness under different future climate scenarios. The preferred resilience option can either be indicated by the public partner in the tender documents or left to the private partner to propose their preferred solution. The vital input from the project appraisal would provide the key inputs to structuring a climate resilient bankable PPP.

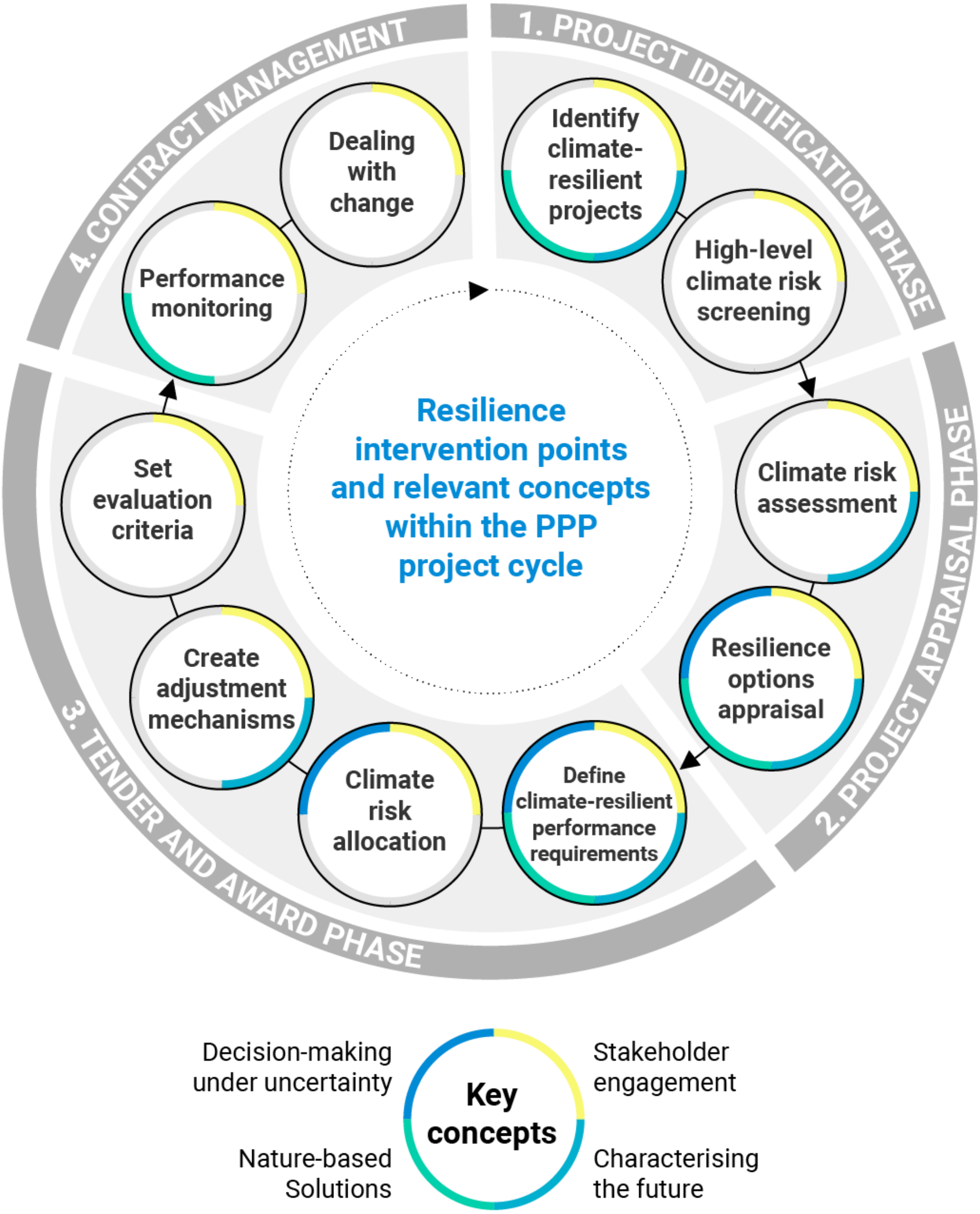
**Tender and Award Phase:** This is the important stage of ensuring a competent investor selection with climate resilience as a core component. Market sounding and dialogue processes should be considered at this stage because it allows for the public and prospective private partners to discuss and refine the Request for Proposal (RFP) and document to ensure the balance in risk allocation. This is useful when managing climate risk uncertainty and particularly well-suited in projects with multiple and complex solutions. Climate risk allocation must ensure that risks and uncertainties are explicitly stated and that there is a clear boundary for extreme climate events to constitute force majeure.

**Contract Management Phase:** The PPP contract supervising agency plays a key role in monitoring the achievement of performance requirements and situations of high climate risk. Proactive engagement with the PPP contractor can help to deal with changes and ensure that best practices in climate resilience are incorporated in operations and maintenance. Monitoring and reporting can also inform future projects and optimize resilience benefits.

Overall, best practice across the PPP project cycle includes:

- Integrating climate risk and resilience expertise among public and private partners
- Tailoring performance metrics to address climate risk and resilience
- Defining time horizons, climate risks and uncertainties
- Explicitly outlining the boundaries of when an extreme climate event would constitute force majeure, outside which the private partner must accept responsibility for repair and recovery costs, and incentivizing resilient design
- Promoting collaborative and participatory processes and maintaining communication channels with all stakeholders, including end users, throughout the project lifecycle
- Mandating maintenance history from the private partner during Contract Management Phase to identify trends in climate change risk and inform future projects

## Resilience intervention points and relevant concepts within the PPP project cycle



# 1. Module 1 – Introduction

**Description:** This Module will provide the foundational background for the course, including a refresher on infrastructure financing and Public-Private Partnerships (PPPs). It also describes the current climate context and outlines existing and possible future climate risk in all its dimensions to inform the planning, financing and implementation of infrastructure projects.

**Learning outcomes:** At the end of this module, learners will be able to

- Explain key concepts around climate change risk and resilient infrastructure
- Explain how PPPs relate to climate resilience
- Explain the case for climate-resilient infrastructure

Our lives and livelihoods are built within and around systems of infrastructure. When we turn on the lights, open the water tap, cycle to work, or call our families from a country away, we are using infrastructure. Infrastructure directly **provides** essential services, such as water and energy, to individuals and businesses. It also **connects** us to key services, such as healthcare and education, and enables us to participate in social and economic activity, by facilitating travel to work or cultural spaces. Infrastructure also **protects** people from climate-related hazards and helps them respond more effectively during and after crises.[2]

However, with every passing year, infrastructure systems are increasingly stressed as a result of growing population and increasing impacts of climate change. In developing countries, this is compounding an already existing infrastructure deficit. Floods, storms, extreme temperatures, wildfires, landslides, permafrost melting, scour, coastal erosion, and other environmental hazards are impacting the performance of infrastructure networks and assets. These impacts will be exacerbated over the coming decades and therefore there is the need to invest in making existing and future infrastructure more resilient to climate change.

This Handbook refers to climate-resilient infrastructure in two ways:

- **Resilient infrastructure** – (also termed resilience *of* infrastructure) Infrastructure that is planned, designed, built, operated, and maintained in a way that anticipates, prepares for, and adapts to changing climate conditions. It can also withstand, respond to, and recover rapidly from disruptions caused by these climate conditions[3]. For example, developing drainage systems to ensure that a road network does not experience washouts.
- **Infrastructure for resilience** – (also termed resilience *through* infrastructure) Infrastructure put in place primarily to increase the resilience of a targeted community or asset by reducing exposure and vulnerability to a climate hazard, or increasing the adaptive capacity of the community or asset. For example, a coral reef restoration to mitigate the risk of tidal/coastal flooding.

Several aspects need to be considered to incorporate climate resilience into infrastructure provision. These include the selection of adequate resilience-building actions and the application of different guiding principles such as sustainability or the Principles for Quality Infrastructure Investment (QII). The latter are endorsed by the G20 to be incorporated in all infrastructure projects – including those governed by PPPs. The six QII Principles are as follows[4]. Principle four specifically relates to climate resilience, however meeting all of these principles is necessary to enhancing infrastructure systems' resilience overall.

1. Maximise the positive impact of infrastructure to achieve sustainable growth and development
2. Raise economic efficiency in view of life-cycle cost
3. Integrate environmental considerations in infrastructure investments
4. Build resilience against natural disasters or other risks
5. Integrate social considerations into infrastructure investment
6. Strengthen infrastructure governance

This Handbook will also highlight a specific type of resilience-building action that incorporates resilience into infrastructure called **Nature-based Solutions (NbS).** NbS are cost-effective solutions that work with nature, provide benefits to the environment, economies and communities, and enhance the resilience of infrastructure. We will delve further into this topics in Module 2.

## 1.1. Refresher on PPPs

This section provides a brief refresher on PPPs to orient the discussion on how PPPs relate to climate-resilient infrastructure. **Appendix A** details key PPP definitions, although some of these definitions will be discussed in this section. For those who wish for a more in-depth refresher or feel the need for more foundational understanding of PPPs, refer to the APMG Public-Private Partnership (PPP) Certification Guide and associated training.

Traditional infrastructure actors, such as governments and state-owned utility service providers, are under financial pressure as the demand for public infrastructure exceeds available public finance. Budgets are strained and will likely remain strained in the mid-term. These actors are increasingly looking to private investment to address and bring efficiencies to this shortfall of public finance. PPPs and private financing offer a strong incentive mechanism for optimizing capital and operational investments, reinforced by the lenders oversight. PPPs allow for incentives from lenders, project owners and the government to be aligned around efficiency.

Under public budgetary constraints, new sources of private sector capital will also need to support infrastructure investment at the scale necessary for sound development. Private sector participation can inject much-needed investment or bring other benefits. It can include end-user benefits of a more competitive environment and improve operational performance of publicly run utility services, in part through mobilisation of the private sector's technological expertise and managerial competences in the public interest[5] (see **Box 1**).

**Box 1** Considerations for using private sector participation in infrastructure

Infrastructure investment involves contracting processes that are more complex and of longer duration than in most other parts of the economy. These investments must ensure financial sustainability while meeting user needs and public goals provision.

Bringing in international investors is even more challenging as they are sensitive to commercial risks involved in working in unfamiliar local environments and very exposed to public opinion and political scrutiny. Creating an enabling environment with robust PPP policies and enforcement is necessary to provide the conditions for international investors to have stronger confidence to invest in infrastructure projects.

The choice between public and private provision and financing of infrastructure services should be guided by an objective assessment of what best serves the public interest. Factors to be taken into account include current levels of service delivery and the condition of assets, affordability to households and companies, coverage of networks, operational efficiency, long-term maintenance of assets, and social and environmental sustainability.

The decision to involve the private sector has to be guided by an assessment of the relative long-term costs and benefits, and availability and reliability of private or public finance options. It should also take into account the pricing of risks transferred to the private operators and prudent fiscal treatment of risks remaining in the public domain[5]. Moreover, the choice of PPP is primarily guided by the assessment of whether or not procuring the project as a PPP will provide Value for Money (VfM) for the public, compared to non-PPP avenues. A successful PPP will take a significant amount of time and requires trust between the stakeholders involved.

PPPs are an option to procure and manage infrastructure assets (including systems, facilities, equipment and plants) and related services. PPPs are a means to deliver public assets and services using private equity, skills, management, and due diligence processes. This includes developing new infrastructure (known as the greenfield market) and upgrading existing infrastructure (known as the brownfield market). While there is no fixed definition of PPPs, since for different countries and political regimes there are different regulations that guide the development of PPPs, for the purposes of this module, PPPs are referred to as: **"a long-term contract between a private party and a government entity, for providing a public asset or service, in which the private party bears significant risk and management responsibility, and remuneration is linked to performance"**[6,7]. A summary of key characteristics of PPPs is presented in **Box 2**.

There are five functions for procurement: Design (D), Build (B) (or Rehabilitate), Finance (F), Operate (O), Maintain (M). Traditional procurement takes form of D, B, DB and O&M contracts, while procurement through PPPs usually refers to DBFOM, DBOM, DBO, BOT and BDFM contracts. The full spectrum of contracts and their definitions are noted in **Appendix F**.

**Box 2** Characteristics of PPPs

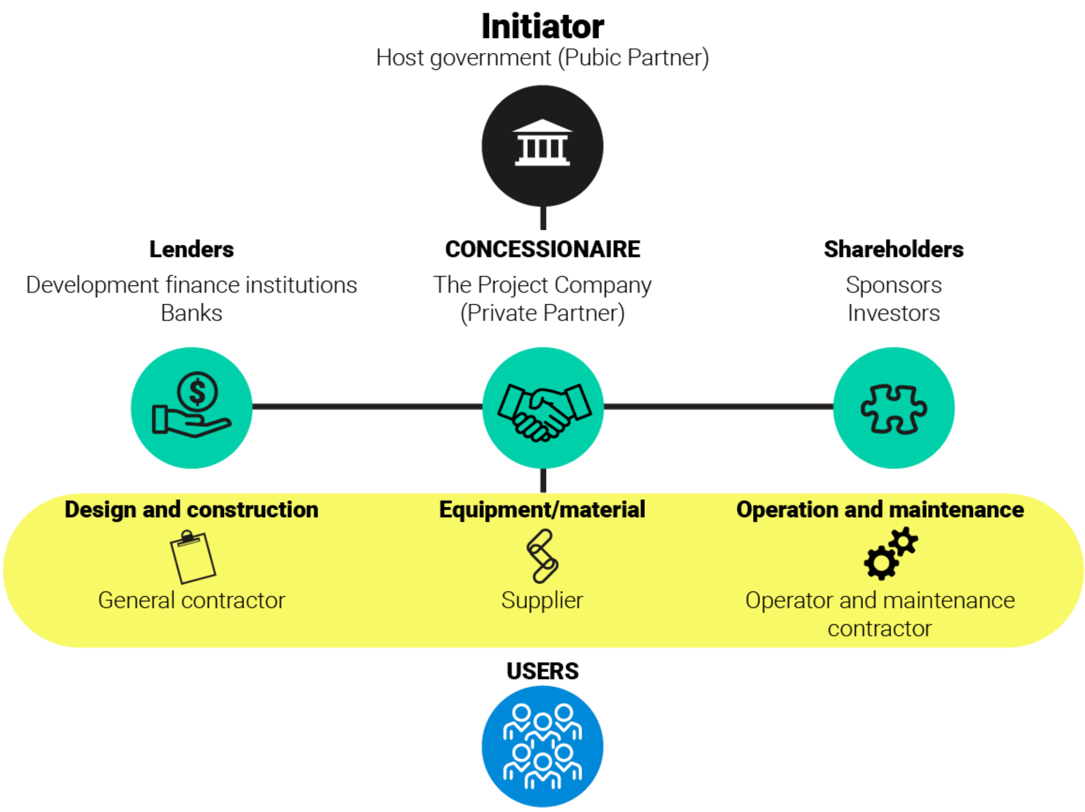
- Unique interlocutor (centralised coordination)
- Ad hoc structure
- Risk allocation
- Public & Private funding

**There are two payment mechanisms for PPPs, user-pays and government-pays.** User-pays PPPs (also known in some countries as concessions) are "a contractual assignment by a public administration to a private party of future/potential revenues associated with the public use of public infrastructure as a means to fund the procurement of the infrastructure and related services"[7]. In other words, authorities charge users for the use of infrastructure. Government-pays PPPs are a contractual assignment in which the revenue from the private partner is covered by payments done by the public partner for the availability of the infrastructure and its related services. It is important to note that for different jurisdictions the payment mechanism is what characterizes a PPP. For example, user-pays are referred to as concessions in Brazil and France, while government-pays are referred to as PPPs and the legislation varies accordingly for each type of contract.

PPPs can offer a number of benefits, including a whole-life costing approach that optimises construction, operation, and maintenance costs, better risk management – with the private sector taking on a level of assessed risk and rewarded for the extent of risk taken on – and efficient project delivery. Well-structured PPPs can help ensure that brown and greenfield projects are delivered on time, within budget and at the same time generate attractive risk-adjusted returns for investors[8].

We will now look at the typical project structure of a PPP. The project structure refers to the architecture of contract relationships and cash flows that govern the development and life of the project. **Figure 1.1** illustrates the basic structure of a common PPP[9].

**Figure 1.1** Typical PPP structure




*Source: Authors. Adapted from ADB, EBRD, IDB, IsDB, and WBG. 2016. The APMG Public-Private Partnership (PPP) Certification Guide. Washington, DC: World Bank Group. License: Creative Commons Attribution CC BY 3.0 IGO.*

The main relationship and core element of the project structure is the PPP agreement or PPP contract between the public partner (also known as the "procuring authority") and the private partner. The PPP contract is developed by the public partner and regulates the rights and obligations of the private partner to whom the development and management of the infrastructure will be delegated or contracted out. It is negotiated to an acceptable and reasonable commercial position by the parties. As the contract is the main or core element of the project structure, the terms PPP project structure and PPP project contract may be used interchangeably in this document. The PPP project structure will therefore be primarily based on the scope of the contract, which delineates the scope of responsibilities of both the public and private partner. The scope and structure may vary amongst projects of the same sector and type of infrastructure.

The project structure will also reflect the financial structure (how the private party will be compensated or paid for the works and services), the risk structure of the PPP contract (that is, how the scope of responsibilities is qualified in terms of risks and how those are allocated between the public and private partners), and other provisions. Risk is defined, identified, measured, and retained by the public sector or transferred to the private partner through specific contract terms and an appropriate payment mechanism. Risk should be allocated where it can be best managed. By "best" managed it is meant the party for whom it costs the least to prevent the risk from realising, or for whom it costs the least to deal with the consequences of realised risk. Value for Money (VfM) in PPP projects is achieved by leveraging private sector efficiency, effectiveness, and economy, and through the appropriate allocation of risks.

The private partner is usually a Project Company or Special Purpose Vehicle (SPV), specifically created with the purpose to deliver the objectives of the project. The SPV will pass through most of the rights and obligations to a downstream structure of contracts, allocating responsibilities, obligations, risks, and cash flows from the SPV to the different private and public actors through different agreements. These include:

- Shareholder's agreements (especially with financial investors).
- Financial or debt agreements.
- Construction/Engineering, Procurement and Construction (EPC) contracts and the like.
- Operation and Maintenance (O&M) contract or contracts.
- Insurance contracts and guarantees.

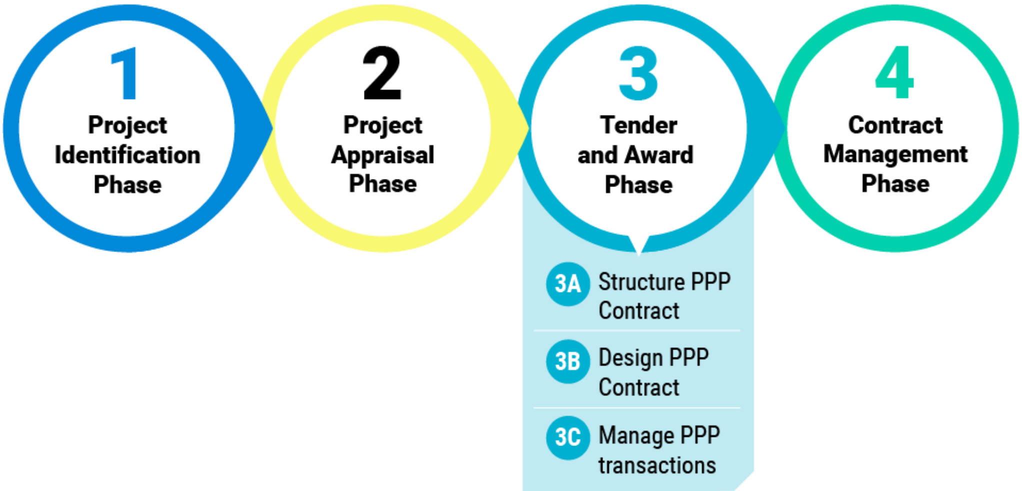
The Construction/EPC and O&M contractors, or related investment companies, are also often shareholders of the SPV. There may be other shareholders that are, in essence, financial investors with no role in the project other than acting as equity providers. However, It is not necessary to be a shareholder to act as a contractor (although the public partner may require this in some projects). Depending on the project type, it can be beneficial for the contractor not to be shareholder so that the SPV can look for VfM outside of the shareholder group.

The procurement process of PPP and conventional are similar. The difference usually lies in the methods used in each of the steps of procurement because PPP projects are in nature long-term and output focused[10].

## PPP Project Cycle

This section provides a brief review on the PPP project cycle, from project identification through design, execution and operation to maintenance (see **Figure 1.2**).

**Figure 1.2** PPP project cycle




*Source: Adapted from ADB, EBRD, IDB, IsDB, and WBG. 2016. The APMG Public-Private Partnership (PPP) Certification Guide. Washington, DC: World Bank Group. License: Creative Commons Attribution CC BY 3.0 IGO.*

1. **Project Identification Phase:** The first stage in the PPP cycle is to identify a potential PPP project. Most PPPs originate from public investment planning processes. During this process, potential projects can be screened for their ability to achieve Value for Money (VfM) through a potential PPP arrangement.
2. **Project Appraisal Phase:** At this stage, the potential project will typically be appraised as part of a detailed business case. Governments will consider the feasibility and economic and commercial viability of the project, the VfM, the fiscal implications, and the project management capacity for the project.
3. **Tender and Award Phase:** This phase incorporates several critical activities such as structuring PPPs, designing the PPP contract, and managing the PPP transactions.
   - **Structuring PPPs:** In this stage, authorities will allocate the responsibilities, rights and risks to each party to the PPP contract. This includes identifying the output required, how risk will be allocated among parties, and the mechanism by which the private partner will be paid.
   - **Designing PPP contract:** The PPP contract establishes the parties' relationship and identifies clear mechanisms to deal with change. Effectively, this stage implements the PPP structure designed into a contracted arrangement. This step also sets out the length of the PPP.
   - **Managing PPP transactions:** The aim of this stage is the selection of the competent private contractor or consortium and the identification of the most effective solution to reach the project's desired output. Most governments use a competitive tender process to procure PPP contracts.
4. **Contract Management Phase:** It includes design, execution, as well as operation and/or maintenance depending on the contract (for example. DBFO or DBFOM): This phase is usually split into two stages: design and execution (that is, asset construction) and then operation and maintenance (including monitoring the performance). PPP contracts are necessarily incomplete

in that not all potential scenarios can be accounted for in the initial structure and design. Therefore, managing the contract at design and execution stage for the grantor will consist in accompanying the private sector to develop the design and supervise delivery. This will ensure that services are consistently and continuously delivered at contractual standard while being responsive to changes in the external environment during the O&M period.

## 1.2. Refresher on PPP project finance

In PPP procurement processes, the private partner is responsible for raising and providing the funds to develop the asset (that is, for design and construction until commissioning of the asset). The private partner will need to provide all the funds or just a part of the finance if the PPP is co-financed by the public partner[6].

As mentioned previously, PPPs commonly involve the creation, by the successful bidder, of a specific company (SPV) to deliver the project. The SPV signs the contract, so all rights and obligations are assumed by the SPV. All cash flows inherent to the project are channelled through the SPV, and assets and liabilities related to the project are recorded in its balance sheet. This is commonly referred to as "ring-fencing" the cash flows.

As for any private company, the funds developed to finance the project will usually be a mix of debt and equity, which provides tax efficiency by creating a "tax shield". This provides efficiency as it diminishes the overall cost of all the financial resources, known as the weighted average cost of capital (WACC).

**For PPP projects, project finance is normally the mechanism adopted for obtaining debt financing from lending institutions.** Project finance is a specific kind of financing in which lending institutions look primarily at the expected project revenue stream as the only means for payment of the interest and repayment of the outstanding debt. PPPs are, in effect, a derivative of project finance that is typically practiced by banks and lenders backed by the public sector.

The lending institutions do not tend to look the firm's asset and liability portfolios when deciding to extend a loan. Rather, they look at a project as a distinct entity with its own project assets, project-related contracts and project cash flows segregated to a substantial degree from the entity sponsoring the project. For this reason, project finance is also known as 'limited recourse' or 'non-recourse' financing, as lenders will normally not have recourse to the entities (sponsors and shareholders) which have initiated the project if the project has difficulty in servicing the debt. This is in contrast to corporate lending in which lenders rely on the strength of the borrower's balance sheet for their loans. However, a project needs to meet several conditions to access this type of finance, including specific lender requests that relate to bankability and reasonable size to offset the higher transaction costs of the mechanism. For instance, basic considerations to access project finance include:

- An agreement to complete the project and commitment to provide all the funding necessary to fulfil the contract terms and requirements.
- Established demand for the project outputs so that the project will generate sufficient cash to meet all its operating expenses and debt servicing requirements (this relates to the adequate

financial structuring of the PPP project), particularly if the project fails to perform on account of force majeure or for any other reason. This could also be in the form of an agreement by a party purchasing the project output.

- Assurance for the availability of adequate funds during the O&M Phase of the project to maintain or restore the project to its operating standards.

Project finance consists of a balance between funding the project in the most robust form (from a risk perspective) and funding the project in the most efficient structure (from an economical perspective, optimisation). It is important to stress that the project finance structure should be designed to optimise the costs of finance for the project. It should also underpin the allocation of risks between the public and private sectors, as agreed in the PPP contract. The project financing should ensure that financial and other risks taken by the private partner are well managed within and between the SPV shareholders, sponsors and its financiers. This should give comfort to the government and procuring authority that the private partner, and particularly its funders, are incentivised and empowered to promptly deal with problems that may occur in the project. To a large extent, the project finance structure should ensure that the interests of the main lenders to the project are aligned with those of the procuring authority.

The concept of project finance requires the sponsors to adopt a unique organizational structure for the SPV described earlier. The SPV will enter into a PPP agreement with the procuring authority to design, build, finance operate and/or maintain the project, depending on the functions (i.e., DBFOM) included in the PPP agreement. This SPV has a finite life equated to the length of the PPP agreement. The sponsors are some of the main shareholders of the project company and their exposure is limited to the amount of equity investment that has been made in the project (with potential exceptions in some projects during the Construction Phase).

PPPs allow building a long-term project structure with financing at the core, where the unique value is the cash-flow that is allowed by the contract. The value is subject to:

- Good performance
- Contract structure resilience
- Protection in the face of unknown and unexpected events.

Each PPP project is different and will require an ad-hoc and tailor-made financing with the following common grounds:

- Contracts to ensure and efficient allocation of responsibilities and protection
- Long-term, secured and reliable future cash-flows to allow the initial financing of the project

Because the SPV will not have any operating history, the lenders look primarily at the projected cash flows of the project as collateral instead of the project assets, which will not have much value in the case of financial distress. The lenders will also look at the component parts of the SPV and the suitability of the stakeholders to deliver the proposed project. Lenders, therefore, require assurance that the project will be put into service on time, and that once the project is in operation it will be an economically viable undertaking. Similarly, in order to avail themselves of the funding, the project sponsors need to convince the lenders that the project is technically feasible and financially viable.

While assessing a project's viability, lenders also examine the technical feasibility, financial feasibility and creditworthiness of the project to decide whether to advance a loan or not. This assessment includes the capacity of the project to service the debt considering a certain degree of downside in the cash flows available. The Bank's Credit and Risk Committee will have final sign-off; or, in the case of an infrastructure fund, the Investment and Risk Committee will.

The technical feasibility of the project is examined to ascertain that:

- The project can be constructed within the proposed schedule and budget
- The project will be able to operate at the planned capacity and operating conditions
- Construction cost estimates, along with the contingencies for various scenarios, will prove adequate for the completion of the project

To evaluate the technical feasibility, it is necessary to consider the influence of environmental and climate risk factors on the construction of the proposed facilities and operation of the constructed facilities. When the technological processes and design envisaged for the project are unproven or on a scale not tried before, there will be a need to verify the processes and optimise the design during the project's technical feasibility. **Box 3** shows an example of a well-structured and well-functioning PPP.

**Box 3** PPPs for rail and property developments, Hong Kong

Most metro systems worldwide are heavily reliant on public financial support. However, Hong Kong's Mass Transit Railway Corporation (MTRC) has leveraged significant financial returns from the development of its network without direct government subsidies. The key to this high profitability was the PPP established between MTRC, the Hong Kong government and private developers using a 'Rail + Property' model, allowing MTRC to develop real estate above the stations of rail network.

Under the partnership, MTRC purchases the right to develop property above railway stations for 50 years from the HK government. This initial cost excludes the expected increase in value derived from the transport project when the metro will service. MTRC then contracts private developers that complete the development and pay for construction costs, as well as the land premium from the new transport project. Additionally, revenues are also derived from profit-sharing mechanisms built into the agreements between MTRC and the private developers.

The partnerships have been largely successful giving Hong Kong world-class railway service with limited financial input and strengthening the growth of local communities along the railway. On top of receiving revenue from real estate, the development of property along the railway attracts residents to amenities and housing near the stations ultimately increasing railway patronage to the benefit of MTRC. The case is highly specific to the context of Hong Kong and would need additional consideration if it were to be replicated in other cities.

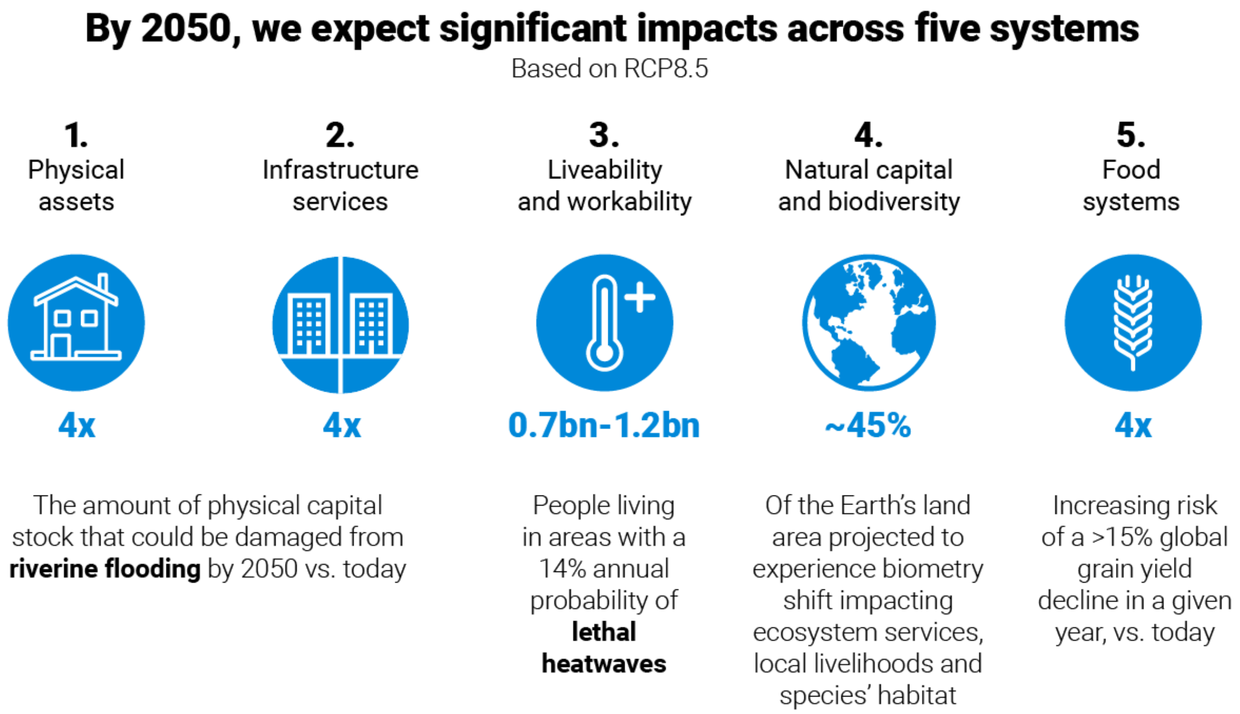
*Source: UNESCAP. 2014. Land Value Capture Mechanism: The Case of Hong Kong MTR. Available from: https://www.unescap.org/sites/default/files/Case%204_Land%20Value_Hong-Kong%20MTR.pdf [Accessed 26 January 2021].*

## 1.3. Why PPPs for climate-resilient infrastructure

The World Bank estimates a global need for urban infrastructure investments that amounts over US$4.5 trillion per year, of which an estimated premium of 9-27% is required to make infrastructure low carbon and climate- resilient[1]. At the same time, while PPPs currently comprise a limited share of total infrastructure investments, their use is accelerating. In the United Kingdom, the new framework to fund low-carbon energy-generation projects strongly resemble a traditional PPP structure[11]. Besides becoming more popular in mature economies, PPPs are also expected to play a major role in addressing the infrastructure challenges of fast-growing economies such as Africa and Asia. For example, the African Development Bank estimates that the African infrastructure financing gap ranges between $68 and $108 billion[12] and the Asian Development Bank estimates a $907 billion infrastructure financing gap[13] for Asia.

Climate-related shocks and stresses are increasing in frequency and magnitude, causing damages to infrastructure systems and disruptions in the provision of services. **Figure 1.3** notes expected impacts by 2050, with infrastructure services anticipating significant impacts. Key climate-related shocks and stresses that will likely impact infrastructure include flooding, erosion, sedimentation, extreme temperatures, drought and more unpredictability in seasonal weather patterns. It is essential that climate resilience is integrated from early stages of the infrastructure lifecycle, to ensure that new and existing infrastructure is climate-resilient. In addition, there is a multi-trillion dollar financing gap for infrastructure, coupled with a ready-to-deliver infrastructure projects[14]. Mobilising private finance will be key to close this gap and ensure that practitioners understand the need for implementing infrastructure that is resilient to the impacts of a changing climate.

**Figure 1.3** Anticipated climate impacts by 2050




*Source: Adapted from McKinsey Global Institute. 2020. Climate risk and response: Physical hazards and socioeconomic impacts. Boston.*

For investors to secure long-term returns, contracts must address the key risks inherent to all infrastructure projects, including climate risks. These risks can be managed through risk-sharing mechanisms, commonly referred to as pain and gain share, where pain (downside) is reasonable to the gain (upside) of a project and ensures that the private sector partner is not taking on unmanageable risks. Additionally, the PPP process provides several opportunities to identify risk mitigation measures, which include integrating resilience principles into project design.

PPPs are a useful way to procure climate-resilient infrastructure projects for several reasons:

**Incentive framework** – The private sector is remunerated through their participation in the PPP, either from mechanisms like user fees (e.g. highway tolls) or through availability payments, in which the public sector pays the private party based on an assessment of performance indicators. Remuneration to the private contractor is typically based on contractual project specifications, creating an incentive for the contractor to deliver the asset according to those specifications. **This provides an opportunity to include climate resilience principles into these incentive structures.**

**Output focus** – PPP structures are typically focused on outputs defined by the public client (service levels) rather than input specifications – that is, the *what* it needs to be achieved rather than *how* it needs to be achieved. **This provides the opportunity for private sector innovation, such as integrating the use of NbS in infrastructure projects from the outset.** For that, tender requirements should promote incentives for innovation and harness the benefits provided by the natural environment, for example, by giving additional points in the evaluation of bids.

**Longer duration and whole-of-life costing** – PPPs are also longer in duration than typical public sector procurement. Instead of the relationship between the public sector and the private contractor ending upon completion of constructions, the private contractor is responsible for operating and maintaining – that is, managing - the asset for a specified duration. **The long-term view of PPPs incentivises the integration of climate resilience principles into the design of the asset.** If a private contractor must be responsible for the design, operation and maintenance of the asset over several decades, it is in their interest to design the asset to be resilient to a changing climate as a means to reduce costs.

**Efficiency in recovery after a hazard occurrence** – PPPs can reduce the strain on governments by **maximizing private sector efficiencies during the operation and maintenance phase in the event of a climate hazard**. As part of the climate resilience component of the project, the private partner needs to ensure that infrastructure continuity of service is maintained in the event of a hazard, or restored rapidly. By sharing the burden of recovery, the public partner would be able to direct its resources to other aspects of recovery.

**Widespread use** –PPPs are a relatively common tool for procuring infrastructure projects across the globe. Governments and private organisations alike already have skills and capacity around these arrangements. **Climate resilience can be integrated into the PPP project cycle,** rather than (or in addition to) using novel mechanisms which would take time to gain traction.

**Risk transfer** – PPPs support risk-sharing among partners. Risks are reviewed at the outset and allocated to the partner that is best-placed to absorb and manage that risk, although in practice this may be the partner who is least able to refuse the risk. Therefore, ensuring good governance of infrastructure delivery is key. Some types of climate-resilient infrastructure, like NbS, diverge from traditional infrastructure assets, and **risk transfer from the private to the public partner can help to attract and stabilise investment into these novel types of infrastructure.** Integrating NbS into the project and not as a stand alone measure can help make the climate-resilient infrastructure project viable and bankable.

Climate resilience – when properly integrated into or supported through infrastructure – can add value for little additional cost, meaning less risk to continuity of service and potential value creation (see **Box 4**). According to the World Bank, the net present value of integrating resilience into new infrastructure assets 'exceed $2 trillion in 75 percent of the scenarios and $4.2 trillion in half of them.'[15]

**Box 4** Institutional Support to the Karnataka Urban Water Supply Modernization

In the mid-2000s, a pioneering Design, Build Operate (DBO) contract for privately operated water service in sections of Hubballi Dharwad, Belagavi and Kalaburagi cities proved that 24/7 water service was possible in India. Until then, despite the availability of enough water resources, residents in the surrounding urban area received water for only a couple of hours a day due to poor management, system leaks, and financial problems of utilities. Considering the climate stressors on remaining water resources, rather than increase the rate of water extraction, the most feasible option to address water shortages was to introduce measures to increase water use efficiency.

Financed as part of a World Bank project and with PPP contracting planning support from the PPIAF, water utilities shifted from a flat rate to volumetric billing and partnered with the private sector in the management and maintenance of water distribution infrastructure. Climate change adaptation measures to increase resilience to climate risks were included in the Environmental Health and Safety Management plan of the DBO contracts. Measures included (i) the construction of buffer strips or other methods of physical separation around project sites; (ii) Incorporation of siting and safety engineering criteria to prevent failures due to natural risks posed by earthquakes, wind, flooding, landslides and fire; (iii) Application of locally regulated or internationally recognized building codes; (iv) Internationally recognized certification of Engineers and architects responsible for designing and constructing facilities, treatment plants, service reservoirs plants and other water distribution infrastructure.

With expert-level inputs from PPIAF, the water utility managed to help the three (3) cities make strategic decisions regarding the PPP structure to tackle a major knowledge asymmetry. While it is relatively easy to estimate the investment, cost needed for treatment plants or new water pipes in a rural area, it is more challenging to know the amount of investment needed to renovate existing water pipes located underground. This posed significant uncertainty to assess the required investment amount from the private investor and the level of effort needed on the behalf of the private contractor to boost water efficiency and climate change adaptation. The PPIAF technical assistance proposed the design of a

PPP contract to get around this problem. The contract structure introduced incentive payments to encourage bidders to optimize investment through fund saving.

*Source: World Bank. Weekes, K. Diaz Fanas, G., Orekhova, S., Khamudkhanov, K. 2021. Climate adaption in infrastructure – case study examples in the PPIAF Portfolio. More information available at: https://ppiaf.org/documents/4122/download*

## 1.4. Key concepts and definitions

Incorporating climate resilience considerations into the design, construction, financing, operation and maintenance of infrastructure can be a daunting task due to the myriad of concepts that may be unfamiliar to many PPP practitioners. **Developing a strong conceptual framework of key concepts is a crucial step towards mainstreaming climate resilience considerations into the different phases of infrastructure projects.** This section provides an overview of key concepts and their definitions, which will be used throughout this Handbook. Please take time to familiarise yourself with these definitions carefully and try to understand how they relate to each other.

| Concept | Definition | Example |
|---|---|---|
| **Climate change** | A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forces such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. | Sea level rise, increased average summer temperatures; increased frequency and length of heatwaves |
| **Climate change mitigation** | A human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs). | Promoting low-carbon transport methods, such as bus-rapid transit (BRT), electric vehicles, and non-motorized transport options (e.g., cycle lanes and pedestrianized areas). |
| **Climate change adaptation** | The process of adjustment to actual or expected climate and its effects to moderate or avoid harm or exploit beneficial opportunities. Human intervention may facilitate adjustment to expected climate and its effects. | Expanding urban green space to mitigate heatwaves; building coastal defenses that include NbS such as the use of mangrove trees to buffer against sea-level rise and associated storm surges |

*Source: IPCC*[16]

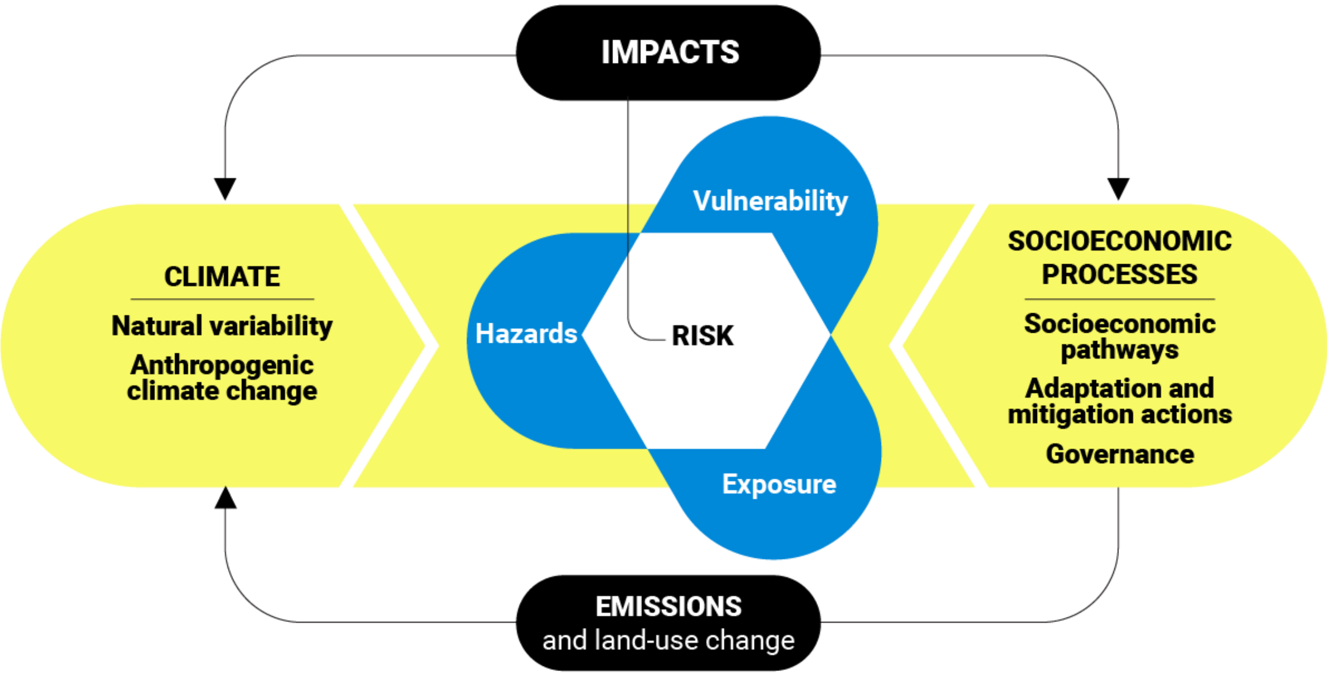
**Resilience** underpins adaptation and refers to the ability of a system and its component parts to **persist in the face of, adapt to, transform** or **recover from** the effects of a hazardous event in a timely and efficient manner – this includes the idea of bouncing back (rebuilding) and bouncing forward (transforming). We will dig further into the concept of resilience in Module 2.

## Climate risk

An important concept at the core of climate resilience is climate risk. Climate risk can be simply defined as the potential for adverse consequences of a climate-related hazard. Those practitioners familiar with risk management activities will already be aware of concepts around risk. This section situates risk in relation to climate change and its associated hazards.

In the context of climate change, new climatic conditions can produce new hazards, increase the exposure of a community to current or novel hazards, or exacerbate the vulnerabilities of infrastructure systems and communities. **Figure 1.4** shows how the Intergovernmental Panel on Climate Change (IPCC), the world's leading scientific authority on climate change, conceptually interprets risk in this context. Here, the interaction of climate change hazards with the vulnerability and exposure of a socioecological system generates new risks or increases existing ones[16].

**Figure 1.4** Risk and its component parts




*Source: IPCC, 2014: Annex II: Glossary [Mach, K.J., S. Planton and C. von Stechow (eds.)]. In: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, pp. 117-130.*

| Concept | Definition | Example |
|---|---|---|
| **Risk** | The potential of likelihood for disruption, damage and losses which would occur to an asset due to the impact of short-term shocks or longer-term stresses and changes. Risk is a function of hazard, exposure, vulnerability and capacity, recognizing the diversity of values (e.g. stakeholders perceive and experience risks differently). In the case of climate change, these risks can be caused by[17]:<br>• Meteorological hazards, which are caused by short-lived small scale conditions which last minutes to days.<br>• Hydrological hazards, which are relate to the occurrence, movement, and distribution. of surface and groundwater<br>• Climatological hazards, which are caused by long-lived processes and atmospheric conditions. Climate variability influences meteorological and hydrological hazards. | Change in rainfall patterns leading to drought and water scarcity or flooding. |
| **Hazard** | Natural or human-induced processes, phenomenon, or events that causes damage or disruption. Hazard is a function of:<br>• Frequency and probability of occurrence<br>• Intensity or magnitude of the event<br>The typical hazards of focus for climate resilience are sea level rise and tidal/coastal flooding, riverine flooding, drought, storms, wind, and wildfire. Module 2 will provide more detail around how these impact project inputs and assets. | Change in rainfall patterns (e.g. there is less or more rainfall over a period of time, and rainfall events may be more intense when they occur). |
| **Exposure** | Location, attributes, and value of people, infrastructure, housing, production capacities, and other tangible assets situated in hazard-prone areas. | A city located in an area experiencing more intense rainfall events. |
| **Vulnerability** | Conditions determined by physical, social, economic, and environmental factors or processes which increase the susceptibility to the impacts of hazards.<br>Vulnerability is a function of sensitivity and adaptive capacity. | |
| **Sensitivity** | Degree to which a system is impacted by exposure | Livelihoods based on agriculture are **sensitive** to climate-related drought. |
| **Adaptive capacity** | The ability to use all the available strengths, attributes and resources to reduce hazard-related risks, cope with adverse conditions and recover from impacts. | Farmers who have diversified their crops to accommodate for failures have increased their **adaptive capacity** to drought. |

The Inter-American Development Bank provides a helpful framework to think about vulnerability in relation to infrastructure by defining different 'project aspects' (see **Table 1.1**).

**Table 1.1** Project aspects

| Project Aspect | Description | Guiding questions |
|---|---|---|
| **On-site assets and processes** | • The asset itself and the equipment and processes required to operate it. | • What are the key onsite assets critical to the functioning of the infrastructure and delivery of related services? |
| **Project-related inputs** | • The inputs required to operate the assets such as wind for a wind turbine or water for a hydropower plant. | • Are there any key inputs – e.g., Water, power, maintenance – to make the project run? What are these key inputs? |
| **Expected project outputs** | • The ultimate products from the outputs, such as electricity from a wind turbine or hydropower plant. | • Is the project expected to generate any outputs?<br>• What services will the project provide?<br>• Would it be a critical impact to the population if the project outputs are affected? |
| **Links to other systems** | • The linkages between projects, such as power line links or transport links. | • Does the project link with any other critical infrastructure systems? For example, does the functioning of the infrastructure project require links with key transport links? Or transmission lines? |
| **Links to other decision-making processes** | • The linkages between the project and other potential decisions, such as the construction of a nearby road or deforestation. | • Is the project likely to be impacted by other decisions at regional or local levels? For example, is the project likely to be affected by other developments? Will these developments impact the project exposure? |

*Source: Adapted from IDB. 2020. Climate-resilient Public Private Partnerships: A Toolkit for Decision Makers. Washington, D.C.*

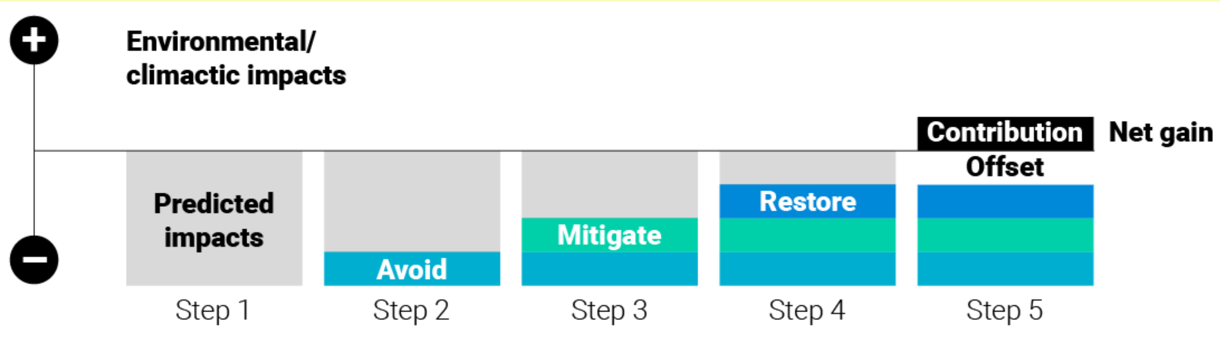
We are able to reduce risk by reducing the hazard, reducing exposure, reducing sensitivity, and increasing adaptive capacity. **Box 5** provides an example of how to frame risk reduction using the risk mitigation hierarchy.

| Concept | Definition | Example |
|---|---|---|
| **Reducing the hazard** | This involves taking active actions to reduce the magnitude, frequency, or probability of occurrence of a hazard. In the context of climate change this is related to mitigation actions which are actions aimed at reducing global warming in our planet by reducing greenhouse gases emissions. | Ensuring all adaptation options are net-zero carbon, planting trees or restoring peatlands to sequester carbon |
| **Reducing exposure** | Ensuring that key activities, resources and assets are located out of harm's way. | Building a house on stilts to prevent flooding during a storm surge |
| **Reducing sensitivity** | Take measures that reduce the susceptibility to harm | Farmers who use greywater for irrigation have reduced their sensitivity to drought or design standards that anticipate future climate change and extreme events can be another example |
| **Increasing adaptive capacity** | Increasing the ability to cope with and adjust to change. | Farmers who use drought resistant crops have increased their adaptive capacity to drought |

**Box 5** The risk mitigation hierarchy

One way to think about risk reduction is through the risk mitigation hierarchy. The risk mitigation hierarchy to guide thinking about how to prioritise resilience options (**Figure 1.5**). This is similar to the hierarchy of risk control, which engineers may be familiar with.

**Figure 1.5** Risk mitigation hierarchy




*Source: Adapted from IISD. No Year. 'Learn – Step 3: Impact Assessment and Mitigation.' Available from: https://www.iisd.org/learning/eia/eia-7-steps/step-3-impact-assessment-and-mitigation/ [Accessed 18 January 2021].*

The principle of the hierarchy is the same when applied to resilient infrastructure. The purpose is to avoid negative impacts where possible, mitigate them if they are unavoidable, ensure the project is restoring the impacted asset and, where that is not possible, offset the negative impact elsewhere to ensure there is net gain.

The next step would be to work to avoid the hazard and potential degradation caused by the project as much as possible. The project team might relocate the bike highway's planned location inland or reroute it to a less susceptible area, and then work to mitigate the amount of degradation where possible, including by integrating NbS into the design of the highway where applicable. The project team can also use the opportunity to restore the ecosystem as part of the bike highway construction process, or in ongoing maintenance of the bike highway. Where all other options are not possible or do not adequately avoid the impact, then the project team should offset or transfer the risk posed to the bike highway through flood insurance schemes or by having a dedicated, ring-fenced fund for maintenance and repair of the bike highway in the event of damage from flooding.

Expanding on the risk mitigation hierarchy, the four guiding principles of a risk mitigation strategies are to avoid risk; accept risk; reduce/mitigate risk; and transfer risk. To avoiding risk a project team could opt to work with proven and existing processes and teams to avoid the uncertainty of working with new methods or people. Accepting risk often involves sharing the risk across team or organisations through collaborations. To mitigate or reduce risk a project team may look for external technical review to increase confidence in their work. Lastly, transferring risk involves shifting the risk away from the project to another party. The most common example of this is getting an insurance.

## 1.5. Making the case for climate-resilient infrastructure

### How does climate change impact infrastructure and why does it matter?

The recent special report from the Intergovernmental Panel on Climate Change of the United Nations (IPCC), titled "Global Warming of 1.5 °C", emphasises that it is far past the time to debate whether or not we must act on climate change. Rather, the question now is the extent to which we are willing to act to avoid the potentially catastrophic impacts of unmitigated climate change.

More immediately, this reiterates the fact that the impacts of climate change are already being felt across the world, and that we are locked into a certain amount of climate change and associated impacts even if greenhouse gas emissions stopped today. As a result, infrastructure needs to be prepared to cope with the impacts of existing and future climate change impacts (see **Table 1.2**). This must be accomplished in a way that accommodates the non-stationary, non-linear, systemic, and spatially determined characteristics of climate risk.

**Table 1.2** Overview of climate change impacts to infrastructure sectors

| Sector | Potential impacts per hazard type | | | |
|---|---|---|---|---|
| | **Temperature changes** | **Changing patterns of precipitation** | **Sea-level rise** | **Changing patterns of storms** |
| **Water** | • Need for more water treatment<br>• *Higher* evaporation loss, mainly on reservoirs<br>• Need for higher storage capacity<br>• Salinization of water supply<br>• Increased water demand | • More risk of overtopping river embankments and flooding<br>• Overwhelming drainage systems<br>• Disruptions to the supply due to water scarcity<br>• Salinization of water supply | • Physical damages to assets like water and wastewater treatment plants | • Physical damages to assets like water and wastewater treatment plants |
| **Transport** | • Buckle of railway lines and melting road surfaces | • Shipping transport disruptions due to lower levels in water ways<br>• Damage to roadbed for non-paved roads<br>• Disruptions due to floods or higher water levels in water ways | • Inundation events of coastal infrastructure like ports, roads, and railways | • Physical damages to assets like bridges and coastal transportation networks<br>• Disruption of port and airport services |
| **Energy** | • Power outages or reduced output from power plants<br>• Impact on transmission lines<br>• Lack of cooling water for thermal plants<br>• Excess pressure and demand on networks from overheating | • Physical damages to assets like wind farms and distribution networks | • Inundation of coastal infrastructure affecting generation, transmission, and distribution. | • Disruptions in the supply of energy<br>• Downed power lines and transmission |
| **ICT** | • Higher demand for cooling like data centers | • Physical damages to above ground transmission (e.g., radio masts) | • Inundation events of coastal infrastructure like telephone exchanges | • Physical damages to above ground transmission (e.g., radio masts, telecom towers) |
| **Urban Develop-ment** | • Higher demand for cooling (e.g., air conditioning) | • Disruptions in distribution of basic services due to reduced water availability | • Inundation events of urban infrastructure (e.g., schools, hospitals) | • Physical damages to homes and commercial assets (e.g., buildings) |

| Sector | Potential impacts per hazard type | | | |
|---|---|---|---|---|
| | Temperature changes | Changing patterns of precipitation | Sea-level rise | Changing patterns of storms |
| Solid Waste | • Increasing incidence of fires in landfills<br>• Disruption to waste<br>• Heat damage to infrastructure<br>• transport (e.g., collection)<br>• Flooding of treatment facilities | • Increase in waste arising from flooding<br>• Inundation events of critical infrastructure (e.g., waste management plants) | • Erosion of coastal landfills | • Disruption to services (e.g., collection) |

*Source: Adapted from GCA[18] and OECD[3]*

Climate change risks fall into two categories:

a) **Chronic stresses** – Hazards due to long-term changes in average climatic conditions, which are typified by their slow onset occurrence. For example, the effects of long-term changes in average temperature, sea-level rise, glacier melting or long-term erosion of coasts or landscapes (see **Figure 1.6**). These are also sometimes referred to as slow onset events.

b) **Acute shocks** – Hazards due to extreme weather events. For example, hurricanes and other extreme storms, droughts or floods (see **Figure 1.7**). These are also sometimes referred to as rapid onset events.

