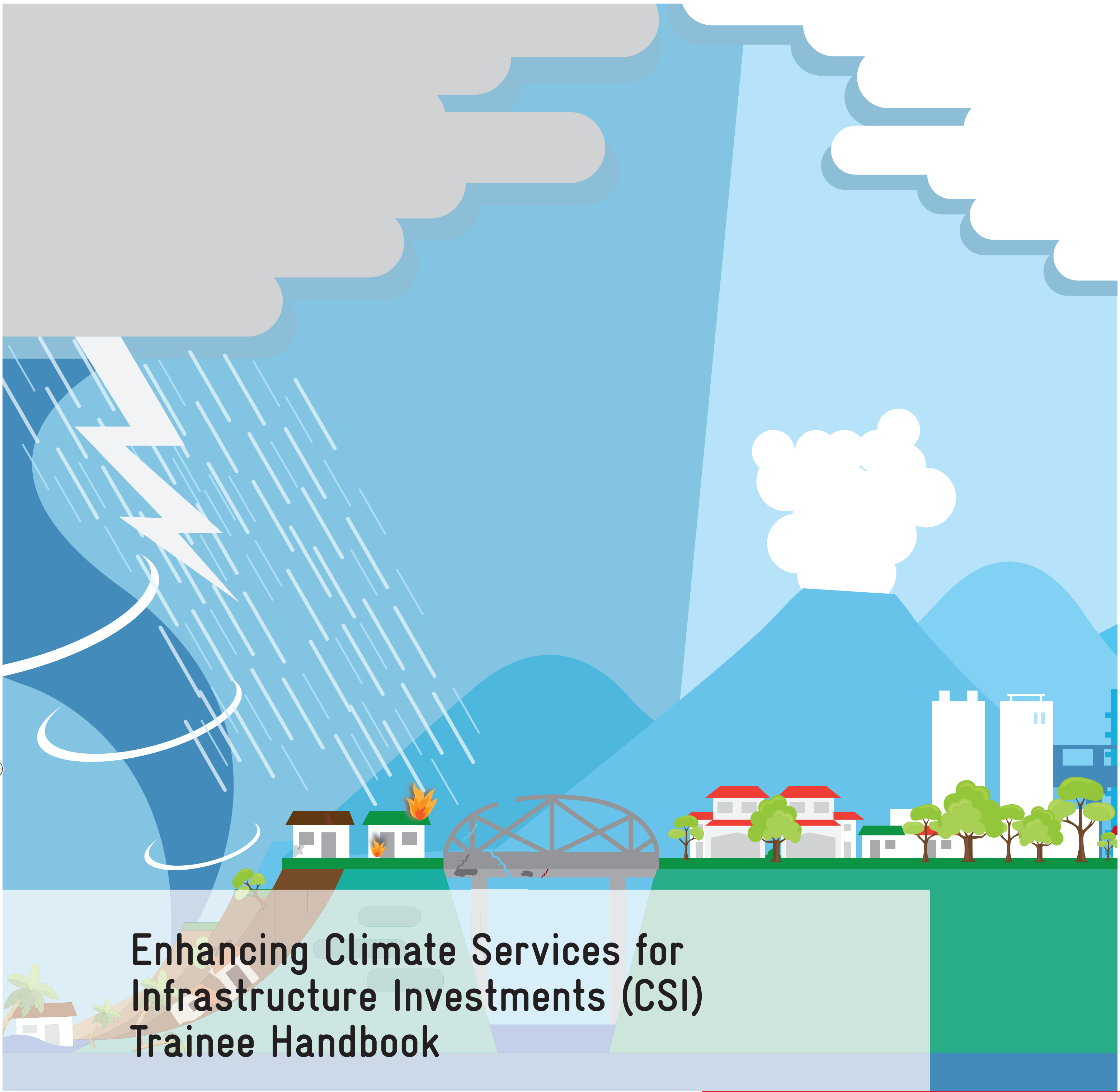

Enhancing Climate Services for Infrastructure Investments (CSI)
Trainee Handbook

On behalf of:

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Federal Ministry
for the Environment, Nature Conservation
and Nuclear Safety

of the Federal Republic of Germany

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Project Enhancing Climate Services for Infrastructure Investments (CSI)

This project is part of the International Climate Initiative (IKI).

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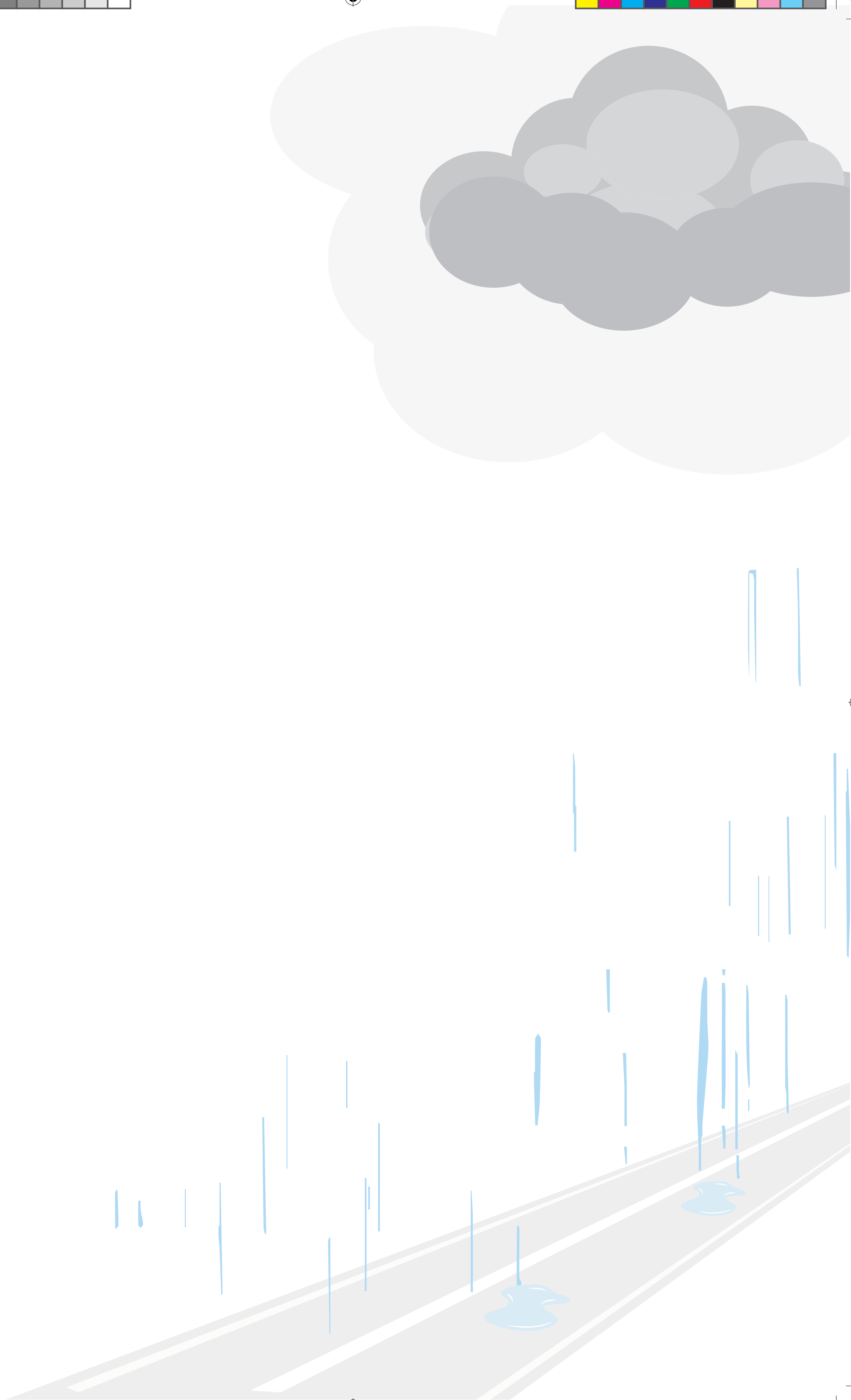

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How to use this trainee handbook

This handbook is designed for trainees in a face-to-face training and its content is complemented by trainer and expert presentations (PPTs), peer discussion groups and interactive role plays. Thus, it shall support the development of the trainees' planning capacities on integrating climate change adaptation into sustainable infrastructure investment and facilitate their understanding of the concept and use of climate services in the context of climate proofing sustainable infrastructure investments. The document provides basic background knowledge, methods and tools complemented by exercises which encourage the learning from experience with a case study in order to learn about:

- the context and objectives of the training (Module 1),
- the concept of climate change and relevance for infrastructure investment (Module 2),
- the concept and need for user friendly climate services (Module 3),
- the methodological approach of climate proofing developed by GIZ based on the OECD Policy Guidance 'Integrating Climate Change Adaptation into Development Co-operation' published in 2009[1] (Module 4),

and supported by:

- the brief description of the fictitious case of Metropolis City (Annex 1) which serves as a reference case for the exercises, and
- the glossary which explains terminology and concepts used in this handbook (Annex 2).

[1] Source: summary available at www.cbd.int/development/presentations/emmbdc-01/2009-05-13-oecd-en.pdf

All sub-chapters of modules 2 to 4 are structured the same and facilitate easy cross-reference between the different modules:

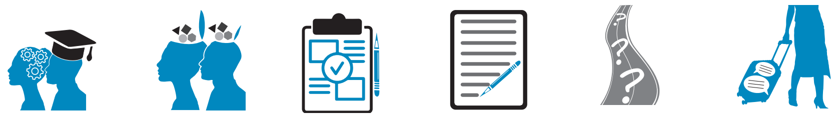
Content guide	Content
1. Skills and knowledge	Description of enhanced skills and knowledge
2. Context	Brief description of relevance of the topic complemented by PPTX
3. Concept	Brief description of methodological approach complemented by PPTX
4. Exercise	Application of methods and tools in a simplified training context
5. Guiding questions for reflection	Recap of lessons learnt during exercise and application to real life
6. Take away messages	Examples of key messages from the learning process
7. References	List of cited and recommended literature
8. Personal notes	Open space for personal notes, e.g. further key messages

Figures, tables and photos illustrate the messages of the text and refer to selected slides of the Powerpoint Presentations of this training.

Finally, this handbook uses boxes to display supporting information.

Icons:

Skills and knowledge | Context | Concept | Exercise | Guiding questions | Take away messages



Module 1

Introduction to the CSI Training

Module 1
Introduction to the CSI Training

1.1 Overview of CSI Training

Developing countries and emerging economies are investing billions in durable infrastructure every year. However, they often fail to take account of future climate change in their planning. As a result, new infrastructure projects are being implemented without consideration of their vulnerability to climate change. This leads to high risks of damage, loss and misguided investment with potentially serious consequences for the economy and society.

Infrastructure adapted to the impacts of climate change is one of the United Nations Sustainable Development Goals. A number of countries, including Brazil, Costa Rica and Viet Nam, have already launched efforts to increase the resilience of their infrastructure and have included infrastructure climate risk management in their National Adaptation Plans (NAP). For implementing their NAPs, the partner countries' are required to establish Climate Services that are aligned to the requirements of decision-making and planning processes. A few international initiatives have begun to address this challenge, including the Global Framework for Climate Services (GFCS). The GIZ-CSI project translates the international framework of action of the GFCS into national level contexts and conditions in its partner countries and focuses on *Enhancing Climate Services for Sustainable Infrastructure Investment* (CSI).

It supports the country-specific institutional and technical design of structures to enable countries to make better use of Climate Services and to include them in their infrastructure planning system. This includes institutionalizing a sustainable interface between users (e.g. infrastructure planners, operators and owners) and Climate Service providers – commonly referred to as a Climate Service User Interface Platform (UIP). It promotes the concept of co-production of Climate Service products. This means including users of Climate Services right from the beginning in the development process of Climate Service products to become tailor-made. Moreover, CSI also focuses on climate-sensitive infrastructure planning methods. Together with decision-makers, the project develops recommendations for adapting planning procedures and regulations in line with the climate-proofing approach, e.g. via cost-benefit analyses, the development of building standards or environmental impact assessments (EIA).

Based on the Public Infrastructure Engineering Vulnerability Committee (PIEVC) protocol that Engineers Canada developed to analyze climate risks to infrastructure, the project aims to build local capacity by means of a learning-by-doing approach. With support of NIRAS – IP Consult GmbH the CSI Training was developed and to disseminate this approach and to operationalize the adapted planning procedures and regulations following the *Climate Proofing* method originally developed by GIZ based in the *Guidelines Integrating Climate Change Adaptation into Development Cooperation* (OECD 2009).

One essential component of the capacity development approach of the CSI project is training and ensuring that training capacities in the CSI partner countries are locally enhanced and sustained. Trainings are envisioned to accompany and complement activities of the project related to enhancing Climate Service provisions and their utilization for infrastructure investments. This specifically refers to the development of training approaches that are complementing learning experiences from selected infrastructure pilot activities focusing on the Climate Proofing of ports and transition lines (Brazil), bridges (Costa Rica), sluice gates (Viet Nam) and dams (Ethiopia-NBI).

With this course trainees will improve their **skills and knowledge:**

- to understand the concept of *Climate Services* and engineering aspects of risk assessment;
- to learn about a more technical approach towards cost-benefit analysis;
- to know how to identify potential *entry points* of climate change adaptation within infrastructure planning frameworks and cycles using the *Climate Proofing* method;
- to be able to provide feedback to policy development and integrate the results of climate proofing infrastructure investment into the context of NAP/NDC-implementation, institutional reform and other enabling mechanisms for change;
- to become aware of challenges and enabling factors for the effective use of *Climate Services* in the context of *Climate Proofing* infrastructure investment;
- to learn to think in systems and understand in this context the importance of *climate value chains* and *Climate Service products* for climate change adaptation which involves the technical, organizational and institutional levels;
- to become aware how to balance interests of different stakeholder groups;
- to be able to reflect on applying *Climate Proofing* infrastructure investment projects, strategies and plans in their own specific contexts.

Besides, trainees will further develop their personal capacities, namely:

- to enhance analytical skills;
- to learn to think strategically;
- to strengthen cooperation and dialogue skills;
- to learn to communicate in an audience-oriented and culture-sensitive way; and
- to enhance reflective skills such as creativity, innovation and adaptive management skills.

- The **target groups** of this training are primarily professionals responsible for the planning and management of (public) infrastructure investment. Considering the interaction of public infrastructure investment with other sectors like environment, nature, health, economically productive sectors, finance etc., besides infrastructure operators, national ministries, local governments or research entities, stakeholder groups from cross-sectorial planning and management bodies should be considered. Thus, the training aims at decisions makers, planners, practitioners and technical staff from governments as well as civil society, academia, the private sector, investors, national and international staff in international or regional cooperation.

Trainers in partner countries receive tailor made **Trainings of Trainers (ToT)** to become able to design and implement CSI Trainings with support of the recommended methods, tools and materials.

1.2 Overview of methods and tools

Human Capacity Development is driven by individual interests which finally contribute to change processes at organizational and institutional level. Professionals who have the mandate to participate actively in these processes are most likely to become effective players if they are motivated, well informed and capable to face new challenges even under conditions of uncertainty.

The training mainly applies the didactic approach of participatory action learning. This implies that trainees assume responsibilities for the development of their training, learn from their own and other participants' experiences developed during the training and construct new skills and knowledge reflecting their new experiences against their previous capacities. The trainers turn into learning process facilitators who introduce into new subjects and methods, while they might seek support from expert presentations, training materials including all information available through internet research. A combination of didactic methods allows to learn with strong emotions which favors the adoption of lessons learnt.

The core approach of the training is working on a specific case with guiding questions. These allow to explore the case systematically, discuss ideas with peer expert groups, present and reflect on the findings as compared to their real working environment, thus, learn about the potential and challenges of the methodological approach. This handbook works with the fictitious case of Metropolis City and the Millennium Bridge Project, a case deduced from real-life conditions and challenges, but simplified for the training context. The fictitious case allows trainees to dig into the matter without direct interests and concerns from their own work context. Nevertheless, the methodology can be applied to a real case, yet this involves further preparation in advance of the training in order to gather and process necessary information according to the fictitious example.

All steps of exploring the case study follow the same sequence:

1. The **introduction**, given by the trainer, provides the necessary theoretical background and introduces trainees to the casework.
2. The **casework** gives trainees the opportunity to work through the different aspects linked to Climate Proofing Infrastructure Investment in a systematic manner. Trainees assume the roles of 'case work experts' in charge of the specific module's task.
3. The **presentation** of results is the opportunity for 'case work experts' to show their results to the plenary, share experiences and foster mutual learning. Trainers offer alternatives and remarks when necessary.
4. In a final **reflection**, the trainees reassume their own real-life position. They reflect on their experiences and link them to their own work in order to make the newly gained knowledge more applicable. Trainers support through guiding questions.

The training is part of a longer-term advisory process aiming at enhancing Climate Services for sustainable infrastructure investment. Based on a stocktaking capacity needs assessment among decision makers and participants, the training program may be tailored to the expressed needs. Each module can even be used independently for a specific training context depending on the focus of the capacity development event. In this regard, the training most likely is not perceived as a single event, but may consist of several training and advisory workshops from awareness raising to understanding the full methodological approach of enhancing Climate Services for sustainable climate proofing of (public) infrastructure investment.

The following training material is available:

- Trainee Handbook (including introduction to each topic, exercises and further resources),
- Trainer Handbook (including guidance on how to run the exercises and interactive dynamics),
- Presentations (providing technical background knowledge & real-life examples).

This present Trainee Handbook is a source for participants before, during and after the training. Although it could be used as a stand-alone publication and will always benefit from further instructions and explanations by the trainers and the complementary presentations.

1.3 Requirements for certification

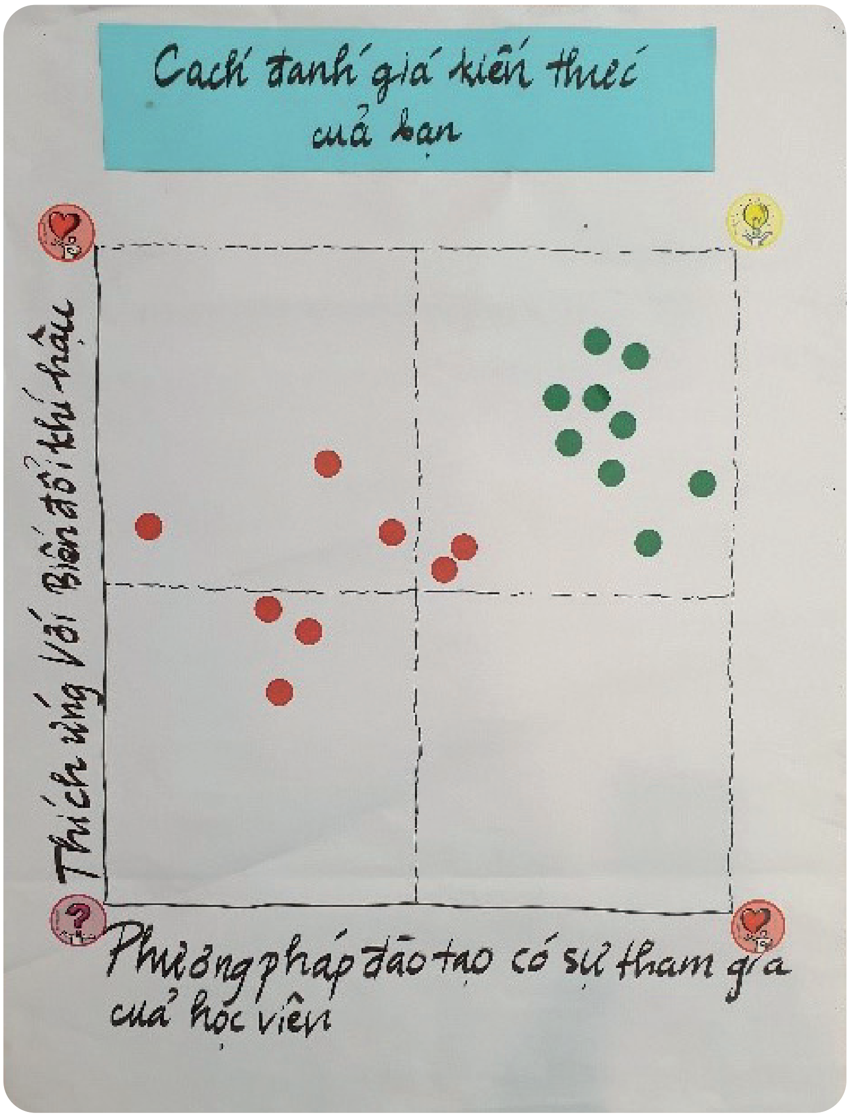
Trainees receive a certificate for participation in the training if they fulfilled the following requirements:

- Participate in all training classes.
- Assume a task of the Training Co-management Committee: i.e. trainees support the trainer team with time management, feedback including recollection of feedback from peers, documentation of the daily training development and other tasks to be agreed upon at the beginning of the training.
- Present at least once the results of a group or individual task.
- Contribute with own ideas to discussions in plenary.
- ToT only: prepare and implement a training session using the training handbooks and materials.

The certificate specifies the modules received during the training and the specific skills and knowledge achieved either as practitioner or trainer.

The *Knowledge Barometer* is a tool which helps to illustrate the knowledge baseline at the beginning of the training and the changes perceived by participants at the end of the training (see figure 1.3.1).

Figure 1.3.1 **Knowledge Barometer. The red dots were placed at the start, the greens at the end of the training.**



1.4 Evaluation of training

The evaluation of the training is an important tool for feedback and adjustment of the training during and after the events:The Mood Barometer reflects the daily mood at the end of each day responding to the question: Which is my level of satisfaction with the training today?

1. Fully satisfied and eager to return tomorrow,
2. Good day but still can be better tomorrow, or
3. I don't want to come back tomorrow.

This tool provides a general impression of the day and together with the feedback from participants it helps to adjust the training development right in time and as far as feasible (see figure 1.4.1). Strong emotions are expressively wanted as part of the learning process, therefore, high satisfaction and frustration might be part of the individual process and occur at the same time, particularly in more heterogeneous trainee groups.

At the end of the training, a *qualitative evaluation form* with additional space for free observations and recommendations is the minimum tool which should be used to invite trainees to express their level of satisfaction with a number of criteria: e.g. achievement of training objectives, selection of contents, methods, materials, exchange with trainers, exchange with peer trainees, organization of the event, training venue, food (see figure 1.4.2). Generally, GIZ applies a standard questionnaire at the end of the training and/or some weeks after completion of the training which asks for more details and seeks to measure the use of the acquired skills and knowledge evaluating the effect of the training.

Figure 1.4.1 Mood barometer, for five days

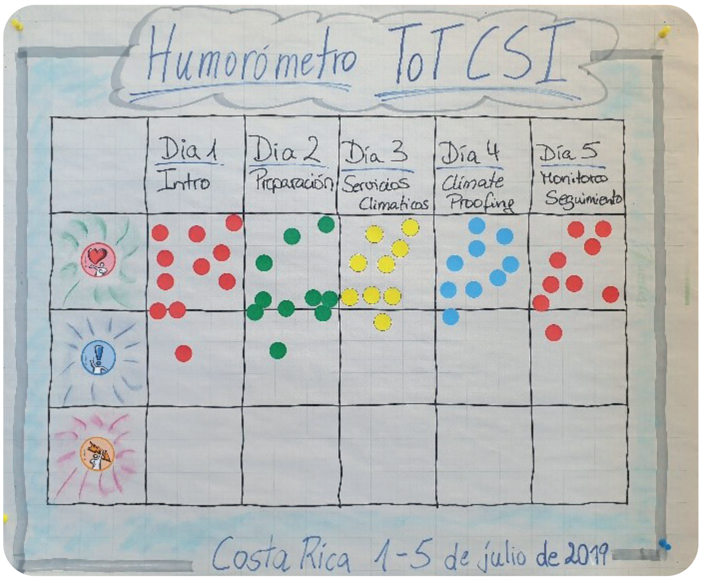


Figure 1.4.2 Qualitative evaluation form

Module 1

Module 2

Concept of climate change and relevance for infrastructure investment

2.1 Introduction to climate change

Climate Change is a factor to take into account when looking into the next years and decades. In order to be able to discuss climate change, it is important to understand basic climate-related vocabulary. While global average temperatures are rising, the effects in single regions or localities can strongly differ one from another. From this starting point, understanding what different sources of climate data and information actually are saying becomes a crucial matter, also to later assess further potential biophysical and socioeconomic impacts of climate change. A tool to assess the probability for changing trends in climate parameters is fundamental to start exploring first elements of climate risk in territories.

2.1.1 Skills and knowledge

- The trainee understands what climate change is and is able to reflect on interactions between climate change and other topics/sectors.
- The trainee understands differences between different climate change related concepts and terms.
- The trainee is able to identify the context of climate change within specific Climate Change Frameworks.
- The trainee is able to understand climate change information and to evaluate it according to trends and consistency.

2.1.2 Context: Climate Change impacts – from emissions to socio-economic impacts and the implications of uncertainty for decision making

> *'Climate is what we expect, weather is what we get.'*
> *Robert Henlein, Novelist, 'The Notebooks of Lazarus long'*

Climate Change has become a buzzword in our society. However, often even experts do not necessarily understand the difference between the term climate change and related terms, like weather and climate (for definitions, see Box 2.1.1).

Box 2.1.1 Glossary

Weather can be described as 'the state of the atmosphere in a specific moment, with regard to factors like temperature, humidity, wind, etc. Weather refers, consequently, to meteorological conditions identified in a specific short period (e.g., one day) in a defined region.'

'Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization.'

Climate variability 'refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events.'

Climate change is defined as '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.' (IPCC 2014)

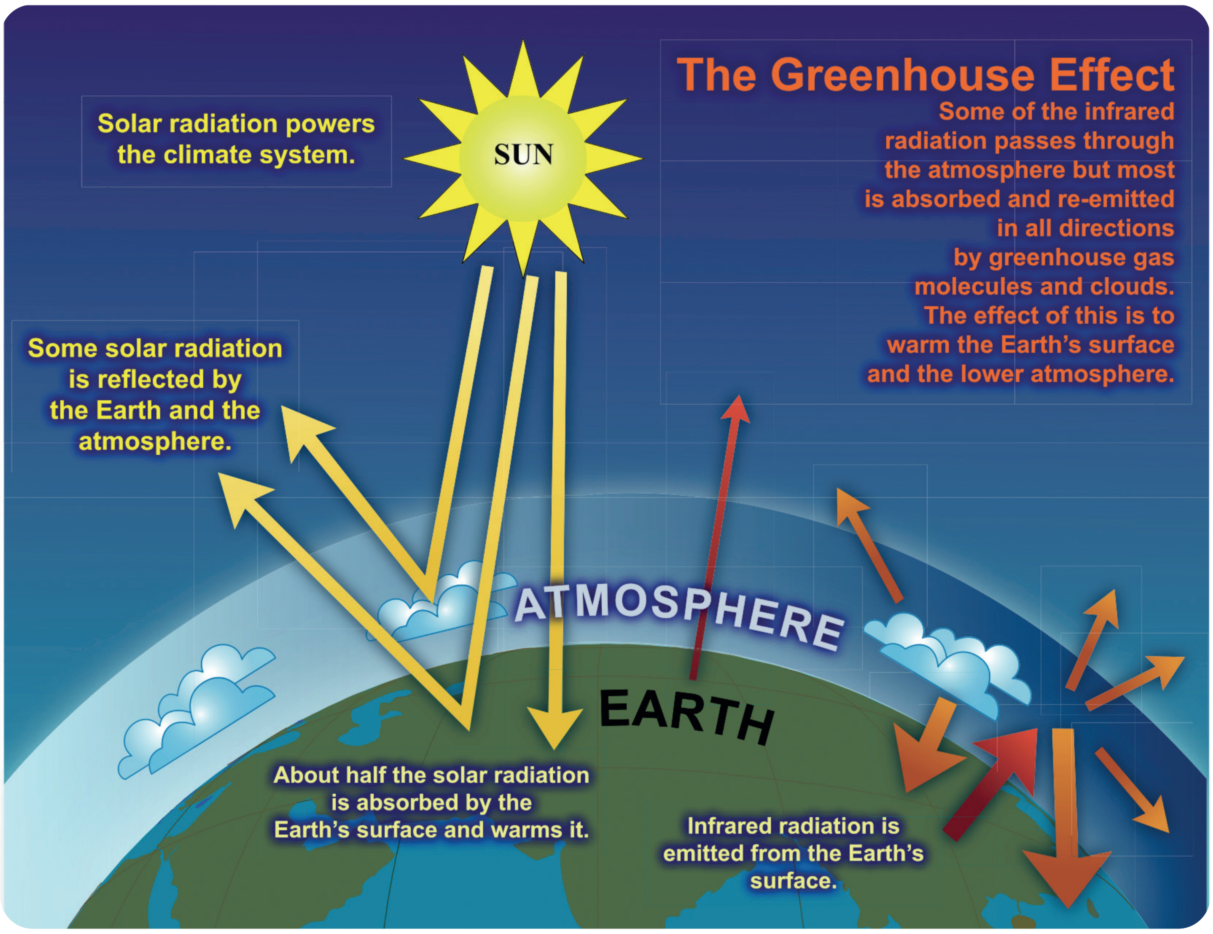
In a nutshell, weather is the current state of the atmosphere, while climate is the average weather over a period of time. This climate can vary around the average, being this variability still part of the climate pattern. Climate change, in contrast, is described as a permanent change in climate patterns beyond normal variability.

Greenhouse gas emissions

The main factor to maintain stable average temperatures – and therefore, stable climates – in our planet is the so-called greenhouse effect, detailed in Figure 2.1.1. It is described as the re-reflection of infrared energy emitted by the Earth's surface back to the Earth, either by clouds or by so-called greenhouse-gases (GHG), like water vapor (H_2O), carbon-dioxide (CO_2), methane (CH_4), nitrous oxide (NO_2), ozone (O_3), and others. In pre-industrial times, these greenhouse gases guaranteed an average temperature on the Earth surface of 14° C.

Since the Industrial Revolution in the 1750s, due to increased emission of greenhouse gases and therefore their concentration in the atmosphere, the average temperature in the planet has shown a tendency to increase. According to the Intergovernmental Panel on Climate Change (IPCC), the United Nations body for assessing the science related to climate change, the main drivers for greenhouse gas emissions have been burning of fossil fuels and industrial processes, as well as deforestation and land use change. Higher temperatures lead also to a higher tendency for evapotranspiration in the atmosphere what again potentiates the Greenhouse Effect.

Figure 2.1.2 The Greenhouse Effect



Source: geographyiseasy.wordpress.com/2014/09/11/gcse-greenhouse-effect-and-global-warming

Table 2.1.1 The RCP scenarios

RCP 2.6: radiative forcing of 2.6 W/m², peeking between 2010 and 2020, with substantial decline afterwards.
RCP 4.5: radiative forcing of 4.5 W/m², peeking around 2040, with subsequent decline
RCP 6: radiative forcing of 6.0 W/m², peeking around 2080, with subsequent decline
RCP 8.5: radiative forcing of 8.5 W/m² or more in 2100, without any reduction of greenhouse gases during the whole 21st Century

Emissions of greenhouse gases are not equally distributed in the world. They vary according to emitting activities in different regions. Based on historic emissions and their consequences, scientists develop studies to assess how the climate may evolve in the future. This analysis is made following different emission scenarios that take into account factors like demographic growth, soil use patterns, energy consumption, and technological change, among others. In its fifth Assessment Report (AR5), the IPCC (2014) presents four different possible scenarios for the year 2100. They are characterized by Representative Concentration Pathways (RCPs) that describe four possibilities for concentration of greenhouse gases in the atmosphere, which indicate modifications in the balance of radiation for the planet. The denominations of the scenarios refer, thus, to the radiative forcing values in the year 2100 relative to pre-industrial values (e.g. +6.0 W/m²), as summed up in the table 2.1.1 (Schloenvoigt et. al., 2018).

Climate change signals and scenarios

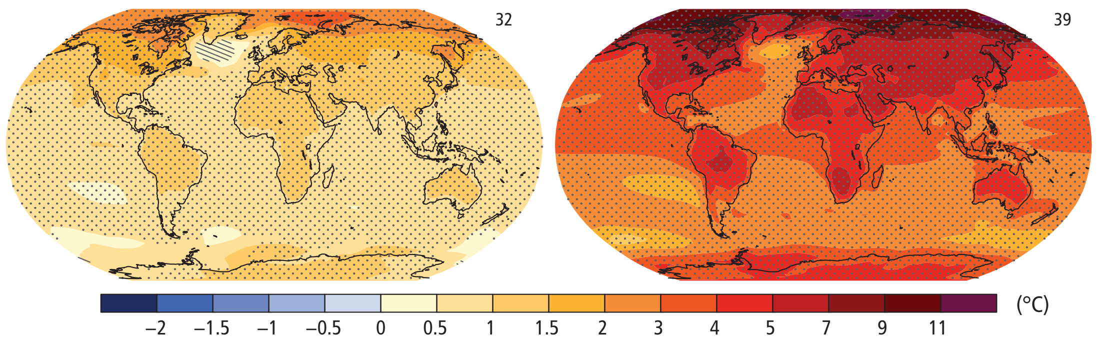
From all four scenarios, only RCP 2.6, that presupposes a rigorous cut in emissions, leads to a limited global temperature rise of 2° C by the year 2100, as compared to pre-industrial times. All other three scenarios lead to substantially higher average global temperatures.

In turn, the prediction on how the climate may respond to different development conditions is done with the support of climate models. These are numeric models that represent physical processes in the atmosphere, the oceans, the glaciers, and the terrestrial surface in certain regions and time frames which are developed and applied via computer technology. Although all models represent a certain level of uncertainty due to the difficulty to model certain physical processes and, e.g., technological restrictions, these models are currently the most advanced tools to simulate climate systems response to greenhouse gas concentrations in the atmosphere. Figure 2.1.2 shows two climate change projections for temperature, comparing the periods 1986–2005 and 20181–2100, considering scenarios RCP 2.6 and RCP 8.5 (Schloenvoigt et. al. 2018, IPCC 2013).

When talking about changes in different climate parameters due to climate change, it is important to highlight that changes across the planet are irregular. Global climate models (GCMs) divide the Earth's surface and atmosphere into grids that represent computational units. These GCMs deliver simulations of changes in climate in different regions due to changing concentra-

Figure 2.1.3 Change in average surface temperature (2081–2100, compared to 1986–2005)

(a) **Change in average surface temperature (1986–2005 to 2081–2100)**



Source: IPCC 2013

tion of greenhouse gases in the atmosphere. However, GCMs just represent the physical atmospheric and oceanic processes. Earth system models (ESMs) additionally include chemical and biological processes, like e.g. the carbon cycle and dynamic vegetation, pursuing to represent all relevant aspects of the Earth system (Climateurope, 2019).

Both GCMs and ESMs mostly work with quite large grids (typically between 1 and 5 degrees in latitude or longitude), making them often not accurately enough for decision makers on the regional or even local level. For this reason, climate scientists develop regional climate models (RCMs) that downscale GCMs to a section of the Earth. Thanks to increasingly powerful supercomputers, these regional climate models nowadays are able to work with a grid resolution of up to 1x1 Km.