**Figure 1.6** Glacier melting as an example of a chronic stress


*Source: Simo Räsänen Ximonic, 2008. Wikimedia Commons. Available from: https://en.wikipedia.org/wiki/File:Briksdalsbreen_Norway_2003_&_2008.JPG [Accessed 5 February 2021].*

**Figure 1.7** Floods as an example of acute shocks

*Bloomberg 2021. Dramatic Photos of Germany's Worst Flooding in Decades Captures Devastation. Available from [https://www.bloomberg.com/news/features/2021-07-16/photos-germany-s-record-flooding-show-devastation](https://www.bloomberg.com/news/features/2021-07-16/photos-germany-s-record-flooding-show-devastation) Photographer: Rhein-Erft-Kreis/Cologne District Government/AP Photo [Accessed 22 August 2021].*

These risks are produced by the increase in frequency or magnitude of different natural hazards due to the effects of climate change. Additionally, chronic stresses and acute shocks can, and often do, compound one another.

The impacts of climatic hazards produce disruptions in the service provided by infrastructure and have negative consequences for the communities they serve. Some of these disruptions can also affect the capacity of a community to recover quickly from the impacts of climatic hazards. For example, a damaged road prevents emergency services to arrive promptly to affected locations after a catastrophic monsoon.

Infrastructure disruptions are problematic because they cost money, time, and productivity by disrupting the provision of services to communities (see **Box 6**). They reduce well-being, income, and access, particularly for those populations who have high levels of vulnerability and exposure. This requires taking action – in terms of the location, design and management of infrastructure – to achieve an acceptable level of risk. The acceptable level of risk is inherently context specific: it depends on factors including the degree of exposure and sensitivity to climate hazards, the impacts of failure, the costs of risk reduction and the ability to adapt. It also requires making decisions in the face of uncertainty, given that knowledge on climate models and scenarios is constantly evolving[18]. Therefore, while planning, designing, constructing and operating infrastructure is important to consider the resilience *of* infrastructure and resilience *through* infrastructure.

**Box 6.** What are infrastructure disruptions?

**Infrastructure disruptions** can be defined as the **temporary or regular stops** to provision of the infrastructure's intended services to users. This includes **damages caused by climate hazards** due to inappropriate planning and design, poor construction, maintenance or mismanagement, specifically where considerations of climate change have not been considered (for example, changing patterns in the frequency and magnitude of extreme weather events).

A recent example of infrastructure disruptions caused in part by climate hazards is the blackouts experienced in the state of Texas in the United States in February 2021 due to extreme cold weather temperatures. The low temperatures generated an increase in the demand for electricity for heating. At the same time, the low temperatures froze natural gas wells, wind turbines and coal piles and blocked pipes across the state which disrupted the generation of electricity in the network. This was compounded by the fact that the gas-fired power stations, which provided most of Texas' energy, were not sufficiently winterized. As a result, blackouts plagued the state for several days affecting thousands of families, especially those from vulnerable and low-income populations.

Infrastructure disruptions occur in the context of complex and interconnected systems, and therefore the causes and extent of the damage are interlinked to multiple drivers. However, in the case of the Texas blackouts, experts widely agree that much of the damage could have been avoided if climate extremes had been more adequately incorporated into planning. And while some have argued that this was an event that could not be planned for, the state's 2018 hazard mitigation plan clearly identified the risk of widespread outages from severe winter weather. Moreover, water, electricity and natural gas are connected, and outages in one system ripple across the others, culminating in cascades of disruptions. Pumps could not extract natural gas without electricity, which compounded the decrease in power generated from gas-fired power stations. This example highlights the need for a systems-approach to mitigating climate risk to infrastructure, particularly by understanding the interconnections between systems, comprehensively integrating climate extremes, and planning for future climatic changes.

*Sources: Nateghi, R. The Texas blackouts showed how climate extremes threaten energy systems across the US. [Online] The Conversation. Available from:* https://theconversation.com/the-texas-blackouts-showed-how-climate-extremes-threaten-energy-systems-across-the-us-155834 *[Accessed 5 May 2021]; and Chang. A. 2021. Why the cold weather caused huge Texas blackouts – a visual explainer. [Online] Guardian. Available from:* https://www.theguardian.com/us-news/2021/feb/20/texas-power-grid-explainer-winter-weather *[Accessed 8 March 2021].*

**Standards have an essential role in underpinning progress towards strengthening the resilience of infrastructure systems.** They can outline a systematic process for identifying and managing risks on a case-by-case basis, as well as set technical and/or management norms that achieve a good outcome in most circumstances – such as ensuring an additional operating margin or safety of construction. Standards can also provide the necessary criteria and guidance to evaluate the climate resilience of a project throughout the lifecycle of the infrastructure.

However, this will only happen if standards have been informed by the concepts of climate risks, resilience and adaptation to climate change. These include uncertainty about current and future climatic conditions, the ability of infrastructure systems to withstand shocks and stresses, and their capacity to adjust to new conditions and reduce the vulnerability to natural hazards. While each of these concepts are crucial to all practitioners, the concept of 'risk' is framed differently by each. Climate change professionals distinguish between hazard, risk, vulnerability and exposure where infrastructure professionals conflate risk with both hazards and impacts, and investors assess risk based on return.

To provide its intended benefits, resilient infrastructure should deploy performance-based engineering codes/standards that consider future changes as well as past events[19]. **Traditional industry standards** typically factor in known risks based on previous events and experience. This means that, although they are beneficial when enforced, they have the tendency to lock-in characteristics in infrastructure that made them no-longer resilient to future conditions. **Performance-based engineering codes**, on the other hand, consider an acceptable risk for operation, health, safety, and public welfare and provide approved methods for demonstrating compliance. This means that approaches to resilient infrastructure should not be descriptive about what construction material will be most effective against storms but rather that the design of an infrastructure asset should withstand storms sufficiently to ensure safe evacuation.

Achieving resilience in infrastructure projects also requires a **systemic and spatial approach** rather than focusing solely on one type of asset or site. It requires organisations to surmount siloed thinking and implementation, and seek collaborative efforts[20]. Infrastructure resilience depends on engineering design and external factors beyond specific technical disciplines and requires **contextualised solutions**. Embedded in a specific local context in environmental and socio-economic terms, the planning and design of infrastructure benefit from greater community consultation to incorporate local knowledge and increase people's buy-in. **Resilience-thinking** should thus be a holistic approach, considering acute and chronic physical damage to infrastructure alongside broader societal impacts[21].

## How does resilient infrastructure help?

The argument for investing in resilient infrastructure is striking. According to the World Bank, the annual cost of infrastructure disruptions to households and firms across the world is around US$390 billion. Resilient infrastructure helps to avoid these costs. The good news is that estimate show that net benefit of investing in resilient infrastructure in low- and middle-income countries is US$4.2 trillion over the lifetime of new infrastructure. That translates to US$4 of benefits for every US$1 invested in resilience in these countries. Hence, resilient infrastructure is not about higher expenditures – it is about better and more effective spending[22].

Investing in resilient infrastructure can generate more than economic benefits. These benefits can be generated by achieving the **"Triple Dividend" of resilience** [23] (avoided losses from disasters, development through investments by households and businesses; and positive economic, social and environmental co-benefits), which will be further investigated in Module 2. Social benefits from investing in resilient infrastructure include significant reductions in the loss of life, injury and numbers of affected people, or reduced disruption of social services, including critical health and education facilities. Environmental benefits include reduction in environmental pollution, reduction in degradation of ecosystems or even the enhancement and regeneration of ecosystems. **Box 7.** looks at an example of building resilient infrastructure and its benefits in the small island developing state of Saint Vincent and the Grenadines. **Box 8** shows an example of how green infrastructure could provide coastal resilience and others benefits in New York. **Box 9** presents an example of a project to climate proof the water supply infrastructure in tows across Kenya.

**Box 7.** Building climate-resilient infrastructure in Small Island Developing States, Saint Vincent and the Grenadines

The small island developing state of Saint Vincent and the Grenadines is increasingly bearing the brunt of changing and unpredictable weather patterns. Between category 5 hurricanes and tropical storms, the island's infrastructure is gradually deteriorating and being destroyed. The 2013 tropical storm killed 9 people and caused over $100 million in damages, equivalent to 15% of the country's GDP[24]. One key infrastructure asset severely damaged from this storm was the Cumberland Bridge. The bridge is an essential transport asset as it connects the northern communities to the capital and its services, such as the island's only hospital. A new bridge was required to protect the communities and allow safe travel across the island.

A UNOPS project funded by the Government of Mexico took on the reconstruction of the Cumberland bridge, construction of subsidiary bridges, river embankment protections, and road repairs. The reconstruction project focused on enhancing the resilience of the bridge by using materials that would withstand high volumes and speeds of floodwaters, and building a flood defence wall along the river bank to prevent adjacent homes. The project included institutional capacity building through workshops for engineers at the Ministry of Transport and it also employed local community constructors who had been impacted by the storm. Overall, building infrastructure that can withstand more extreme weather events is crucial to improving resilience to climate change and is reducing its impacts on local livelihoods.

Source: UNOPS. 2017. At the water's edge: adapting to climate change through resilient infrastructure. Available from: https://www.unops.org/news-and-stories/stories/at-the-waters-edge-adapting-to-climate-change-through-resilient-infrastructure [Accessed 19 January 2021]. Further information can be found at here: https://www.youtube.com/watch?v=1U2uhhZ3q2A
Picture credit: @UNOPS/Elise Laker

**Box 8** Improving the coastal resilience of Howard Beach, Queens, New York with green and grey infrastructure

Howard Beach is a low-density residential neighbourhood along Jamaica Bay in the southwestern portion of Queens, New York. The community covers approximately 1,530 acres (2.4 square miles) and is home to approximately 14,700 residents. Given its waterfront location, flat topography, and canals, the most significant climate-associated risks to Howard Beach are coastal flooding and storm surges. Most of the neighbourhood is inside the 1-in-100-year flood zone designated by the Federal Emergency Management Agency (FEMA) and Howard Beach, and it has already experienced significant damage from Hurricane Irene in 2011 as well as Superstorm Sandy in 2012 as 1-in-100 year events occur more frequently.

The assessment done by The Nature Conservancy and CH2M Hill in 2015 showed that a hybrid solution that uses both green and grey infrastructure was the resilience option that provided the most community protection while also maximizing environmental benefits at a reasonable cost. This option included the use of restored marshes, mussel beds, flood beds and flood walls for flood protection. This solution can save around US$225 million in damages from more frequently occurring 1-in-100-year storm events while generating ecosystem services, for the highest net benefit.

*Source: The Nature Conservancy. 2015. Urban Coastal Resilience: Valuing Nature's Role. Case Study: Howard Beach, Queens, New York. Available from: https://www.preventionweb.net/files/48690_urbancoastalresiliencereportappendi.pdf [Accessed 11 March 2021].*

**Box 9** Kenya Towns Sustainable Water Supply and Sanitation Program, African Development Bank, 2016-2021

Due to rapid rates of urbanization in Kenya, demand for effective and efficient water and sanitation services across towns is far exceeding the current supply. This is compounded by rising temperatures, erratic rainfall patterns, frequent and recurring droughts, flooding, and water scarcity – impacting the towns at different intervals.

The selected project towns are not able to cope with the rate of demand and demographic changes that are occurring and the Government is facing difficulty in delivering the much needed water and sanitation services. Climate change impacts such as increasing temperatures, droughts are affecting the availability and quality of water, while floods and heavy rainfall pose the risk of damaging key water and sanitation infrastructure and contaminating water.

The project seeks to improve access, quality, availability, resilience and sustainability of water supply and wastewater management services across multiple towns in Kenya. This will catalyze commercial activities, drive economic growth, create employment, improve quality of life of the people and enhance adaptation to increasing climate variability and change.

These objectives will be realised through i) construction, rehabilitation and expansion of water supply infrastructure in 19 towns and sanitation infrastructure (including expansion into informal settlements) in 17 towns which will lead to improved, reliable and resilient water and sanitation services; and ii) capacity development of water service providers and the sector regulator, which will improve service efficiency and increased employment opportunities for women and youth.

To climate proof the water supply and sanitation systems of the towns, technical designs for proposed infrastructure will reflect projected climatic changes in the respective project towns. Recommendations were given to ensure that the design and physical location of the structures being built were in areas less prone to flooding. This will ensure that adequate measures are incorporated to strengthen the infrastructure against damage as a result of heavy rainfall and floods.

The project also provide support for the Water Resource Management Authority (WARMA) to execute river flow monitoring, and to enhance their capacity for flood, and drought prediction and monitoring in the catchment. Water service provider's laboratories will also be rehabilitated and equipped for effective water quality monitoring especially during periods of weather-related events and their capacity built and strengthened to enable them to mainstream climate change into their water service provider business plans.

It is expected that the supply and rehabilitation of infrastructure will provide more than 2.1 million people with reliable, resilient and sustainable water supply services and more than 1.3 million people with water-borne sewerage systems. In addition, the program will create more than 15,000 new jobs during and after construction.

*For further information, please see: AfDB. 2021. 'Kenya - Towns Sustainable Water Supply and Sanitation Program.' https://projectsportal.afdb.org/dataportal/VProject/show/P-KE-E00-011*

## 1.6. References for further learning

If you want to further investigate the topics covered in Module 1, please refer to the sources and suggestions for further reading, which are organised by theme.

| Theme | References |
|---|---|
| **Finance** | ADB. 2020. Financing Disaster Risk Reduction in Asia and the Pacific: A Guide for Policy Makers. Manila. *https://dx.doi.org/10.22617/TIM200415-2* |
| **Resilient Infrastructure** | Becker, Rachel, and Greg Foliente. 2005. PBB International State of the Art. PeBBU 2nd International SotA Report. Performance Based Building Thematic Network. Rotterdam (CIBdf). Available at: *https://www.irbnet.de/daten/iconda/CIB21987.pdf*<br><br>Gallego-Lopez, C. and Essex, J. 2016. Designing for infrastructure resilience. Evidence on Demand. London. Available at: *https://www.preventionweb.net/publications/view/50247* |

| Theme | References |
| --- | --- |
| | OECD. 2018. Climate-resilient Infrastructure: OECD Environment Policy Paper NO.14. Paris. Available at: *https://www.oecd.org/environment/cc/policy-perspectives-climate-resilient-infrastructure.pdf*<br><br>Hallegatte, S., Rentschler, J., and Rozenberg, J. 2019. Lifelines: The Resilient Infrastructure Opportunity. Washington, D.C: World Bank. © World Bank. License: CC BY 3.0 IGO. Available at: *https://openknowledge.worldbank.org/handle/10986/31805*<br><br>Reeves, S., Winter, M., Leal, D., and Hewitt, A., 2019. Roads: An industry guide to enhancing resilience. Resilience Primer. TRL and Resilience Shift. London. Available at: *https://www.resilienceshift.org/publication/primer-roads/* |
| **Public-Private Partnerships** | ADB, EBRD, IDB, IsDB, and WBG. 2016. The APMG Public-Private Partnership (PPP) Certification Guide. Washington, DC: World Bank Group. License: Creative Commons Attribution CC BY 3.0 IGO. Available at: *https://ppp-certification.com/ppp-certification-guide/about-ppp-guide*<br><br>UNESCAP, 2015. Module 1: Public-Private Partnership (PPP) Concept, Benefits, and Limitations. [Online] Available at: *https://www.youtube.com/watch?v=WYoXWNm62Zw* [Accessed 16 January 2021].<br><br>World Bank, 2021. PPP Knowledge Lab – PPP Cycle. [Online] Available at: *https://pppknowledgelab.org/guide/sections/73-managing-ppp-contracts* [Accessed 4 January 2021]. |
| **Nature-based Solutions** | IPCC. 2014. Annex II: Glossary [Mach, K.J., S. Planton and C. von Stechow (eds.)]. In: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, pp. 117-130. |
| **Overarching Concepts** | Arup. 2014. City Resilience Framework. The Rockefeller Foundation, City Resilience Index. Available at: *https://www.rockefellerfoundation.org/report/city-resilience-framework/*<br><br>Tanner, T. Surminski, S. Wilkinson, E. Reid, R. Rentschler, J. Rajput, S. 2015. The Triple Dividend of Resilience. Realising development goals through the multiple benefits of disaster risk management. Global Facility for Disaster Reduction and Recovery (GFDRR) at the World Bank and Overseas Development Institute (ODI). Washington. Available at: *https://www.gfdrr.org/sites/default/files/publication/The_Triple_Dividend_of_Resilience.pdf*<br><br>Depietri, Y. and McPhearson, T., 2017. Integrating the Grey, Green, and Blue in Cities: NbS for Climate Change Adaptation and Risk Reduction. In: Kabisch N., Korn H., Stadler J., Bonn A. (eds) NbS to Climate Change Adaptation in Urban Areas. Theory and Practice of Urban Sustainability Transitions. Springer, Cham. https://doi.org/10.1007/978-3-319-56091-5_6<br><br>G20, 2019. G20 Principles for Quality Infrastructure Investment. Available at: *https://www.mof.go.jp/english/international_policy/convention/g20/annex6_1.pdf* [Accessed 17 December 2020].<br><br>McKinsey Global Institute, 2020. Climate risk and response: Physical hazards and socioeconomic impacts. Boston. Available at: *https://www.mckinsey.com/business-functions/sustainability/our-insights/climate-risk-and-response-physical-hazards-and-socioeconomic-impacts* |

# 2. Module 2 – Overview of resilient infrastructure

**Description:** This Module will delve deeper into the concept of resilience and how it relates to infrastructure.

**Learning outcomes:** At the end of this module, learners will be able to:

- Identify the core components of a resilient system
- Articulate the difference and synergies between green, blue, and grey infrastructure
- Take a systems-planning approach to resilient infrastructure
- Communicate the difference between climate resilient infrastructure and infrastructure to support climate resilience

## 2.1. Defining resilient infrastructure systems

### Sustainability and resilience

The concept of resilience was first introduced in ecology by C.S Holling in 1973 to explain the behaviour of complex ecological systems in response to shocks. Since then, it has been adopted by several different disciplines including sustainability, psychology, psychiatry, engineering, sociology and economy[25,26,27].

As noted in Module 1, resilience can be defined as the ability of a system and its component parts to persist in the face of, adapt to, transform or recover from the effects of a hazardous event in a timely and efficient manner – this includes the idea of bouncing back (rebuilding) and bouncing forward (transforming). In the context of climate change, resilience refers to the ability of a system and its components parts to effectively sustain functionality when subjected to extreme (acute) shocks and chronic stresses caused by the effects of climate change.

The relationship between the concepts of resilience and sustainability is a topic of discussion amongst academics and practitioners over the past few years. Thanks to the inclusion of resilience goals and targets in the United Nations' Sustainable Development Goals (SDGs), resilience has become commonly interpreted as an aspect of sustainability (see **Box 10** for an explanation of the concept of Sustainable Development). Sustainability can be defined as "a dynamic process that guarantees the persistence of natural and human systems in an equitable manner".[28] In other words, sustainability can be understood as achieving balance with the natural environment, whereas resilience is about economies and societies being able to thrive despite the lack of balance. Investing in resilient infrastructure helps to make these systems sustainable and is essential to the achievement of the Sustainable Development Goals as they influence up to 72% of all SDGs[29].

Through the provision and delivery of essential services, networked infrastructure systems, which include water, energy, transportation, waste management and digital communications, form the backbone of modern societies. The services form a collective of infrastructure systems that support other non-networked infrastructure systems that are critical for the functioning of society, including to service people and their homes. Non-networked systems are mainly single asset types, such as a building or a facility, which supports the delivery of a service (hospitals, schools, industrial facilities). However, no infrastructure system exists in isolation. Interdependencies between the assets that make up an infrastructure system mean that infrastructure must be considered as a 'system-of-systems'. Networked infrastructure is explicitly mentioned in SDG: 9 (Industry, innovation and infrastructure) and at the sectoral level in SDG 6 (Clean water and sanitation) and SDG 7 (Affordable and clean energy). Overall, infrastructure underpins all SDGs to some extent. **Figure 2.1** shows the SDGs which are most impacted by investing in infrastructure resilience.

**Figure 2.1** SDGs most impacted by investment in resilient infrastructure systems


*Source: Authors.*

**Box 10** The origin of the concept of sustainable development

The Brundtland Report, also called "Our Common Future", was published in 1987 by the World Commission on Environment and Development (WCED) and introduced the concept of **sustainable development.** The report presents the most widely known definition of the concept of sustainable development:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs".[30]

Based on this definition, achieving sustainable development requires to understand that:

- There is a need to put an emphasis on intergenerational issues and justice.
- Human needs are basic and essential.

- Economic growth is required to sustain human needs, but also equity to share resources justly especially with the poor.
- Regarding the environment, the report states that "the concept of sustainable development does imply limits - not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities. But technology and social organization can be both managed and improved to make way for a new era of economic growth".

## Primary traits of a resilient system

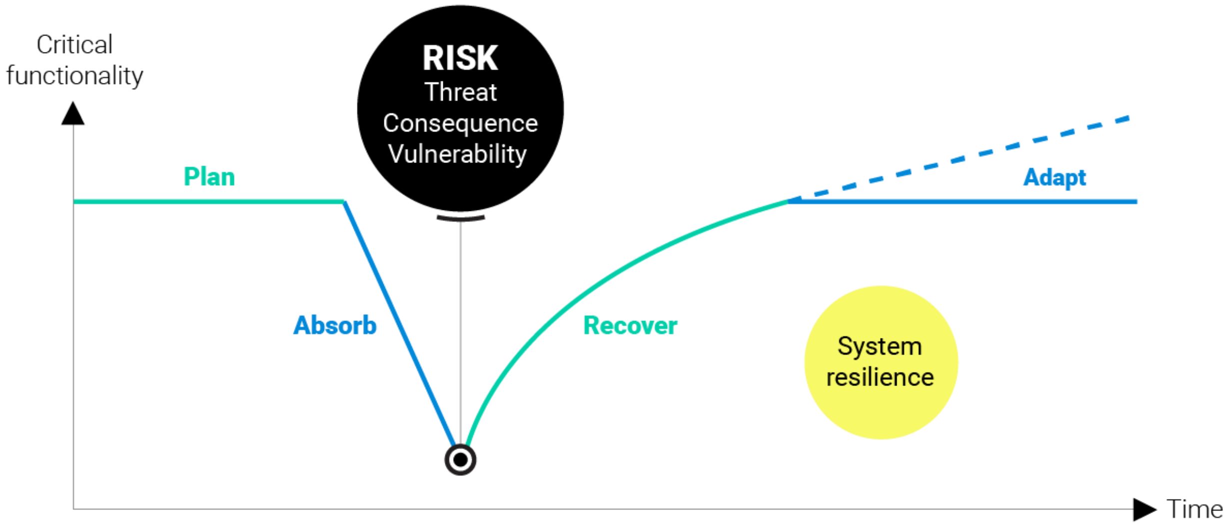
All resilient infrastructure systems share the similar core capacities and properties that allow them to cope with acute shocks and chronic longer-term stresses. These capacities and properties are what permits them to provide their functions to people, communities, other assets, ecosystems and economies even when in the face of different types of hazards. These functions include connectivity (e.g., road, ports, bridges), services provision (e.g., water, energy and telecommunication), and protection (e.g., shelter, accommodation, flood protection).

Resilient infrastructure systems are characterised by having the following capacities:[27]

- **Absorptive capacity:** The degree to which a system can absorb the impacts of system disturbances and minimize consequences with little effort. For example, earthquake resistant structures, which absorbs earthquake shocks or air conditioning systems and building insulation which can mitigate the impacts of extreme temperatures.
- **Recovery and restorative capacity:** The rapidity of return to normal or improved operations and system reliability. For example, social protection programs through crop insurance or cash transfers, flood insurance to support recovery in the aftermath of a flood event.
- **Adaptive capacity:** The ability of a system to adjust to undesirable situations by undergoing some changes. For example, flexible zoning regulations, daylighting rivers for flood control and to improve the system's flood regulating capacity.

In **Figure 2.2,** a theoretical model of critical functionality of a system vs time, also known as a Resilience Triangle graph, is presented. The graph shows how the functionality of a system changes over time when affected by a risk. The resilience of a system is inversely proportional to the area between the curve and the normal functionality of the system. In the figure, the capacities of a resilient system are depicted, and **the dashed line suggests that highly resilient systems can adapt in a way that allows them to bounce forward (transform).**

**Figure 2.2** The resilience triangle graph



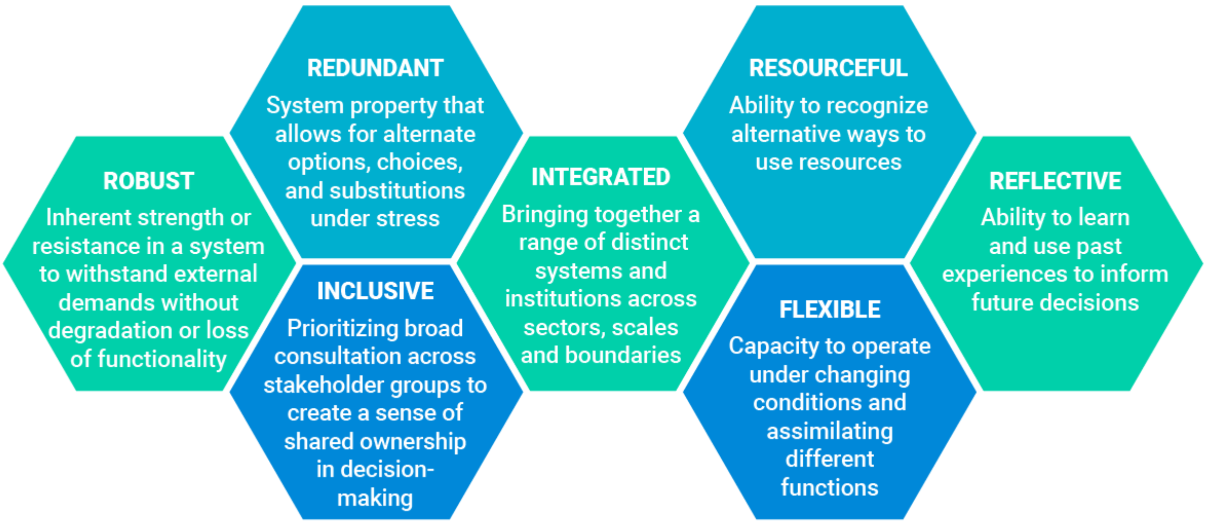

**Note: This figure shows a theoretical model of critical functionality of a system vs time, depicting the capacities of a resilient system.*
*Source: Adapted from Linkov, I., Bridges, T., Creutzig, F. et al. 2014. Changing the resilience paradigm. Nature Clim Change 4, 407–409.*

Due to their capacities, resilient infrastructure systems are able to:

- **Persist** – At times referred to as 'robustness' – which is the ability to maintain coherent function in response to disruption and changing conditions within an expected range of variation.
- **Adapt** – The ability to maintain coherent function by modifying its identity to accommodate change – this requires monitoring and detection of conditions that increase the probability of failure (beyond the above expected range of variance) and require 'proactive' recovery.
- **Transform** – Ability to change identity and to establish a new, stable function when pushed beyond tipping points that preclude maintaining its prior state, which could include the abandonment of the earlier design where the utility losses are consistently too great.

To achieve these capabilities, resilient infrastructure systems possess many of the following qualities (**Figure 2.3**):

**Figure 2.3** Qualities of a resilient system




*Source: Adapted from Arup. 2014. City Resilience Framework. The Rockefeller Foundation, City Resilience Index. Available at: https://www.rockefellerfoundation.org/report/city-resilience-framework/*

## Resilience of and resilience through infrastructure

Before advancing to the next section on the co-benefits of investing in resilient infrastructure, it is important to recap the difference between resilient infrastructure (resilience of infrastructure) and infrastructure for resilience (resilience through infrastructure), mentioned in Module 1.

These definitions also relate to the World Bank's Resilience Rating System (RRS), which identifies the qualities that score projects from C (lowest) to A+ (highest) based on how well they integrate resilience into the project design[31]. The RRS proposes thinking about the resilience *of* the project and the resilience *through* the project, which reflects the discussion of climate-resilient infrastructure and infrastructure *for* resilience (see **Table 2.1**). The RSS will be a consistent tool referenced throughout this Handbook as its scoring methodology provides a robust framework that PPP practitioners can refer to when assessing the resilience of their projects.

**Resilience of a project** refers to the extent to which the project's design has considered and mitigated climate and disaster risk in its design. The higher score indicates that the climate and disaster risks have been addressed to ensure the viability and value of the project. **Resilience through a project** indicates the extent to which a project enhances the resilience of the project beneficiaries, including both human and technical systems. Not all projects will aim to enhance resilience through a project, but this layer helps provide an added distinction that can help practitioners prioritise projects that can provide transformational outcomes to the project beneficiaries.

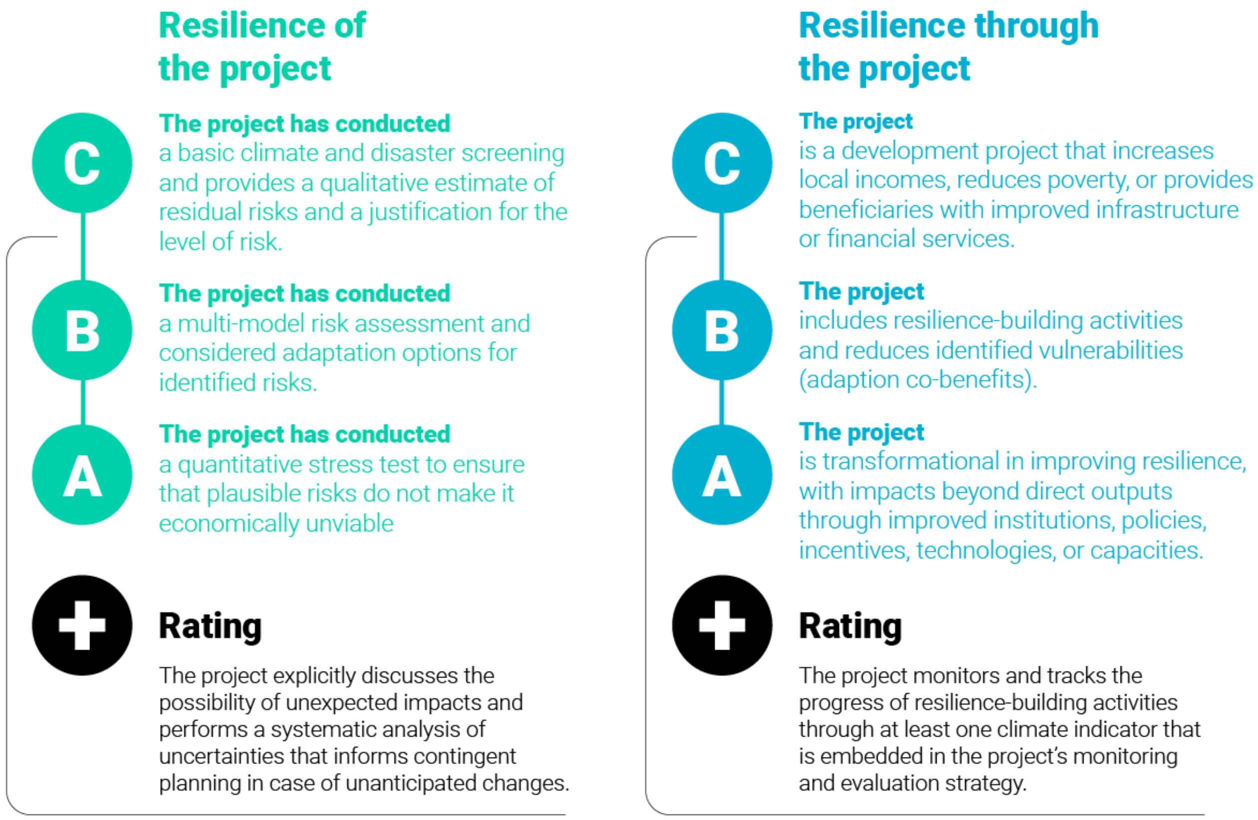
**Table 2.1** Identifying resilience of and through a project

| Topic | Resilience of the project | Resilience through the project |
|---|---|---|
| **Link with climate-resilient infrastructure** | Resilient infrastructure | Infrastructure *for* resilience |
| **Key focus** | Does the project itself consider and mitigate its climate change risks? | Does the project outcome aim to build the resilience of the communities it serves to climate change? |
| **Example** | A new bus rapid transit network is being developed to increase public transport access and efficiency. The location and operations of the network has been assessed for climate risks. Where the bus lanes pass through low-lying areas of the city prone to flooding, the project has been designed to accommodate and absorb runoff through sustainable drainage systems. These measures increase the resilience of the project to flooding. | The new bus rapid transit network has implemented sustainable drainage systems in its design, which decreases flood risk in the area beyond just to the bus network itself. The bus network, paired with behavioural campaigns that increase people's use of public transport, aims to decrease the number of private cars on the road. In the event of an emergency, decreased congestion means more people are able to evacuate an area faster. |

*Source: Adapted from World Bank Group. 2021. Resilience Rating System. Washington, D.C.*

To provide a standardized framework for use, we will also introduce the scoring of the RRS (**Figure 2.4**). This will become especially relevant in Module 5 as it will support PPP practitioners to identify, design, and prioritise resilient projects. As mentioned, projects can be rated from C at the lowest to A+ at the highest. The difference between a C and A+ rating for resilient infrastructure or resilience *of* infrastructure is essentially the extent to which climate risks have been identified, quantified, residual risk has been justified, and resilience options have been identified to mitigate risk. An A+ rated project will have undertaken a multi-model climate risk assessment, stress tested the project to different impacts, identified viable resilience options, and identified ways to cope with unanticipated or uncertain outcomes. For projects that support infrastructure *for* resilience or resilience *through* infrastructure, the main difference between a C and A+ rating is the extent to which the project's benefits impact its beneficiaries. Does it only impact resilience in relation to its direct output (e.g., improves access to public services in target location) or does it enhance institutional capacity (e.g. increases cross-sectoral knowledge-sharing and collaboration)?

**Figure 2.4** World Bank Resilience Rating System - scoring




*Source: Adapted from World Bank Group. 2021. Resilience Rating System. Washington, D.C.*

**The main message to take is that all infrastructure must be climate-resilient infrastructure.** To make existing infrastructure more climate-resilient, there is the need to retrofit or construct new infrastructure with the specific aim to reduce hazard exposure, the sensitivity or increase the adaptive capacity of the original asset and the community it serves. An example of this is the construction of flood protection infrastructure upstream to protect a community and the assets it contains against future flood hazards due to climate change. Nature-based Solutions (NbS), like mangrove forests or wetlands, can serve this purpose and help increase the adaptive capacity of existing assets and communities while at the same time providing other co-benefits. You will see this in more detail later in the next section.

## Overview of resilience co-benefits

As mentioned in Module 1, investing in resilient infrastructure not only has economic benefits. Resilient infrastructure systems have also social benefits and environmental benefits associated with them. In order to generate these benefits, the objective of a resilient infrastructure investment should be to achieve the **"Triple Dividend" of resilience** [23] (see **Figure 2.5**).

**Figure 2.5** The Triple Dividend of Resilience


*Source: Adapted from Tanner et al., 2015. The Triple Dividend of Resilience. Realising development goals through the multiple benefits of disaster risk management. GFDRR and ODI. Washington; and AECOM. 2020. Guidance Note for Assessing Climate and Disaster Risks and Climate Co-Benefits. London/Ankara.*

**The first dividend of resilience** – *Avoiding losses from disasters* – focuses on saving lives, avoiding losses, minimising disruptions, and promoting effective recovery.

**The second dividend of resilience** – *Development through investment by households and businesses* – aims to unlock the economic potential of investing in resilient infrastructure. Studies show that climate and disaster events are increasing in strength and frequency; making them an ever-present background risk (i.e., risk that cannot be avoided or diversified). Building resilience manages background risk, which can help governments, businesses, and households to build up savings, invest in productive assets, and improve the livelihoods of their communities. It enables forward-looking planning, long-term capital investments, and entrepreneurship.

**The third dividend of resilience** – *Positive economic, social and environment co-benefits* – generates co-benefits from integrating resilience into infrastructure. As most investments serve multiple purposes, infrastructure investments should not only address one specific purpose. Integrating multi-purpose designs into resilient infrastructure can unlock synergies, save costs and improve efficiency and liveability.

Realising the Triple Dividend of resilient infrastructure requires to **integrate and plan for climate co-benefits** at the outset. The term 'climate co-benefits' has a wide range of definitions in the literature. For the purpose of this Handbook, **co-benefits** are defined as the positive, secondary, often indirect outcomes from infrastructure investments. It is important to note that those secondary outcomes could also be derived from other actions, such as policies or operational activities.

In the context of climate change, two types of climate co-benefits can be generated:

- **Mitigation co-benefits:** reduction of emissions or enhancement of the sinks of greenhouse gases.
- **Adaptation co-benefits**: process of adjustment to actual or expected climate effects to moderate harm or exploit beneficial opportunities.[28]

**Table 2.2** provides a simplified illustration of what constitutes primary and secondary benefits and how climate and non-climate related co-benefits can be differentiated. For instance, non-climate related co-benefits include social, economic and health benefits.

**Table 2.2** Simplified example of primary and secondary benefits from infrastructure projects

| **Project Example** | **Primary Benefits** *Guiding Question: What is the primary positive outcome from this project?* | **Secondary Benefits (= Co-Benefits)** *Guiding Question: What are additional, second-order positive outcomes from this project besides its immediate direct benefits?* | | |
|---|---|---|---|---|
| | | **Non-Climate Related** | **Climate-Related** | |
| | | | **Mitigation Co-Benefits** | **Adaptation Co-Benefits** |
| Building a sea wall in front of a harbour | Protection from storm surges | Providing additional public open space on top of the sea wall | Not applicable (unless trees would be added to function as carbon sinks) | Providing some protection against rising sea levels |
| Designating parts of a road as a dedicated bicycle path | Providing more and dedicated space for bicycling | Reduction in traffic fatalities | Reduction in emissions due to mode shift from motorized transportation to bicycles | Fostering improved community health due to uptake in bicycling |
| Expanding a drinking water facility | Serving more customers with drinking water | Job creation due to more personnel needed to operate the facility | Potentially reduced emissions from more energy-efficient technology | Increased capacity to respond to higher drinking water demand during heatwaves |

*Source: AECOM.*

There are several advantages from climate co-benefits:

- In contrast to interventions that only focus on single-sector primary benefits, investments that consider climate co-benefits in their planning and design can support innovation, deliver economic benefits, and **enhance the quality of life for citizens in a holistic way** (see **Box 11**).[32]
- The integration of climate co-benefits into resilient infrastructure investments can also lead to **greater political support** as the improvement of livelihoods becomes tangible for citizens.[33]
- It also can allow **access to funds for green and climate solutions** as multilateral donors require a systemic integration of climate co-benefits into infrastructure projects[34]. This can provide for additional and/or concessional finance for climate-friendly infrastructure projects and, therefore, help scale up resilient infrastructure.
- Investment in resilient infrastructure can also generate **alternative revenue streams from secondary benefits** or attract alternative private investment that wishes to unlock these revenue streams.

Several of the climate co-benefits from resilient infrastructure investment can be interlinked with the SDGs, for instance:

- Speeding up the renewable energy transition (SDG 7) and managing more sustainably forests and other terrestrial ecosystems (SDG 15) directly and positively affect greenhouse gas emissions.
- Sustainable industrialization (SDG 9), sustainable food production systems and resilient agricultural practices (SDG 2), and responsible consumption and production (SDG 12) contribute to low-emission pathways.
- Building better insulated and resilient homes is an adaptation co-benefit to extreme colds, heatwaves, strong winds, and floods that can reduce poverty (SDG 1). Such infrastructure projects address fuel poverty caused by heating and cooling, as much as they reduce the costs of rebuilding after a shock leaving more money for other necessities such as food, water, accommodation, and education.

These examples showcase that integrating and planning for climate co-benefits in resilient infrastructure can **distribute scarce resources effectively while achieving several primary and secondary benefits.** Primary benefits for waste, air quality, transport, and energy are particularly strong in producing mitigation co-benefits due to their potential of reducing greenhouse gas emissions and impacts of climate change. Adaptation co-benefits are particularly strong for disaster and emergency, food security and tourism, culture and sports due to their potential of helping people and systems adapt to climate impacts. Primary benefits for land use and infrastructure planning, health, water, and education tend to be strong in achieving both climate mitigation and adaptation co-benefits.

In order to identify climate co-benefits**, two directions of analysis** are useful:

- **Extrapolating climate co-benefits from resilient infrastructure solutions** – Guiding question: What climate co-benefits can be derived from a project or its features?

- **Devising resilient infrastructure solutions from intended climate co-benefits** – Guiding question: How does a project need to be designed to achieve certain climate co-benefits? ("Optimization" of co-benefits)

These two perspectives are not exclusive to each other. It is recommended to use both 'directions of analysis' when developing new infrastructure projects (or retrofitting existing infrastructure).

The next section will describe the types of resilience-building actions that need to be incorporated into infrastructure projects to generate the desired co-benefits, with a focus on NbS, and a description of some examples of best practice for resilient infrastructure.

**Box 11.** Improving water and sanitation in the Philippines using private sector participation

The Philippines is highly vulnerable to a range of natural hazard risks that will intensify with climate change including typhoons, storm surge, sea level rise, coastal erosion and land subsidence. As a largely low-lying island chain, these put a significant proportion of freshwater resources at risk to salination from encroaching sea levels and coastal flooding. There is a strong effort from the local governments to develop infrastructure considering climate hazards given the high vulnerability of the islands. From this perspective, improving water efficiency to sustain available water resources are relevant to support sustainable tourism.

The World Bank operation currently underway undertakes an assessment of the climate-induced threats to fresh water supply in the tourism hotspots of Siargao, Bohol and Siquijor provinces. Assessments will explicitly consider the different risks to water sustainability with a range of likely climate change scenarios.

The PPIAF technical assistance supports the climate resilience by providing alternative technical, financial and institutional options for improvement through private sector participation (PSP), which could be replicated widely throughout the country. The scope of work includes support to the provinces in preparation of DBO/DBL contracts through capacity building targeting national government agencies such as the National Economic and Development Authority (NEDA). Capacity building will ensure that water supply DBO's are in sync and within the implementation reforms that will be instituted under the currently approved National Philippine Water Supply and Sanitation Master Plan (PWSSMP), specifically the achievement on the Key Performance indicators (KPIs) and proper operationalization of the Unified Resource Allocation Framework (URAF). The PPIAF is also strengthening technical and economic analysis of the projects by assisting in the market survey taking into account the interests of the private sector. Finally, the TA supports the preparation of an Operations and Maintenance (O&M) plan for PSP.

*Source: World Bank. Weekes, K. Diaz Fanas, G., Orekhova, S., Khamudkhanov, K. 2021. Climate adaption in infrastructure – case study examples in the PPIAF Portfolio. More information available at: https://ppiaf.org/activity/philippines-support-psp-local-government-unit-lgus-water-supply-and-sanitation-system-key*

## 2.2. Measures to enhance the resilience of infrastructure

### Resilience-building actions

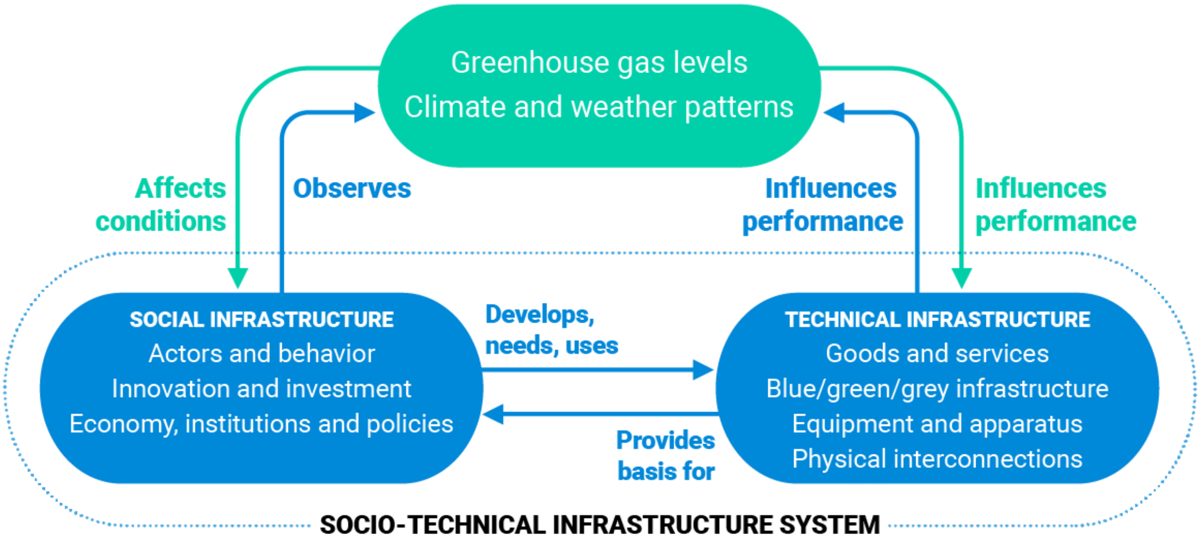
Before presenting the types of actions that can be performed to build resilience in infrastructure systems, it is important to acknowledge that infrastructure systems should be understood as being part of wider complex socio-technical systems. In a socio-technical system, the social infrastructure, technical infrastructure and the environment elements continuously interact with each other and their behaviour cannot be fully understood without acknowledging these interactions. This is shown in **Figure 2.6**. The **technical infrastructure systems** include physical infrastructure such as roads, telecommunication infrastructure and electricity grids. Goods or services flow through these systems and networks providing the basis for many daily activities. The **social infrastructure** is understood here as the humans, organizations and governments that make decisions and form the economy as well as institutions and policies. Purposive actors in the system, therefore, need and use the technical infrastructure to function. These elements continuously interact with each other and the **environment** (which includes the natural environment, the greenhouse gas levels and the climate and weather patterns), but it is also worth noting that there are additional interactions with other interconnected socio-technical infrastructure systems as shown by the layers in this figure.

Understanding infrastructure systems as part of wider complex socio-technical systems have implications in terms of what the objects of resilience-building actions should be. **Resilience should be built not only in the technical/physical elements, as in traditional engineering practices, but also in the social/ organisational elements such as institutional arrangements.** Without taking care to properly build resilience in both types of elements, the socio-technical system will not be able to fulfil its purpose effectively.

It should also be acknowledged that resilience must be built in the whole system and not only in its component parts. Siloed decision-making can be the cause of a lack of systemic resilience around some infrastructure systems. It is still common that different organisations focus on building resilience on the particular elements of the system they manage but forget to include efforts to understand how to strengthen the resilience of the wider systems in which their elements belong and interact. A potential solution to achieving systemic resilience would be to promote cross-sectoral working groups to ensure coherence across the resilience efforts in the system.

Individual infrastructure systems are interconnected with other infrastructure systems and these interconnections should also be acknowledged whenever any resilience-building actions are planned. For example, road infrastructure is highly interconnected with water management infrastructure for the management of run-off water during rainfall. In order to increase the resilience of road networks to climate change, this interconnection with water management infrastructure should be acknowledged, since increasing the resilience of drainage systems can make a road more likely to cope with future flooding events.

**Figure 2.6** A socio-technical systems perspective on climate-affected infrastructures




*Source: Adapted from Chappin, E J. L. and van der Lei, T. 2014. "Adaptation of Interconnected Infrastructures to Climate Change: A Socio-Technical Systems Perspective." Utilities Policy 31:10–17.*

Actions to strengthen the resilience of infrastructure systems can be divided broadly into two categories:

- **Structural measures:** Any physical construction that reduces or avoids possible impacts of hazards, reduces exposure or sensitivity, or the application of engineering techniques, such as green/blue/grey infrastructure or technology to achieve hazard resistance and resilience in structures or systems. For example, implementing a stormwater solution that incorporates both grey and green infrastructure such as drainage pipes and permeable pavements (see **Figure 2.7**). Structural measures are also sometimes referred to as "hard" measures.

- **Non-structural measures:** Non-physical measures (operational / managerial) to reduce climate risks and impacts, such as policies, strategies, plans and governance to enhance the enabling environment; and knowledge, practice, capacity building, and education for public awareness raising. For example, enhancing the cross-sectoral communications between departments responsible for intelligent transport systems (ITS) and road maintenance (see **Figure 2.8**). Non-structural measures are also sometimes referred to as "soft" measures.

**Figure 2.8** Example of structural measures for drainage

*Source: Drake, J. 2015. Stormwater innovations mean cities don't just flush rainwater down the drain. [Online] The Conversation. Available from: https://theconversation.com/stormwater-innovations-mean-cities-dont-just-flush-rainwater-down-the-drain-40129*

**Figure 2.7** Non-structural measures include capacity building

*Source: AECOM, 2021.*

In order to achieve resilient infrastructure systems, a combination of both structural and non-structural measures is required. This combination of actions will be different for each infrastructure system as they will be context-dependant.

More detailed typologies of actions have been developed by different authors and organisations. A comprehensive typology of resilience-building actions is presented in Biagini et al. (2014)[35]. The authors present the following 10 types of resilience-building actions:

- **Capacity building:** Developing human resources, institutions, and communities, equipping them with the capability to adapt to climate change.
- **Management and planning:** Incorporating understanding of climate science, impacts, vulnerability and risk into government and institutional planning and management.
- **Practice and behaviour:** Revisions or expansion of practices and on the ground behaviour that are directly related to building resilience.
- **Policy:** The creation of new policies or revisions of policies or regulations to allow flexibility to adapt to changing climate.
- **Information:** Systems for communicating climate information to help build resilience towards climate impacts (other than communication for early warning systems).
- **Physical infrastructure:** Any new or improved hard physical infrastructure aimed at providing direct or indirect protection from climate hazards.
- **Warning and observing systems:** Implementation of new or enhanced tools and technologies for communicating weather and climate risks, and for monitoring changes in the climate system.
- **Green infrastructure:** Any restored, new, or improved soft, vegetated, natural infrastructure or ecosystem aimed at providing direct or indirect protection from climate hazards. These infrastructures are an essential part of Nature-based Solutions (NbS).
- **Financing:** New financing or insurance strategies to prepare for future climate disturbances.
- **Technology:** Develop or expand climate-resilient technologies.

As can be seen from this typology, green infrastructure (which are part of NbS) are one of the different types of resilience-building measures that can be performed. The next section will discuss in more detail how green infrastructure interacts with blue and grey infrastructure to create more resilient infrastructure systems, as well as the co-benefits that can be gained from using NbS. Although this Handbook will be focusing on the role of NbS in creating resilient infrastructure, do not forget that other types of resilience-building actions will also be needed in each project. For instance, this Handbook also presents how to implement "management and planning", "policy" and "financing" resilience-building actions through the implementation of PPPs.

## Integrating grey, blue and green infrastructure

In the built environment, different types of infrastructure that provide different services and benefits to our lives. These different types of infrastructure can be positioned in a continuum that goes from grey infrastructure to green and blue infrastructure based on their characteristics (see **Table 2.3**). Grey infrastructure are all those types of infrastructure that have been designed and constructed with engineered materials, usually concrete or steel, hence the denomination grey (see **Figure 2.9**). Green and blue infrastructure are those composed of natural elements, like vegetation (the green element) and water bodies (the blue element), that can provide certain services like water control (see **Figure 2.10** and **Figure 2.11**). These types of infrastructure can be connected and designed to work together in hybrid and more resilient infrastructure systems. Grey, green and blue infrastructure can be defined more precisely as follows[36]:

- **Grey infrastructure** – Grey infrastructure are built up, engineered and physical structures, often made of concrete or other long-lasting materials. These include roads, railways, canals, energy, ports, dikes, embankments, sea walls, centers and breakwaters for riverine and coastal flood protection, piped drainage systems for storm water management (such as storm sewers or concrete detention basins), and air conditioning or cooling centers to cope with extreme heat.
- **Green infrastructures** – Green infrastructure is principally characterized by well-functioning biophysical systems, primarily related to green spaces, that support biodiversity, natural ecological processes and to which some management and restoration may apply. They are represented, by healthy oyster reefs, coastal salt marshes, mangroves, coral reefs, sea grasses, sand beaches and dunes in the coast environment and mainly by forests, parks, street trees, and grasslands inland.
- **Blue infrastructure** – Blue infrastructure can be also characterized by well-functioning biophysical systems, but primarily related to water. This includes water bodies, including ponds, wetlands, rivers, lakes, and streams, as well as estuaries, seas, and oceans.

**Table 2.3** The infrastructure continuum

| Grey | Hybrid or mixed approaches | Green and blue |
|---|---|---|
| Hard, engineering structures | Blend of natural and engineering structures | Biophysical systems, ecosystems and their services |
| Very limited role of ecosystem functions | Allows for some ecosystem functions mediated by technological solutions | Mainly relying on existing or restored ecosystem functions and water bodies |
| *e.g., canals, pipes and tunnels of the drainage system; dikes; wastewater treatment plants; water filtration plants* | *e.g. bioswales; porous pavement; green roofs; rain gardens; constructed wetlands; Sustainable Drainage Systems (SuDS)* | *e.g. wetlands restoration; installation of grass and riparian buffers; urban trees; stream restoration; rivers, lakes, ponds, oceans and seas* |

*Source: Depietri Y., McPhearson T. 2017. Integrating the Grey, Green, and Blue in Cities: NbS for Climate Change Adaptation and Risk Reduction. In: Kabisch N., Korn H., Stadler J., Bonn A. (eds) NbS to Climate Change Adaptation in Urban Areas. Theory and Practice of Urban Sustainability Transitions. Springer, Cham. https://doi.org/10.1007/978-3-319-56091-5_6*

**Figure 2.9** Example of grey infrastructure. Transbay Transit Center Construction, USA

*Source: AECOM, 2021*

**Figure 2.10** Examples of green and blue infrastructure. San Elijo Lagoon Restoration, USA

*Source: AECOM, 2021*

**Figure 2.11** Examples of green and blue infrastructure. Qingdao Waterfront Park, China

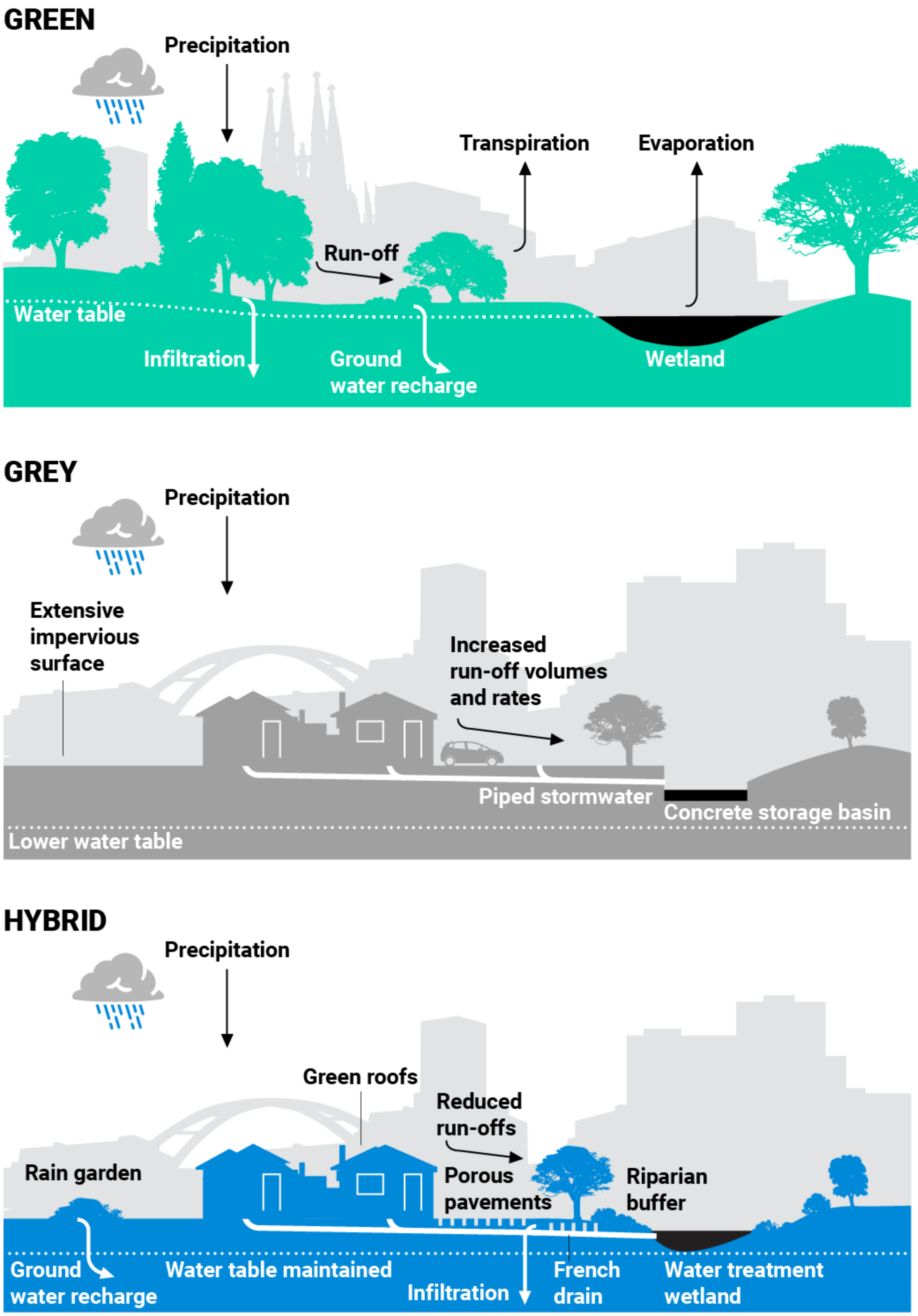
*Source: AECOM, 2021*

**Figure 2.12** shows an example on how an exclusive green-and-blue-infrastructure approach, an exclusive grey-infrastructure approach, and a hybrid infrastructure approach can be used to manage stormwater in an urban setting.

All three approaches can have a relevant role in resilience building thanks to their relative strengths and weaknesses. Grey infrastructures can provide an important means to create resilience to climate related hazards, however, they are often costly to construct and maintain, can have long-term (negative) effects on ecosystems, and tend to have low flexibility which can lead to system lock-ins, path dependency and even maladaptation. Maladaptation in this context refers to "an action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups"[37]. It can be argued that there are at least five types of maladaptation actions. These are adaptation actions that, "relative to alternatives: increase emissions of greenhouse gases, disproportionately burden the most vulnerable, have high opportunity costs, reduce incentives to adapt, and set paths that limit the choices available to future generations [path dependency]".[37]

Green and blue infrastructure rely on healthy, functioning ecosystems and can provide multiple co-benefits such as carbon sequestration, biodiversity, recreation, psychological well-being and water-control opportunities. Nonetheless, it is not possible to rely merely on this type of infrastructure for resilience building purposes as they may require large amounts of land to deliver the desired services, and reliability of performance may be an issue.

**Figure 2.12** Three contrasting approaches, green and blue only, grey only, and hybrid for dealing with urban water




*Source: Adapted from Depietri Y., McPhearson T. 2017. Integrating the Grey, Green, and Blue in Cities: NbS for Climate Change Adaptation and Risk Reduction. In: Kabisch N., Korn H., Stadler J., Bonn A. (eds) NbS to Climate*

Hybrid approaches that combine engineering and ecosystem functions can be the solutions that perform better when trying to create resilience of the built environment as they can combine the strengths of both grey and blue and green infrastructures, while minimising the issues associated with each. Consequently, it is important to begin thinking how NbS could be included into the infrastructure projects procured by PPPs to achieve resilience in the built environment. The next section will provide more detail on what NbS are and which are the co-benefits associated with their implementation in resilient infrastructure projects.

## Nature-based Solutions

The concept of NbS as a terminology was first introduced by the World Bank at the end of the 2000s as a new solution to mitigation and adaptation to climate change[38]. They were later adopted and promoted as a concept by the International Union for Conservation of Nature (IUCN) and the European Commission and expanded in scope to tackle other issues besides climate change action such as biodiversity and urban sustainable development. The European Commission presents the following definition[39].

- "**NbS** are solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social, and economic benefits and help build resilience; such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes, and seascapes, through locally adapted, resource-efficient and systemic interventions".

It is important to note that, although NbS are referred to as being innovative in some instances, they should not include exclusively novel solutions. There are already plenty of existing ideas and lessons from past experiences that can already be considered NbS, including those of indigenous and traditional communities. There should also be space for local and traditional knowledge when considering the design and implementation of NbS since traditional environmental management systems often already include sustainable, locally-adapted and biodiversity-enhancing practices. However, many NbS remain relatively novel solutions, presenting important challenges and unknowns in terms of their (co)design, operation, maintenance and how to organise their implementation.

The main features of NbS can be broadly summarised in the following four points according to Pauleit et.al (2017):[40]

1. The concept of NbS is broad in definition and scope. While the concept is rooted in climate change mitigation and adaptation, it is understood as an umbrella term for simultaneously addressing several policy objectives.
2. NbS can be differentiated from conventional engineering approaches for being multifunctional, conserving and adding to the stock of natural capital, and being adaptable and contributing to the overall resilience of landscapes.
3. The concept of NbS embraces and promotes the use of integrative, participatory and governance-based approaches for their creation and management.
4. The concept of NbS is action-oriented. This means that the concept, as its name suggests, focuses on implementing solutions and actions on the ground. This requires that attention is placed on regulatory frameworks, planning systems and economic instruments.

The concept of NbS is associated with other similar concepts such as ecosystem-based adaptation, ecosystem-based disaster risk reduction, green infrastructure, ecosystem services, natural systems agriculture, natural capital and ecological engineering. NbS is the most recent of these concepts and, due to its broad definition, it is commonly believed to represent an umbrella concept to the other concepts but with a distinct focus on deployment of actions on the ground. One such definition from IUCN (2016) describes NbS as "actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits."[41] **Box 12** presents more detail around the typology of NbS.

**Box 12**. Typology of Nature-based Solutions

According to Eggermont et.al. (2015:244), NbS can be divided into three types[42,43]:

**"Type 1 – Low human intervention:** consists of no or minimal intervention in ecosystems, with the objectives of maintaining or improving the delivery of a range of ecosystem services both inside and outside of these preserved ecosystems. Examples include the protection of mangroves in coastal areas to limit risks associated to extreme weather conditions and to provide benefits and opportunities to local populations, and the establishment of marine protected areas to conserve biodiversity within these areas while exporting biomass into fishing grounds. This type of NbS is connected to, for example, the concept of biosphere reserves incorporating core protected areas for nature conservation and buffer and transition areas where people live and work in a sustainable way.

**Type 2 – Medium human intervention:** corresponds to the definition and implementation of management approaches that develop sustainable and multi-functional ecosystems and landscapes (extensively or intensively managed), which improves the delivery of selected ecosystem services compared to what would be obtained with a more conventional intervention. Examples include innovative planning of agricultural landscapes to increase their multifunctionality; and approaches for enhancing tree species and genetic diversity to increase forest resilience to extreme events. This type of Nature-based Solution is strongly connected to concepts like natural systems agriculture, agro-ecology, and evolutionary-orientated forestry.

**Type 3 – High human intervention:** consists of managing ecosystems in very intrusive ways or even creating new ecosystems (e.g., artificial ecosystems with new assemblages of organisms for green roofs and walls to mitigate city warming and clean polluted air). Type 3 is linked to concepts like green and blue infrastructures and objectives like restoration of heavily degraded or polluted areas."

The boundary between these three types is obviously fuzzy and depending on the context and problems faced, hybrid solutions can be developed. For example, a constructed wetland can be developed as a Type 3 Nature-based Solution but, when well established, may subsequently be preserved as a Type 1.

The effective implementation of NbS can have different positive environmental, economic and social impacts. For instance, these benefits include:[39]

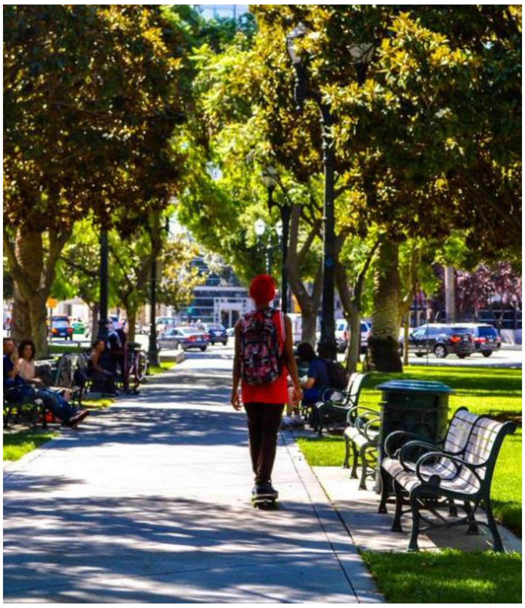
- **Climate change mitigation:** NbS can contribute to climate change mitigation efforts by sustaining or enhancing carbon storage and carbon sequestration. This is achieved through the conservation, restoration or enhancement of forests, wetlands, grasslands, and agricultural lands. In urban settings, NbS can contribute to climate mitigation by reducing energy demand for thermal control through microclimate regulation and by providing adequate spaces for active transport like walking or cycling, thus reducing the use of cars and their emissions.
- **Net Biodiversity Gains (conservation and restoration):** To provide their services, NbS need to be based on healthy and biodiverse ecosystems, thus, biodiversity conservation actions should be always at the core of this type of solutions. Effective NbS provide co-benefits that enhance ecosystem restoration and management, urban biodiversity, agrobiodiversity, and ecosystem resilience.
- **Improvement of water quality and waterbody conditions** (see **Figure 2.13**): Effective NbS can address the following issues related to water quality and waterbody conditions:
    - Point sources of pollution, including combined sewer overflows;
    - Urban drainage and stormwater quality, including urban diffuse pollution control;
    - Agricultural pollution, land drainage and soil erosion in rural catchments;
    - Hydro-morphology (the shape and physical characteristics of rivers, estuaries and open coastlines) and the restoration of modified waterbodies; and
    - Wider relationships with social cohesion, regeneration, health and wellbeing.

**Figure 2.13** Wetland restoration bringing improvement of water quality and waterbody conditions.

*Source: AECOM, 2021.*

- **Climate change adaptation and resilience:** NbS contribute to mitigating natural hazards and those exacerbated by climate change, for instance flooding and storm surges. While supporting communities to adapt to a changing climate, NbS reduce the impact of disasters and increase the resilience of people, assets, and ecosystems. These solutions can be either small-scale, applied at urban or local level, like porous pavements, green roofs, vegetated swales, and rainwater harvesting. Alternatively, large-scale solutions are often applied in rural or coastal areas, river basins or at regional level and include lakes, floodplains, wetlands, and mangroves.
- **Microclimate regulation and air quality:** NbS can contribute to microclimate regulation, especially in urban spaces, through shading, evaporative cooling, or wind shielding. As established before, this has not only implications for the thermal comfort of people and of the urban ecosystems but can also contribute considerably to energy savings and to indirect carbon savings. This is because NbS can reduce the intensity of heatwaves or mitigate the urban heat island effect, therefore leading to a reduced need for energy for cooling. For instance, according to the European Commission (2020) "the indirect carbon saving related to the shading and cooling effect can be 3 times or bigger than the direct carbon sequestration by the same tree".[39] Additionally, NbS are considered highly effective in taking up or removing a number of air pollutants. Nevertheless, designing solutions for this purpose is quite complex since there is a great diversity of air pollutants, different plants have different sensitivities to these pollutants, and some species can even create ecosystem disservices in terms of air quality thanks to pollen emissions and biogenic volatile organic compounds (BVOCs) (compounds emitted from vegetation into the atmosphere that have significant effects on other organisms and on atmospheric chemistry and physics). **Figure 2.14** provides an example of trees providing shading for microclimate contrrol in urban settings.

**Figure 2.14** Trees providing shading for microclimate control in urban settings.



*Source: AECOM, 2021.*

**Figure 2.15** Spaces for active transport creating climate mitigation and health and well-being benefits

*Source: AECOM, 2021.*

- **Health and well-being:** Access to the ecosystems embedded in NbS is a fundamental component of life quality, increasing health and well-being, improving townscapes, and favoring social cohesion. Some NbS provide the appropriate spaces for physical activity, the regulation of microclimates and air quality which has positive impacts on health reducing cardiovascular mortality or respiratory diseases. Additionally, it has been proven that access to green spaces has positive impacts to mental health and psycho-social wellbeing. See **Figure 2.15** above for an example of NbS alongside a cycleway.
- **Sustainable and inclusive communities:** NbS initiatives can and should allow for the involvement of local communities in their design and implementation. Without inclusion of effective participatory processes in the preparation and implementation of these solutions there is the risk of exacerbating inequalities and generate outcomes that are incompatible with goals for sustainable communities.

## The role of NbS in PPPs

NbS necessarily requires the adoption of a systematic approach to identify the impacts of a project and influence the design of solutions that will contribute to achieving the project's goals. In this way, they can be a helpful catalyst for practitioners to think through the interrelation of their projects on a broader scale. NbS can also be a critical factor in enhancing resilience *through* infrastructure, particularly important for vulnerable communities, who typically rely on natural resources and functioning ecosystems for their livelihoods.

Moreover, there is an estimated funding gap for ecosystem conservation and restoration of approximately US$330 to US$400 billion annually, of which half could potentially be filled by private investment[44]. The private sector has historically lacked interest in investing in NbS because of relatively low returns and long time horizon, alongside limited liquid investment opportunities and non-transparent risks[44]. However, it is possible for project developers to design a business case for NbS that generate returns on the money invest and save costs.

**PPPs can provide a vehicle to scale up development of projects incorporating NbS.** Blended finance offers opportunities for private and public finance to support investment in NbS. Additionally, PPP practitioners should integrate NbS into project design to enhance resilience *of* infrastructure and in the 'resilience options' to help to mitigate identified climate risks. When integrating NbS into PPP rather than a stand-alone measure it is also important to consider the challenges for the private sector investment model. Integrating NbS solutions into the structuring PPPs can help build resilience and potentially add to overall savings from CapEx to OpEx over the life of the project

NbS are not "the one and only" possible solution, but need to be embedded in a wider, coherent strategy at research and policy level. Typical challenges such as access to land and permitting remain for NbS as they do for many other investments. These solutions need to be one part of a wider portfolio of sustainability and resilience-building actions and appropriate investment and planning should be done for all of the possible solutions. Resilience must be built not only in the technical/physical elements, as in traditional engineering practices, but also in the social/organisational elements such as institutional arrangements. Without taking care to properly building systemic resilience, the built environment will not be able to cope with the challenges of climate change.

## 2.3. Best practice case studies

This section will present case studies from different geographies to illustrate climate resilience measures can be integrated into different infrastructure projects, including PPPs.

### As-Samra Wastewater Treatment Plant, Jordan

Amman and Zarqa are Jordan's largest cities. Their growing population, combined with the influx of Syrian refugees, and Jordan's declining groundwater levels has put increasing strain on the country's water supply. To combat this, much of Jordan's agricultural water supply comes from treated wastewater. The As-Samra Wastewater Treatment Plant (WWTP) was built to upgrade the city's aging water infrastructure and increase the available supply.

The project was delivered through a Build, Operate, Transfer (BOT) model using blended finance, where the project company, the Samra Plant Company, received a 25-year concessional loan. Investment for Phase 1 of the project was a 54:46 split between public and private entities. USAID and the Jordanian government provided public investment for phase one. For Phase 2, there was a 51:49 split between public and private entities. The Millennium Challenge Corporation and the Jordanian government provided the public investment for phase two. Private investment for both phases came from a consortium of banks led by the Arab Bank and the Samra Plant company.

The As-Samra WWTP supplies enough water to irrigate approximately 4,000 farms across 10,000 acres. The plant itself generates 80% of its electricity from renewable on-site supplies, providing a cost savings of approximately US$14 million annually in operations. Additionally, the project generates revenue from water tariffs, and provides the lowest cost of treatment per cubic meter in Jordan.

This project exemplifies resilience *through* infrastructure because it addresses historical constraints on water supply by prioritizing water reuse, mitigating drought risk to an extent and working to extract less water from the Jordan River Valley. Furthermore, it supports the livelihoods of those in Jordan's agricultural sector.

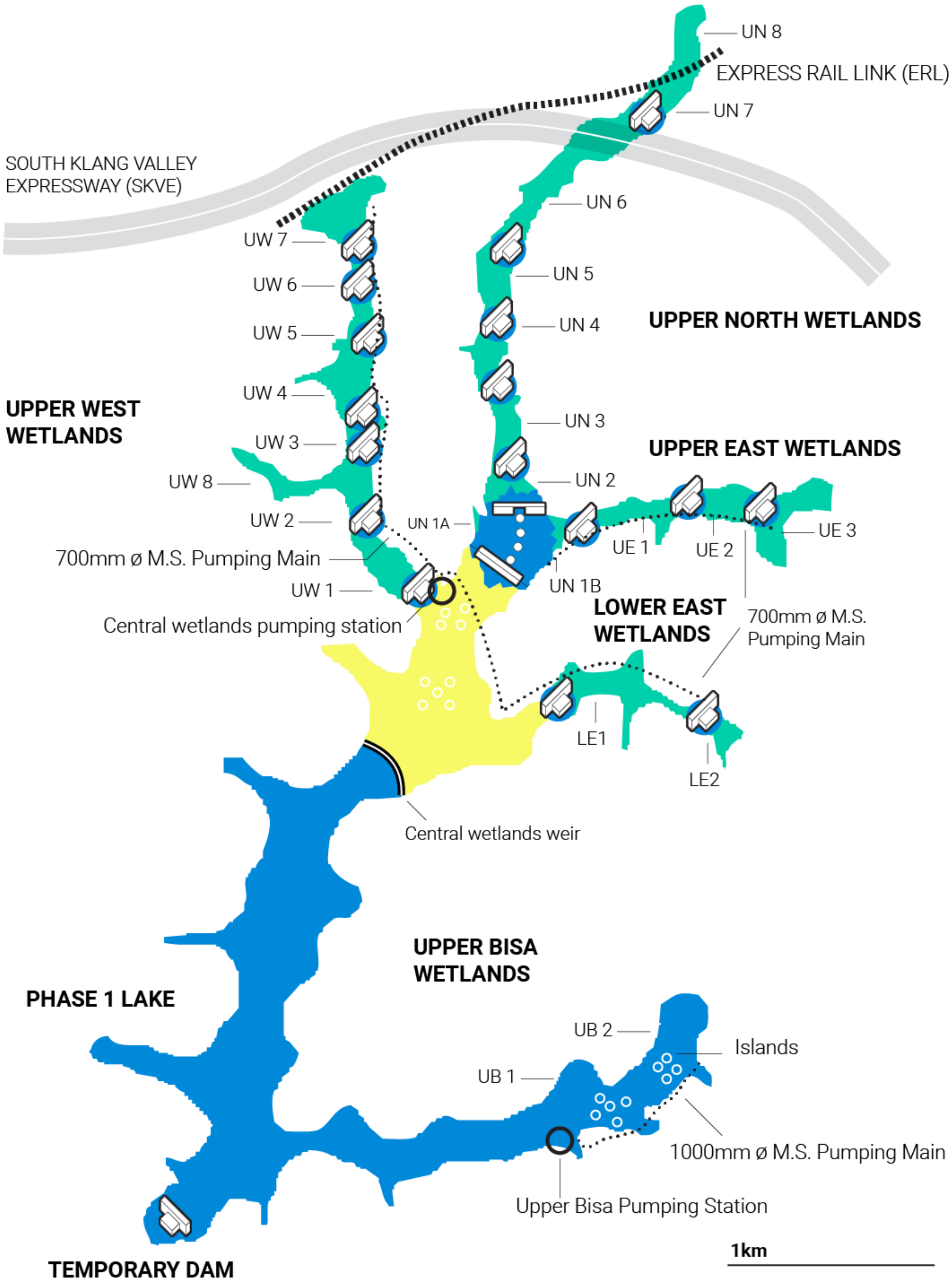
*For more information, please check: WWF. 2020. Bankable Nature Solutions. Amsterdam. P. 75.*
*https://wwfint.awsassets.panda.org/downloads/bankable_nature_solutions_2__1.pdf*

### Putrajaya constructed wetland in Putrajaya, Malaysia

Putrajaya is the administrative capital of Malaysia and the largest public sector urban development project on a greenfield site in the country covering 49 $km^2$. It has been designed to be a model city of sustainable development to demonstrate how new development can be compatible with nature. This includes avoiding the degradation of the natural environment inside and around the development.

The Putrajaya Wetland is located at the north of the development in the valley of the Chuau and Bisa rivers and covers approximately 200 hectares of water and land (see **Figure 2.16**). The Putrajaya Wetland is considered to be the largest constructed freshwater wetland in Southeast Asia. Its construction began in 1997 and was finished in 2002. Its key function is to improve the quality of catchment water before it enters the Putrajaya Lake. It has wider economic and social co-benefits by having a role in increasing urban aesthetics, attracting tourism, and as a space for education and research.

**Figure 2.16** The Putrajaya Wetland system




*Source: Adapted from PLWMOS. plwmos.ppj.gov.my*

The Putrajaya Wetland uses a multicell, multistage system with flood retention capability. The system consists of 24 cells divided into six arms. A series of rock-filled weirs was constructed along the six arms of the wetland to divide the 24 cells. All the six arms are connected but they differ in size, depth, plant communities, and pollutant load capacity. Each cell is planted with wetland plants native to Malaysia.

The benefits of this project include natural stormwater and flood management, increase in wildlife habitat and conservation zones and creation of a site for the development of nature education and research. The increase in jobs and revenue from outdoor tourism from internal and international travellers and the opportunity for livelihood diversification through fishing and provision of food. The wetland area successfully filters pollutants from both the air and water, improving the quality of both to benefit public and ecosystem health. Wetlands are known to be highly effective for sequestering and storing carbon, having a profound climate mitigation impact while establishing an aesthetically stimulating environment, to improve mental wellbeing.

*For more information please check: Asian Development Bank. NbS for building resilience in towns and cities: Case studies from the Greater Mekong Subregion. Mandaluyong City, Philippines: Asian Development Bank, 2016. (https://www.adb.org/publications/nature-based-solutions-building-resilience-towns-cities-gms)*

## Public-Private Partnership for a new flood proof district in Bilbao, Spain

Bilbao is located in the Nerbioi valley in the north of Spain through which the Nerbioi River flows, influenced by ocean tides. The most common threat in the valley is river flooding caused mainly by increased runoff due to land cover changes in the region. Based on regional climate models, it is expected that the effects of climate change will increase the threat of flooding due to the increase in extreme precipitation events and the increase in sea level rise which will produce higher tides that will aggravate flooding potential along the estuary.

Bilbao is a city with a thriving and expanding economy and is facing high demand for new housing units and related infrastructure. As the city is located in a valley, there is not much room for the city to expand and the redevelopment of some areas has been found as the most promising solution. Because of this, the city decided to redevelop an abandoned industrial peninsula situated in the Nerbioi River called Zorrotzaurre. The objective of the redevelopment project is to turn Zorrotzaurre from an industrial site to a residential area with the adequate protection from flooding. The urban redevelopment in Zorrotzaurre started in 2017 and is expected to be finished within 30 years.

The project was structured as a PPP, consisting of Zorrotzaurre landowners and public authorities, which have created the SPV Comisión Gestora de Zorrotzaurre. The members contribute financially relative to the ownership of land (51% public, 49% private). The main stakeholders of the redevelopment project, the land owners of Zorrotzaurre, created the Public-Private Partnership as a necessary element to advance the project. In other words, without this initiative from the landowners, the project would have not started. Due to the importance of the project and the amount of land owned by public authorities (Port, City and Province), the public sector joined the 'Comisión Gestora'. The 'Comisión Gestora' is a union of owners with no special legal status. The 'Junta de Concertación', the organization that was created to develop the first phase of the project, is an organisation defined in the Basque law for urbanism. Both are not-for-profit, since the final objective is to balance the costs with investments made by the owners.

The new quarter will be well-connected to the rest of the city and will be equipped with affordable housing (50% of new housing units will be social housing), areas for environmentally-friendly industry and two thirds of the area will be reserved for public use, including open green spaces and public facilities for education, health, sport and cultural uses. To protect Zorrotzaurre from flooding, the following measures are being taken:

- Opening of the Deusto canal converting the peninsula into an island.
- Elevation of the ground level (about 1.5 meters).
- Construction of a flood protection wall
- Green open spaces like a 20-meter-wide park along the 7.5 km long river bank, a 40,000 square meters park in the center of the island and more than 5,000 square meters of "green fingers" inside the island.
- 3 storm water tanks to store excess water.

This project shows a very good example of how the adoption of hybrid approaches that integrate NbS to the use of infrastructure PPPs in urban spaces can make them more sustainable and resilient. The likely co-benefits of integrating green open spaces include a multitude of advantages for public health, reducing morbidity and mortality by offering space for physical exercise, stimulating mental wellbeing and alleviating stress. Likewise, urban green spaces are known to reduce the urban heat island effect while purifying air quality and removing pollutants. The cultural benefits of urban green spaces might include social cohesion, recreation and tourism growth further to the potential biodiversity gains.

*For more information see: Climate Adapt. 2021. Public-private partnership for a new flood proof district in Bilbao. [online] Available at: <https://climate-adapt.eea.europa.eu/metadata/case-studies/public-private-partnership-for-a-new-flood-proof-district-in-bilbao> [Accessed 3 March 2021]*

## Hybrid green-grey infrastructure in Puerto Morelos, Mexico

Puerto Morelos is a seaport and resort town about 35 kilometres south of Cancun on Mexico's Yucatan Peninsula. Beach erosion has been a growing problem in the town since the early 2000s and has been exacerbated by construction of a marina and other structures. The port is also quite susceptible to storm damage, which became evident in August 2007 during the occurrence of Hurricane Dean[45].

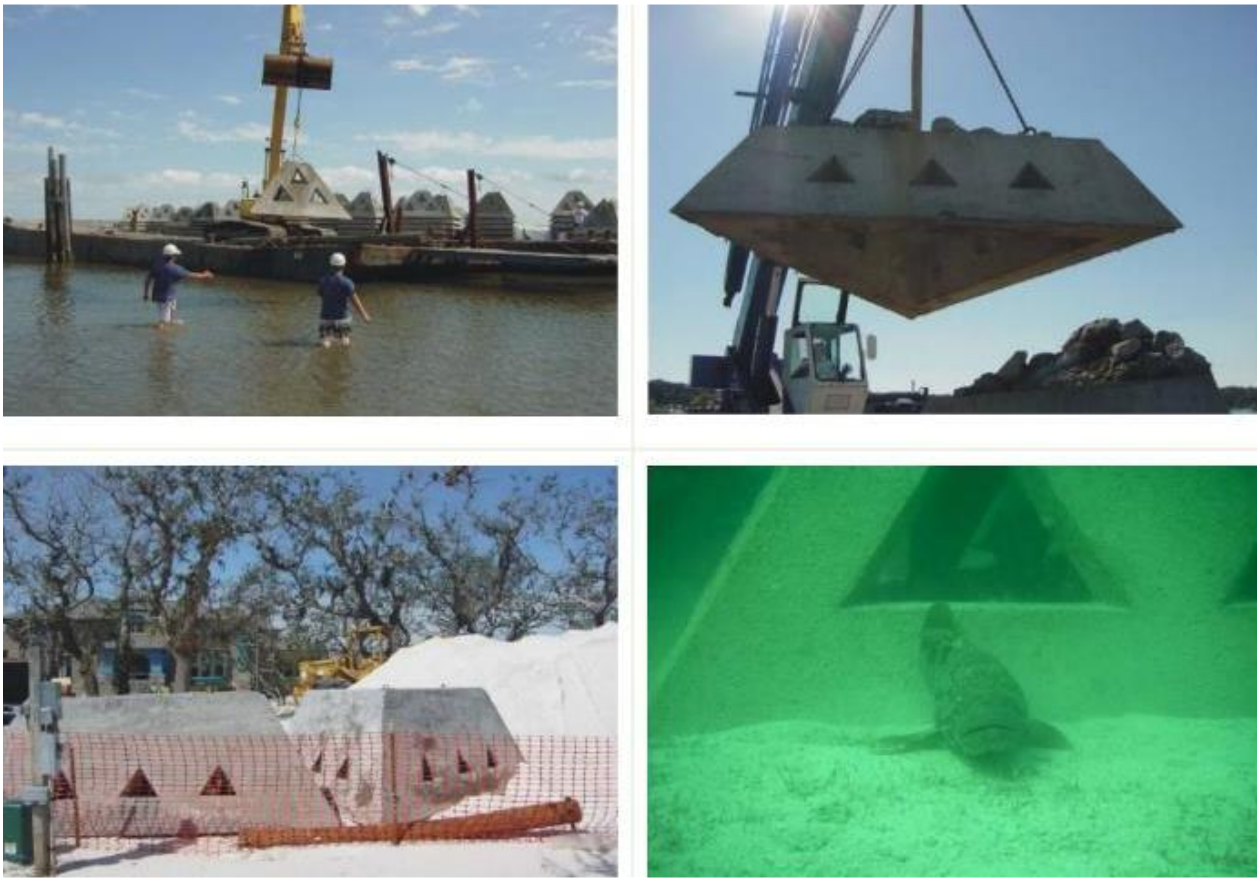
Local planners worked together with scientist at the coastal engineering laboratory of the National Autonomous University of Mexico (UNAM) to come up with a solution to Puerto Morelos' susceptibility to storm damages and chronic beach erosion. They decided to build an artificial reef (see **Figure 2.17**) that could dissipate wave energy, help restore natural beach replenishment processes, be colonised at low cost by coral reef from the Mesoamerican reef and preserve the aesthetics of the area which are valued by tourists.

A Wave Attenuation Device made of pH-neutral reinforced marine-grade concrete was selected for the artificial reef. Prefabricated sections were placed in 2010 to form a 60-meter long artificial reef. Since then, Puerto Morelos beach has been stabilised and the artificial reef has been successfully colonised by coral and other marine flora and fauna.

Besides the climate and environmental benefits, the artificial reef will entice biodiversity and support healthy marine ecosystems which, in turn, create possibilities for fishing to support the local economy and provide food. Establishing new habitats for fishing reduces the pressure on marine protected areas and fish stocks at other overexploited or sensitive locations. In the same way marine ecosystems, like coral reefs, can be a platform for both education and research. Both natural and artificial coral reefs are known to attract local and international travellers for recreation and tourism purposes, generating further income and opportunities for livelihood diversification.

*For more information see: Cavallo, E. A., Powell, A., & Serebrisky, T. (2020). From Structures to Services: The Path to Better Infrastructure in Latin America and the Caribbean. IDB Publications (Books).*

**Figure 2.17** Building an artificial reef



*Source: Government of Mexico. No year. Arrecife Artificial Frente Al Hotel NH Puerto Morelos. Available from: http://sinat.semarnat.gob.mx/dgiraDocs/documentos/qroo/estudios/2009/23QR2009T0032.pdf [Accessed 8 March 2021].*

## Balephi Landslide Slope Stabilization, Nepal

Roads construction and maintenance in the mountainous region of Nepal presents several challenges like steep slopes, weak rock mass, thick soil profile, and high rainfall during the monsoon period. The most common and destructive disasters during and after road construction are landslides, debris flows, slumping, and erosion on slopes.

The Balephi Landslide occurred in Sindhuplachowk during the 2002 monsoon affecting the Balephi–Jalbire Road. The Balephi to Jalbhire road is an important access road for people living in the areas around and beyond Jalbhire and provides a route for agricultural products on their way to major markets in Dhulikhel, Kavre, and Kathmandu. The landslide completely washed away a 120-meter section of the road and disconnected the traffic flow for days.

The Balephi Landslide was independently assessed, and designs were drawn up by a geotechnical and structural engineer using conventional engineering methods. A bioengineering specialist was also called in to incorporate suitable bioengineering techniques to enhance the performance of the proposed structure and to create a more sustainable long-term solution.

The landslide was split into nine segments according to the nature of the materials, water movement behaviour on the slope, and the failure mechanisms. Each segment was handled according to its needs, which included debris removal, slope trimming, drainage, stabilization, and erosion control. Standard engineering technologies such as stone and concrete revetments acted as the base of the stabilization. However, native grasses, shrubs, and wood cuttings were added to increase stability and provide natural water management. Brush layering increased slope stability and created more habitat for plant and wildlife species.

The Balephi Landslide slope stabilization project demonstrates that bioengineering techniques that use NbS can produce better economic and environmental results for slope stabilization when compared to conventional engineering solutions, and they can be implemented at a lower cost (see **Figure 2.18**). For instance, an analysis of the project from the ADB showed that the cost of conventional engineering alone would have been 48% higher than the combination of conventional and bioengineering (hybrid approach). The use of NbS in slope stabilization can bring other benefits including improved water quality, increased wildlife habitat, and improved aesthetics.

**Figure 2.18**. Slope stabilization in Nepal with bioengineering techniques

*For more information please check: Asian Development Bank. NbS for building resilience in towns and cities: Case studies from the Greater Mekong Subregion. Mandaluyong City, Philippines: Asian Development Bank, 2016. (https://www.adb.org/publications/nature-based-solutions-building-resilience-towns-cities-gms)*

## Additional case studies

More information about additional case studies can be found in the following documents:

**Table 2.4** Additional case studies

| Project Title | Topic | Link |
|---|---|---|
| **Room for the River Waal – protecting the city of Nijmegen** | The report focuses on the city of Nijmegen, which sits at a bend of the Waal River and faces significant flood risk as a result. This case study focuses on the decision to move the existing dike inland, dig a new ancillary channel to accommodate high river flows, and develop an urban river park through the process. | *https://climate-adapt.eea.europa.eu/metadata/case-studies/room-for-the-river-waal-2013-protecting-the-city-of-nijmegen* |
| **Itaipú Dam: How natural ecosystems support one of the world's largest hydroelectric dams** | This case study focuses on the world's largest hydroelectric dam and how the project harnessed NbS to enhance the resilience of the dam, including planting 44 million trees around the dam. | *https://www.resilienceshift.org/wp-content/uploads/2020/08/Itaipu-Dam-case-study-Resilience-Shift.pdf* |
| **Green Roads for Water: Example in Ethiopia** | This case study focused on mitigation erosion, flooding, and siltation on roads in Africa through road water harvesting and management. | *https://roadsforwater.org/wp-content/uploads/2019/12/latest-paper-ptractices-and-hydrological-effects-of-roads.pdf* |
| **North West Cambridge Surface Water Management** | As part of the North West Cambridge urban development project, this case study looks at pioneering water management strategies that have been integrated into the plan to capture, store and naturally treat stormwater runoff. | *https://publications.aecom.com/water/managing-flood-risk/projects/north-west-cambridge-development* |
| **Wadi Hanifah in Riyadh, Saudi Arabia** | The Wadi Hanifah stormwater management plan harnessed the natural features of the watershed to address flood risk. | *https://www.burohappold.com/projects/wadi-hanifah-flood-management-plan/* |

## 2.4. Recap

This Module covered the concept of resilience and how it relates to climate change and infrastructure. We also took a look at NbS, which may be a new concept to many. Harnessing NbS and working to integrate them within grey infrastructure projects is a great way to maximise co-benefits. In the next Module, we will identify some key tools and capacities that will be useful when integrating resilience into the PPP project cycle.

## 2.5. References for further learning

If you want to further investigate the topics covered in Module 2, please refer to the sources, which are organised by theme.

| Theme | References |
|---|---|
| **Resilient Infrastructure** | Adshead, D., Fuldauer, L.I., Thacker, S., Román García, O., Vital, S., Felix, F., Roberts, C., Wells, H., Edwin, G., Providence, A., and Hall, J.W. 2020. Saint Lucia: National Infrastructure Assessment. United Nations Office for Project Services. Copenhagen. Available at: *https://content.unops.org/publications/Saint-Lucia-National-Infrastructure-Assessment.pdf*<br><br>Biagini, B., Bierbaum, R., Stults, M., Dobardzic, S., & McNeeley, S. M. 2014. A typology of adaptation actions: A global look at climate adaptation actions financed through the Global Environment Facility. Global Environmental Change, 25, 97-108. . *https://doi.org/10.1016/j.gloenvcha.2014.01.003*<br><br>Cavallo, E. A., Powell, A., & Serebrisky, T. (2020). From Structures to Services: The Path to Better Infrastructure in Latin America and the Caribbean. IDB Publications (Books). *http://dx.doi.org/10.18235/0002505*<br><br>Chappin, E J. L. and van der Le, T.. 2014. "Adaptation of Interconnected Infrastructures to Climate Change: A Socio-Technical Systems Perspective." Utilities Policy 31:10–17. *https://doi.org/10.1016/j.jup.2014.07.003*<br><br>OECD. 2018. Climate-resilient Infrastructure: OECD Environment Policy Paper NO.14. Paris. Available at: *https://www.oecd.org/environment/cc/policy-perspectives-climate-resilient-infrastructure.pdf*<br><br>Tanner, T. Surminski, S. Wilkinson, E. Reid, R. Rentschler, J. Rajput, S. 2015. The Triple Dividend of Resilience. Realising development goals through the multiple benefits of disaster risk management. Global Facility for Disaster Reduction and Recovery (GFDRR) at the World Bank and Overseas Development Institute (ODI). Washington. Available at: *https://www.gfdrr.org/sites/default/files/publication/The_Triple_Dividend_of_Resilience.pdf* |
| **Nature-based Solutions** | Barnett, Jon, and Saffron O'Neill. 2010. "Maladaptation." Global Environmental Change 20(2):211–13. *https://doi.org/10.1016/j.gloenvcha.2009.11.004*<br><br>Depietri Y., McPhearson T. 2017. Integrating the Grey, Green, and Blue in Cities: NbS for Climate Change Adaptation and Risk Reduction. In: Kabisch N., Korn H., Stadler J., Bonn A. (eds) NbS to Climate Change Adaptation in Urban Areas. Theory and Practice of Urban Sustainability Transitions. Springer, Cham. *https://doi.org/10.1007/978-3-319-56091-5_6* |

| Theme | References |
|---|---|
| | Eggermont, H., Balian, E., Azevedo, J. M. N., Beumer, V., Brodin, T., Claudet, J., ... & Le Roux, X. (2015). NbS: new influence for environmental management and research in Europe. GAIA-Ecological Perspectives for Science and Society, 24(4), 243-248. *http://dx.doi.org/10.14512/gaia.24.4.9*<br><br>European Commission. 2020. "NbS - State of the Art in EU-funded Projects". *https://ec.europa.eu/info/files/nature-based-solutions-state-art-eu-funded-projects_en*<br><br>IUCN. 2020. Ensuring effective Nature-based Solutions. Gland. Available from: *https://www.iucn.org/resources/issues-briefs/ensuring-effective-nature-based-solutions* [Accessed 12 January 2021.]<br><br>Pauleit, S., Zölch, T., Hansen, R., Randrup, T. B., & van den Bosch, C. K. (2017). NbS and climate change–four shades of green. In NbS to climate change adaptation in urban areas (pp. 29-49). Springer, Cham. *http://dx.doi.org/10.1007/978-3-319-56091-5_3* |
| **Resilience concepts** | Ayyub, Bilal M. 2014. "Systems Resilience for Multihazard Environments: Definition, Metrics, and Valuation for Decision Making." Risk Analysis 34(2):340–55. *https://doi.org/10.1111/risa.12093*<br><br>Francis, R., & Bekera, B. 2014. A metric and frameworks for resilience analysis of engineered and infrastructure systems. Reliability Engineering & System Safety, 121, 90-103. *https://doi.org/10.1016/j.ress.2013.07.004*<br><br>IPCC. 2018. Annex I: Glossary [Matthews, J.B.R. (ed.)]. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Pres<br><br>Righi, Angela Weber, Tarcisio Abreu, Priscila Wachs, Tarcisio Abreu Saurin, and Priscila Wachs. 2015. "A Systematic Literature Review of Resilience Engineering: Research Areas and a Research Agenda Proposal." Reliability Engineering & System Safety 141:142–52. *https://doi.org/10.1016/j.ress.2015.03.007* |

# 3. Module 3 – Key tools and capacities to integrate climate resilience into PPPs

**Description:** This Module will provide a high-level introduction to core competencies that we will refer back to in Modules 4 and 5, specifically on stakeholder engagement, decision-making uncertainty, and prioritizing options to enhance resilience.

**Learning outcomes:** By the end of this module, learners will be able to:

- Communicate the importance of stakeholder engagement
- Outline the basic steps of a stakeholder engagement plan
- Articulate what uncertainty means in relation to climate resilience
- Identify methods to deal with uncertainty in decision-making processes

## 3.1. Stakeholder engagement and communication

Stakeholder engagement is a crucial component of any project planning process. Engaging stakeholders ensures the process is participatory, transparent, and incorporates a breadth of knowledge and practice. There are several benefits of engaging stakeholders, including to:

- Provide more detailed information to input into project preparation processes, such as climate risk assessments
- Support the prioritization of resilience options and understanding of willingness to pay for resilience
- Help to understand whether the project will deliver value for society, particularly by identifying and optimizing co-benefits that arise from different resilience options
- Mitigate risk by engaging a range of stakeholders to better understand inter-dependencies, commonalities and trade-offs of a project, thereby potentially highlighting any issues and securing buy-in through participatory planning processes

This section will discuss how to identify relevant stakeholders and how to engage them.

### Who are stakeholders?

Stakeholders as "persons or groups who are directly or indirectly affected by a project, as well as those who may have interest in a project and/or the ability to influence its outcome, either positively or negatively."[46] It is important to consider stakeholders relevant to both climate resilience and the PPP process. This includes public and private sectors alongside civil society and non-governmental organisations, as well as stakeholders directly impacted by the project geospatially and those who may have interests in the project but are not geospatially impacted by it. [47] See **Table 3.1** for examples of stakeholders relevant to climate resilience and PPPs.

**Table 3.1** Examples of types of relevant stakeholders to engage

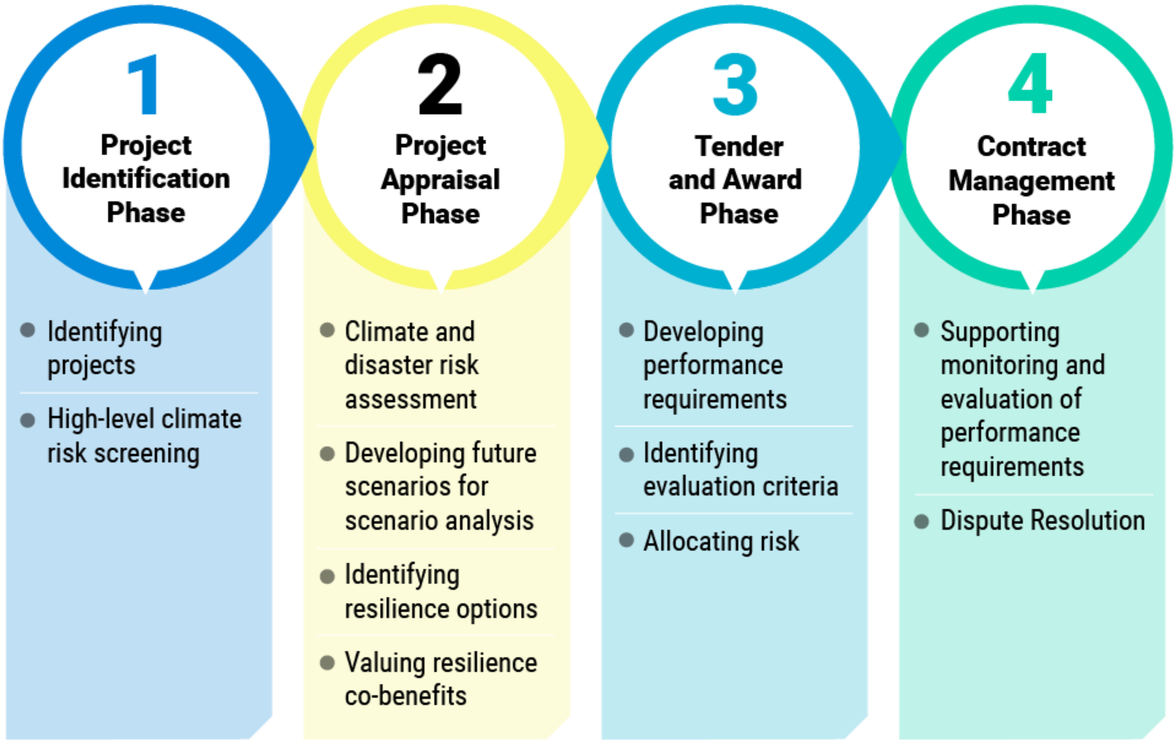
| Topics | Stakeholders |
|---|---|
| **Climate resilience** | • Municipal/state/federal departments and other public entities linked to climate change science and policy (incl. mitigation and adaptation)<br>• Academia and research organisations<br>• Community-based organisations and NGOs<br>• Private sector investors, financial institutions, and suppliers/service providers<br>• Affected groups<br>• Regulators<br>• Government planning agencies |
| **PPPs** | • PPP Unit<br>• Consultants hired by the public sector that need to share strategic information about the PPP initiative<br>• Municipal/state/federal departments and other public entities linked to PPP projects<br>• Government legal staff<br>• Lenders<br>• Private equity/sponsors<br>• Affected groups<br>• Beneficiary/service users |

*Source: Adapted from PPP Knowledge Lab. 2020. Stakeholder Communication and Engagement. Available from: https://pppknowledgelab.org/guide/sections/39-stakeholder-communication-and-engagement*

## How are they engaged?

Stakeholder engagement is core to each stage of the PPP project cycle. **Figure 3.1** identifies the key ways that stakeholders can be engaged in each phase of the project cycle to contribute to the steps specific to climate resilience.

**Figure 3.1** Key ways in which stakeholders can contribute to steps specific to climate resilience




A clear Stakeholder Engagement Plan (SEP) should be developed as part of a Project Identification Phase and will identify how stakeholder engagement for the climate resilience aspects will change over the course of the project during different phases. The SEP should include, but is not limited to, the following steps:

1. Outline purpose of SEP and how it relates to climate resilience and PPPs
2. Develop a stakeholder engagement map
3. Identify proposed set of engagement activities throughout the project cycle, alongside key objectives of these activities
4. Articulate how stakeholders will be kept engaged during the project progress and any grievance mechanism
5. Describe the stakeholder engagement monitoring plan and associated key performance indicators

The first step is to **outline the purpose of the SEP**. Stakeholder engagement is important to climate resilience because stakeholders can provide more comprehensive and tailored insights into local climate risks, what is valued and what is the adaptive capacity of the community to implement resilience measures. This can influence PPP project screening and developing environmental and social safeguards.

The second step is to **map out relevant climate resilience stakeholders** and to what degree they will be engaged. A common way to map stakeholders is through the International Association of Public Participation (IAP2) spectrum, which identifies stakeholders who should be informed, consulted, involved, collaborated with, or empowered (see **Table 3.2**).

**Table 3.2** IAP2 spectrum of public participation, adapted to the context of PPPs and climate resilience

| | Inform | Consult | Involve | Collaborate | Empower |
|---|---|---|---|---|---|
| Public Participation Goal | To engage with stakeholders with balanced and objective information to assist them in understanding their priorities and goals, besides helping to inform them about the need for the project and how resilience can contribute to its benefits | To obtain feedback from stakeholders on the formulation and development of the project, alternatives and/or decisions. This includes prioritising resilience options. | To work directly with the stakeholders throughout the process to ensure that their perspectives and concerns around the project and its resilience as consistently considered. | To partner with stakeholders in each aspect of the decision including the development of alternatives and the identification of the preferred resilience solution. | To place final decision-making in the hands of the stakeholders. This will fall with project 'deciders' who will sign off for all key stakeholders within the PPP structure. |

*Source: Adapted from IAP2. 2018. IAP2 Spectrum of Public Participation. Available from: https://iap2.org.au/wp-content/uploads/2020/01/2018_IAP2_Spectrum.pdf*

**Table 3.3** provides an example of matrix to map stakeholders based on the following criteria:

- *Relevance of stakeholders* – How critical is their role in each process? Do they hold specific information that can inform the PPP project or climate risk assessment and associated resilience options? Do they have decision-making power in relation to the project and therefore must play a role in the assessment? Are they otherwise impacted or related to the assessment or the project as whole? – Scored "1 – low, 2 – medium, 3 – high"
- *Engagement of stakeholders* – How are they best involved in the process – is it just about sharing information ('inform') or obtaining their advice ('consult'), or jointly working on the assessment ('collaborate')? Are there any legal requirements for a certain style of engagement of this stakeholder?[47] – Scored "1 – inform, 2 – consult, 3 – collaborate

**Table 3.3** Example stakeholder mapping matrix

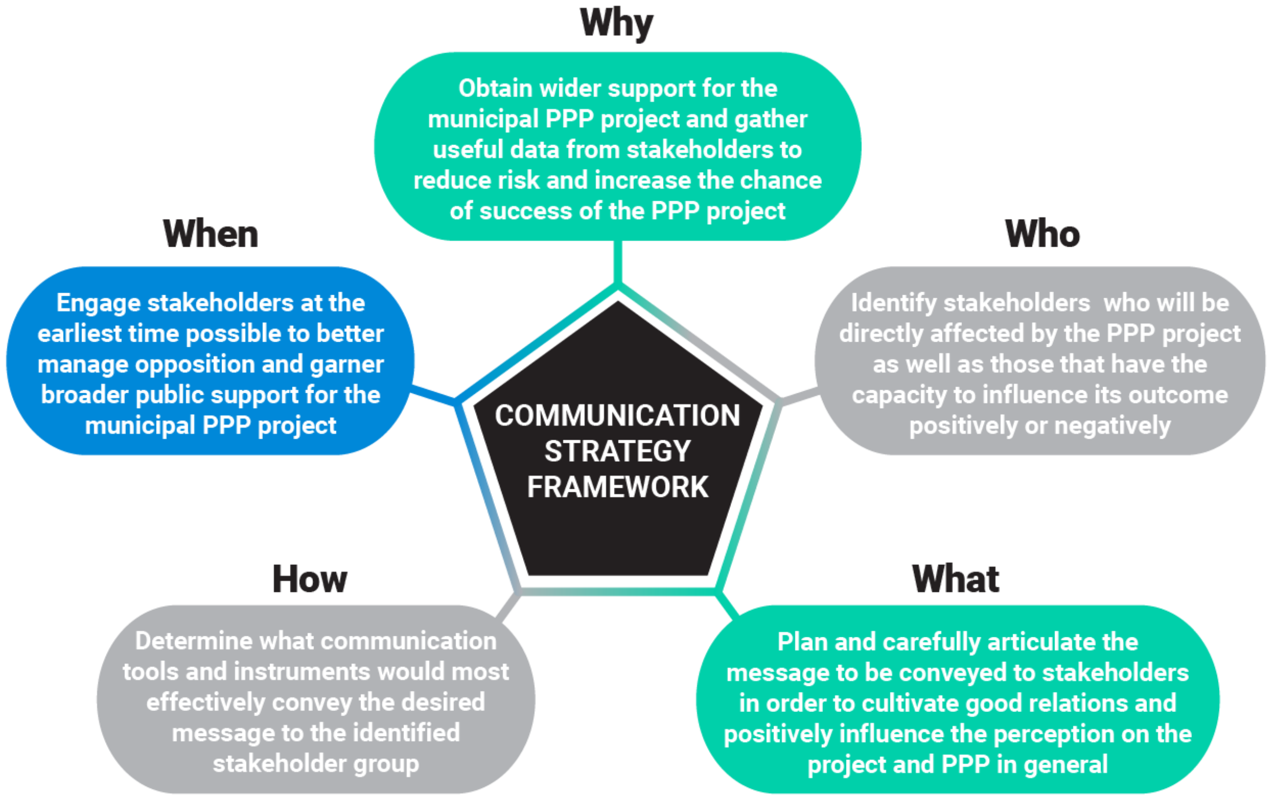
| Organiza-tion | Role | Type of stakeholder | Interests / concerns | Level of relevance (1 – low, 2 – medium, 3 – high) | Level of engagement (1 – inform, 2 – consult, 3 – collaborate) | Project phase | Key contact name and contact details | Recom-mended engagement actions |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |

The third step is to **identify proposed engagement activities.** This can include focus group interviews, roundtable discussions, and tailored workshops to collect information on a particular issue (e.g. key transport issues in a locality, capacity gaps in government around climate data, preferred design specifications for a project to be integrated into culture fabric of built infrastructure). Engagement activities should be identified against key project milestones[48]. At this point, the 10 typologies for adaptation actions prescribed by Biagini et al. (2014) (see Section 2.2) can be evaluated within the potential engagement activities to determine how best to support these in existing projects and how to incorporate these in the future. These typologies include capacity building, management and planning, practice and behaviour, policy, information, physical infrastructure, warning and observing systems, green infrastructure, financing and technology.

The fourth step is **to articulate how stakeholders will be kept engaged of the project.** There should be a clear communication strategy framework to support the engagement of stakeholders throughout the PPP project (see **Figure 3.2**). The communication can be, for example, through short summary notes of each project stage sent via email, or else updates post on government/contractor websites or social media.

The fifth and final step is to **establish a monitoring plan** to assess the success of stakeholder engagement activities. Key performance indicators like 'percentage of invited stakeholders who attended event' can be used to monitor such activities.

**Figure 3.2** Stakeholder communication strategy for PPP projects




*Source: World Bank. 2019. The Municipal Public-Private Partnership Framework. Washington, D.C.*

**Box 13** showcases an example of how stakeholders in Nepal were engaged to develop a Pilot Program for Climate Resilience.

**Box 13**. Stakeholder engagement for climate resilience, Pilot Program for Climate Resilience (PPCR) in Nepal

In 2009, Nepal joined as one of the nine pilot countries for the Pilot Program for Climate Resilience (PPCR), a program of the Climate Investment Funds to support the implementation of programs and investments led by the country. The objective of the Nepal PPCR was to demonstrate ways to integrate climate risk and resilience into development planning. As a first step in the PPCR process, a Strategic Program for Climate Resilience (SPCR) was developed by the Government of Nepal in partnership with the World Bank, IFC and ADB. To ensure that the most impactful investment priorities were identified, a wide-ranging consultation process was undertaken, involving over 850 people at national, district and community level, including representatives from NGOs, government ministries, development partners, private sector, academicians, women's groups, and disadvantaged groups. The stakeholder consultation process included an innovative private sector working group, which was central in convincing the government of the importance (and relevance) of the private sector as a stakeholder in the SPCR process. Some relationships where temporarily stretched, mainly with civil society stakeholders, as their engagement was managed reactively rather than with proactive consultation. This was eased through strong outreach by the government and responsible engagement by CSOs. Overall, the stakeholder engagement and consultations were central to the high quality PPCR and SPCR in Nepal and led to a more inclusive process with good country ownership.