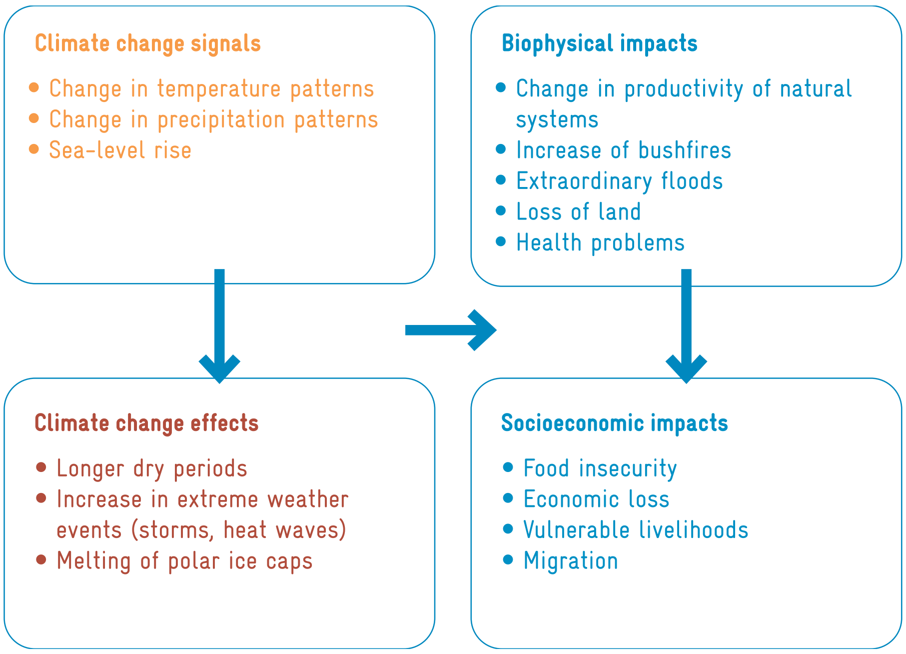
In addition to climate models that look into the future, it is also possible to analyze climate-related trends by analyzing historic data (of preferably at least 30 years), like e.g. temperature or sea level. Trends in the past can also indicate possible trends in the future. When quantitative data is not available, qualitative data, like e.g. expert interviews or news clippings, can deliver relevant trends.

Climate effects and biophysical/ socio-economic impacts

Although effects of climate change can be observed directly, as e.g. the melting of glaciers due to rise in temperature, some consequences of this change are only perceived indirectly: e.g., the melted ice leads to sea-level rise, and this leads to changes in coastal dynamics, causing migration, and further on. These sets of cascading effects are also called impact chains: different climate change signals (direct climate change manifestations) lead to a series of effects (direct results from this change) and, finally, their impacts (their direct and indirect consequences), which can be both biophysical and socioeconomic. Climate change signals can also be interpreted as climate effects, depending on the impact chain under analysis (Schloenvoigt et. al., 2018; see also Figure 2.1.3).

Impacts tend to spread along the impact chains, potentially impacting humans and their livelihoods (Figure 2.1.4; see also Chapter 4.2). From a global perspective, some impacts related to climate change can already be observed with regard to an increased occurrence of extreme weather events (like windstorms and hail), to the availability of water resources in sufficient quantity and quality, to change in population dynam-

Figure 2.1.4 Impact chains caused by climate change signals and effects



Source: adapted from Schloenvoigt et. al., 2018 ics and patterns of aquatic and terrestrial organisms, to the occurrence of water and vector borne diseases, and to change in the productivity of food crops. It is worth remembering that also positive impacts can be attributed to climate change, like e.g. crops that are favored by new temperature and precipitation patterns in certain regions. However, globally, negative impacts of climate change on food crops exceed positive impacts (Schloenvoigt et. al., 2018; IPCC, 2014).

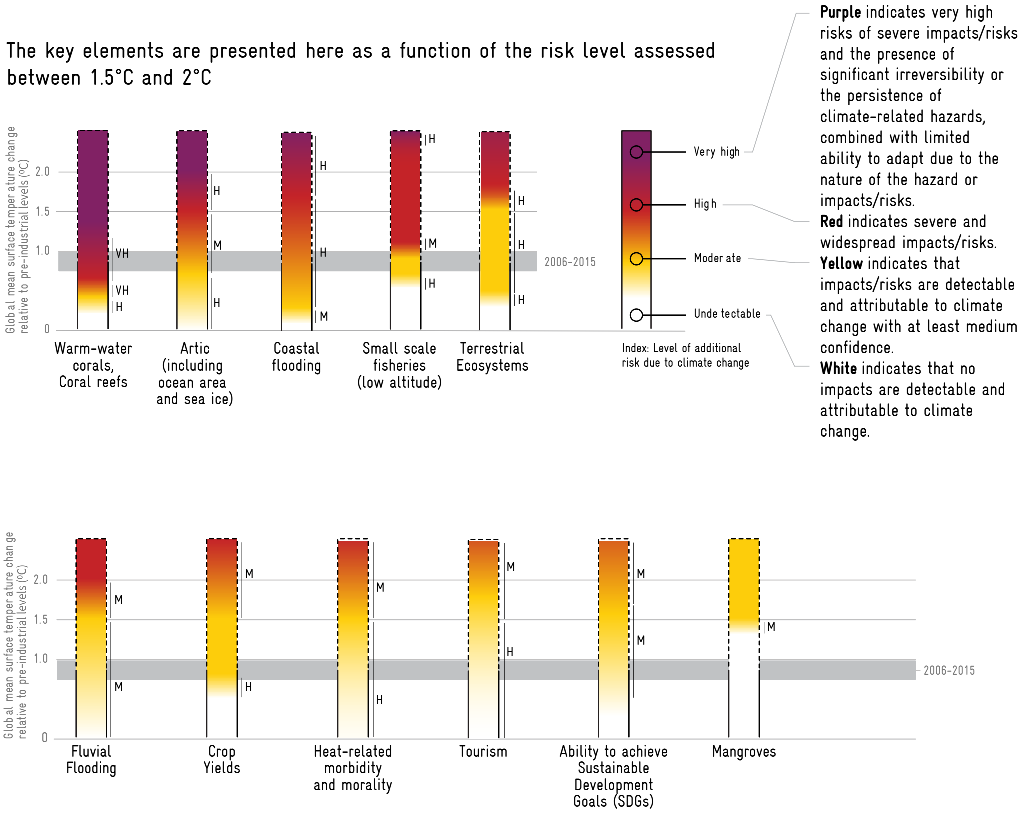
Cascade of uncertainty and implications for decision making

Due to uncertainties in climate projections, climate data and information always need to consider agreement on trends and evidence, in order to be able to estimate the likelihood of a trend or event in a certain location or region (see Box 2.1.2).

Uncertainties regarding climate projections increase with the future time spell of projection they cover. This mainly has to do with a cascade of assumptions that then lead to new assumptions. A schematic of a cascade of uncertainty is shown in Figure 2.1.5, illustrating various steps of a 'top-down' assessment of climate risks, starting from uncertainties regarding future societies, which then lead to GHG emissions affecting GCM circulations and therefore regional scenarios, what again leads to regional and local impact models, which would be the basis of adaptation responses.

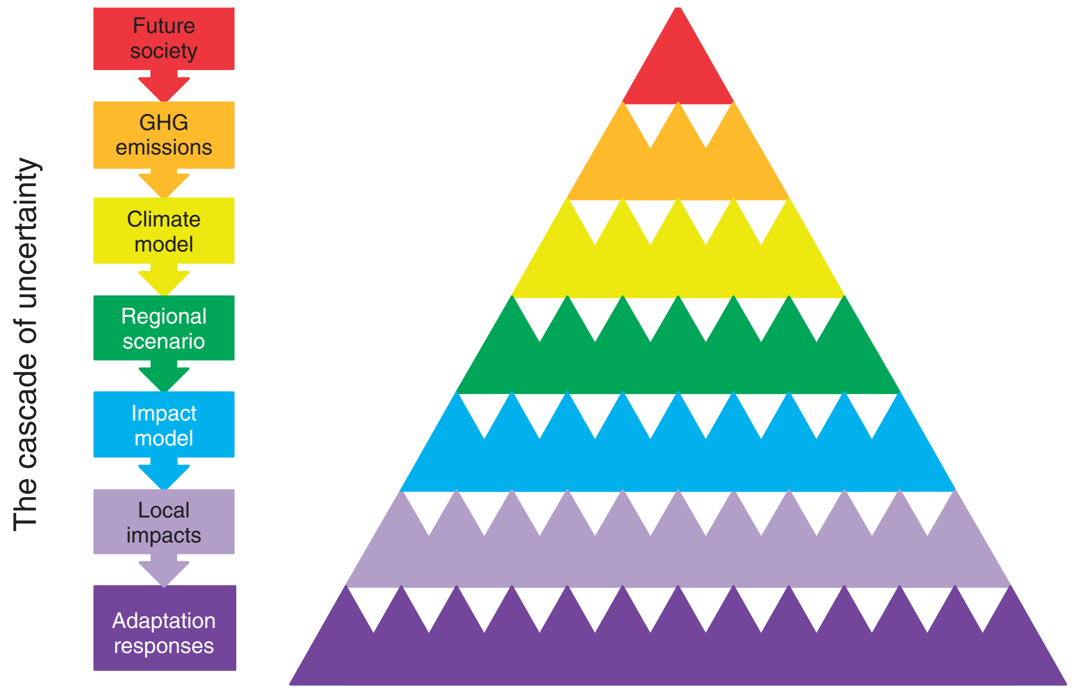
While this approach leads to overwhelming uncertainties with regards to adaptation decisions, it also helps to discuss the need of understanding these uncertainties, eventually leading to invest into 'low-regret' adaptation measures that have a positive effect even if climate change does not impact as expected.

Figure 2.1.5 Risk and/or impacts for specific natural, managed and human systems



Source: Hoegh-Guldenberg et al. (2018), p 252

Figure 2.1.6 **The cascade of uncertainty**



Source: Wilby & Dessai, 2010

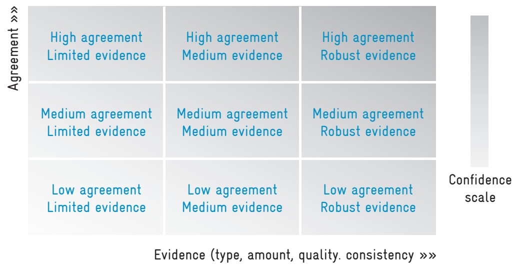
Communication of the Degree of Certainty in Assessment Findings

Based on the Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties, the WGII AR5 relies on two metrics for communicating the degree of certainty in key findings:

- Confidence in the validity of a finding, based on the type, amount, quality, and consistency of evidence (e.g., data, mechanistic understanding, theory, models, expert judgment) and the degree of agreement. Confidence is expressed qualitatively.
- Quantified measures of uncertainty in a finding expressed probabilistically (based on statistical analysis of observations or model results, or both, and expert judgment).

Each finding has its foundation in evaluation of associated evidence and agreement. The summary terms to describe evidence are: limited, medium, or robust; and agreement: low, medium, or high. These terms are presented with some key findings. In many cases, assessment authors in addition evaluate their confidence about the validity of a finding, providing a synthesis of the evaluation of evidence and agreement. Levels of confidence include five qualifiers: very low, low, medium, high, and very high. Box TS.3 Figure 1 illustrates the flexible relationship between the summary terms for evidence and agreement and the confidence metric. For a given evidence and agreement statement, different confidence levels could be assigned, but increasing levels of evidence and degrees of agreement are correlated with increasing confidence.

Figure 2.1.7 **Evidence and agreement statements and their relationship to confidence. Generally, evidence is most robust when there are multiple, consistent independent lines of high-quality evidence.**



When assessment authors evaluate the likelihood, or probability, of some well-defined outcome having occurred or occurring in the future, a finding can include likelihood terms (see below) or a more precise presentation of probability. Use of likelihood is not an alternative to use of confidence. Unless otherwise indicated, findings assigned a likelihood term are associated with high or very high confidence.

Term	Likelihood of the outcome
Virtually certain	99–100% probability
Extremely likely	95–100% probability
Very likely	90–100% probability
Likely	66–100% probability
More likely than not	>50–100% probability
About as likely as not	33–66% probability
Unlikely	0–33% probability
Very unlikely	0–10% probability
Extremely unlikely	0–5% probability
Exceptionally unlikely	0–1% probability

Where appropriate, findings are also formulated as statements of fact without using uncertainty qualifiers. (IPCC, 2014:59)

Module 2

2.1.3 Exercise: Interpretation of historic climate data and climate projections

Learning Objective

You will learn how to do interpret different available climate data in order to identify how different climate parameter have been changing in the past or may change in the future.

Content and main tasks

- Assessing different types of climate data and climate information.
  > *Definition of existing data and information.*

- Assessing trends for different climate change signals and climate effects.
  > *Definition of the strength of relevant trends.*

- Assessing the strength of evidence of available climate data and information for different climate change signals and effects.
  > *Rapid assessment of type, amount, quality and consistency of available climate data and information.*

- Identifying climate events with a relevant probability of occurrence.
  > *Calculation of agreement in trends vs evidence.*

- Discuss on next steps:
  > *Which impact chains should be further explored, departing from relevant climate trends?*

Case description

For the following case study, you can use any set of different climate data and information related to your project region, no matter if from GCMs, ESMs, RCMs, historic quantitative or qualitative data. If you don't have any specific case study at hand, you may refer to the Metropolis case and select the following climate information, detailed in Annex 1.

Your specific tasks

First, agree with 2 – 4 peers to work with as a team.

Second, read the instructions carefully and in case of doubts, first ask your fellows or – if still necessary – the trainers.

Third, guide your analysis with the following questions and draft your answers based on the climate data and information that is available (note that for this exercise, real climate data and information are needed). Use a pin board and moderation cards to assess all relevant aspects for each source of information (e.g. climate models, statistical models, time series, news clippings, etc.):

1. Identify which climate parameter or event is addressed (e.g. annual precipitation).
2. Identify which type of climate information or data this parameter addresses, e.g. GCM, historical data, news clippings, etc.
3. Name the publisher and source of the climate data or information. This is relevant to assess the confidence on the source.
4. Assess the quality of climate data. Are projections following the state of the art? Are grids sharp enough for the analyzed region? Are there some years of historic data recording missing? Did instruments used for data recording follow technical standards? Is meta data provided?
5. Assess the consistency of climate data. Measurements take place on the same location? How many models and scenarios are considered for projections?
6. For each climate parameter, assess the level of robustness of available climate data and information in a scale of 0 (virtually no robustness) to 7 (very robust data and information). Use expert discussion to reach a result. Outside the training, inform yourself on different benchmarks.
7. In a second matrix, identify first again the addressed climate parameter.
8. In the following columns, place the sets of climate data and information, grouped by type of climate data (, e.g. GCM, historical data, news clippings, etc.).

Matrix 2.1.1 Results of Interpretation and Robustness Assessment of Climate Data (results for illustration only)

1. Climate parameter/event addressed	2. Type of climate data	3. Source of climate data	4. Quality of climate data	5. Consistency of climate data	6. Level of robustness
Annual precipitation	Historical weather data in Metropolis	National Meteorological Institute	Good quality, 53 years of data with no gaps, measuring 4 times per day	Good consistency, no change in location on measuring equipment	7
	Global Climate Models: HadGEM2, MIROC, and CanCM4, for RCP 4.5	Met Office UK	Good quality, although only in grids of 150x150 Km	Good consistency, but only three models and one scenario	5
	RCP of HadGEM2, for RCP 4.5	Met Office UK	Good quality, in grids of 5x5 Km	Good consistency, but only one model and one scenario	4
	Literature review	Global Climate Change Journal	Good quality, reviewing several climate models for RCP 8.5	Good consistency, several climate models used, but only one scenario	6
Heat waves	...	...			

9. Place under each type of climate data and information the level of robustness identified before. If you had different sources of climate data or information for each type, calculate the average. This number corresponds to the weighting.
10. For each type of climate data assess what kind of trend is shown for your region of interest, as shown in Matrix 2.1.2. Use '+1' for a trend to increase, '-1' for a trend to decrease, and '0' for no trend of change for the climate parameter. Include a written description to justify your choice. The reason of focusing on trends has to do with the fact that climate information rarely show 100% concordance, what can be the result of using different climate models or scenarios, or gathering different type of data. For this reason, focusing on trends are at least an indicator for tendencies.
11. Sum up the weighted trend for each source within each climate parameter, counting increasing trends as positive, and decreasing trends as negative. When there is no trend or there is uncertainty about the trend, this is not counted. The weighted trend is the product trend multiplied by robustness.
12. Sum up all weighted trends for each climate parameter.
13. Finally, compare final scores for each climate parameter. In the example the maximum value is 4 * 7 = 28. The higher the score (both negatively and positively), the stronger a climate trend can be considered. For the example the increasing trend seems more likely than not, given the sum of the weighted trend just resulting in 9 (out of a maximum of 28) and slightly more robust data for the increase.
14. Discuss within your group how strong the agreement in trend (trend concordance) is in a scale from 0 (no agreement in trend at all) to 7 (virtually perfect agreement in trend) and place this figure under the final score.

Matrix 2.1.2 **Results of Interpretation of Trends of Climate Data**

	8. Climate data/information				
	Historical weather data in Metropolis	Global Climate Model, HadGEM2, for RCP 4.5	RCP of HadGEM2, for RCP 4.5	Literature review	
9. Robustness:	7	5	4	6	
7. Climate parameters addressed	10. Trend for each set of climate data/information 11. Weighted trend = trend * robustness				12. – 14. Trend (final score)
Annual precipitation	+1 (an average of +0,2 mm/year) (+1)*7 = +7	0 (no perceived change) 0*4 = 0	-1 (an average of -0,1 mm/year until 2100) (-1)*5 = -5	+1 (an average of 0,3 mm/year until 2050) (+1)*6 = +6	Sum of weighted trend: 7+0-4+6 = +9 Agreeent in Trend: 4
Heat waves	…	…	…	…	+18 Agreeent in Trend: 6

As mentioned in Box 2.1.2, the interpretation of likelihood is the multiplication of agreement in trend by robustness. This multiplication has been performed in the above described exercise. Depending on the amount of samples of climate information, the maximum result is different, umping by 7 for each sample.

It makes sense to develop an according likelihood matrix for the selected amount of samples. The example in Matrix 2.1.3 has been developed for 7 samples. A matrix for 4 samples would have a maximum value of 4 at 'Agreement in Trend', a matrix of 10 samples – accordingly – 10.

Matrix 2.1.3 **Results of Interpretation of Likelihood of Climate Parameter Trends**

Agreement in trend								
7	0	7	14	21	28	35	42	49
6	0	6	12	18	24	30	36	42
5	0	5	10	15	20	25	30	35
4	0	4	8	12	16	20	24	28
3	0	3	6	9	12	15	18	21
2	0	2	4	6	8	10	12	14
1	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
	0	1	2	3	4	5	6	7

Robustness (type, amount, quality, consistency

exceptionally unlikely	extremely unlikely	very unlikely	about a likely as not	more likely than not	likely	very likely	extremely likely
0	1	2	3	4	5	6	7

Colour code for likelihood

2.1.4 Guiding questions for reflection

- Where do users obtain the climate data and climate information they need for decision making?
- Which kind of climate data and climate information is needed to assess future impact of climate change?
- Who should be invited to assess climate data and information?
- What are relevant criteria for climate data robustness? Are the criteria different, depending on parameters and sources?
- What can users do if available climate data is not helpful enough for decision making, e.g. because they are not sufficient or the robustness is poor?
- What are the results of the interpretation of the probability of climate parameter trends useful for?

2.1.5 Take away messages

- Climate change is an issue that affects societies and their livelihoods now, and it will affect even more in the future, depending on how greenhouse gases concentrate in the atmosphere in the following years.
- It is uncertain how the climate will evolve in the next years and decades, but societies need to be prepared for this change.
- Climate change affects different regions with different intensity. Even within regions impacts of climate parameter can be different.
- Climate information helps to assess how climate parameter are changing and may change in the future. Accessing different sources of climate data and information helps to confirm eventually identified trends.
- The probability for climate change-related events to happen is connected to the clearness of trends and the robustness of available and accessed climate data and information.
- Climate parameters and effects lead to (bio-)physical and socioeconomic impacts. They can be determined by applying impact chains.

2.1.6 References

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2.1.7 Personal notes

2.2 Climate Change and Public Infrastructure Investment

Climate Change is a factor which will affect current and future investment into public infrastructure. The Nationally Determined Contributions to the Paris Agreement (NDCs) or the National Adaptation Plans (NAPs) set goals at national levels which are entry points to discuss the need for integrating adaptation to climate change into infrastructure investment planning. These entry points go beyond engineering options for a given infrastructure project. At governance level, the interest is in achieving the goals of these policy instruments, thus to prioritize projects, funding sources and stakeholder groups who should take a role in the following processes. To better understand the approach, a Climate Lens is applied at a territory covered by a given policy framework. This tool supports the identification of infrastructures at risk which should receive attention soon, key stakeholder groups who should participate in the following processes, the need for climate services and possible finance from different investor groups.

2.2.1 Skills and knowledge

- The trainee understands the importance of adaptation to climate change for sustainable infrastructure investments and is able to reflect on the role of climate services and climate proofing.
- The trainee is able to identify entry-points for adaptation to climate change in infrastructure investment planning.
- The trainee is able to identify relevant stakeholder groups who should be involved in detailed infrastructure investment planning processes.

2.2.2 Context

> *'We are not on track to meet climate change targets and rein in temperature increases.'*
> *Petteri Taalas, Secretary-General of the World Meteorological Organization*

Climate Change and infrastructure

The 20 warmest years on record have been in the past 22 years, with the top four in the past four years. The Intergovernmental Panel on Climate Change (IPCC) concludes that the average global temperature in the decade prior to 2015 was 0.86 degrees centigrade above pre-industrial levels. Between 2014 and 2018, this average already has risen to 1.04 degrees centigrade above the pre-industrial baseline. It makes a difference to the speed of glacier melt, water supplies, and increasing sea level (IPCC 2018).

Every fraction of a degree of warming makes a difference to economic productivity, food security, and to the resilience of infrastructures and cities. The requirement to accomplish sustainable public infrastructure investments under conditions of climate change (e.g. mass transportation, energy distribution and coastal protection) is more challenging and urgent than ever: Unless the world embarks on large-scale economic transformation to reduce greenhouse gas emissions, in approximately 10 years, average world temperatures will increase by 1.5 degrees above pre-industrial levels. This will put added stress on the aging infrastructure over time. Sea level rise and storm surge, in combination with the development in coastal areas, already represent a threat to infrastructures such as roads, buildings, ports, and energy facilities. Floods along the rivers and on lakes, following heavy downpours and prolonged rains, damage infrastructure in urban and rural areas. In addition, extreme heat causes damages to transportation infrastructure such as roads, bridges and energy supply systems.

Every dimension of the climate change and infrastructure investment agenda must shift from business as usual to climate proofed. Therefore, the sustainability of investment for maintenance of existing or planning of new infrastructures depends on the consideration of projected climate change effects, including sea level rise, storm surge, and extreme weather events, in every step of the infrastructure investment planning cycle.

Funding a Resilient Transformation

Budget constraints mean that governments already struggle to keep up with the need for infrastructure investments. According to OECD, 95 trillion USD will need to be invested into infrastructure until 2030 (OECD (2017). Making existing and new infrastructure resilient towards climate change will require additional funding for adaptation, not only in terms of costs for adaptation measures but also as Climate Risk Management requires additional, or the redistribution of existing resources. It also means that priorities for how money is spent on infrastructure need to change in order to ensure the money spent unfolds its full potential in terms of furthering sustainable development.

Instead of following incremental adaptation approaches, the mainstreaming and institutionalization of processes of climate proofing in the infrastructure investment cycle is a key factor for ensuring enough funding for adaptation. It does not only offer cost-saving potentials (e.g. by already addressing climate-risks in land use planning which reduces resource requirements for building back better operations of infrastructure assets in post-disaster recovery processes) it also offers the potential of reaping co-benefits.

The effort to measure the impact of climate resilient investment is important for quantifying the benefit to investors. The multilateral development banks (including the World Bank, the Inter-American Development Bank and the European Bank for Reconstruction and Development) are developing common principles for climate resilience metrics for their investments, while the ratings agency Standard & Poor's is also working on metrics to quantify the impact of resilience investment (Baum and Davies 2017).

Private Sector as key stakeholder for ensuring climate-resilient infrastructure

The private sector plays an essential role in the climate proofing of infrastructure. On the one hand, the private sector is a major beneficiary of a well-functioning infrastructure system. Reliable, climate-resilient infrastructure substantially contributes to reducing business risks, making a given location more attractive for private sector investment. On the other hand, the private sector is itself involved in planning and managing infrastructure. The interdependencies between infrastructures and the criticality of some privately-owned ones, such as communication infrastructure, means that for the resilience of society, the private sector needs to be involved in any climate proofing efforts.

2.2.3 Concept: Entry points for adaptation to climate change in sustainable infrastructure investments

National political climate change frameworks and sector crosscutting cooperation in disaster risk reduction are important entry points to consider adaptation to climate change in public infrastructure investment.

Policy Framework for Climate Resilient Infrastructure

Countries which are committed to the Paris Agreement (2015) of the UNFCCC and approved the guidelines for implementation in 2018 set the national framework for selected economic, social and environmental sectors. Economic and social wellbeing depend on climate resilient public infrastructure, namely roads, bridges, airport runways, electricity assets, seawalls, damns or others which fulfill protective or communicative tasks. National Adaptation Plans (NAPs) and Mitigation Plans (NMPs) shall be integrated into the national framework which facilitates the achievement of the Nationally Determined Contributions (NDCs). Finally, all sectors of a country, including infrastructure, have to present their own strategies, plans, programs and projects addressing these NDCs.

Entry points to mainstream adaptation to climate change in infrastructure investment

The first entry point is during the formulation of policies and plans (Phase 1, Fig. 2.2.1). Here, climate scoping helps to identify if the policy's or plan's targets are endangered by climate risk. Project preparation (Phase 2, Fig. 2.2.1) offers entry points for climate proofing like allocating specific funding to climate change adaptation. In project development (Phase 3, Fig. 2.2.1), incorporating a component-based climate risk assessment (see chapter 4.2) as part of the environmental and social assessment can contribute to reducing climate risk. In the financing phase (Phase 4, Fig. 2.2.1), climate criteria would be part of the safeguards applicable to infrastructure project finance. During project implementation (Phase 5, Fig. 2.2.1), climate change criteria could be decisive in the selection of construction bids, based on a procurement framework that incorporates climate criteria. During operation (Phase 6, Fig. 2.2.1), resilience to climate change criteria can prove decisively in monitoring, with the results of monitoring feeding back and forward into the process both of planning new as well as the operation and maintenance of existing infrastructure. While the policy and sector level are the focus of this sub-chapter, the project level will be followed up in depth in chapter 4.

The case of Costa Rica

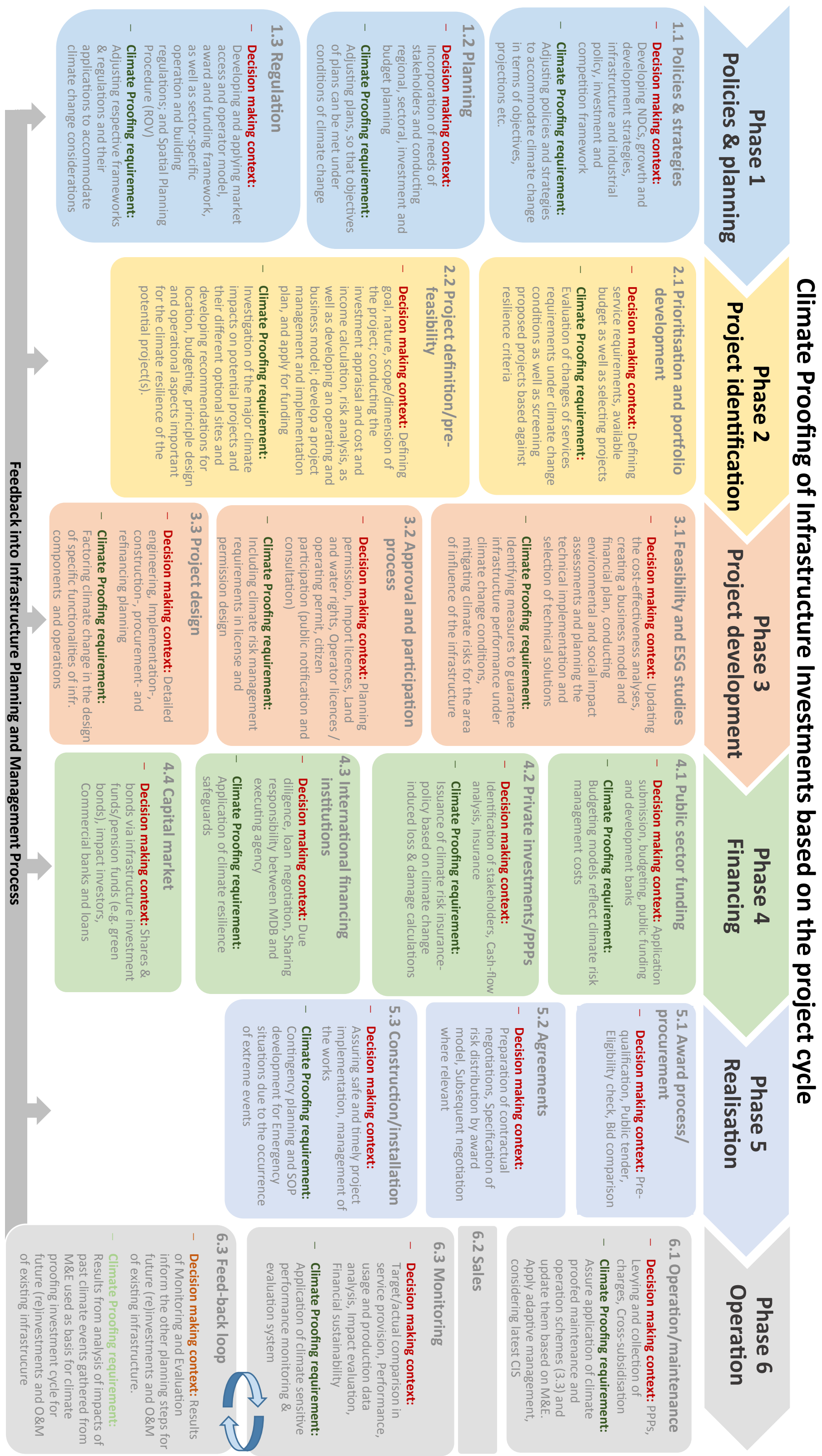
Costa Rica is aware of climate change and related effects and adopted a National Climate Change Strategy (NCCS) in 2006. The adaptation of public infrastructure to climate change is highlighted in the Intended Nationally Determined Contributions (INDCs 2015). One goal until 2020 is the utilization of methods for the identification and prevention of infrastructure vulnerability as well as the development of a respective monitoring system. The National Adaptation Policy was decreed in July 2018. Selected goals are:

- Strengthening of norms and guidelines for public investment with criteria of adaptation to Climate Change that guarantee the design of infrastructures and adapted services and ensure their utility and continuity of services.
- Protection of public infrastructure, through appropriate risk assessment and the adoption of protection mechanisms ensuring the robustness of infrastructure works.
- Implementation of an open climate data policy by 2020.
- Enabling information platforms and climate services, […], in order to collect data and generate and disseminate climate scenarios at the necessary scales that facilitate a better decision-making and guide adaptation actions within the framework of public and universal access information systems.
- Promotion of scientific research, systematic data collection and current and prospective analysis of information on impacts, losses and damages due to hydro-meteorological threats, as well as quantifying and analyzing costs, opportunities and social benefits associated with Climate Change adaptation measures in different sectors for decision-making.

Further details, watch https://youtu.be/4sTBWQEC2TA

Source: GIZ-DWD 2018

Figure 2.2.8 Climate Proofing entry points in infrastructure investment



Source: Baumert und Lotzen, GIZ 2019

Climate Services - Effective Cooperation as basis for evidence-based decision making

The elaboration of tailor-made climate information provides the opportunity for evidence-based decision making in each of the optional entry points for climate proofing in the different phases of the infrastructure investment cycle. More than ever before, the successful implementation of climate proofing of infrastructure depends on Climate Services and the regulation that stimulates the demand for Climate Services.

The elaboration and tailoring of climate information products require effective cooperation and institutionalized arrangements across sectors, between the stakeholders involved in the planning and operation of infrastructure as well as the providers of Climate Services (e.g. risk assessments). Thereby, processes of co-design of climate knowledge products, the sharing of resources and knowledge still has great potential for efficiency gains. These will be achieved by making data as well as existing Climate Service products centrally accessible; and avoiding the duplication of efforts by different actors working in the same sectors.

However, so far meteorological and hydrological data bases are dispersed; and comprehensive catalogues of available Climate Services are virtually non-existent. This and other challenges lead to the fact that the co-production and use of Climate Services in infrastructure investments are not yet well established. Although, in the agricultural sector Climate Services are already part of agricultural advisory services (especially in the area of now-casting, as well as short-term and seasonal forecasting), Climate Service that allow climate predictions (long-term) based on the established live cycle of an infrastructure are the exception.

2.2.4 Exercise Climate information for decision making

Learning objectives

1. You will learn how uncertainty related to climate change affects investment-related decision-making under this kind of uncertainty.
2. You will experience how investments get increasingly endangered due to climate-change.
3. You will experience the value of proper climate information in decision-making, and how they contribute to reduce climate related risks of loss and damage.
4. You will understand how adaptation measures help to reduce your climate-related risks of adverse impacts.

Content and main tasks

- Getting into the role of a decision-maker facing climate risk in the context of infrastructure development.
  > Challenge definition

- Making decisions on risk-mitigating measures.
  > Decision-making under uncertainty.

- Setting the price to purchase by auction climate information.
  > Investment decisions towards needs-adapted Climate Services.

- Setting the price to purchase by auction climate-proofing services.
  > Investment decisions towards climate-proofed infrastructure.

- Experiencing how climate change modifies risk patterns of infrastructure investment.

Table 2.2.1 **Results sheet for Exercise**

	Decision: mark 1 option	Rainfall	
		Regional	Local
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
	Remaining beans:		

Offered ____________ beans at the Climate Service auction.

Did your team win the Climate Service auction?
(yes/no): ____________

Offered ____________ beans at the climate-proofing auction.

Did your team win the climate-proofing auction?
(yes/no): ____________

Method: Learning from experience with a case study

This is an activity that simulates decision-making processes under uncertainty (based on Red Cross Red Crescent 2014). You are Infrastructure Delegates, each one placed in different cities and different states of the fictitious South Country. As each state of South Country has a total of three cities, participants will sit in teams of three players. While consultation with team members is encouraged, each participant's decisions are individual decisions.

The task of you and your colleagues as Infrastructure Delegates is to keep the infrastructure in your cities working, no matter how the weather or the climate is like.

The exercise will be directed by the trainer, based on the Trainer Handbook. Please use Table 2.2.1 as indicated by the trainer.