*Source: ADB. 2013. Stakeholder Engagement in Preparing Investment Plans for the Climate Investment Funds Case Studies from Asia. Available from: https://www.adb.org/sites/default/files/publication/30043/stakeholder-engagement-investment-plans-asia.pdf [Accessed 22 January 2021]; and Government of Nepal. No Year. Introduction of PPCR/BRCH Project. Available from: http://brch.dhm.gov.np/project-introduction/ [Accessed 12 February 2021].*

## 3.2. Climate risk assessments

Climate risk assessments are a crucial component to guide and design resilient infrastructure investments. Risk assessments for infrastructure refer to the process of identifying how key infrastructure (facilities and networks) can resist, absorb, accommodate, adapt to, transform and recover from the effects of different shocks and stresses. For spatial areas, risk assessment refers to the process of analysing the economic, social and environmental characteristics or urban or rural areas to identify spaces at particular climate risk. Both assessments – for infrastructure and spatial areas – are required to ensure that specific infrastructure facilities or networks are resilient and to identify key infrastructure needs that can support the climate resilience of a broader area. The aims of a climate risk assessment are to:

- Develop a risk registry
- Identify key hazards, exposure to hazards, and vulnerabilities

- Understand the potential impact on the natural and built environment, people and communities.

For PPP practitioners, this will also be a useful stage to begin thinking about how to allocate risk. This will be discussed further in Module 5. Climate risk assessments include the following characteristics:

- Spatial assessment
- Perspective on current and future development and its impact
- Analysis of climate and natural hazards
- Identification of aspects at particular risk
- Identification of potential structural and non-structural measures to reduce or better manage risk
- Often linked to spatial and investment planning for the prioritization of investments

**Top Tip: Streamline data collection and monitoring.**

High quality data underpins robust risk climate assessments and decision-making about future infrastructure investments or upgrades. Data availability and accessibility remain a major challenge in many countries. One cannot carry out climate risk assessments without access to data.

There are a few key principles to keep in mind when preparing to undertake a climate risk assessment[31]:

1. Use climate indices to evaluate exposure and impacts
2. Use multiple climate scenarios and data sources to manage uncertainties
3. Use project-relevant timescales
4. Incorporate non-monetary outcomes

**Figure 3.3** outlines the typical steps of climate risk assessments. For PPPs, the public partner will be responsible for undertaking a high-level and in-depth climate risk assessment in the Project Screening and Project Appraisal Phase respectively. This is because in order to effectively score bids received from private parties, the public partner needs to have a clear understanding of the risks and potential ways to mitigate those risks. The private partner should undertake a climate risk assessment and this can also be a requirement of the bid. In both cases, the private partner will have to show how the project design proposed has considered climate risk, which will requires the development of a climate risk assessment. The degree to which the project incorporates uncertainty into the climate risk assessment will also influence its Resilience Rating. Uncertainty is discussed in the next section.

The Resilience Options Appraisal step within the climate risk assessment provides a key opportunity for the project developers to identify adaptation options that could enhance the resilience of the project against anticipated current and future climate risks. During this step, practitioners can use a number of tools to make decisions about which option(s) maximize climate resilience (see Section 3.3), which typically make use of net present value (NPV) and benefit-cost ratio (BCR) to evaluate different options. Module 5 provides a detailed walk-through of the steps of a climate risk assessment in relation to the PPP project cycle.

**Figure 3.3** Typical steps of climate risk assessments

**Climate Risk Screening**

1. Rapid screening of the project's and/or beneficiaries' exposure to climate hazards.
2. Source relevant project studies, affiliated reports, and other knowledge.
3. Map stakeholders and prepare TOR for climate a risk assessment.
4. Online preliminary findings of how the project can enhance broader resilience.

**Climate Risk Assessment**

1. Collate data required for climate risk assessment.
2. Analyse the hazards to which the project is exposed.
3. Analyse the project's vulnerability.
4. Assesses the negative impacts of the project through an Environment and Social Impact Assessment (ESIA).
5. Apply different scenarios to assess future climate and disaster risk.
6. Summarise the climate and disaster risk assessment findings.

**Resilience Options Appraisal**

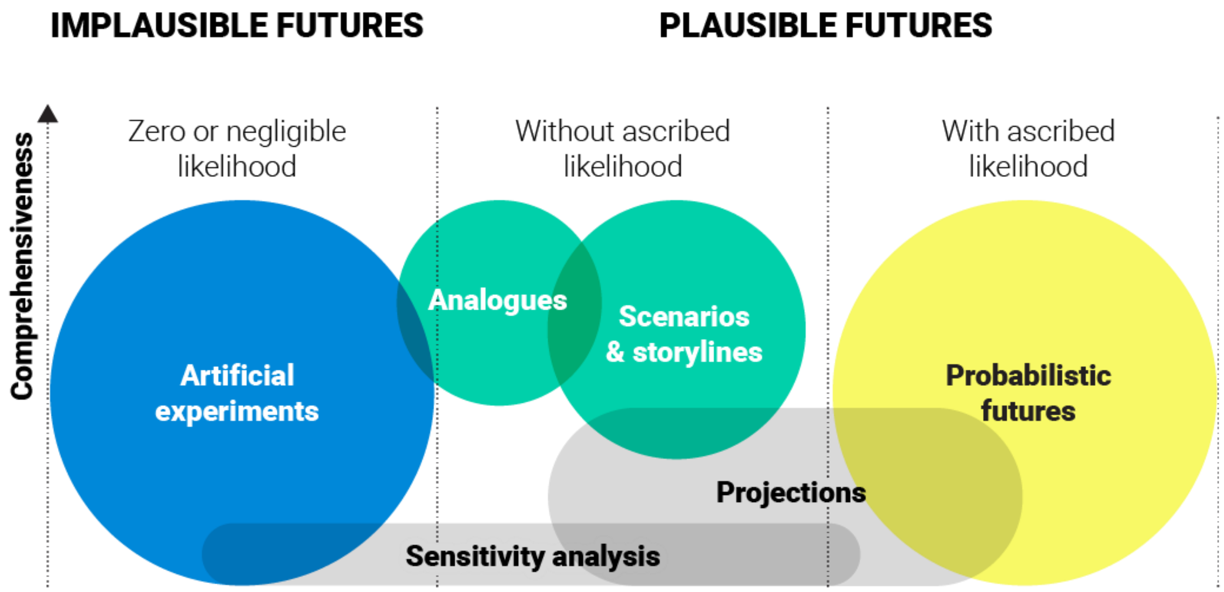
1. Establish objectives of climate and disaster resilience.
2. Identify applicable resilience options.
3. Evaluate applicable resilience options from a technical perspective.
4. Identify resilience option co-benefits.
5. Conduct an economic analysis of applicable resilience options.
6. Combine technical and economic evaluation to prioritize and select preferred resilience options.

*Source: AECOM. 2020. Guidance Note for Assessing Climate and Disaster Risks and Climate Co-Benefits. London/Ankara.*

## Characterising the future

Before we move on to uncertainty, it is important to discuss a core competency for climate risk assessments – defining plausible future scenarios to identify climate risks and appropriate resilience measures, and then stress-test those measures again these plausible future scenarios. The most common methods include scenario analysis and sensitivity analysis. The IPCC provides a helpful schematic in **Figure 3.4** of methods to characterize future scenarios.

**Figure 3.4** Methods to characterise future states




*Source: Adapted from Carter, T.R., R.N. Jones, X. Lu, S. Bhadwal, C. Conde, L.O. Mearns, B.C. O'Neill, M.D.A. Rounsevell and M.B. Zurek, 2007: New Assessment Methods and the Characterisation of Future Conditions. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 133-171.*

**Scenario analysis** is a technique that analyses the possible future impacts on system performance by considering a range of alternative outcomes (e.g. scenarios) to present different options and implications for future development pathways[49]. The costs and benefits of a potential PPP project would then be assessed under each scenario. This is the recommended analysis if the project team has access to defined climate scenarios, as it will help to standardise climate risk analysis in PPP projects[50]. Scenario analysis is undertaken through the following steps:

1. **Identify the focal issue:** This step requires to identify what is the project or issue that is been undertaken. The following questions need to be answered: What is the issue that we are discussing? The decision to build a new bridge? The decision to retrofit existing housing blocks?
2. **Establish a baseline:** To do the analysis, establishing a baseline is required. For that, the following questions need to be answered: What is the baseline against which we will be comparing the future scenario? Is it in comparison to existing conditions today? What is the study area?
3. **Identify key internal and external factors:** Many key factors will already be included in a typical business planning process (e.g. customer demand, competitors, production technologies, capacity, etc.) but it is important to ensure that external factors like climate change, geopolitical forces, technological innovation, and socioeconomic change are also considered.
4. **Identify critical uncertainties:** In this step, the key internal and external factors identified are narrowed down by prioritising those that are most uncertain and have greatest bearing on the focal issue.
5. **Identify scenarios:** Based on the critical uncertainties, identify which two to five scenarios are most appropriate. Key existing sources for scenarios are listed in **Table 3.4** and an introduction to the IPCC scenarios is described in **Box 14.**

6. **Describe scenarios:** You may also detail the existing scenarios by describing the scenario narratives. This will include using past performance as an indicator of future performance and observed data as a proxy for future events (i.e., if past events will be relevant in the future).
7. **Scenario implications and options:** In this step, it is necessary to answer the following questions: What conclusion about the focal issue can you come to as the scenarios identified play out? Are there options to leverage opportunities or mitigate risks presented by the scenarios? Which is a desirable future scenario and how can the focal issue be tailored to achieve this? For evaluators in the PPP process, the main question they need to assess is whether the proposed solution(s) is able to withstand the potential scenarios.

Scenario analysis can be taken a step further by assigning probabilities (**probabilistic analysis**) to either the future scenarios themselves or the parameters that set up the future scenarios. For climate change, we will typically be dealing with subjective probabilities, which are derived from an individual or a group's personal judgment or experience about whether a specific outcome is likely to occur[51]. This is because we are dealing with uncertainty of future scenarios, rather than chance, where the probabilities are known (e.g., in card games). Section 3.3 discusses uncertainty in more detail.

**Sensitivity analysis**, on the other hand, is a method that identifies how changes in a particular model variable impact the model's output. For example, how would the occurrence of a climate hazard like a heatwave impact an urban electrical grid. One could change the degree of intensity of the heatwave to see how the assumptions of the electrical grid's performance would be impacted. This method is useful if a project team does not have the capacity to undertake a full probabilistic analysis.

**Table 3.4** Key sources of climate scenarios

| Physical changes to the climate | Energy system transition scenarios |
|---|---|
| IPCC | IEA |
| National Meteorological Agencies | IRENA |
| MetOffice | Greenpeace Advance Energy Scenario |
| EUMetStat | International Institute for Applied Systems Analysis |
| | Potsdam Institute for Climate Impact Research |
| | Network for Greening the Financial System – NGFS Scenarios Portal |

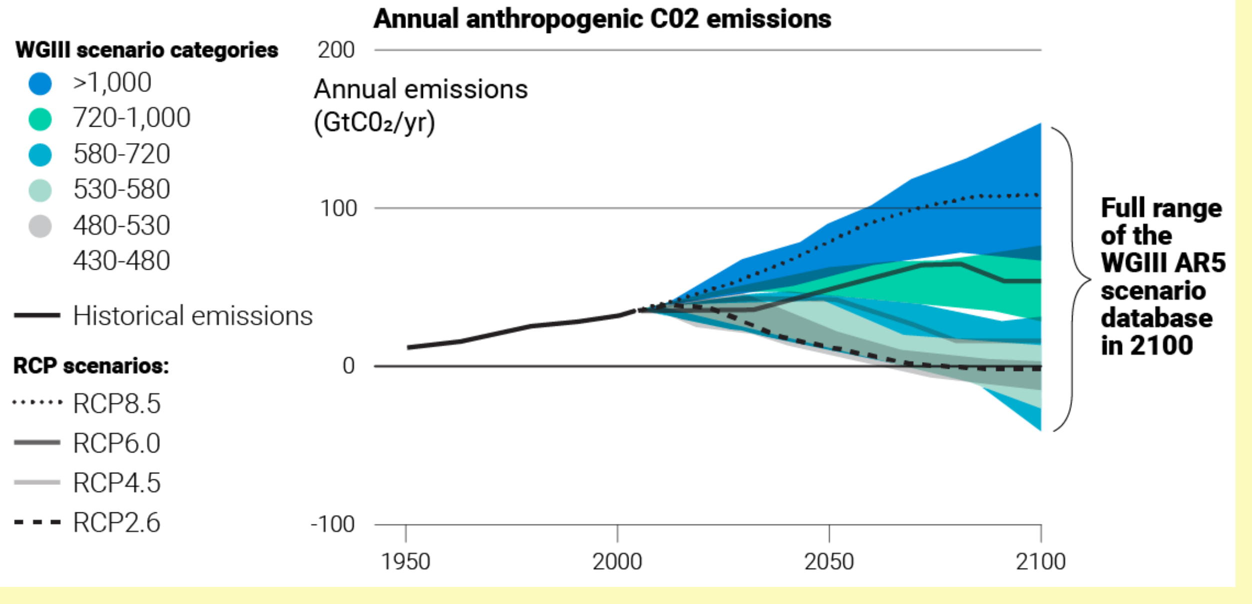
It is important to note that each of these sources in **Table 3.4** present projections at different levels of granularity. Therefore, there is the need to check which level of granularity in the data is required in each project, as sometimes global figures might not provide the necessary level of detail.

**Box 14**. Introduction to the IPCC scenarios

The Intergovernmental Panel on Climate Change (IPCC) is an intergovernmental body of the UN with the mandate to provide independent and objective information and advice on how the physical science of climate change interacts with our socio-ecological systems. Similarly, the aim is to understand how to proceed with mitigation and adaptation strategies based on this understanding.

The four central future climate scenarios developed by the IPCC's Fifth Assessment Report (AR5) are called Representative Concentration Pathways (RCPs) – RCP8.5, RCP6, RCP4.5 and RCP2.6. The RCP scenarios describe different potential future levels of greenhouse gases and other radiative forcings.

At the same time, a second group of IPCC researchers developed the Shared Socioeconomic Pathways (SSPs) (published in 2016), which look at the ways in which the world might evolve under different climate policy futures, and the ways in which these SSPs, in combination with the RCPs, dictate ways society can achieve different levels of climate mitigation[52].




*Source: IPCC. 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. 9.*

These pathways can be used in a scenario analysis within industries to understand, prepare for and test the resilience of a project to future uncertainties. This can be done through data-heavy means like using Integrated Assessment Models, or can be used as a guide for a qualitative stress-testing of decisions against future scenarios.

## 3.3. Decision-making uncertainty

Key to undertaking a robust climate risk assessment and prioritising options is understanding uncertainty and how to make decisions under varying degrees of uncertainty. This section discusses what is meant by uncertainty, how it influences risk, and how practitioners can make decisions under uncertainty. This section will outline how to approach uncertainty, with a specific focus on understanding and integrating uncertainties inherent to climate change, and then identify how to integrate this into the Project Appraisal Phase (Stage 2) and further stages of the PPP project cycle.

### What is uncertainty?

Uncertainty about future states is inherent in any planning process. We think of the future in terms of a set of possible states of nature that are determined by external factors. How much value an action yields depends on these future states of nature[53]. Uncertainty is, effectively, risk that cannot be quantified. This is how decision-making under conditions of uncertainty difference from decision-making under conditions of risk. With risk, probabilities are explicitly known. With uncertainty, they are not.

We rarely have perfect information with which to identify future states with certainty. As a result, there are many techniques available to address and embed uncertainty into decision-making and planning. These future states are derived from the interaction of multiple overlapping, interlinking and evolving systems. And while historically uncertainty has been seen as a deterrent to private investment[54], **in order to mainstream resilient infrastructure it is crucial to acknowledge that uncertainty is inherent in nearly all decision-making.** To ignore it would be to undermine effective risk management.

Climate change presents challenges in that many decisions must be made under conditions of deep uncertainty. Deep uncertainty refers to a situation in which analysts do not know or cannot agree on[55]:

- Models that relate key forces that shape the future;
- Probability distributions of key variables and parameters in these models; and
- The value of alternative outcomes.

There are a vast number of parameters that go into climate models and socioeconomic pathways, and those parameters must be based on clear assumptions. Different analysts may have different assumptions and there is no universally accepted vision for what good scenarios look like in future, which makes it hard to prioritise future scenarios that people may think are likely and that should be aimed for. That is why dedicated stakeholder engagement is key to processes around decision-making for climate change, to ensure that there is a breadth and depth of perspectives that can provide a general consensus.

In the context of climate change, uncertainty relates to a variety of factors, including the confidence levels on future projections that a decision-maker needs to address or the lack of complete information around concepts like 'tipping points' (i.e., a threshold that when reached could cause large, potentially near-irreversible changes to the climate system). For example, reaching a certain level of warming may cause ice sheets to destabilise sooner than expected, which may trigger a cascade of other tipping points.

Uncertainty influences the confidence levels that comprise climate risk. This means that there may be some divergence among climate models about the localized impacts of climate change, which would impact the degree of exposure of a particular asset under future scenarios. Certain socioeconomic pathways may also yield different results for strengthening people's adaptive capacity. This can be because one future might see technological advances that make individuals more equipped to deal with climate hazards, or because their level of real income has increased such that they are more readily able to recover from or proactively prepare for a climate hazard.

## Key principles for decision-making under deep uncertainty

Uncertainty will always be inherent in decisions about the future, and there will be some decisions that we can be more certain about than others. Just because there is uncertainty it does not mean all is lost. Practitioners have dedicated significant time and expertise to examining the question of deep uncertainty and developing best practice for how to deal with it. Particularly, decision-makers should prioritise robustness and flexibility when dealing with uncertainty. **Robustness** refers to the ability of a project or plan to meet its intended goals under multiple plausible futures. **Flexibility** means leaving options open so that updated information or fluctuating situations can be accommodated. Robust and flexible plans include[55]:

- **No-regret strategies** – measures that have positive benefits even in the absence of climate change. For example, reducing development in flood prone areas will yield benefits even if climate change does not make flooding worse in future. This includes measures that have significant co-benefits aside from climate mitigation or adaptation, such as encouraging more active transport methods (e.g., walking and cycling) which yields health benefits.
- **Reversible and flexible strategies** – measures that can be undone if future scenarios prove incorrect. Such measures would include insurance or early warning systems.
- **Safety-margin strategies** – measures that reduce vulnerability at no- or low-cost by including a cushion for estimates. For example, this could be using a worst-case estimate of drought frequency to plan or upgrade water and wastewater networks. It is inexpensive in the design phase to integrate low-flow measures, wastewater treatment measures, or water reserve measures. However, it is much more costly to be in a situation with too little water and having to make emergency investment in infrastructure, such as desalination, or else turning taps off entirely (as was nearly the case in Cape Town, South Africa; and occurred in Chennai, India).
- **Strategies that reduce decision-making time horizons** – prioritizing measures that have shorter lifespans to avoid infrastructure lock-in. This way, measures can be reassessed as future states become clearer.

The World Bank's Resilience Rating System[31] proposes three key principles that projects should follow in order to account for uncertainty:

1. Accept uncertainty – project developers must acknowledge that projects need to be designed to perform under a range of potential future scenarios. Uncertainty will thus be a design factor.
2. Account for low-probability scenarios – project developers should have a contingency plan for extreme cases, even if a model or data analysis suggests that a project would not fail. This is particularly relevant because extreme events can cause cascading consequences, and there is deep uncertainty around climatic tipping points[56].

3. Ensure decision-making is robust – a robust decision is one that performs well under a multitude of plausible future scenarios.

## Key tools for prioritising resilience options under conditions of uncertainty

### Multi-criteria analysis

Multi-criteria analysis (MCA), also known as multi-criteria decision analysis (MCDA), is a tool to assess which is the optimal course of action to take when there are conflicting priorities or values[57]. MCA is an approach whereby multiple, sometimes conflicting criteria in decision-making are evaluated. We can use this in resilience to prioritise the optimal resilience option for a given objective. The key steps of an MCA are to[58]:

1. **Identify the decision-making body and/or decision context.** Who are the stakeholders that need to be engaged and who will ultimately be signing off on the decision? In the case of climate-resilient infrastructure PPPs, this can refer to the decision-maker within the public partner who will be deciding which resilience options to include in a project, although there may be other instances where an MCA is useful.
2. **Identify options to prioritise.** What are the relevant resilience options that we are seeking to evaluate and rank?
3. **Establish criteria.** Which criteria does the project team want to use to rank the options against? The benefits of the project? The contribution towards the Paris Agreement? The costs?
4. **Assign weights to each criterion if relevant to reflect the relative importance of each.** Are any of the criteria more important to realise the project, to align with broader goals or to public interests? To what degree?
5. **Rank the options using the identified criteria and associated weights.** Calculate the ranking of each resilience option by adding the scores for each criteria.
6. **Conduct a sensitivity analysis using different weights to validate or compare results.** Are there major differences in the outcomes of the prioritisation based on the sensitivity analysis? Does that inform which resilience options will be prioritised?

Let's use the electrical grid as an example. In this case, the objective is to increase the resilience of the electrical grid to climate-related hazards (e.g. heatwaves, storms, wildfires, wind). **Table 3.5** presents a simplified list of supply-side electricity options to think about how to prioritize resilient options using an MCA. The scoring has been calibrated so that the higher scores are higher priority.

**Table 3.5** Prioritisation matrix for an electricity network resilience MCA

| Resilience options | CapEx Cost (1 - high, 5 - low) | OpEx Cost (1 – high, 5 – low) | Avoided damages (1 – low, 5 – high) | Net- zero options for construction / operation (0 – no, 1 – yes) | Feasibility (1 – low, 5 – very high) | Job creation (1 – low, 5 – very high) | Length of time to undertake (1 – 20+ years, 5 – 1-5 years) | Total |
|---|---|---|---|---|---|---|---|---|
| Increase renewable energy sources | 3 | 3 | 4 | 1 | 5 | 5 | 5 | 26 |
| Optimize storage | 4 | 3 | 4 | 1 | 2 | 4 | 3 | 21 |
| Move power lines underground | 1 | 2 | 5 | 0 | 1 | 5 | 1 | 15 |
| Deploy smart microgrids | 4 | 2 | 4 | 1 | 3 | 3 | 3 | 20 |
| Create redundancy in substation routing | 5 | 5 | 4 | 1 | 5 | 1 | 5 | 26 |
| Identify and implement engineered adaptation approaches (e.g., flood defenses) around vulnerable/critical assets | 3 | 2 | 4 | 0 | 4 | 5 | 4 | 22 |

To place a weighting on a criterion in the same matrix, such as net-zero options for construction, it is necessary to add an adequate weighting to prioritize this solution (e.g. multiply each criterion by 2), as shown in **Table 3.6**. The weighting can be included in the calculations based on decisions made by stakeholders through an MCA workshop.

**Table 3.6** Prioritisation matrix for an electricity network resilience MCA with an added weighting

| Options | CapEx Cost (1 = high, 5 = low) | OpEx Cost (1 – high, 5 – low) | Avoided damages (1 – low, 5 – high) | Net- zero options for construction / operation (0 – no, 1 – yes) weighted by 2 | Feasibility (1 – low, 5 – very high) | Job creation (1 – low, 5 – very high) | Length of time to undertake (1 – 20+ years, 5 – 1-5 years) | Total |
|---|---|---|---|---|---|---|---|---|
| Increase renewable energy sources | 3 | 3 | 4 | 1 (x2) = 2 | 5 | 5 | | 28 |
| Optimize storage | 4 | 3 | 4 | 2 | 2 | 4 | | 23 |
| Move power lines underground | 1 | 2 | 5 | 0 | 1 | 5 | 1 | 15 |
| Deploy smart microgrids | | | 4 | 2 | 3 | | | 22 |
| Create redundancy in substation routing | 5 | 5 | 4 | 2 | 5 | 1 | | 28 |
| Identify and implement engineered adaptation approaches (e.g., flood defenses) around vulnerable/critical assets | 3 | 2 | 4 | 0 | 4 | 5 | | 22 |

The main drawback of MCA is that it typically is used to prioritise options designed for one future scenario. Practitioners can manage uncertainty by developing approach that is suitably robust and flexible. Regardless, it is essential to include a diversity of experts and practitioners in MCA workshops when working to address uncertainty[59]. The prioritised options should be stress-tested under the range of future scenarios to better integrate uncertainty. Those that perform reasonably well across plausible scenarios are more robust[60]. **Box 15** shows how MCA was applied in Ethiopia to identify priority adaptation projects under the National Adaptation Programme of Action.

**Box 15** Multi-criteria decision analysis for National Adaptation Programme of Action, Ethiopia

The Ethiopian National Adaptation Programme of Action (NAPA), created under the National Meteorological Agency, used an MCA method to prioritize a list of urgent and immediate adaptation projects under its NAPA development process. NAPA is a mechanism within the UNFCCC, designed to help the Least Developed Countries identify their priority adaptation needs to climate change. Ethiopia used an MCA to provide a structured framework for decision makers to compare and make sense of the wide range of information that was relevant to making adaptation choices. Assessments had to be made regarding the identification of who is vulnerable and to what. Adaptation options were evaluated across five criteria, which included cost effectiveness, climate change risk (measured in economic losses avoided by poor people per year), and existing links to national and sectoral plan. By using an MCA, the project team could break down the complexity of the problem into smaller components and establish a prioritized list of projects meeting their needs. Through the NAPA process, twenty priority project ideas were identified that broadly focused on the areas of human and institutional capacity building, improving natural resource management, enhancing irrigation agriculture and water harvesting, strengthening early warning systems and awareness raising. Overall, the MCA supported the successful completion of Ethiopia's NAPA by allowing a balanced evaluation of adaptation options across a range of priorities.

*Source: USAID. 2013. Analysing Climate Change Adaptation Options Using Multi-Criteria Analysis. Available from: https://www.climatelinks.org/sites/default/files/asset/document/Multi-Criteria%2520Analysis_CLEARED_0.pdf [Accessed 12 January 2021]; and UNFCCC. 2007. Climate Change National Adaptation Programme of Action (NAPA) of Ethiopia. Available from: https://unfccc.int/resource/docs/napa/eth01.pdf [Accessed 4 February 2021].*

## Cost-benefit analysis

Cost-benefit analysis (CBA) is a commonly used method to make investment decisions. CBA is a process by which the costs and benefits of a project are measured and quantified. Projects can then be prioritised based on either their Net Present Value (NPV) or their Benefit-Cost Ratio (BCR). A key component of either option is deciding a discount rate, which assigns a numerical value to discount future costs or benefits into present value (that is, the present is valued more highly than the future).

The NPV is the sum of present value of future benefits minus the present value of future costs. The BCR is the sum of the present value of future benefits divided by the sum of the present value of future costs. If the NPV is positive or the BCR is greater than 1, then the net benefits outweigh the net costs. Projects can be prioritised based on the magnitude of the BCR or NPV.

CBAs do, however, face critical challenges when we are dealing with uncertainty. In the context of climate change, uncertainty tends to crop up in:

- Choice of discount rate
- Probability of hazard occurrence
- Costs of impacts of a climate hazard
- Heterogeneity of damages – the fact that damages do not impact everyone or everything equally

To accommodate this, it is possible to use subjective probabilities. In this case, the subjective probabilities reflect beliefs on the likelihood of future states of the world. We can then use a probability weighted average of the benefits and costs in different future scenarios.

CBAs may not be useful under conditions of deep uncertainty because they are dependent on many parameters and assumptions underlying those parameters. However, they can still be useful as a means to gather information and stakeholder opinion about the costs and benefits of a project, and also about future climate scenarios[55].

## Real options

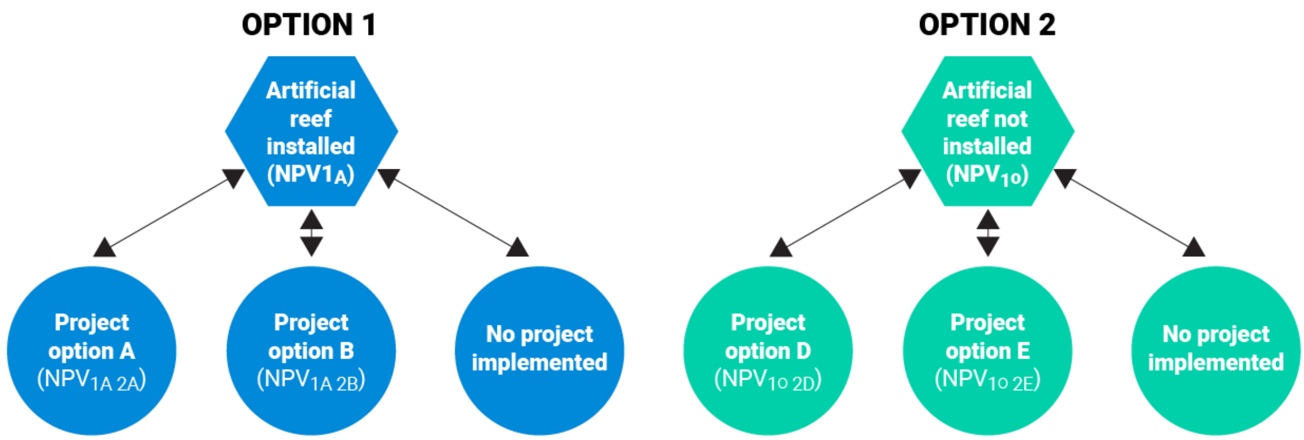
The real options approach provides a decision-making methodology that allows practitioners to consider whether it is reasonable to invest in a project now, at a known cost but under uncertain future outcomes, or whether it is better to wait to invest when there is better information available, although this may cost more. This approach is especially appropriate if it is difficult to reverse the project after the decision is made. For example, a real options approach could prioritise a project that has a negative NPV, but create opportunities down the line. Real options provides us with a focus on timeliness and flexibility[55].

With real options, the focus is on the extended NPV of an investment by considering the value of the options it creates versus the value of the options destroyed. Effectively, this approach takes traditional cost-benefit analysis one step further due to the additional focus on options created and options destroyed.

***Extended Net Present Value (ENPV) = NPV + (Value of Options created – Value of Options Destroyed)***

To undertake a real options approach, we can assess a project under two time periods. Let us imagine that an urban waterfront is being regenerated through the use of a PPP, and the project also addresses coastal flood risk compounded by projections of rising sea levels. One measure that the private partner might propose is to build an artificial reef to buffer against storm surge and coastal erosion. A real options approach assesses future project opportunities that are conditional on whether or not the project moves forward presently. In this case, Option 1 is to install the reef, and Option 2 is to not install the reef. The value of the choices of projects in the second period (e.g. option A, B, D, E) is dependent on whether the project was installed or not in the first period (see **Figure 3.5**).

**Figure 3.5** Example of a real options approach under two time periods




The real options approach is typically suited for dynamic uncertainty – that is, when the assumption is that we will have more information over time. It also provides a degree of robustness because it explicitly values created and destroyed capabilities that may be relevant for future decision-making.

## Climate risk informed decision analysis

Climate risk informed decision analysis (CRIDA) is a method that accepts deep uncertainty and seeks to marry bottom-up vulnerability analysis with top-down climate model information[55]. It is suitable for decisions relating to long-term investments vulnerable to climate impacts and when the certainty around those climate impacts cannot be well-characterised.

CRIDA was designed to slot into traditional planning frameworks and be used as a method to include climate risk analysis or as a means to prioritise different options. See **Table 3.7** for an overview of the steps of the CRIDA method.

**Table 3.7** CRIDA steps

| Steps | Typical planning process | CRIDA Additions |
|---|---|---|
| **1. Decision context** | Identify problems and opportunities | Define a critical performance threshold |
| **2. Bottom-up vulnerability assessment** | Inventory and forecast conditions | Vulnerability assessment using a stress test.<br>Assess the level of concern from future failure. |
| **3. Formulate robust and flexible actions** | Formulate alternative plans | Formulate robust and/or flexible alternatives |
| **4. Evaluate plan alternatives** | Evaluate alternative plans | Evaluate robustness to incrementally more stressful futures |

| | | |
|---|---|---|
| **5. Compare plan alternatives** | Compare alternative plans | Recommendation of robust and/or flexible plans<br>Risk communication to decisionmakers and feedback |
| **6. Institutionalize decisions** | Select alternative plans | Institutionalize the decision<br>Monitoring program |

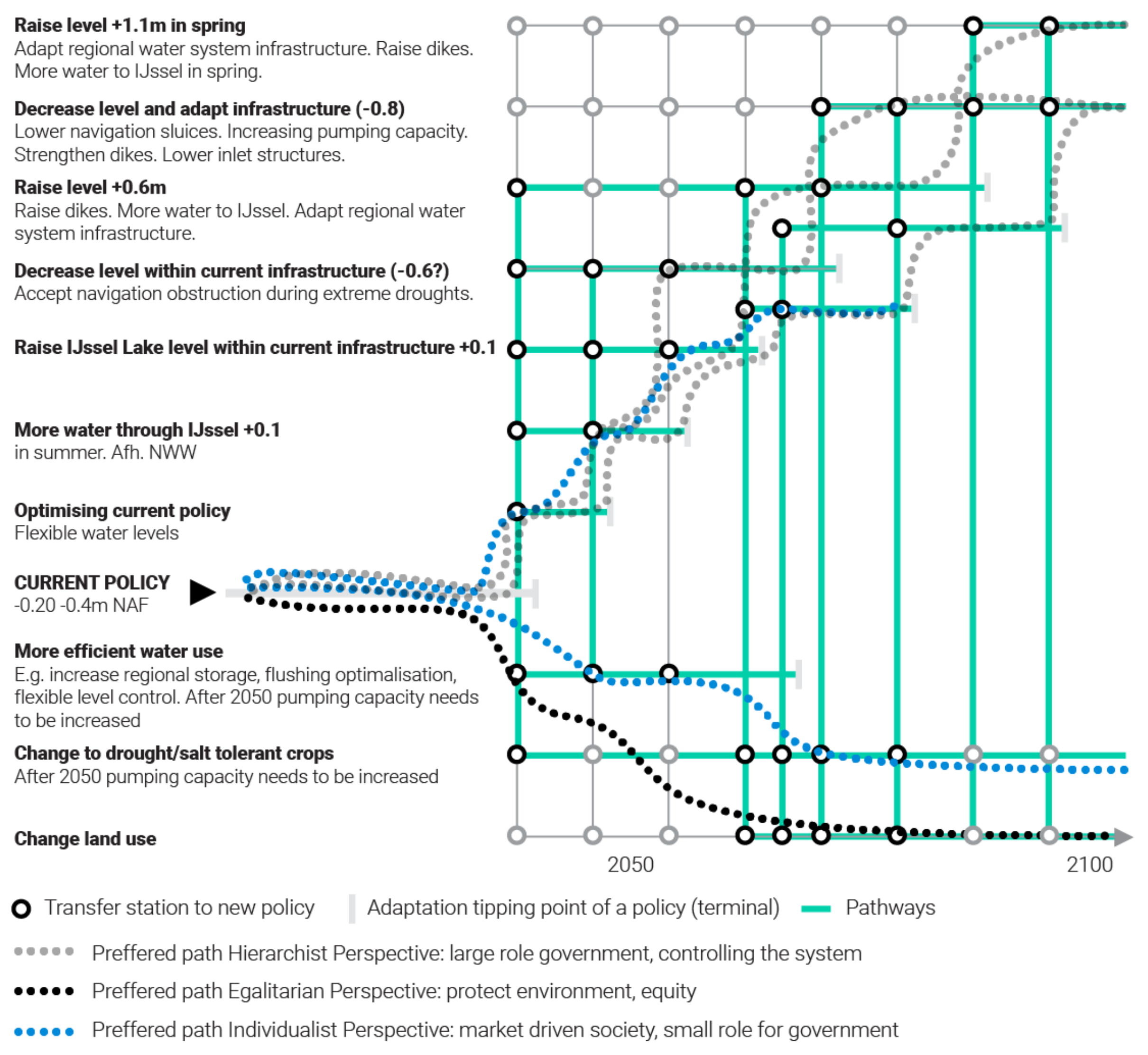
*Source: UNESCO and ICIWaRM. 2018. Climate Risk Informed Decision Analysis (CRIDA) Collaborative Water Resources Planning for an Uncertain Future. Washington, D.C.*

The main benefit of CRIDA is that it maps decision options to climate futures and allows for the programme to be flexible and tailored over time. CRIDA incorporates the adaptive pathways approach, which is described in **Box 16.**

**Box 16** Adaptive pathways – integrating flexibility into infrastructure decisions

Adaptive pathways are a sequence of actions which can be implemented progressively depending on how the future unfolds and knowledge develops[61]. **Adaptive pathways are especially relevant for large-scale, long-term infrastructure projects because they incorporate flexibility in the adaptive strategy from the outset by identifying key 'triggers' at which time different measures are implemented in response[62].** Because of this strategic 'pathway' nature, they are often visualized as route maps (such as the example in **Figure 3.6**).

**Figure 3.6** Lower Rhine Delta adaptation pathway




*Source: Haasnoot, M. & Kwakkel, Jan & Walker, Warren. 2021. Designing Adaptive Policy Pathways for Sustainable Water Management under Uncertainty: Lessons Learned from Two Cases.*

Pathways are composed of a set of adaptation strategies that pursue a long-term adaptation goal. As knowledge of climate change evolves or climate change impacts occur or change in relation to the asset or location of focus, different strategies will be implemented. These are called **trigger points**, which signal when a climate hazard is nearing a **critical threshold** where deleterious or irreversible impacts are likely to occur. Adaptation strategies are then adjusted to avoid these impacts. Adaptation pathway strategies often incorporate other tools like MCA and CBA to assist in prioritising which strategies to choose. The main component of adaptation pathways is that they identify acceptable and unacceptable levels of risk, and then develop adaptation strategies within that framework.

The key principles of adaptation pathways include[63]:

- Accommodating uncertainty by incorporating flexibility to deal with changes over the lifespan of the project
- Embedding learning as an objective that underpins the process
- Based on scenario analysis and knowledge around adaptation tipping points, decision triggers, and decision lifetime
- Focusing on decision makers and design processes rather than geographical regions
- Aim to avoid maladaptation and remain within boundaries of acceptable risks

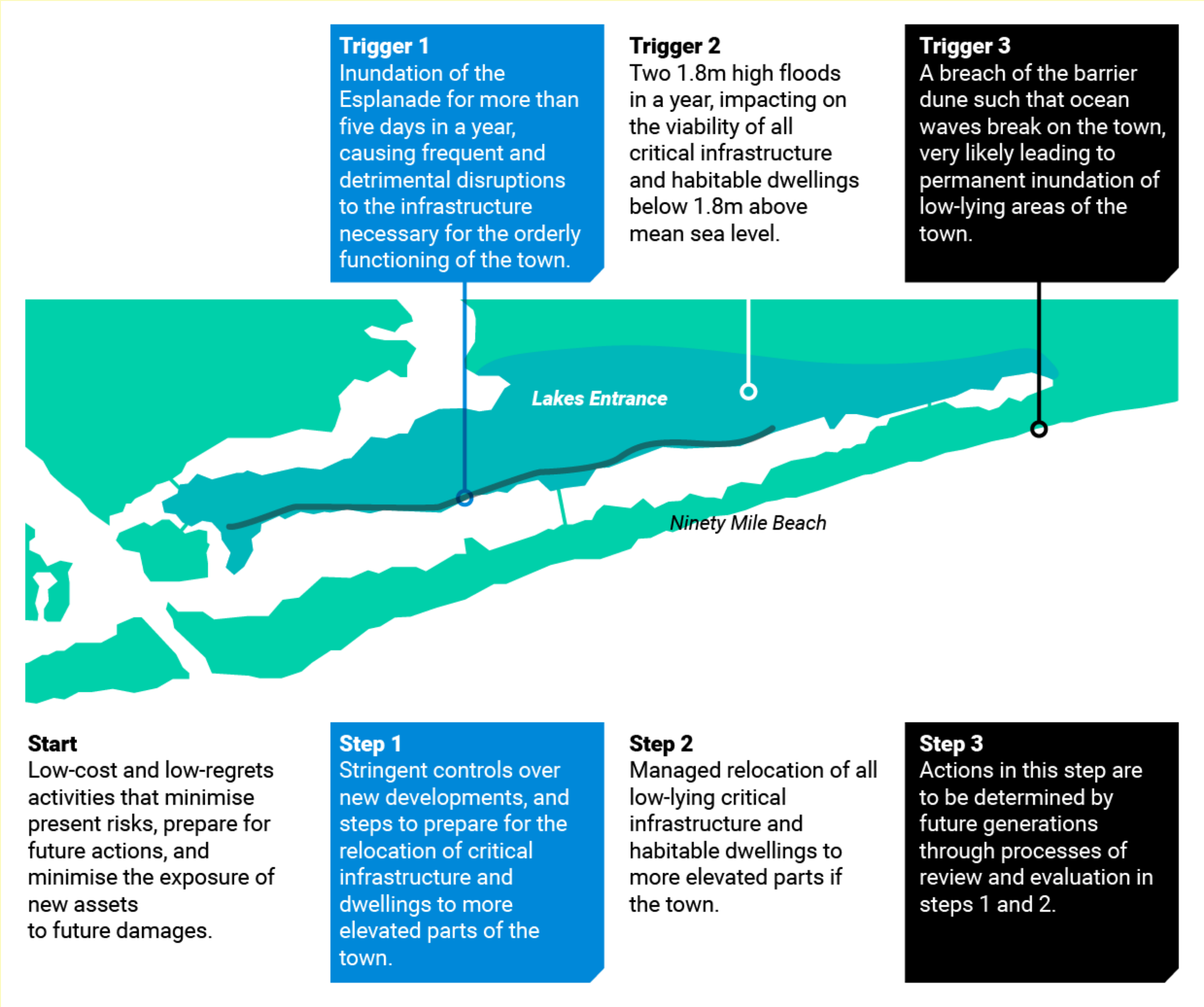
Let's use the example of the town of Lakes Entrance in Queensland, Australia to illustrate how adaptation pathways work. Lakes Entrance is at risk of inundation from rising sea levels, with studies indicating that the major climate change impacts that will occur include a 2 to 20 cm increase in the one in one-hundred-year flood levels by 2030 and between 4 and 59 cm by 2070, compared to the 1952 baseline. The local government has historically used zoning regulations to restrict development, which local residents opposed as they were concerned about the devaluation of their property investments. As a result, the decision was made to work to develop a locally-derived adaptation pathway through participatory workshops and focus group interviews.

Lakes Entrance identified three trigger points and associated measures (see **Figure 3.7**). The first trigger point is the inundation of the lakeside Esplanade for more than five days per year, which residents indicated was the number of times where the infrastructure and service disruptions to the town would be significant enough to warrant action. At that point, the local government would defend critical infrastructure and prepare it for relocation uphill, in combination with further strategic planning.

The second trigger point occurs if there are more than two 1.8 metre floods in one year. Residents articulated that floods at this level would require months of recovery. At this point, the previous strategic plans (e.g. relocation/rezoning) would then be implemented.

The final trigger is a permanent breach of the barrier dune, which would likely lead to semi-permanent or permanent inundation of the town. This is not anticipated until next century and thus participants have articulated that strategies at trigger three will be decided further down the line.

**Figure 3.7** Schematic of Lakes Entrance trigger points




*Source: Barnett, J., Mortreaux, C., Graham, S., and Waters, E. 2014. A local coastal adaptation pathway. Nature Climate Change. DOI: 10.1038/nclimate2383*

## Robust decision-making

Robust decision-making (RDM) provides an analytic framework to identify robust strategies, their vulnerabilities, and the trade-offs between them[64]. RDM takes a bottom-up approach to address uncertainty, where rather than asking what the future level of risk will be, it starts by looking at one or more proposed strategies. The vulnerabilities of these strategies are then assessed using typical analysis. For example, we can run multiple model simulations to identify conditions under which the strategies meet or do not meet their goals. As a result, it can be identified strategy modifications that increase the likelihood that these strategies will reach their goals under a wider range of futures. These modified strategies then go through multiple rounds of RDM until they are modified to an extent that their vulnerabilities are below acceptable levels[55].

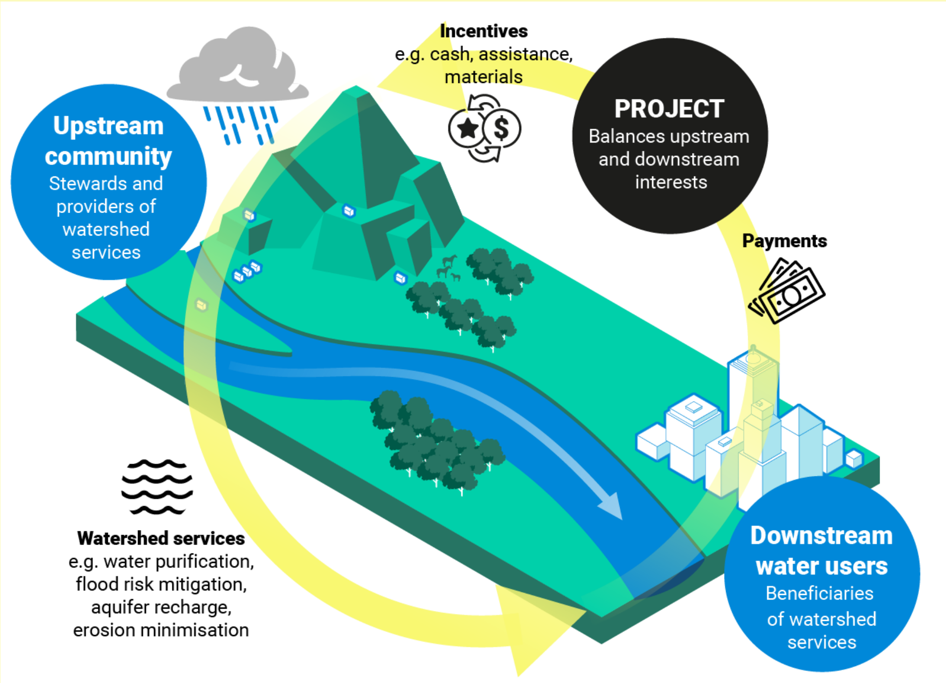
## 3.4. Valuing nature

Nature and biodiversity play an essential role in maintaining our economy and wellbeing. It is key to understand the value of nature and the services ecosystems can provide, such as food provision, clean air and water, climate regulation and outdoor recreation. These ecosystem services can be divided in four groups: provisioning, supporting, regulating and cultural services. Integrating ecosystems, such as NbS or green infrastructure, is challenging for both policy makers and private sector. Natural ecosystems like forests and wetlands are complex to interpret and compare with traditional infrastructure interventions. To assess ecosystem value effectively, stakeholders need to have tools to accurately reflect the benefits of ecosystems and make informed decisions. These decisions can not only support healthy ecosystems but also allow governments and businesses to prepare for and mitigate risks. This is particularly important when working to value and invest in nature in the context of PPPs.

One common means of valuing nature is through a Payments for Ecosystem Services scheme (see **Box 17**), where the beneficiaries of the 'service', such as a business protected from coastal erosion by the conservation of a mangrove forest, pay the land owner for that benefit.

**Box 17.** What are Payments for Ecosystem Services?

Biodiversity, ecosystems, and the vital contributions that these make to people and society are deteriorating worldwide. The rate of biodiversity decline and wider environmental degradation is unprecedented, requiring a drastic shift in the way humans interact with nature to arrest this trend. This shift requires greater recognition of the economic benefit provided by biodiversity and a healthy natural environment and the growing costs of biodiversity loss and environmental degradation, in order to support efforts to incentivise conservation and restoration of ecosystems. Payment for Ecosystem Services (PES) are a way to value nature and generate benefits to the project and communities.




*Source: Bennett, G., Carroll, N., and Hamilton, K. 2013. Charting New Waters: State of Watershed Payments 2012. Washington, DC: Forest Trends. Available online at http://www.ecosystemmarketplace.com/reports/sowp2012.*

Nature is one of five areas of capital known to underpin the economy and encompasses the supply of natural resources worldwide including biodiversity, air, soil and forests. Some of the services provided by nature are readily quantifiable and traded in markets, like food and timber. Others services such as flood protection, landscape amenity and air quality, are equally vital to human health and wellbeing but are non-traded and therefore more challenging to value. Natural capital approaches perceive nature as an asset which supplies services and delivers benefits. This allows decision-makers and private sector to consider ecosystems as an opportunity to achieve wider societal benefits and understand any financial or other applicable trade-offs. It comprises both the natural assets, in their ecological terms of quantity, condition and sustainability[65], and the socio-economic benefits produced from these assets. At a national level, natural capital accounting enables governments to cope with changes in natural capital stock and maintain ecosystem services.

Cost-benefit analysis (CBA) is another approach to valuing nature, which attempts to interpret ecosystem value in monetary terms. The CBA develops an understanding of the costs of maintaining or restoring natural ecosystems compared with the environmental and social benefits derived from the ecosystem. The associated benefits of ecosystem regeneration or conservation might include food provision (reduced pesticide and fertiliser use), flood protection (reduced damage to assets and infrastructure) or improved water quality (increased recreation and tourism). When assigning the monetary benefits derived from ecosystems it is possible to predict the added value or reduced costs by supporting ecosystem services.

There are a growing number of methodologies for valuing nature but this remains a challenge for decision-makers and private investors, particularly when the benefits and return on investment of NbS and green infrastructure operates on longer temporal scales than traditional interventions. One of these methodologies is the Sustainable Asset Valuation (SAVi) method which is described in through the following case study in Sri Lanka (see **Box 18**).

**Box 18.** SAVi Method in Sri Lanka.

Beira Lake is a freshwater lake in Colombo, Sri Lanka. Situated in the centre of the capital city, the civil-engineered lake is subject to numerous environmental stresses, and the impacts of pollution have created a depleted ecosystem, susceptible to eutrophication, algae blooms and deoxygenation. Recognising the potential value that a healthy freshwater ecosystem could provide through its services, a novel method for valuing nature was applied. Sustainable Asset Valuation (SAVi) in the case of Beira Lake utilises the principles of the cost benefit analysis (CBA) to value ecosystems and their services.

SAVi was created by MAVA Foundation and IISD with the aim to assess the risks and costs to infrastructure projects and the risks from externalities. The SAVi method uses a simulation of the outputs of a system and a model of the project finance to accurately estimate the costs of risks and externalities to the project, portfolio or policy. The result of this simulation allows the user to verify the financial returns of investing in sustainable and resilient infrastructure.

In the case of Beira Lake, the SAVi assessment evaluated four scenarios for various ecosystem restoration practices using CBA. The process of the analysis uses both the property value and the recreational benefits that the improved ecological conditions could provide to assign a monetary value to the improved water quality. The first scenario of the assessment was the business-as-usual (BAU) approach which presumed no immediate interventions to restore Beira Lake, declining water quality resulting in depreciating property values by US$170,000. There would be no added financial benefit from tourism or recreation due to the poor water quality and environment of the lake. Scenario two assessed the potential of reducing inflow from sewage drains and found that the reduction in phosphorus and nitrogen leaching directly reduces the incidences of eutrophication, improves water quality and could increase the value of properties by over US$14 million by 2025. In addition, there would be an increase in recreation and tourism to the Beira Lake with improved water quality. Scenario two would thus yield benefits almost 40 times the expenditure on wastewater treatment.

Scenario three involved dredging the lake sediment which would marginally improve water quality without impacting the phosphorus and nitrogen inflow. The assessment found that this scenario would yield benefits but algal blooms and eutrophication would persist. The benefit value would be double the costs and there would be little to no benefit in terms of property value or recreation. The fourth and final scenario employed improvements to wastewater treatment in addition to a singular dredging of the sediment. This scenario would lead to significant improvements in the water quality and by extension could lead to the greatest increase in property value of more than USD 43 million by 2025. In addition, increased recreation and tourism would result in USD 19.5 million additional spending between 2020 and 2025. Overall, the analysis confirmed that the benefit to cost ratio for scenario four was 9.92.

*For more information see: Bassi, A., et al. 2019. The Context of Colombo and Beira Lake. [online] Available at: <www.jstor.org/stable/resrep21990.5.> [Accessed 14 April 2021]*

When it comes to climate resilience, practitioners should take an ecosystem services approach to prioritising and designing resilience *of* and resilience *through* infrastructure. By valuing avoided damages alongside their societal and potential economic benefits (e.g. if markets for natural capital are available), practitioners can more clearly see their potential to cost-effectively enhance climate resilience, either as stand-alone measures or in conjunction with grey infrastructure solutions (see example of **Box 19**).

**Box 19.** Increasing resilience through infrastructure with sustainable forestry

Indonesia has experienced significant deforestation and biodiversity loss as a result of clearing for large-scale agriculture and illegal mining. This contributes to carbon emissions and vulnerability of local populations to climate hazards such as wildfire and drought as a result of hydrometeorological changes following deforestation. Moreover, land degradation has led to income instability of local communities that typically relied upon forestry-related activities for their livelihoods.

Fairventures Social Forestry was established to regenerate the land and improve the livelihoods of local residents. The project rehabilitates degraded lands by introducing agroforestry schemes like fast-growing tree species and cash crops and by managing forests as protected areas, including through planting non-timber forest products. The project generates revenue through timber sales of fast-growing timber, cash crops, and carbon revenue (e.g. through trading in carbon markets). Local community members were granted the right to the largest share of labour, and share in the profits generated from sales.

This project supports resilience through infrastructure by regenerating a key ecosystem, which thereby improves the regulating services provided by that ecosystem and the associated impacts on resilience (e.g. through temperature regulation and contribution to the hydrological cycle). It also supports community resilience by providing income opportunities, which increase their adaptive capacity.

*Source: WWF. Bankable Nature Solutions. Amsterdam. P 103. Available from: https://wwfint.awsassets.panda.org/downloads/bankable_nature_solutions_2__1.pdf [Accessed 4 May 2021].*

## 3.5. Recap

This Module provided insight into the kinds of tools that will be helpful to understand while working to integrate climate resilience thinking into PPP projects, which will be the focus on the next Module. It also focused on the importance of stakeholder engagement and broadly how to undertake a stakeholder engagement process. We also looked at uncertainty in the context of climate change and how to plan for uncertainty when developing infrastructure projects through tools like multi-criteria analysis and adaptation pathways.

## 3.6. References for further learning

If you want to further investigate the topics covered in Module 3, please refer to the sources, which are organised by theme.

| Theme | References |
|---|---|
| **Climate risk assessment** | Hallegatte, Stephane; Anjum, Rubaina; Avner, Paolo; Shariq, Ammara; Winglee, Michelle; Knudsen, Camilla. 2021. Integrating Climate Change and Natural Disasters in the Economic Analysis of Projects : A Disaster and Climate Risk Stress Test Methodology. World Bank, Washington, DC. © World Bank. License: CC BY 3.0 IGO *https://openknowledge.worldbank.org/handle/10986/35751*<br><br>World Bank, 2021. Risk Stress Test Tool. Available at: *https://www.worldbank.org/en/topic/climatechange/brief/risk-stress-test-tool* |
| **Stakeholder engagement** | ESCAP. 2018. Effective Stakeholder Engagement for the 2030 Agenda. Bangkok. Available at: *https://www.unescap.org/sites/default/files/Final.Effective%20Stakeholder%20Engagement%20for%20the%202030%20Agenda%20rev.pdf*<br><br>IFC. 2007. Stakeholder Engagement: A Good Practice Handbook for Companies Doing Business in Emerging Markets. Washington, D.C. *https://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/sustainability-at-ifc/publications/publications_handbook_stakeholderengagement__wci__1319577185063*<br><br>PPP Knowledge Lab. 2020. Stakeholder Communication and Engagement. Available at: *https://pppknowledgelab.org/guide/sections/39-stakeholder-communication-and-engagement* |
| **Uncertainty** | BlackRock. 2015. Viewpoint: Infrastructure investment: Bridging the Gap Between Public and Investor Needs.' Available at: *https://www.blackrock.com/corporate/literature/whitepaper/viewpoint-infrastructure-investment-november-2015.pdf*<br><br>Carter, T.R., R.N. Jones, X. Lu, S. Bhadwal, C. Conde, L.O. Mearns, B.C. O'Neill, M.D.A. Rounsevell and M.B. Zurek, 2007: New Assessment Methods and the Characterisation of Future Conditions. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 133-171.<br><br>Global Infrastructure Hub. 2020. Infrastructure Futures Report. Available at: *https://www.gihub.org/futures/*<br><br>Hallegatte, S, Shah, A, Lempert, R, Brown, C, and Gill, S. 2012. Investment Decision Making Under Deep Uncertainty: Application to Climate Change. Policy Research Working Paper; No. 6193. Washington, DC: World Bank. *https://openknowledge.worldbank.org/handle/10986/12028*. |
| **Scenario-planning** | Hausfather. Z. 2018. 'Explainer: How 'Shared Socioeconomic Pathways' explore future climate.' CarbonBrief. Available from: *https://www.carbonbrief.org/explainer-how-shared-socioeconomic-pathways-explore-future-climate-change* [Accessed 26 January 2021].<br><br>Kunreuther H., S. Gupta, V. Bosetti, R. Cooke, V. Dutt, M. Ha-Duong, H. Held, J. Llanes-Regueiro, A. Patt, E. Shittu, and E. Weber, 2014: Integrated Risk and Uncertainty Assessment of Climate Change Response Policies. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. |
| **Multi-criteria analysis** | UK Government. 2009. Multi-criteria analysis: a manual. Available from: *https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/191506/Mult-crisis_analysis_a_manual.pdf* [Accessed 8 February 2021]. |

| Theme | References |
|---|---|
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# 4. Module 4 – Furthering the enabling environment for climate-resilient PPPs

**Description:** This Module will identify the key intervention points to better integrate climate resilience into PPPs for infrastructure assets. This includes providing context on the climate governance landscape and the key priorities for each PPP stakeholder, alongside potential innovative mechanisms for financing PPPs to enhance resilience.

**Learning outcomes:** By the end of this module, learners will be able to:

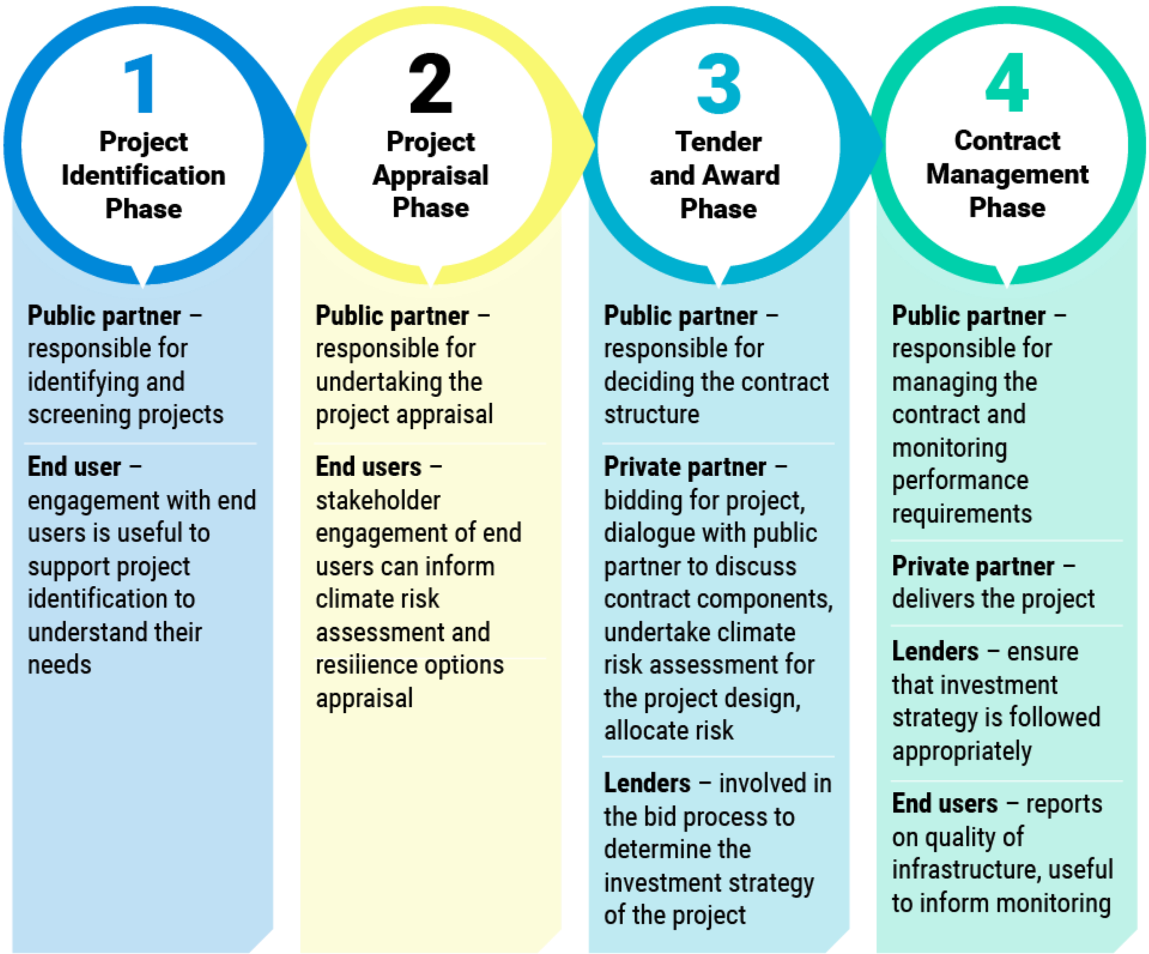
- Articulate the key policies governing climate adaptation globally
- Identify innovative mechanisms of project finance for PPPs
- Express key levers to improve the structure of PPPs to better incorporate climate resilience

This section will identify the key stakeholders involved in PPPs and ways in which these stakeholders can evolve to better meet resilient infrastructure needs (see **Figure 4.1**). This includes the public and private partners, the lenders, and the end users[66]. Depending on their involvement in the project, the stakeholders can have different expectations (short vs. long term view) and their interests might not always be aligned.

The enabling environment is determined by national, provincial and local policies and legislation that constitute the "rules of the game" and facilitates all stakeholders to play their respective roles. An enabling environment for PPPs is generally composed of four enablers which are[67]:

- A public investor commitment, to ensure public funding and fiscal support
- Capable private and public sectors, to ensure effective partnerships and protections of public interests
- Effective risk management, to ensure the maximum benefits from the PPP
- Favourable investor climate, to ensure private funding.

**Figure 4.1** Overview of stakeholder roles in the PPP Project Cycle




## 4.1. The public partner

Institutional and regulatory frameworks that relate to climate change, infrastructure, and PPPs differ by country, although there are several supranational frameworks which are cross-cutting. While this Handbook cannot delve into the intricacies of country-by-country differences, this section will provide a broad overview of how these regulatory frameworks broadly influence PPPs and the levers that governments have to better integrate climate resilience into PPPs. This section then explore key institutions and developments driving climate change adaptation and provide a short refresher on the governance of PPPs. An important point to note is that, as infrastructure systems grow in their intra- and inter-country connectedness, integrating climate resilience considerations into PPPs provide the opportunity to scale up international collaboration around development.

**Top Tip: Infrastructure needs to be supplemented by relevant policy.**

Climate-resilient infrastructure is key to thriving communities and economies. At the same time, infrastructure alone will not provide overall climate resilience. Infrastructure investments need to be met with and supported by policies that work towards the same goals. For example, upgrading a water supply network and integrating water efficiency principles on the supply side is essential to combatting drought risk in drought-prone areas. However, unless it's met with demand-side measures to reduce overconsumption of water, then the resilience picture is incomplete.

Governments have the following essential functions in relation to PPPs and climate resilience:

- To set policy and pass policy into law
- Regulate laws
- Procure services for public good
- Provide essential risk management services.

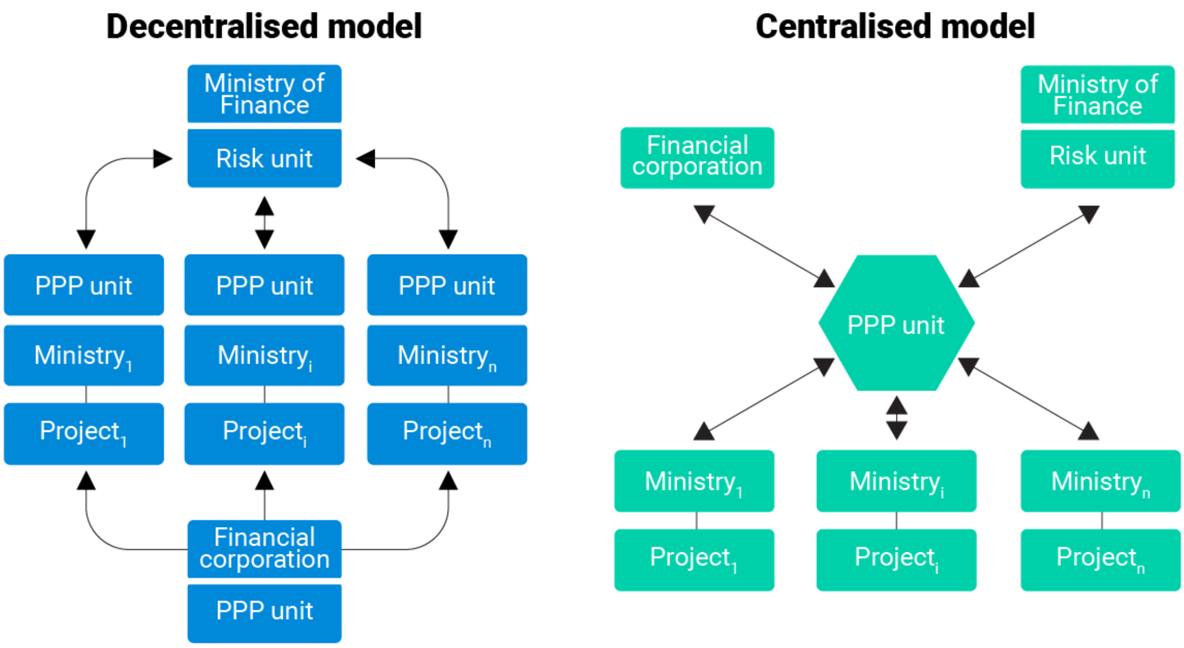
Through these functions, the public sector can drive forward climate-resilient infrastructure via PPPs and via other routes. This includes providing good information, laying a policy foundation that enables rather than undermines resilience overall, setting the standards around resilience, enforcing these standards, and supporting capacity development internally and externally through educational grants, fellowships, among others.

## PPP governance

PPPs also share decentralised and centralised models (see **Figure 4.2**). In the centralised model, PPP units are the main entities responsible for PPPs throughout the project cycle. In this model, PPP units validate and structure PPP projects that have been promoted. The centralised model takes advantage of economies of scale in providing technical support through the PPP project cycle, particularly during project design and structuring, as it enables the procurement units of the various ministries to channel their projects through the same PPP unit.

On the other hand, in decentralised models, PPP projects are developed and structured by a wider range of government entities. The procurement units drive the process in the absence of the support of a dedicated PPP unit, which may be useful in developing inter-country agreements.

**Figure 4.2** Different models of PPP




*Source: IDB. 2019. The Governance of Public-Private Partnerships: A Comparative Analysis. Washington, D.C.*

Decentralised systems call for more flexible and autonomous procurement units, as there can be high costs associated with coordinating multiple entities. Centralization takes greater advantage of specialization without bearing the costs of coordination, as the central PPP unit promotes and structures projects.

Each PPP governance system has its own logic and operates on a given macro-institutional level. The effectiveness of PPP governance is determined by its capacity to promote PPP projects without compromising relevance and quality. This capacity mainly depends on the ability to align the incentives of each stakeholder involved and, therefore, climate resilience should be seen as a priority for every PPP stakeholder.

The design and implementation of PPPs requires the coordination of several governmental entities:

- Sectoral ministries will usually be responsible for developing overall sectoral policy;
- Finance ministries will usually have a close interest in the public revenue or liability implications of particular projects; and
- Environmental ministries or authorities may have an interest in the projects, as may ministries of justice, competition authorities, and others.

Coordination will often also be necessary between actors at central, provincial, and municipal governments, for example, in obtaining necessary approvals or the granting of guarantees. When the government does not effectively coordinate all relevant actors, it risks sending mixed signals to private investors and causing delays, either of which can deter investors or increase development costs substantially. **Table 4.1** identifies the benefits of the different governance systems for PPPs.

**Table 4.1** Benefits of decentralised vs centralised PPP units

| Decentralised approach | Centralised approach |
|---|---|
| • Flexibility to adapt local conditions, priorities, and preferences<br>• Experimentation with different approaches<br>• Development of expertise that is specific to local conditions<br>• Better information provided to decisionmakers and promotion of their accountability<br>• Development of sector specific expertise<br>• Minimisation of the impact of sectoral politics<br>• Opportunity to avoid applying inappropriately precedents from one sector to other sectors | • Consistent policies that is, reduces the risk of distortions arising from inconsistent approaches to common issues<br>• Learning between jurisdictions<br>• Economies of scale to deal with the problem of constrained capacities<br>• Resistance to improper influences from particular industries or political authorities |

## Core capabilities of the public partner

In addition to the typical skills required to execute PPP procurement, the public partner should also seek to have the additional skills to support the integration of climate resilience into the PPP process. These include climate scientists, climate economists, climate policy experts, environmental economists, environmental engineers, socials specialists, sector experts, and stakeholder engagement experts. Such capabilities are not necessarily required within the PPP unit itself, but they should be readily available for collaboration within the government.

**Top tip. Furthering climate readiness**

The public partner should support projects that work towards national or local 'climate readiness' and respond to climate shocks through programs. Readiness is enabled through programmes that strengthen the technical and managerial capacities of governments, organizations and communities.

Readiness measures may include:

- Emergency trainings
- Preparedness plans, which outline specifically what measures to be taken during a disaster alert period to minimize loss of life and physical damage
- Warning systems, which need to be tested regularly
- Establishing emergency communication systems
- Evacuation plans and trainings, such as educating and training officials
- Emergency personnel and contact lists
- Mutual aid agreements
- Public information and awareness

## Governance for climate resilience

Governance refers to policies, processes and structures or organisations that are designed to transparently and equitably reach a collective goal based on rule of law and accountability. As noted in Module 1, climate change impacts are non-linear, and this uncertainty must be incorporated into governance.

**Governance for climate resilience** aims to reduce the harm caused by climate change impacts or help to create opportunities to leverage climate change impacts. In their work on adaptation governance for the Oxford Research Encyclopaedia on Climate Science, Termeer et al. (2017) note that[68]: "[Increasing resilience to] climate change is not only a technical issue; above all, it is a matter of governance. Governance is more than government and includes the totality of interactions in which public as well as private actors participate, aiming to solve societal problems. [Resilience] governance poses some specific, demanding challenges, such as:

- institutional fragmentation, as climate change involves almost all policy domains and governance levels;
- the persistent uncertainties about the nature and scale of risks and proposed solutions;
- the need to make short-term policies based on long-term projections."

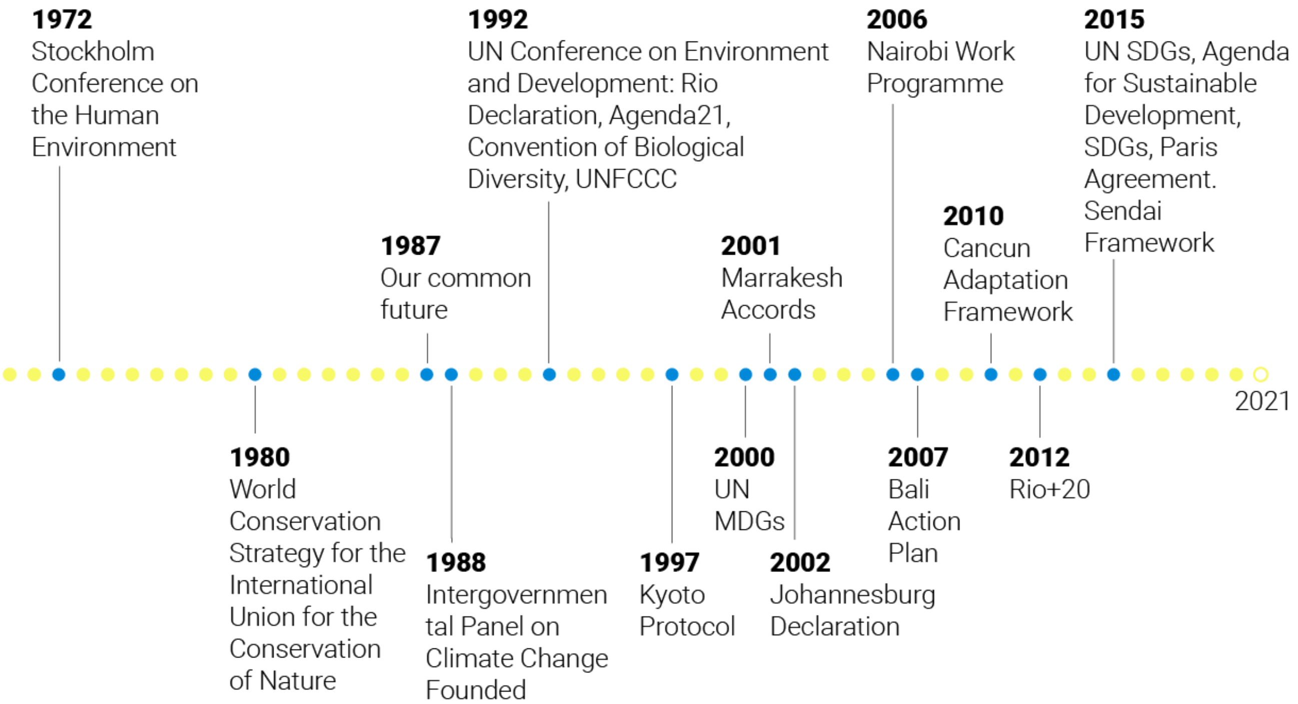
Climate resilience governance specifically seeks to address climate risk by instituting and enacting policies, programmes, processes, and institutions that reduce the hazard (e.g. through adaptation activities), exposure to hazards (e.g. by developing climate-responsive zoning laws), and vulnerability (e.g. through direct means like providing subsidies for low-income residents to implement greywater recycling systems, or indirect means like improving access to social services so people can recover faster from a hazard).

The climate resilience governance has a long history and the key events are noted in **Figure 4.3**. This history is important for practitioners to understand so they can feel confident communicating about the climate resilience agenda, and how local or regional actions fit into a wider, supranational movement. The policies and frameworks that currently influence climate resilience have been building since at least the 1970s, with the Stockholm Conference on the Human Environment (1972). In 1988, the United Nations established its intergovernmental body, the Intergovernmental Panel on Climate Change (IPCC), with the mandate to provide independent and objective information and advice on how the physical science of climate change interacts with our socio-ecological systems.

The first major conference – the **UN Conference on Environment and Development** (1992). i.e. UN Earth Summit – established the **UN Framework Convention on Climate Change**, a treaty that seeks to stabilise atmospheric greenhouse gas concentrations and that was signed by 197 parties (signatory nations and territories make up the 'parties'). This conference also produced the **Rio Declaration**, which outlined 27 principles to guide countries' future sustainable development, and the **Agenda 21**, a non-binding action plan for sustainable development with a view towards the 21st century.

In 1997, the UNFCCC treaty was extended via the signing of **Kyoto Protocol**. This treaty specially seeks to reduce atmospheric greenhouse gas concentrations[69] through the concept of common but differentiated responsibilities – that is, countries have differing capacity to address climate change, and more squarely placed the responsibility of combating climate change to developed countries. It established the Adaptation Fund, with the aim to finance adaptation projects and programmes in developing countries. The Adaptation Fund was officially launched at the COP13 in 2007.

**Figure 4.3** Key developments in the climate resilience agenda



At the 7th Conference of the Parties (COP7), the **Marrakesh Accords** ultimately established National Adaptation Programmes of Action, which targeted Least Developed Countries (LDCs) and Small Island Developing Nations (SIDS). These Accords increased the recognition of the importance of climate change adaptation, not just mitigation. LDCs were able to identify adaptation priorities.

At COP 12, the **Nairobi Work Programme** (NWP) on Impacts, Vulnerability and Adaptation to Climate Change was established. This created the Adaptation Knowledge Portal, which aims to share knowledge and best practice, particularly for LDCs and SIDS.

In 2010, the **Cancun Adaptation Framework** was established at COP16. The Framework aims to strengthen action on adaptation in developing countries, encourage better adaptation planning and implementation by providing increased technical and financial support, research and knowledge-sharing. It also established the Adaptation Committee, which enhances adaptation action in a way that coherently integrates with the UNFCCC and is highly relevant for PPPs (we will get to this in the next section). Cancun is also seen as the birthplace of the Green Climate Fund.

Parties agreed to develop plans for targeted greenhouse gas reduction as part of the UNFCCC and plans for adaptation. These are referred to as **Intended Nationally Determined Contributions** (INDCs). Parties that signed the UNFCCC then published their INDCS at COP19 in Warsaw in 2013.

2015 was a particularly big year for climate adaptation and the broader resilience agenda with the adoption of the **Paris Agreement** at COP21. The Paris Agreement is a legally binding international treaty that aims to keep global temperature rise well below two degrees Celsius compared to pre-industrial levels. It also established a global goal on adaptation, aiming to significantly strengthen national adaptation, particularly by ensuring parties undertake and implement **National Adaptation Plans (NAPs)**, which were initially established in the Cancun Adaptation Framework[70]. Building on the INDCs introduced at COP19 in Warsaw, the Paris Agreement also requires all parties to prepare, communicate and maintain successive **Nationally Determined Contributions** (NDCs)[71]. See **Box 20** for more details on the NDCs and NAPs.

Additionally, 2015 also saw the establishment of the **Sendai Framework** on Disaster Risk Reduction (**Figure 4.4**) and the UN **Sustainable Development Goals (SDGs).** The Sendai Framework recognises the interconnectedness between climate and disaster risk and, consequently, the need to align disaster risk reduction and climate adaptation efforts, especially through the concept of building resilience. The UN SDGs were developed as part of the 2030 Agenda for Sustainable Development and consist of 17 actions with 169 indicators that underlie these actions. SDG 9 – Industry, Innovation and Infrastructure – is of particular relevance as it explicitly calls for building resilient infrastructure. SDG 11 – Sustainable Cities and Communities – also underscores the importance of resilience, alongside SDG13 – Climate Action. Of course, resilient infrastructure ideally provides co-benefits that supports many of the other SDGs, not only those focusing on the resilience of infrastructure itself – infrastructure has been shown to influence 72% of the 169 targets of the SDGs[29].

**Box 20.** Spotlight on Nationally Determined Contributions and National Adaptation Plans

Understanding your country's commitments under the Paris Agreement, along with its NDCs and NAPs, will inform project development, screening, design, and implementation of PPPs. The NDCs and NAPs are tied to infrastructure development and retrofit. If, for example, reducing a countries' emissions means increasing public transport availability to reduce emissions from private vehicles, it is important that adaptation considerations are taken into account when planning for public transport (e.g. what risks might the network face from climate change?).

**Nationally Determined Contributions**

The NDCs lie at the heart of the Paris Agreement. They are each party's action plans that aim to reduce national greenhouse gas emissions and adapt to the impacts of climate change. In 2023 and then every five years, each party will undertake a stocktake assessing their performance against their NDCs, which will inform the preparation of the subsequent NDCs to align with achievement of the Paris Agreement.

**Key facilitators:**

Signatory parties, UNFCCC, The NDC Support Facility, Green Climate Fund

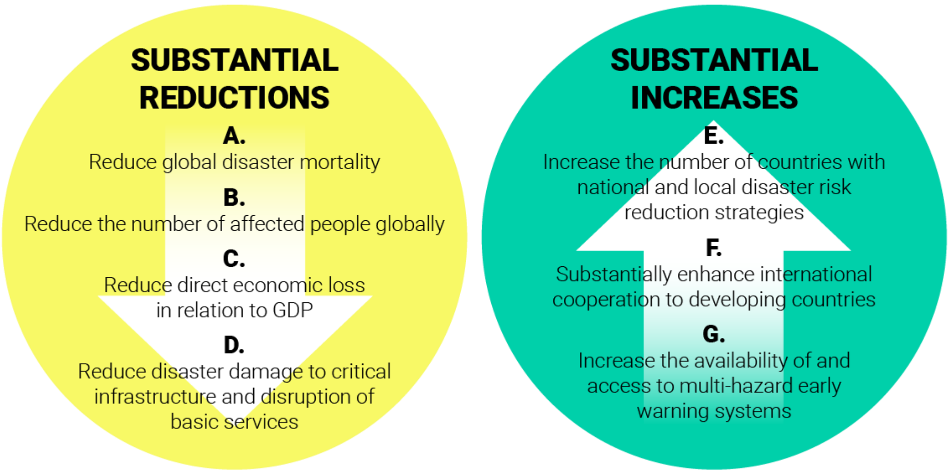
**National Adaptation Plans**

The NAPs encourage adaptation efforts, with particular technical and financial support made available to developing countries. The two main objectives of the NAPs are to reduce vulnerability to the impacts of climate change by building adaptive capacity and resilience, and to integrate adaptation into new and existing policies and programmes, especially development strategies.

**Key facilitators:**

Signatory parties, UNFCCC, NAP Global Network, UNEP National Adaptation Plan Global Support Programme (NAP – GSP).

**Figure 4.4** Objectives of the Sendai Framework for Disaster Risk Reduction




*Source: UNDRR. 2015. What is the Sendai Framework for Disaster Risk Reduction? Available from: https://www.undrr.org/implementing-sendai-framework/what-sendai-framework [Accessed 9 January 2021].*

## How governments can encourage climate-resilient infrastructure PPPs

Infrastructure investment relies on the assumptions around the stability of legal frameworks and public policy over the project investment period. Government agencies play a central role in encouraging PPPs for resilient infrastructure, both by developing an overarching enabling environment for climate resilience, and tying this into the PPP project contract.

### Developing an overarching enabling environment for climate resilience

**Understand and communicate current and future climate risks.** To set the foundations for resilience practices it is important that governments have a clear understanding of both current and future climate risks. The information and data on climate risks should be made publicly available and updated regularly. Toolkits should accompany the data so that users understand how to work with it.

**Move climate resilience upstream.** For most effective systems-wide mainstreaming, climate resilience principles should be integrated into upstream planning and processes within government, rather than on a case-by-case basis[72]. This includes setting policies that incentivize climate resilience across the board, including in infrastructure but also in institutional operations down to individual behaviour.

**Proactively invest in adaptation projects.** While integrating resilience into infrastructure PPP projects it is undoubtedly an essential approach to reduce long-term climate risk, it may often be a reactive solution if the type of project has already been developed. Governments can holistically improve resilience by developing projects to support resilience and also by making risk information openly available[72]. Additionally, they can seek to make financial and non-financial incentives for such adaptation projects available.

**Mainstream climate-resilient standards.** Standards distil and promote the use of best practice in developing infrastructure and should be legally required either in the form of minimum requirements or standards-based incentives. Standards can also support in shifting upstream approaches[72]. The private partner should reflect how they are meeting these standards through their bids, and the public partner should weight the evaluation criteria to score more highly those proposals which go beyond minimum standards. Governments can also consider integrating green infrastructure solutions and other forms of NbS as standards.

**Support data collection and monitoring.** Collection, monitoring, and availability of data are a public good that the government can provide directly or in collaboration with research organisations and the private sector. A robust data environment will contribute to robust decision-making and monitoring the impact of investments and policies for climate resilience.

**Integrate consultative and participatory processes.** Climate-resilient projects require decision-makers to consider and integrate deep uncertainties into long-term investments. This demands consistent, inclusive, and participatory engagement with stakeholders – mainly the end user – to understand priorities, concerns, and observations on the ground. Therefore, consultative and participatory processes must be a feature of government processes on the whole.

## Tying these concepts into the PPP context

**Provide clear pipeline of investment.** Governments are more likely to attract long-term investment if they can provide a clear pipeline of investment opportunities that incorporate climate resilience. Investors will only develop internal knowledge and skills in a specific sector, such as resilient infrastructure, if concrete investment opportunities exist.

**Establish clear timelines.** Similarly, government agencies must establish clear guidelines and reasonable timelines from project announcement to award in order to convince investors to develop their internal skills. This will be instrumental to building credible pipelines of investable opportunities and enabling institutional investors to engage.

**Investment planning and assessment.** Governments need to have a clear picture of their brownfield assets and the overall strategy when it comes to upgrading or retrofitting these assets. This includes understanding whether these are best delivered via PPP or through traditional funding routes. In addition, this will avoid the development of greenfield projects when it is adequate to enhance the resilience of existing assets.

**Design or enforce financial regulations to ensure economic and financial stability.** Governments should consider the need for financial regulators (e.g., Central Banks, Federal Reserve Board) to assess risks that climate change could pose on the country's economy and financial market and to take necessary measures to enhance the system's overall stability and climate resilience. This includes the use of disclosure recommendations (such as Financial Stability Board and the Task Force on Climate-related Financial Disclosure) to tie financing to climate resilience and risk mitigation. If governments are able to demonstrate that they have invested in building resilience, then the long-term investments in the area become more lucrative.

**Provide technical and financial support.** Government agencies in different regions and countries will likely have different skill levels around climate-resilient infrastructure. Supranational and national agencies, such as the Ministry of Environment or Ministry of Planning, can work to provide the necessary technical and financial support to increase capacity and feasibility of resilience projects across different government levels[72].

**Ensure visibility into cash flow.** PPP frameworks and, in particular, contracted cash flows, provide visibility and ensure predictability. Predictability, besides the natural correlation of cash flows to inflation, contributes to the attractiveness of PPP projects for institutional investors seeking assets that match their long-term goals.

**Address market failures.** Government agencies can play a key role in addressing market failures, either directly or through public development banks. They can act as facilitators and provide credibility to infrastructure projects. By funding transactions or supporting active market players, development banks provide a powerful signal to the private sector. Their presence suggests political support and stability over the long term. Dedicated financial instruments — such as guarantee instruments, long-term funding, seed investment, and early-development stage facilities — can also encourage long-term investment.

**Abide by rule of law.** Governments, businesses and citizens alike must adhere to the law. This is relevant for PPPs because there needs to be a strong rule of law and transparency in case PPP contract arrangements are not upheld by partners. Otherwise, investors may be hesitant to enter into partnership with the government or else there is room for public and private partners – as well as any participant of the PPP – to abuse the system within the terms of the PPP.

**Enforce contracts.** Governments need to maintain the integrity of contract enforcement, particularly for PPPs, and be able to show a track record to this end. This includes enforcing contracts even in the face of climate-related force majeure or torts.

## 4.2. The Private Partner

While the public partner is responsible for identifying, screening, and appraising PPP projects, the private partner is responsible for designing and implementing the project. The project outputs and outcome are monitored by both parties. This means that the private partner needs to have the relevant skills and partnerships in place to integrate best practice on climate resilience into infrastructure investment, design, operation, and maintenance. This includes understanding how to undertake the analyses outlined in Module 3 to assess climate risk and prioritise different decisions under conditions of uncertainty.

### Special Purpose Vehicle

The SPV is an entity created to undertake a single task or project in order to protect the shareholders with limited liability. It is created to act as the legal manifestation of a project consortium. The sponsor or sponsors typically entering the private partnership in the form of a SPV are the contract partner(s) of the government.

The SPV is the contact point between the public and private partners, and the guarantor of the proper execution of the project as the PPP contract is signed between the procuring authority and the SPV. All the obligations and responsibilities of the contract fall on the SPV, even though the SPV passes them to the EPC and O&M contractors through the downstream contracts. The SPV has a central role to play in ensuring the implementation and effectiveness of climate resilience measures, confirming that the project is meeting the performance requirements set out in the PPP contract, and ensuring that commitments made in the contract, including around climate resilience, are respected by the different contractors.

### Shareholders: industrial sponsors

Industrial sponsors are often shareholders of the SPV, and their teams run the EPC and O&M contracts. Promoting climate-resilient infrastructure is largely dependent on the industrial sponsors putting forward innovative solutions and technologies. To promote climate resilience more comprehensively, the SPV should incorporate industrial sponsors with diverse expertise. For example, in green and blue infrastructure projects, more specialised actors should be involved (e.g. planting-trees companies in reforestation projects and social enterprises) that, at present, are rarely incorporated into PPP project consortiums[73].

This is in part because the approaches to design and construction will vary greatly depending on the infrastructure and the associated resilience options integrated into the design. For example, designing a living reef as part of a waterfront development will require different steps and expertise than integrating heat-resistant materials in a rail network.

O&M activities can contribute to resilience by ensuring that the project is operating according to the performance requirements. It also provides an opportunity to collect data or feedback from stakeholders on the assumptions that supported the original design. That is, as more information and technologies become available to assess climate risk, the private partner can assess whether or not climate risks at various stages are occurring in a way that follows the original projections used to develop the project design or not. Moreover, the monitoring component can feed into future project design, or even publicly available knowledge-sharing networks to support climate-resilient design. Key points to consider to have an efficient climate resilience strategy during O&M include:

- **Frequency:** O&M activities should be planned at appropriate time-intervals, which in the future may differ from conventional infrastructure maintenance. For example, seasonality may increase maintenance requirements in summer months compared to winter months, or during wet seasons compared to dry season. Maintenance requirements may also be greater in regions where there is high climate variability.
- **Funding:** ensure that there are dedicated funding streams for maintenance costs, including for labor and equipment.
- **Personnel:** ensure that personnel have the proper skill set and capacity on climate resilience during O&M, as some activities may require a highly specialized skillset and even additional training. For example, constructed wetlands maintenance not only requires knowledge about how plants remove the contaminants but also about the pre-treatment process, pumps when they are used, and monitoring of the treatment capacity.
- **Contingency:** build-in contingency into maintenance and inspection schedules to account for extreme event projections and climate-related uncertainties.

In addition, regular project Monitoring & Evaluation (M&E) should take on:

- **Implementation:** the project is being implemented according to the design and schedule.
- **Effectiveness:** the project is operating effectively (once implemented).
- **Performance:** the project is delivering the intended results and, if not, identify how it can be adjusted to achieve the intended results. This is critical to building the evidence base and ensuring effectiveness and improvements over time.

The industrial sponsors, along with the public partner, should include KPIs relevant to climate-resilient infrastructure in the technical and performance requirements of the PPP, which would further help to mainstream resilience into infrastructure. KPIs can also provide the boundaries that the operator needs to serve or design against, which will have clear climate consideration. For example, this might be the number of hours within which the infrastructure service needs to resume after a climate hazard. See Sections 5.3 and 5.5 for further details on KPIs and performance monitoring.

## Shareholders: financial sponsors

Investors are conscious of the increasing role that climate resilience plays in the success of long-term projects, including PPPs. However, many investors may not have be familiar with how to apply common financial or ecosystem-based valuation methods to prioritise different resilience options under conditions of uncertainty[74]. Financial sponsors must increase their awareness of tools and methodologies to analyse the financial value of climate-resilient projects, particularly the value they generate in their co-benefits and avoided losses (refer back to Module 3).

Financial sponsors should be aware that not all climate-resilient infrastructure may generate revenue streams in the traditional way, but that does not mean that the benefits cannot be captured. For example, NbS can be tied into Payments for Ecosystem Services schemes (see **Box 17** in Section 3.4) or by harnessing land value capture. Climate-resilient solutions can also help gain access to funding by reducing the project's climate-related risks. In other words, it is important for project developers to find innovative solutions to capture those benefits in monetary terms (e.g. carbon credits, reduced risk premiums).

Establishing and implementing robust stakeholder consultation processes throughout all phases of the PPP project cycle is the responsibility of the public and private partners. Climate-resilient infrastructure is context-specific and this calls for interaction with local financial institutions and intermediaries. In addition, PPPs aim to deliver public services and end-beneficiaries should be duly considered to ensure that climate-resilient PPPs address "on-the-ground" needs effectively.

## How the private partner can contribute to climate-resilient infrastructure within PPPs

**Build their capacity in climate resilience.** The private partner must have the skill to understand and incorporate climate change projections and decision-making under uncertainty into their project decision processes. This includes having experience in climate risk assessment, resilient design standards and resilience options appraisal.

**Leverage M&E to enhance data availability and access.** The M&E process within the O&M phase can be used in part to collect data on how different resilience options perform in a given context. This can then inform current and future projects to maximise resilience benefits.

**Encourage collaboration or partnerships to share knowledge.** Climate change does not operate in siloes and neither does infrastructure. Neither should the private partner. Rather, they should seek to draw on professional practice ecosystems within the climate resilience and sustainability space to share knowledge and innovate on best practice.

**Set higher benchmarks around climate resilience.** By including climate-resilience aspects into the O&M standards and Quality Management Systems (QMS), the private sector can set a heightened benchmark for sub-contractors. This can have a catalysing effect on other private partners to apply climate resilient standards in their O&M and QMS to become more attractive for the public partner (see **Box 21** for standards and principles being applied for climate-resilient infrastructure).

**Box 21.** Standards and principles relevant to climate-resilient infrastructure

Climate-resilient infrastructure is quickly becoming mainstreamed in general practice as institutions, organisations, and communities acknowledge the need for net-zero infrastructure and prepare to adapt to the impacts of climate change. The **EU Design Standards for Infrastructure** (also known as Eurocodes) provide a common set of standards for the design of civil engineering works across Europe. More recently, the EU passed a **Taxonomy Regulation** (June 2020)[75] that established the overarching conditions economic activity has to meet in order to be considered sustainable:

1. Climate change mitigation
2. Climate change adaptation
3. The sustainable use and protection of water and marine resources
4. The transition to a circular economy
5. Pollution prevention and control
6. The protection and restoration of biodiversity and ecosystems

When it comes to investments, the Climate Bonds Initiative developed the **Climate Resilience Principles.** These principles provides insights if assets and activities are compatible with a climate resilience economy and could be eligible for a Climate Bond Standard certification. In summary, the asset or activity manager(s) must clearly indicate that: [76]

- Climate risks that affect the asset, activity or system are understood;
- Risk reduction measures and flexible management plans are adopted to address those risks and ensure that the asset, activity or system accounts for the uncertainty of climate change,
- Resilience benefits can be delivered (for system-focused investments); and
- Regular (re)evaluation of the asset and/or system's climate resilience performance is undertaken to adjust the risk reduction measures.

The private partner, in addition to other PPP stakeholders, should be aware of and keep up to-date on these standards, regulations, and principles in order to align their investments and project designs with existing best practices.

## 4.3. The Lenders

Understanding the distinction between financing and funding is key to understanding where the problem lies in paying for infrastructure. Financing is how you meet the upfront costs of building the infrastructure, whilst funding is how you pay for it over its lifecycle. For example, when building a new energy plant, the foreign investment may be used to finance the plant (pay for the construction up front) but the funding will be generated from energy bills charged to consumers.

Financing cannot address the problem of poor funding. Without a clear funding stream that indicates how the infrastructure project will meet the operation and maintenance costs over its lifecycle, it can be difficult to access the upfront cash needed for construction. A clear arrangement for funding is necessary to unlock more investment and contributes to new infrastructure being built.

## Financing resilient infrastructure

Building infrastructure systems requires significant financial and human capital, and a long-term view of operations, maintenance and value of the infrastructure asset. **Table 4.2** identifies a high-level taxonomy of the modes and vehicles of infrastructure finance. Broadly, infrastructure finance modes fall under three broad categories[77]:

1. **Debt instruments** –instrument in which an investor provides a lump-sum investment which the borrowed is obliged to return on a fixed schedule. These instruments can have a maturity period that corresponds to the asset lifetime.
2. **Hybrid instruments** – are mostly debt instruments but that can have both debt and equity characteristics.
3. **Equity finance** – when financial resources are provided to firms in return for ownership interest, either in the form of shares or proceeds when the asset is sold.

**Table 4.2** Taxonomy of infrastructure finance

| Asset Category | Instrument | Infrastructure Project | Capital Pool |
|---|---|---|---|
| **Debt** | Bonds | Project Bonds, Municipal, sub-sovereign bonds, Green Bonds, Sukuk | Bond Indices, Bond Funds, ETFs |
| | Loans | Direct/Co-investment lending to infrastructure project, syndicated project loans | Debt Funds (GPs), Loan indices, Loan Funds |
| **Mixed** | Hybrid | Subordinated loans/bonds, mezzanine finance | Mezzanine Debt Funds, Hybrid Debt Funds |
| **Equity** | Listed | YieldCos | Listed Infrastructure Equity Funds, Indices, trusts, ETFs |
| | Unlisted | Direct/Co-investment in infrastructure project equity, PPP | Unlisted Infrastructure Funds |

*Source: Adapted from OECD. 2015. Infrastructure Financing Instruments and Incentives, p.15. Paris.*

## Financing and funding PPPs for climate-resilient infrastructure

As a brief reminder, most of the resources that fund infrastructure PPPs are sourced by the private partner. The public partner may act as a co-lender or co-financer of the project.

### Reconsidering value

The default thinking when considering value may be the cost of an item or how much it is worth to society in monetary terms. However, in the case of climate change, the propensity to discount the future is particularly challenging (i.e., we feel that a dollar today is more valuable than 100 dollars in five years). Policy and practice must actively address those biases and inform standard policy or economic evaluation to ensure that the benefits of climate-resilient infrastructure are properly valued.

This section will focus on ways that lenders from the public and private sector must continue to change their mindsets around what constitutes value in order to encourage climate resilience in their investments, including through PPPs. For example, asset optimization supports the improvement of the effectiveness of overall asset management by providing more holistic adjustments. Whole-life cycle optimisation can help improve financial performance of projects through increased returns on investment and reduced costs, while preserving asset value and ensuring long-term realization of organizational objectives.

## Existing and emerging PPP financing mechanisms for climate-resilient infrastructure

In order for a PPP to be successful, we need to know who is going to pay for its operation – that is, how will it be financed and funded? There has been a growth in innovative financing and funding mechanisms that are useful for climate-resilient PPPs but before diving into these mechanisms, it is necessary to first think about how we identify funding opportunities, and which one is best-suited to the type of project identified. The Inter-American Development Bank sets out four criteria to guide a project team's choice around funding opportunities[50] (see **Table 4.3**).

**Table 4.3** Criteria to evaluate potential financing mechanisms

| Criteria | Guiding questions |
|---|---|
| **Benefits** | What are the main benefits and avoided costs of the climate-resilient project? Does it increase the value of or opportunities around existing assets? |
| **Value** | Can we quantity the benefits (including the co-benefits as much as possible) and avoided costs or estimate their value in some way? |
| **Distribution** | Who are the main beneficiaries of the project and how value is distributed? |
| **Capture** | Are there any existing mechanisms to capture the value a climate-resilient investment (e.g. land value capture)? |

*Source: Adapted from IDB. 2020. Climate Resilient Public Private Partnerships: A Toolkit for Decision Makers. Washington, D.C.*

## Concessional finance, blended finance, and viability gap funding

**Concessional finance** refers to financing that is provided on conditions that are more favourable than market conditions. National, bilateral and multilateral development banks are key institutions that provide concessional finance. **Blended finance** is a specific type of concessional finance that blends public concessional funds with private capital and that seeks to finance high-impacts projects where the risks may be too high for commercial lenders alone to take on[78].This is particularly relevant to resilient infrastructure projects as resilience investments may not generate high or particularly quick returns on investment and blended finance can allow for a risk-matched entry and exit of different public and private investors.

The institutions providing these types of financing are also becoming increasingly engaged with climate mitigation, adaptation and resilience, tying some of their financing to investments that meet specific criteria. For example, the European Bank for Reconstruction and Development's Green Cities Programme requires member cities to develop a Green City Action Plan (GCAP), a strategy that outlines investments and associated measures that promote sustainable and low-carbon development. Once the GCAP is formalised, cities then have access to EBRD's infrastructure finance and also other sources of financing such as the Green Climate Fund[79].

Similarly, **viability gap funding** is a common financing tool in PPPs. National or subnational governments, along with multilateral development banks or development finance institutions, establish viability gap funding mechanisms when a public good is involved in order to fill the gap between possible revenue and the cost of infrastructure[80]. This occurs when that gap prevents the infrastructure project from being developed. Typically, viability gap funding is applied to projects that use new technologies or when the project has high environmental or social value such that private sector appetite may be low, or the project might not be able to receive affordable debt through traditional financing mechanisms. This is relevant to climate-resilient infrastructure as the resilience co-benefits may not provide direct revenue, which would deter private sector interest, but are of significant social and environmental value to warrant the project's delivery. Viability gap funding seeks to facilitate the private sector in investing in the risk layers of an asset that best match their investment horizons and risk profiles, while the public sector or international donors then take on the remaining shares or finances up-front project preparation costs[81].

## Financing mechanisms

Developing a sound financing plan is critical to the success of any PPP. There are a range of emerging tools, or iterations of existing ones, that seek to promote resilient investments. Lenders and the private partner can leverage these tools to develop innovative solutions to finance climate-resilient infrastructure. An important point to highlight in financing climate-resilient infrastructure is that of intergenerational equity. Climate change disproportionately burdens future populations but financing resilient investments now reduces the overall societal costs to these future generations. Innovative finance mechanisms aim to spread the costs of these investments across longer time periods to ensure their affordability and their fairness. Such mechanisms include:

- **Resilience grant** – a grant given by a multilateral bank or specialized fund for the purpose of improving resilience. These grants are tied to quality criteria that an investment must meet.

For example, ADB's Asian Development Fund 12 has created a special window for providing grants to poorest countries for projects that build resilience through infrastructure[82].

- **Resilience bond** – inspired by catastrophe bonds (see below in contingency financing), the resilience bond is a specialized instrument that uses a 'resilience rebate' to fund risk reducing investments[81]. Bond issuers model the estimated damage where a trigger event (e.g. a typhoon) occurs with and without the resilient investment, and the value of the difference in the coupon payments that investors accept in these two scenarios is captured in the form the resilience rebate. That rebate is then used to finance resilient investments[83]. The EBRD issued the world's first resilience bond for US$700 million in 2019, which is for bundled projects but marks a huge step forward in financial practice[84].
- **Green bond** – a debt security issued to raise capital specifically for environmental or climate-related projects. The use of the funds is what differentiates green bonds from traditional bonds[85]. For example, AC Energy, based in the Philippines, is one of the country's leading green bond issuers, using them to finance renewable energy projects. In 2020, US$455 million was allocated to 11 renewable energy projects[86].
- **SDG bond** – a bond linked to the SDGs, where investors receive a coupon payment based on the issuer's performance against criteria in the SDGs[76]. HSBC launched the world's first SDG bond in 2017 of $100 billion, aligned to seven of the SDGs including sustainable cities, renewable energy, and access to freshwater[87].
- **Environmental impact bond** – provide up-front capital to environmental projects to pilot new approaches or to scale-up tested approaches, where the payment mechanisms is called 'pay for success.[81]. In Louisiana, USA's Coastal Protection and Restoration Authority financed wetland restoration efforts for coastal resilience using environmental impact bonds, using the pay for success model[88].
- **Aggregation** – aggregation allows for the bundling of several smaller-scale projects into an investment vehicle, which could then be (re)financed in the capital market through bonds and sale of equity shares[81]. Tamil Nadu Urban Development Fund, for instance, uses aggregation to finance priority resilient infrastructure investments through the Tamil Nadu Urban Flagship Investment Program[89].
- **Securitization** – securitization is often linked to aggregation – in this case, a bundle of small projects becomes tradable in the market as asset-backed securities, which would then attract investors[81]. For instance, Beijing Enterprises Water Group which has a green asset security backed by receivables from the water treatment services fee. The proceeds are then invested into resilient infrastructure projects in the water sector[90].
- **Tax increment financing** – tax increment financing is used to finance development projects or other investments using the anticipation of future tax revenue resulting from new development[50,91]. Chicago leveraged tax increment financing to set up the city's Green Roof Improvement Fund, which provides financing for green roof retrofits for stormwater management[92].

## Contingency financing

In addition to identifying financing mechanisms, there are also mechanisms to reduce the cost of the infrastructure asset over time by providing a method of contingency financing, that considers the cost of damage or disruption. These include:

- **Insurance premium** – insurance premiums reflect the risk profile. Investment in climate resilience will reduce the risk profile and allows for reduction of insurance premiums[93]. Austria, for example, is characterized by several multi-risk insurance products related to the agricultural strategy with premium subsidies of about 50% of the total. It also has a single overarching body that aims to improve agricultural risk management, including climate-related risks, and Austrian law dictates that all arable land is insured, thereby spreading risks across landowners and land managers[93].
- **Regional catastrophe risk pool** – a group of governmental entities joining together through written agreement to fund an exposure or risk, so that when the risk occurs, participants can more swiftly access financial resources[50]. For example, the Caribbean Catastrophe Risk Insurance Facility was established in 2007 as a way to facilitate quick disaster recovery, owned and managed by a consortium of Caribbean governments[94].
- **Weather index insurance** – an index insurance which pays out based on an index, in this case from adverse, measurable weather conditions. It thereby protects against the potential financial loss resulting from stated indices[95]. For example, the Kenya Index Based Weather Insurance Project sought to scale up the use of insurance products among smallholder farmers in Kenya. A farmer could be paid based on triggering events like too high or low of rainfall or temperature that might cause a decrease in crop yields[96].
- **Catastrophe bond** – an instrument that provides good rates of return to investors to compensate for the risk of a triggering event[97].

## Funding mechanisms

PPPs are not solely concerned with how to finance the development of climate-resilient infrastructure, but also how to fund the ongoing operation and maintenance of the asset. There are several ways that this can be achieved:

- **Charges –** user charges (also known as user pays) such as toll charges on toll roads, which support ongoing operation and maintenance of the asset[6].
- **Government pays –** this is the case of PPPs where governments are the only source of revenue. For example, a government might fully fund ongoing maintenance to a wetland restoration because of the lack of available funding opportunities but where there is clear public good that provides.
- **New development charge –** a fee imposed by government on a new development project to pay for the costs of providing public services to the new development[50]. Governments can use such a charge to specifically fund additional resilience measures in public infrastructure PPPs that may not have a clear revenue-generating component.

- **Taxes** – funding that arises from government tax.
  - **Real estate transfer tax** – a tax imposed on those transferring real property within a jurisdiction.
  - **Sales Tax** – a consumption tax imposed by the government on the sale of goods and services.
  - **Property tax** – property taxes reflect the value of the underlying asset. Investment and climate resilience will increase the asset value and therefore property tax.
- **Land value capture** – capturing the increase in land value because of the resilient investment. This can also be used to finance infrastructure and is particularly relevant for investing in NbS, as it captures the value that can be generated by NbS co-benefits. For example, a waterfront real estate development could fund ongoing maintenance of resilience measures by capitalizing on land value capture.

## Public financing and funding considerations

To integrate climate resilience upstream into decision-making governmental institutions need to tie public financing more readily to resilient principles. This would allow for climate resilience to become the norm for all infrastructure projects, not just those procured through PPPs. Public institutions need to reconsider what type of infrastructure might qualify as a PPP, and how public financing can be positioned to support. Much of the thinking behind how this might be structured will likely need to be done in conjunction with private stakeholders, truly leveraging the *partnership* in Public-Private Partnerships. This is particularly relevant for projects that seek to strengthen resilience through infrastructure development, and especially for projects that focus primarily on blue and green infrastructure.

Another change in mindset in finance would be to weight resilience in the bid evaluation criteria as high or more highly than cost. Changing the criteria of the bid would force prospective private partners to develop innovative solutions, more climate-resilient than what would have been done initially. Estimates indicate that this would increase up-front costs by about 3%, but the cost-benefit ratio is on the order of 1:4[22]. Although PPPs are unlikely to capture all benefits as free cash flows, this is a clear argument that justifies government support for the cost of resilience measure because they are able to bring broad and distributed benefits to society on the whole.

Depending on the PPP arrangement, governments are typically the party to which climate risk is allocated and thus it is in the interest of the public partner to enforce resilience more strictly as a key criterion for infrastructure projects, including those procured through PPPs. Finally, governments would have to integrate the additional costs required for climate-resilient infrastructure in their budgets and work jointly with private parties to lower these costs in the near future.

## Private financing and funding considerations

One of the key concepts in PPPs financing is Value for Money (VfM). VfM is the process by which the public partner assesses the value of undertaking a project using a traditional procurement method versus PPP procurement. It helps them to identify the connections between what you spend, what you do, what you get, and how people experience the outcome of the project. VfM does not mean achieving the lowest cost. Achieving VfM occurs when the whole life costs and quality are optimised when providing public goods and services.

For private investors, considering the design life instead of the financial life of an asset provides the lenders with a clearer understanding of the benefits of climate-resilient infrastructure over the long-term (see **Box 22** for an example of how a government entity aimed to align financial and design life considerations). Private investors could leverage this consideration to charge a risk premium.

Infrastructure projects have a broader function for communities and economies, and thus cannot be looked at from only an investment perspective. Although the higher function and systemic role infrastructure plays may not directly impact return on investment, it does have reputational implications for investors. Investors should proactively assess and plan for likely policy scenarios, in which Environmental, Social, Governance (ESG) investments are the norm and financing becomes tied to programmes such as Science-Based Targets .

**Box 22.** DC Water's Century Bonds

Traditionally, infrastructure financing timespans do not align with the full project lifecycle, which is disadvantageous for properly incentivizing resilient infrastructure design. Climate change impacts, while occurring now, may not begin to cause sustained and intense damage to public infrastructure until after the financing period is over. However, there are incentives for financiers, investors to build resilience assets to ensure a return on investment a full repayment of the debt. This is also important, particularly for the private partner, as there will be ongoing O&M costs that may be affected by climate impacts.

DC Water, which that supplies water to Maryland, Virginia, and District of Columba in USA, acknowledged this challenge and addressed it by developing and issuing century-long green bonds. A portion of the bonds are financing the DC Clean Rivers Project and the DC Waters Blue Plains Advanced Wastewater Treatment Plant. DC Water explicitly identified three key reasons as to why it chose to issue bonds which reach maturity after 100 years:

- Asset-liability matching – DC Water has long-lived assets, and the century bonds allow it to match the assets and liabilities on its balance sheet
- Intergenerational equity and fairness – the century bonds spread the cost of the projects across generations, including future generations
- Committed, long-term, low-cost capital – the bonds were issued at a time with historically low interest rates, which allowed DC Water to lock-in funding for their assets' lifecycles.

*Source: DCWater. 2014. DC Water Announces Successful Sale of $350 Million Green Century Bonds. Available from: https://www.dcwater.com/whats-going-on/news/dc-water-announces-successful-sale-350-million-green-century-bonds [Accessed 9 April 2021].*

## Other financial considerations

Climate considerations should also be factored into contractor reporting, as this is becoming increasingly focused on financing. For example, lenders can use climate-related financial disclosure recommendations released by the **Task-Force for Climate-Related Financial Disclosures (TCFD)** in 2017 to better understand the contractors' exposure to climate risks [98]. The TCFD was established by the Financial Sustainability Board to develop effective climate-related disclosures recommendations to increase the understanding of exposure of the financial systems to climate-related risks and to improve investment, credit and insurance decisions. Another example recommendations that can be factored into reporting are indicators for green finance, which are typical tied to specific climate-resilient standards (see **Box 23.** ).

Environmental, Social, Governance (ESG) considerations should also be factored in as increasing regulatory pressures and demand from investors are promoting the incorporation of ESG in investments – it is important for ESG standards from lenders and organizations to be aligned to facilitate the due diligence process. Embedding sustainable investment and considering the full spectrum of ESG has risen to the top of the regulatory agenda. The signatories to the UN-backed Principles of Responsible Investment (the PRI) have publicly committed to integrate ESG factors into their investment processes, and now have combined assets under management of $83 trillion[99].

**Box 23.** Green Climate Finance Indicators, Green Climate Fund

There is an increasing availability of green finance internationally but access to this funding is largely dependent on the inclusion of climate-resilient principles and indicators within the project proposal. The Green Climate Fund (GCF), which sets out to assist developing countries in adaptation and mitigation practices to counter climate change, outlines clear indicators for the impact potential of mitigation and adaptation projects. For adaptation, these state: "project proposals should describe the expected change in loss of lives, value of physical assets, livelihoods, and/or environmental or social losses due to the impact of extreme climate-related disasters and climate change in the geographical area of the intervention. Proposals should also refer to the number of direct and indirect beneficiaries of the project, taking into account the needs of developing countries that are particularly vulnerable to the adverse effects of climate change".[100] Specific to mitigation, project proposals are required to describe the expected reductions in emissions resulting from the intervention.