2.2.5 Take away messages

- Infrastructure investment might be under threat due to climate change related effects. For this means, it is key to take climate change into consideration when planning to invest in infrastructure.
- Different infrastructure investment frameworks and cycles require different kinds of Climate Services. Climate Service needs may vary regarding
    - the context of use. i.e. sector,
    - the type of decision which needs to be made based on this climate information (e.g. planning investments, mainstreaming climate change into pre-feasibility and feasibility studies, developing new building codes and standards etc.),
    - the decision-maker and his/her demands regarding the three dimensions of CS (user type),
    - the characteristics of the climate-value chain for the specific CS product, i.e. the kind of stakeholders who are involved.
- The context of use may have consequences on the required temporal and spatial resolution, time-frame of projections, accuracy/uncertainty of projections, the tailoring and provision of the Climate Service product, required services like guidance and support as well as access mechanisms and provider-user interaction.
- Competences and requirements of Climate Service 'knowledge brokers' who guide the co-design of Climate Services include communication & social skills, technical skills and managerial skills.
- User-interfaces for Climate Services can be operationalized and set up on an ad hoc-basis, or institutionalized as a permanent service within a Climate Service governance regime (Link to 3.1).

2.2.6 References

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2.2.7 Personal notes

Module 3

Concept and need for user friendly climate services

3.1 Introduction to Climate Services

3.1.1 Skills and knowledge

- The trainee gains awareness and understanding of the 5 main components of the concept of Climate Services.
- The trainee understands key issues related to the Climate Service value chain, needed to construct Climate Service products.
- The trainee gains awareness about the 'three dimensions of Climate Services' and their relevance to create needs-oriented Climate Service products.

3.1.2 Context Emergence of Climate Services

> *'[…] apart from the role of the IPCC in providing comprehensive user friendly assessments of the state of knowledge of climate change, less progress has been made in translating scientific progress into user-friendly climate services and their application for the benefit of society' (WCC-3 statement).*

Relatively stable climate conditions in the past, upon which our society is built, and has been resilient to for many decades or even centuries, are no longer reliable. Already today and much more in the future, climate conditions change up to a level that exacerbates the coping range of today's society, causing loss and damage to our societal systems and subsystems. Hence, the combined effects of climate change and the factors and processes that increase society's vulnerability to these changes in climate (e.g. due to macro-societal trends such as population growth, intensifying exposure of settlements, economic assets and infrastructures to climate events, environmental degradation, maladapted land-use practices, weak governance systems etc.) pose unprecedented challenges for current and future decision makers. In pursuit of tackling these challenges and develop well-adapted societal systems to the changing climate a key question and challenge to follow-up on is:

> *What is the evidence base that our societies can build upon for the development of climate resilience pathways?*

Indeed there is a 'growing need to better understand
a. climate,
b. the interrelation between climate and socio-economic systems; as well as
c. climate predictions and
d. how to better use this information to serve society's needs.

The growing recognition of this need has floored the emergence of the term and debate around 'climate service' at international and increasingly also national levels. Many countries are currently investing in the development of climate service capabilities (WMO 2014). The World Meteorological Organization (2014) defines Climate Services as follows:

> *'Providing climate information in a way that assists decision making by individuals and organizations. A service requires appropriate engagement along with an effective access mechanism and must respond to user needs.'*

But, how do we build up local, national and international capacity to strengthening the provision and use of climate services as an evidence base for taking adaptation decisions? How a climate-service-governance system can and shall look like? How can climate services provide such information to support decisions on robust and economic viable solutions?

From this point of view, key aspects of Climate Services can be framed:

- Climate Services are **ready to use** for the decision-maker, both regarding preparation (i.e. availability of tailored product) and provision (i.e. accessibility of tailored product). The first may also involve the collation with other (non-climate) data in order to provide the required information.
- Climate Services **consider user needs** by being tailored to the context of the user's problem and location (usefulness) and the user's specific needs as decision-maker (usability). The usefulness can be ensured by adjusting the technical characteristics of the products (e.g. parameter/indices, analysis, scale, etc.) to user needs. The usability can be enhanced

by providing an appropriate presentation of the climate information as well as support service and material (e.g. guidance, training, etc.) together with the products according to the individual needs of the decision-maker. Ultimately, these user needs can be assessed by building and maintaining relationships and cooperation with stakeholders of the Climate Service value chain. This not only enhances the understanding of Climate Service providers on user needs, but also improves availability and access to Climate Services by its users, as well as the knowledge about usability.

Key infrastructure and capabilities for climate information provision exist in many countries and regions of the world. However, there still is limited access to effective climate impact information for decision-making. In order to meet these challenges, to coordinate existing initiatives and to develop new infrastructures, the World Climate Conference-3 (WCC-3) in 2009 established the Global Framework of Climate Services (GFCS).

The GFCS accelerates and coordinates the technically and scientifically sound implementation of measures to improve climate-related outcomes at national, regional and global levels. Here fore, it enables the development and application of Climate Services, assisting decision-making at all levels in support of addressing climate-related risks (GFCS 2019).

In order to achieve this mission, the GFCS formulated five goals that guide its work:

1. Reducing the vulnerability of society to climate-related hazards through better provision of climate information;
2. Advancing the key global development goals through better provision of climate information;
3. Mainstreaming the use of climate information in decision-making;
4. Strengthening the engagement of providers and users of Climate Services;
5. Maximizing the utility of existing Climate Service infrastructure.

By institutionalizing Climate Services via the GFCS, the WCC-3 also ensured that Climate Services take into account climate change as risk multiplier. Climate information and its services were here perceived as having a key role to protect livelihoods and save lives. Therefore, it is key to mainstream it into policy frameworks and the development discourse.

3.1.3 Concept Climate Services Value Chain and Climate Service Products

The vision of the GFCS is 'to enable better management of the risks of climate variability and change and adaptation to climate change, through the development and incorporation of science-based climate information and prediction into planning, policy and practice on the global, regional and national scale'.

Climate information should be ready to use, while considering user needs. In order to ensure this, the concept of the 'three dimensions of Climate Services' has been created (see also Figure 3.1.1). These dimensions are defined as follows:

- The **technical dimension** defines the usefulness of a climate information product. It refers to the content of climate information and its relevance for a specific user, user group or sector (e.g. suitable parameters and indices and the type of statistical analysis). It also refers to the contextualization of climate information with respect to temporal and spatial scale and resolution. And furthermore, it comprises the quality of climate information and the provision and communication of meta-data and information on uncertainty along with the climate information.
- The **service dimension** defines the usability of a climate information product. It refers to dissemination and utilization of climate information. Dissemination comprises the provision of physical access to climate information (e.g. data platforms, filter systems, etc.) but also the promotion of climate information to enhance visibility and perception of the added value for the user. A critical aspect of dissemination is the timing of delivery and update frequency of climate information. Utilization refers to the format and style of presentation of climate informa-

Climate Services Value Chain for Water Infrastructure in Viet Nam

Viet Nam is aware of potential climate-related risks for the Mekong delta and its water infrastructures with functions of regulating water resources and coastal protecting. In order to guarantee the functionality of the water infrastructure in the future and minimize costs for their preservation and reconstruction, climate proof-infrastructure systems are essential. Climate risk management processes require the availability of adequate climate information which can be incorporated into development decisions and policy at relevant scale. In the context of the CSI project, a baseline to assess and analyze the current state of a National Climate Service for the context of the water infrastructure sector was performed, with case study at Cai Lon – Cai Be sluice gate construction project in Kien Giang province.

The results from the analysis of the climate value chain can be summarized by the following statements:

- The PMU 10, as owner of the infrastructure project, is the user of the provided climate service, including climate products and climate-proof recommendations for the infrastructure.
- The Southern HydroMet is climate service provider
- The Southern Institute for Water Resource Planning (SIWRP) takes a central position within the climate-value-chain of the water infrastructure sector coordination, both regarding the coordination of sectoral tasks of technical consultancy and planning processes as well as the use of climate information. This stakeholder also takes functions of Climate Service intermediates which imply the provision of value-added climate information products.
- There is a gap in the systematic production and management of such value-added products relevant for the water infrastructure sector. Four possible reasons for this gap are identified:
  (1) Lack of capacity to develop and provide climate services, especially in the context of NHMS upgrading its role as HMA;
  (2) Limited in product vision and lack of marketing of climate products;
  (3) Limited access and access to data and climate services;
  (4) Lack of integrated cooperation structure with key stakeholders from planning and construction investment in water infrastructure and coastal protection of Mekong Delta.

This baseline is a relevant point of departure to identify measures to improve the value chain. (GIZ 2018)

Further details, watch https://youtu.be/4sTBWQEC2TA

Source: GIZ-DWD 2018

tion (e.g. maps, graphs, diagrams, etc.) but also the support of the user in using climate information for his decision-context. This may comprise assistance for data interpretation, decision-support tools and advice for the implementation in decision-making processes as well as training and educational material on these issues.

- The **institutional dimension** constitutes a framework for the formation of the technical and service dimension. It refers the cooperation of relevant stakeholders which are involved in the production of a Climate Service. This implies the cooperation between various (climate) data and information providers as well as the relationship to users to guarantee usefulness and usability of climate information. But also cooperation to political stakeholders to ensure appropriate data policies (data access and availability) mandates and guidelines for the use of climate information' (GIZ 2018:18f).

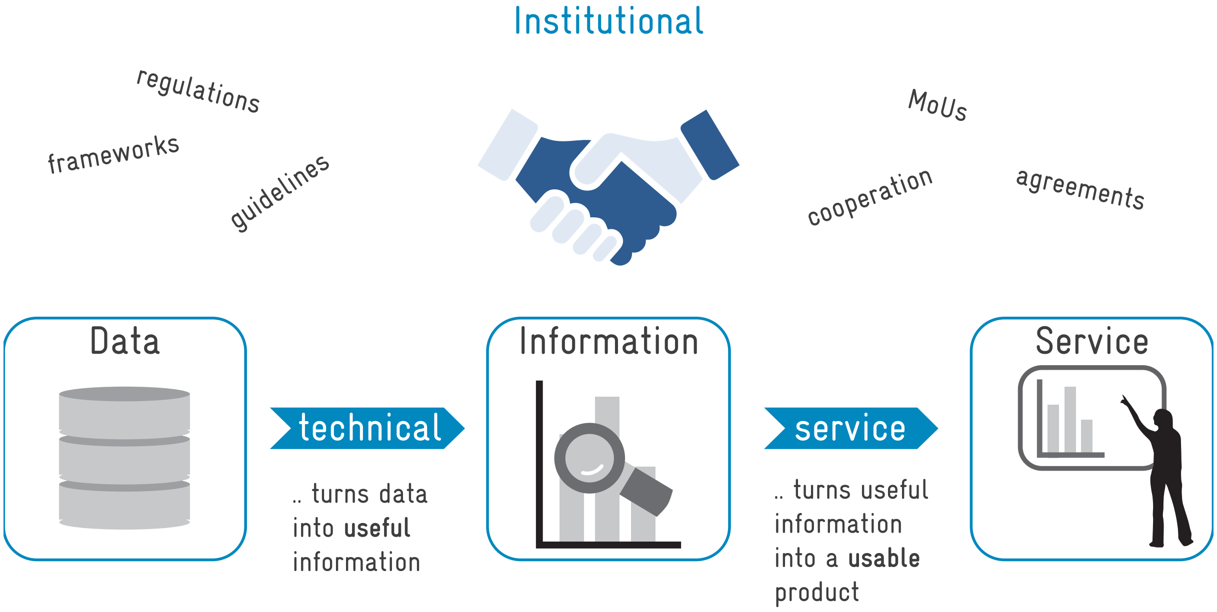
By these means, a Climate Service product does not only need technical input but also needs to focus on the provision, communication, and advice on climate information, as well as the interaction with users and other stakeholders. Hence, the governance of climate information production and provision plays a major role. From this point of view, a Climate Service product needs to be considered in most cases as a joint product of several stakeholders, what requires cooperation and coordination in order to produce added value to users and – therefore – be ready to use.

In this context, the term climate value chain has been created. It describes an end-to-end climate information production cycle that 'is characterized by one or several steps of value-adding which might be tailoring of data or provision of information and services, etc. to make climate information usable' (GIZ 2018:19). These steps are performed by various stakeholders, characterized as follows (see Fig. 3.1.2):

- '**Providers:** providers of climate information collect, manage, archive and provide climate data and also basic climate diagnostic- and monitoring products as well as climate predictions and projections. Key providers at national level are mainly National Meteorological and Hydrological Services (NMHS). Also important are academia (e.g. universities, research institutes) for model and product development as well as external data providers which provide data and products from the regional or global level. In many contexts the private sector may also collect relevant climate data for own interests which is, however, not systematically provided to a central database of a NCS.

- **Intermediates:** intermediates have the function of adding value to climate data or purely climate information in order to make it useful for the context of the decision-maker. They can be differentiated in basically two types: (1) technical intermediates refine basic climate data or information by tailoring and/or adding external data (e.g. modelling future river flow, based on climate data and river flow models). Important stakeholders may be impact modelers, risk managers or authorities (line ministries) who can often be found at the sectoral level; (2) institutional intermediates or boundary or-

Figure 3.1.1 **The three dimensions of Climate Services. The technical dimension turns data into useful information by tailoring of the data. The service dimension turns useful information into a usable climate information product by tailoring the presentation and format of the information as well as providing user-specific support and advice. The institutional dimension provides the institutional framework within a co-production of Climate Services can be realized by the cooperation of climate information providers and users.**



ganizations have the function as communicators of climate information as well as advisors for decision-making. This can be the preparation of special publications, or the communication of climate information in reports or trainings. Private companies, None Governmental Organizations (NGOs), Community-based Organizations (CBOs) and media are important stakeholders. Another group of institutional intermediates are 'enablers' who provide basic resources like global and regional data, knowledge and capabilities (e.g. UN organizations) and funding (e.g. development banks). Intermediates are also users of climate information but with the main function as a value-adder, communicator or purveyor of climate information.

- **End-Users:** the term end-user predominantly targets stakeholders who use climate information for decision-making in a practical context, from the national to the community level. In this concern they can be distinguished from intermediates. Important stakeholders for infrastructure sectors are managers, planners, engineers or politicians' (GIZ 2018:19).

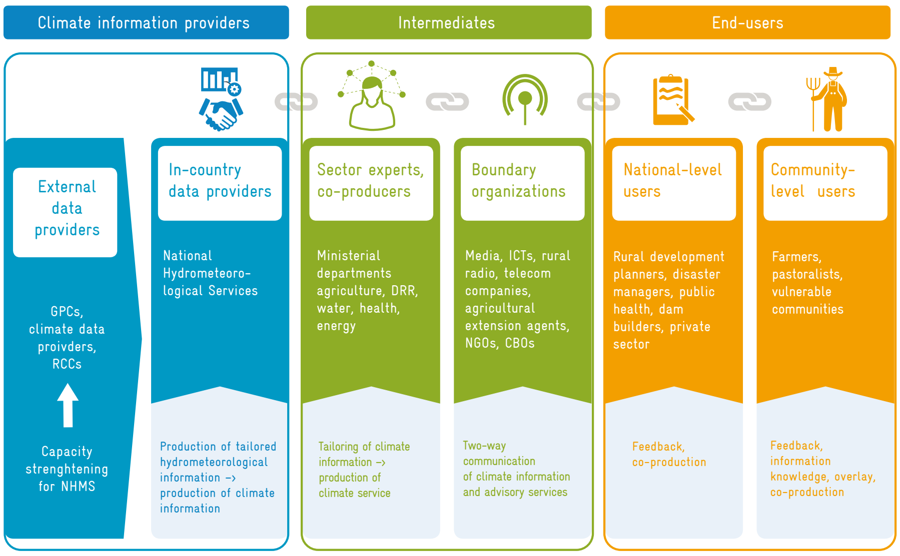
In order to successfully develop, produce and provide Climate Service products for different user groups, the GFCS has developed five components of tasks that interact one with each other, as detailed in Figure 3.1.3, which are also called the 'Big 5 of Climate Services'. Their scope can briefly be characterized as follows:

- **Observations and Monitoring (OM):** OM refers to the observation and monitoring of all relevant climate variables (Essential Climate Variables (ECV's2)) and climate phenomena and weather events. Additionally, the integration of socio-economic, biological, and environmental data should be considered in order to produce sector-specific Climate Services.

- **Research, modelling and prediction (RMP):** RMP refers to the improvement of the knowledge of the climate system and especially the interaction with other systems (e.g. impacts and consequences of cli-

[2] ECV – Essential Climate Variable. An ECV is a physical, chemical or biological variable or a group of linked variables that critically contributes to the characterization of Earth's climate.

Figure 3.1.2 **Concept of the climate value chain including the three major stakeholder types: climate information providers (blue box), intermediates (green box) and end-users (yellow box). The stakeholder types are subdivided by sub-types. For each sub-type examples for specific stakeholders are given (colored area) as well as their functions regarding Climate Service development and provision (grey area)**



(GIZ 2018, modified from WMO 2018)

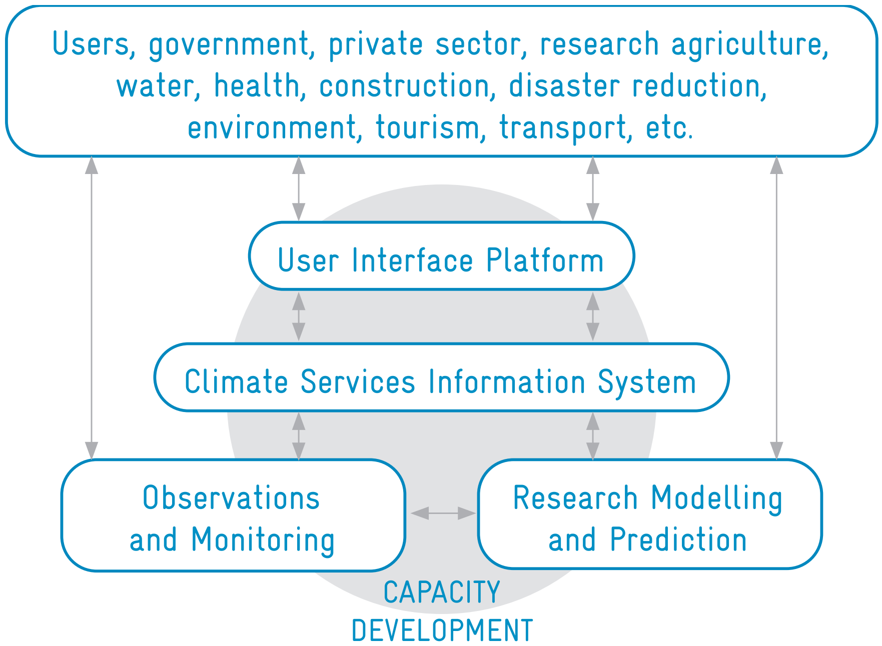
mate change) as well as enhancement and development of climate models, tools and methodologies.

- **Climate Service Information System (CSIS):** The CSIS is the operational hub of all other pillars at which data, information and knowledge is turned into CS products. This includes the physical infrastructure of institutes, centres, and computer capabilities, as well as professional human resources that routinely process and/or interpret data and products in order to generate and deliver user-relevant climate information and knowledge. This includes the generation, exchange and dissemination of climate information and products in a timely manner, with a focus at the national level.

- **User interface platform (UIP):** The UIP is a managed methodology, or a collection of methods, means, approaches, and processes of systematic and mutually beneficial collaboration that provides a structured means for users, climate researchers and climate data and information providers who come together, exchange on needs and capabilities regarding climate products and who co-develop them in a structured way. Within a UIP the co-design of Climate Services is facilitated and negotiated. User interfaces can take many forms, such as Face-to-Face meetings and workshops, or even digital solutions apply. A UIP shall be best facilitated by a professional knowledge broker.

- **Capacity Development (CD):** CD 'is the process through which individuals, organizations and societies obtain, strengthen and maintain the capabilities to set and achieve their own development objectives over time' (CADRI). It aims to meet capacity development requirements for each of the four other components by setting the foundation to create the enabling environment for implementation, institutionalization and coordination of these components at a national level (i.e. adjustment of national policies/legislation; CD for institutions, infrastructure and personnel). The organization and institutionalization of these tasks at a national level by consideration of all relevant stakeholders is termed as National Framework of Climate Services (NFCS).

Figure 3.1.3 The five functional components of GFCS



(WMO 2018)

The role and interaction of these 5 components can be briefly exemplified in a generic case study: a climate risk assessment shall be developed for infrastructure planning. The need for climate information relevant for the risk assessment is identified and communicated via a User Interface Platform were users formulate their needs for relevant climate information products and providers inform their capabilities in providing such products. The CS providers rely on Observations and Monitoring data, as well as on knowledge and tools (e.g. models) from the national, regional and global Research Modelling and Prediction community in order to develop and produce appropriate Climate Services in cooperation with other relevant stakeholders within the Climate Service Information System. Capacity development is fundamental to both to generate the knowledge on how to prepare a climate risk assessment, as well as to understand on how to communicate its outcomes and use it in infrastructure planning.

A key issue to be considered for the implementation of the five components - is the question of governance of Climate Services which implies the organizational and legal mechanisms on how to coordinate, facilitate and strengthen collaboration of CS stakeholders in order to improve the co-production, tailoring, delivery and use of science-based climate information and services. The governance concept of the GFCS is the National Framework for Climate Services which defines the functions of such a framework. However, the implementation of such framework is dependent on the national context and provides many challenges and open questions. E.g.: shall Climate Services be generally being freely available for all CS stakeholders and if yes to which degree of value-adding? How can Climate Services being produced economically and at the same time meet individual user needs? I.e. to what degree are standard products being produced and from which level starts individual tailoring? Who will do all the individual tailoring of climate information envisioning a broad demand and usage of Climate Services? What will be the role of the NMHS in this process? What will be the role of the private sector in this process? How to guarantee quality of CS when private stakeholders are involved who also have commercial interests?

3.1.4 Exercise Climate Services Product Development

Learning objectives

You will understand how each of the Big 5 components contributes to the development of useful Climate Services.

Content and main tasks

- Defining the scope of each component of the Big 5 of Climate Services
  > *Scope definition.*

- Defining tasks of each component
  > *Definition of technical, service, and institutional tasks needed to contribute to the development of Climate Services.*

- Identifying challenges of each component
  > *Identification of technical, service, and institutional challenges hindering the development of Climate Services.*

- Explore the Capacity Development component
  > *Identification of capacity development tasks and stakeholders that are required to achieve the goals of the other components.*
  > *Focus on the successful implementation of a National Framework of Climate Services.*

Method: Learning from exchange with others

You are part of the expert team that assesses each of the five components for Climate Services Product Development.

You and your colleagues explore tasks and challenges existing in each component that need to be taken into account in order to ensure the provision of useful Climate Services.

Please find some hints for a fruitful cooperation in the box 'Guidance for effective group work'.

Your specific tasks

- Review the sections 3.1.2 and 3.1.3, especially regarding the five components for Climate Service Development.
- Use a flipchart or board with cards.
- Form four groups, each of one working only on one of the below mentioned components of the Big Five of Climate Services:
  1. Observations and Monitoring (OM)
  2. Research, modelling and prediction (RMP)
  3. Climate Service Information System (CSIS)
  4. User interface platform (UIP)

Respond to the following tasks and present your results guided by matrix 3.1.1. You may use a concrete example, e.g. developing a map of potential climate impacts in a river basin for the year 2040, in order to be used in infrastructure investment.

- **Step 1.**
  - Identify the scope/objective of the component assigned to your group.
  - What makes this component relevant for the provision of Climate services?
  - What are essential characteristics of this component that would make it conducive to the development of Climate Services?/What are preconditions that need to be fulfilled in this component that would need to be fulfilled to allow the tailor-made provision of Climate Services?

- **Step 2.**
  - List approximately six tasks that need to be performed in order to meet the scope of the component.
  - If you understand that this task may also be part of another component, please specify.
  - Differentiate between technical, service, and institutional tasks.

- **Step 3.**
  - List all the challenges that can potentially hinder meeting the scope of the component.
  - If you understand that this challenge may also be part of another component, please specify.
  - Differentiate between technical, service, and institutional challenges.

Guidance for effective group work

- For effective and efficient work, a working group should select a facilitator, a time keeper and a presenter.
- Take your time to read through the task description and see if everybody is on board.
- The working groups work independently.
- Trainers can be asked for advice.
- The main learning objective is to learn about the systematic approach and not to be comprehensive in the task.

Matrix 3.1.1 **Revision of tasks and challenges under the scope of the component:**

______________________________ include name

Step 1: Scope		
	Step 2	Step 3
	Tasks	Challenges
Technical		
Service		
Institutional		

Once you finished the analysis of the component, discuss with your group peers the need for Capacity Development and present your results guided by matrix 3.1.2., following these steps:

- **Step 4.**
  - Identify the scope/objective of the Capacity Development (CD) component as part of the National Framework of Climate Services.

- **Step 5.**
  - Identify possible capacity gaps for all three dimensions and for linkages to other components: Technical, Service, and Institutional.
  - List capacity development measures which focus on bridging possible capacity gaps.

- **Step 6.**
  - Who are the stakeholders that would need to be involved in implementing the CD measures you identified?
- **Step 7.**
  - What are institutional tasks and challenges, and specific frame conditions, within your component to be considered in the establishment of a NFCS?

Matrix 3.1.2 **Revision of CD-gaps, measures and stakeholders of Component: ____________________ include name ______________________________**

Step 4: Scope				
	Step 5		Step 6	Step 7
	CD-gaps	CD-measures	Stakeholders (CVC)	Institutional tasks and challenges for NFCS
Technical				
Service				
Institutional				

Finally, all groups perform together the following steps:

- **Step 8.**
  - After finishing, all groups rotate to the next component. On each station, one person stays as 'host', introducing newcomers to the discussions that already occurred before.
  - Discuss the already displayed results.
  - If needed, complement the results.
  - Rotate four times, until coming back to the component that each group worked originally on.
- **Step 9**
  - Discuss the final results of your component with all inputs received from peers.
  - The 'host' presents a summary of the results to the plenary.

3.1.5 Guiding questions for reflection

- What is the selling point of Climate Services?
- What is the scope of 'considering user needs' in the context of Climate Services?
- What are the elements of the climate value chain and what does it describe?
- Which tasks and roles should be covered by a National Framework for Climate Services, and how should the different components interact with each other?

3.1.6 Take away messages

- Climate Services are defined as climate information which is customized to user needs.
- User needs refer to three dimensions of Climate Services (technical, service, institutional) which need to be adequately met to guarantee the usefulness and usability of Climate Service products and thus the impact on decision-making.
- A Climate Service product requires an end-to-end provision which (most often) implies a cooperative production process at which several stakeholders working together, either collectively, concurrently or successively. The process of CS production by successive value-adding by several stakeholders is termed as climate value-chain. Stakeholders of the value-chain can be classified as providers, intermediates and end-users.
- The development, production and provision of Climate Services requires five elements which need to

be covered and coordinated by stakeholders from the value-chain: (i) observation & monitoring, (ii) research, modelling and prediction, (iii) Climate Service information system (iv) user interface platform and (v) capacity development

- The governance of the CS development, production and provision (coordination of the five elements) is structured within a National Framework for Climate Services that delineates tasks and responsibilities of individual stakeholders and defines legal settings. Key stakeholder groups are: NMHS, line ministries, academia, enablers, boundary organizations and users.

3.1.7 References

CADRI. Capacity Development. www.cadri.net/en/areas-we-work/capacity-development (accessed 02. 05.2019).

GIZ-DWD 2018. Climate Services for the road infrastructure sector in Costa Rica. A baseline assessment report. GIZ Eschborn/Bonn, Germany.

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WMO 2014: Implementation Plan of the Global Framework for Climate Services. Geneva, Switzerland. www.wmo.int/gfcs/sites/default/files/implementation-plan//GFCS-IMPLEMENTATION-PLAN-FINAL-14211_en.pdf

WMO 2018: Step-by-step Guidelines for Establishing a National Framework for Climate Services. Geneva, Switzerland. www.wmo.int/gfcs//step-by-stepguidelines-nfcs

3.1.8 Personal notes

3.2 Demand driven Climate Services for resilient public infrastructure investments

3.2.1 Skills and knowledge

- The trainee understands the different requirements for Climate Service (CS) products for the specific sectoral and decision-making contexts of use and its challenges and opportunities.
- The trainee is able to apply and transfer knowledge about CS concepts into the field of infrastructure planning and climate risk assessments.
- The trainee understands the relevance of the three dimensions of CS to construct user-needs-oriented CS.
- The trainee is able to identify CS needs for specific infrastructure planning stages.

3.2.2 Context Use of Climate Services

> *'Use of climate information for decision-making requires bringing together organisations which in many cases have little or no experience of working together and do not have a well-established understanding of each other's ways of working.'*
> *Filipe Lúcio, GFCS Director*

Decision-makers in the context of public infrastructure investments often struggle to acquire and use Climate Services that are designed according to their needs. In certain situations, the provided services do not offer the required information for the specific context, or they are simply not understood. In other cases, the Climate Services have not been made available or access is very limited.

This issue, however, is also related to the fact that users often lack the capacity to define clearly their need or to process climate data appropriately in order to get the required information for their decision-making processes. Simultaneously, Climate Service providers fail to ask and/or understand which exactly the users' needs are, therefore also failing to design ready-to-use and demand-driven products.

With this in mind, the GFCS also includes among its principles to 'ensure greater availability of, access to, and use of Climate Services' (GFCS 2019), also by ensuring that Climate Services are developed following users' needs. This is both related to 'building user capacity to make beneficial use of climate services [and] including the capacity of providers to understand the specific needs of the end users' (ibid.).

Hence, the GFCS promotes the creation of User Interface Platforms (UIPs), which define user needs and provider capabilities, reconcile these, and supports the development and promotion of usable and decision-relevant Climate Service products (see also Figure 3.2.1).

3.2.3 Concept User Interface Platform and the co-design of Climate Services

The User Interface Platform is an indispensable instrument to bring Climate Service stakeholders together, pursuing to develop and implement an effective Climate Service value chain.

The User Interface Platform (UIP) is a forum or platform for Climate Service stakeholders to meet and interact, to establish mutually beneficial collaborations and finally develop usable and decision-relevant Climate Service products.

It can be defined as managed methodology, or a collection of methods, means, approaches, and processes of systematic and mutually beneficial collaboration. Its institutional structure and organization can be at national, regional, and/or local levels. Additionally, it can be structured user-specific, product-specific, or sector-specific. The set of methodologies and approaches, as well as the institutional frame, needs to be discussed and elaborated for each individual context and adapted if needed (see Figure 3.2.1).

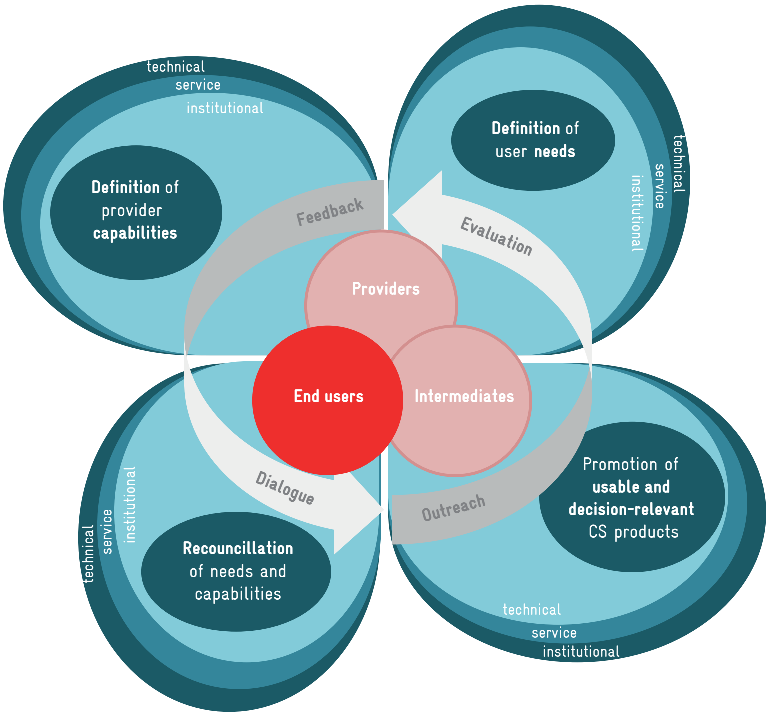
Following this purpose, the UIP brings together Climate Service stakeholders that can be differentiated as providers, intermediates, and end-users. These stakeholders are provided room to formulate their needs, define their capabilities and capacities, and finally reconcile and harmonize user needs and provider capabilities, following all three dimensions of Climate Services, meaning Technical, Service, and Institutional dimension (see also Module 3.1 for further detail on stakeholders and the three dimensions).

Between Climate Service users and intermediates, the UIP provides room for users to formulate needs regarding the technical dimension, mainly regarding needs on tailoring and contextualization of climate data and information (e.g. relevant temporal and spatial scales and resolutions; relevant parameters and indices; adequate statistical analysis; adequate format and presentation of data). Following Bessembinder (2012:12), climate information within Climate Services needs to fulfil three criteria in order to be useful for the decision maker: salience, credibility, and legitimacy:

- '**Salient** information/data are context sensitive and tailored to the users' requirements.' This implies the selection of appropriate climate variables, impact variables, events and/or indices, appropriate information content (i.e. type of statistical analysis), appropriate temporal scales, and appropriate spatial scales.
- 'Data users should consider [if] the information/data they are working with [is] credible. **Credibility** in the data may be achieved by various pathways ranging from scientific peer review processes, via strong communication between producers and users to the inclusion of users in the data production process. Jacobs (2005) stated ease of interpretation, clear communication of 'accuracy', or the possibility to assess the 'accuracy' of the provided data by themselves (e.g. by hands on training), to be essential. Furthermore, clear communications about the assumptions made, methodological shortcomings, validation methods as well as statements about uncertainties are important attributes that support enhanced credibility (Maraun et al., 2010);
- **Legitimacy** means that the provided information/data have been generated free from political persuasion or bias and that the interests of the users have been considered in the generation process' (Bessembinder 2012:12).

On the service dimension of the UIP, users can articulate needs on support-systems to get timely access to up-to-date climate information, including adapted formats to access information. Also within this dimension, needs on guidance, training and advice on the comprehension and interpretation of climate information (including formats of data and uncertainty levels), on the integration of climate information into de-

Figure 3.2.1 Functioning of User Interface Platforms



cision-making, and on the use of tools and guidelines (including its language) can be articulated by users to Climate Service intermediates.

User needs referring to the service dimension often depend on the user type. Different types of users have different knowledge about climate and capabilities to process climate data and deal with climate information. The capabilities and capacities to process data are often congruent to the specific positions of user groups within the value chain: especially consultants, engineers or researchers have the roles of intermediates and thus their capabilities and capacities to deal with climate data are different to the classical end-user.

The context of decision making (decision framework) is a very dominant factor for the determination of user needs, since it determines the addressee of the Climate Service product (end-user or decision-maker) and thus the user type as well as the need for the information content which the decision-context requires. For the infrastructure investment context, different implementation steps have different questions to climate and have thus different needs for the design of Climate Services. Depending on the context, the needs for climate information vary widely, with different considerations to be taken into account for different tasks (see also Table 3.2.1). E.g., for the pre-feasibility study of an infrastructure investment project a climate risk screening is required; for the feasibility study a detailed climate risk analysis; and for the assessment of risk management options also different Climate Services are required. Accordingly, decision frameworks are likely to be different in each implementation step (see also chapter 3.1).