*Source: Green Climate Fund. 2020. Project Criteria. https://www.greenclimate.fund/projects/criteria*

## 4.4. The End User

PPPs in climate resilience are intimately tied to environmental, social and economic sustainability and therefore end users' quality of life. This societal complexity, combined with their inherent requirements, warrants careful consultation of public, private as well as civil society stakeholders. The context-specific requirements of resilient infrastructure call for interaction with local institutions and intermediaries. PPPs also aim to deliver public services and thus end-beneficiaries should be duly considered to ensure that projects address "on-the-ground" needs effectively.

### The social aspect of PPPs

An appraisal exercise intimately connected with the evaluation of environmental feasibility is the assessment of the project's impact on the lives of people that live and work in the project's area of influence. The social impact analysis (or social feasibility assessment) is a critical component of appraisal of PPP projects at the Tender Phase, since many infrastructure projects can cause adverse impacts on communities surrounding the site where the project is being implemented if not properly addressed.

Social impact analysis is an exercise aimed at identifying and analysing such impacts to understand the scale and reach of the project's social impacts. This analysis ensures that the impacts are mitigated in the requirements of the Tender, to the extent possible, and fully considered in the decision of best resilience option. In addition, social impact analysis greatly reduces the overall risks of the project, as it helps to reduce resistance, strengthens general support, and allows for a more comprehensive understanding of the costs and benefits of the project.

The process of analysing social impacts is regulated in many countries as part of the appraisal of infrastructure projects. The project team must therefore follow any applicable legal or regulatory rules. Several jurisdictions name the process of evaluating the social feasibility as a social impact assessment, sometimes integrated with the Environmental Impact Assessments, and sometimes separated as an independent evaluation.

As it is the case for Environmental Impact Assessment of large projects, it might not be possible to conclude all the social impact assessment during the Appraisal Phase. Nonetheless, it is very important that this exercise is significantly advanced before the project is awarded decision is made, so the approval can be made with a reasonably clear view of the social impacts and all the possible mitigation strategies. Whether integrated or not, the exercise typically includes the following steps:

1. **Identify the people residing and/or working within a project's area of influence,** including to map the communities and their social, economic, and cultural connection with the siteh the project will be implemented. This first step also includes the listing of the social issues to be considered.
2. **Establish a social baseline that indicates the status of the issues to be considered before the implementation of the project.** This social baseline can be obtained through public consultation. All the issues identified in the first step should be incorporated in a social description of the communities affected.
3. Public consultation plays a critical role in **raising awareness of a project's impacts and gaining agreement on management and technical approaches** to maximise benefits and reduce negative

consequences. For the procuring authority, consulting affected parties early and frequently throughout the development process makes good business sense. In many cases it can lead to reduced financial risks and delays, a positive public image, and enhanced social benefits to local communities. Experience has shown that the process of engaging stakeholders as a means to build relationships is often as important as the analysis derived from that engagement.

4. **Estimate the impacts of the project in the communities identified within the area of influence.** This is done by projecting the existing baseline into the future with and without the PPP project, and comparing the issues that were identified as relevant for the specific project. Good practice suggests the need to classify each identified impact in terms of its relative importance, considering the number of people affected and the reach of the damage produced. This will allow for ordering or prioritising the impacts in terms of their relative social significance.
5. **Projects generate clear adverse social impacts, which requires the investigation of issues with extreme care.** One example are projects that require land expropriation and forced relocation, especially of large communities and those that interfere with indigenous communities and their heritage sites. The scope of the social impact analysis in this case needs to highlight all the costs that these communities endure through a comprehensive approach.
6. **Develop Social Impact Assessment (SIA) and identify the mitigation strategies for the adverse impacts identified in the previous steps.** Concluding the previous step leads to a social action plan. The plan should indicate the strategy recommended and a basic estimation of costs to implement it, as well as its distribution in time.

## Raise public awareness

Increasing public participation in PPPs is essential to their success. Developing climate-resilient projects also requires the public's awareness on the benefits that incorporating climate resilience may bring. This can be achieved at the project level, where all the impacts and benefits of the project should be communicated clearly to the public. As mentioned, conducting several public consultations is a good way to involve the local population in the process as they are the main final users of the infrastructure. This can also provide an opportunity for the public to communicate their needs and visions for the area, as this may have bearing on the types of resilience options developed or prioritised, including integrating more NbS.

To promote climate-resilient infrastructure, the public needs to have a better understanding of the benefits of this infrastructure, so that there is a clear demand for it– not just by the discrete end user of the infrastructure, but for everyone in the project area. Government, business and community organisations alike can support the public's awareness through communication and information campaigns, and integrating resilience into education. All stakeholders should be aware of shifting perspectives already occurring. For instance, EIB's 2020 survey on Climate Change and COVID-19 Recovery indicated that 57% of European respondents and 73% of Chinese respondents favoured an economic recovery from COVID-19 that takes into account low-carbon and climate-resilient growth[101].

### Integrating the end user

Beyond raising awareness with stakeholders, the end user must play integral role in the design and delivery of climate resilient infrastructure. As the primary beneficiaries, the end user will be faced with the shocks and stresses of climate change in addition to pre-existing socio-economic circumstances. It is known that climate change has a disproportionate impact on vulnerable and marginalised groups and without sufficient consultation and participatory processes communities could be excluded from resilience benefits.

The contractor of the PPP is accountable for understanding and determining the end user need, enabling context specific measures to be incorporated into the project. There is a need to build resilience into infrastructure but also building resilience into communities and stakeholders. Early warning systems assist private and public sector actors as well as communities to prepare for hazards, supporting them to be resilient. To do this, the system must be stakeholder specific to be fully effective and have the desired outcome of boosting resilience. Likewise, community engagement facilitates communications on the reliability of services as well as any interruptions resulting from disasters, maintaining vertical communication. To fully integrate the end user, it is necessary to place the emphasis on the *partnership* of PPPs, working across levels to increase resilience for all stakeholders.

### Supporting emerging PPP markets

As discussed previously in this course, PPP governance is essential to their implementation. Depending on the authority procuring the PPP, the legal framework vary from country to country as will the financing abilities and overall capabilities. Some countries have been procuring numerous projects through PPPs for decades whereas some countries have only started using PPPs[102].

There is also a gap in maturity in the PPP market. More mature markets should support the emergence of PPPs in younger markets by initiating a transfer of skills at first. Sharing the experience and good practices of mature markets' PPP practitioners with developing markets is key to help develop and implement successful PPPs quickly. By acquiring field experience, emerging countries will be able to better identify and define the local needs that will be more and more climate related. Even though PPP frameworks vary across the world, defining international PPP and climate resilience standards will help unify the practices and provide a more common experience on which all stakeholders can rely to continuously improve the implementation of infrastructures and their climate-resilient.

## 4.5. Recap

This Module looked at each of the stakeholders involved in the PPP process to understand their role and potential intervention points and opportunities to bring climate-resilient infrastructure into the PPP process, and also to use the PPP process to proliferate climate resilience. This includes by leveraging innovative financing options, making the PPP process more inclusive of the final user, and mainstreaming standards of climate resilience into public policy.

## 4.6. References for further learning

If you want to further investigate the topics covered in Module 4, please refer to our sources, which are organised by theme.


| Theme | References |
|---|---|
| **Policies and framework** | UNDRR. 2015. What is the Sendai Framework for Disaster Risk Reduction? Available from: *https://www.undrr.org/implementing-sendai-framework/what-sendai-framework* [Accessed 9 January 2021]. |
| **Finance** | AC Energy. 2020. AC Energy upsizes senior green bonds to US$ 470M. Available from: *https://www.acenergy.com.ph/2020/07/02/ac-energy-upsizes-senior-green-bonds-to-us-470m/* [Accessed 28 April 2021]. |
| **Resilient infrastructure** | Silva Zuniga, M. C., Watson, G., Watkins, G. G., Rycerz, A., Firth, J. 2020. Increasing infrastructure resilience with Nature-Based Solutions (NbS). Inter-American Development Bank and Acclimatise. Washington, D.C. *http://dx.doi.org/10.18235/0002325* |
| **PPP Governance** | ADB. 2021. A Systems-Wide Approach for Infrastructure Resilience. Manila.<br><br>OECD. 2012. Mobilising Private Investment in Sustainable Transport: The case of land-based passenger transport infrastructure. Available from: *http://www.oecd.org/env/cc/Mobilising%20Private%20Investment%20in%20Sustainable%20Transport_Ang%20and%20Marchal.pdf* [Accessed 30 January 2021].<br><br>UNESCWA. 2019. ESG Financing for PPP Projects. Available from: *https://www.unescwa.org/sites/www.unescwa.org/files/events/files/esg_financing_for_ppp_projects.pdf* [Accessed 27 January 2021]. |

# 5. Module 5 – Embedding resilience in the framework of a PPP

**Description:** This Module will identify how to embed resilience principles into the PPP project cycle. This includes reviewing the typical governance of PPPs, applying climate and disaster risk assessments through the PPP project cycle, and implementing resilience considerations specifically into the transaction and contract management phases.

**Learning outcomes:** By the end of this module, learners will be able to:

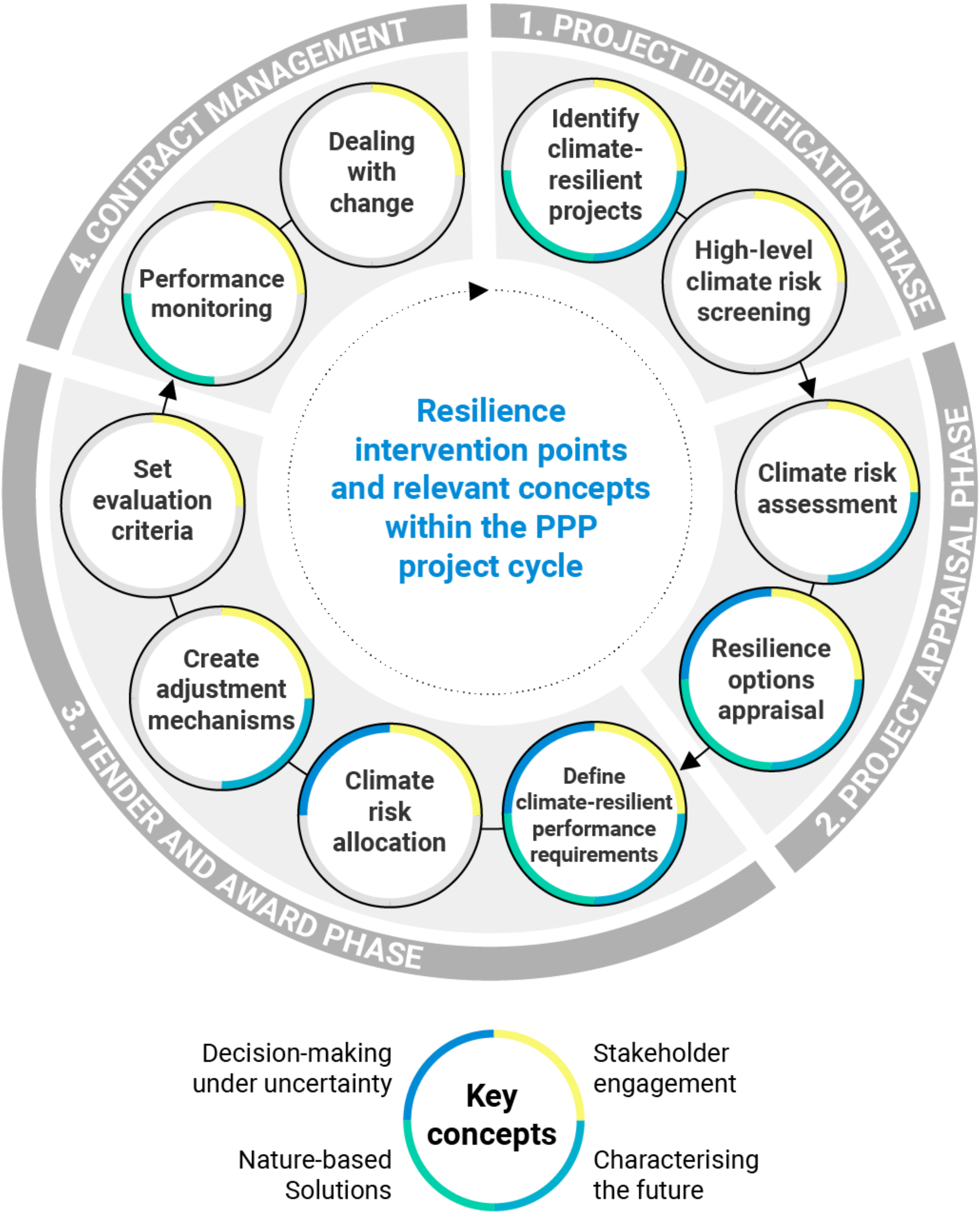
- Identify the key points within the PPP project cycle where resilience can be incorporated
- Use tools such as climate and disaster risk assessment to screen for and mitigate risks
- Integrate resilience thinking into quantitative assessments like VfM and CBA
- Apply different techniques to account for future scenarios and planning under conditions of uncertainty as discussed in Module 3 to a PPP

## 5.1. Reviewing the PPP project cycle

The purpose of this section is to detail the possible strategies for integrating climate-resilient principles into the main stages of the PPP procurement process. For each of the stages, the next sections will indicate key intervention points to integrate climate resilience and sustainable development in the PPP process. This will typically occur through enhancement of critical aspects like stakeholder's participation, risk environment impact assessment, value for money analysis, user's charges, risk allocation policies, transaction and bidding cost, and bid evaluation criteria.

The public partner should consider the resilience of and resilience through the project across the PPP project cycle. This framework will help to guide project development to ensure that projects are designed, operated and managed in ways that optimise resilience and provide co-benefits where possible. **Figure 5.1** outlines the key intervention points for climate resilience in the PPP project cycle and **Table 5.1** identifies a high-level checklist to achieve Resilience Rating 'A' for each stage in the project cycle.

**Figure 5.1** PPP project cycle and key intervention points for climate resilience




*Source: Authors, adapted from ADB, EBRD, IDB, IsDB, and WBG. 2016. The APMG Public-Private Partnership (PPP) Certification Guide. Washington, DC: World Bank Group. License: Creative Commons Attribution CC BY 3.0 IGO.*

**Table 5.1**. High-level checklist for Resilience Rating 'A'

| Project phase | Resilience of the project? | Y/N | Resilience through the project? | Y/N |
|---|---|---|---|---|
| **Project Identification Phase** | The project includes a climate risk screening | | Transformational resilience projects have been proposed to build the resilience of beneficiaries and the broader society and/or economy | |
| | The project corresponds to demand from national level and from stakeholders | | The project affects upstream policies, plans and frameworks, systematic change or technology and data enhancements | |
| **Project Appraisal Phase** | The project undertakes a robust climate risk assessment considering different future climate scenarios and adaptation options. | | N/A | |
| | The project identifies design and performance requirements and metrics that could be part of the RFP. | | *N/A* | |
| | The project provides a quantitative stress test (e.g., in economic analysis) and estimate of residual risk and failure scenarios to ensure economic viability. | | *N/A* | |
| **Tender and Award Phase** | The project has clear contingency plans in the event of a failure | | *N/A* | |
| | The project discusses specific resilience-related performance requirements and expectations to encourage the proposal based on transformational solutions | | *N/A* | |
| **Contract Management Phase** | The project integrates and tracks the use of new information into procedure and policy to address climate risks | | The project monitors or tracks the progress of resilience-building actions through at least one climate or disaster resilience indicator. | |

*N/A: Not Applicable*

## 5.2. Project Identification Phase

The first stage of the PPP process is to identify potential projects and screen them for technical, economic and financial feasibility, and to identify their Value for Money (VfM). Screening projects for climate risks is a crucial component of this phase, as it will allow practitioners to integrate resilience early on, either by highlighting a project as unviable due to climate risk or by identifying risks so that mitigation and adaptation measures can be taken to make the project more resilient to these risks.

The key steps of the project identification phase are:

- Identifying the priority projects ☆
- Screening projects as PPPs ☆

We can incorporate climate resilience into both stages.

### Identifying projects

As the public partner typically initiates the project, they also have leverage in promoting resilience of and through infrastructure, through the Project Identification phase. The public partner has the ability to broaden the aims of infrastructure development and think innovatively about the potential projects that can be developed to meet these aims.

The government of a coastal city may want to develop flexible modes of transport to decrease traffic congestion and associated air pollution. One way they could do this is to develop a bicycle route along the coast, which allows people access to key social and economic hubs throughout the city. They may also want to protect their coastline from the impacts of climate change and to propose conservation or restoration projects like restoring coastal wetlands or developing artificial reefs to reduce the impacts of storm surges and coastal flooding. This type of infrastructure enhances the resilience of existing and planned infrastructure in this coastal city, and also supports the natural and cultural heritage of the area (see **Box 24**).

**Top Tip: Use existing plans and strategies to identify projects**

The public partner may seek to identify projects that emerged or align with national or local climate adaptation plans and/or DRR strategies which often include prioritized action plans with projects. National adaptation plans (and other climate resilient plans and strategies) can provide governments with an opportunity to identify projects as well as direct and influence investments by the private sector and others to support the implementation of prioritized adaptation actions. To realize this potential, governments should gain a clear understanding of the actors involved and of the investments already being made in climate change

The point is that the public partner has the responsibility to think innovatively about how it can bring value to its citizens beyond simply economic terms. It is the public partner's responsibility to identify and bring forward projects that enhance resilience through infrastructure, as adding this to the project scope later on becomes more difficult. Further, in order to identify projects, the public partner requires an understanding of the key climate risks as well as an understanding of the other ongoing planning processes. This in turn will support the identification of projects that promote resilience through infrastructure (see **Figure 5.2**). The public or private partner can use the RRS to identify projects focused on resilience *through* **infrastructure**. Not every project may have the overarching goal of building resilience, but often these measures will go hand-in-hand with other development priorities.

**Box 24.** Udaipur uses wastewater treatment to maintain the health of its rivers and lakes

Udaipur is a rapidly urbanising city in the Indian state of Rajasthan. Rajasthan, recognising Udaipur's strategic location within the National Capital Region, is working to promote investment and development in the city to expand access to services and ensure the sustainability of the city's development. Also known as the City of Lakes, the city faced a major environmental and public health challenge in that it generated some 60 million litres of wastewater per day, most of which found its way untreated into the region's rivers and lakes.

To combat this, Udaipur's first WWTP was developed through a public-private partnership (DBOOT model) in concert with Hindustan Zinc and the local government (Udaipur Municipal \corporation and Rajasthan State-Owned Urban Improvement Trust). The WWTP initially had a capacity of 20MLD and is expanding with to 60 MLD. The manure generated by the WWTP is sold for horticulture and 50% of the wastewater is reused for the systems' own processing needs. The sale of manure is estimated to provide Rs10 million annually.

This project takes a landscape approach, working to improve or maintain the quality of the regional rivers and lakes, reduce freshwater consumption, and providing essential services to the public.

*Source: WWF. 2020. Bankable Nature Solutions. Amsterdam. P. 115*
*https://wwfint.awsassets.panda.org/downloads/bankable_nature_solutions_2__1.pdf*

**Figure 5.2** Developing projects that promote resilience through infrastructure based on RRS

| C rating | B rating | A rating |
|---|---|---|
| **Development** | **Resilience building** | **Transformational projects** |
| – Project is focused on poverty reduction or promoting development | – Project is focused on poverty reduction or promoting development<br>– Identification of climate risks and vulnerabilities<br>– Clear articulation of the intent to reduce risk and/or vulnerability<br>– Risk/vulnerability reduction measures identified<br>– At least one indictor related to resilience included in the project results framework (for B+ rating ) | – Project is focused on poverty reduction or promoting development<br>– Identification of climate risks and vulnerabilities<br>– Clear articulation of the intent to reduce risk and/or vulnerability<br>– Risk/vulnerability reduction measures included<br>– Explanation of the project's transformational dimension, with an identification of how the project will address existing barriers or obstacles to adaptation<br>– At least one indictor related to resilience included in the project results framework (For A+ rating) |

*Source: World Bank. 2021. Resilient Rating System: A methodology for building and tracking resilience to climate change. Washington, D.C.*

## Screening projects

Once the public partner has identified priority projects, they will then need to do a rapid risk scan of these projects to assess exposure to climate and disaster hazards. Note that the public partner can also do a high-level risk screening of an area or system if this will help them to identify projects that will build resilience *through* infrastructure. They would then need to do a secondary screening of these proposed projects. Additionally, they will seek to identify ways in which the project design might affect resilience *through* the project.

The output of this screening is a high-level climate risk profile which identifies the key hazards facing a project and how those hazards interact with the asset vulnerabilities to determine the risk profile associated with that specific hazard. The specific focus is on how climate change will impact:

- Location and design of the project
- Material and maintenance
- Performance of project outputs

For example, a water supply network may face decreased rainfall or more frequent drought as a result of climate change. Decreased precipitation or drought are **hazards**. The water supply network may face **vulnerabilities** such as deteriorating infrastructure that is prone to leaks, or heavy reliance on surface water storage. Leaks and surface water storage can lead to higher volumes of water loss. Another vulnerability may be demand for water; for example, if the water supply network serves a population that does not have water-wise principles. Maybe the community has swimming pools or uses a lot of water to landscape non-native plants. Maybe there are many old buildings that did not incorporate water-efficient fixtures. These are all examples of the types of vulnerabilities that the public partner should consider when screening projects because infrastructure is one component of an integrated system, as discussed in Module 2.

The intersection of these hazards, exposures and vulnerabilities is what determines risk. They also help us identify intervention points to mitigate that risk. For example, once decreased precipitation has been identified as a key hazard, mitigation measures can then be identified This might include diversifying water sources through surface, groundwater, and potentially desalinated water in extreme cases; and enhancing wastewater reuse for certain purposes like irrigation. If individual behaviour is a key vulnerability, the public partner can also seek to implement behaviour change campaigns and incentives like block tariffs on water consumption to deter overconsumption.

## Climate and disaster risk screening

As part of the PPP project screening process, the public partner will undertake a high-level climate and disaster risk screening. The aim of this climate and disaster risk screening is to develop a high-level climate risk profile, which identifies the key climate risks facing an asset (resilience *of* the project) or community (resilience *through* the project). Since not all projects may be aiming to achieve resilience *through* the project, the public partner should undertake the relevant steps related to resilience *through* the project is considered. All projects should, however, be screened to maximize the resilience *of* the project. This involves:

1. Rapid screening of the project's and/or community's exposure to climate and disaster hazards
2. Source relevant project studies, affiliated reports, and other knowledge
3. Map stakeholders and preparing Terms of Reference (TOR) for climate and disaster risk assessment if required.
4. Outline preliminary findings of how the project can enhance broader resilience (resilience through infrastructure).

1 **Rapid screening of the project's and/or beneficiaries' exposure to climate hazards.** The purpose of this step is to gain an initial understanding of the hazards to which a project may be exposed and ultimately establish its preliminary risk category. Based on the project's location and historical climate and disaster hazards, list of the key hazards that are relevant (see Appendix B for key sources of data and **Table 5.2**). Note that some hazards like earthquakes and volcanic activity is not climate-related, but they have been included for comprehensiveness' sake).

**Table 5.2** Key hazards that can impact projects and/or communities

| Environmental hazard | Geophysical hazards | Hydrometeorological hazards | Other hazards |
|---|---|---|---|
| • Air pollution<br>• Water pollution<br>• Soil degradation and pollution<br>• Deforestation and loss of biodiversity<br>• Wildfires<br>• Salinization | • Earthquakes<br>• Volcanic activity and emissions<br>• Landslides/other surface collapses<br>• Liquefaction<br>• Erosion<br>• Tsunamis | • Storms / strong winds<br>• Pluvial (rainfall) and fluvial (riverine) floods<br>• Coastal storm surges / floods<br>• Sea-level rise<br>• Droughts<br>• Heatwaves<br>• Cold spells<br>• Snowfall, hail, avalanches | • Technological hazards (e.g. industrial pollution, toxic wastes, accidents, explosions, fires, chemical spills)<br>• Biological hazards (e.g. bacteria, viruses, parasites, disease-causing agents) |

*Source: Authors.*

You will then work to fill out a rapid hazard screening matrix (see **Table 5.3**) to identify the likely frequency a hazard occurring and the likely intensity of that hazard in the project location(s).

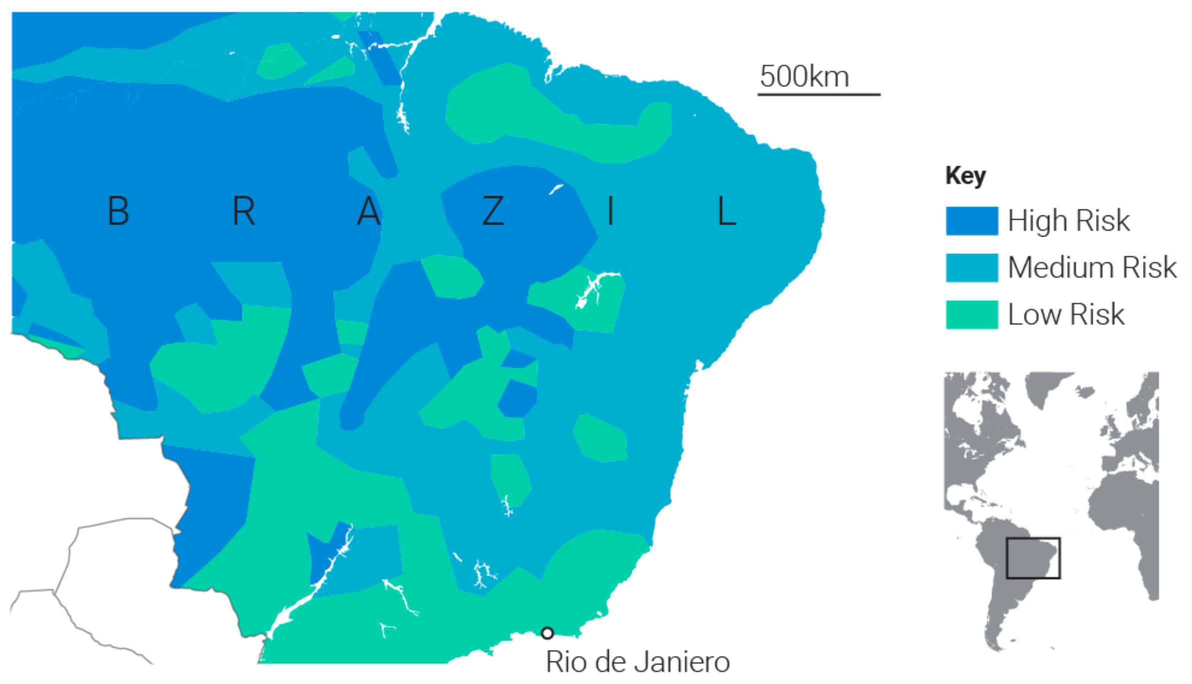
- Frequency – the likelihood of a hazard's impact occurring in the project area
- Intensity – the level of disruption of the hazard's impact in the project area

To help illustrate how to undertake the climate and disaster risk screening, we will use an example of a project that was developed by PPP, the Belo Monte – Rio de Janeiro UHVDC Transmission Project. This project was developed in Brazil, which needed to expand and reinforce its transmission network while also facilitating the construction of new renewable energy sources[103]. **Box 25** provides a case study brief with key project and climate details which informs the discussion.

**Box 25.** Case study brief - Belo Monte-Rio de Janeiro UHVDC Transmission Project

**Project overview:** The UHVDC Transmission Project aimed to transmit power from the Belo Monte Hydroelectric plant via Xingu converter station, to a terminal converted station in Paracambi, in the state of Rio de Janeiro[104]. The infrastructure of transmission networks in itself should be made resilient, but note that transmission networks are also a vehicle of community resilience, as they are an essential service and also facilitate access to other essential services. Transmission lines are exposed to heavy precipitation events and associated riverine, urban and coastal flooding; extreme heat, landslides, and wildfires. **Figure 5.3** shows a multi-layer map of Brazil, which shows the economic stock exposure (dark grey areas indicate highly exposed areas), multi-hazard mortality risk (yellow in the south of the country) and the multi-hazard average annual losses of US$ 600 – 6,000 million across Brazil. This figure indicates that economic stock is concentrated in urban areas, with particular exposure in the south of the country around the cities of São Paulo, Rio de Janeiro, and Curitiba.

**Figure 5.3** Multi-layer map of Brazil, including exposed economic stock, urban assets, and multi-hazard mortality risk




*Source. Adapted from UNEP. 2021. Global Risk Data Platform. Available from: https://preview.grid.unep.ch/index.php?preview=map&lang=eng [Accessed 15 February 2021].*

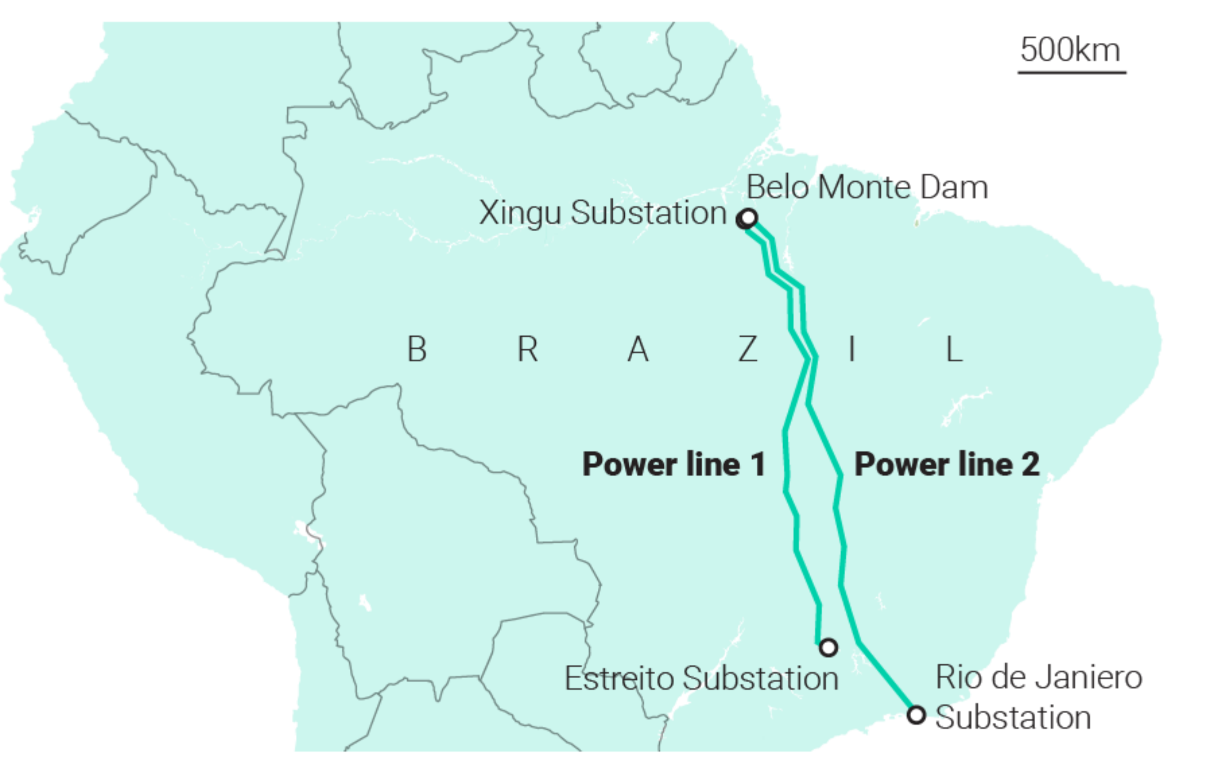
**Climate hazard overview:** The key data sources that used for the high-level risk screening are the World Bank's Climate Change Knowledge Portal[105], GFDRR's ThinkHazard platform[106] and USAID Climate Risk Profile for Brazil[107]. It is critical that the authority use up-to-date and well-informed information to ensure that the assessment is robust. Most countries will also have national databanks of key hazards, which should be sought out where possible.

Using USAID's fact sheet, key climate projections for Brazil are:

- 1.7 – 5.3°C increase in average temperature by 2085
- Increased length of the dry period and increased Amazonian drought
- 0.2 to 2 meters rise in sea levels by 2100
- These climate projections will have significant impacts on ecosystems, agriculture, tourism, and health.

**Figure 5.4** details a rough map of the Belo Monte transmission project. It runs nearly the length of the country and passes through elevations between 43 and 1350 metres. This span of the project along with the changes in topography indicate that it is exposed to several hazards, including wildfires, extreme heat, landslides, and riverine flooding.

**Figure 5.4** Map of the Belo Monte transmission project




*Source: Leal, M. 2016. Belo Monte power line passes through Brazil's Amazon and Cerrado Savannah. ChinaDialogue. Available from: https://chinadialogue.net/en/energy/9266-belo-monte-power-line-passes-through-brazil-s-amazon-and-cerrado-savannah/ [Accessed 15 January 2021].*

Based on this data, identify the key hazards that could impact the transmission networks. Now that the relevant hazards are identified, rank their likely frequency and intensity given the high-level information review conducted. Then calculate exposure score in the right-most column by multiplying the hazard's frequency score by its intensity. Any hazard with an exposure score of 3 or higher should be taken forward into the climate and disaster risk assessment stage.

**Table 5.3** Rapid hazard screening matrix

| Hazards | Information Sources Used | Likelihood of frequency (occurrence) in location (0 – none, 1 – low, 2 – medium, 3 – high, 4 – very high) | Level of intensity (disruption) on project (0 – none, low – 1, 2 – medium, 3 – high, 4 – very high) | Frequency x Intensity = Exposure Score |
|---|---|---|---|---|
| **Wildfires** | ThinkHazard USAID | 3 | 4 | 3*4 = 12 |
| **Extreme heat** | USAID | 3 | 2 | 6 |
| **Landslides** | ThinkHazard | 2 | 3 | 6 |
| **Riverine flooding** | USAID | 3 | 1 | 3 |

*Source: Authors; adapted from AECOM. 2020. Guidance Note for Assessing Climate and Disaster Risks and Climate Co-Benefits. London/Ankara.*

**2 Source relevant project studies, affiliated reports, and other knowledge.** The rapid hazard screening used readily available information. However, in this step, identify what further information is needed to undertake a detailed climate and disaster risk assessment. **Box 26** identifies key baseline information that is useful to undertake a detailed assessment. This includes identifying any existing studies and reports that have been conducted on similar project types in similar project locations or with exposure to similar hazards. Identify if any alternative information is required.

**3 Map stakeholders and prepare TOR for climate a risk assessment.** At this stage, map the stakeholders that need to be engage throughout the detailed climate and disaster risk assessment process. We covered the key stakeholders to involve in climate-resilient PPP processes in Module 3.1. For the climate and disaster risk assessment, this should certainly include climate experts, relevant governmental stakeholders, infrastructure experts, local NGOs, academia, and representatives of research organisations.

**Box 26** Baseline information checklist

- Geological survey
- Hydrogeological survey
- Geophysical survey
- Project proposal
- Preliminary design documents
- Project map
- Zoning plans
- Ownership documents
- Allotment documents
- Act of parliament
- Protocol documents
- Economic assessment
- Technical assessment
- Financial assessment

*Source: Source: AECOM. 2020. Guidance Note for Assessing Climate and Disaster Risks and Climate Co-Benefits. London/Ankara.*

Depending on the capacity or expertise of the public partner, it might be more robust to contract out the climate and disaster risk assessment, in which case draft a TOR including the project description, preliminary finds from the rapid hazard screening, and the objectives of the climate and disaster risk assessment. In this case, the objective is to identify the hazards and vulnerabilities that make up the risk to a project. Then use this to identify whether it is sensible to carry the project forward or else identify resilience options to mitigate the risks.

4 **Outline preliminary findings of how the project can enhance broader resilience.** If the project is specifically seeking to address resilience through infrastructure, then the public partner needs to identify how the project aims to do that (see **Table 5.4**). This is also an applicable albeit optional step for project's that focus on resilience of project. We will use the characteristics of a resilient system (see Module 2) as a high-level check-list to assess these projects.

**Box 27** shows a case study on a preliminary risk screening for the Coastal Cities Environmental Sanitation Project in Vietnam.

**Table 5.4** Checklist to identify how a project contributes to resilience through infrastructure

| Resilience characteristic | Y/N | Details |
|---|---|---|
| **Absorptive capacity**<br>Does the project increase the system's ability absorb the impacts of climate change and minimize consequences? | | |
| **Adaptive capacity**<br>Does the project increase the system's ability to adjust to climate impacts by undergoing changes? | | |
| **Recovery and restorative capacity**<br>Does the project support the system's ability return to normal or improved operations and system reliability after an impact? | | |

**Box 27.** Improving sanitation services sustainability in Vietnam's coastal cities

The Coastal Cities Environmental Sanitation Project is a project that will provide drainage, wastewater collections and treatment plants as well solid waste management facilities and conducted a comprehensive capacity building program in the cities of Dong Hoi, Quy Nhon, Nha Trang and Phan Rang Thap Cham. The project will support climate adaptation by these cities, particularly with regard to flooding.

Effective and efficient city-wide sanitation services will contribute to the protection of the quality of water supply sources, which may become scarcer or degraded with climate change impact as well as flood risk reduction as extreme weather events increase in intensity and frequency. Furthermore, in two to three years after the completion of this activity, it is expected that the cities will improve their performance in their O&M activities, and that there will be an increase in participation by the private sector in this area.

The Coastal Cities Environmental Sanitation Project included a preliminary climate and disaster risk screening for the project at the concept stage. The identified climate and disaster risks include increased frequency and degree of extreme weather events: heatwaves (moderate), extreme precipitation and flooding (moderate), drought (moderate), sea level rise (moderate), storm surges (high), and strong winds (moderate). This broad range of risks was addressed during project preparation, in particular through the hydraulic modelling used to design the sewerage/drainage networks which included a range of climate-related scenarios. These measures will be part of the management tools and assets that would be operated by potential private operations and maintenance contractors.

*Source: World Bank. Weekes, K. Diaz Fanas, G., Orekhova, S., Khamudkhanov, K. 2021. Climate adaption in infrastructure – case study examples in the PPIAF Portfolio. More information available at: https://ppiaf.org/activity/vietnam-improving-sanitation-services-sustainability-vietnam%E2%80%99s-coastal-cities and https://www.youtube.com/watch?v=HBpqk4M9Rhg*

## 5.3. Project Appraisal Phase

The aim of the project appraisal phase is to identify whether the proposed project is feasible and whether it is suitable for delivery as a PPP. The screening phase provided a high-level analysis of the project's feasibility, risks, and potential mitigation measures. During the project appraisal phase, the project will undergo an in-depth analysis of the project's viability in social, environmental, economic and technical spheres. Additionally, the government typically initiates project preparation protocols during this phase, such as due diligence to assess the risks and obstacles, some of which are likely to be climate-related.

The key steps of the project appraisal phase include:

- Appraise technical feasibility, including identifying and mitigating risks ☆
- Commercial viability, including allocating risks and responsibilities ☆
- Assess Value-for-Money ☆
- Fiscal analysis

The stars indicate where climate resilience can be integrated.

### Appraise technical feasibility

The first step of the project appraisal phase is assessing its technical feasibility. Component to this step is to identify risks and propose measures to mitigate them where possible. While identifying risks and seeking ways to mitigate them are typical to the project appraisal phase, there are a few key steps that need to be emphasized or amended to reflect climate resilience. First, it will be necessary to undertake a detailed climate and disaster risk assessment. Once the key climate risks are identified, it will be necessary to identify and appraise the resilience options that could mitigate these climate risks. This includes identifying the resilience option co-benefits to estimate the net present value of making a project climate-resilient.

With a PPP, the public partner can do this on a high-level as a means to inform the VfM assessment and whether or not the project should be taken forward as a PPP. In the next phase, the public partner can structure the PPP tender such that prospective private parties must propose the resilience measures they that can be scored against the RRS. Either way, the public partner needs to have the expertise to undertake and evaluate a climate risk assessment to ensure that the methodology that underpins the prioritised resilience option is sound.

## Climate risk assessment

The aim of this climate risk assessment is to build on the findings of the high-level climate risk screening, developed during the Project Identification Phase, to assess the risks qualitatively or quantitatively, depending on the methodology. The key steps of the assessment are:

1. Collate data required for climate and disaster risk assessment
2. Analyse hazards to which the project and/or beneficiaries are exposed
3. Analyse the project's or beneficiaries' vulnerability
4. Analyse the project's potential negative impacts on its surroundings or the project beneficiaries
5. Apply different scenarios to assess future climate and disaster risks
6. Summarise the climate and disaster risk assessment findings for the project

Note that is recommended to conduct stakeholder workshops during the first five steps. These workshops can include several steps at one time, but are critical to ensure that all information and perspectives are brought to the table to inform the risk assessment.

1 **Collate data required for climate risk assessment.** Baseline information has already been collected as part of the rapid hazard screening. In this step, build up on this existing information and create a data registry. A template for the data registry is located in **Appendix D**. This step may include developing memorandums of understanding with different governmental departments or data owners to access datasets. This may also include GIS data if undertaking a GIS-based climate risk assessment. As mentioned, GIS-based climate risk assessments require specialised skills in GIS and therefore will not be described in detail in this course. We will, however, include references where you can learn more.

2 **Analyse the hazards to which the project is exposed.** In the rapid risk screening, hazards to which the project was exposed were identified, and used high-level information to analyse the frequency and intensity of exposure to come up with a final exposure score. In this step, we will build up on the high-level risk screening using detailed information and stakeholder input. Let us take a look again at the rapid risk screening matrix. In the high-level case, assume that the rankings of frequency and intensity remain the same following examination of all new information and stakeholder input. At

this stage, work is done to identify the key impacts on the physical features of the project and the root causes of hazard impact. The impacts of key hazards focus on how the hazard may impair the physical elements of the infrastructure piece (e.g. damages to structures, blockages, or temporary disruptions, shortfalls in resource inputs/outputs, or knock-on effects onto the project's staff and users). The root causes for these impacts refer to the features of the hazard event that are actually causing the impact onto the infrastructure. This will help inform resilience options to mitigate the risks.

**Table 5.5** Hazard assessment table

| Hazards | Information Sources Used | Likelihood of frequency (occurrence) in location | Level of intensity (disruption) on project | Frequency x Intensity = Exposure Score | Impacts on the physical features of the project | Root causes of the hazard's impact on the project |
|---|---|---|---|---|---|---|
| **Wildfires** | ThinkHazard<br>USAID<br>Hydrometeor-ological surveys<br>Stakeholders | 3 | 4 | 3*4 = 12 | • Damage or destruction of physical structures and equipment<br>• Disruption of maintenance or repair | • Location itself – the infrastructure cannot easily be modified to be fully fireproof |
| **Extreme heat** | USAID<br>Hydrometeor-ological surveys<br>Stakeholders<br>Past temperature records | 3 | 2 | 6 | • Infrastructure defects<br>• Transmission lines failing | • Electrical load<br>• Demand on other aspects of the electrical network/ overburdening |
| **Landslides** | ThinkHazard<br>Geophysical surveys<br>Stakeholders | 2 | 3 | 6 | • Damage or destruction of physical structures and equipment<br>• Disruption of maintenance or repair | • Integrity of the structural foundations |
| **Riverine flooding** | USAID<br>Hydrometeor-ological surveys<br>Project map | 3 | 1 | 3 | • Damage or destruction of physical structures and equipment | • Integrity of the structural foundations (e.g. could pylons be uprooted by powerful floodwaters, thereby bringing down transmission lines?) |

**3 Analyse the project's vulnerability.** This step will assess the project's vulnerability to the hazards. This includes identifying the project and user's susceptibility to damage if exposed to the hazards, and the ability of the system or its features to resist impacts, cope with losses, or recover following impacts. We can do this by assessing the project aspects described in **Table 5.6**, bringing forward the impacts and root causes identified in **Table 5.5**.

**Table 5.6** Project aspects for an electrical transmission network

| Project Aspect | Guiding questions | Responses |
|---|---|---|
| **On-site assets and processes** | • What are the key onsite assets critical to the functioning of the infrastructure and delivery of related services? | • Assets: Poles, lattices, pylons, conductors, vibration damper, anchors, mass concrete |
| **Project-related inputs** | • Are there any key inputs – e.g., Water, power, maintenance – to make the project run? What are these key inputs? | • The inputs required to operate the assets such as wind for a wind turbine or water for a hydropower plant. |
| **Expected project outputs** | • Is the project expected to generate any outputs?<br>• What services will the project provide?<br>• Would it be a critical impact to the population if the project outputs are affected?<br>• How are the project outputs tied to the project financial streams? If the project were disrupted or else the beneficiaries unable to use it services, how would this impact the financial streams? | • Electrical transmission, key to electrical delivery to end users<br>• Functioning of the transmission network is essential to derive revenue from the whole electrical grid. Users are typically entitled compensation in the event of a power failure |
| **Links to other systems** | • Does the project link with any other critical infrastructure systems? For example, does the functioning of the infrastructure project require links with key transport links? Or transmission lines? | • Transmission lines are a key component of the electrical grid, connection generating stations and substations and ultimately supporting delivery to individual customers |
| **Links to other decision-making processes** | • Is the project likely to be impacted by other decisions at regional or local levels? For example, is the project likely to be affected by other developments? Will these developments impact the project exposure? | • Conversations with other utilities and land use planners necessary to understand ongoing activities in the project location |

*Source: Adapted from IDB. 2020. Climate-resilient Public Private Partnerships: A Toolkit for Decision Makers. Washington, D.C.*

Based on the guiding questions, score the **criticality of the impact on project aspects** (1 – low, 2 – medium, 3 – high) and the **repair/recovery capacity of the impact project aspects** (1 – easy, 2 – medium, 3 – difficult). The vulnerability score is the critical multiplied by the recovery capacity (see **Table 5.7**).

**Table 5.7** Vulnerability screening for example project: coastal bicycle highway

| Hazard | Description of impacts on project aspects | Scoring of criticality of impacted project features (1 – low, 2 – medium, 3 – high) | Scoring of repair/ recovery capacity of impacted project features (1 – easy, 2 – medium, 3 – difficult) | Criticality x recovery capacity = vulnerability score (out of 9) |
|---|---|---|---|---|
| Wildfires | Damage or destruction of physical structures and equipment<br>Disruption of maintenance or repair | 3 | 3 | 9 |
| Extreme heat | Infrastructure defects<br>Transmission lines failing | 3 | 1 | 3 |
| Landslides | Damage or destruction of physical structures and equipment<br>Disruption of maintenance or repair | 2 | 3 | 6 |
| Riverine flooding | Damage or destruction of physical structures and equipment | 1 | 3 | 3 |

**4 Assess the negative impacts of the project through an Environmental and Social Impact Assessment (ESIA).** Ensuring that the project is in line with environmental and social safeguards is a key component of due diligence. Therefore, undertaking an ESIA that incorporates climate risk is essential. The step will assess whether the project itself could have any negative impacts on the physical or socioeconomic features of its surroundings. This includes identifying whether the project will aggravate any environmental, economic, or social vulnerabilities. In the case of this example, construction of the transmission lines may incur damage and/or degradation to the ecosystems in which they are being built. However, as ESIAs are required of PPPs, this process will not be detailed here.

5 **Applying different scenarios to assess future climate and disaster risk.** Broadly, this step will support the public partner to obtain a comprehensive perspective on a project's future risk through the use of scenarios. There are multiple ways to undertake the scenario analysis, described in the previous sections. We will outline a simple scoring matrix here to support the overall climate and disaster risk assessment. In this method, identify the potential exacerbation of a hazard as a result of climate change, and assess the expected change in frequency or impact using the following scoring methodology:

- *Expected climate change impact on the hazard's frequency* – the likelihood of hazard's impact occurring within the project area: -1 - less frequent; 0 - same frequency; +1 - more frequent
- *Expected climate change impact on the hazard's intensity* – the level of disruption of the hazard's impact within the project area: -1 - less intense; 0 - same intensity; +1 - more intense

You will then create an adjusted exposure score by adding changes **Table 5.8** below to the original frequency and intensity scores from **Table 5.5 (**Step 2).

**Table 5.8** Future climate change assessment

| Hazard | Potential exacerbation of hazard by climate change | Expected climate change impact on hazard frequency | Expected climate change impact on hazard intensity | Adjusted Likelihood x Intensity = exposure score |
|---|---|---|---|---|
| Wildfires | Likely to increase with increasing temperatures, deforestation and more frequent spells of drought/decreased rainfall | +1 | +1 | (3+1) x (3+1) = 16 |
| Extreme heat | Extreme heat is expected to increase across the country in both frequency and intensity. | +1 | +1 | 8 |
| Landslides | While changes in precipitation are anticipated, the available information was not sufficient to identify changes to landslide frequency and intensity as a result of climate change. | 0 | 0 | 6 |
| Riverine flooding | While climate change projections indicate drier conditions in and around the Amazon, climatological patterns indicate that this will correspond to increased rainfall in the southeast, more mountainous regions of the country, which will likely exacerbate flood risk. | +1 | +1 | 8 |

In full scenario analysis, the practitioner would identify the impacts under a range of plausible future storylines, which include socioeconomic changes that may have bearing on how a hazard could impact infrastructure or change the vulnerabilities of that infrastructure. For example, a plausible future scenario is one where the cities being served by the Belo Horizonte transmission network have larger populations, increasing demand for electricity. Additionally, climate projections indicate increased instances of extreme heat and also higher average temperatures, which may lead for greater demand in electricity for cooling. This also has impacts on the vulnerability of the transmission system.

**6** **Summarise the climate and disaster risk assessment findings.** In this step, consolidate the findings from the climate and disaster risk assessment, using the template in **Table 5.9**.

**Table 5.9** Climate and disaster risk assessment summary table

| Topic | Summary |
|---|---|
| Key hazards, their score and primary impacts on the project features: | |
| Most vulnerable project features: | |
| Key potential negative impacts of the project on its surrounding environment: | |
| Key potential negative impacts of the project on its surrounding people: | |
| Main climate change features influencing key hazards and their impacts on the project: | |
| Main considerations of uncertainty around data and information on this assessment: | |

*Source: Authors, adapted from AECOM. 2020. Guidance Note for Assessing Climate and Disaster Risks and Climate Co-Benefits. London/Ankara.*

## Resilience options identification and appraisal

The climate risk assessment analysed quantitatively or qualitatively the key climate risks to the project, taking into account future scenarios. The resilience options appraisal stage seeks to conceive solutions to strengthen the project's resilience. The public partner may actually wish to leave the resilience options appraisal as a criterion within the tender and award phase, where the private partner must actually propose the optimised resilience option. This is the case for circumstances where there are multiple no/low-regret or flexible options available. For resilience options that require significant participatory processes (such as the adaptive pathways approach), it is better that the public partner dictates this specifically. Either way, it is still crucial that the public partner understands the process. The appraisal is made up of the following steps:

1. Establish objectives of climate and disaster resilience
2. Identify applicable resilience options

3. Evaluate applicable resilience options from a technical perspective
4. Identify resilience options co-benefits
5. Conduct an economic analysis of applicable resilience options
6. Combining technical and economic evaluation to prioritize and select preferred resilience options

1 **Establish objectives of climate and disaster resilience.** The climate and disaster risk assessment will have identified the main climate risks to the project, taking into account future climate scenarios. The next step is to identify the main climate resilience objectives for the project. In the case of Brazil's transmission networks, the key resilience objectives can be divided into the resilience *of* the project and the resilience *through* the project (see **Table 5.10**)

**Table 5.10** Resilience of and through a transmission network project

| Resilience of the project | Resilience through the project |
|---|---|
| • Continuity of service – ensure that the physical structure is resilient to extreme events up to a certain probability (for example, a 1 in 500 year river flood event) | • Provision of electricity to populations<br>• Ensure construction mitigates impacts on ecosystems to ensure that they continue providing resilience-enhancing services (e.g. forests stabilize mountainous slopes). |

*Source: Authors.*

2 **Identify applicable resilience options.** This stage will consider what options can be implemented to enhance the resilience of the transmission networks. Assess these against the hazards identified in the climate and disaster risk assessment. **Table 5.11** shows a non-exhaustive list of resilience options for these hazards. **Appendices H and I** further detail a short list of resilience options for the water and transport sectors as examples.

**Table 5.11** Resilience options for transmission networks

| Climate hazard | Resilience options for transmission networks |
|---|---|
| **Wildfires** | • Develop an urban-wild interface fire design plan to mitigate risks posed by drought impacted vegetation, high wind areas and high voltage assets<br>• Fire-proof wooden structures with resistant materials<br>• Develop and implement proactive vegetation management practices to reduce combustible growth in vicinity of high risk power lines<br>• Implement greater minimum clearance for vegetation and identify high risk areas for greater maintenance |
| **Extreme heat** | • Install thicker gauge overhead wiring |
| **Landslides** | • Manage construction on- and near-site to maintain soil integrity<br>• Reinforce slopes with high slide-risk; integrating NbS where possible, in accordance with fire design plan |

| | |
|---|---|
| **Riverine flooding** | • Install stainless steel equipment in areas susceptible to flooding, particularly if there may be saltwater intrusions near coastal locations<br>• Elevate critical hazards about future flood projections<br>• Install smart technology and sensors for equipment in high-risk flood areas |

*Source: Authors.*

**3** **Evaluate applicable resilience options from a technical perspective.** In this step, the public partner would identify the proposed resilience options from a technical perspective. However, as the options will be implemented by the private partner, it will be their responsibility for illustrating their technical capabilities to implement one or all of the resilience options.

**4** **Identify resilience option co-benefits.** The aim of this step is to identify any co-benefits that the resilience options for the project is likely to generate in addition to its primary objectives. These are additional to the project's co-benefits in itself, which should have been assessed as normal through the typical project appraisal phase. These co-benefits become relevant when conducting general cost-benefit assessments to decide if the project should be carried out. **Table 5.12** provides some high-level examples of co-benefits of five resilience options.

**Table 5.12** Examples of co-benefit impact areas

| Resilience option | Impact areas | Co-benefits |
|---|---|---|
| Fire-proof wooden structures with resistant materials (relevant to wildfire) | Environmental impact areas | • Not applicable (NA) |
| | Social impact areas | • Decrease risk of spreading fire through non-combustible materials, protecting local communities' lives and livelihoods |
| | Economic impact areas | • Decrease risk of spreading fire through non-combustible materials, protecting local communities' lives and livelihoods |
| Elevate critical hazards about future flood projections (relevant to flooding) | Environmental impact areas | • NA |
| | Social impact areas | • NA |
| | Economic impact areas | • Potential job creation |
| Develop and implement proactive vegetation | Environmental impact areas | • Support integrity of ecosystem<br>• Maintain or enhance biodiversity, soil quality and water quality of the site area and its surroundings |

| Resilience option | Impact areas | Co-benefits |
|---|---|---|
| management practices to reduce combustible growth in vicinity of high-risk power lines (relevant to wildfire) | Social impact areas | • Decrease risk of spreading fire through non-combustible materials, protecting local communities' lives and livelihoods |
| | Economic impact areas | • Job creation in form of site maintenance |
| Reinforce slopes with high slide-risk; integrating NbS where possible, in accordance with fire design plan<br>(Relevant to flooding and landslides) | Environmental impact areas | • Support integrity of ecosystem<br>• Maintain or enhance biodiversity, soil quality and water quality of the site area and its surroundings |
| | Social impact areas | • Ecosystem services provide multiple benefits for nearby localities<br>• Reduced landslide risk and associated damages on lives or livelihoods in nearby areas |
| | Economic impact areas | • Potential job creation |
| Develop an urban-wild interface fire design plan to mitigate risks posed by drought impacted vegetation, high wind areas and high voltage assets (relevant to wildfire) | Environmental impact areas | • Support integrity of ecosystem<br>• Maintain or enhance biodiversity, soil quality and water quality of the site area and its surroundings<br>• Potential that this must be done in surrounding areas or off-site if vegetation needs to be removed from the immediate vicinity to reduce fire risk |
| | Social impact areas | • Reduced fire risk from combustion of flammable vegetation |
| | Economic impact areas | • Potential job creation |

*Source: Authors, adapted from AECOM. 2020. Guidance Note for Assessing Climate and Disaster Risks and Climate Co-Benefits. London/Ankara.*

5 **Conduct an economic analysis of applicable resilience options.** This step will identify the economic feasibility of the project without any resilience options, and the net benefits of alternative resilience options for the project. Appendix E and F provides detailed steps and resources to this end. This will support the business case development later on. To do so, estimate the net present value of the project with no resilience measures based on the physical impacts of climate change on the project, as identified in the climate and disaster risk assessment. Use a relevant time horizon, typically the full performance life of the asset, and a discount rate according to national or international standards. The key steps of the economic analysis are:

1. Estimate the net present value of the project with no resilience measures.
2. For each resilience option identified, identify and value incremental costs and benefits of alternative project designs that incorporate different resilience options.
3. Identify and evaluate any net benefits (refer back to the co-benefits identified) that are additional to the direct resilience benefits. This is particularly relevant for NbS, as these will often have knock-on benefits outside of the direct resilience benefits they offer to the project.
4. Convert the cost and benefit flows into present values using the discount rate chosen according to national or international standards.
5. Compare the estimated incremental costs of project design with the resilience option and the benefits of integrating that resilience option.
6. Conduct a sensitivity analysis to account for uncertainties.
7. Rank the NPV of the alternative resilience options.

**Table 5.13** provides an example of this economic analysis.

**Table 5.13** Economic analysis of resilience options

| Shortlisted resilience options | Present Value Costs | Present Value Benefits | Net Present Value | Cost-Benefit Ratio |
|---|---|---|---|---|
| Fire-proof wooden structures with resistant materials | 4,200,000 | 3,800,000 | -400,000 | 0.9048 |
| Elevate critical hazards about future flood projections | 5,500,000 | 5,000,000 | -500,000 | 0.9091 |
| Develop and implement proactive vegetation management practices to reduce combustible growth in vicinity of high risk power lines | 1,500,000 | 2,500,000 | 1,000,000 | 1.6667 |
| Reinforce slopes with high slide-risk; integrating NbS where possible, in accordance with fire design plan | 4,800,000 | 6,000,000 | 1,200,000 | 1.2500 |
| Develop an urban-wild interface fire design plan to mitigate risks posed by drought impacted vegetation, high wind areas and high voltage assets | 3,200,000 | 3,200,000 | - | 1.0000 |

*Source: Authors, adapted from AECOM. 2020. Guidance Note for Assessing Climate and Disaster Risks and Climate Co-Benefits. London/Ankara.*

6 **Combine technical and economic evaluation to prioritize and select preferred resilience options.** If the public partner were implementing the resilience options themselves, or were seeking to specify a particular resilience option that the private partner should take, then this step would be useful to prioritizing the resilience option. In this case, the recommendation is for the public partner to understand how to assess the NPV and BCR under optimistic and pessimistic future climate scenarios that have been assigned specific probabilities, ensuring that the project meets an A ranking on the World Bank's Resilience Rating System[31].

## Integrate risk, potential resilience options and co-benefits into the business case

In this stage, we will integrate the findings of the climate risk assessment and resilience options appraisal into the broader business case. This involves the following steps:

1. Value the risks and co-benefits within the business case
2. Allocate risks

1 **Value the risks and co-benefits.** In this step, we will discuss how to integrate climate risk into typical PPP valuation processes such as financial feasibility analyses and Value for Money (VfM) assessments. Regardless of the valuation process, it bears repeating that when we are talking about value, we are not just talking about economic value.

The **VfM assessment** is the process by which the public partner assesses the value of doing a project using a traditional procurement method versus PPP procurement. It helps the project team to identify the connections between what you spend, what you do, what you get, and how people experience the outcome of the project. VfM is achieved if the project provides greater value at the same value or provides the same value at a lower cost when delivered as a PPP versus solely by the public sector.

As mentioned, climate risk is just one of the project risks which should be incorporated into the VfM assessment. The main difference is that, given the resilience options appraisal – even a high-level one, the public partner needs to identify whether sharing the cost of the resilience benefit provides greater VfM than if the public partner were to implement, operate and maintain the project themselves.

Similar to the climate risk assessment, evaluators will need to undertake the VfM assessment under multiple scenarios, where the project has different resilience features based on the outcome of the resilience options appraisal. Evaluators would then need to model these 'resilience scenarios' against a PPP delivery versus traditional delivery. In addition, they would need to stress test these 'resilience scenarios' against the future climate scenarios agreed upon in the climate risk assessment phase.

Within the VfM calculation, there are few explicit places to integrate concepts of uncertainty and climate resilience. The first is in the choice of the discount rate. This choice is subjective and should involve consultation with impacted stakeholders to agree upon the rate. The other main components that will likely be influenced by the future scenarios stress test are the operation and maintenance costs, the renewal and replacement costs, risk adjustments, and socio-economic consequences.

$$VfM = \sum_{t=0}^{n} \frac{YC_t + ARC_t}{(1+r)^t} - \sum_{t=0}^{n} \frac{CC_t + OM_t + RR_t + ACO_t + ACN_t + ASE_t}{(1+r)^t}$$

| | | |
|---|---|---|
| VfM | = | Value for Money |
| $YC_t$ | = | Yearly cost of the PPP scheme in year t (for instance, availability payments) |
| ARCt | = | Adjustment for regulatory costs |
| r | = | Discount rate |
| $CC_t$ | = | Construction costs (including overruns) of the PSC in year t |
| $OM_t$ | = | Operation and maintenance costs of the PSC in year t |
| $RR_t$ | = | Renewal and replacement costs of the PSC in year t |
| $AR_t$ | = | Adjustments for risk in year t |
| $ACN_t$ | = | Adjustments for competitive neutrality in year t |
| $ASE_t$ | = | Adjustments for differences in socio-economic consequences of the project in year t |

Based on the outcomes of these VfM scenarios, the public partner can decide generally whether the project provides VfM, or particularly whether they want to specify a resilience option in the bid because that specific option provides VfM through a PPP (see **Box 28** for an example of how VfM was applied in Sendai City, Japan).

As highlighted, a challenge with climate resilience are the uncertainties that practitioners need to acknowledge at the outset of the project. This will lend itself to incorporating qualitative components into the VfM assessment in addition to a quantitative one. Even without considering climate risk, the assumptions underpinning the quantitative VfM assessment are subjective and, therefore, a positive VfM does not automatically mean the public partner should take the project forward as a PPP, nor does a negative VfM mean that the project should not be taken forward as a PPP.

When considering a qualitative VfM approach for a climate-resilient project, the public partner should consider the following:

- Is the project itself suitable for private financing, at least in part?
- Is the private partner better able to manage some or all the climate risk? This includes addressing operational and maintenance concerns falling a hazard event
- Will using a performance-based payment mechanism incentivize climate risk mitigation?
- Do we know if there is available expertise in the market today to address this risk? Is the technology or sector well known and stable over the long term?
- Is there capacity in the government to manage and monitor the PPP?
- Is the project too small or makes it too complicated?

In this stage, the public partner will also undertake a financial analysis to estimate the financial viability of the project. This will be conducted using traditional methodologies and inputs, and the key outcome sought is for the public partner to identify the contingent liabilities arising from climate risk. Typically, the public partner will assume these liabilities if they are highly uncertain. In cases where the government is taking on these liabilities (that is, 'insuring' the private partner against them), then these liabilities need to be explicitly identified and they necessitate a discussion with the private partner about what liability protection will be provided in the PPP contract.

**Box 28.** VfM analysis in Sendai City

Sendai City, Japan leveraged PPPs to supply various types public infrastructure, including the Aichi Toll Road. Japan faces several types of natural hazards, including earthquakes, volcanos and tsunamis. While slightly different from climate risk, natural disaster risk also requires decision-making under boundaries of uncertainty, which means that Sendai City had to manage these uncertainties throughout the PPP project cycle.

Sendai City explicitly integrated disaster response considerations into the VfM analysis to assess whether the project should be delivered via PPP or through a public administrator. The ultimate analysis indicated that a BOT model  had more advantages over public delivery because the private partner would be able to respond more quickly to a disaster event, whereas Sendai City would have to go through the process of gaining and contingency budget and submitting documents to the municipal assembly to get approval for disaster recovery works.

*Source: World Bank. 2017. Resilient Infrastructure Public-Private Partnerships (PPPs): Contracts and Procurement – The Case of Japan. Washington, D.C. Available from: https://openknowledge.worldbank.org/bitstream/handle/10986/29208/122703-WP-PUBLIC-P161727-ResilientInfrastrcuturePPPJapanCaseStudyFINALweb.pdf?sequence=1&isAllowed=y [Accessed 14 February 2021].*

**2 Allocate risks.** Similar to the risk screening, the project team can identify measures to mitigate the risks that are identified through the climate and disaster risk assessment. In terms of risk allocation, it is a general rule in PPP practice that risks are allocated on the ability and willingness of different entities to manage each risk. This will be discussed further in Section 5.4. The World Bank PPIAF advises risk allocation in the following order[108]:

1. Allocate risk to the party best able to control the likelihood of the risk occurring
2. Allocate risk to the party best able to control the impact of the risk on the project outcomes
3. Allocate risk to the party able to absorb the risk at lowest cost

Traditionally, climate risk that is highly uncertain will be borne by the public partner. However, in a scenario where there is uncertain climate risk within a highly profitable project, it is more reasonable that the private partner takes on the risk[109].

It is important to remember, of course, that while CBA, VfM, and risk allocation exercise produce a good theoretical assessment of risk, the marketplace will be the ultimate detractor or confirming party for the risks as being commercially acceptable. This is also determined by the tender requirements but more broadly by ongoing or likely trends in policy and regulation and consumer preference. Ultimately, the business case has given the public partner an informed opinion to take to the market-place, but there may be fine tuning of the proposals necessary in the tender and award phases.

Risk allocation refers to deciding which party of the PPP contract will bear the cost or reap the benefits of a change in project outcomes arising from predefined risk factors. Allocating project risk efficiently is one of the main ways of achieving better Value for Money through PPPs.

Contracts allocate risks through several mechanisms, including but not limited to:

- **The revenue regime and payment mechanism**, which can define how and when compensations to the private partner can be triggered
- **Express contractual provisions**, including explicit guarantees and compensation obligations, which adjust the risk allocation implicit in the project structure
- **Provisions for financial re-equilibrium** of contracts in the occurrence of supervening events such as a grantor's breach event.

Risk allocation begins in the Project Appraisal Phase, with the establishment of a risk allocation matrix, in which all the identified risks are described, and a preliminary allocation is proposed. In the Tender and Award Phase, the risk allocation is finalised with a detailed description of contractual instruments to allocate risks that is agreed at financial closure.

There are some limits to how risks can be allocated in a PPP project which include the determination of the level of detail of risk allocation, the fact that some risks cannot be transferred (e.g. certain political risks) or incomplete contracts: even well-designed contracts may suffer from the absence of certain necessary provisions. While PPP contracts cannot provide solutions for every possible situation, they should provide rules (templates or formulas) for the range of foreseeable scenarios, and a decision-making methodology for any other situation.

Climate risk and associated resilience considerations present a particular nuance for risk allocation in that we are constantly gathering new and more detailed information on future climate scenarios and impacts. Therefore, incorporating this uncertainty – which was discussed in detail in Module 3 – and flexibility into risk allocation in the contract is helpful to avoid activating dispute resolution mechanisms.

PPPs are often conferred for projects that can have significant environmental impacts in sectors such as electricity transmission, ports, hydropower, airports, railways, and roads. Safety and health standards can also affect the planning and operation of the contract (in, for example, water and power plants). During all the phases of the PPP cycle, public authorities should endeavour to answer the following:

- Does the law require environmental impact studies, environmental permits, or licenses?
- What procedures are used? For example, does the SPV need to submit a project summary? What assessments must be performed?
- Does the law affect the construction and operation of facilities? For example, what conditions apply to the preservation of the natural environment, to temporary facilities, and to the state-use of pollutants?
- Will the SPV be liable for future environmental damages?

- What are the standards of environmental compliance and reporting?
- What laws and regulations apply to wildlife, health, water, and land use?
- Who is responsible for applying them? What safety regulations apply to the PPP?

The SPV typically takes on the risk of non-performance in PPP contracts, even if the cause is not in their control. As a result, several mechanisms have been developed to deal with these supervening events. Most jurisdictions have adopted a three-tiered approach to these events, as noted in **Table 5.14**.

**Table 5.14** Three-tiered approach to supervening events

| Supervening events | Description |
|---|---|
| **Compensation Events** | These events for which the authority takes the risk. The authority pays compensation to the private partner and gives any other form of contractual relief required to leave the private partner in the position that it was in before the relevant Compensation Event occurred ("no better, no worse"). |
| **Relief Events** | Also called delay events if they occur during the construction phase. These are events for which the private partner is expected to take financial risk but is given relief from other consequences of non-performance that such events cause. These are, by nature, events that are either insurable or not expected to continue for many days. |
| **Force Majeure Events** | Events beyond the control of the parties; and that render the performance of all, or a material part, of one party's obligations impossible. The definition often focuses on events that are uninsurable, outside of the control of either party, or are catastrophic in nature. Each party will typically bear its own consequences of a Force Majeure Event. |

*Source: IDB. 2020. Climate-resilient Public Private Partnerships: A Toolkit for Decision Makers. Washington, D.C.*

Climate shocks and stresses have historically been considered force majeure events, which are out of the control of all PPP parties. However, climate-resilient infrastructure needs to plan for these shocks and stresses and thus it is no longer acceptable for all climate shocks to be characterised as force majeure.

To ensure this does not include any and all potential climate risk events, the project team can articulate what qualifies as an unforeseen climate risk event and that should be agreed between the public and private partners. For example, if we know that climate projections indicate cyclones are going to intensify and become more frequent in a region, that should be included in the due diligence process. Rather, exceptional climate events are qualified as force majeure, such as a 1 in 100-year cyclone event.

Under some PPP contractual frameworks, the private partner is the main bearer of disaster risks and is mandated by the contract to purchase necessary insurance to transfer such risks to the insurance market. For example, in 2017 Hurricane Maria hit Puerto Rico, causing damage to the PR22-PR5

Highways Concession. Damages were mostly covered by insurance and the public authority did not bear the risk of additional costs from this disaster event.

Incentives for the private sector can also be formulated through the risk allocation. For the Chennai Water Desalination plant in India, the authority has provided to accept uninsurability risk in case of termination and act as an insurer of last resort for 80 percent of uninsurable or unclaimable assets. This was done mainly to incentivize private developers to undertake the project given that the project was the first PPP project in the sector.

Temporary FM events may be treated as relief or compensation events if such events have been pre-agreed to in the PPP contract. A particular climate risk, like flooding, is transferred to the private party, then the private party may need to take out insurance to cover any expected losses resulting from this risk. Extreme events, like natural disasters related to climate change, pose a set of challenging problems to insurers – they are uncertain but involve potentially high-losses. The insurance industry is actively trying to stay ahead of the curve with regards to responding to climate change related disasters, though there is a chance given the long length of a PPP contract that a particular climate related event becomes 'uninsurable' at some point over the contract's life.

Insurance transfers covered risks to third-party insurers. In PPPs, insurance provides significant value by way of third-party due diligence, while instilling disciplined risk-management practices to meet insurers' required standards. Additionally, innovative risk-management tools and products (e.g., weather index-based instruments) are also constantly being developed. In principle, the level of insurance coverage is a trade-off between the expectations of the public sector (aligned with the lenders) for maximum asset protection and affordability, and the expectations of the private sector to optimize coverage with respect to availability and competitiveness.

Uninsurability arises from non-availability, unaffordability and/or the lack of a specific fit for a risk being considered. In such cases, the public sector remains by default the "insurer of last resort" or, in rare cases, the private sector retains the risk, with higher return expectations.

Uninsurability therefore does not mean that the market has no insurance, but that insurance is unavailable on the international insurance market by insurers of an adequate credit rating/reputable insurers of good standing; and insurance premiums are prohibitively high (not merely more expensive)—for example, at such a level that the risk is not generally being insured against in the worldwide insurance market with reputable insurers of good standing by contractors in the same country.

From active partnerships with the insurance industry and engineering firms on wider infrastructure development, to the use of climate screening tools and risk-forecasting tools (such as climate vulnerability indexes, etc.) for project appraisal, there are various decision-support tools for adaptation that can be used for making decisions under uncertainty. For example, in the PR22-PR5 Highway Concession in Puerto Rico mentioned earlier, following the damage caused by Hurricane Maria the SPV noticed that the total value covered by the insurance was higher than expected. More detailed seismic and hurricane studies allowed to assess the risks related to such events which ultimately led to a renegotiation of the insurance terms.

## 5.4. Tender and Award Phase

During the tender phase, the government selects the private party that will implement the PPP. This is either the preferred bidder or selected bidder, based on a structured criteria and evaluation committee. We will get to this a little later. This stage builds on the analysis of the business case to determine the effective terms of the contract and concludes when the PPP reaches financial close—that is, when the government has selected and signed a contract with a private party, and the private party has secured the necessary financing to deploy and can start deploying it in the project.

This stage offers many opportunities for the project team to embed, evaluate and develop climate resilience considerations. These exist when designing the contract, qualifying bidders, tendering the project, and evaluating bids received. As much of the project-related analysis will have been completed, the project team should have a good understanding of the climate and disaster risks involved. When building climate resilience measures into the PPP contract and evaluation of bidders, project teams would be wise to bear in mind the transaction costs involved—both on the public side (i.e. is there government capacity) and on the private party side (i.e. is what the government is requesting in terms of climate resilience so burdensome so as to temper private interest?).

The following sections provide several possible decision-making tools that PPP project planners and teams can use during the Tender and Award Phase to ensure that climate resilience is considered.

### Draft the PPP contract

This stage includes the following components:

- Define performance requirements ☆
- Define payment mechanisms
- Create adjustment mechanisms ☆
- Establish dispute resolution mechanisms ☆
- Set the evaluation criteria ☆
- Provide for termination

The stars indicate the key places to integrate climate resilience into the contract-drafting stage is when the public partner is defining performance requirements, creating adjustment mechanisms, and establishing dispute resolution mechanisms.

## Define performance requirements

Performance requirements specify the contractual output, the standards to which the construction must adhere, and the service level standards for the operational phase of the project. Performance requirements represent the bar to measure the performance, that is, they represent the benchmark for service measurement, usually defined through a description of the target level of services, based on a key performance indicator (KPI) regime (see examples in **Table 5.15**).

Performance contracts are a tool that the public partner can use to ensure the private partner is executing the project following the standards and requirements agreed in the contract. This is an expectation of any PPP contract. The performance requirements are tied to payment mechanisms in performance-based contracts, in that the private partner does not receive remuneration if the asset does not meet the performance requirements.

Performance requirements and the level of service prescribed are intrinsically linked to the payment mechanism in availability or quality-based mechanisms. The lack of performance will have consequences in terms of payment deductions. The payment is adjusted to reflect the level of service, depending on whether the asset is considered available or unavailable, as described in "payment mechanisms".

**Top Tip: Ongoing communication between stakeholders**

Remember we learned in Module 2 that infrastructure components are part of larger socio-technical system. As a result, the public and private partners should not solely be focused on the resilience *of* the infrastructure itself, but should seek to build the resilience of communities *through* infrastructure as noted earlier in this Module. There is a civic imperative to do so, but again there are revenue considerations to account for as well. If people are not using infrastructure r are unable to because of a disruption, that impacts the cash flow of that asset.

Therefore, the public and private partners can work seek to identify ways to integrate resilience measures, particularly are proactive climate risk management and disaster risk management, to build resilience. This can be through social media  accounts that provide climate information relevant to the asset. For example, a water treatment plant is dependent on there being water available. It is in the operators' best interest to ensure that people understand their consumption patterns and be able to leverage those communication channels in the event of, say, a drought.

The immediate consequence of failure to reach the performance targets required by the contract is deductions (or penalties). Therefore, payment adjustments and penalties represent the first remedial tool for the procuring authority to manage and protect performance.

We can integrate climate resilience principles into the performance requirements in several ways.

**1 Continuity of quality service**

Ultimately, the aim of any infrastructure asset is to provide the services for which it was developed. In the case of a bridge, that is to allow people and goods to get from one side of a water body to another in a timely manner. In the case of a sea wall, that is to ensure that storm surges or sea-level rise do not irreparably damage coastal lives and livelihoods. In the case of a montane forest, a key ecosystem service is to maintain the integrity of the mountainside's soil structure and absorb runoff, to decrease the risk of flooding and landslides.

In some instances, occasional infrastructure disruptions are to be expected and, ideally, there will be redundancies in place to circumvent the disruptions for a short while. For example, if the bridge needs repairs, there should be other routes in place to allow people and goods to get from one side to the other. A key way that the private partner can achieve the expected level of services and deliver broader resilience benefits is through proactive climate and disaster risk management. That means that, as part of the PPP project, the public partner should also integrate requirements, such as supporting early warning systems for local areas and ensuring timely disaster recovery (see KPIs in **Table 5.15**). Moreover, the private partner can support communications around continuity of service, whether through providing information to a public alert system, or through their own channels.

There are types of infrastructure should be treated as 'too critical to fail.' A sea wall, for example, only needs to fail once for catastrophic damage to occur. This is the case of New Orleans, which was slowly rebuilt following the breach of its levee system during Hurricane Katrina in 2005. If the levees had been built with future climate scenarios in mind or had been maintained adequately, then countless lives, livelihoods, and critical infrastructure could have been saved. Even now, the United States Army Corps of Engineers – after completing the $14 billion work to upgrade the levee system in 2019 – acknowledges that the risk reduction provided by the levees may not be sufficient by 2023 because of faster-than-anticipated sea-level rise[110].

Other types of infrastructure may have longer repair or recovery time. For example, if a montane forest were chopped down it would take decades to centuries for that ecosystem to recover and provide the same level of ecosystem services that it originally did. Therefore, when considering continuity of service, it is also important to consider the value generated by the asset, whether there is redundancy in the infrastructure network and services could still be provided in the event of a temporary disruption, and the repair or recovery time of the asset.

## 2 Design standards, including environmental and social safeguards

The public partner has the opportunity to specify clear design standards or safeguards that the project should meet for increased resilience. Each country will have **specific engineering, construction and built environment standards, codes or rating systems** focused on climate and disaster risk mitigation (see **Box 29** for the differences between these typologies). These may also vary regionally within countries. The challenge, of course, is that many of these standards are often based on historical trends rather than future scenarios[111].

Climate resilience is increasingly becoming mainstreamed into international design codes and financial reporting and due diligence (see **Box 31.** for a country-specific example from Canada). The challenge is that many codes often lag behind updated climate scenarios and may not reflect local variation. Procuring authorities have a significant role to play in integrating these standards into the procurement phase or in the terms of the contract requirements. This will require engaging external stakeholders, including climate and physical infrastructure specialists, to support in identifying project-specific requirements. The public partner can also introduce requirements that the private partner must meet a specific and pre-defined standard for resilient infrastructure (see **Box 30.** for recent standards for resilient infrastructure). All bids must include resilience standards and if the project is not designed to meet these standards, then it has not met the performance requirements.

The public partner must be proactive in **articulating clear resilience benchmarks within the contract** that the private partner must meet, even if these are above statutory. PPPs should take into **account environmental and social safeguards** regardless of climate resilience. In this course, it is important to underscore that climate-resilient infrastructure should be incorporating environmental and social considerations as a matter of principle. The triple dividend of resilience ideally produces social and environmental co-benefits that are not tied to the service provided by the asset. **Box 32** describes the Philippines' recent resolution on safeguards for PPPs.

**Box 29.** What are standards, codes, and more?

The Global Center on Adaptation (GCA, 2021) highlights the differences between standards, codes, guidance documents and rating systems:

- **Standards** – definitions, procedures, and frameworks used to promote the consistent use of a topic throughout the stages of the infrastructure lifecycle.
- **Codes** – standards consolidated through legislation and regulation, which typically refer to minimum technical requirements that aim to achieve safety in infrastructure delivery.
- **Guidance documents** – recommendations or research that inform requirements to that informs standard development and can include good practice on infrastructure implementation.
- **Rating systems** – frameworks encompassing the metrics of standards, codes, and guidance documents to evaluate an infrastructure project against a specified level of performance.

**Box 30.** Example of standards, certifications or ratings for resilience

**ISO 37123.** The Intentional Organization for Standardization released its standard – Sustainable cities and communities – indicators resilient cities – in late 2019. The indicators have been developed to help cities to prepare for, recover from and adapt to shocks and stresses and learn from other cities by comparing across the range of performance measures and sharing good practice[112].

**SuRE Standard.** The Standard for Sustainable and Resilient Infrastructure (developed by GIB, Natixis and Iseal Alliance) integrates requirements for infrastructure projects to contribute at project level to the achievement of the objectives of international frameworks including the United Nations Framework Convention on Climate Change (UNFCCC), the Convention on Biological Diversity (CBD), the Sendai Framework for Disaster Risk Reduction, the International Labour Organisation (ILO) Declaration on Fundamental Principles and Rights at Work and others.'[113]

**Envision.** Envision is a third-party rating system that identifies clear requirements of sustainable infrastructure and, in particular, incentivizes higher performance beyond minimum requirements. The system uses 64 sustainability and resilience indicators organised around the following categories: climate and resilience, natural world, resource allocation, leadership and quality of life[114].

**Box 31.** Canada's PIEVC Engineering Protocol

Canada has developed a specific Protocol to support climate risk assessment for a range of infrastructure systems in the country. Best practice dictates that all public infrastructure projects apply the Protocol to their design and execution, although it is not a legislative requirement. This includes infrastructure projects that are delivered as a PPP. The outcomes of the Protocol can support decisionmakers judge what components of the infrastructure asset require adaptation and options for adaptation. This includes explicit design modifications but also changes to the operation and maintenance procedures.

*Source. PIEVC. 2021. PIEVC Engineering Protocol. Available from: https://pievc.ca/protocol/ [Accessed 8 March 2021].*

**Box 32.** Safeguards in PPP. Mainstreaming environmental displacement, social and gender concerns

The Government of the Philippines established Resolution No. 2018-12-02 to support to integration of key environmental and social considerations into PPP projects. This guideline incorporates multiple safeguard standards into a single document to ensure that the PPP project and development is streamlined. The government specifically integrated safeguards from environmental impacts and resilience to climate change, alongside gender equality and preserving culture and heritage.

*Source. Government of Philippines. N.d. Environmental and social safeguards. https://ppp.gov.ph/press_releases/environmental-and-social-safeguards-for-ppp-projects-pushed/*

**3 Monitoring and evaluation, including co-benefits**

While continuity of service of the infrastructure asset itself is critical to the performance requirements, the indirect benefits of climate-resilient infrastructure should also be clearly identified by the private partner and should be assessed regularly throughout the operation and maintenance of the asset (see examples of KPIs in **Table 5.15**). The private partner should indicate and undertake a clear monitoring, evaluation and reporting plan to ensure continuity of quality service and report back on the trends in co-benefits, including a data collection protocol. This could potentially serve other subnational, national, or supranational goals by providing centralised data on resilience indicators (see **Appendix C** for an example of key performance indicators for water resilient infrastructure).

**Table 5.15** Example KPIs

| Project | Performance requirement | Key performance indicator | Explanation |
|---|---|---|---|
| **Water supply network upgrade** | Improve water efficiency | • Number of groundwater monitoring stations installed<br>• Groundwater monitoring report produced annually<br>• Groundwater consumption per year<br>• Water table levels | As part of a water supply network upgrade delivered as a PPP, one specific climate resilience objective was to enhance water efficiency to decrease the potential impacts of drought. To monitor progress, the private partner is required to install groundwater monitoring stations to monitor groundwater consumption. This way, they can gather information on groundwater consumption, which has an implication on the success of the water efficiency measures of the whole water supply network. |
| **Electricity transmission network** | System must be back up and running within X hours after a climate hazard of Y. The X and Y here reflect that the hours would be calibrated to the severity of the climate hazard. This would be set out in the contract details. | • Rapid emergency repair teams and mutual aid agreements among utilities are in place to fix transmission and distribution infrastructure | To ensure the continuity of service as dictated by the performance requirements, the private partner needs to have a system in place to manage outages. |

## Create adjustment mechanisms

A well-designed contract is clear, comprehensive, and creates certainty for the contracting parties. Changes to PPP contracts are inevitable given the long timeframes of the project. Despite the uncertainty posed by climate change, we can be certain of change, whether that is new climate circumstances that could not originally be anticipated when the PPP contract was signed or else there may be advances in technology that are better able to enhance standards around resilience. Moreover, acute climate events might require an infrastructure asset and associated operations to quickly adapt to these acute climate events.

The aim of PPP contract design is therefore to create certainty where possible and bounded flexibility where needed — thereby retaining clarity and limiting uncertainty for both parties. This is typically done by creating a clear process and boundaries for change. Hence, it is important to anticipate possible changes to the project related to climate change, price them and include them in the PPP contract.

**Top tip: Build in flexibility to PPP policies**

For regions and countries that have high climate risk, PPP policies should be modified with additional flexibility built in to allow for active management. Such flexibility can also be extended to countries whose climate risks are currently low but may increase in the future. The pre-defined minimum protection can be related to a low-regret option that not only meets current adaptation deficits at low-cost but is flexible enough to respond to future changes.

Actively managing long-term climate risks during the life of a PPP contract requires the expertise of both the public and private sectors in a joint decision-making forum. Flexibility should be built into PPP processes starting with the project selection, preparation, and procurement, through to implementation and contract management, while setting appropriate incentive structures for both parties. This active approach also requires strategic partnerships with stakeholders representing multiple disciplines (e.g., insurance industry, engineering and scientific climate communities), and partnerships are underpinned by openness, transparency and cost effectiveness. These partnerships should seek to identify solutions focusing on technical, financial, legal and institutional capacities.

The PPP contract should have roles and responsibilities that will manage changes when they inevitably arise – including force majeure events. The contract should incorporate flexibility at the outset to anticipate the likely need for changes over the length of the agreement. For example, if a project team wanted to integrate adaptation pathways into the project approach, the trigger points would need to be established in the contract, or accommodating these trigger points would need to be clearly stated in the contract if the trigger points are not yet known.

IDB identifies several guiding questions for how to think about instituting mechanisms to accommodate climate resilience changes to the PPP contract[50]:

- In the identification and business case stages was a climate risk analysis conducted? Are there likely to be any climate related phenomena that will impact the project?
- Are there any possible climate related changes or variations to the infrastructure asset (e.g., a higher sea wall that does not make sense under current climate conditions but could if sea

levels rise) that can be foreseen? Can these be preidentified and priced as part of the PPP contract?

- Is the process for executing a change to the PPP process clear and easy to follow? Is it possible to have a separate process for climate related changes, which is more streamlined (in terms of numbers of approvals or documents required)?
- For any type of change to PPP contract, does change process require explanation of how proposed change, impacts project's resilience?
- Does the contract management team have someone with climate change expertise to help in reviewing changes to the contract and how they will impact a project's resilience to climate change? If not, is it easy to gain access to climate change expertise?

Adjustment mechanisms to the PPP contract related to climate change can enhance the resilience of infrastructure throughout its lifespan. Current contractual tools being implemented to address climate-related changes include:

- **Variation and renegotiation:** PPP contracts offer variation and renegotiation mechanisms that may be used to manage unforeseen risks. Variation mechanisms are often based on pre-agreed-upon cost levels or types of changes allowed to the contractual scope. Similarly, renegotiation of pre-agreed-upon contractual obligations may be allowed under specific circumstances but requires extreme caution on how it is managed. These contractual protections may appear comprehensive, but since climate risks are not explicitly allocated, and most climate uncertainties manifest during the contract implementation and management phases, these measures are ineffective over the life of PPPs.
- **Update of masterplans in concessions:** a masterplan is set up and then updated every 5 years to accommodate changes and respond to a real need. Incorporating updated climate scenarios or new technologies that can support resilience needs in the masterplan and its updates would help develop climate-resilient infrastructure. This may affect the identification of projects as PPPs and resilience options considered.
- **Change in law:** The provision of change in law (for example, change in design and construction codes or regulatory limits on GHG emissions, or new statutory codes of climate resilience etc.) protects private investors from the consequences of certain changes ex-post bid award, particularly if they result in delays, additional costs or prevent the private sector from meeting contractual obligations.
- **Relief and compensation events:** Both relief and compensation events require private-sector investors to reinstate a PPP asset to its normal condition after a pre-identified risk event (e.g., flood or storm) has interrupted the contractual performance. Relief events offer "time only" relief, whereas compensation events offer "time and compensation" to private-sector investors[115].
- **Hand-back provisions requirements:** Incorporate whole-asset-life-cost optimization approach instead of only PPP project life. For example, a smart lighting PPP project in Walloon, Belgium requires the concessionaire to return the assets and its components to the public authority with residual lives of at least 5 years, which enforces the maintenance contractor to build its maintenance plan in a such way to incorporate these requirements.

## Establish dispute resolution mechanisms

As in any complex contract, especially those of a long-term nature, it is not possible to foresee every event that may happen and affect a PPP contract. Changes will happen and this can often lead to disputes. It is expected that such disputes will be more and more triggered by extreme climate events and thus it is necessary to include specific provisions in the contract regarding dispute settlement. This should include a Dispute Resolution Process (DRP), a Dispute Resolution Board (DRB) and an arbitration clause.

- The DRP will aim to encourage and facilitate the search for high level negotiations between the parties that light eventually lead to a negotiated agreement. Involving a neutral third party, a mediator, could also be an option to facilitate such negotiations.
- A DRB will usually include two independent experts (one designated by each party) and another designated by mutual agreement. Their mission is to make decisions or recommendations on how to resolve the dispute.
- In arbitration, two disputing parties present their respective sides of the story to a neutral third party (the arbitrator). Each party will have the opportunity to make statements and present evidence, and the arbitrator will make a final decision that is binding on both parties. Arbitrators are usually construction attorneys or contractors.

For climate-related disputes, designating climate experts as mediators, board members or arbitrators could help reaching an agreement, or provide recommendations to resolve such disputes.

## Manage the PPP transaction

The procurement strategy determines how the private sector partner will be selected, and it focuses on developing an approach to procuring the project that helps obtain the best Value for Money (VfM). So, when actual alternatives are legally feasible, the project team should search for a strategy capable of creating the correct incentives for all the players involved. This stage consists of the following steps, and the stars indicate where climate resilience can be integrated:

- Decide the procurement strategy ☆
- Market PPP
- Establish evaluation criteria ☆
- Manage bid process
- Reach financial closure

## Decide the procurement strategy

The public partner first needs to decide the strategy it will use to procure the project. There are multiple different types of procurement strategies, including:

- Open tender or one-stage tender process
- Open tender with pass/fail pre-qualification
- Restrict procedure

- Negotiated process
- Dialogue or interaction process

Details for these strategies are located in **Appendix G**. However, it is important to highlight that the dialogue process is a particularly useful strategy for dealing with climate-resilient projects because it allows for an opportunity to discuss and refine some aspects of the Request for Proposal (RFP). While the dialogue process requires more planning, it is well-suite to complex projects which can have multiple different solutions. In this process, bidders are qualified based on specific criteria. Following an initial proposal, they are then engaged in dialogues with the public partner before a final proposal is requested.

## Setting evaluation criteria

Evaluation criteria can have a significant impact on the market´s appetite or willingness to submit an offer. It is customary and good practice that for every criterion, the RFP describes a definition or explanation for transparency purposes — including a description of the main factors that will be considered when assessing the respective sub-criteria.

The evaluation criteria need to assess the degree to which the private partner has communicated their understanding of the project objectives and performance requirements, as well as their proposed technical capacity to do so. As PPPs focus on performance and PPP specifications are mostly based on outputs rather than inputs, the technical requirements in the RFP should not be overly prescriptive. Instead, they should provide only a reference design in a pre-design form or a "functional design", but the service requirements should be focused on the results/quality of the service through key performance indicators (KPIs), rather than the amount of inputs or activities.

It should be noted that, in a number of jurisdictions, including experience as an evaluation factor is prohibited by law because using experience as a selection criterion creates a risk of perpetuating the status quo where the most experienced bidders frequently win the projects. If experience has already been used to qualify bidders (or even to short list), it should not be necessary to also use experience as a criterion in evaluating the bids. Consequently, the technical proposal evaluation should not be based on inputs committed, but should check that the means proposed by the bidder respond to the minimum requirements established in the RFP. It should also evaluate the extent to which the means and methods proposed by the bidder will result in quality and reliability of the output.

As mentioned in discussion during the project appraisal phase, the public partner can decide whether or not to specify resilience options that the bidder must undertake or consider as part of the overall project design. While this is context-specific, it is generally recommended to allow the potential private partner to suggest resilience options so as to best harness the innovation in the private sector, and compare across bidders.

The financial package is sometimes subject to evaluation in terms of reliability, such as the commitment level shown by the equity investor, the level of confidence in the financing availability, and the degree of robustness of the project finance structure. In processes with staged evaluation, it can be difficult to manage the evaluation of the financial package without information on the reliability and robustness of the financial structure that would allow the appraiser of the offers to know in advance or infer the price offered. Strict instructions should be provided to bidders, emphasizing that the financial package documentation should not disclose the overall price offered.

Finally, there is a feature in the evaluation process that is sometimes (in some countries) described and committed to in the RFP: some jurisdictions will consecutively evaluate the technical and financial criteria. This means that the financial (price) criteria will be only evaluated (and the financial envelope will only be opened) once technical evaluation is finished and scorings are assigned to each proposer. This is the case of the EU where procurement regulations universally adopt this approach. We recommend this approach for climate-resilient infrastructure, as the public value of this infrastructure and the returns on the investment to society typically outweigh the up-front costs of investment over the long-term.

Another key way to enhance climate resilience in the design, delivery and operation of the infrastructure is to set relevant qualification standards for bidders. This means ensuring that the private partner has available technical capacity to bring to the project. **Table 5.16** provides an example of the types of staff that could be required within the RFP to ensure that climate-resilient experts are included.

**Table 5.16** Example required staff qualifications related to climate-resilient infrastructure

| Title | Description |
|---|---|
| **Lead climate resilience designer** | At least 10 years of relevant work experience in developing and designing resilient infrastructure, preferably in the context of climate hazards and resilience. |
| **Modelling expert** | At least 8 years of relevant work experience in financial and economic modelling and research, preferably in the context of climate hazards and resilience. |
| **Environmental economist** | At least 8 years of relevant work experience in economic modelling and assessments of environmental assets, including natural capital. |
| **Climate-resilient infrastructure expert** | At least 8 years of relevant work experience in climate-resilient infrastructure |

*Source: Authors*

In addition to the performance requirements, the public partner can leverage the evaluation criteria of the bid to incorporate climate resilience.

Beyond specific engineering standards, the public partner can also integrate evaluation criteria related to how the infrastructure fits into broader climate-related goals. For example, this could include a provision for the private partner to articulate how they would work to ensure that their infrastructure supports the country in achieving the NDCs and NAPs. This could potentially also be tied to the performance requirements.

To develop a clear list of technical and/or quality criteria, it is good practice to assign to each of the criteria a specific weighting in the overall scoring, or the maximum number of points that will be allocated, out of the total scoring considered for the technical criterion (see **Table 5.17**). For some projects, a weighting for the second layer of criteria or sub-criteria may be provided.

**Table 5.17** Example bid criteria with weightings

PUBLIC PARTNER
**SUMMARY EVALUATION SHEET FOR TECHNICAL PROPOSAL**
**QCBS**
**Selection XXXXX for Climate-Resilient PPP Project**

| EVALUATION CRITERIA | | Max. | Bidder 1 | | Bidder 2 | | Bidder 3 | | Bidder 4 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Weight | Rating | Score | Rating | Score | Rating | Score | Rating | Score |
| **I. Approach and Methodology** | | **800** | 91% | **727** | 93% | **747** | 96% | **766** | | **793** |
| a | Quality of Approach and Work Plan | 125 | 80% | **100** | 99% | **124** | 95% | **119** | 100% | **125** |
| b | Resilience approach | 200 | 99% | **197** | 96% | **192** | 88% | **175** | 98% | **196** |
| c | Monitoring and evaluation plan | 150 | 73% | **110** | 87% | **130** | 99% | **149** | 100% | **150** |
| d | Stakeholder engagement plan | 150 | 99% | **148** | 86% | **129** | 100% | **150** | 98% | **147** |
| e | Personnel Schedule | 125 | 98% | **122** | 98% | **122** | 99% | **124** | 100% | **125** |
| f | Proposal Presentation | 50 | 100% | **50** | 100% | **50** | 98% | **49** | 100% | **50** |
| **II. Personnel (Areas of Expertise)** | | **800** | | **751** | | **772** | | **746** | | **769** |
| **International Staff** | | **800** | | **751** | | **772** | | **746** | | **769** |
| a | Team Leadership | 100 | 100% | **100** | 98% | **98** | 87% | **87** | 93% | **93** |
| b | Lead climate risk analyst | 200 | 92% | **183** | 100% | **200** | 90% | **179** | 98% | **195** |
| c | Macro-economist | 150 | 100% | **150** | 97% | **145** | 100% | **150** | 99% | **149** |
| d | Environmental economist | 150 | 80% | **120** | 99% | **149** | 100% | **150** | 100% | **150** |
| e | Climate-resilient infrastructure expert | 200 | 99% | **198** | 90% | **180** | 90% | **180** | 91% | **182** |
| | **TOTAL** | **1000** | | **1478** | | **1519** | | **1512** | | **1562** |

**Rating:** Excellent = 100% Very Good = 90 - 99% Above Average = 80 - 89% Average = 70 - 79% Below Average = 1 - 69% Non-complying = 0%
**Score:** Maximum Weight x Rating / 100

*Source: Authors.*

## 5.5. Contract Management Phase

The contract management phase aims to ensure that the services specified in the output specifications are obtained and to ensure ongoing affordability and appropriate risk transfer. The contract management phase also provides an opportunity to proactively manage future needs, including those that may present as a result of continued learning around climate change. Climate resilience is especially relevant to the monitoring and reporting and dealing with change within the contract management phase.

### Performance monitoring

Monitoring is pertinent for the contract management of PPPs during construction, operation and maintenance phases. During the construction phase, monitoring will ensure that the work progresses properly according to the schedule and technical requirements[116]. During the operation phase, performance monitoring seeks to ensure that the asset is meeting service performance requirements, including service standards or target levels of services. During the maintenance phase, performance monitoring focuses on whether the specification around maintenance are being met so that the infrastructure maintains operational standards.

Updating key performance indictors (KPIs) is one means to integrate resilience into performance monitoring. This ensures that the target levels of service and service standards are designed to a resilient standard. These KPIs should be designed with resilience principles in mind. A useful tool to identify resilience-related KPIs is the World Bank Resilience Rating System.

**Top Tip: The role of the PPP contract supervising agency.**

The PPP contract supervising agency is essential to monitor situations of high climate risk. This agency provides expertise and attention to monitoring. Best practice by the supervising agency would enhance KPIs in the monitoring framework itself and also maintain a proactive engagement with the PPP contractor to ensure that new knowledge on climate risks is incorporated in operations and maintenance, for example through early warning systems.

Stakeholder engagement is also a critical part of performance monitoring of climate-resilient infrastructure. At different points in performance, the public partner can conduct public consultations to gauge user satisfaction with the infrastructure asset itself, and any other benefits that they have derived beyond the direct service.

Many external actors are involved in a PPP process, whether they are advisers (legal, technical, financial) or independent entities. However, they do not all intervene at the same time and stages. Advisers provide their services (to public parties at least) from the project appraisal phase to the end of the award phase, even further for some advisers. As more and more climate risk advisers are emerging, it would useful interesting to involve them early in the procurement process, so climate-related risks are well identified, and their mitigation is discussed with the other advisers.

There are also Independent Engineers and Independent Certifiers that provide independent technical assessments of the project process as mandated by the public partner and the lenders. Their functions start usually with the execution of the PPP contract and continues through construction, operation & maintenance, and hand-back stages. Their scope of work includes review, inspection and monitoring of construction works, examining the designs and drawings for their conformity with the concession agreement and conducting tests and issuing completion certificates during the construction period. During the O&M phase, the Independent Engineer is expected to monitor compliance with the performance and maintenance standards.

## Dealing with change

When a compensation event occurs, the private partner has the right to claim compensation to offset the loss suffered or that will be suffered, or part of the loss suffered in shared risk events. The loss may include forgone revenues (for example, revenue lost due to a delay in construction, where the delay is a result of a risk covered by the contract as a compensation event).

This process is commonly known as "rebalancing the contract" in most civil code countries, that is, the process of restoring the financial equation of the project cash flows as if the event had not occurred. The contract should set out the process of claiming, determining, and implementing the compensation, including in the last case the potential means to grant the compensation. Rebalancing can also be linked to pain and gain sharing; meaning that climate change can provide opportunities alongside risk, and these opportunities could benefit the private partner[117].

Once the loss is determined (or estimated in events that impact future cash flows), the government will have to proceed to compensate the private partner. As a common rule, events that impact on Capex will be compensated by a direct payment, and events that affect future revenues or costs will be compensated by supplementary payments or by agreeing to a change (increase) in the service price or in the tariff (in user-pays contracts).

During this stage, the government must ensure that promises agreed in the contract are delivered and that new events or changes in general – specifically changes to the climate risk profile – are responded efficiently and adequately, without disrupting the project. In regards to climate resilience considerations, this stage will require tracking any climate-related agreements set during the Transaction Stage and managing any unforeseen climate related risks that occur. For projects deemed to have medium to high-climate related risks it is wise to include climate change expertise as part of the contract management team.

## 5.6. Recap

We covered quite a bit of ground in this Module. And while there was a lot of detail for each phase of the PPP project cycle, the main points to take away are that:

- Climate risk is just another risk that should automatically be included in any risk analysis during the project screening and business case phases. This section has provided a conceptual and practical overview of how to identify and mitigate climate risks throughout this module, using principles learned in Modules 2 and 3.
- Setting standards of climate resilience in both the tender process as a criterion for bidders, and in the performance-based contract ensures that resilience is embedded in the development of the infrastructure asset.
- Climate resilience requires integrating and accommodating change. This includes in the change mechanisms and force majeure definitions of the PPP contracts.

This concludes the Handbook of the Knowledge Module on Public-Private Partnerships for Climate-Resilient Infrastructure.

## 5.7. References for further learning

If you want to further investigate the topics covered in Module 4, please refer to the sources, which are organised by theme.

| Theme | References |
|---|---|
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# Appendix A PPP Terminology

- **Availability Payments:** Payments made over the lifetime of a contract in return for the private party making the infrastructure available. This is defined in the contract, and it is a common form of payment in PPPs.
- **Base Case:** The financial description of the project in terms of costs, revenues, and resulting conclusions. It combines the sensitivity variables to consider the most likely scenario.
- **Brownfield projects:** projects targeting infrastructure assets that were existing before the time of procurement.
- **Capital expenditure (CapEx):** The initial construction costs of the infrastructure plus any expenditure on the constructed PPP assets that is not an operating expense (OpEx).
- **Changes in Law:** The amendment or passing of new laws that conflict with the laws affecting the project and impact upon the project; change in law protection may be subject to a specified level of materiality before any protection is given (e.g., demonstrating the change has a minimum financial impact on the Private Partner).
- **Co-financing:** the provision of finance by the public sector to finance a portion of the capital expenditures.
- **Construction contract:** An agreement entered between the special purpose vehicle (SPV) and the construction contractor for the design and construction of the PPP project assets. Also referred to as a "design build (DB) contract", "design and construction (DaC) contract", or "Engineering-Procurement-Construction – EPC contract."
- **Construction Phase:** The period from when the Private Partner takes control of the project site (typically by reference to the date of signing or effective date (if conditional) of the concession agreement or the commencement of construction by reference to certain works) until the commercial operations date.
- **Cost-Benefit Analysis (CBA):** A type of analysis used to compare two or more options for a project, or a decision based on economic flows duly adjusted, following some patterns.
- **Cost-effectiveness Analysis (CEA):** CEA relates the cost of an alternative to a measure of project objectives or to its key outcomes or benefits.
- **DBFOM (Design-Build-Finance-Operate-Maintain):** In a DBFOM contract, the contractor develops the infrastructure with its own funds, that is, it will provide all or most of the financing. The contractor is also responsible for managing the infrastructure life cycle (assuming the life-cycle cost risks) in addition to being responsible for current maintenance and operations. The contract is often referred to as a DBFM when operations are not included in the scope of the contract.
- **Deductions:** A method, set out in the payment mechanism by which payments to the Private Partner are reduced if it fails to meet the key performance indicators. Sometimes called Abatements.
- **Demand/Traffic risk projects:** Projects which rely on demand forecasting (e.g., road and rail use) to determine the bankability of the project.
- **Downstream contractual structure:** The structure of contracts wherein the responsibilities, risks, rights, and obligations are delegated from the SPV to the different private actors participating in the PPP.
- **Due diligence:** Review and evaluation of the project, the project contracts, and their related risks. The term may be also applied to the project preparation activities or some aspects of the preparatory works to be handled by the procuring authority before the tender launch.
- **Environmental Impact Assessment (EIA):** The formal process used to predict the environmental consequences, positive or negative, of a project and may result in changes being requested or necessary in the design and construction of the project.

A comprehensive glossary of terms can be found at: [https://ppp-certification.com/ppp-certification-guide/glossary](https://ppp-certification.com/ppp-certification-guide/glossary).

## Data sources

| | |
|---|---|
| **Environmental hazards** | |
| Air pollution | **European Environment Agency** *[Air Pollutant Levels by Stations - from 2010-2016 and Interpolated Air Quality]*<br>(https://www.eea.europa.eu/) |
| Water pollution | **European Environment Agency** *[Water Framework Directive – category, ecological status, chemical status, pressures, and impacts]*<br>(https://www.eea.europa.eu/) |
| Soil degradation and pollution | **Copernicus** [Corine Land Cover – Imperviousness]<br>(https://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness) |
| Deforestation and loss of biodiversity | **Global Resilience Atlas [Land Cover** [Land Cover - Degradation]<br>https://www.resilienceatlas.org/map?tab=layers&layers=%5B%5D |
| Wildfires | **NASA FIRMS** *[Active and Historical Fire Events]*<br>https://firms.modaps.eosdis.nasa.gov/map/#z:3;c:0.0,0.0;d:2020-04-21..2020-04-22<br>*Fire Information for Resource Management System* |
| Salinization | **European Environment Agency** *[Water Framework Directive – category, ecological status, chemical status, pressures, and impacts]*<br>(https://www.eea.europa.eu/) |
| **Geophysical hazards** | |
| Earthquakes | **UN Office for Disaster Risk Reduction** [*Global catalog of earthquakes from 1970-2014*]<br>**NASA Socio-Economic Data and Applications Centre (SEDAC)**<br>https://sedac.ciesin.columbia.edu/data/sets/browse<br>Contains Satellite Global Earthquake Hazard Distribution - Peak Ground Acceleration.<br>**SHARE The European Database of Seismogenic Faults**<br>(http://diss.rm.ingv.it/share-edsf/SHARE_WP3.2_Downloads.html) |
| Volcanic activity and emissions | **Smithsonian Institute National Museum of Natural History Global Volcanism Program**<br>https://volcano.si.edu/<br>*Volcano location and details* |
| Landslides/other surface collapses | **NASA Socio-Economic Data and Applications Centre (SEDAC)**<br>https://sedac.ciesin.columbia.edu/data/sets/browse<br>Global Landslide Hazard Distribution (2000)<br>**Partnership for Resilience and Preparedness [Landslide Susceptibility]**<br>https://www.prepdata.org/explore |
| Liquefaction | General dataset not available |
| Erosion | **European Soil Data Centre ESDAC** *[Soil erosion]*<br>https://esdac.jrc.ec.europa.eu/<br>**Partnership for Resilience and Preparedness** *[Erosion Risk]*<br>https://www.prepdata.org/explore<br>**Global Forest Watch** *[Erosion]*<br>http://water.globalforestwatch.org/map/ |
| Tsunamis | **National Oceanic and Atmospheric Administration (NOAA)** *[Estimated Tsunami Travel Times to Coastal Locations]*<br>https://maps.ngdc.noaa.gov/viewers/ttt_coastal_locations/<br>*[Historical Tsunami Events]*<br>https://maps.ngdc.noaa.gov/viewers/hazards/?layers=0 |
| **Hydrometeorological hazards** | |

| | |
|---|---|
| Storms / strong winds | **Department of Wind Energy** [Global Wind Atlas – webmap viewer]<br>http://science.globalwindatlas.info/map.html |
| Pluvial (rainfall) and fluvial (riverine) floods | **GFDRR InnovationLab** *[Fluvial/Pluvial Flood Hazard Level – 1 in 10, 50 and 1000-year return periods]*<br>https://int.geonode-gfdrrlab.org/layers/hazard:adm2_fu_raster_v2 |
| Coastal storm surges / floods | **Coastal Dataset for the Evaluation of Climate Impact (CoDEC)** *[high-resolution global dataset of extreme sea levels, tides and storm surges including future projections]*<br>Data https://zenodo.org/record/3660927#.Xucl45pKhPY<br>Research paper - https://www.frontiersin.org/articles/10.3389/fmars.2020.00263/full |
| Sea-level rise | **Ocean Health Index**<br>https://ohi-science.org/<br>**Global Resilience Atlas**<br>https://www.resilienceatlas.org/map?tab=layers&layers=%5B%5D<br>**IPCC SROCC**<br>(https://www.ipcc.ch/srocc/download/)<br>**Permanent Service for Mean Sea Level**<br>(https://www.psmsl.org/data/obtaining/map.html#metadataTab)<br>**GESLA** *[Global Extreme Sea Level Analysis]*<br>(https://gesla.org/) |
| Droughts | **GlobeDrought** *[Irrigated Agricultural Drought Risk – 42x42km resolution]*<br>https://grow-globedrought.net/data/global-scale-drought-risk-assessment-for-agricultural-systems/<br>*[Rainfed Agricultural Drought Risk – 42x42km resolution]*<br>https://grow-globedrought.net/data/global-scale-drought-risk-assessment-for-agricultural-systems/ |
| Heatwaves | **Partnership for Resilience and Preparedness** [Urban heat island effect]<br>https://www.prepdata.org/explore<br>**NASA Socio-Economic Data and Applications Centre (SEDAC)**<br>https://sedac.ciesin.columbia.edu/data/sets/browse<br>Global Urban Heat Islands Dataset |
| Cold spells | **GIS Climate Change Scenarios**<br>https://gisclimatechange.ucar.edu/gis-data-ar5<br>*Contains climate change scenario datasets to 2006 - 2100 with an extensive range of temperature variables and all RCP model simulations* |
| Snowfall, hail, avalanches | **Derive Avalanche risk from Terrain data – UGSG EROS** *[Digital Terrain Elevation Data]*<br>https://www.usgs.gov/centers/eros/science/usgs-eros-archive-digital-elevation-global-multi-resolution-terrain-elevation?qt-science_center_objects=0#qt-science_center_objects |
| **Other hazards** | |
| **Technological hazards**<br><br>(e.g., industrial pollution, toxic wastes, accidents, explosions, fires, chemical spills) | **European Environment Agency** *[European Pollutant Release and Transfer Register (E-PRTR)]*<br>https://prtr.eea.europa.eu/#/home<br>**Global Alliance on Health and Pollution** *[Air Pollution and Contaminated Sites]*<br>https://www.pollution.org/<br>**International Tanker Owners Pollution Federation Limited** *[Major Oil Spill Locations]*<br>https://www.itopf.org/knowledge-resources/data-statistics/statistics/ |
| **Biological hazards**<br><br>(e.g., bacteria, viruses, parasites, disease-causing agents) | **Global Health Data Exchange** *[Catalog of surveys, census, and vital health statistics – country summaries]*<br>http://ghdx.healthdata.org/<br>**World Health Organization** *[Observatory of Health Data – download multiple indicators for countries]*<br>https://www.who.int/data/gho |

# Appendix B Example key performance indicators for water resilient infrastructure

| Key performance indicators | Unit | Notes |
|---|---|---|
| Water abstraction | m3/yr | Amount of water abstracted annually. Can provide a reference point for water efficiency or demand management over time (a co-benefit of resilient infrastructure). |
| Water exploitation index | % | A city's or province's withdrawal ratio (amount of fresh water compared to the long-term average resources). Indicates the pressure placed on freshwater resources by abstraction. |
| Water infrastructure damaged by extreme weather conditions or events | % | This indicator provides information on the resilience of infrastructure to disaster events over time. |
| Disaster event damage and repair costs to water infrastructure | TL | This indicator provides information on water facilities' resilience (e.g., can absorb the impact of extreme rainfall). |
| Number of days of interrupted water services | # | This indicator provides information on the performance effectiveness of water services throughout a service year and indicates towards a level of resilience against disruptions. |
| Number of water quality warnings issued | # | Water quality can be impacted by several causes, including climate change overall (e.g., changing pests/higher temperatures), and the impact of flooding or drought. It also may be compromised by the quality of existing infrastructure, which has bearing on that infrastructure's resilience. |
| Number of water efficiency measures used in systems | # | Water efficiency increases resilience to droughts and hydrometeorological changes due to climate change. |
| Physical non-revenue water losses | % | The amount of water lost because of leaks etc. Has implications on the quality of the existing infrastructure, which has bearing on that infrastructure's resilience. |
| Water being conserved | % of m3 | Water conservation measures increases resilience to droughts and hydrometeorological changes due to climate change. |
| Current water consumption per capita vs. future projections | m3/capita | This indicates the water sector's overall resilience to changing conditions. Relates to the potential need for future infrastructure to expand capacity. |

| Key performance indicators | Unit | Notes |
|---|---|---|
| Total length of sewer and drainage system at high risk from climate and disaster hazards | km | This indicator provides information on the resilience of sewer and drainage network infrastructure to disaster events over time. |
| Total length of water supply network at high risk from climate and disaster hazards | km | This indicator provides information on the resilience of water supply network infrastructure to disaster events over time. |
| Share of water and wastewater treatment facilities at risk of climate hazards | % | This indicator provides information on the resilience of water/wastewater facilities to disaster events over time. |

Source: AECOM, 2021.