Table 3.2.1 Key adaptation decision components and their requirements for climate information.

Adaptation decision stage	Level of requirement for climate information	Type of climate information required	Key considerations
Initial risk screening	Low – Medium	▸ Long-term observed climatologies and characteristics of extreme events ▸ Trends in projections of future climate	▸ Selected climate variables to be physically plausible and appropriate in relation to the key parameters of the system/activity being screened; ▸ Duration of data series to be sufficiently long to derive trends; ▸ Alternative projections of selected climate variables ▸ for future time periods to be considered for deriving ▸ robust directions of change
Detailed risk analysis	Medium- High	▸ Observed climatologies and characteristics of extreme events ▸ Climate change projections with varying spatial and temporal details	▸ Climate variables to be physically plausible and appropriate; ▸ Spatial and temporal scales of climate information to be fit for the objectives and context of the analysis
Evaluating the efficacy of adaptation options	Low, Medium, High	▸ Climate change projections with varying spatial and temporal details	▸ Climate information related uncertainties to be adequately treated according to the type(s) and planning horizon(s) of adaptive measures being considered

Source: NCSP 2009

Finally, users can formulate institutional needs regarding collaboration and agreements (MoUs) with relevant stakeholders to enhance provider-interaction, to enhance data access and flow, and to clarify the right-of-use of climate information. This is especially relevant in the context of a National Framework of Climate Services, where the coordination and organization of all stakeholders should be regulated at a national level, and not bilaterally only (see also chapter 3.1 with regard to Capacity Development).

Between Climate Service providers and intermediates, the UIP provides room for providers to formulate their capabilities and capacities of Climate Service development and provision, referring to the three key dimensions.

Regarding the technical dimension, providers formulate their capacities and capabilities on providing contextualized climate data and information (e.g. uncertainty and skill of products/model run regarding specific scales and resolutions, parameters/indices, statistical analysis, etc.). This aids to understand what to expect and to not expect from Climate Service products. WMO (2016) gives an overview of general types of climate products that can potentially be delivered:

- **Climatological data periodicals:** Most National Meteorological and Hydrological Services (NMHSs) issue periodical bulletins containing data from selected stations within particular regions or countries as a whole. This kind of data can be relevant to various economic, social and environmental sectors, which usually use them on a regular basis, e.g. water and energy providers.
- **Occasional publications:** Publications designed for those users who need information in infrastructure planning and investments, for members of the general public whose interests are academic or casual, or for researchers. They are also designed to summarize or explain unusual events or occasional predicted events (e.g. El Niño), eventually including potential impacts and thresholds.
- **Standard products:** Products that usually can be used by a wide range of users, e.g., both energy management entities and farmers. 'Such standard products fill the gap between the climate data periodicals and those tailored for individual users.' (WMO 2016:18)
- **Specialized products:** Products that are specific to an individual user or sector, focusing on the specifications that will enable the user to gain optimum benefit from the application of the information (e.g. flood analysis, required for the planning and assessment of flood defenses or the design of bridge structures).
- **Climate monitoring products:** Products aiming to understand current climate conditions in the country, region, or locality. They are essential for climate predictions and updates, and are often also used to prepare for extreme weather events.

- **Indices:** Products 'used to characterize features of the climate for climate prediction and to detect climate change. They may apply to individual climatological stations or describe some aspect of the climate of an area. Indices usually combine several elements into characteristics of, for example, droughts, continentality, phenological plant phases, heating degree days, large-scale circulation patterns and teleconnections' (WMO 2016:18f; see Module 2.1 for further detail). They are often used to assess potential future impacts of climate change with a focus on specific thresholds.

Providers usually face a key-challenge regarding their wish to provide Climate Services as specifically as possible to user needs, while not having the resources to satisfy this demand. For this reason, Climate Service providers often try to recycle their products and to only specify them as much as required to also satisfy the needs of other users or contexts.

With regard to the service dimension, providers and intermediates articulate capabilities and capacities on providing support-systems to enable timely access to up-to-date climate information, as well as on providing guidance, training, and advice on the comprehension and interpretation of climate information. In this context, they also assess possibilities on the integration of climate information into decision-making and on the development of tools and guidelines that eventually meet the needs of end-users or intermediates.

From an institutional point of view, Climate Service providers formulate their needs via the UIP regarding collaboration and agreements with relevant stakeholders to enhance user-interaction, pursuing to improve data access and flow and clarify right-of-use of climate information.

After assessing users' needs and providers' capabilities, the UIP – including all its stakeholders – reconciles and harmonizes all aspects in all three dimensions in order to coordinate the co-production of usable and decision-relevant Climate Service products and the corresponding organizational structures.

However, the co-production and promotion of Climate Services (and thus of reconciliation of interests, needs, and capacities) is a complex organizational process that potentially deals with a multitude of adverse factors. Briley et al. (2015) describe the three main barriers to create Climate Services as follows:

- **Mismatched terminology:** Climate Service providers and users often mean different things when referring to the same term. An example is the term 'downscaled climate projections'. 'Downscaling' for providers usually means 'output from numerical climate models that have either been dynamically simulated at very high spatial resolution or statistically adjusted to provide information at the regional scale' (ibid., 44). However, Climate Service users often mean by this term 'locally-relevant, narrative climate information about specific climate change impacts' (ibid.). Summing up, providers often want to discuss technical options on climate parameter delivery, while users in most cases just want to know how the climate might impact locally.
- **Unrealistic expectations:** Climate Service users are inspired in certain occasions by aesthetically pleasing maps regarding future climate from other contexts and regions. They tend to think that such a product will match their needs for climate information. However, spatial downscaling of future climate models does not always generate relevant information and often even represents information that has substantial inconsistencies.
- **Disordered integration – information fit:** Climate Service users often expect climate information to 'fit' their decision-making process. In these cases, they usually have not gathered local information and expect to receive ready-to-use information on vulnerabilities, impacts, and risk. In several cases, they rely on information that is released by Climate Service providers, without questioning its use and accuracy for their specific context. In these cases, there classically is not enough discussion from providers about users' specific key climate issues of concern.

In this context, the so-called Knowledge Brokers play a major role to help users overcome these challenges by working in chains to connect producers with users of information. They are intermediaries between users and providers, but mainly act as facilitators and communicators, e.g. by synthesizing information for a particular user and contextualizing it with information from the user's own sector and/or locality.

Being aware of these challenges, the UIP needs to be designed to bridge these barriers. The process of definition of needs and capabilities, reconciliation/harmonization and product development is an iterative process and a result of an integrated interactive communication structure. This should be provided by the UIP and its objectives formulated in four outcomes:

- **Feedback:** Identifying the optimal methods for obtaining feedback from user communities;
- **Dialogue:** Building dialogue between Climate Service users and those responsible for the observation, research and information system pillars of the GFCS;
- **Outreach:** Improving climate literacy in the user community, and literacy of the climate community in user needs;
- **Evaluation:** Developing monitoring and evaluation measures for the frameworks that are agreed between users and providers.

3.2.4 Exercise User-Provider Interaction on Climate Service co-production

Learning objectives

Participants shall learn the functionality and benefits of a User Interface Platform (UIP). The participants shall get aware of the value of direct and structured interaction between CS providers and users in order to identify and clarify user needs and to identify and communicate suitable CS products, their potentials and limitations (for the specific context). Thereby, the participants shall become aware of importance of the co-design of climate information for decision-making where the following questions are addressed:

- **What are the technical necessities to tailor CI products in order to get the most accurate information?**
- **How to tailor the presentation/format of the information in order to make it understandable and usable?**
- **What guidance is required to make not perfectly accurate information useful for the decision-maker? How and what kind of uncertainty needs to be communicated?**

Content and main tasks

- Getting into the role of a provider of climate information, broker of climate information, and user of climate information.
  > *Challenge definition*

- Making decisions on asking for, or preparing Climate Service products.
  > *Offer and demand under uncertainty.*

- Exchanging information on needs and possibilities.
  > *Understanding how to design needs-adapted Climate Services.*

- Experiencing how dialogue enhances the provision of Climate Service Products.

Method: Learning from experience with a role play and a case study

The exercise will be executed as a role-play. The role-play achieves best possible attachment of the learner to the circumstances and context he/she shall become knowledgeable about. As the co-design of climate information is an interactive process between stakeholders, a role-play on the importance of co-design is the best suitable method. Thereby, role-play actors are jumping into the role of climate information providers and users and have to negotiate and co-design tailor-made climate information.

Best learning output will be achieved through a sequence of role-plays where the first has almost no co-design elements revealing only limited usability of the climate information, and the second is programmed with a fully-fledged provider-user interaction revealing best possible and usable climate information. The comparison of outputs of both role games reveals the challenges and requirements for the successful co-design of climate information products.

Guidance for effective group work

- For effective and efficient work, a working group should select a facilitator, a time keeper and a presenter.
- Take your time to read through the task description and see if everybody is on board.
- The working groups work independently.
- Trainers can be asked for advice.
- The main learning objective is to learn about the systematic approach and not to be comprehensive in the task.

Form three stakeholder groups:

- Users of climate information: users are here defined as sectoral decision-makers who base their decisions on the provided climate-related information. The general task of the users will be to formulate their needs as detailed and sufficient as necessary in order to identify suitable CS products.
- Providers of climate information: providers are here defined as stakeholders who actually produce climate-related information products. This goes beyond the pure provision of data and may include stakeholders who do not observe and monitor climate themselves but do 'only' value-adding. The general task of the providers is to identify and provide suitable CS products for the specific context of the user.
- Brokers of climate information: brokers are here defined as intermediates that rather focus on the communication and facilitation of climate information rather than do technical tailoring of climate data. They can either be individuals or organizations (self-) entitled to perform this role. The general task of the brokers will be the moderation, observation and documentation of the interaction process.

The trainer will conduct the role play, based on the information in his Trainer Manual.

3.2.5 Take away messages

- Different infrastructure planning frameworks and cycles require different kind of Climate Services. Climate Service needs may vary regarding
  - the context of use, i.e. sector,
  - the type of decision which needs to be made based on this climate information (e.g. planning investments, mainstreaming climate change into pre-feasibility and feasibility studies, developing new building codes and standards etc.),
  - the decision-maker and his/her demands regarding the three dimensions of CS (user type),
  - the characteristics of the climate-value chain for the specific CS product, i.e. the kind of stakeholders who are involved.

- The context of use may have consequences on the required temporal and spatial resolution, time-frame of projections, accuracy/uncertainty of projections, the tailoring and provision of the Climate Service product, required services like guidance and support as well as access mechanisms and provider-user interaction.
- Competences and requirements of Climate Service 'knowledge brokers' who guide the co-design of Climate Services include communication & social skills, technical skills and managerial skills.
- User-interfaces for Climate Services can be operationalized and set up on an adhoc-basis, or institutionalized as a permanent service within a Climate Service governance regime (Link to chapter 3.1).

3.2.6 References

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3.2.7 Personal notes

3.2.8 Annexes

3.2.8.1 Annex 1 for the exercise: User needs – basic info (owned by providers)

- **Sector:** inland shipping
- **User:** logistic company
- **Region:** Rhine catchment, Germany
- **Hazard:** low flow conditions
- **Problem:** conditions in the context of climate change

3.2.8.2 Annex 2 for the exercise: Narrative user case

The user is a logistic company. The company transfers goods with trucks, train and boat all through the country and neighboring countries. Inland shipping is very attractive in the region of concern, since major waterways can be used to bypass distances of about 1000km and providing access to the maritime traffic lines.

The daily business is often affected by severe weather events that cause delays in the operating schedule due heavy rain, black ice or storms which impede full travel speed or even cause blockage of the roads or rails due to accidents, fallen trees or landslides. However, a relatively new disruption of the user's business refers to the transport by ships on large rivers.

Floods, especially during spring, as well as low flows disrupt the shipping traffic and impede the transport of goods. Low water levels are of special concern since they cause a rather long-term disruption of traffic. Furthermore, there is little routine in managing such events since such events didn't happen very often in the past and there is no reliable forecast for such events.

Up to now, normal low water events were manageable by the company in a way to mitigate economic losses and avoid the disruption of transport. This is done by charging the vessels not to the maximum, using smaller boats and more boats in a row as well as by temporary storage of the non-perishable goods. These measures reduce the maximum flotation depth of 4m by around 25% and allow shipping also at low water levels. However, such a situation is only acceptable for about two weeks without suffering substantial economic losses.

In the last couple of years, the low water situations at which no traffic is possible at all tend to occur more often than normal. Such extreme events occur when there is less than 1.5 m between the vessel and the ground. Such situations are only acceptable for 1-2 days and can only be met by organizing different vessels with different construction design, e.g. less flotation depth which would be a major investment. Another opportunity would be the deepening of the waterway which would be not in control of the logistic company alone. The acquisition of new vessels would be a big investment for the company which needs to be carefully weighted regarding costs and benefits of the added value of the new vessels for the upcoming couple of around a half century.

3.2.8.3 Annex 3 for the exercise: Structured user needs assessment for CS

1. **Delineate the context of your infrastructure system**
   - What is the infrastructure of concern?
   - Do you deal with a single infrastructure object or an infrastructure network?
   - What is your infrastructure investment context?
   - What is the spatial coverage of the infrastructure (network)?
   - What is the geographic type of region of your infrastructure?

2. **Identify & select critical climate sensitive infrastructure components**
   - What a components or operational processes which are most critical for the functionality and safety of the infrastructure?
   - What are the life cycles of the identified components?
   - Which of the selected infrastructure components and operational processes are sensitive to climate effects?
     - > What are the consequences of climate-related impacts on these components or operational processes? Are they critical?

- What are the climate-related hazards/events/phenomena that infrastructure components and operational processes are sensitive to?

3. **Define load thresholds of selected infrastructure components for specific climatic parameters (sensitivity analysis)**

   - What are climate-related thresholds of the selected components and operational processes that cause the undesired consequences when being exceeded?
   - How are they characterized regarding intensity, duration and frequency?

4. **Translate load thresholds into critical climate events/'hosting events' representing infrastructure thresholds**

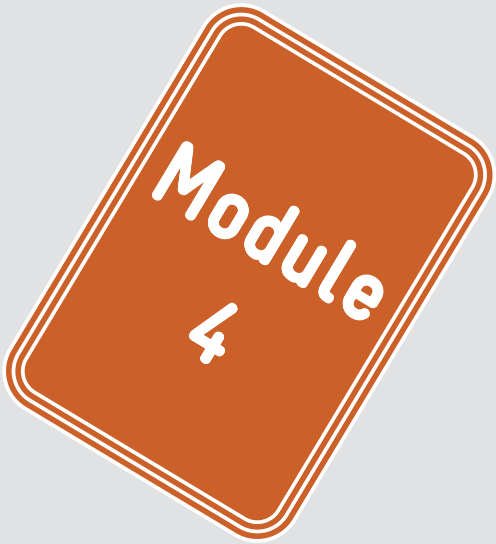
   - What are climate parameters, events, phenomena or indices which correlate best with the identified climate-related hazards causing the exceedance of component-specific thresholds?

5. **Projection of these critical climate events or surrogate events and develop climate indices for scenario construction**

   - Are there climate-projections available for the identified critical climate events?
   - If not, is there any other climate parameter, index or phenomena which indicate the identified critical climate event and which can be projected or rather shows some signal?

Module 4

Climate Proofing for Sustainable Infrastructure Investments



4.1 How to get started

'Climate Proofing […] is a methodological approach aimed at incorporating issues of climate change into […] planning.' (Hahn and Fröde 2011). See also Box 2.2.1

4.1.1 Skills and knowledge

- The participant understands the common climate proofing approach to be applied in the context of each climate proofing entry-point in the infrastructure investment cycle.
- The participant is able to identify entry-points for climate change adaptation for infrastructure investment from national or territorial perspective.
- The participant is able to identify potential climate related risks, affected infrastructures, related land use systems (landscape approach) and stakeholders.
- The participant is able to identify non-climate factors which put pressure on the territory and its assets.

4.1.2 Context

Based on the OECD Guidelines for Integrating Climate Change Adaptation into Development Planning, GIZ developed the method of Climate Proofing for Development (OECD 2009; Hahn and Fröde 2011). The Climate proofing (CP) approach covers the full infrastructure investment process. As presented in Fig. 2.2.1, each of the six phases of the infrastructure investment process shows potential entry-points for climate proofing. Climate proofing will support the following tasks of the different phases:

- **Policies and investment planning (Phase 1.1 and 1.2):** The climate proofing reveals measures to maintain major policy, planning, and budget objectives under climate change conditions at national or sector level.
- **Regulation (Phase 1.3):** This phase benefits from the development of climate proofed building codes and standards for the design of infrastructure.
- **Project level / Specific infrastructure investment (Phase 2-6):** When it gets down to specific infrastructure investments, the objective is a climate resilient infrastructure project. Climate Proofing (see figure 4.1.1) can be applied for project preparation (screening / scoping / pre-feasibility), project development (feasibility, physical design, maintenance schemes), finance, construction and operation / maintenance of the infrastructure, as well as in times where monitoring results offer feedback to the different investment cycle elements; e.g. when rehabilitation of infrastructures are at the center of attention.
- Different tools exist to evaluate options (cost-benefit analysis (CBA), cost-effectiveness analysis (CEA), multi-criteria analysis (MCA), comparative effectiveness assessment etc.). Adaptation Options are revised and prioritized with key stakeholders (contributes to phases 2 - 4).
- **Step 4: Project design and implementation** focusses on the integration of the before selected adaptation measures into the feasibility studies, project design, construction, and operation of the infrastructure to be climate proofed (contributes to phases 3.3, 5, 6).
- **Step 5: Monitoring and reporting** of the effectiveness of the implemented measures for transparency is an essential request from investors. Therefore, Climate Services developed for Climate Risk Assessment are designed to support the future need of monitoring. Different contexts and settings have manifold application areas. This means that different approaches and aggregation levels towards assessing risks and therein, developing climate service products exist. Climate service providers need to be capable to respond to these different demands and follow structured approaches towards understanding user needs (contributes to phase 6.3).

Table 4.1.1 demonstrates the logic, how climate proofing may support each step in the infrastructure investment process. This module focuses on the project development, implementation, as well as operation phase of the infrastructure investment cycle.

Table 4.1.1 Links between the infrastructure investment process and climate proofing

Investment cycle steps	Climate Proofing Steps				
	Scoping (defining decision making context, actors)	Risk Assessment/ Climate Service	Adaptation Assessment	Project Design and Implementation	Monitoring & Evaluation
Policies and Planning	Are infrastructure policies and plans, as well as regulations in risk of failing or loosing effectiveness due to climate change?	Risk Screening to receive an overview on key infrastructure-related exposures and vulnerabilities, and their underlying reasons.	Identify and select measures to adjust plans and policies (e.g. indicators, activities) according to identified risks	Mainstream selected adaptation measures into infrastructure-related policies and plans	Monitor & re-assess whether climate resilience indicators and activities of the plans have reduced the risks.
Project preparation	Are the key quality criteria regarding finance, design, and operations potentially under risk from changing climate conditions?	Spatial risk screening for understanding roughly climate impacts on potential project sites	Identify and select measures that ensure the resilience framing for the project development	Mainstream measures that ensure the resilience framing for the project development	Monitor & re-assess whether key criteria for the investment are valid or need to be changed due to changing climate conditions
Project development	Are the developed infrastructure assets and their operational procedures potentially under risk of climate change?	Asset focused detailed risk assessment focusing on detailed physical design and operational aspects of the specific infrastructure, including non-climate aspects	Identify and select measures for the climate resilient budgeting, design, operation and maintenance of the infrastructure investment	Mainstream selected measures Into the budgeting, design, operation and maintenance of the infrastructure investment	Re-Assess whether identified measures have been proofed successful and viable
Finance	Is the investment potentially under risk due to climate change?	Detailed economic risk assessment on loss and damage, as well as cost for recovery of the asset in focus	Climate resilient insurance policy covering climate risks (monetary loss) identified.	Climate resilient insurance policy covering climate risks (monetary loss) contracted.	Re-Assess whether policies contracted cover current & future climate risks
Implementation	Is the construction of the infrastructure able to respond to climate related extreme events?	Detailed scenarios for climate-related hazard impacts on the construction site in different phases of construction	Development of standard operating procedures (SOPs) for the construction site with regard to warning and immediate response options to protection of assets and people in case of climate related extreme events	Implementation of SOPs for the construction site with regard to warning and immediate response options to protection of assets and people in case of climate related extreme events	Re-Assess performance of these SOPs
Operation	Is the performance of the infrastructure potentially under risk due to climate-related hazards?	Continuous performance and vulnerability assessment (physical design, operations) under conditions of climate change (similar to risk assessment in project development phase)	In case changes in risks are identified, identification and selection of measures to increase the resilience of the project	Implementation of operation-related measures to increase the resilience of the project	In case changes in risks are identified, provide feedback into the entire investment cycle where appropriate

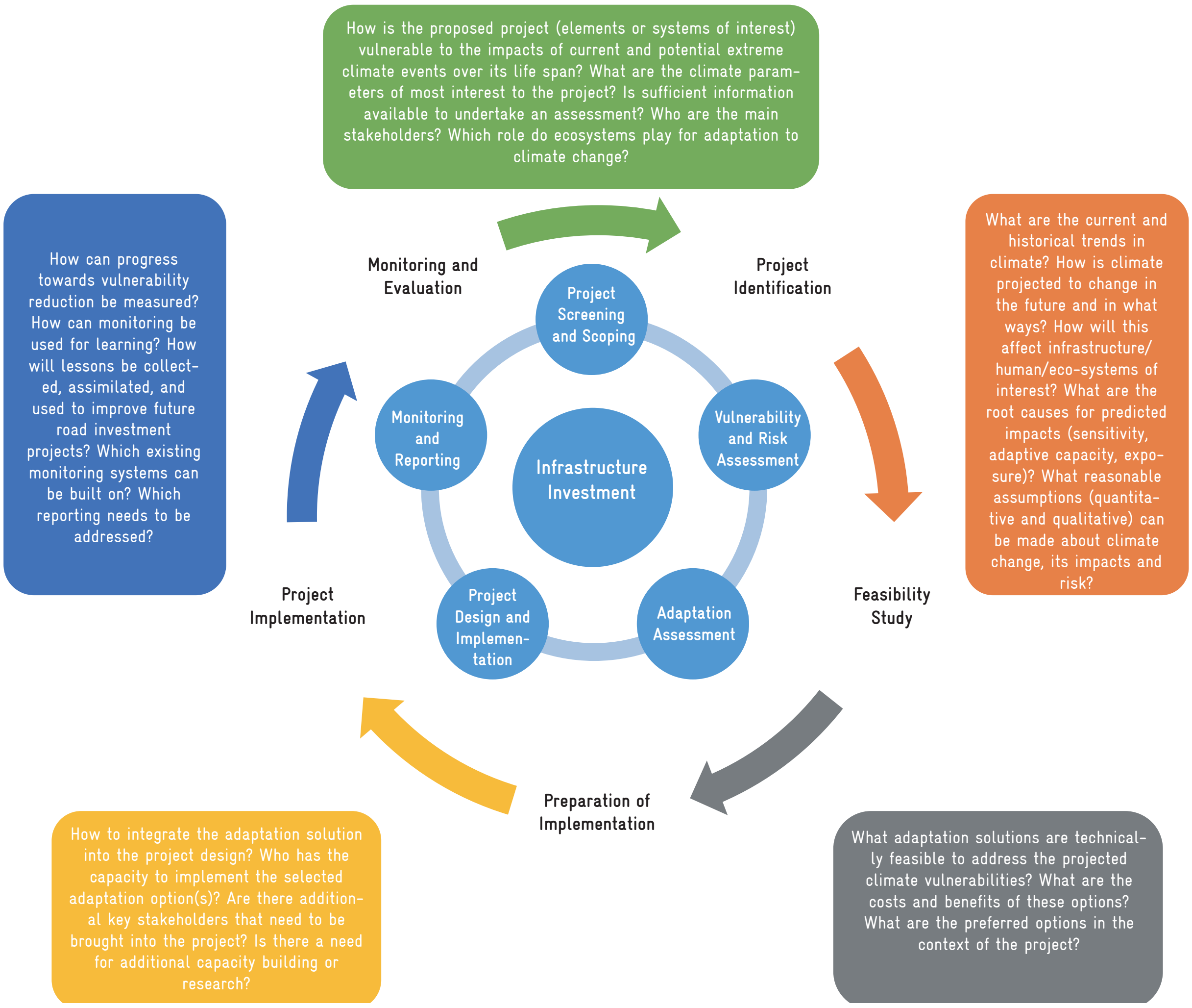
The main steps of climate proofing are described as follows:

- **Step 1: Screening and Scoping** is the first step in order to clarify and identify whether the objective of the infrastructure is under potential climate risk (contributes to phase 2). For example, if you are conducting a feasibility study, the question in the scoping phase is the identification of the infrastructures' physical and operational components and sub-components that require in-depth vulnerability and risk assessment. Hence, the system(s) of interest need to be defined based on the anticipated assessment scale, as well as on the infrastructure specific design-, functional- and operational components.
- **Step 2: Climate risk assessment** is a climate service that entails the evaluation of both the vulnerability and climate hazard components, and reflects a multi-stakeholder process representing different disciplines. It is also considered a decision support tool. Hence, results shall provide direct utility for taking adaptation decisions. This step is important, e.g. during pre-feasibility and feasibility studies (contributes to phases 2-3).
- **Step 3: Adaptation assessment** is linked to approaches towards climate risk management approaches that include options to reduce / prevent exposure, protect from impacts, transform the subject of analysis, manage residual risks to ensure / provide contingencies to maintain serviceability / business continuity (develop mechanisms for early warning & response, rescue and relief, as well as recovery). Climate risk management options can be mutually exclusive, but also complementary. Different tools exist to evaluate options (cost-benefit analysis (CBA), cost-effectiveness analysis (CEA), multi-criteria analysis (MCA), comparative effectiveness assessment etc.). Adaptation Options are revised and prioritized with key stakeholders (contributes to phases 2 - 4).
- **Step 4: Project design and implementation** focusses on the integration of the before selected adaptation measures into the feasibility studies, project design, construction, and operation of the infrastructure to be climate proofed. Stakeholder participation and needed capacities at individual, organizational and society level are identified (contributes to phases 3.3, 5, 6).
- **Step 5: Monitoring and reporting** of the effectiveness of the implemented measures for transparency is an essential request from investors. Therefore, Climate Services developed for Climate Risk Assessment are designed to support the future need of monitoring. Different contexts and settings have manifold application areas. This means that different approaches and aggregation levels towards assessing risks and therein, developing climate service products exist. Climate service providers need to be capable to respond to these different demands and follow structured approaches towards understanding user needs (contributes to phase 6.3).

It is important to note that it is not compulsory to perform all CP steps for each infrastructure investment phase. The decision on how and when to implement different climate proofing steps within the investment process depends on the local circumstances and investment objectives, including resources, stakeholders, and possibilities. Table 4.1 details different options that need to be customized according to current needs.

This module starts with a climate lens at territorial level (4.1), which can be used as an optional step at territorial level (e.g. national investment plan) or at the beginning of screening and scoping of a project (e.g. territorial context). The following sub-chapters 4.2-4.6 show the logic of the 5-Step approach of Climate Proofing at project level.

Figure 4.1.1 Mainstreaming adaptation to climate change into infrastructure projects



Adapted after ADB 2011

4.1.3 Exercise Apply a Climate Lens to infrastructure investment goals

Learning Objective

You will learn how to do a rapid appraisal of climate risk in order to identify the relevance for adaptation to climate change within sustainable infrastructure investment planning, development, financing, and implementation.

Content and main tasks

- Agreement on infrastructure investment decision making context
  >> *Definition of scope of infrastructure portfolio development & planning*
- Screening goals of infrastructure investments against projected climate change risks.
  >> *Problem definition*
- Mapping of regions, infrastructure and ecosystems at risk of current and future climate related threats.
  >> *Definition of the system of interest/scope of work/ implementation area.*
- Mapping of key stakeholders for future climate resilient infrastructure investment.
  >> *Rapid assessment of socio-economic and governance systems (e.g. public organizations/institutions, non-governmental organizations, private sector companies)*
- Identifying important hydro-meteorological, socio-economic and environmental variables, data and types of products (e.g. maps, or graphs etc.) needed for Climate Services in infrastructure investment planning development, financing, or implementation, and understanding how they were developed.
  >> *Rapid assessment of temperature, precipitation, sea level rise, flooding, estimates of loss and damage etc.*
- Beyond engineering: Understanding the value of ecosystem services for sustainable infrastructure investment.
  >> *Rapid assessment of environmental systems (e.g. ecosystems and their protective services for infrastructures)*
- Brainstorming on next steps:
  >> *Which infrastructure systems are most at risk and need a detailed vulnerability and risk assessment to guide sustainable infrastructure investment?*

Case description

For the following case study, you can use any national policy framework, program or project which emphasizes public infrastructures for sustainable investment. If you don't have one at hand, you may refer to the fictitious case of Metropolis (description see Annex 1) and select the following goal:

- Protection of public infrastructure, through appropriate risk assessment and the adoption of protection mechanisms ensuring the robustness of infrastructure works.

The case description of Metropolis provides further background information on important climate threats, road infrastructure sub-systems, stakeholders etc. If you use your own case, please make sure that you have access to some basic data which allow for the rapid assessment.

Your specific tasks

First, agree with 2-4 peers to work with as a team.

Second, read the instructions carefully and in case of doubts, first ask your fellows or - if still necessary - the trainers.

Third, guide your analysis with the following questions and draft your answers based on a risk and stakeholder map of the country, province, community or area of choice which you want to focus on. Use markers of different colours to highlight different aspects on a flipchart paper:

1. Map the limits of the territory of your interest.

2. Mark regions exposed to risk of current or future climate threats (e.g. extreme weather events, sea level rise etc. and related effects like flooding, storm surge, extended droughts, and heat waves). Use different colors or symbols for different threats.

3. Map infrastructure systems (e.g. road x,y,z, bridge a,b,c) which are located in the regions at risk.

4. List key stakeholder groups who are already or should be involved in infrastructure investment planning. If you have more time for the task, please map the stakeholder groups by the different subsystems of infrastructure (e.g. road x, bridge a), sectors which they represent and their level of influence on the planning process.

5. Functional ecosystems contribute to the mitigation of climate threats related effects like flooding, storm surges, heat waves etc. by increased water infiltration, natural barrier or shade. Therefore, the mapping of ecosystems located in the direct surroundings of the infrastructure systems or in the upper watersheds which drain into these regions supports the understanding of potential ecosystem services which should be considered for sustainable infrastructure investment.

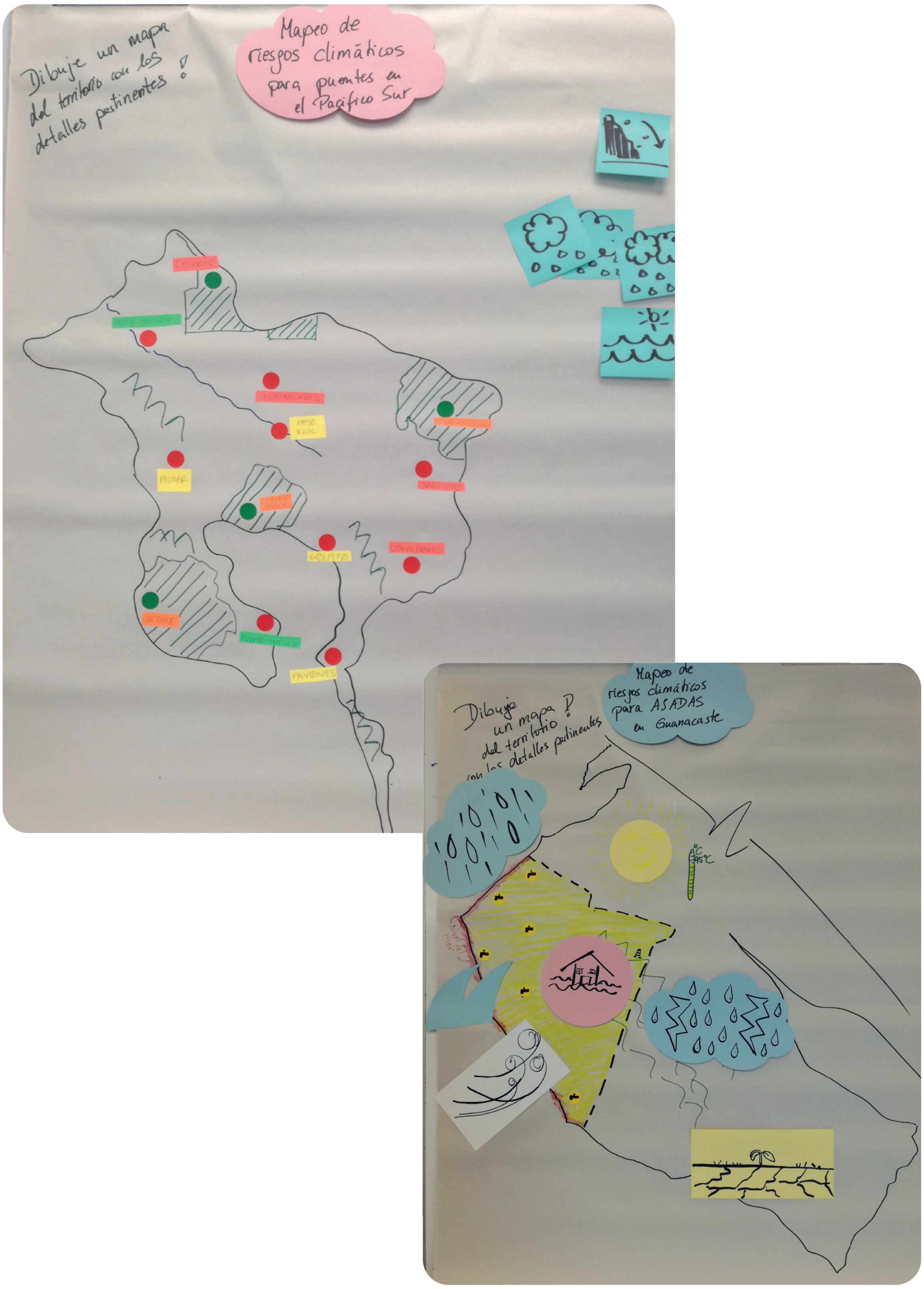
6. Discuss with your colleagues and then draft your answers beneath the map:
   - Which infrastructure systems need a detailed vulnerability and risk assessment to guide the sustainable infrastructure investment?
   - Apart from the political framework, which other entry points would facilitate the integration of climate change adaptation into the investment planning? E.g. specific financial support programs? National development priorities? Physical design, operations & maintenance program for infrastructure?

7. Present your major findings to the plenary.

Guidance for effective group work

- For effective and efficient work, a working group should select a facilitator, a time keeper and a presenter.
- Take your time to read through the task description and see if everybody is on board.
- The working groups work independently.
- Trainers can be asked for advice.
- The main learning objective is to learn about the systematic approach and not to be comprehensive in the task.

Figure 4.1.2 Examples of risk maps



Instead of the drawing you may guide your work with matrix 2.2.1 and elaborate the answers completing line by line. The examples in the matrix are only for illustration how to draft the text.

Matrix 4.1.1 **Results of Climate Lens assessment**

Goal: Protection of public infrastructure

Climate threat	Region at risk	Infrastructure systems at risk	Stakeholder groups	Ecosystems of interest	Further points that may drive risk
Flooding	Metropolis	Millenium Bridge as a whole, including its infrastructure and operations	Local government Ministry of Public Works Civil Defense	Forest at the river source Agriculture along Karibu River	…
…					

4.1.4 Guiding questions for reflection

- Which are strategic entry points for taking up the discussion on adaptation to climate change as a support to sustainable infrastructure investment?
- Who are the relevant stakeholders to participate in the planning and other decision-making processes?
- Which role does climate already play in investment planning, both at the national / policy level, the sector level, and the object / project level??
- In which phases of the infrastructure investment cycle climate-related information should be taken into consideration?

4.1.5 Take away messages

- The climate change related increase of extreme weather events and slow onset disasters like sea level rise puts stress on public infrastructure and related public and private goods.
- Successful transformation towards climate-resilient infrastructure requires integrating climate proofing into the whole investment cycle, adapting the objectives and safeguards infrastructure is evaluated against.
- Introducing climate-resilience criteria in the planning of infrastructure is a key element of ensuring sufficient funding for adapting infrastructure to climate change. It needs to be reflected, i.e., in how the costs and benefits of investments are evaluated as well as in budget planning.
- Ecosystem services have the potential to mitigate climate change effects like flooding, storm surges, heat waves etc. and should be considered in a holistic approach of climate smart infrastructure investment.

4.1.6 References

Hahn, M. and Fröde. A. 2011. Climate Proofing for Development – Adapting to Climate Change, Reducing Risk. Deutsche Gesellschaft für Internationale Zusammenarbeit GIZ, Eschborn, Germany. www.preventionweb.net/files/globalplatform/entry_bg_paper-giz2011climateproofing.pdf

OECD Policy Guidance – Integrating Climate Change Adaptation into Development Cooperation, Part 1: Understanding the Challenge. Introduction to climate change adaptation: www.eldis.org/go/topics/dossiers/climate-change-adaptation

4.1.7 Personal notes

4.2 Screening and Scoping

4.2.1 Skills and knowledge

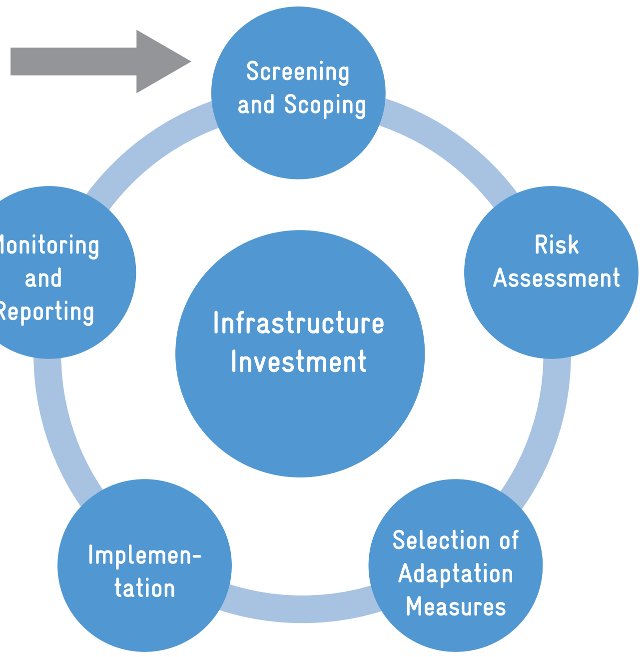
- The participant understands the common climate proofing approach to be applied in the context of integrating climate change adaptation into infrastructure investment processes.
- The participant is able to identify entry-points for climate change adaptation into the infrastructure project process.
- The participant is able to frame the context and objectives of climate proofing according to the selected entry point in the infrastructure investment cycle.
- The participant understands the role of climate proofing and climate services in the project development phase of the infrastructure investment cycle.
- The participant is able to identify non-climate factors which interact with climate effects.
- The participant is able to identify and appoint key stakeholders and their roles, tasks and interaction within the project.

4.2.2 Context

This sub-chapter is complementary to sub-chapter 2.2 Climate Change and Infrastructure Investments. While sub-chapter 2.2 applies the screening at the goal of a national or sector infrastructure investment policy or plan in order to identify the need for action at institutional level, this chapter has a closer look at entry points for adaptation at project level to identify the scope of work.

Project Screening and Scoping is the first step in order to identify elements which need an in-depth vulnerability and risk assessment. The system(s) of interest in the context of infrastructure needs to be defined based on the anticipated assessment scale, as well as on an infrastructure specific design-, functional- and operational components.

Figure 4.2.1 The 5-step approach of Climate Proofing. Step 1 Project Screening and Scoping



4.2.3 Concept

Project Screening and Scoping is the first step of mainstreaming adaptation into a project investment cycle. The goal is to determine a project's risk level as a result of climate change, to identify how climate change impacts can affect the overall project objectives and to identify the systems of interest and set the boundaries within which the assessment of adaptation options will be undertaken.

Questions to be answered are: How is the proposed project vulnerable to the impacts of climate change over its life span? Which infrastructure elements (systems of interest) are most at risk and which ones represent the highest impact to the system if affected? What are the climate parameters of most interest to the project? Is sufficient information available to undertake an assessment? Who are the main stakeholders? (Asian Development Bank 2011)

Infrastructure projects have to respond to institutional frameworks established in all countries. Thus, mainstreaming adaptation to climate change into any project has to respond to national policies, plans, standards and priorities (see figure 4.2.1) which can be considered as general objectives of the project (project impact on national development goals defined in NDCs, NAPs or other policy instruments).

The Screening and Scoping step within the Climate Proofing approach can be performed during each infrastructure investment phase and puts emphasis on identifying if potential climate risks exists, and which infrastructure components or subsystems of the infrastructure investment may be specially at risk. As an example, a transport infrastructure project can include different elements like bridges, roads, tunnels, railways etc. and each of these elements has distinct characteristics. Therefore, each element could be perceived as one sub-system of interest of a transport system and each might consist of further sub-systems (roads: dirt roads, paved roads). Screening the project helps to identify those systems of interest and apply a rough appraisal if these are vulnerable to current or potential climate threats.

An important reminder: 'a chain is only as strong as its weakest link'. The same rule applies to assessing vulnerability and adaptation of an infrastructure system. Thus, it is important to always take into consideration the most vulnerable 'link' of each structure – that is, what is the most vulnerable element that, when affected, could render the whole system non-operational or cause the most damage. It is important to note that, although this often denotes the most vulnerable component of the system (e.g. electricity lines in a electricity grid that, when affected, would disrupt services), it is not uncommon that a more robust element represents the weakest link (e.g. the collapse of a bridge causes more disruption than damages to the road surface within a road grid). Infrastructure systems do not only consist of engineering elements but also include environmental sub-systems. Infrastructure interacts with ecosystems while putting pressure on these or receiving protective services like flood prevention by increased water infiltration or natural barriers. Therefore, the knowledge about ecosystems located in the direct surroundings of the infrastructure systems or in the upper watersheds which drain into these regions supports the understanding of potential ecosystem services which should be considered upon analyzing and designing sustainable infrastructure projects.

Having an initial scope for the adaptation work as well as a survey of existing information will likely expand the relevant stakeholders to include climate change focal points, disaster risk reduction focal points, and other stakeholder groups. A number of institutions and research organizations may be conducting work relevant to the project. Specific engagement of local communities, nongovernmental organizations, and small to large businesses operating in the area will be important for conducting a vulnerability assessment and for engagement in selecting the most cost-effective adaptation strategies.

The CSI Program suggests five steps for the Screening and Scoping of an infrastructure project:

- Step 1: Identify the objective of the project.
- Step 2: Identify all infrastructure (sub-)components (=> (sub-)system of interest).
- Step 3: Identify historic, current, projected climate parameters, possibly critical climate events and relate to systems of interest.
- Step 4: Identify ecosystems which interact with the project.
- Step 5: Identify stakeholders to be engaged.

4.2.4 Exercise Screening and Scoping of an Infrastructure Project

Learning objectives

1. **You will learn about how to scope your system of interest that will be subject to risk assessment. This means identifying and agreeing on the infrastructure components considered in the assessment. Scoping your system of interest is a crucial first step in risk assessment.**

2. **You will understand the need for multisector cooperation for climate resilient infrastructures.**

3. **You will learn about the key features of the PIEVC risk matrix: Identifying and agreeing on the climate change signals and the critical climate events to be considered in the assessment.**

4. **You will understand the role of ecosystems for risk reduction and the importance to consider these during the scoping of the system of interest.**

Content and main tasks

- Screening goals of the infrastructure project against projected climate change risks.
  >> *Problem definition*

- Mapping key stakeholder groups involved in vulnerability and risk assessment.
  >> *Rapid assessment of socio-economic and governance systems (e.g. public organizations/institutions, non-governmental organizations, private sector companies)*

- Mapping or description of infrastructure project elements at risk of current and future climate related threats (optional: include ecosystems which provide some kind of protection to the infrastructure). Reminder: focus on the 'weakest link'.
  >> *Definition of the system of interest/scope of work/implementation area.*

- Identifying relevant climate change signals and their adverse effects on the infrastructure project.
  >> *Rapid assessment of temperature, precipitation, sea level rise, flooding, estimates of loss and damage etc*.

- Beyond engineering: Identify the value of ecosystem services for sustainable infrastructure investment (e.g. natural barriers of surface water flow or storm, increased water infiltration).

Guidance for effective group work

- For effective and efficient work, a working group should select a facilitator, a time keeper and a presenter.
- Take your time to read through the task description and see if everybody is on board.
- The working groups work independently.
- Trainers can be asked for advice.
- The main learning objective is to learn about the systematic approach and not to be comprehensive in the task.

Method: Learning from experience with a case study

You are part of the expert team, preparing the check-up mission for the **Metropolis Millennium Bridge, South State** (see Box 4.2.1 for summary and Annex 1 for details) and work together in teams of 3 to 7 experts.

You and your colleagues bring in the engineering, climate change, environmental and cooperation expertise, based on the case description and your own experience.

Please find some hints for a fruitful cooperation in the box 'Guidance for effective group work'.

Your specific tasks

- Review the case description (either Metropolis / Annex 1 or your own real case).
- Use a flipchart or board with cards.
- Respond to the following tasks and present your results guided by matrix 4.2.1.

- **Step 1.**
  - Identify the objective of the project.

- **Step 2.**
  - List all infrastructure components that you find in the case description (=> systems of interest).
  - Ideally cluster the components, e.g. according to different aspects of the bridge management or construction.
  - Identify linkages between components (i.e. how the impact in one component can affect functioning of others).
  - If possible, give indications for the design load for each component (in case you can identify them in the case description: watch out for them).

- **Step 3.**
  - Define the critical climate events related to the sensitivity of the infrastructure components.
  - Based on the case, list all relevant climate parameters (historic, recent and projected).
  - Ideally cluster the different climatic factors that relate to each other.
  - Mark components which are vulnerable to the factors and which should undergo a detailed vulnerability and risk assessment.

- **Step 4. (optional)**
  - Identify all ecosystems located in the direct surroundings of the infrastructure system or in the upper watersheds which drain into these regions.
  - Describe their interactions with the project (e.g. benefits, pressure, stress).
  - Describe their current conditions and trends (e.g. functional, fragmented, degraded).

- **Step 5.**
  - List key stakeholder groups who should be engaged in the climate risk and adaptation assessments.

- **Step 6.**
  - Prepare your presentation to the plenary and focus on your most important results within 5 minutes.

Box 4.2.1 **The fictitious case of Metropolis**

Metropolis is a mega city with about 6 Million inhabitants in South Country, and an area of major importance for economic activity and social life throughout the country. Equipped with residential and commercial/industrial areas, green spaces for recreation, hospitals, schools and universities, as well as vast shopping facilities covering all needs, the city is of major importance for the surrounding region, especially the smaller villages and dwellings who benefit from the services and facilities offered by the city. With having a harbour, the city receives importance as a gateway for the trade of goods and commodities within the region. The roads leading across the Millennium Bridge is of crucial importance for traffic, transport and overall mobility.

The city is located in the Karibu River Watershed. The Northern parts of the catchment are characterized by the high Upper Mountains, gently sloping south. These are a renowned destination for ambitious hikers and climbers in summer. However, in the past years much of the forests had been degraded due to rapid urbanization and uncontrolled land-use changes. In the rainy season, the peaks of the mountains are often covered in clouds with intense rains occurring every afternoon causing tremendous water discharges. Two tributaries add their waters before Karibu River reaches the major bridge connecting both parts of the city accessible for vehicles.

The frequency of disruptive high water levels of the river appears to be increasing and a severe flood similar to the one in 1888- has re occurred once since. A relatively new feature are random thunderstorms accompanied by strong rains in the northern part of the watershed, where steep, bare rock slopes are common, leading to extraordinary high water levels, and eventually causing flooding of the cities original flood plain, that is now urbanized.

See Annex I for further details.

Matrix 4.2.1 **Results of the screening and scoping exercise**

Step 1. Objective of the project:

Step 2		**Step 3**		**Step 4**	**Step 5**
System of interest	**Infrastructure components and design load**	**Critical climate events**	**Climate parameters**	**Ecosystem(s) description**	**Stakeholder groups**
Bridge X	A				
	B				
	C				
Road Z	A				

4.2.5 Guiding questions for reflection

- Which entry point for adaptation to climate change did you use at the level of the exercise?
- Which were the major challenges you had faced during the exercise?
- Which information and knowledge were missing with specific reference to climate services?
- Which stakeholder groups are key as participants in the screening and scoping exercise and who should be involved in the development of climate service products?

4.2.6 Take away messages

- Different entry points for climate proofing of infrastructure investments exist, e.g. the development or revision of building codes and standards for the design of infrastructure, project preparation such as pre-feasibility and feasibility studies of infrastructure project development, as well as during the realization of such projects and the monitoring of their performance. In addition, infrastructure investment policies and plans can be subject to climate proofing.
- The existence of all these entry points reveals that climate services are required in different contexts and settings and hence have manifold application areas. This means that also different approaches and aggregation levels towards assessing risks and therein, developing climate service products exist.
- Climate service providers need to be capable to respond to these distinct demands and follow structured approaches towards understanding user needs.
- The first step of climate proofing, the screening and scoping helps to identify the most relevant climate hazards, vulnerable infrastructure components of a project (strategy or plan) with respect to these, further information gaps and key stakeholders.

4.2.7 References

Asian Development Bank (ADB) 2011. Guidelines for climate proofing investment in the transport sector: Road infrastructure projects. ISBN 978-92-9092-388-6. Publication Stock No. TIM113627 - Cataloging-In-Publication Data - Asian Development Bank, Mandaluyong City, Philippines. www.adb.org/sites/default/files/institutional-document/32772/files/guidelines-climate-proofing-roads.pdf

Asian Development Bank (ADB) 2014. Climate risk management in ADB projects. Publication Stock No. ARM146926-2 November 2014 - Cataloging-In-Publication Data - Asian Development Bank, Mandaluyong City, Philippines. www.adb.org/sites/default/files/publication/148796/climate-risk-management-adb-projects.pdf

Hahn, M. and Fröde. A. 2011. Climate Proofing for Development - Adapting to Climate Change, Reducing Risk. Deutsche Gesellschaft für Internationale Zusammenarbeit GIZ, Eschborn, Germany

GIZ-DWD 2018. Climate Services for the road infrastructure sector in Costa Rica. A baseline assessment report. GIZ Eschborn/Bonn, Germany: tbd

Ray, P.A. and Brown, C. M. 2015. Confronting Climate Uncertainty in Water Resources Planning and Project Design: The Decision Tree Framework. Washington, DC: World Bank. ©World Bank. https://openknowledge.worldbank.org/handle/10986/22544 License: CC BY 3.0 IGO

Selected Climate Change Risk Screening Tools (recommended by ADB 2011):

Department for International Development, United Kingdom: Opportunities and Risks of Climate Change and Disasters (ORCHID) and Climate Risk Impacts on Sectors and Programmes, http://tinyurl.com/ccorchid

Dutch Ministry of Foreign Affairs: Climate quick scans, www.nlcap.net

German International Cooperation: Climate check, www.gtz.de/climate-check

World Bank: Climate change portal including ADAPT tool, http://sdwebx.worldbank.org/climateportal

International Institute for Sustainable Development: Community-based Risk Screening Tool–Adaptation and Livelihoods (CRiSTAL), www.iisd.org/pdf/2011/brochure_cristal_en.pdf

4.2.8 Personal notes

4.3 Climate risk assessment

4.3.1 Skills and knowledge

- The trainee understands the terminology and concept of Climate Risk Assessment for infrastructure projects as a Climate Service product following the PIEVC Engineering Protocol.
- The trainee is able to identify needs for the development of climate services products.
- The trainee is able to apply the experiences from the exercise to other infrastructure projects.

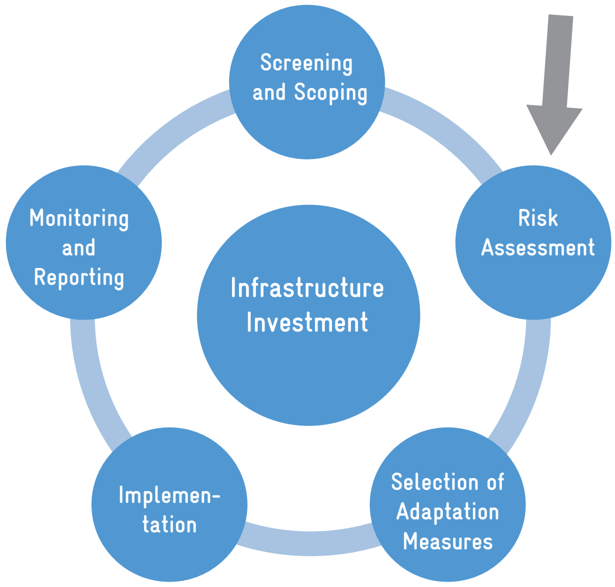
4.3.2 Context

'One of the key messages that comes out very strongly from this report is that we are already seeing the consequences of 1 °C of global warming through more extreme weather, rising sea levels and diminishing Arctic sea ice, among other changes,'
Panmao Zhai, Co-Chair of IPCC Working Group I (IPCC 2018)

Climate Risk Assessment is a decision support tool. It follows the Project Screening and Scoping step within the 5-step approach of Climate Proofing, and it includes assessing climate hazards, exposure, vulnerabilities and their drivers. As a decision support tool that considers climate information, it can also be considered a highly value-added Climate Service, which in many cases is ready-to-use for end-users. Project Screening and Scoping is the preparatory step for the following risk assessment.

This step frames the project to be analyzed against national policies, plans, standards and priorities. Moreover, it defines the decision making context for climate proofing along the infrastructure investment cycle that has significant influence on the identification of those systems of interest that are potentially vulnerable to current or potential climate threats. E.g. in a pre-feasibility phase of a project the selection of an appropriate location for the infrastructure is of interest. Hence, in the pre-feasibility phase, the focus is rather on the selection of alternative geographic entities suitable for an infrastructure investment, whereas in the feasibility phase the focus is rather on specific assets of an infrastructure to ensure that design of components are climate proofed. Once the decision-making context is clearly defined (different phases of investment cycle) and the system of interest is scoped accordingly, the climate risk assessment can be framed and conducted, pursuing to provide direct utility for taking climate sensitive investment decisions.

Figure 4.3.1 The 5-step approach of Climate Proofing. Step 1 Project Screening and Scoping.



Hence, once more, the type of risk assessment to be followed depends on the selected decision-making context (entry point for climate proofing based on the investment project process) as well as in occasions of feasibility studies, the type of infrastructure assets in focus (e.g. physical and operational assets, single infrastructure, network of infrastructure, life cycle). Hence, careful scoping is a very important preparatory step that defines the way climate sensitive investment decisions can be taken.

4.3.3 Concept Climate vulnerability and risk assessment of infrastructures

4.3.3.1 Definition of climate risk

The concept of climate risk is defined in the Fifth Assessment Report of the IPCC (AR5). Climate risk is a function from the potential impact of a climate hazard on a system of interest and the probability for this hazard to happen. The potential impact, on the other hand, is the function of exposure of the system of interest to a climate hazard and its vulnerability. Vulnerability is defined by the sensitivity (impact thresholds) and the adaptive capacity of the system of interest. Therefore, climate risk can be summarised by the following equation:

$$\text{Climate risk} = \text{hazard (probability)} * \text{exposure} * \frac{\text{sensitivity}}{\text{adaptive capacity}}$$

Detailed definitions and the logic behind the concept of climate risk is displayed in Figure 4.2.2. Figure 4.2.3 illustrates some risk causality paths and emphasises to understand the drivers of risk for the development of adaptation options. Hence, the result of a well-performed climate risk assessment details reasons for and drivers of climate risk of systems of interest with regard to exposure, sensitivity, and adaptive capacity, disclosed by different hazards. The more detailed the climate risk assessments are performed, the more decisive underlying (bio-physical) and socioeconomic drivers for climate risk may be identified. These underlying causes for risk also represent adaptation entry points, which can be addressed in the following step of the 5-Step Approach of Climate Proofing ('Adaptation Assessment').

Figure 4.3.2 Concepts defining climate risk, based on IPCC AR5

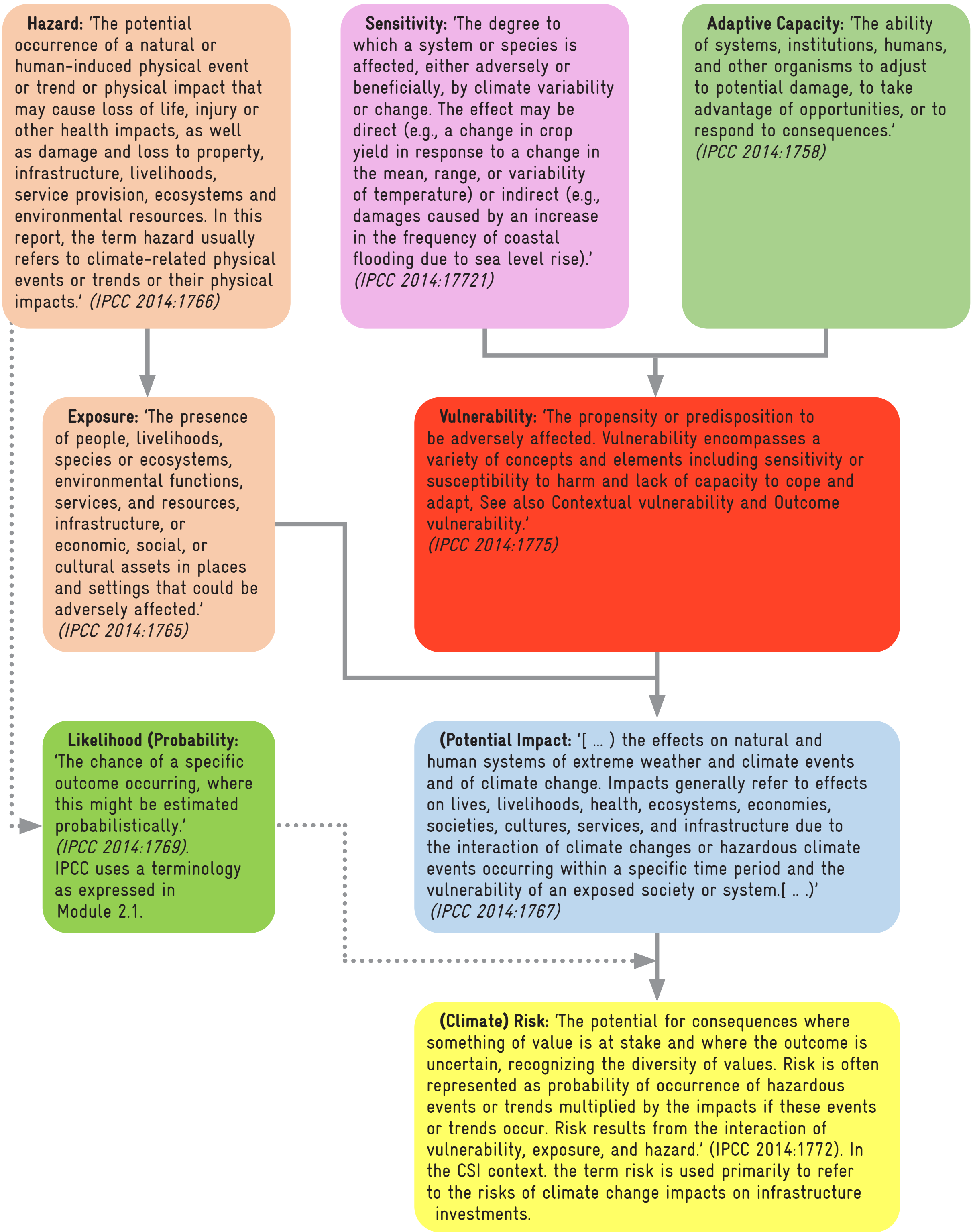
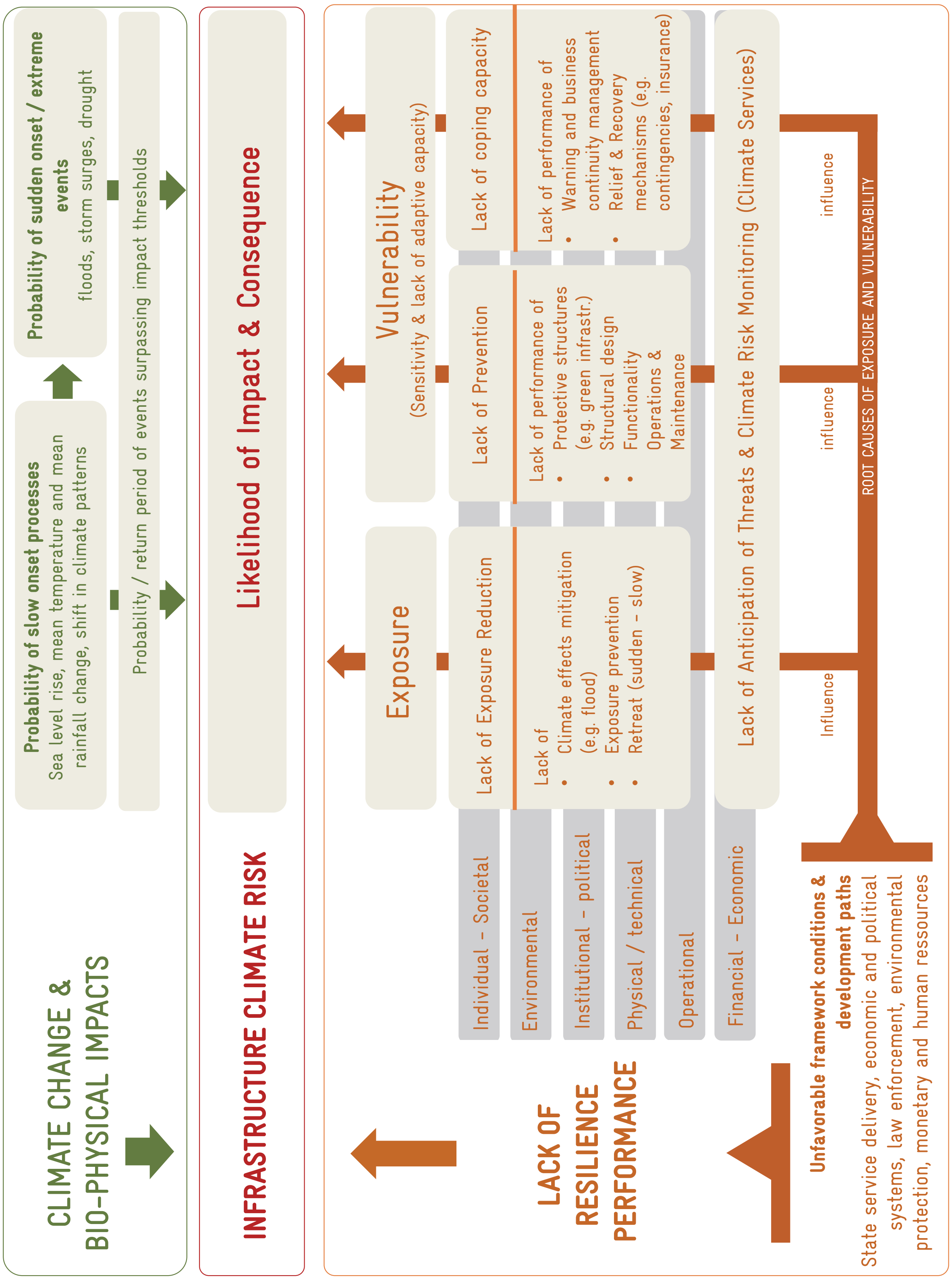


Figure 4.3.3 Causal structure of risk, based on Baumert (2016)



Infrastructure specific risk causalities

As described above, climate risk assessment of infrastructure systems focusses on understanding those mechanisms and processes that create might lead to loss of serviceability and loss of infrastructure assets resulting from (1) climate change and its bio-physical impacts and (2) the lack climate resilience performance (due to lack of coping & adaptive capacity) of infrastructure systems, leading to exposure and overall sensitivity of the system to these bio-physical impacts. For identifying adaptation options understanding the causal structure of risk and their root causes is essential. For infrastructure systems the causal structure of risk of loss & damage (as a result of lack of resilience performance) can be analysed based on the following causality frames (Compare Figure 4.3.3):

- Risk as the outcome of the lack of capacity for anticipating current and future risks and vulnerabilities in pursuit of reducing exposure, sensitivity and increasing adaptive capacity.

- Risk as the outcome of high level of exposure as a result of the lack of
  - mitigating climate effects (e.g. afforestation upstream to reduce flood run-off speed),
  - anticipatory risk zoning for new investments, and
  - adequately governing retreat in cases where increasing resilience on the spot is no option anymore.

- The lack of the infrastructure systems to be adequately protected (e.g. lack of green infrastructure), to be adequately robust regarding its physical structure and functionality, and to be adequately equipped with climate sensitive operational and maintenance procedures to withstand bio-physical climate impacts.

- The lack of infrastructure systems to adequately perform disaster management and business continuity management in the course and aftermath of climate related physical extreme events, including effective warning and response systems; as well as reconstruction contingencies.

These risk narratives provide entry points for assessing narrative specific causalities that can be searched in unfavourable societal, political, regulative, economic, and environmental framework conditions and contexts in which infrastructures investments are carried out.

Module 4

4.3.3.2 Infrastructure Vulnerability and Risk Assessment

Vulnerability and Risk Assessments form together the second step of Climate Proofing. They identify vulnerability (as a function of sensitivity and adaptive capacity) and exposure of infrastructure project components to climate change effects, which result in impacts of varying severity from hazards that may occur with an estimated probability. Thus, uncertainty is part of climate risk assessment. Risk Assessment is an important Climate Service Product for decision makers.

In the following some key considerations are outlined that are crucial to follow once carrying out climate risk assessment.

1. **Type of risk assessment depends on the decision making context in the different steps of the infrastructure investment cycle**

   Risk information is required in different steps of infrastructure investments (compare entry points for climate proofing in the infrastructure investment process, Module 2.2). Hence, risk information needs to be tailored according to the decision making context in these different steps. For example, whereas in the pre-feasibility phase a geographic position for the entire infrastructure needs to be selected (risk information shall support this decision: exposure / hazard information), in the feasibility phase the resilience of the infrastructure at a specific selected spot needs to be established. Here, risk information shall define load thresholds / impact thresholds for infrastructure specific physical-, functional- and operational components based on anticipated climate events.

   To conclude, risk assessments start after the definition of the decision making context, the system of interest and / or sub-systems of interest that are likely to be under climate risk.

2. **Bottom-up vs. top down approaches towards risk assessment – the role of impact-threshold based risk assessment**

   In dealing with climate change and the uncertainties of climate related risks, various approaches or

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Box 4.3.2 Impacts of Climate Change on Road Infrastructure in New York and Seattle

New York and Seattle (among other urban and coastal areas in the United States) have been the subject of climate change studies.

In the city of Seattle, the following components of the road infrastructure system were found to be most vulnerable:

- bridges and culverts (from increased mean annual rainfall, rainfall intensity, and sea level rise),
- causeways and coastal roads (from sea level rise and increased frequency and intensity of storm surges),
- pavement surfaces (from increased mean annual temperature),
- surface drainage (from increased intensity of rainfall), and
- hillside slope stability (from increased mean annual rainfall and rainfall intensity).

In the New York metropolitan area, it was found that the transportation systems would be significantly affected by floods and rising water tables, especially because many of the critical transport facilities are in tunnels.

See Cohen, S., W.K. Soo Hoo, and M. Sumitani. 2005. Climate Change Will Impact the Seattle Department of Transportation. Seattle, Washington: Office of City Auditor; and Rosenzweig, C. and W.D. Solecki. 2001. Climate Change and a Global City: The Potential Consequences of Climate Variability and Change—Metro East Coast. Report for the US Global Change Research Program, National Assessment of the Potential Consequences of Climate Variability and Change for the United States. New York: Columbia Earth Institute.

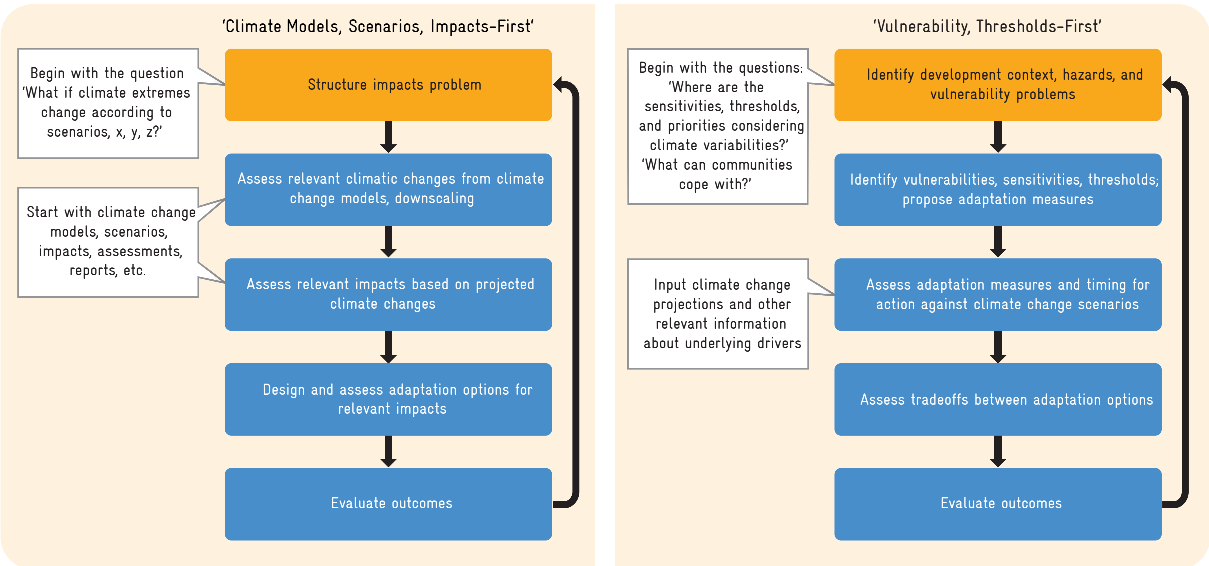
gradations of approaches of adaptation and disaster risk management planning do exist. Most approaches can be divided in 'top-down' approaches (scenario-impact-first) and 'bottom-up' approaches (vulnerability-threshold-first).