# Appendix C Example Data Registry Template

| Theme | Dataset | Format | Recommended data source | Title of dataset obtained | Dataset producer / author | Dataset provided by (name and contact details) | Dataset weblink (if available) | Dataset scale | Dataset status | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| Topography | **Geology** | GIS / Shapefile / Vector Polygon / Excel Spreadsheet | Municipalities | | | | | | | |
| | **Terrain** | GIS / Shapefile / Vector Polygon / Excel Spreadsheet | Municipalities | | | | | | | |
| | **Slope** | GIS / Shapefile / Vector Polygon / Excel Spreadsheet | Municipalities | | | | | | | |
| | **Waterbodies** | GIS / Shapefile / Vector Polygon / Excel Spreadsheet | DSI (Turkish State Hydraulic Works)<br>Municipalities | | | | | | | |
| | **Aspect** | GIS / Shapefile / Vector Polygon / Excel Spreadsheet | Municipalities | | | | | | | |
| Land use | **Land use** | GIS / Shapefile / Vector Polygon / Excel Spreadsheet | Municipalities<br>Ministry of Environmental and Urbanization | | | | | | | |
| | **Public open space** | GIS / Shapefile / Vector Polygon / Excel Spreadsheet | Municipalities | | | | | | | |
| | **Environmentally protected space** | GIS / Shapefile / Vector Polygon / Excel Spreadsheet | Municipalities<br>Provincial Directorate of Environment and Urbanization<br>Directorate of Protection of Natural Assets<br>Ministry of Agriculture and Forestry | | | | | | | |
| | **Culturally protected space** | GIS / Shapefile / Vector Polygon / Excel Spreadsheet | Municipalities<br>Provincial Directorate of Environment and Urbanization<br>Directorate of Cultural Protection | | | | | | | |
| | **Contaminated sites** | | Municipalities | | | | | | | |

| Theme | Dataset | Format | Recommended data source | Title of dataset obtained | Dataset producer / author | Dataset provided by (name and contact details) | Dataset weblink (if available) | Dataset scale | Dataset status | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| | | GIS / Shapefile / Vector Polygon / Excel Spreadsheet | Ministry of Agriculture and Forestry | | | | | | | |
| | Military areas | GIS / Shapefile / Vector Polygon / Excel Spreadsheet | Municipalities | | | | | | | |
| Social | Population | Excel Spreadsheet | TurkStat | | | | | | | |
| | Population Density | Excel Spreadsheet | TurkStat | | | | | | | |
| | Gender | Excel Spreadsheet | TurkStat | | | | | | | |
| | Age profile | Excel Spreadsheet | TurkStat | | | | | | | |
| | Life expectancy | Excel Spreadsheet | TurkStat | | | | | | | |
| | Disabilities | Excel Spreadsheet | TurkStat | | | | | | | |
| | Refugees | Excel Spreadsheet | TurkStat | | | | | | | |
| | Occurrence of vector-borne diseases | GIS / Shapefile / Vector Polygon / Excel Spreadsheet | Ministry of Health Provincial Health Directorate | | | | | | | |
| | Occurrence of water-borne diseases | GIS / Shapefile / Vector Polygon / Excel Spreadsheet | Ministry of Health Provincial Health Directorate | | | | | | | |
| Economy | Employment | Excel Spreadsheet | TurkStat | | | | | | | |
| | Unemployment | Excel Spreadsheet | TurkStat | | | | | | | |
| | Household income | Excel Spreadsheet | TurkStat | | | | | | | |
| | Population below poverty line | Excel Spreadsheet | TurkStat | | | | | | | |
| | Gross domestic product | GIS / Shapefile / Vector Polygon / Excel Spreadsheet | Development Agencies<br>Presidency of Strategy and Budget<br>Ministry of Treasury and Finance | | | | | | | |
| | Visitors/tourists | GIS / Shapefile / Vector Polygon / Excel Spreadsheet | Ministry of Culture and Tourism<br>Provincial Directorate of Culture and Tourism<br>TurkStat | | | | | | | |

*Source: AECOM. 2020. Guidance Note for Assessing Climate and Disaster Risks and Climate Co-Benefits. London/Ankara.*

# Appendix D Steps for Undertaking Economic Analysis of Resilience Options

| Key steps | Key considerations | Guidance Notes, tools, and other resources |
|---|---|---|
| **1. Estimate the NPV of the project with no resilience measures, taking account of the physical impacts of climate change and natural disasters on project assets and performance**<br><br>*This is effectively the baseline against which each of the alternative resilience options is assessed and should help answer the questions:*<br><br>• *How will the expected impacts of climate change and disasters affect the estimated costs and benefits of the investment project if there were to be no climate or disaster risk resilience measures in place?*<br><br>• *If there were no technically feasible measures to mitigate these impacts and strengthen the resilience of the project to climate and disaster risks, would the project still be economically viable (i.e., is the NPV >0)?* | • Climate and disaster risks to, and physical impacts on, project assets or the project's performance over its design life.<br>• Costs of damage and repair to physical project assets because of climate and disaster impacts (i.e., above and beyond those that would be incurred in the absence of disasters and climate change) over the design life of the project. For example, an increase in the frequency and intensity of flood events compared to historical trends may necessitate more frequent and extensive repairs to assets, or an increase in the rate of erosion may increase pollution discharge into waterways and groundwater sources.<br>• Damage and disruption costs and impacts on revenue generated from asset, and the broader impacts on end users.<br>• The profile of costs and benefits over the life of the project and how these may change as the effects of climate change become more pronounced in future (e.g., more frequent and intense flooding events in future may result in a gradual increase in maintenance or repair costs over time)<br>• Physical impacts and associated costs and benefits of the project on local communities and the environment, taking account of the combined effects of future climate conditions and changes in population, behavior, and land cover/land use over the assessment period.<br><br>⇨ *If the NPV < 0, then consider whether the inclusion of resilience measures in the project design could make the project economically viable.*<br><br>⇨ *If NPV > 0, then consider whether the project design could be modified through the inclusion of resilience measures to further increase the NPV of the project.* | ADB (2015) Economic Analysis of Climate-Proofing Investment Projects<br>UN (2011) Assessing the Costs and Benefits of Adaptation Options: An Overview of Approaches.<br>European Commission (2014) Guide to Cost-Benefit Analysis of Investment Projects. Contains information and good practice guidance on incorporating climate change considerations into the appraisal of major investment projects.<br>UKCIP Cost of climate impacts guidelines and spreadsheet tool<br>EconoAdapt Toolbox and Library – contains information on economic assessment of adaptation activities including guidance, methodologies, tools, data, and case studies.<br>National Academies of Sciences, Engineering, and Medicine 2019. Climate Resilience and Benefit Cost Analysis: A Handbook for Airports. Washington, DC: The National Academies Press. https://doi.org/10.17226/25497.<br>IISD (2014) The Economic Implications of Climate Change on Transportation Assets: An analysis framework.<br>ADB (2017) Guidelines for Climate-Proofing Investment in the Water Sector: Water supply and sanitation. A step-by-step guide to managing climate risk in the context of water supply and sanitation projects. See Part B: Adaptation |

| Key steps | Key considerations | Guidance Notes, tools, and other resources |
|---|---|---|
| | | Assessment which sets out the key steps and considerations for economic analysis.<br><br>ADB (2011) Guidelines for Climate-Proofing Investment in the Transport Sector: Road Infrastructure Projects. A step-by-step guide to managing climate risk in the context of road projects. See Part B: Adaptation Assessment which sets out the key steps and considerations for economic analysis. |
| **For each of the technically feasible resilience options identified:**<br><br>**2. Identify and value incremental costs and benefits of alternative project designs that incorporate different resilience options**<br><br>*When compared to the NPV of the project with no resilience measures, this should help answer the question:*<br><br>• What are the incremental costs and benefits associated with alternative technically feasible measures (resilience options) to mitigate or alleviate adverse impacts or to promote or enhance positive impacts? | • The costs of resilience measures should include both direct costs (e.g., investment and regulatory) and indirect costs (e.g. social welfare losses).<br>• The profile and magnitude of costs and benefits may vary over the project investment design life. For example, the benefits of resilience options (in terms of avoided damages or service failures) may be higher at later stages in the project as the impacts of climate change become more pronounced. Similarly, the expected annual clean-up and repair costs may be lower than in the 'no resilience' case as the resilience measures serve to reduce the exposure or sensitivity of the project to the impacts of climate change and disasters.<br>• The principal benefits of any resilience option are likely to be the avoided damage and repair costs from climate change and disaster impacts. These benefits These benefits will be captured as the difference in costs between the project with the resilience option and the option without the resilience option (i.e., the baseline established in Step 1). They should not therefore be specified as additional benefits of the resilience option as to do would result in the benefits being counted twice (double counting)<br>• This should include a review of each resilience option for possible maladaptation costs, i.e., potential negative impacts that a resilience option may have on the wider environment or infrastructure system; | **Guidance:**<br>ADB (2015) Economic Analysis of Climate-Proofing Investment Projects<br>UN (2011) Assessing the Costs and Benefits of Adaptation Options: An Overview of Approaches.<br>EIT Climate-KIC Introduction to cost-benefit analysis for climate change adaptation Online learning module (35 mins)<br><br>Chambwera et al (2014) Economics of Adaptation. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. See section 4 on costing adaptation.<br><br>European Commission (2012) Guidelines for Project Managers: Making vulnerable investments climate resilient. See Module 6 – Appraisal of adaptation options.<br><br>EconoAdapt Toolbox and Library – contains information on economic assessment of |

| Key steps | Key considerations | Guidance Notes, tools, and other resources |
|---|---|---|
| | where those impacts are known and can be quantified, they should be incorporated into the economic analysis. | adaptation activities including guidance, methodologies, tools, data, and case studies.<br>National Academies of Sciences, Engineering, and Medicine 2019. Climate Resilience and Benefit Cost Analysis: A Handbook for Airports. Washington, DC: The National Academies Press. https://doi.org/10.17226/25497.<br><br>**Tools:**<br>UKCIP Cost of climate impacts guidelines and spreadsheet tool<br>ClimateADAPT Urban Adaptation Support Tool – Conducting a cost-benefit analysis of adaptation measures<br>EIT Climate-KIC Cost-benefit analysis for climate adaptation tool<br>While developed specifically for use in the USA, FEMA's Benefit Cost Analysis Toolkit provides detailed guidance and a spreadsheet tool (which is calibrated for use in the USA only) for evaluating the impacts of a range of major natural hazards and project types. |
| **3. Identify and evaluate any net benefits (co-benefits) that are additional to the direct resilience benefits to the project itself**<br><br>*This should answer the question:*<br>• *Are there other environmental, economic, or social benefits that are additional to the resilience benefits from the project itself and that should be included and* | • Co-benefits may include positive impacts on livelihoods, health, communities, biodiversity, and ecosystem services (see Chapter 5 Climate Co-Benefits Assessment for step-by-step guidance on how to identify, assess, and monitor them).<br><br>• If there is no market for the goods or services provided by the adaptation activity or resilience measure, benefits can be estimated in indirect ways through non-market-based approaches, such as contingent valuation or revealed preferences (see OECD, 2018, Bakhtiari, 2016 and Defra, 2007). | ADB (2015) Economic Analysis of Climate-Proofing Investment Projects<br>Ashden (2019) A Toolkit for City Regions and Local Authorities. Climate Action Co-Benefits. Cutting Carbon and Improving People's Lives. London.<br>OECD (2018) Cost-Benefit Analysis and the Environment. Further Developments and Policy Use |

| Key steps | Key considerations | Guidance Notes, tools, and other resources |
|---|---|---|
| *reflected in the economic analysis of the resilience options besides, or over and above, climate and disaster resilience benefits?* | • There may also be additional costs associated with harnessing or realizing co-benefits and these need to be accounted for in the economic assessment. For example, measures to stabilize railway embankments There may also be additional costs associated with harnessing or realizing co-benefits and these need to be accounted for in the economic assessment.<br><br>• Co-benefits may continue to accrue beyond the design life of the project. If this is the case, then consider extending the **time horizon** for the assessment to coincide with the lifetime of the resilience option itself. In such cases, the costs and benefits associated with climate- and disaster-proofing of the investment project (e.g. reducing exposure to flood risk or building capacity to cope with heatwaves) should extend to the design life of the project itself (as there is no longer a climate- or disaster-proofing benefit once the project ceases to exist) while the assessment of co-benefits will extend to the life of the climate- or disaster-proofing measure or resilience option. | Chambwera et al (2014) Economics of Adaptation. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. See section 2 on economic consideration of ancillary effects.<br><br>Bakhtiari, F. (2016) Valuation of climate change mitigation co-benefits. A non-technical guide for valuing the co-benefits associated with climate change mitigation actions.<br><br>Raymond et al (2017) An Impact Evaluation Framework to Support Planning and Evaluation of NbS Projects. Provides detailed guidance for measuring the environmental, social, and economic benefits of NBS projects.<br><br>Defra (2007) Introductory guide to valuing ecosystem services.<br><br>WHO (2013) Climate Change and Health: A Tool to Estimate Health and Adaptation Costs. See also the Health and Climate Change Toolkit for project managers. |
| 4. Convert the cost and benefit flows into present values using the appropriate discount rate<br><br>*This should help answer the question:*<br>• *What is the value of the future flows of costs and benefits (which may be accrued in different years of the life the resilience measure) in today's terms?* | • Subtract estimated costs from benefits across each year of the relevant time horizon. This should be representative of when costs and benefits are likely to occur over time. Then apply the discount rate to this difference each year to arrive at present values. Sum over the time horizon to arrive at a 'Net Present Value' (NPV) for each option.<br><br>• All options should be evaluated using the same **discount rate** and the one that is typically used by the funding agency in the economic analysis of investment projects. | ADB (2015) Economic Analysis of Climate-Proofing Investment Projects<br><br>UN (2011) Assessing the Costs and Benefits of Adaptation Options: An Overview of Approaches. |

| Key steps | Key considerations | Guidance Notes, tools, and other resources |
| --- | --- | --- |
| **5. Compare the estimated incremental costs of project design including the resilience option with the expected benefits of the climate-proofing investment**<br><br>*This should help answer the questions:*<br>• *Is the project viable without resilience options (see Step 1)?*<br>• *Which of the technically feasible resilience options is economically viable?* | ⇨ *If the project NPV with all resilience options < 0, then the project investment should not proceed.*<br><br>⇨ *If the project NPV with the resilience option > 0, then that option should be included in the ranking.*<br><br>⇨ *If the project NPV without the resilience option > 0, then the option to proceed without resilience measures should be included in the ranking.* | **Guidance:**<br>ADB (2015) Economic Analysis of Climate-Proofing Investment Projects |
| **6. Conduct sensitivity analysis to account for uncertainties**<br><br>*This should help answer the questions:*<br>• *How might the appraisal outcomes change because of changes in the key underlying assumptions?*<br>• *By how much would a particular parameter of interest (e.g., capital costs, repair costs) must change to bring the NPV of the project to zero?*<br>*By how much would a particular parameter of interest (e.g., value of co-benefits) must change in order to change the ranking of options?* | • What are the variables or underlying assumptions to which the investment decision may be sensitive and where the greatest uncertainties lie? This may include, for example, uncertainties in:<br>  ○ climate projections and the nature, significance, and timing of climate and disaster impacts upon project assets, project performance or those that may be otherwise affected by project activities.<br>  ○ socio-economic changes and technological advancements that may affect the demand for certain goods and services<br>  ○ the extent to which co-benefits may be realized<br>  ○ how quickly benefits may be realized and/or how long they may continue to accrue<br>• Sensitivity analyses may be conducted using various techniques, with various levels of sophistication and resource requirements, including:<br>  ○ Scenario assessment to determine how different combinations of variables may impact upon appraisal outcomes. At its simplest, this may involve using alternative values for individual key parameters (e.g., choice of discount rate, time horizon, cost estimates, etc.) to reflect the range of uncertainty in each of the underlying assumptions. Alternatively, one could construct best and worst case scenarios by varying one or more key parameters to reflect | **Guidance:**<br>ADB (2015) Economic Analysis of Climate-Proofing Investment Projects<br>UKCIP (2003) Climate adaptation: Risk, uncertainty and decision-making<br>Ranger, N. et al. (2010). Adaptation in the U.K.: A Decision-Making Process. Policy Brief September 2010. Grantham Research Institute on Climate Change and the Environment and Centre for Climate Change Economics and Policy.<br>National Academies of Sciences, Engineering, and Medicine 2019. Climate Resilience and Benefit Cost Analysis: A Handbook for Airports. Washington, DC: The National Academies Press. https://doi.org/10.17226/25497.<br><br>**Examples:**<br>Nassopoulos, H., P. Dumas, and S. Hallegatte. (2012). Adaptation to an uncertain climate change: cost benefit analysis and robust decision making |

| Key steps | Key considerations | Guidance Notes, tools, and other resources |
|---|---|---|
| | the full range of possible outcomes and/or to determine the point (known as the switching value) at which the net benefits become negative.<br>○ Probabilistic risk analysis and Monte Carlo simulation analysis to provide a probability distribution of net present values. This requires the use of mathematical expressions and computers to replicate and predict behavior and is more resource intensive.<br>○ Real option analysis to evaluate the benefits of delaying investments in resilience options or incorporating flexibility into project design to allow climate-proofing to take place later if appropriate. | for dam dimensioning. *Climatic Change*. 114. 497–508. |
| **7. Rank the NPV of the alternative resilience options**<br><br>*This should help answer the question:*<br>• *Which is the most preferred option (which may include combinations of climate and disaster risk resilience measures) from an economic perspective, including the option to proceed without resilience measures?* | • Rank options based on the results of the previous step – from highest estimated NPV to lowest (**Excel Tool Tab R.C.4**). | |
| **8. Consider the appropriate timing of investment in resilience options**<br><br>*The outcome of the economic analysis of resilience options may result in three different types of decisions:*<br>*(i) Invest in resilience measures now*<br>*(ii) Make the project 'climate and disaster ready' so that it is possible to incorporate resilience measures later, if necessary* | • Are any of the resilience options *no-regret* or *win-win*, such that they would deliver net positive economic benefits regardless of the nature and extent of climate change or disasters, or that deliver significant social, environmental, or economic benefits (co-benefits) in addition to reducing climate and disaster risks to the project?<br><br>• Are there any *low-regret* resilience options where the costs of climate- and disaster-proofing now are estimated to be relatively small while the benefits (avoided costs of not climate- or disaster-proofing) are estimated to be relatively large? Conversely, are the costs of climate- | ADB (2015) Economic Analysis of Climate-Proofing Investment Projects<br>UKCIP Factors to consider when evaluating options<br>Van Ierland , E.C. , de Bruin, K. and Watkiss,<br>P. (2013). Multi-Criteria Analysis: Decision Support Methods for Adaptation, MEDIATION Project, Briefing Note 6. |

| Key steps | Key considerations | Guidance Notes, tools, and other resources |
|---|---|---|
| (iii) Wait, collect information and data, and make changes to the project later as necessary | and disaster-proofing now estimated to be large relative to the expected benefits?<br><br>• How flexible is the project design? If it is limited, technically not possible, or if the costs of climate- or disaster-proofing at a later point in term are expected to be prohibitive, then resilience measures may need to be implemented upfront. Alternatively, if there is flexibility in the project design such that it could incorporate changes later (e.g., raising a sea wall), then a decision may be made to invest minimally at the time of project design and implementation and adapt in future time if the case for investment in resilience measures (or a particular resilience measure) strengthens. | |
| **9. Obtain feedback from reviewers on the results of the Economic Analysis** | • Complexities arising from the economic analysis, including assumptions, caveats, and uncertainties, should be reviewed by relevant technical experts and considered in the selection of the preferred options, alongside the outcomes of the technical evaluation. | |
| **10. Monitoring**<br><br>*This should help answer the questions:*<br>• *Is the resilience measure working as expected?*<br>• *Have there been any other unexpected impacts (positive or negative) associated with the implementation of that measure (or combination of measures)?*<br>• *If no resilience measures were implemented previously, has new information on climate and disaster risks and impacts come to light that merits further consideration of the need to strengthen the resilience of the project by investing in adaptation measures?* | • Monitoring the effectiveness of climate- and disaster-risk resilience measures can help identify where adjustments may be necessary to strengthen the effectiveness of the measure, enhance co-benefits or mitigate unintended adverse impacts. Similarly, monitoring and evaluating the performance of resilience measures can provide useful information to guide similar investment decisions on future projects.<br><br>• In cases where it was decided to delay investment in resilience measures, monitoring provides an opportunity to re-assess the exposure and vulnerability of the project to climate and disaster risks and to determine the need for investment in resilience measures later in the project life in light of a changing climate and as new information about the nature and significance of risks emerges. | UKCIP (2013) Monitoring & evaluation for climate change adaptation: A synthesis of tools, frameworks and approaches.<br><br>ClimateADAPT Adaptation Support Tool: Monitoring and Evaluation. |

*Source: AECOM. 2020. Guidance Note for Assessing Climate and Disaster Risks and Climate Co-Benefits. London/Ankara.*

# Appendix E Hypothetical Example of Economic Analysis of Resilience Options

| Key steps | Hypothetical example<br>Note that all figures presented in this example are purely illustrative and should not be considered as real or indicative |
|---|---|
| **1. Estimate the Net Present Value (NPV)[118] of the project with no resilience measures, taking account of the physical impacts of climate change and natural disasters on project assets and performance**<br><br>*This is effectively the baseline against which each of the alternative resilience options should be assessed and should help answer the questions:*<br>• *How will the expected impacts of climate change and disasters affect the estimated costs and benefits of the investment project if there were to be no climate or disaster risk resilience measures in place?*<br>• *If there were no technically feasible measures to mitigate these impacts and strengthen the resilience of the project to climate and disaster risks, would the project still be economically viable (i.e., is the NPV >0)?* | In this example, a municipal authority is seeking to construct a new water treatment facility to augment existing water supplies to a rapidly growing urban area. Construction is expected to take 5 years. The capital cost is estimated to be US$10 million per year for each year of construction. Once completed, the facility has an estimated lifetime of 60 years. Annual operation and maintenance costs are projected to reach US$2 million per year from year 6 to year 65 (60-year lifetime).<br><br>The area in which the facility is to be located is prone to both earthquakes and flooding. Historical records show that 10 severe flood events and two major earthquakes have been experienced over the course of the last 50 years in the region where the project will take place. On this basis, the probability of a severe flood in any given year is estimated to be 20% (10/50) and that of an earthquake is 4% (2/50). Again, based on historical records, it is estimated that typical damage and repair costs following an earthquake of this magnitude have been on average US$30 million (measured in today's prices) while the damage and repair costs of flood events of this magnitude are US$10 million. Given this information, the annual damage and repair costs that can be attributed solely to flood and earthquake events (i.e., distinct from normal operation and maintenance costs) in an unchanging climate is estimated to be US$4.2 million (4% * US$30 million + 20% * US$10 million).<br><br>However, analysis of downscaled climate projections for the region in which the water treatment facility is located, show that temperatures are likely to increase by up to 2.5°C by 2050 and by 5°C by 2100 and that both droughts and floods are likely to become more frequent and intense over coming decades. Discussions with climatologists, hydrologists and economists suggest that the expected annual losses from flooding may treble (from US$2 million to US$6 million) by 2060 because of either an increase in the frequency of flood events or higher damages associated with each event. Furthermore, rising temperatures and low flow events are expected to increase the occurrence of algal blooms which will necessitate higher levels and costs of water treatment.<br><br>The direct revenues and enabled benefits of the project (resulting from a more reliable supply of safe water for residents and industry) were estimated to reach US$12 million per year from year 6 to year 30. However, as the effects of the changing climate (warmer average temperatures become more pronounced, it is expected that the demand for water for cooling and drinking will increase substantially such that the benefits from the additional supplies enabled by the water treatment facility will increase to US$15 million per year from year 31. |

| Key steps | Hypothetical example<br>Note that all figures presented in this example are purely illustrative and should not be considered as real or indicative |
|---|---|
| | With no climate- or disaster-risk resilience measures in place, the NPV of the project (assuming a 10% discount rate[119]) is expected to be negative US$0.69 million. This means that the investment, as it currently stands (with no resilience measures) is unviable.<br><br>Given both the urgent need for a new water treatment facility and uncertainties in the climate change projections and the magnitude of impacts of climate change on the facility, the project proponents wish to consider whether there are any modifications that could be made to the project design to strengthen the resilience of the facility to the impacts of both flooding and earthquakes and that could also increase the NPV of the project and make it economically worthwhile. |
| For each of the technically feasible resilience options identified:<br><br>**2. Identify and value the direct incremental[120] costs and benefits of alternative project designs that incorporate different resilience options**<br><br>*When compared to the NPV of the project with no resilience measures, this should help answer the question:*<br><br>• *What are the incremental costs and benefits associated with alternative technically feasible measures (resilience options) to mitigate or alleviate adverse impacts or to promote or enhance positive impacts?* | Several potential solutions for enhancing the resilience of the water treatment plant to the effects of temperature increases, flooding and earthquakes were identified. Following an assessment of their technical viability, the following solutions were shortlisted for further investigation in the economic analysis:<br><br>• Relocate the water treatment facility into an area that is less prone to flooding and employ modern aeration techniques to prevent algal blooms during periods of high temperature. This option would entail the construction of a new road, at a cost of US$1 million (over two years), to access the plant and the enhanced aeration techniques would cost an additional US$0.25 million per year. However, the implementation of these measures is estimated to reduce the flood damage costs that would be incurred in the absence of these measures by 85%.<br>• Construct bund walls around storage tanks to prevent ingress of flood waters, use reinforced steel piping that is resistant to earthquakes and flooding and employ modern aeration techniques to prevent algal blooms. The floodwater diversion and piping would add 25% to the construction costs in the 'do nothing' option but would reduce the total annual damage and repair costs by 75%.<br>• A catchment-based approach that involves working with farmers and other land managers in the upper watershed to (a) improve drinking water quality at source by reducing the amount of nutrient-laden agricultural run-off into watercourses and the prevalence of algal blooms at the treatment facility and (b) reforest parts of the catchment to slow the flow of surface water run-off during heavy rainfall events. This approach requires additional capital investment of US$1 million per year for 5 years for tree-planting as well as annual payments of US$0.5 million to farmers for their participation in the program. Modelling shows that the land management activities mean that investment in the water treatment facility can be delayed by 8 years and, once constructed, |

| Key steps | Hypothetical example<br>Note that all figures presented in this example are purely illustrative and should not be considered as real or indicative |
|---|---|
| | would result in reduced treatment costs with savings of up to US$0.75 million per year and a 30% reduction in flood damage costs compared to the do nothing option. |
| **3. Identify and evaluate any net benefits (co-benefits) that are additional to the direct resilience benefits to the project itself**<br>*This should answer the question:*<br>• *Are there other environmental, economic, or social benefits that are additional to the resilience benefits from the project itself and that should be included and reflected in the economic analysis of the resilience options besides, or over and above, climate and disaster resilience benefits?* | In addition to reducing the treatment costs associated with harmful algal blooms from nutrient-laden water sources, the catchment management option is also expected to result in significant benefits for biodiversity within the watercourses. Several species that are sensitive to pollution are expected to return to the watercourses and fisheries populations are also expected to recover. Furthermore, farmers are expected to have to spend less on chemical and other applications but will maintain or even improve their yields because of improving soil quality. Finally, the reduction in the level of treatment required at the plant reduces the energy requirements (and hence greenhouse gas emissions) and results in savings to the consumers in the form of lower water bills than in the do-nothing option. In total, these co-benefits are valued at US$2 million per year from year 6.<br><br>Note that it may not be possible to reliably value all the benefits in monetary terms, particularly some of the non-market benefits which are harder to measure because they are not routinely traded and therefore do not have established market prices. In cases where it is not possible to obtain reliable monetary estimates of costs and benefits, then these should be described or assessed in qualitative or other terms, and attributed a level of significance (i.e., how important are they and, if they were included, would they significantly change the NPV or the ranking of alternative options?). |
| **4. Convert the flows of cost and benefits of the resilience measures over the project life (or assessment time horizon) into present values using the appropriate discount rate**<br>*This should help answer the question:*<br>• *What is the value of the future flows of costs and benefits (which may be accrued in different years of the life the resilience measure) in today's money?* | Since the costs and benefits of each of the alternative resilience options occur at different times over the assessment time horizon, with most of the capital costs being incurred early on in the project and benefits continuing for many years into the future, they need to be converted to a common 'present value' basis, using an appropriate discount rate which must be applied consistently across all options, so that the options can be compared on a like-for-like basis. Applying a 10% discount rate results in the present value costs and benefits of each option as follows: |

| Resilience option | PV costs (US$ million) | PV benefits (US$ million) |
|---|---|---|
| No resilience measures | 77 | 76 |
| Relocation | 69 | 76 |
| Protective measures | 71 | 76 |
| Catchment management | 44 | 88 |

| Key steps | Hypothetical example<br>Note that all figures presented in this example are purely illustrative and should not be considered as real or indicative |
|---|---|
| **5. Compare the estimated incremental costs of project design including the resilience option with the expected benefits of the climate-proofing investment**<br>*This should help answer the questions:*<br>• *Is the project viable without resilience options (see Step 1)?*<br>• *Are any of the technically feasible resilience options economically viable?* | Comparing the discounted flows of costs and benefits for each of the alternative options results in the following net present values and benefit-cost ratios: |

| Resilience option | Net Present Value (US$ million) | Cost-benefit ratio |
|---|---|---|
| No resilience measures | -0.69 | 1:0.99 |
| Relocation | 7.32 | 1:1.11 |
| Protective measures | 5.33 | 1:1.08 |
| Catchment management | 44.53 | 1:2 |

The economic analysis shows that the project is not economically viable without resilience measures because of the costs that it would incur because of flood and earthquake damage.

If any of the resilience measures were introduced the project would become economically viable. The most cost-beneficial option is catchment management which also has the highest NPV, largely because the costs of investment in the treatment facility can be delayed by several years while there are valuable co-benefits that accrue from the outset. Note that these are not necessarily financial (private) returns to the investor; rather, they represent the wider societal returns that would be delivered.

| Key steps | Hypothetical example |
|---|---|
| **6. Conduct sensitivity analysis to account for uncertainties**<br>*This should help answer the questions:*<br>• *How might the appraisal outcomes change because of changes in the key underlying assumptions?*<br>• *By how much would a particular parameter of interest (e.g., capital costs, repair costs) must change to bring the NPV of the project to zero?* | Given uncertainties in the costs of construction, impacts of climate change on the water treatment facility and therefore on the costs of flood damages, and uncertainties in the extent to which people value the improvements in biodiversity and fisheries in the catchment, the project proponents wish to test the sensitivity of the appraisal outcomes to changes in the underlying assumptions. To do this, they obtain several quotes for constructing the facility, consider the range of uncertainties in the climate impact projections as cited in the most up-to-date peer-reviewed literature to examine the outcomes in a best and worst case which correspond to a halving and doubling of flooding costs respectively. For the worst-case scenario, they also assume that improvements in fisheries and biodiversity hold no value to people and that construction costs are 25% higher than in the base case. Applying these assumptions, results in the following outcomes: |

| Key steps | Hypothetical example<br>Note that all figures presented in this example are purely illustrative and should not be considered as real or indicative |
|---|---|
| • *By how much would a particular parameter of interest (e.g., value of co-benefits) must change in order to change the ranking of options?* | (see table below)<br><br>This shows that neither relocation of the water treatment facility nor inclusion of protective measures in the project design is economically viable under a worst-case scenario; the only viable option is catchment management because of the delayed expenditure and the co-benefits. Under a best-case scenario, all the options (including the do-nothing option) become economically viable with catchment management and protective measures being the most and least preferred options respectively from an economics perspective. |
| **7. Rank the NPV of the alternative resilience options**<br>*This should help answer the question:*<br>• *Which is the most preferred option (which may include combinations of climate and disaster risk resilience measures) from an economic perspective, including the option to proceed without resilience measures?* | Based on the analysis above, it is evident that the most preferred option from an economics perspective is catchment management while the least preferred option would be to proceed without any resilience measure except in a best-case scenario in which case the costs of protective measures outweigh the damage costs that would result if no resilience measures were implemented. |
| **8. Consider the appropriate timing of investment in resilience options**<br>*The outcome of the economic analysis of resilience options may result in three different types of decisions:*<br>*(iv) Invest in resilience measures now*<br>*(v) Make the project 'climate and disaster ready' so that it is possible to incorporate resilience measures later, if necessary*<br>*(vi) Wait, collect information and data, and make changes to the project later as necessary* | Although modelling showed that it would be possible to delay investment in the water treatment facility if catchment management measures were introduced, there are uncertainties as to the speed at which land managers can be engaged as well as around how the costs of construction may change in future. Further analysis reveals that even if investment in constructing the treatment facility was not delayed under the catchment management option (i.e., if it were constructed immediately), this would still result in a positive NPV of US$20 million. |

| Resilience option | Worst case<br>Net Present Value (US$ million) | Best case<br>Net Present Value (US$ million) |
|---|---|---|
| No resilience measures | -29 | 8.76 |
| Relocation | -8 | 9 |
| Protective measures | -14 | 4.83 |
| Catchment management | 20 | 48 |

| Key steps | Hypothetical example<br>Note that all figures presented in this example are purely illustrative and should not be considered as real or indicative |
|---|---|
| **9. Obtain feedback from reviewers on the results of the economic analysis** | Upon review, a consensus is reached that, given the need for a new water treatment facility, the project should proceed. It is further decided that given the wider benefits that catchment management delivers – besides improved water quality and flood alleviation – it is worth pursuing this option.<br><br>It must be remembered that the outcomes of the economic analysis are only one element in the decision-making process and there may be other important factors to consider such as the risks involved in trying to aggregate disparate groups of land managers across a catchment over whom the investor may have limited control. |
| **10. Monitoring**<br>*This should help answer the questions:*<br>• *Is the resilience measure working as expected?*<br>• *Have there been any other unexpected impacts (positive or negative) associated with the implementation of that measure (or combination of measures)?*<br>• *If no resilience measures were implemented previously, has new information on climate and disaster risks and impacts come to light that merits further consideration of the need to strengthen the resilience of the project by investing in adaptation measures?* | Given the uncertainties underlying the analysis, it is agreed that the costs and benefits of the project should be monitored over its lifetime. A comprehensive monitoring plan is prepared, setting out the key parameters to be reviewed and outlining specific responsibilities for collection, analysis, and reporting of monitoring data. |

*Source: AECOM. 2020. Guidance Note for Assessing Climate and Disaster Risks and Climate Co-Benefits. London/Ankara.*

# Appendix F Procurement types

| Type and features | Qualification approach – Submission of Qualification (SoQ) | Qualification approach – short listing | Time for closing and issuing Request for Proposal (RFP) and contract | Negotiations versus interaction or dialogue | Bidding and selection approach – submission of proposals | Country examples |
|---|---|---|---|---|---|---|
| ***Open tender or one-stage tender process*** | The SoQ are called and submitted together with proposals.<br>Request for Qualifications (RFQ) and RFP are integrated in one document. | No short listing. | The RFQ and RPF are integrated and closed together. Issuance of tender package at one time. | Negotiations and dialogue are not permitted after the tender is launched.<br>Request by the bidders for clarifications is allowed, and responses are public during the bid phase. | Only one bid and one straight-forward decision on awardee, with no negotiations. | Most countries in Latin America and Spain.<br>Quite common in the EU vis-a-vis competitive dialogue. |
| ***Open tender with pass/fail pre-qualification (or two-stage open tender)*** | The RFQ is issued in advance of the RFP to qualifying bidders, under pass/fail criteria. | No short listing. | The RFP is closed after the SoQ are received. The contract may be refined during the RFQ phase. | Not allowed, but clarifications request and response during the bid phase are permitted. | Only one bid and one straightforward decision on awardee, with no negotiations. | Columbia, India, Mexico, and some other countries in Latin America for some projects. |
| ***Restricted procedure (short listing with one bid)*** | As in pre-qualification, the RFQ is issued in advance of the invitation to propose to qualifying bidders. | The essential feature of this type: qualifying bidders are short listed (selection of a maximum number of bidders). | As in open tender with pre-qualification. | Not allowed, but clarifications are usual as in the former types. | One only bid and one straightforward decision on awardee, with no negotiations as in former types. | Considered an option under the EU regulations, but less commonly used than the former types. |
| ***Negotiated process (short listing with negotiations, or best and final offer – BAFO)*** | The SoQ is issued and assessed in advance, as in the restricted procedure. | Short listing as in the restricted procedure. | The RFP is commonly closed at the same time as the RFQ. The fundamental characteristics of the selection process and | Negotiations permitted by definition. | Consecutive or sequential bids are frequently used, commonly under a BAFO process. | Considered in the EU by legislation.<br>More marginal, yet traditional, method of procurement in the EU. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | contract should be defined and explained in the RFQ. | | | |
| ***Dialogue process*** | The SoQ is issued and assessed in advance, as in the restricted procedure. | Short listing as in the restricted procedure. | The RFP may be refined during the RFQ phase, for example in the EU, or it may be also close at the same time as the RFQ. Fundamental characteristics of the selection process and contract should be defined and explained in the RFQ. | Negotiations are usually not permitted (EU), but the contract and some aspects of the RFP may be discussed and refined during the dialogue or interactive process. | The dialogue method typically considers only one bid after dialoguing, refining the contract, and some aspects of the RFP. | An option regulated by legislation in the Arab Republic of Egypt.<br>Regulated option by the EU legislation for specific types of projects meeting some features, mainly related to complexity.<br>Used in some states in the United States (US). |
| ***Interaction process*** | The SoQ is issued and assessed in advance as in the restricted procedure. | Short listing as in the restricted procedure. | The fundamental characteristics of the selection process and the contract should be defined and explained in the RFQ. The RFP is typically finalized following the completion of the short-listing process. | The RFP and contract are discussed during the interactive process and may be refined or clarified by the government, if necessary.<br>Final negotiations are usually conducted with one or more bidders after the initial evaluation of bids. | Following the issue of the RFP and contract, bidders refine their proposals through interactive workshops with the government. Bidders then submit a single complete proposal. | This is the standard approach used in Australia and New Zealand. |

*Source: AECOM. 2020. Guidance Note for Assessing Climate and Disaster Risks and Climate Co-Benefits. London/Ankara.*

# Appendix G Infrastructure Contract Nomenclature

| Contract Nomenclature | Overview Description and Reference | Type of Asset | Functions Transferred | Payment Source |
|---|---|---|---|---|
| Design-Build-Finance-Operate-Maintain (**DBFOM**); Design-Build-Finance-Operate (**DBFO**)<br><br>Design-Construct-Manage-Finance (**DCMF**) | Under this nomenclature, the range of PPP contract types is described by the functions transferred to the private sector. The *maintain* function may be left out of the description (so instead of DBFOM, a contract transferring all those functions may simply be described as DBFO, with responsibility for maintenance implied as part of operations). An alternative description along similar lines is Design-Construct-Manage-Finance (DCMF), which is equivalent to a DBFOM contract. | New infrastructure | As captured by contract name | Can be either government or user pays |
| Build-Operate-Transfer (**BOT**), Build-Own-Operate-Transfer (**BOOT**), Build-Transfer-Operate (**BTO**) | This approach to describing PPPs for new assets captures legal ownership and control of the project assets. Under a BOT project, the private company owns the project assets until they are transferred at the end of the contract. BOOT is often used interchangeably with BOT, as Yescombe (2007) describes. In contrast, a Build-Transfer-Operate (BTO) contract, asset ownership is transferred once construction is complete. As Delmon (2015, p.20–21) describes, ownership rights mainly affect how handover of assets is managed at the end of the contract. | New infrastructure | Typically, design, build, finance, maintain, and some or all operations<br><br>Under some definitions, BOT or BTO may not include private finance, whereas BOOT always includes private finance | Can be either government or user pays |
| Rehabilitate-Operate-Transfer (**ROT**) | In either of the naming conventions described above, *Rehabilitate* may take the place of *Build* where the private party is responsible for rehabilitating, upgrading, or extending existing assets. | Existing infrastructure | As above, but *rehabilitate* instead of *build* | As above |
| Concession | *Concession* is used for a range of types of contracts, as described in Delmon (2010, p.9**)**. In some jurisdictions, concession may imply a specific type of contract, while in others it is used more widely. In the PPP context, a concession is mostly used to describe a user-pays PPP. For example, in Brazil, the Concession Law applies only to user-pays contracts; a distinct PPP Law regulates contracts that require some payment from government. On the other hand, *concession* is sometimes used as a catch-all | New or existing infrastructure | Design, rehabilitate, extend, or build, finance, maintain, and operate—typically providing services to users | Usually user pays—in some countries, depending on the financial viability of the concession, the private party might pay a fee to government or might receive a subsidy |

| Contract Nomenclature | Overview Description and Reference | Type of Asset | Functions Transferred | Payment Source |
|---|---|---|---|---|
| | term to describe a wide range of PPP types—for example, all recent PPPs in Chile have been implemented under the Concession Law, including fully government-pays contracts. | | | |
| Private Finance Initiative (**PFI**) | The United Kingdom was one of the first countries to introduce the PPP concept under the term *Private Finance Initiative*, or *PFI*. It is typically used to describe a PPP to finance, build and manage new infrastructure. | New infrastructure | Design, build, finance, maintain— may include some operations, but often not providing services directly to users | Government pays |
| Operations and Maintenance (**O&M**) | O&M contracts for existing assets may come under the definition of PPP where these are performance-based, long-term, and involve significant private investment (sometimes also called performance-based maintenance contracts). | Existing infrastructure | Operations and maintenance | Government pays |
| Affermage | An *affermage* contract is similar to a concession, but with the government typically remaining responsible for capital expenditures. *Affermage* may have a specific meaning in some jurisdictions. The **World Bank's explanatory notes on water regulation** (Groom et al. 2006, 36–42) describe lease contracts, as well as concessions. Such contracts may or may not come under the definition of PPP, depending on the duration of the contract. | Existing | Maintain and operate, providing services to users | User pays—private party typically remits part of user fees to government to cover capital expenditures |
| Management Contract | The state retains asset ownership, and capital expenditure is the responsibility of the public sector, whereas operations and maintenance are handled by the private sector. These types of contracts are 3-5 years in duration. | Existing | Operations and maintenance | Management fees extended to the contractor |
| Franchise | *Franchise* is sometimes used to describe an arrangement similar to either a concession or a lease or affermage contract, as described in Yescombe (2007). | Existing or new | May include design, build, and finance, or may be limited to maintaining and operating an asset | User or government pays |

# Appendix H Examples of resilience solutions for water infrastructure

| Resilient Intervention | Solution Type | Impact Area/ Sector | Hazard Addressed | Potential Impact Addressed | Adaptation Approach |
|---|---|---|---|---|---|
| Avoid pumping water and sewage as much as possible | Non-Structural | Design considerations | Cross-cutting | Cross-cutting | Decreasing sensitivity (reduce impact) |
| Design in additional space and capacity for unknown future changes and needs beyond masterplan volumes. | Non-Structural | Design considerations | Cross-cutting | Cross-cutting | Increasing adaptative capacity (cope with and adjust) |
| Provide extended water storage within the water distribution network to maintain supply in case of short-term interruption. | Non-Structural | Planning for operation | Cross-cutting | Cross-cutting | Decreasing sensitivity (reduce impact) |
| Selective abstraction to abstract water at varied water levels to avoid algal blooms | Structural | Water treatment | Drought | Odor or algal blooms associated with low flow events changing source water quality | Decreasing sensitivity (reduce impact) |
| Have a robust water safety plan in place and use it to manage the water system. | Non-Structural | Planning for operation | Cross-cutting | Cross-cutting | Increasing adaptative capacity (cope with and adjust) |
| Implement a system of calculating short-term water supply allocations based on risk levels. | Non-Structural | Planning for operation | Cross-cutting | Cross-cutting | Increasing adaptative capacity (cope with and adjust) |
| Integrate operational plans for continuity of supply/service during disasters and extreme weather events. | Non-Structural | Planning for operation | Cross-cutting | Cross-cutting | Increasing adaptative capacity (cope with and adjust) |
| Plan for the effective execution of emergency repairs of water infrastructure damaged in disasters. | Non-Structural | Planning for operation | Cross-cutting | Cross-cutting | Increasing adaptative capacity (cope with and adjust) |

| Resilient Intervention | Solution Type | Impact Area/ Sector | Hazard Addressed | Potential Impact Addressed | Adaptation Approach |
|---|---|---|---|---|---|
| Break down infrastructure into smaller semi-independent units to reduce the impact of one unit's loss on total capacity. | Non-Structural | Systems thinking | Cross-cutting | Cross-cutting | Decreasing sensitivity (reduce impact) |
| Create exclusion zones around dams, rivers, or boreholes to protect water sources from potential contamination during disasters. | Non-Structural | Systems thinking | Cross-cutting | Cross-cutting | Decreasing sensitivity (reduce impact) |
| Design new sewers and sewage pump station to minimize retention time | Structural | Collection | Extreme Temperature | High temperatures turn sewer quality faster into septic | Design new sewers and sewage pump station to minimize retention time |
| Enforce stormwater management using sustainable drainage systems (SuDS) and separation of sewer and stormwater to reduce impact of stormwater runoff quality and quantity on all water infrastructure. | Non-Structural | Systems thinking | Cross-cutting | Cross-cutting | Decreasing sensitivity (reduce impact) |
| Provide back-up generators at all sewer pump stations | Structural | Collection | Flooding | Damaged power supply infrastructure leading to loss of power supply to sewage pump stations | Provide back-up generators at all sewer pump stations |
| Use flushing gates to flush sediment | Structural | Source | Deforestation | Loss of storage volume behind a dam due to sedimentation | Decreasing sensitivity (reduce impact) |
| Build berm to divert flood flows | Structural | Source | Flooding | Damage to infrastructure due to weirs and surface abstractions | Build berm to divert flood flows |
| Design electrical equipment and top level of structures to be located above flood lines | Structural | Wastewater treatment | Flooding | Wastewater treatment works flooded (especially vulnerable as they are usually built-in low locations) | Design electrical equipment and top level of structures to be located above flood lines |

| Resilient Intervention | Solution Type | Impact Area/ Sector | Hazard Addressed | Potential Impact Addressed | Adaptation Approach |
|---|---|---|---|---|---|
| Increase dam capacity to be able to accommodate extra sediment | Structural | Source | Deforestation | Loss of storage volume behind a dam due to sedimentation | Increasing adaptative capacity (cope with and adjust) |
| Increase sewer network maintenance | Non-Structural | Collection | Drought | Reduced wastewater flow in sewers can lead to settlement in sewers leading to blockage and/or odor problems | Decreasing sensitivity (reduce impact) |
| Incorporate rainwater / surface water recycling and use in green space watering | Structural | Distribution | Drought | Reduction in available fresh water | Increasing adaptative capacity (cope with and adjust) |
| Lower abstraction levels | Non-Structural | Source | Drought | Water flow drops too low due to water surface abstraction | |

*Source: AECOM. 2020. Guidance Note for Assessing Climate and Disaster Risks and Climate Co-Benefits. London/Ankara*

# Appendix I Examples of resilience solutions for transport infrastructure

| Resilient Intervention | Solution Type | Impact Area/ Sector | Hazard Addressed | Potential Impact Addressed | Adaptation Approach |
|---|---|---|---|---|---|
| Pedestrianize central city streets (Link) | Structural | Non-Motorized Transport | Air pollution | Increased GHG emissions from private cars and diesel busses | Decreasing exposure (out of harm's way) |
| Introducing/expanding Bus Rapid Transit Lanes (Link) | Structural | Public Transit Systems | Air pollution | Increased GHG emissions from private cars and diesel busses | Decreasing exposure (out of harm's way) |
| Promote a step change in the uptake of electric buses | Non-Structural | Public Transit Systems | Air pollution | Increased GHG emissions from private cars and diesel busses | Decreasing exposure (out of harm's way) |
| Increase cleaning and maintenance of roadways | Non-Structural | Non-Motorized Transport | Drought | Droughts causing decrease of vegetation that can contain water making roads dustier and sandier. This can lead to reduced friction in braking and less sighting of roadway markings | Decreasing sensitivity (reduce impact) |
| Plant roadside vegetation with drought-tolerant species | Structural | Non-Motorized Transport | Drought | Droughts causing decrease of vegetation that can contain water making roads dustier and sandier. This can lead to reduced friction in braking and less sighting of roadway markings | Decreasing sensitivity (reduce impact) |
| Increase cleaning and maintenance of roadways | Non-Structural | Roads | Drought | Droughts causing decrease of vegetation that can contain water making roads dustier and sandier. This can lead to reduced friction in braking and less sighting of roadway markings | Decreasing sensitivity (reduce impact) |

| Resilient Intervention | Solution Type | Impact Area/ Sector | Hazard Addressed | Potential Impact Addressed | Adaptation Approach |
|---|---|---|---|---|---|
| Plant roadside vegetation with drought-tolerant species | Structural | Roads | Drought | Droughts causing decrease of vegetation that can contain water making roads dustier and sandier. This can lead to reduced friction in braking and less sighting of roadway markings | Decreasing sensitivity (reduce impact) |
| Plant trees alongside walkways and bicycle lanes provide shade and cooling (Link) (Link) | Structural | Non-Motorized Transport | Extreme heat | Heat island effects due to urban density, choice of surface material and lack of cooling ability causing health issues especially to vulnerable groups (outdoor workers, elderly, and people with underlying health conditions) | Decreasing exposure (out of harm's way) |
| Develop sufficiently large opening windows and tinted windows to shade off the sun for trains, metro, and tramline vehicles (Link) | Structural | Rail | Extreme heat | Extreme heath trapped in trains can cause health issues especially for vulnerable groups (outdoor workers, elderly, and people with underlying health conditions) | Decreasing sensitivity (reduce impact) |
| Develop green roofs on rail stations | Structural | Rail | Extreme heat | Heat island effects due to urban density, choice of surface material and lack of cooling ability causing health issues especially to vulnerable groups (outdoor workers, elderly, and people with underlying health conditions) | Decreasing sensitivity (reduce impact) |
| White painted roofs for rail vehicles (Link) | Structural | Rail | Extreme heat | Heat island effects due to urban density, choice of surface material and lack of cooling | Decreasing sensitivity (reduce impact) |

| Resilient Intervention | Solution Type | Impact Area/ Sector | Hazard Addressed | Potential Impact Addressed | Adaptation Approach |
|---|---|---|---|---|---|
| | | | | ability causing health issues especially to vulnerable groups (outdoor workers, elderly, and people with underlying health conditions) | |
| Audit drains regularly | Non-Structural | Non-Motorized Transport | Flooding | Overloaded and debris-clogged drainage and culverts leading to flooded bicycle and pedestrian ways | Decreasing sensitivity (reduce impact) |
| Determine and construct appropriate flood defenses which incorporate climate change projections (Link) | Structural | Non-Motorized Transport | Flooding | Flooded bicycle and pedestrian ways damaging and decreasing structural integrity | Decreasing sensitivity (reduce impact) |
| Enhance foundations to prevent washouts | Structural | Non-Motorized Transport | Flooding | Dirt roads and other roads with limited foundations and poor or no drainage are at risk of being washed away or scoured | Decreasing sensitivity (reduce impact) |

*Source: AECOM. 2020. Guidance Note for Assessing Climate and Disaster Risks and Climate Co-Benefits. London/Ankara*

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**118.** The Net Present Value (NPV) is the difference between the present value of benefits and the present value of costs for the time horizon over which the assessment is being conducted; usually the design life of the project. It provides a measure of the overall impact of an option. Other assessment criteria may also be considered including the Benefit-Cost Ratio (BCR) which is the ratio of the present value of benefits and costs and provides a measure of the benefits relative to costs, and the Internal Rate of Return (IRR) which is the specific value of the discount rate for which the project's NPV is zero. NPV is a more reliable way of ranking alternative options as BCR may give rise to the incorrect ranking of mutually exclusive projects of different scales, while the IRR may rank mutually exclusive projects or options incorrectly if the time profile of benefits and costs differs across projects. The NPV criterion, by contrast, always results in the correct ranking of alternatives and the selection of the by most.

**119.** Discounting renders benefits and costs that occur in different time periods comparable by expressing their value in present terms. In practice, it is accomplished by multiplying the changes in future consumption (broadly defined) caused by a policy or intervention by a discount factor or discount rate. Broadly, discounting reflects that people prefer consumption today to future consumption, and that invested capital is productive and provides greater consumption in the future. Once applied, discounting tells us how much future benefits and costs are worth today. The selection of the rate at which to discount future economic costs and benefits of an investment project is subject to much debate and controversy. With sufficiently high discount rates, the economic consequences of disaster events appear small if they happen sufficiently far in the future. In effect, the higher the discount rate, the lower the value that is placed on the welfare of future generations. Countries and institutions have different rationales for the choice of discount rate, depending on whether they are basing the discount rate on the rate of social time preference (generally people prefer to receive goods and services now rather than later), the economic cost of capital or as a means of rationing access to subsidised funding. A rate of 10% is used here but the impacts on the NPV of employing a different discount rate could be analysed through sensitivity testing.

**120.** Incremental costs and benefits are those that are additional to, or over and above, what would have otherwise been incurred in the absence of the resilience measure

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