Their main difference lies in the timing or sequencing of individual steps of the risk analysis (see fig. 4.3.4) which may have, however, significant implications for management of uncertainties, the timing of adaptation options, and the efficiency of policymaking. Top-down approaches start with scenarios of future climate conditions and model possible impacts of changing climate conditions and subsequently identify adaptation options. This approach is most useful to raise awareness of the problem, to identify possible adaptation strategies and to identify research priorities. However, top-down approaches are often not able to consider the scale and purpose of decision-makers and usually give less consideration of current risks from natural climate variability, to non-climatic stressors and to key uncertainties.

In contrast, bottom-up approaches can be independent of any specific future climate condition. They are particularly useful for identifying priority areas for acute action, when the role of climatic stress factors cannot clearly be demarcated from non-climatic factors or uncertainties about future climate impact are very large (IPCC 2012). Consequently, for the identification of adaptation options for on-site decision-making, a detailed knowledge of current climate risks is necessary in order to assess future climate risks in the vicinity of deep uncertainty. This in turn requires problem- or user-tailored climate information.

As mentioned in chapter 3, the co-design of climate service products is a pre-condition for the uptake of climate information in processes of risk assessment and adaptation decision making. For instance, it makes little sense to make a risk assessment to a hazard which is not related to a specified 'load-threshold' of an infrastructure's component. A load-threshold is related to maximum loads (e.g. kN/m^2) for different infrastructure components. I.e. assessing the change of daily temperature extreme values in the context of climate change has

Figure 4.3.4 **Sequence of steps of top-down approaches (left) vs. bottom-up approaches of assessing climate risks**



Source: SREX 2012

little information value for components which are vulnerable to moderate high temperatures which occur several days in a row (heat spell). While in the first case the magnitude of temperature is in focus, in the second case the sensitivity of the component rather refers to the duration and frequency of high temperature periods. Consequently, by not considering the appropriate user-specific climate hazard, the risk for this component would be dramatically underestimated or even neglected. Hence, the definition of climate parameters, indices and projections to be applied depends on decision-makers' requirements, the impact thresholds of the infrastructure, as well as the life cycle of the infrastructure.

3. **Methods to be applied for risk assessment are highly contextual**

   Risk assessments can use a variety of approaches. These deeply depend on time, people, knowledge and financial resources. In turn, metrics to be used greatly depend on the working context and the system of interest under analysis, as well as available data or existing data gaps that force practitioners to work with proxies. These quite open variables also mean that climate risk assessments should always be designed in a flexible way, allowing for methodological adjustments on the run, grounded on evolving requirements, capacities, and resources.

4. **Understanding drivers of risk reveal options for climate risk management**

   Overarching, risk assessment puts emphasis on identifying drivers for climate-induced risks. As an example, a bridge infrastructure project or existing structure, such as its bridge pillars, can be at risk because it is likely that they will be exposed in the future to stronger flash floods that exacerbate the pillars impact thresholds. The drivers for this risk are on the one hand the bridge pillars' physical design and its conditions (i.e. age) itself, but also the river basin landscape that allows for flash floods due to previous river regulation. Screening for the drivers for risk both regarding exposure, sensitivity, and adaptive capacity, allows for an understanding of all factors leading to risk. In order to understand the significance of these factors for potential (bio-physical) and socio-economic impacts of climate change, it is important to weight each one of them, in order to have instruments to simulate in further steps on how to effectively reduce climate risk.

5. **Uncertainty in risk assessment & the role of decision makers**

   Even with significant data and information available, climate risk assessments always occur under conditions of uncertainty. This is due to the fact that it is not possible to entirely picture the complexity of risk conditions, including the projection of climate change. For this reason, it is key for decision-makers to define acceptable levels of liabilities and accountabilities facing risk (i.e. 'residual risk'). This is especially relevant when performing engineering-centred risk assessments, as in particular in the absence of data, quantitative assessment approaches may need to be mixed with qualitative data. To ensure trust in the process under conditions of uncertainty, decisions on procedures, methods applied, and results of the risk assessment need to be made transparent and based on consensus. A method for consensus building can be e.g. through the quantification of qualitative judgement. To ensure liability, acceptability, and accountability documentation of decision making within each risk assessment step is crucial.

6. **Risk assessment as a multi-stakeholder process requires clear governance and facilitation**

Since conducting climate risk assessments (and defining the Climate Information therein) depend on data related to the infrastructure setup, processes of Climate Risk Assessments should be designed and conducted within a multi-stakeholder process representing different disciplines, from engineers and planners, to climate service providers and relevant decision makers. Moreover, risk assessment not only needs to be developed and validated by experts in the area, but also by decision makers and general public that might be affected by the identified risks. Hence, in order to achieve adequate commitment for the achieved results it is recommended to reserve time and resources for the participation of all relevant stakeholders, e.g. local communities, non-governmental organizations, and small to large businesses operating in the area. Multi-stakeholder processes can become difficult to manage. Good management and facilitation skills are needed.

7. **Resource intensity of risk assessments is variable and context specific**

A climate risk assessment can be carried out with different levels of resource intensity. Digitalization tools might help to increase the efficiency of risk information selection and evaluation. An express workshop format is also a valid method to create in-depth knowledge and validated results, although it is recommended to be performed after assessing general information.

4.2.3.3 Step-by step guidance for Infrastructure Climate Vulnerability and Risk Assessment

The climate risk assessment of infrastructure based on Engineers Canada's Public Infrastructure Engineering Vulnerability Committee (PIEVC) protocol suggests that the 3 elements of the Climate Risk equation shall be assessed via 5 steps:

Once the context of Climate Risk Assessment is defined (Step A), Climate Risk Assessment elaborates on the exposure of the system of interest to the potential climate effects (Step B). Based on these climate parameters, the sensitivity of the infrastructure is assessed. This is done by investigating on the systems of interest (e.g. infrastructure assets / components) the impact thresholds (defining load capacity based on forensic analysis, design parameters, building codes etc.) as well as evaluating the consequences of their failure with regard to the service provided by the infrastructure (Step C). Based on the identified impact thresholds, climate indices are defined and projected. They are calculated by the probability of certain climate indices to change (Step D). Finally, factors of adaptive capacity are identified that can support the adaptation process (Step E).

In the following guidance more detail of the risk assessment procedure is provided. A case is made for assessing the risk of existing infrastructure that requires climate proofing in the course of general maintenance planning:

Step A Define the context of your risk assessment

Step A is the Scoping Exercise, which has already been defined in chapter 4.1. As a reminder, relevant questions to be asked for are:

- What is the decision making context of your infrastructure investment?
- What is the infrastructure of concern?
- Do you deal with a single infrastructure object or an infrastructure network?
- What is the (potential) location and spatial coverage of the infrastructure (network)?

Step B Elaborate on the exposure of specific infrastructure assets and operational units to potential climate-related hazards (Exposure, Hazards)

Climate and thus climate change may become critical as affecting infrastructures and changing physical characteristics of individual components or operational processes and consequently causing undesired impacts. These impacts may be induced directly by (primary) climate events (e.g. heat influences physical or chemical characteristics of material or the capacities and functionality of staff in order to fulfil tasks) or indirectly by the interaction of several climate and / or non-climate parameters which can be termed as secondary or tertiary climate events or climate-related events (e.g. heavy precipitation causes floods or landslides which impede to hit infrastructure assets).

In a bottom-up approach the event that directly impedes the infrastructure's components are the events to be considered as most relevant no matter if it is a primary, secondary or tertiary climate event. All climate events (primary or sub-sequent) that constitute a threat to an infrastructure will be termed as climate-related hazards according the AR5 terminology.

The relevance of climate-related hazards for infrastructure and their components or operational processes varies drastically depending on the infrastructure itself, its intrinsic characteristics and thus its individual impact-related thresholds (please refer to step C). Therefore, considering the threshold issue, climate-related hazards cannot be considered as absolute events with standalone validity but as relative to the affected system (or infrastructure component). E.g. a flood becomes a climate-related hazard for a component (or a component will be exposed to a climate-related hazard) as soon as the intensity / duration / frequency relationship of the flood becomes relevant for the component (i.e. causes a defined undesired outcome). This outcome is defined by a threshold.

Until this threshold is not reached, the exposed component is not sensitive or the sensitive component is not exposed to the specified climate-related hazard. On the other hand, all types of floods which cause an effect exceeding the component's threshold are relevant for the infrastructure and constitute thus a climate-related hazard. This is often in contrast to the consideration of climatological defined extreme events. The statistical extremity of climate-related events is related to the likelihood of their occurrence and not to the consequence in the case of an impact. This approach assumes that the component is adapted to all events but extreme events which is often not the case. Consequently, considering only the exposure of a component to a statistical extreme event would systematically underestimate its risk related to this type of event.

The consequence of the complex relationship between hazard and exposure which is outlined above and which also integrates aspects of sensitivity requires a practical approach for the assessment of these elements. The exposure of a component to a climate-related hazard can therefore be defined generically and specifically. The generic type of exposure can be defined as follows: a component is exposed to a climate-related hazard type. This type of climate-related hazard might become relevant for the component as soon as a certain intensity / magnitude / duration / frequency relationship is reached which is, however, not defined yet. In order to assess which infrastructure components or even sub-components might potentially be at risk from different climate-related events the following sub-steps are recommended:

> Box 4.3.3 **The life cycle of infrastructure**
>
> Each infrastructure is designed to have a certain life cycle. This means an amount of years to last and function. For public infrastructure, life cycles usually are between 25 to 100 years. However, different components of the infrastructure may have reduced life cycles, and therefore might need to be replaced before the life cycle of the whole infrastructure.
>
> Regarding climate risk, it is therefore relevant to analyze climate conditions for the whole life cycle, in order to assess possible exposure and vulnerability.

> Step B1: Identify & select critical infrastructure components and operational processes (screening of most important components for the assessment):

- What are components or operational processes which are most critical for the functionality and safety of the infrastructure?
- What are the life cycles of the identified components?

> Step B2: For each identified infrastructure component or operational process identify types of climate-related events which potentially may have a relevant impact:

- What are the climate-related event types that might have an effect for the exposed infrastructure component or operational process?

- What is the generic bio-physical impact of the identified climate-related event on the exposed infrastructure component or operational process?

Support

(B1) The identification of component life-cycles is relevant for the choice of the time slice of climate projections. If a component has a life-cycle of about 25 years, the development of the identified climate-related hazard in 100 years is not relevant for the assessment of adaptation options for this component.

(B2) The identification of a generic bio-physical impact helps to identify possible climate-related hazard types by tracing back on that event which might cause a bio-physical impact of concern. Some examples on climate-related hazard types and their generic impacts are provided in table 4.2.1. Furthermore, for several infrastructure sectors there are lists available on typical climate-related hazards and generic impacts on specific infrastructure components and operational processes. These lists easen the assessment of climate-related hazards which are relevant for a specific infrastructure or might be relevant in the context of climate change (see 4.3.9.3 Annex 3 of this subchapter for an example from the road transport infrastructure sector).

Table 4.3.1 Examples of temperature-related hazard types and their generic impacts on infrastructure components or operational processes (with additional examples related to road infrastructure in 4.2.9.3 Annex 3)

Climate stressors	Climate-related hazard types	Specifications/ definitions	Generic impacts
Temperature	Extreme high temperatures	Short-term (day) occurrence of critically high air temperature (max values)	Warming of road surface > thermal expansion > breakage > not usable for vehicles
	Periods of high temperatures (heat spells)	Period (days-weeks) of critically high air temperature (high-max values)	Stress or damage of physical/ecosystem entities due to iterative heat increase (e.g. permanent heat-stress) Medium-term change of physical/chemical/behavior characteristics of physical/ecosystem entities due to iterative heat increase (e.g. change of gaseous state, mechanical or electrical characteristics, behavior patterns or other functionalities).
	Warm season	Season (months) of critically high mean air temperatures	Drying of Soil conditions that might affect stability of bridge pillars.
	Extreme low temperatures	Short-term (day) occurrence of critically low air temperature (min. values)	Stress or damage of physical/ecosystem entities due to sudden temperature drop (e.g. super-cooling) Short-term change of physical/chemical/behavior characteristics of physical/ecosystem entities due to sudden temperature drop (e.g. change of gaseous state, mechanical or electrical characteristics, behavior patterns or other functionalities).
	Extreme temperature oscillations	Short-term (day) extreme oscillation of air temperature	Stress or damage of physical/ecosystem entities due to short-term temperature oscillations (e.g. thermo-mechanical stress) Short-term change of physical/chemical/behavior characteristics of physical/ecosystem entities due to short-term temperature oscillations (e.g. inconsistent gaseous state, mechanical or electrical characteristics, behavior patterns or other functionalities).
	Wet season	Season (months) with critically high mean rainfall	Start of period for relevant socio- or ecosystem-based processes and phenomena due to exceeding certain minimum rainfall sums/achievement of certain mean rainfall sums (e.g. growing periods, etc.)

Step C Identify sensitivities of the infrastructure components to the identified climate-related events and climate change.

Sensitivity is defined as the degree to which a system is affected by climate change. Or in other words: a system is sensitive if the impact is high relative to the change of a climate parameter.

Factors of an exposed system's sensitivity are: (1) the existance of threshold and characteristics within the system (i.e. sudden change); (2) thresholds within infrastructure components leading to serviceability, functionality or safety loss of a component; (3) the criticality of the system regarding the consequences of the impact beyond the system's boarders (i.e. cascading effect).

1. Considering the discussion of climate-related events above, it is important to realize that the sensitivity to climate change of an infrastructure component or operation process is dependent on the length and characteristics of the climate-impact chain: E.g. in the case of a flood, catchment characteristics like soil conditions, land use, vegetation cover, bedrock conditions and others influence the hydrological conditions and therefore also influences the sensitivity of the hydrological system (e.g. flood generation) to a change in climate drivers (like changes in precipitation or temperature). Hence, the way precipitation or temperature influences flood characteristics depends on catchment characteristics.

2. The exeedance of a threshold within a system implies a significant change in the behaviour or characteristics of the affected system. Thresholds of infrastructure components are determined by e.g. the load capacity (design load) of building materials influenced by quality of materials, aging and maintenance schemes or operational management of the assets.

   In the context of infrastructures, thresholds can refer to the (i) serviceability, (ii) functionality and (iii) safety of a component or entire infrastructure. In the case of a bridge, the affection of serviceability may refer to a temporal closure due, e.g. to a flooded access road (however, without physically damaging the bridge). The affection of functionality may refer to partial damage of the bridge, which can be repaired in rather short time but requires temporal restriction in service or even closure. The affection of safety refers to the serious physical damage or even failure of a component, which might require effortful renovation or even rebuilding of the bridge and thus long-term closure. Theoretically, for each component at least three thresholds can be defined which consider all three aspects. The impact of concern (affection or loss of serviceability, functionality or safety of a component) needs to be defined by the decision-maker of the infrastructure. Even when design codes exist that define certain thresholds (especially safety thresholds), there are seldom universal thresholds available since local conditions are always individual. Thus, thresholds always refer to local environmental conditions and specific decision-making processes of infrastructure operators.

3. Sensitivity may also refer to the subsequent consequences of the affection / failure of a component, which might be critical for the functionality or safety of other components or for socio-economic systems which are inter-related or dependent on the infrastrucutre. E.g. when the closure of the bridge takes too long, because critical components failed and the bridge is destroyed or the maintenance activites take very long, other systems which are dependent on the bridge may be seriously affected. However, there are also factors in place which might mitigate such effects, such as managing residual risk (or disaster management) through a business continuity management appoach.

The following sub-steps provide deeper insights:

> Step C1 Construction of a climate hazard chain

Once the relevant climate-related hazards are identified which may have an undesired impact on exposed components, the climate-impact chain between impact and hazard needs to be traced back and characterized in order to identify factors of sensitivity. I.e. the interlinkage of the climate-related

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hazard with the climate shall be identified and factors which influence this interlinkage being identified. In the case at which a primary climate signal (i.e. sea-level rise, temperature or precipitation pattern) is the climate hazard, there is no climate-hazard chain existent. However, in case of exposure to a secondary hazard (e.g. a flood, caused by extreme precipitation), an additional linkage to climate parameters has to be established. The relationship between climate change signals and secondary hazard events is usually also influenced by the system's characteristics, like e.g. catchment area characteristics such as topography or biodiversity, which function as sensitivity factors.

- How is the identified climate-related hazard to which our components are exposed interlinked with climate? What is the qualitative cause-effect logic between climate signal and the emergence of the climate-related hazard?
- What are the bio-physical and socio-economic factors that influence the effect of climate on the identified climate-related hazard of concern?

> Step C2 Identification of impact thresholds

After the identification of the relevant climate-related hazards which may have an undesired impact on exposed components and the associated climate-hazard chain, the characteristics of the climate-related event that make it critical for the infrastructure component need to be identified (i.e. quantified), therefore, expanding the climate-hazard to a climate-impact chain. The event becomes critical when the provided load from the event (e.g. intensity / magnitude, duration, frequency of events) exceeds the load capacity of the infrastructure component and thus triggers an impact on the infrastructure component. The quantitatively characterized climate-related event should then be analyzed regarding its probability of occurrence (see Module 2.1).

- What are the climate-related thresholds of the selected components and operational processes, regarding intensity / magnitude, duration and frequency, which cause the undesired consequences once being exceeded?
- What are the bio-physical and socio-economic drivers influencing the identified impact thresholds (e.g. aging, over-use, lack of maintenance etc. – vulnerability-causality analysis)?

> Step C3 Consequences for the infrastructure as a whole or sub-processes

The impact identified in Step A is the main point of attention. However, other impacts deriving from this may cause even more losses. For this reason, it is relevant to explore additional (bio-)physical and socio-economic impacts that could afford generate additional risk.

- Considering the identified impacts and their thresholds of each component: what are potential subsequent consequences of these impacts on other parts of the infrastructure or on other interrelated socio-economic systems? Are these consequences critical?
- What are available coping options in order to mitigate the severity of the subsequent consequences?

Support

(C1) More details on the construction of climate-impact chains can be found in the Vulnerability Sourcebook (www.adaptationcommunity.net/vulnerability-assessment/vulnerability-sourcebook).

(C2) The impact chain is always performed with regard to the current status, and not to possible future statusses. This means that possible – but still not implemented – adaptive capacity measures shall not be taken into account.

(C3) Sources of information are forensic analysis of already experienced damages, as well as building codes and design studies of the infrastructure.

(C4) This type of sensitivity is also part of a criticality analysis1 which may help to further prioritize

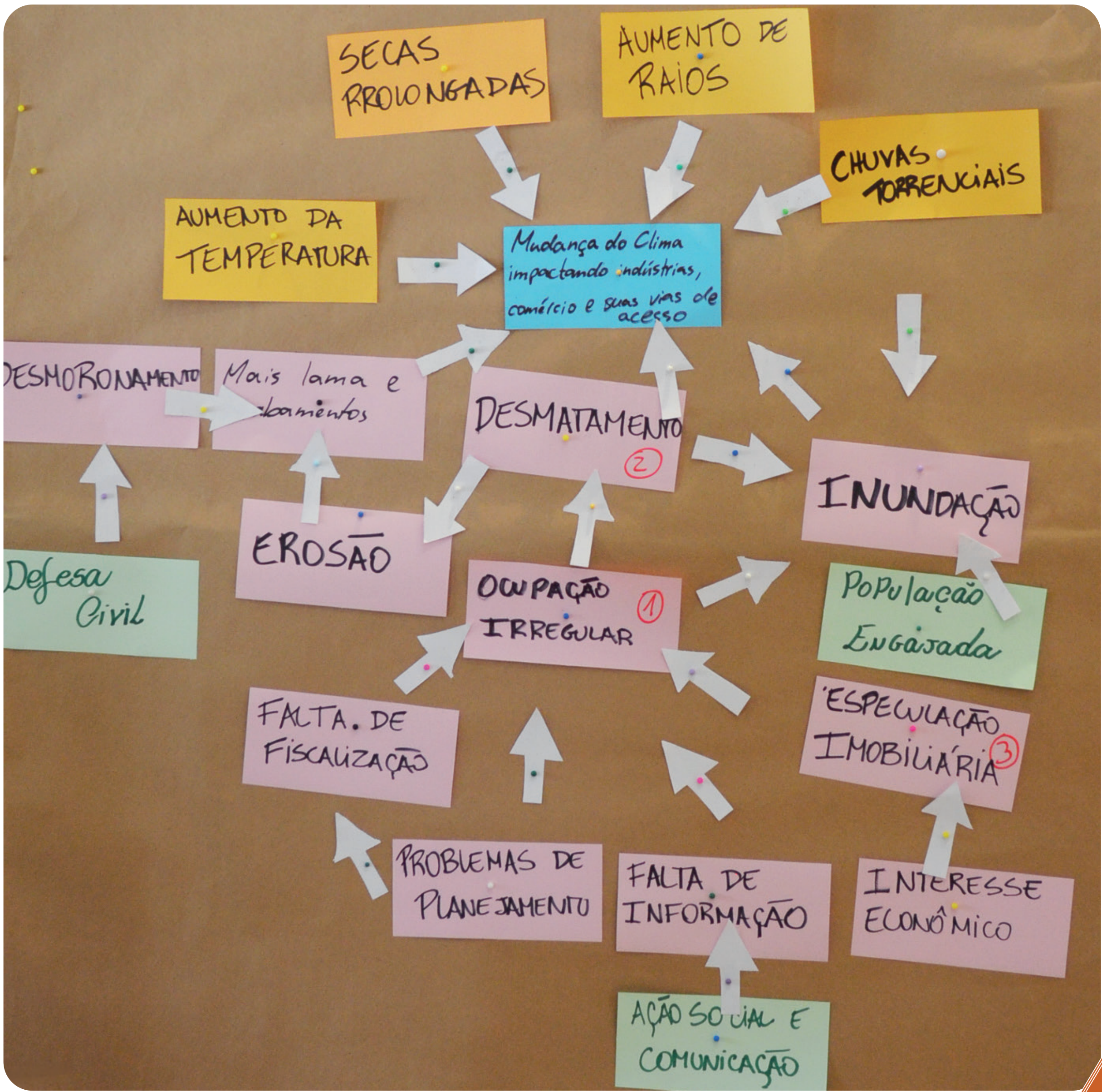
[1] Fekete, Alexander. (2010). Criticality analysis of Critical Infrastructures (CI)-developing generic criteria for identifying and evaluating the relevance of CI for society.

infrastructure components or operation processes for further analysis.

Step D Identify probability of component-specific climate-related hazards in the context of climate change

In order to assess the risk of loss and damage in the context of climate change (i.e. the impact on an infrastructure component), the probability of the climate-related hazard occurring in the future must be assessed. However, depending on the complexity of the climate-related hazard, this is not always a straight forward and easy task. In the simplest case, the climate-related hazard is a primary event and composed of only climate variables, ideally even only one variable. In the case of complex interactions of climate parameters (e.g. phenomena like hurricanes or indices which relate to specific vulnerabilities) the predictability has to be checked. If this is not possible, a representative variable or 'hosting event' (i.e. surrogates, proxies) need to

Figure 4.3.5 Example of impact chain



be identified in order to assess the probability of such events from climate projections. For secondary or tertiary events, climate impact models are required. If they are not available, again surrogates need to be identified.

> **Step D1 Identify probability and certainty of climate-related hazards for current climate conditions.**

What are probabilities of occurrence of the climate-related hazards in the current climate? What are the uncertainties of the analysis?

> **Step D2 Check the predictability of the component-specific climate-related hazards and identify climate surrogate parameters if applicable.**

Can the climate-related hazard of concern be projected with adequate precision? If required: are adequate impact models available?

If not, what are climate parameters, events or systems which are predictable and correlate well with the identified climate-related hazards?

> **Step D3 Identify probability and certainty of climate-related hazards in the context of climate change.**

What are probabilities of occurrence of the climate-related hazards in the context of climate change? What are the uncertainties of the projections?

How to communicate these uncertainties to decision makers?

Support

(D1) A step-by-step approach here fore is provided in Chapter 2.1, following IPCC AR5 criteria.

Step E Identify adaptive capacity and its socioeconomic drivers.

Adaptive capacities are the properties or variables within or in connection of the system of interest that have an influence or adjust to potential impacts, to make use of their opportunities, or to respond to their consequences. Examples are financial resources, technical know-how, or back-up plans in case of infrastructure failure.

Step F Calculate climate risk

Certain decision-makers feel the need to quantify climate risk. This makes sense when they need to decide about the urgency of the action to take up risk-reducing measures. The calculation of climate risk is only performed for systems which already have been assessed as exposed to climate hazards. For this reason, exposure is not taken into account in the calculation.

Quantification most often poses a certain challenge to climate risk advisors, as indicators are usually not unambiguous. For this reason, it is key to identify key factors leading to vulnerability, and multiply these findings by the likelihood for the occurrence of the climate hazard leading to the event. Many of the factors are not quantifyable per-se, and need to be discussed based on expert judgement.

> **Step F1 Calculate the sensitivity of your exposed system.**

Taking into account the previously identified sensitivity factors leading to the potential impact, how would you assess the sensitivity on the scale of 0 (not sensitive at all) to 7 (extremely sensitive)?

> **Step F2 Calculate the lack of adaptive capacity of your exposed system.**

Taking into account the previously identified adaptive capacity factors acting upon the identified sensitivity and potential impact factors, how would

Matrix 4.3.1 **Vulnerability calculation matrix**

Sensitivity								
7	0	7	14	21	28	35	42	49
6	0	6	12	18	24	30	36	42
5	0	5	10	15	20	25	30	35
4	0	4	8	12	16	20	24	28
3	0	3	6	9	12	15	18	21
2	0	2	4	6	8	10	12	14
1	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
	0	1	2	3	4	5	6	7

Adaptive capacity

0	1	2	3	4	5	6	7

Colour code for Vulnerability

Matrix 4.3.2 **Climate Risk calculation matrix**

Vulnerability								
7	0	7	14	21	28	35	42	49
6	0	6	12	18	24	30	36	42
5	0	5	10	15	20	25	30	35
4	0	4	8	12	16	20	24	28
3	0	3	6	9	12	15	18	21
2	0	2	4	6	8	10	12	14
1	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
	0	1	2	3	4	5	6	7

Likelihood

0	1	2	3	4	5	6	7

Colour code for Climate Risk

Risk thresholds

Up to 12	Low risk, discard from further analysis
13–35	Medium risk, retain for further analysis
>35	High risk, go directly to recommendations

you assess the lack of adaptive capacity on the scale of 7 (no adaptive capacity at all) to 0 (full adaptive capacity to the expected sensitivities and potential impact) in your system?

> **Step F3** Calculate the vulnerability of your exposed system

Taking into account the previously identified sensitivity and adaptive capacity scores, assess the vulnerability score using matrix 4.3.1.

> **Step F4** Calculate the risk of your exposed system

Taking into account the previously identified vulnerability scores and the likeliness scores identified in chapter 2.1, assess the risk score using matrix 4.3.2.

Support

(F1) Calculating climate risk makes sense in order to prioritize adaptation efforts. Therefore, it often makes sense to also perform this exercise for different sub-components within your system, pursuing to identify critical points that my increase the risk for the whole system.

(F2) To assess the sensitivity and adaptive capacity of your system, try to first identify key factors that define most of your sensitivity and adaptive capacity, and centre discussions on those.

(F3) When calculating the lack of adaptive capacity, compare it to identified sensitivities. 'No lack of adaptive capacity' means that existing adaptive capacity currently completely equalizes existing sensitivity.

4.3.4 Exercise Infrastructure vulnerability and risk assessment

Learning objectives

1. **You will learn about how to identify climate-related vulnerabilities and risks within your infrastructure-centered system of interest. This means exploring all aspects of climate risk, including exposure sensitivity and adaptive capacity, exploring single climate hazards. Performing a vulnerability and risk assessment is crucial to identify possible entry points for adaptation.**
2. **You will learn about the key features of the PIEVC risk matrix: Identifying and agreeing on the climate change signals and the critical climate events to be considered in the assessment.**
3. **You will learn how to identify potential impacts to your system of interest, linked to climate change trends for specific infrastructure components and specific performance goals.**
4. **You will understand how potential (bio-physical) impacts to your system of interest are linked to thresholds within single components of your system.**
5. **You will learn how to construct impact chains linking potential impacts to hazards to which your system of interest is exposed.**
6. **You will learn how to construct indices based on your impact chain that add meaning to the single components that conform the climate risk of your system of interest.**
7. **You will understand how factors apart from your infrastructure investment can increase its climate risk or potentially be part of the solution to decrease it.**

Content and main tasks

- Estimation of potential (bio-)physical impacts linked to climate change trends for specific infrastructure components and specific performance goals
  >> Definition of the point of departure for the vulnerability and risk assessment
- Assessment of thresholds leading to (bio-physical) impacts
  >> Definition of sensitivity leading to (bio-physical) impacts

- Link (bio-)physical impacts to specific hazards
  >> Construction of the main impact chain

- Identification of sensitivities
  >> Identification of direct and indirect sensitivities

- Identification of adaptive capacities
  >> Assessment of direct and indirect adaptive capacities, and their link to exposure and sensitivities

- Mapping of socioeconomic consequences of the (bio-physical) impact
  >> Identification of socioeconomic impacts

- Calculate climate risk
  >> Calculation of climate risk, based on the calculation of vulnerability and likeliness of a hazard.

Method Learning from experience with a case study

You are part of the expert team, developing the risk-assessment mission for the **Metropolis Millennium Bridge, South State** (see Box 4.3.4 for summary and Annex 1 for details) and work together with 3 to 7 experts in a team.

You and your colleagues bring in the engineering, climate change, environmental and cooperation expertise, based on the case description and your own experience.

Please find some hints for a fruitful cooperation in the box 'Guidance for effective group work'.

Guidance for effective group work

- For effective and efficient work, a working group should select a facilitator, a time keeper and a presenter.

- Take your time to read through the task description and see if everybody is on board.

- The working groups work independently.

- Trainers can be asked for advice.

- The main learning objective is to learn about the systematic approach and not to be comprehensive in the task.

Your specific tasks

- Review the case description (Annex 1).
- Review the results from exercises performed in Modules 2.1 and 4.2. (in case you did these before).
- Use a flipchart or board with cards.
- Respond to the following tasks and present your results in form of impact chains (see also figure 4.3.5). The information in brackets refers to the PIEVC-steps explained in the previous chapter.

- **Step 1. (A)**
  - Name the system of interest to be assessed (e.g. one identified in the Scoping Exercise of Module 4.2).

- **Step 2.**
  - Select one climate hazard with a relevant likeliness to happen more frequently (e.g. from results of the exercise in chapter 2.1 of Module 2 or expert judgement). Place it to the top of the board.

- **Step 3. (B1)**
  - Identify and select critical infrastructure components and operational processes.
  - Focus on most critical infrastructure components and take the life cycle into consideration.

- **Step 4. (B2)**
  - For each identified infrastructure component or operational process identify types of climate-related events which potentially may have a relevant impact and to which the infrastructure is or might be exposed within its life cycle (use the results of chapter 2.1 exercise to assess future exposure).
  - Define a generic bio-physical impact of the identified climate-related event on the infrastructure component or operational process.
  - Place the selected (bio-physical) impact near to the middle of your board.

- **Step 4. (C1)**
  - Name the climate-related hazard leading to the selected (bio-physical) impact. Pin it next to the card with the (bio-)physical impact.
  - Identify a climate signal leading to the identified climate-related hazard. Pin it next to the card with the hazard.
  - Establish the link between the climate-related hazard and the climate signal. Take the qualitative cause-effect logic between climate signal and the emergence of the climate-related hazard into account.
  - Pursue to explore all intermediate impacts leading to the selected (bio-)physical impact.
  - Include the bio-physical and socio-economic sensitivities that influence the effect of climate on the identified climate-related hazard of concern.
  - Place the sensitivities (written on cards with a different color than the impacts and climate change signals) attached to the impacts they influence, connecting them with arrows.
  - Construct a climate change impact chain linking the climate hazard to the selected (bio-)physical impact using arrows.
  - Explore and identify sub-sensitivities / driving forces that lead to the prior identified sensitivities (e.g. 'deforestation' lead to 'erodible soil structure'), by these means constructing sensitivity-chains.

- **Step 5. (C2)**
  - Identify climate-related thresholds of the selected components and operational processes, regarding intensity, duration and frequency, which cause the undesired consequences once being exceeded.
  - Name the bio-physical and socio-economic drivers influencing the identified impact thresholds.

- **Step 6. (C3)**
  - Name potential subsequent consequences of the before identified impacts on other parts of the infrastructure or on other interrelated socio-economic systems and place them into the impact chain.
  - Assess these impacts' criticality.

- **Step 7. (E)**
  - Identify and name existing adaptive capacities to reduce sensitivity and potential impacts and place them on the impact chain.
  - Place the adaptive capacities (written on cards with a different colour than the impacts, climate change signals, and sensitivities) attached to the impacts or sensitivities they influence, connecting them with arrows.

- **Step 8.**
  - Discuss within the group if the impact chain is constructed in a logical way, e.g. if connections and formulations make sense.

- **Step 9. (F1)**
  - Identify key factors of sensitivity.
  - Assess the sensitivity on the scale of 0 (not sensitive at all) to 7 (extremely sensitive).

- **Step 10. (F2)**
  - Identify key factors of adaptive capacity.
  - Assess the lack of adaptive capacity within your system on the scale of 7 (no adaptive capacity at all) to 0 (full adaptive capacity to the expected sensitivities and potential impact).

- **Step 12. (F3)**
  - Calculate your system's vulnerability, using matrix 4.3.3.

- **Step 13. (F4)**
  - Calculate your system's climate risk, using matrix 4.3.4.
  - For likeliness, use the results of the exercise performed in chapter 2.1.
- **Step 14.**
  - Prepare your presentation to the plenary and focus on your most important results within 5 minutes.

Box 4.3.4 **The fictitious case of Metropolis**

Metropolis is a mega city with about 6 Million inhabitants in South Country, and an area of major importance far economic activity and social life throughout the country. Equipped with residential and commercial/industrial areas, green spaces far recreation, hospitals, schools and universities, as well as vast shopping facilities covering all needs, the city is of major importance far the surrounding region, especially the smaller villages and dwellings who benefit from the services and facilities offered by the city. With having a harbour, the city receives importance as a gateway far the trade of goads and commodities within the region. The roads leading across the Millenium Bridge is of crucial importance far traffic, transport and overall mobility.

The city is located in the Karibu River Watershed. The Northern parts of the catchment are characterized by the high Upper Mountains, gently sloping south. These are a renowned destination far ambitious hikers and climbers in summer. However, in the past years much of the forests had been degraded due ta rapid urbanization and uncontrolled land-use changes. In the rainy season, the peaks of the mountains are often covered in clouds with intense rains occurring every afternoon causing tremendous water discharges. Two tributaries add their waters before Karibu River reaches the major bridge connecting bath parts of the city accessible far vehicles.

The frequency of disruptive high water levels of the river appears ta be increasing and a severe flood – similar ta the one in 1888 – has reoccurred once since. A relatively new feature are random thunderstorms accompanied by strong rains in the northern part of the watershed, where steep, bare rack slopes are common, leading ta extraordinary high water levels, and eventually causing flooding of the cities original flood plain, that is now urbanized.

See Annex I far further details.

Box 4.3.5 **Factors for Sensitivity**

Factors leading to sensitivity can be identified, e.g., in:

- Characteristics of public and private infrastructure, or its sub-components;
- Environmental characteristics and ecosystem services;
- The social structure of a system (demography, health, social dynamics, education, social cohesion, etc.);
- The governance system (distribution of power, human rights, access to resources, gender equality, public perception of risk factors, political stability, etc.); and
- The economic situation (conditions for socioeconomic balance, macro-economic factors, risk transferring schemes, etc.

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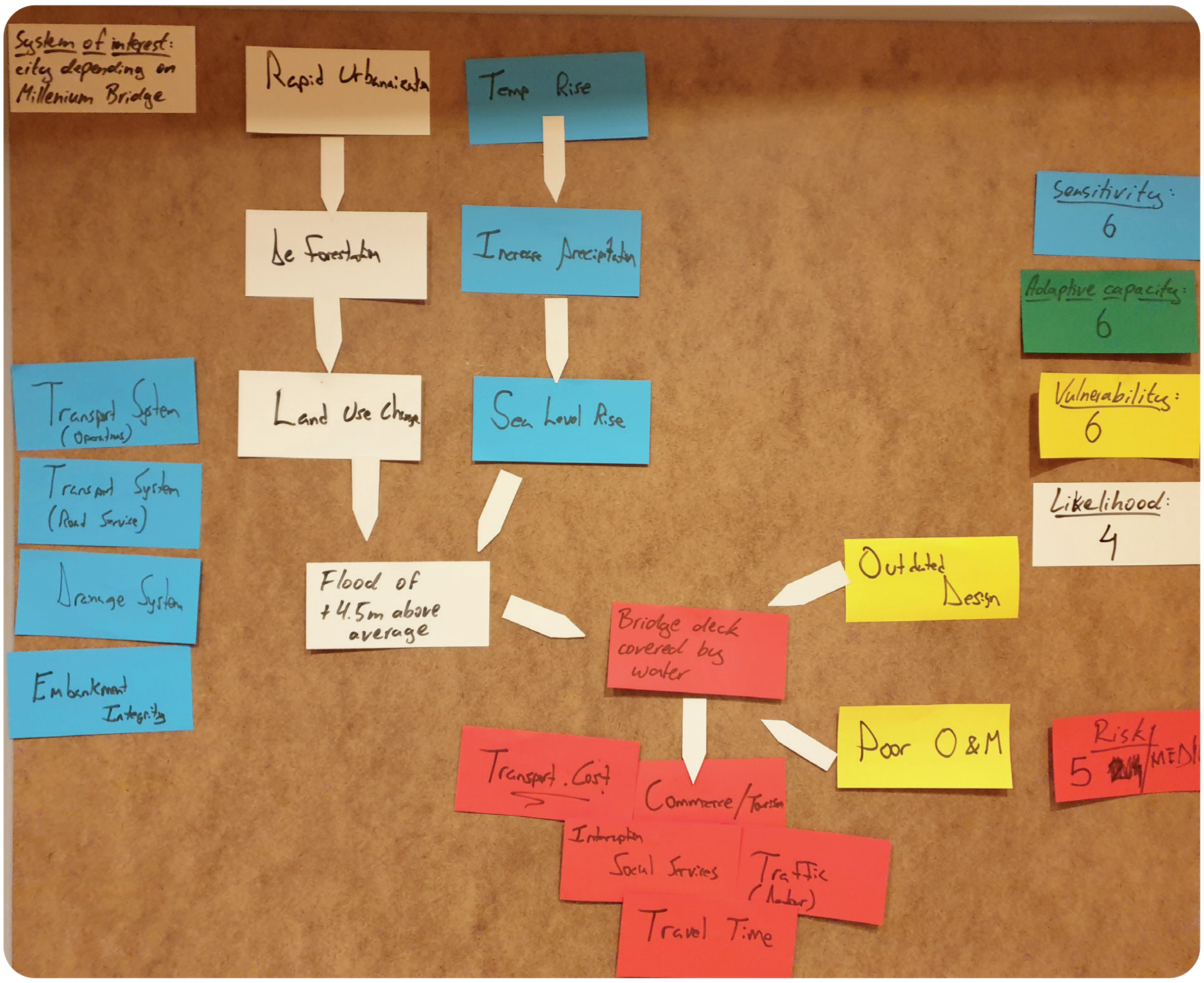
4.3.5 Guiding questions for reflection

- Which were major challenges you faced when performing this exercise?
- Why is it important to perform a climate risk assessment?
- What can be done if information to perform the climate risk assessment is very scarce?
- Which are key factors when planning to perform a climate risk assessment?
- What kind of resources are needed to perform a climate risk assessment?
- Which climate services are needed to perform a climate risk assessment?
- Which stakeholders groups are key as participants in the climate risk assessment process (refer to the Climate Service Value Chain)?
- How should a climate risk assessment be designed to fit to your working reality?

4.3.6 Take away messages

- Climate risk assessment is a decision support tool. Hence, results shall provide direct utility for taking adaptation decisions.
- Climate risk assessment is a climate service and represents a multi-stakeholder process representing different disciplines.

Figure 4.3.6 Results of the Climate Risk Assessment Impact Chain



- Facilitating a climate risk assessment process relates to the coordination of support and contributions of a range of stakeholders.
- Risk assessments and related adaptation decision support always occur under conditions of uncertainty influencing the distribution of liabilities, and accountabilities for decision- making.
- Metrics and approaches towards risk assessment can vary depending on actors' capacity, whilst the equation for assessing risk remains the same. Flexibility in the operationalization of the assessment is needed depending on requirements, capacities and resources.
- Engineering risk assessment can include a mix of qualitative (in the absence of data) and quantitative assessment approaches.
- The system of interest in the context of infrastructure needs to be defined based on the anticipated assessment scale, as well as on an infrastructure specific design-, functional- and operational components.
- The definition of climate parameters, indices and projections to be applied depend heavily on political requirements, the sensitivity / vulnerability of the infrastructure (Impact thresholds), as well as the life cycle of the infrastructure.
- Easy access and tapping effectively on climate service capacities and resources is a pre-conditions for the uptake of climate information in processes of risk assessment.

4.3.7 References

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4.3.8 Personal notes

4.3.9 Annexes for the exercise 'Vulnerability and Risk Assessment'

4.3.9.1 Annex 1 Climate Change Hazards

Primary climate drivers:

1. Annual/seasonal/monthly average (air) temperature
2. Extreme (air) temperature (frequency and magnitude)
3. Annual/seasonal/monthly average rainfall
4. Increased/extreme rainfall (frequency and magnitude)
5. Reduced rainfall
6. Average wind speed
7. Maximum wind speed
8. Humidity
9. Solar radiation

Secondary effects/climate-related hazards:

1. Drought
2. Water availability
3. Storm (tracks and intensity) including storm surge
4. Flooding
5. Inundation
6. Ocean pH
7. Dust storms
8. Coastal erosion
9. Soil (including shoreline) erosion
10. Soil salinity
11. Wild fire
12. Air quality
13. Sea level rise
14. Sea/water temperatures
15. Ground instability/subsidence
16. Landslides/avalanche
17. Urban heat island effect
18. Epidemics/pandemics
19. Insect infestation
20. Growing season length

Adapted from European Commission, 2011.

4.3.9.2 Annex 2 Climate-Related Impacts in Infrastructure

(Adapted from HM Government, 2011)

Please note this is by no means an exhaustive list of potential climate-related impacts in urban infrastructure, and should serve for reference purposes only.

Energy	Hazards	Potential Impacts
Fossil fuel and nuclear generation	▸ Increased rainfall intensity ▸ Sea level rise ▸ Shoreline erosion ▸ Higher temperatures ▸ Reduced summer rainfall	▸ Flooding of fossil fuel and nuclear power plants, decommissioned nuclear sites and nuclear waste reprocessing and storage facilities ▸ Reduced efficiency ▸ Reduced available water for cooling
Renewable wind energy	▸ Increased rainfall intensity ▸ Reduced wind	▸ Reduced efficiency ▸ Increased storm damage
Electricity transmission and distribution	▸ Higher temperatures ▸ Increased/more intense precipitation ▸ Surface water, tidal and fluvial flooding ▸ High winds ▸ Ground subsidence	▸ Overheating of transmission lines ▸ Reduced capacity of network ▸ Flood risk to substations ▸ Damage to overhead power lines and ancillary infrastructure ▸ Reduced stability of foundations and tower structures
Fuel processing and storage	▸ Sea level rise ▸ Storm surges	▸ Flood risk to fuel storage, transporting and processing facilities

ICT	Hazards	Potential Impacts
Wireless infrastructure	▸ Higher temperatures ▸ Increased risk of subsidence ▸ Increased risk of storminess ▸ Increased/more intense precipitation	▸ Location/density of wireless masts may become sub-optimal as wireless transmission is dependent on temperature ▸ Reduced stability of foundations and tower structures ▸ Damage to above ground transmission infrastructure ▸ Reduced quality of wireless service
Copper and fibre optic cables	▸ Flooding ▸ Erosion	▸ Inundation of low-lying infrastructure, access holes and underground facilities ▸ Transport infrastructure (roads/bridges) affected exposing cables and trunk routes

Transport	Hazards	Potential Impacts
Road	Increased/more intense precipitation Wetter winters and drier summers Higher temperatures Increased sea level Wildfires	Increased scour of bridges Increased instability of embankments Damage to road surfaces and foundations Flooding of roads Damage to bridges and tunnels Traffic accidents Increased pollution levels
Rail	Increased/more intense precipitation Wetter winters and drier summers Higher temperatures Increased sea level Wildfires	Flooding of rail lines, increased risk to train traffic Increased scour of bridges Increased instability of embankments Increased rail buckling
Ports	Sea level rise Increased storminess Higher winds	Flooding of equipment Disruption to operations Safety issues for navigation
Airports	Increased/more intense precipitation Higher temperatures	Flooding of runaway Disruption to operations Increased risk during landing and taking off Lift of aircraft reduced (affecting fuel use and take-off slots)

Sanitation	Hazards	Potential Impacts
Water supply and treatment	Changing precipitation patterns Drought Increased/more intense precipitation Higher temperatures	Reduced security of supply Flooding to water supply/treatment infrastructure Water treatment processes affected Exposure/damage of piping
Wastewater collection, treatment and disposal (including drainage systems)	Increased/more intense precipitation Drought Higher temperatures	Sewer flooding Pollution incidents (e.g. overflow of treatment facilities) Treatment processes affected Fluvial flooding to wastewater infrastructure Exposure/damage of piping Material expansion and rupture of surfaces
Solid waste collection, treatment and disposal	Increased/more intense precipitation Higher temperatures	Street waste carried away to water bodies Street waste clogging drainage system causing flooding Damages to disposal facilities

Environment and food production	Hazards	Potential Impacts
Water bodies	▸ Increased/more intense precipitation ▸ Wetter winters and drier summers ▸ Higher temperatures	▸ Increased pollution levels (e.g. by waste carried away to rivers) ▸ Lower water availability for consumption or other ends ▸ Higher risk of contagious diseases transmission ▸ Reduced water quality
Green areas, farms	▸ Increased/more intense precipitation ▸ Wetter winters and drier summers ▸ Higher temperatures ▸ Wildfires	▸ Damage of crops (e.g. by flooding) ▸ Food insecurity ▸ Damage of recreational and leisure facilities (e.g. parks)
Air	▸ Changed atmospheric conditions	▸ Increased pollution ▸ Increased public health issues

4.3.9.3 Annex 3 Some Potential Impacts of Climate Change on Road Infrastructure.

Positive impacts are marked with '*'

Potential Climate Change	Impacts on Road Transport Infrastructure
Increases in very hot days and heat waves	▸ Deterioration of pavement integrity, such as softening, traffic-related rutting, and migration of liquid asphalt due to increase in temperature (sustained air temperature over 32°C is identified as a significant threshold). ▸ Thermal expansion of bridge expansion joints and paved surfaces
Increases in very hot days and heat waves and decreased precipitation	▸ Corrosion of steel reinforcements in concrete structures due increase in surface salt levels in some locations
Later onset of seasonal freeze and earlier onset of seasonal thaw	▸ Changes in road subsidence and weakening of bridge supports due to thawing of permafrost ▸ Reduced ice loading on structures such as bridges*
Sea level rise and storm surges	▸ Damage to highways, roads, underground tunnels, and bridges due to flooding, inundation in coastal areas, and coastal erosion ▸ Damage to infrastructure from land subsidence and landslides ▸ More frequent flooding of underground tunnels and low-lying infrastructure ▸ Erosion of road base and bridge supports ▸ Reduced clearance under bridges ▸ Decreased expected lifetime of highways exposed to storm surges
Increase in intense precipitation events	▸ Damage to roads, subterranean tunnels, and drainage systems due to flooding ▸ Increase in scouring of roads, bridges, and support structures ▸ Damage to road infrastructure due to landslides ▸ Overloading of drainage systems ▸ Deterioration of structural integrity of roads, bridges, and tunnels due to increase in soil moisture levels
Increases in drought conditions for some regions	▸ Damage to infrastructure due to increased susceptibility to wildfires ▸ Damage to infrastructure from mudslides in areas deforested by wildfires
Increase of storm intensity	▸ Damage to road infrastructure and increased probability of infrastructure failures ▸ Increased threat to stability of bridge decks ▸ Increased damage to signs, lighting fixtures, and supports
Increase in wind speed	▸ Suspension bridges, signs, and tall structures at risk from increasing wind speeds

Source: ADB 2011:5.

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4.3.9.4 Annex 4 Infrastructure component assessment for consideration on risk assessment

Climate parameter	Infrastructure component	Threshold for serious damage on component for parameter	Likelihood to happen in the life time of the infrastructure (see results from Module 2.1)	Need to consider in risk assessment (Y/N)
Heat wave	Pile	–	–	N
	Cap	–	–	N
	Beams	–	–	N
	Deck	3 days >38° C	5	Y
Heavy rainfall	Pile	>300 mm/4 hours, leading to river speed of 5 m/s	4	Y
	Cap	>200 mm/4 hours, leading to river speed of 3 m/s	6	Y
	Beams	>200 mm/4 hours, leading to river speed of 3 m/s and water levels of >4.2 m	6	Y
	Deck	>250 mm/5 hours, leading to river speed of 3 m/s and water levels of >5.1 m	5	Y
Strong winds	Pile	–	–	N
	Cap	Wind speed of >200 Km/h	2	N
	Beams	Wind speed of >130 Km/h	5	Y
	Deck	Wind speed of >130 Km/h	5	Y

4.4 Identification and selection of adaptation measures

Benefits from adaptation can be obtained today if current risks and impacts are addressed and in the future while addressing emerging risks. Adaptation has the potential to reduce climate change impacts over the next few decades (IPCC 2014). Infrastructure projects are long-term investments which are well advised to take this into account. According to the identified vulnerabilities and risks of the infrastructure projects, the availability and access to technical, environmental and (socio-) economic data and the resources to gather and analyze these for the selection of the recommended adaptation option, several tools are available for the evaluation and comparison of a number of options, Cost-Benefit Analysis, Cost-Effectiveness Analysis and Multi-Criteria-Analysis are three examples used most frequently. The Development and current update of specific Climate Service Products is a non-engineering adaption option and should be part of the adaptation strategy of any infrastructure project.

4.4.1 Skills and knowledge

- The trainee understands the concept of Adaptation Assessment for infrastructure projects.
- The trainee is able to identify and cluster adaptation options.
- The trainee understands the difference among tools available for prioritization of options.
- The trainee understands the role of Climate Service Products as an adaptation option.

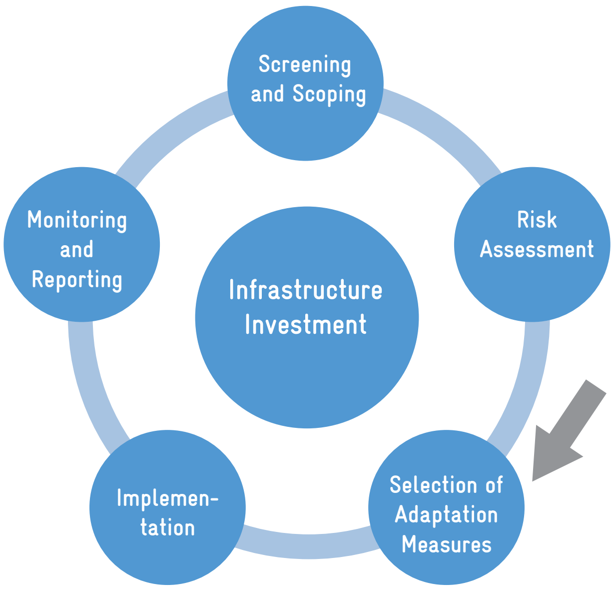
4.4.2 Context

The goal of the adaptation assessment is to identify and prioritize the most appropriate adaptation options to incorporate into the project. This includes the identification of strategies to minimize damages projected due to the changing climate and to take advantage of the opportunities that a changing climate may present.

Adaptation Assessment is linked to approaches towards climate risk management that include options to reduce or prevent exposure, protect from impacts, transform the subject of analysis, or manage residual risks to ensure or provide contingencies to maintain serviceability or business continuity (develop mechanisms for early warning & response, rescue and relief, as well as recovery). Climate risk management options can be mutually exclusive, but also complementary.

Adaptation research since the IPCC Fourth Assessment Report in 2007 has evolved from a dominant consider-

Figure 4.4.1 The 5-step approach of Climate Proofing. Step 3. Adaptation Assessment



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ation of engineering and technological adaptation pathways to include more ecosystem-based, institutional and social measures. A previous focus on cost–benefit analysis, optimization and efficiency approaches has broadened with the development of multi-metric evaluations that include risk and uncertainty dimensions integrated within wider policy and ethical frameworks to assess tradeoffs and constraints (IPCC 2014). Nevertheless, transparent infrastructure investments still need cost-benefit, comparative effectiveness or multi-criteria analysis for the prioritization of options for project design and implementation.

4.4.3 Concept: Identification of adaptation options

Adaptation Assessment is the third step of Climate Proofing infrastructure projects and considers a methodological approach which includes the Multi-criteria Analysis and Economic Analysis of adaption options.

Selecting appropriate adaptation options always represents a multi-stakeholder decision-making process that includes the elaboration, assessment and selection of adaptation measures. In the following some key considerations are laid down that are important to note, once starting the discussion about adaptation options.

Holistic climate risk management entry points

Adaptation options in the infrastructure investment sector may generally be defined for the following generic adaptation domains that are defined based on the climate risk management framework:

a. **mitigation of climate change effects** to reduce the exposure of the infrastructure to climate change (e.g. upstream management);

b. **protect the infrastructure** (e.g. dyke systems / mangroves etc.);

c. **increase physical and operational robustness** of the infrastructure (design / material, creating redundancy);

d. employ adequate **warning and response systems** (institutionalized and threshold based warning decision

Flooding in the Mekong Delta and Rural Road Development

Many parts of **Cambodia** already experience regular and severe flooding. Through its National Communications on Climate Change published in 2001, the government has produced flood vulnerability maps that identify segments of the ADB transport project area as being priority areas for addressing flood problems.

The transport project aims to rehabilitate and pave 505.4 kilometers of rural roads of 5–6 meters in width to improve rural connectivity to paved national and provincial road networks.

While flooding is a more obvious challenge in the project area due to recent floods, droughts are at the same time getting more intense. A possible adaptation strategy would combine engineering, environmental, and policy-oriented tools to address this increased variability. A combination of measures have been suggested, including

i. elevating vulnerable segments of the road;
ii. using materials that accommodate greater moisture content;
iii. improving flood management through revegetation, using more flood- and heat-tolerant indigenous species; and
iv. developing a vulnerability map and early warning system for the Ministry of Rural Development to use to improve its master planning.

Options that conserve and redistribute water from times of excess to times of shortage would complete a package of adaptation measures.

Source: ADB. 2010. Proposed Loan Kingdom of Cambodia: Rural Roads Improvement Project. Report and Recommendation of the President to the Board of Directors, Manila making and warning chains, temporary protection of assets, change in operations, evacuation);

e. as well **institutionalize business continuity management** mechanisms and procedures (recovery mechanisms). Finally, as an option of last resort;

f. **relocation** might become a realistic adaptation path.

All these options represent the foundation for a holistic climate risk management of infrastructure, including their physical assets, operational procedures and maintenance schemes.

Adaptation options always come with a bundle of complementary measures

For each option, multiple mutually exclusive or / and complementary social, environmental, economic, institutional, and physical-structural adaptation measures can be identified. Thereby, it is important to note the difference between complementary and mutually exclusive measures.

Climate risk management does not only refer to implementing structural-physical adjustments to the infrastructure, but also refers to adjustments of operational and institutional procedures that often go hand in hand with introducing new structural-physical features. This is especially true for the adjustment of maintenance schemes that are tailored to specific physical assets.

But also ecological solutions, e.g. to mitigate climate change effects, can go hand in hand with the implementation of structural measures. For example, when aiming at mitigating climate and man-made increased sedimentation of water reservoirs, up-stream afforestation is a complementary measure for the effective implementation of technical sedimentation extraction mechanics of the reservoir dam system. Many other examples exist.

Mutual-exclusive options

Climate risk management domains and options can also be mutually exclusive, and a decision one over the other has to be taken. For example, establishing warning and response systems, as well as business continuity mechanisms can be more acceptable from a cost-benefit point of view than investing substantial amounts of money into changes in the physical structure of an infrastructure asset. This can become obvious in circumstances where return periods of an anticipated critical climate event are really low.

Hence, the careful assessment of competing adaptation measures that e.g. might have different cost-benefit ratios is an important step in adaptation decision making and requires to provision of climate services. Adaptation option selection criteria other than cost-benefit ratio are for example quick-wins, minimization of negative side-effects, cost-effectiveness and feasibility.

Effective climate risk management addresses cross-sectoral issues and occurs at different scales

Adaptation measures are embedded and need to be implemented at different scales. Some measures need to be addressed at the policy level and rather higher administrative levels, e.g. when the risk condition for the infrastructure is influenced by general land use practices, or the absence of an integrated and cross-sectoral approach towards flood management.

Hence, synchronizing climate risk management requirements of a single infrastructure with the adjustments of cross-sectoral policies and strategies is challenging. Often, multi-scale approaches and integration towards infrastructure adaptation to climate change are not achievable. But then, infrastructure climate risk management at the asset level might be less effective.

Do nothing is also an option

Nonetheless, a decision not to act, or to maintain a business as usual approach ('do nothing' option) should also be retained as a possible option. In a number of circumstances, findings from the climate risk and adaptation assessments may indicate that doing nothing (no climate proofing) is the best course of action.

Table 4.4.1 Potential adaptation options for road infrastructure

Critical climate events	Climate risk management domains and measures					
	Mitigation of climate change effects	Infrastructure protection	Physical and operational robustness	Warning structures	Business continuity management	Relocation (Exposure reduction)
Sea level rise and storm surge	Plant suitable mangroves, planting artificial reefs to reduce wave onset power	Drainage system, providing lateral protection, constructing levy bank with seawall	Using suitable materials, increasing maintenance budget, replacing metal culverts with reinforced concrete	Establish and institutionalize warning chains and event thresholds for response actions to take effect	Introduction of measures and mechanisms for Interrupting or limiting traffic, for more intense and resourceful maintenance, Anticipatory planning for defining alternative routes in the event of a road closure or damage	Road realignment: Identify and construct alternative routes for roads
Reduction in rainfall or increased erosion	Increasing water retention capacity and slow infiltration through environmental measures to recharge aquifers and reduce surface flow runoff	Re-vegetation with drought-tolerant species, mulching, using matting/ erosion control blankets, applying granular protection, moistening of construction materials	Using flexible pavement structures, ensuring the selection of materials with high resistance to dry conditions	Establish and institutionalize warning chains and event thresholds for response actions to take effect	Introduction of measures and mechanisms for Interrupting or limiting traffic, for more intense and resourceful maintenance (dust & landslide clearance), Anticipatory planning for defining alternative routes in the event of a road closure or damage	Road realignment: Identify and construct alternative routes for roads
Increase in precipitation	Increasing upstream water retention capacity and slow infiltration through natural or bioengineered systems	Adding drainage capacity, using water capture and storage systems, reducing the gradients of slopes, enclosing materials to protect from flood water (impermeable linings)	Applying a safety factor to design assumptions, increasing size and number of engineering structures (hydraulic structures, high river crossings), raising pavements, using materials that are less affected by water	Establish and institutionalize warning chains and event thresholds for response actions to take effect	Introduction of measures and mechanisms for Interrupting or limiting traffic, for more intense and resourceful maintenance, Anticipatory planning for defining alternative routes in the event of a road closure or damage	Road realignment: Identify and construct alternative routes for roads
Increased wind strength	Planting coastal forests and mangroves	Installing windbreaks	Modifying the design of supports and anchorages	Establish and institutionalize warning chains and event thresholds for response actions to take effect	Introduction of measures and mechanisms for Interrupting or limiting traffic, Defining alternative routes in the event of a road closure or damage	Identify and construct alternative routes for roads

Adaptation approaches can also be introduced at a number of different entry points within the infrastructure project investment process (see also chapter 2.2). E.g., making site-specific infrastructure adjustments to a road design is often possible within project preparation or project development. As projects are often limited in terms of location and scope and lack of understanding of cross-sectoral interactions, it can be difficult to introduce non-engineering options such as ecosystem-based measures or alignment review at later stages, if this has not already been considered in the phases of policies and planning, or project preparation. Greater attention to the upstream decision-making processes at an early project phase (e.g. transport master planning for road infrastructure planning) and the involvement of key stakeholder groups support an integrated adaptation strategy.

The following exercise allows to experience the application of the four steps of Adaptation Assessment:

- Step 1: Identify all potential adaptation options
- Step 2: Conduct adaptation options assessment
- Step 3: Conduct multi-criteria and economic analysis of the options
- Step 4: Prioritize and select adaptation option(s)

4.4.4 Exercise Identification and selection of adaptation measures

Learning objectives

1. **You will learn about how to identify adaptation options based on the results of the previous climate risk assessment.**
2. **You will learn about different types of adaptation options considerable for infrastructure projects.**
3. **You will learn about different methods and tools which support the prioritization of adaptation measures.**

Content and main tasks

- Brainstorming of potential adaptation options which reduce exposure or sensitivity of infrastructure components / systems of interest to climate change or increase adaptive capacity. Consideration of ecosystem services for sustainable infrastructure investment (e.g. natural barriers of surface water flow or storm, increased water infiltration).
  >> Identification and cluster of all potential adaptation options (engineering, non-engineering, business as usual)
- Application of a multi-criteria analysis with cost-effectiveness of the adaptation options as one criteria.
  Ranking of adaptation options based on scores for effectiveness, cost-efficiency and sustainability.
- Consultations with key stakeholder groups about the prioritized adaptation measures.
  Revision of prioritized adaptation options and agreements on final list of measures for integration into the project design and implementation.

Guidance for effective group work

- For effective and efficient work, a working group should select a facilitator, a time keeper and a presenter.
- Take your time to read through the task description and see if everybody is on board.
- The working groups work independently.
- Trainers can be asked for advice.
- The main learning objective is to learn about the systematic approach and not to be comprehensive in the task.

Method: Learning from experience with a case study

You are part of the expert team, developing the check-up mission for the **Metropolis Millennium Bridge, South State** (see Annex 1 for details) and work together with 3 to 6 experts in a team.

You and your colleagues bring in the engineering, climate change, environmental and cooperation expertise, based on the case description and your own experience.

Please find some hints for a fruitful cooperation in the box 'Guidance for effective group work'.

Your specific tasks

- Review the case description and your results of the previous steps considering climate change impacts, exposure, sensitivity and adaptive capacity of the most affected infrastructure components (Annex 1).
- Use a flipchart or board with cards.
- Respond to the following tasks and present your results guided by matrix 4.4.1.

- **Step 1: Identify potential adaptation options.**
  - Keep in mind the objective of the project and copy it to matrix 4.4.1.
  - Select one impact expected from climate change and brainstorm adaptation options based on the elements of vulnerability (sensitivity; if applies, adaptive capacity) and exposure identified in the risk assessment. Think of a wide range of adaptation options without considering possible challenges for implementation. Please get inspired by table 4.4.1.
  - Discuss for each adaptation option to which adaptation category it mainly contributes.

- **Step 2 (optional): Conduct consultations.**
  - Present your results to a selection of key stakeholder groups like local population, ministry of environment, transport, agriculture, finance, pri-

Matrix 4.4.1 Identification and selection of adaptation measures

Objective of the project:							
System of interest:							
Step 1 and Step 2: Identify list of potential adaptation options and adaptation categories Categories of adaptation: ▸ Mitigation of climate change effects ▸ Infrastructure protection ▸ Physical and operational robustness ▸ Warning structures ▸ Business continuity management			**Step 3 Multi-criteria Analysis** Score 1 very poor (high cost) Score 2 poor Score 3 satisfactory Score 4 good Score 5 excellent (low cost)			**Step 4 Prioritization and additional stakeholder groups**	
Climate Change Impact on System of Interest	Adaptation Option	Adaptation category	Effectiveness	Costs	Feasibility	Total	Additional stakeholder groups (optional)

vate investor, research etc. affected by the project and ask for their inputs (e.g. Role Play or Vernissage).
The identification of adaptation options will necessarily reflect the knowledge and interests of the expert team members. Conducting roundtable consultations with key stakeholders provides useful input for the process of identifying and appraising the whole range of adaptation options.

- **Step 3: Conduct a Multi-Criteria Analysis.**
  - Develop a rapid appraisal of a Multi-Criteria Analysis with the criteria Effectiveness, Costs and Feasibility, or apply an economic analysis of the adaptation options (go to next bullet).
  - The goal of the economic analysis of adaptation options is to provide decision makers with information pertaining to the expected costs and benefits of each technically feasible option and to rank these options according to the net total benefit (measured in present value terms) that each delivers. In circumstances where all adaptation options are expected to deliver exactly the same benefits, it is sufficient to undertake a cost-effectiveness analysis where adaptation options are compared simply in terms of the cost of achieving the stated benefits. In this sense, the cost-benefit analysis of adaptation options is no different than for any other investment project and should be implemented by economists along a similar stepwise process.

Figure 4.4.2 Results of the Identification and Selection of Adaptation Options

- **Alternative Step 4 (optional):**
  Conduct an economic analysis of the adaptation options (guided by matrix 4.4.2).
  - **Looking into the future**, the expected annual O&M / REHAB[2] regime and expenditures that will be needed to maintain the millennium bridge to a given desired standard for each year of its useful life without climate change is specified as 10 mill. M$.

    In the absence of climate change, past O&M / REHAB regime and expenditures may provide a reasonable basis for assessing future O&M / REHAB regime and expenditures.

  - **Looking into the future,** the expected annual O&M / REHAB expenditures for each year of the useful life of the road with climate change, but assuming no adaptation is specified as 20 mill. M$.
    In circumstances where climate change is expected to increase the need for road maintenance, O&M / REHAB expenditures would generally be expected to increase.
  - Calculate the cost of climate change as the difference between the present value of the O&M / REHAB expenditures without climate change and the present value with climate change and record the value in Matrix 4.4.2:

    Present annual value of O&M / REHAB expenditures with climate change
    ./. Present annual value of O&M / REHAB expenditures without climate change
    Annual Cost of Climate Change

  - **Column A** shows a set of adaptation measures that shall prevent or avoid some or all of the projected cost of climate change. These adaptation measures include structural and bioengineering options (e.g., reforestation of a watershed).
  - Monetize the relative impact (**column B**) of the identified adaptation measures on the 'cost of climate change.' Record the values in **column C.** This monetized impact (avoided cost of climate change) will represent the present value of the expected benefits of the adaptation measures.

  - The present value of the cost of each adaptation measure itself is given in column D.

[2] Operation, Maintenance and Administration Costs / Rehabilitation

Matrix 4.4.2 **Economic analysis of adaptation measures**

Objective of the project:					
System of interest:		Millennium Bridge, Metropolis			
Annual Cost of Climate Change (M$):					
A	B	C	D	E	F
Adaptation Measures	% of Annual Cost of CC avoided (relative benefit)	Annual Cost of CC avoided (monetary benefit) M$ (x 1,000)	Present Annual Value of Cost of Adaptation Measure M$ (x 1,000)	Net Present Value of Adaptation Measure M$ (x 1,000)	Ranking of Adaptation Measures poor=lowest excellent=highest
Increase design load of bridge abutments	50		10		
Periodical update of Climate Services	20		5		
Reforestation in upper watershed	10		2		

- Calculate the net present value (NPV) of each adaptation measure and record the result in column E:

Present annual value of O&M / REHAB benefits of adaptation measure
./. Present annual value of O&M / REHAB expenditures of adaptation measure
Annual Net Present Value of Adaptation Measure

- **Step 4: Prioritize and Select Adaptation Option(s)**
  - For this step of selection of adaptation measures, in the case that this economic analysis were the only evaluation tool, recommend adoption if the NPV of the adaptation measure is positive; reject the measure otherwise. If more than one adaptation measure delivers a positive NPV, recommend the adaptation measure with the highest NPV or assign a ranking.
  - If the results of the economic analysis are considered as criterion NPV in a multi-criteria analysis, these replace effectiveness and cost. In this case, translate the NPVs into scores according to the scoring system used for all criteria; i.e. best NPV = 5, lowest NPV = 1) as part of the following Step 4. Other criteria could be sustainability, feasibility, urgency etc.
  - Revise the selection criteria with your team and make sure that you have a common understanding on what these mean to you and how you are going to evaluate the criteria.
  - For a qualitative evaluation, on a scale from 1 (very poor) to 5 (excellent), evaluate each adaptation option and assign the scores agreed upon to the suggested criteria. Document your results in column F.
    The adaptation assessment results in a prioritized list of adaptation options for implementation, which are selected from among several possibilities. Their prioritization can be based on an assessment of their technical feasibility, their benefits and costs, their social acceptability, and the opportunities they may offer for synergies with national priorities. While the use and outcome of a cost-benefit analysis is often given more weight in the prioritization process, it is important to recognize that other factors and criteria may also influence decision making.
  - Discuss with your team, if the results might be biased due to the composition and interests of the expert team and the lack of other stakeholders.
    The expertise required is multidisciplinary and as such is one of the more challenging aspects of adaptation planning. Options must be scientifically sound, socially beneficial, and economically viable. Roundtable discussions involving different stakeholders can work well and can include, for example the project engineers, environmental specialists, social safeguards experts, nongovernment organizations, implementing entities, and national climate change representatives.
  - Indicate which options need further planning processes in cooperation with other stakeholders (e.g. environmental ministry, forestry department, farmer community).

It is important to recognize that in some cases, the best adaptation option(s) may be beyond the scope of an existing project or beyond the authority of a given sector ministry such as a transport ministry. For example, watershed reforestation may be the most appropriate option, but may fall outside the scope of authority of a ministry of transport. Therefore, other stakeholder groups need to be considered in the development of the adaptation strategy of the project.

4.4.5 Guiding questions for reflection

- What are the major challenges and risks during the process of identifying adaptation options for infrastructure projects?
- Which elements are essential for an integrated adaptation strategy for an infrastructure project?
- Which tools for selecting adaptation options for the project design and implementation work under real conditions?
- Which role plays Risk Assessment as a Climate Service Product for decision making in the process of prioritization the adaptation options?

4.4.6 Take away messages

- Adaptation options are linked to approaches towards climate risk management approaches that include options to reduce or prevent exposure, protect from impacts, transform the subject of analysis, manage residual risks to ensure or provide contin-

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gencies to maintain serviceability or business continuity (develop mechanisms for early warning & response, rescue and relief, as well as recovery).

- Climate risk management options or adaptation options can be mutually exclusive, but also complementary.
- Different tools exist to navigate through mutually exclusive options (CBA, CBE, MCA, comparative effectiveness assessment, adaptation performance assessment etc.)
- Risk Assessment shall be applicable as a decision support tool for the application of these (economic) evaluation tools.

4.4.7 References

Asian Development Bank (ADB) 2011. Guidelines for climate proofing investment in the transport sector: Road infrastructure projects. Mandaluyong City, Philippines: Asian Development Bank. www.adb.org/sites/default/files/institutional-document/32772/files/guidelines-climate-proofing-roads.pdf

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.

Data bases for further reading recommended by ADB (2011)

Adaptation Learning Mechanism. www.adaptationlearning.net

weAdapt Knowledge Base. www.weadapt.org/knowledge-base/guidance/knowledge-base

United Nations Framework Convention on Climate Change (UNFCCC) compendium of methods and tools to assess impacts, vulnerability and adaptation to climate change. http://unfccc.int/adaptation/nairobi_workprogramme/knowledge_resources_and_publications/items/5457.php

UNFCCC database of local coping (adaptation) strategies. http://maindb.unfccc.int/public/adaptation

4.4.8 Personal notes

4.5 Implementation

A climate proofed project integrates previously identified and selected adaptation options. Depending on which phase of the project investment process includes the necessary activities, resources, responsibilities and stakeholders who have to be involved for taking further action, as well as complementary tasks which support the expected results. Most commonly, public infrastructure projects are steered by the transport ministry. However, as shown before non-engineering measures often need the cooperation and support of other non-traditional stakeholder groups (e.g. from the environmental sector, territorial planning, agriculture). The goal of establishing implementation arrangements is to ensure the effective implementation of the identified adaptation option(s).

4.5.1 Skills and knowledge

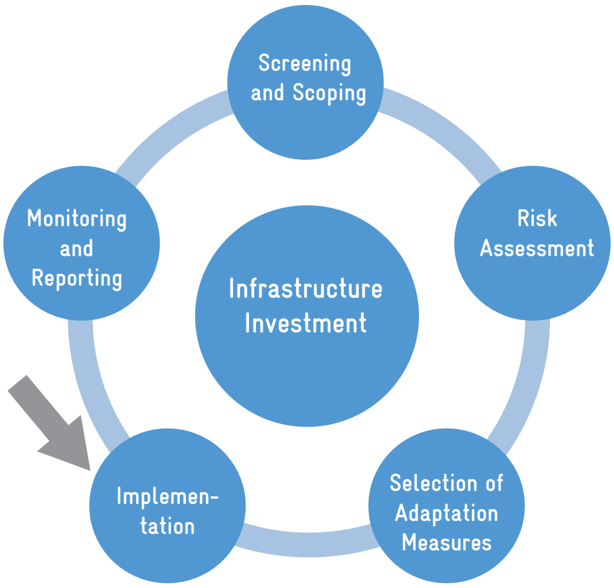
- The trainee understands why climate proofing does not end with the identification or rejection of adaptation measures, but the integration of these into the project design and operation plan for implementation.
- The trainee is able to define the roles of key stakeholder groups for successful implementation of the climate proofed project.
- The trainee is aware of complementary capacity development measures which facilitate the implementation of the project and coordination among key stakeholders.

4.5.2 Context

'Most assessments of adaptation have been restricted to impacts, vulnerability, and adaptation planning, with very few assessing the processes of implementation or the effects of adaptation actions.'
IPCC (2014)

The Adaptation Assessment performed in chapter 4.3 leads to a set of adaptation options. These have been evaluated previously with the help of a Multi-Criteria Analysis, and particularly an Economic Analysis. Based on the results and in consultations with key stakeholders of the project, an expert team develops a proposal for integrating adaptation into the Project Design considering the areas of operation, maintenance, administration and rehabilitation of physical assets and includes complimentary measures for research and capacity development.

Figure 4.5.1 The 5-step approach of Climate Proofing. Step 4. Project Design and Implementation



The Project Design needs to take into account future needs for transparency and reporting to the public and investors. Thus, the periodical observation of smart indicators for monitoring adaptation has to be foreseen in the organizational structure of the project and resource allocation. Further details follow in chapter 4.6 Monitoring and Reporting.

4.5.3 Concept

Project Design and Implementation is the fourth Step of Climate Proofing which integrates adaptation into the climate proofed project and establishes arrangements for implementation.

Without an updated project design and operational plan including resources, responsibilities, stakeholders etc. or, if otherwise decided, the approval of the climate resilience of the existing planning, the results of the previous steps of Climate Proofing are likely to remain an exercise without implications, nor the expected results.

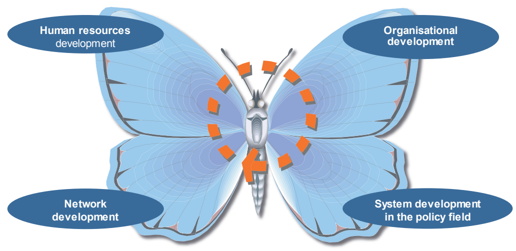
A lead organization should be selected to coordinate the integration of the adaptation measures into the project design. While this organization may be the main executing agency responsible for the sector of the project (e.g. Ministry of Transport, of Rural Development, or Energy), involving other ministries, organizations, and institutes are needed as soon as the adaptation activities cut across sectors. For instance, the development of Climate Service Products need the cooperation of departments and experts who are involved in disaster risk management for the infrastructure sector and managing climate change and disaster data. This is important for planned activities which improve the information base or early warning systems. As flooding is often a key impact on infrastructure projects, national disaster preparedness committees may have a role to play. Likewise, many of the 'low-risk' adaptation strategies, such as improved watershed management or mangrove rehabilitation to protect coastal infrastructure, require engagement of land management and forestry experts and organizations.

Capacity Development at individual, organizational and institutional level support climate resilient infrastructure investments

Definition of Capacity Development: Develop capacities to manage resources efficiently in order to achieve desired results in a sustainable manner

Capacity Development for Adaptation:
Capacities that enable decision makers to
(1) undertake adaptation measures and
(2) continue adaptation on an ongoing basis.

Levels of Capacity Development



Human resources development
- How: Coaching and training
- What: Technical skills, management skills, soft skills

Organisational development
- How: Change management
- What: M&E, adaptive management processes, steering and planning, knowledge management,

Network development
- How: Network management
- What: Development and steering of cooperative systems to benefit from comparative advantages and economies of scale

System development/policy field
- How: Policy advice
- What: Negotiation schemes, process design to ensure rule of law and participation

Source: GIZ 2009, Capacity WORKS

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These examples demonstrate the need for considering not only capacity development of human resources involved in your infrastructure project, but also needs at organizational, network and system / policy field level to strengthen the implementation framework and facilitate innovation. Climate change experts should provide scientific and technical backstopping to project implementers. When the project partners are already selected, the scope of the project is likely to be limited by each partner's lines of responsibility. E.g., while the ideal adaptation approach may include engineering and environmental measures, the latter is likely to fall outside the roles and functions if the Ministry of Transport is responsible of the infrastructure project.

4.5.4 Exercise Develop a project-focused capacity development strategy

Learning objectives

1. You will learn the importance of considering the human resources, organizational, network and system / policy field level for capacity development to achieve your project goals.
2. You will learn how to think on strategies to engage different stakeholders to develop their capacities.
3. You will learn how different levels interact with each other, and how they are interdependent.

Content and main tasks

- Define the focus and objective of your capacity development strategy.
  >> Definition what kind of impact you want to achieve with your project.

- Discuss and agree on strengths, weaknesses, opportunities, and threats (SWOT) existing in your areas of activity.
  >> Perform of SWOT analysis for the human resources, organizational, network and system / policy field.

- Identify intended capacities and measures to be implemented, including their intended impacts.
  >> Perform of analysis for the human resources, organizational, network and system / policy field.

Guidance for effective group work

- For effective and efficient work, a working group should select a facilitator, a time keeper and a presenter.
- Take your time to read through the task description and see if everybody is on board.
- The working groups work independently.
- Trainers can be asked for advice.
- The main learning objective is to learn about the systematic approach and not to be comprehensive in the task.

Method: Learning from experience with a case study

You are part of steering committee of the **Metropolis Millenium Bridge** project. You perform a capacity development strategy to help your project to implement the before identified climate adaptation options.

Please find some hints for a fruitful cooperation in the box 'Guidance for effective group work'.

Your specific tasks

First, agree with 3-6 peers to work as a team.

Second, read the instructions carefully and in case of doubts, first ask your fellows or - if necessary - the trainers.

Third, guide your analysis with the following questions and draft your answers based on the previous exercises of this training. Use a pin board and moderation cards to assess all relevant aspects, filling the matrix 4.5.1:

1. Identify the goal of your project, based on the identified adaptation measures of chapter 4.4.

2. Determine the project life cycle. This does not necessarily mean the same life cycle of your infrastructure.
3. Identify capacities that are needed to achieve your goal (check box 4.5.1 for definitions).
   - Which abilities, which knowledge, which political will or requirements are needed to make the project a success? Which change will be needed for that?
   - Perform this analysis for the individual, organizational, and society level (both regarding the development of cooperation, and the development of framework conditions).

4. Define current strengths, weaknesses, opportunities, and threats (SWOT) to achieve your identified goals within the field of action that you are acting.
   - Perform this analysis for the human resources, organizational, network and system / policy field level.

5. Identify measures and their intended impacts needed to reach the needed capacities.
   - What can your project do, in order to develop or maintain strengths in different levels?
   - What can be done to seize opportunities?
   - What can be done to neutralize weaknesses?
   - What can be done to reduce risks or to learn to deal with them?
   - How can stimuli on one level act at the other two levels?
   - Perform this analysis for the human resources, organizational, network and system / policy field level.

Matrix 4.5.1 **Capacity Development-Matrix**

1: Goal of Capacity Development:					
2: Project life cycle:		Human Resources development	Organisational development	Network development	System/policy field development
3: Needed capacities					
4: SWOT of capacities	S W O T				
5: Measures to strengthen needed capacities (see box 4.5.1 for examples)					

Module 4

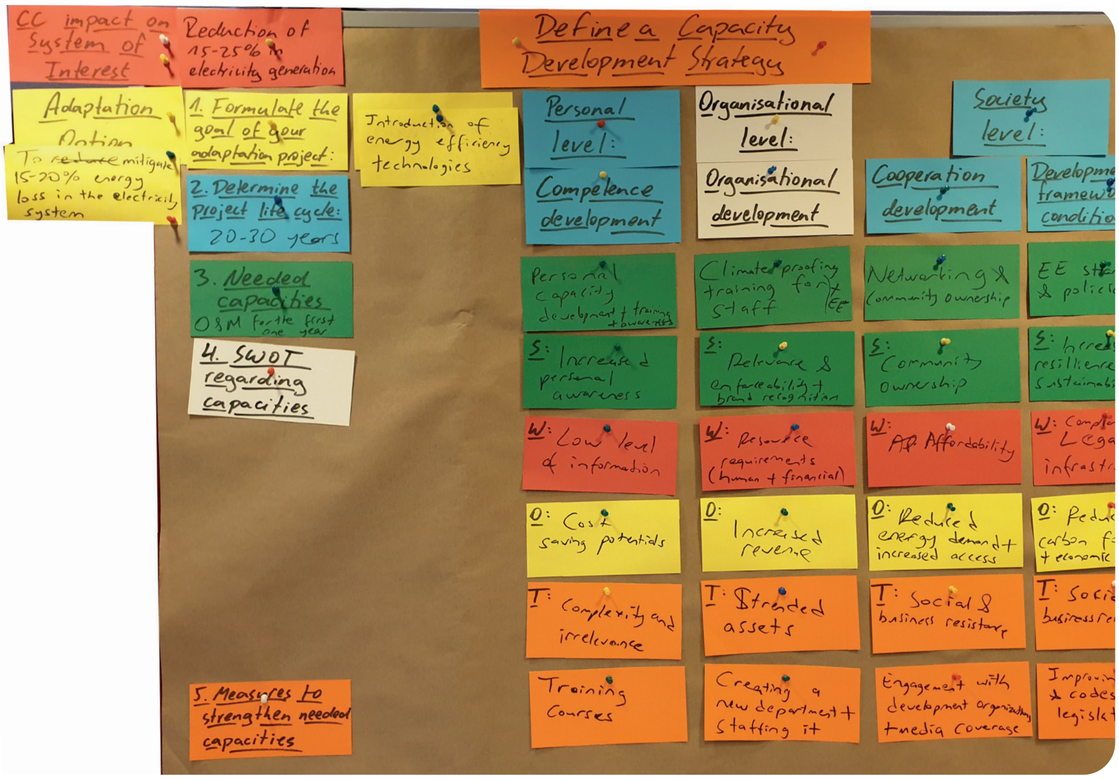
4.5.5 Guiding questions for reflection

- What was the most challenging part of this task?
- What kind of information is needed to perform this task?
- What kind of stakeholders should be invited to this assessment?
- What are key points to consider when wishing to implement a capacity development strategy?

4.5.6 Take away messages

- Establishing implementation arrangements is a requisite to ensure the effective implementation of the identified adaptation option(s).
- Capacity development at individual, organizational and institutional level are needed to improve sector crosscutting cooperation and a better understanding of the need for climate proofing infrastructure projects and climate service products for decision making during the process.
- Upscaling lessons learnt from project to policy level facilitates innovation for new cooperation models.

Figure 4.5.2 Results of the Capacity Development Matrix



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4.5.7 References

Asian Development Bank (ADB) 2011. Guidelines for climate proofing investment in the transport sector: Road infrastructure projects. Mandaluyong City, Philippines: Asian Development Bank. www.adb.org/sites/default/files/institutional-document/32772/files/guidelines-climate-proofing-roads.pdf

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4.5.8 Personal notes

4.6 Monitoring and reporting

The goal of establishing monitoring frameworks is to ensure accountability and ensuring that lessons are learned to inform future adaptation efforts.

4.6.1 Skills and knowledge

- The trainee is aware of the importance and challenges of monitoring adaptation measures of infrastructure investments.
- The trainee understands how to identify indicators for monitoring and provide recommendations for transparent reporting.
- The trainee is able to identify a monitoring framework for public infrastructure investments.

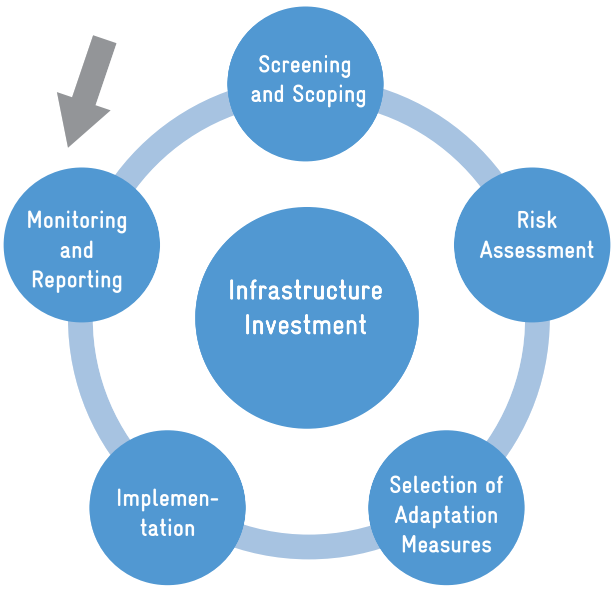
4.6.2 Context

> *'Monitoring and evaluating impacts is usually both costly and laborious. Often, it is also a challenging process, particularly when complex causal linkages or uncertain framework conditions are involved.'*
>
> *Silvestriniet al. (2015)*

Developing and implementing an adaptation-focused monitoring and evaluation (M&E) system is key to measure if and how infrastructure investment projects are performing with regard to managing climate-related risk. Moreover, it provides knowledge about what works and what does not work with regard to risk management, indicating critical points for amelioration. Additionally, it is a permanent learning process, useful to replicate successful and avoid unsuccessful lessons learnt in the future. Finally, M&E of the effectiveness of the implemented measures for transparency is an essential request from investors, being a mandatory exercise to account for used resources.

ProM&E for climate adaptation projects related to infrastructure investments has specific challenges that are different from other set-ups. Since such projects vary regarding the individual project, contexts, locations, and scales, no universal indicators exist. Unlike other contexts, the success regarding adaptation to climate change cannot be measured with one indicator only. In this sense, and as climate is constantly evolving, the establishment of a baseline is crucial to create a reference point, pursuing to measure impact. This baseline can often be a climate risk assessment (see also Module 4.3).

Figure 4.6.1 The 5-step approach of Climate Proofing. Step 5. Monitoring and Reporting



With regard to climate and its changing patterns, uncertainty is another challenge that needs to be addressed. E.g., it is not possible at the start of a project to predict when the next extreme climate-related event will occur, which might help to measure if our retrofitted infrastructure is prepared for such situation. Finally, long time horizons with regard to climate change and project impacts need to be taken into account in order to assess all aspects of risk-reduction (Silvestrini et al., 2015). This argument is also related to the self-commitment of countries in line with the Paris Agreement, which calls for enhanced transparency of adaptation actions and requires Parties to the UNFCCC to share information on adaptation progress.

In this context, Climate Services developed for Climate Risk Assessment can be a strong asset to support the future need of monitoring, and should be designed accordingly. Different contexts and settings have manifold application areas. This means that different approaches and aggregation levels towards assessing risks and therein, developing Climate Service products exist. Climate Service providers need to be capable to respond to these different demands and follow structured approaches towards understanding user needs.

According to the OECD's Development Assistance Committee (DAC), impact evaluations take into account intended and unintended, positive and negative as well as expected and unexpected changes. They are supposed to not only provide information on all possible changes that have occurred during the implementation of an intervention but also to link these observed changes to their causes. Therefore, the establishment of causality (cause / effect relationship) is crucial in order to understand why particular incidents occurred during and after a project as compared to the question 'What would have happened without the project (Silvestrini et al. 2015).

Departing from this thinking, the development and implementation of a proper M&E system needs to mirror the complexity of adaptation measures and projects, significantly measuring its impact towards risk-reduction. Therefore, M&E processes also need according resource allocation regarding financial, human, and technical resources.

Box 4.6.1 Questions for determining the evaluation framework

The design of an evaluation framework depends on a variety of variables that are goal- and objective-driven. Therefore, Silvestrini et al,, (2015:13) define a number of questions to define the final framework.

- What is the object of the evaluation? What is the scope of the evaluation in terms of observed period, regions, activities, etc.?
- What are the objectives of the evaluation and which criteria will it use to assess the object of the evaluation?
- Who are the recipients and who are the stakeholders of the evaluation?
- What is the time frame of the evaluation? When are the evaluation findings needed by?
- Which human, financial and organisational resources are available for the evaluation?
- Who will implement the evaluation? What qualifications and experience do the responsible persons have?
- How will the evaluation be implemented? What is the intended evaluation design? Is it feasible with the available resources?
- Which data collection instruments and analysis methods will be applied? Are the people in charge of data collection and analysis familiar with these instruments and methods?
- What tasks need to be performed during the evaluation and who will be in charge.

4.6.3 Concept Monitoring effective adaptation

Adaptation-centered M&E is key to support ongoing management or risk-reducing interventions. It also supports learning – and thereby helps to improve adaptation actions – and provides accountability towards infrastructure investors. Last but not least, M&E helps countries to gather information to prove their climate-related impacts within the framework of the Paris Agreement.

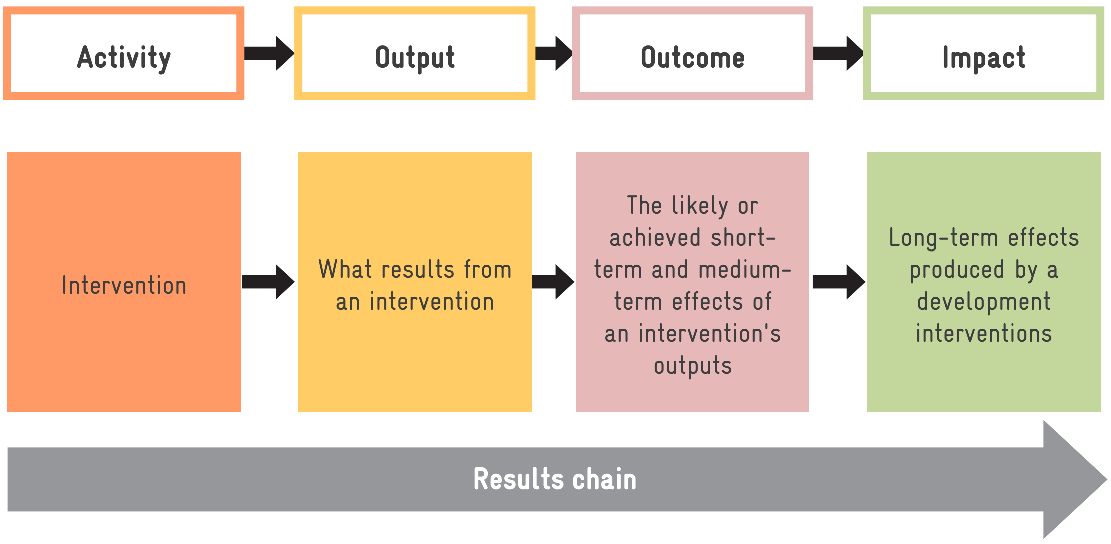
The development of a monitoring system starts with reflecting the goals and context of the monitoring and evaluation of data. This might include the definition of

- the overall objective: e.g. monitoring the achievements of defined outcomes of adaptation and / or supporting a learning process for successful adaptation;
- users of information generated: e.g. politicians, decision-makers and / or general public;
- institutional set-up for the monitoring: e.g. part of national development monitoring, specific climate monitoring; and
- system of metrics (what should be measured): e.g. climate change impacts, vulnerabilities, risk, outputs, outcomes of adaptation measures.

M&E systems in the context of adaptation to climate change can be designed focusing on a variety of metrics. Commonly, measuring variables can be climate parameters, climate change impacts, vulnerability, implementation of adaptation measures, or the impact of adaptation measures. All these foci are valid, however, they do not always necessarily contribute to measuring relevant variables in the context of infrastructure investment.

Generally, M&E systems developed within adaptation to climate change of infrastructure investments focus on tracking the effectiveness of reduction of risk. However, due to the before mentioned challenges in measuring adaptation on the long-term, such as the need to acquire appropriate baseline data and metrics for measuring vulnerability, and isolating vulnerability to climate change from other sources of pressure, it is necessary to work with the concept of results chains. 'Results chains describe a logical sequence from inputs (money, time, knowledge) invested in activities to achieve first outputs which short term or medium term effects (outcomes) that contribute to long term effects (impacts). Results chains involve assumptions of how each category leads to the next, i.e. under what circumstances a certain output leads to the associated outcome' (Eberhardt et al. 2013:42; see Figure 4.6.2).

Figure 4.6.2 The results chain



Source: Eberhardt et al. 2013

From this point of departure, the following steps, based on Eberhardt et al. 2013, guide to the design of an M&E system focused on climate adaptation in infrastructure investments, departing from the construction of a results chain:

- **Step A: Define Outcome**
  In order to get short-term and medium-term – and therefore, realistically measurable – results from impact, the results chain is unfolded from the end to the start. For this reason, the long-term impact of the identified set of measures in Module 4.3 is defined in the first step. This impact should always be linked to reducing the climate risk of the system of interest identified in the risk assessment (see Module 4.3). An example of an impact can be to reduce the climate risk related to heavy rainfall for the road infrastructure in Metropolis.

  Then, these measures are combined into thematic components, which are usually implemented as one working line. The differentiation can be e.g. done by differentiating the measures according to their geographic scale, their partners, or their approaches. A common differentiation is also a focus either on reducing exposure, reducing sensitivity, or increasing adaptive capacity towards changing climate parameters, building a bridge back to the climate risk assessment. An example of a component can be to implement measures to reduce vulnerability related to heavy rainfall at the Millenium Bridge.

  For each component, an outcome is then defined, which are short-term and medium-term effects that contribute to the impact, e.g. that adaptation measures have been adopted based on existing Climate Services.

- **Step B: Define Outputs**
  Analyzing each of the identified outcomes, define outputs / results from the designed intervention and selected in Modules 4.4 and 4.5 that contribute to achieving this outcome. Examples herefore are that decision-makers are aware of existing risks and that the Millenium Bridge's design takes into account these risks.

  This exercise eventually acts as a quality-check to the before designed bundle of adaptation measures. At this stage, designers of M&E systems often notice that measures not necessarily lead to outputs that eventually lead to outcomes. For this reason, it is relevant to name either additional measures that need to be implemented in order to reach the outcomes or name assumptions under which outputs will lead to outcomes.

- **Step C: Construct indicators**
  Indicators are ways to measuring the progress of your project towards achieving its outputs and outcomes. By these means, they are key to monitor the performance of the project, aiming at one specific target. Formulating high-quality indicators is a difficult task that needs to fulfil certain minimum criteria, also called SMART criteria:

  - **S > Specific:** the indicator is valid and describes the underlying issue.
  - **M > Measurable**, practicability, rely on sound data obtained through reproducible methods independent from the individual collectors of the information.
  - **A > Achievable** (only applicable to targets).
  - **R > Relevant:** address an important issue for the users and related to the objective of M&E.
  - **T > Time-bound:** related to time and milestones so that progress can be shown during the course of implementation.

  Following this rationale, formulate indicators both for your outputs and outcomes, also considering the following steps:

  1. Define its subject, e.g. qualification of civil defense staff;
  2. Specify quantity of change, e.g. 50% of all civil defense staff trained;
  3. Specify quality of change, e.g. trained in up-to-date climate information interpretation techniques;
  4. Define time horizon, e.g. within the next twelve months;
  5. If applicable: specify regional aspect, e.g. civil defense staff within Metropolis.

Table 4.6.1 Examples of unspecific indicators for measuring adaptation results in transport projects

Indicator Type	Indicator
Impacts (long-term effect)	▸ Increased robustness of infrastructure design and long-term investment-development ▸ Increased resilience of vulnerable natural and managed systems, such asflood management
Outcomes (process indicators)	▸ Percent reduction in road closures due to landslides or flooding ▸ Percent reduction in flooding where drainage capacity has been increased ▸ Improved decision making and sector planning based on climate change-considerations
Outputs	▸ Transport sector planning documents include adaptation strategies ▸ Length of road constructed to withstand climate change impacts ▸ Area of mangrove planted to protect coastal roads

Source: ADB 2011

Measuring the indicators during the whole project and also after the project end is critical to track the impact and to ensure that risk is also reduced over time. In order to ensure that data needed to measure is named and potentially available, the sources for the data need to be named together with the indicator. Sources often are not necessarily within the project context, but can e.g. also be external Climate Service providers or indirect project beneficiaries, as e.g. Climate Service end-users.

4.6.4 Exercise Develop a monitoring framework

Learning objectives

1. **You will learn how to construct a M&E results chain, based on your previously performed climate risk assessment.**
2. **You will learn how to formulate expected outcomes and outputs that contribute to measuring your project's impact.**
3. **You will learn how to formulate SMART indicators that contribute to measuring your outputs and indicators, as well as selecting useful sources of information.**

Content and main tasks

- Defining outcomes that contribute to achieving the project impact.
  >> *Outcome definition*
- Defining outputs that result from the outcomes.
  >> *Output definition.*
- Formulating high-quality indicators following the SMART rule.
  >> *Construction of indicators*.

Method: Learning from experience with a case study

You are part of the expert team, developing the check-up mission for the **Metropolis Millennium Bridge, South State** (see Box 4.5.1 for summary and Annex 1 for details) and work together with 3 to 7 experts in a team.

You and your colleagues bring in the M&E, engineering, climate change, environmental and cooperation expertise, based on the case description and your own experience.

Please find some hints for a fruitful cooperation in the box 'Guidance for effective group work'.

Module 4

Your specific tasks

- Review the case description (Annex 1).
- Use a flipchart or board with cards.
- Respond to the following tasks and present your results guided by matrix 4.5.1, based on the results of Modules 4.3, 4.4, and 4.5.

- **Step 1.**
  - Identify the adaptation impact of the infrastructure investment (project).

- **Step 2.**
  - List all components that compose the infrastructure investment (project) (see example matrix 4.6.1).
  - Ideally, cluster the components e.g. according to their geographic scale, their partners, their approaches, or their impact to reduce climate-related risk (by climate parameter, reduction of exposure, reduction of sensitivity, increase of adaptive capacity).

- **Step 3.**
  - Formulate one outcome for each component.
  - Consider that this outcome needs to be significant to represent the outcome's impact on the short-term and medium-term.

- **Step 4.**
  - Formulate one to three outputs for each outcome.
  - Consider that the outputs need to contribute to achieving the outcome.

- **Step 5.**
  - List assumptions under which outputs lead to outcomes.

Matrix 4.6.1 **Develop a results chain**

Step 1. Adaptation impact of the project: Reduce the climate risk related to heavy rainfall for the road infrastructure in Metropolis

Step 2	Step 3	Step 4	Step 5
Component (Action Line)	**Expected outcome**	**Expected outputs**	**Assumptions** under which outputs lead to outcomes
Implementation of measures to reduce vulnerability of Millenium Bridge to extreme rainfall events.	Adaptation measures have been adopted, based on existing Climate Services	a. Decision-makers are aware of existing risks. b. The Millenium Bridge's design takes into account these risks.	Reliable data to support Climate Services are accessible.

Starting from this point, proceed to work on Matrix 4.6.2 to construct indicators, re-utilizing results from Matrix 4.6.1:

- **Step 6.**
  - Formulate one to two indicators for each outcome.
  - Make sure that each indicator fulfils the SMART criteria.
  - Check if the indicator(s) properly measure the outcome.
  - Identify sources of information to measure each of your indicators.

- **Step 7.**
  - Formulate one to two indicators for each output.
  - Make sure that each indicator fulfils the SMART criteria.
  - Check if the indicator(s) properly measure the output.
  - Identify sources of information to measure each of your indicators.

- **Step 8.**
  - Prepare your presentation to the plenary and focus on your most important results within 5 minutes.

Matrix 4.6.2 **Develop a results chain**

Step 2	Step 3	Step 6	Step 4	Step 7
Component	**Expected outcome**	**Suggested outcome indicators and source of information**	**Expected outputs**	**Suggested output indicators and source of information**
Implementation of measures to reduce vulnerability of Millenium Bridge to extreme rainfall events.	Adaptation measures have been adopted, based on existing Climate Services	At least 80% of measures to ensure the Millenium Bridge's stability towards 100-yearly floods taking in account new bridge's design that considers results from the climate risk assessment have been implemented 3 years after the start of the project. Source of information: list of implemented measures.	a. Decision-makers are aware of existing risks; b. The Millenium Bridge's design takes into account these risks.	a. Results of a climate risk assessment have been validated by at least 10 Metropolis decision-makers in a 3-day workshop. Source of information: participants' list and workshop documentation b. …

Module 4

4.6.5 Guiding questions for reflection

- Why is it relevant to have a well-developed M&R system accompanying adaptation projects?
- Why is it important to formulate outcomes and outputs, apart from long-term adaptation impacts?
- What are the challenges when formulating indicators?
- What are key stakeholders and key aspects to ensure that enough data is available to measure indicators?
- Which role does the User Interface Platform for Climate Services play to eventually provide data for M&R?

4.6.6 Take away messages

- M&R is more than a 'nice-to-have': it is key to measure the impact of adaptation efforts over time and therefore demonstrate results to investors, to steer activities, for learning, and finally for international reporting framed in the Paris Agreement.
- M&R for adaptation faces a number of challenges, being some the inexistence of always valid metrics to measure adaptation, long time horizons regarding possible impacts, uncertainty in climate and socio-economic developments, and the complexity of understanding all factors leading to climate risk.
- Trickling long-term adaptation impacts of adaptation measures to results chains and therefore outcomes and outputs helps to explain intermediate stages towards long-term impacts.
- Indicators are ways to measuring the progress and progress in your project towards achieving its outputs and outcomes. This is why they should meet the SMART criteria in order to be qualitatively relevant to measure outcomes and outputs.

4.6.7 References

Asian Development Bank (ADB) 2011. Guidelines for climate proofing investment in the transport sector: Road infrastructure projects. Mandaluyong City, Philippines: Asian Development Bank. www.adb.org/sites/default/files/institutional-document/32772/files/guidelines-climate-proofing-roads.pdf

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4.6.8 Personal notes

Annexes

Annex 1
Fictitious Case

Setting the Scene for the Climate Risk Assessment of the Millennium Bridge of the City of Metropolis and an Assessment of the Karibu Power Plant and Transmission System

1 Case study setting – The Karibu River and the city of Metropolis

1.1 Environment

The Karibu River Watershed lies in the Eastern Province of South Country. The Northern parts of the catchment are characterized by the high Upper Mountains, gently sloping south. The Upper Mountains have been classified an Area of Extraordinary Beauty and they are a renowned destination for ambitious hikers and climbers in summer. However, in the past years much of the forests had been degraded due to rapid urbanization and uncontrolled land-use changes. In the rainy season, the peaks of the mountains are often covered in clouds with intense rains occurring every afternoon causing tremendous water discharges. Currently, a new dam to provide hydropower is being built at the river midstream, to supplement power that is provided by an aging Power plant, just upstream. One tributary adds its waters before Karibu River reaches the major bridge connecting both parts of the city accessible for vehicles. Electricity is supplied by one main transmission line and serves the city core first, including the region's hospital, with power lines crossing the Karibu River slightly upstream from the Millennium Bridge to serve the city's western suburb.

1.2 The city of Metropolis

Metropolis has about 6 Million inhabitants. A mega city in the Eastern Province, and an area of major importance for economic activity and social life throughout the country. Metropolis is equipped with residential and commercial/industrial areas, green spaces for recreation, hospitals, schools and universities, as well as vast shopping facilities covering all needs. Thereby, the city is of major importance for the surrounding region, especially the smaller villages and dwellings who benefit from the services and facilities offered by the city. With having a harbor, the city receives importance as a gateway for the trade of goods and commodities within the region. The road leading across the bridge is of crucial importance for traffic, transport and overall mobility. The city is also an energy center for the region, with the existing Power plant and the hydro plant under construction having the combined capacity to provide electricity to a growing population and economy to at least 2050.

2.1 The Millennium Bridge

The Millenium Bridge has been rebuilt, after the last bridge was severely damaged during a so-called centennial flood in 1998 and had to be taken down due to safety reasons. During that event, people and authorities noticed that early-warning and contingency plans were not functioning properly, leading to severe human and economic losses.

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Outline of socio-economic consequences due to the bridge failure

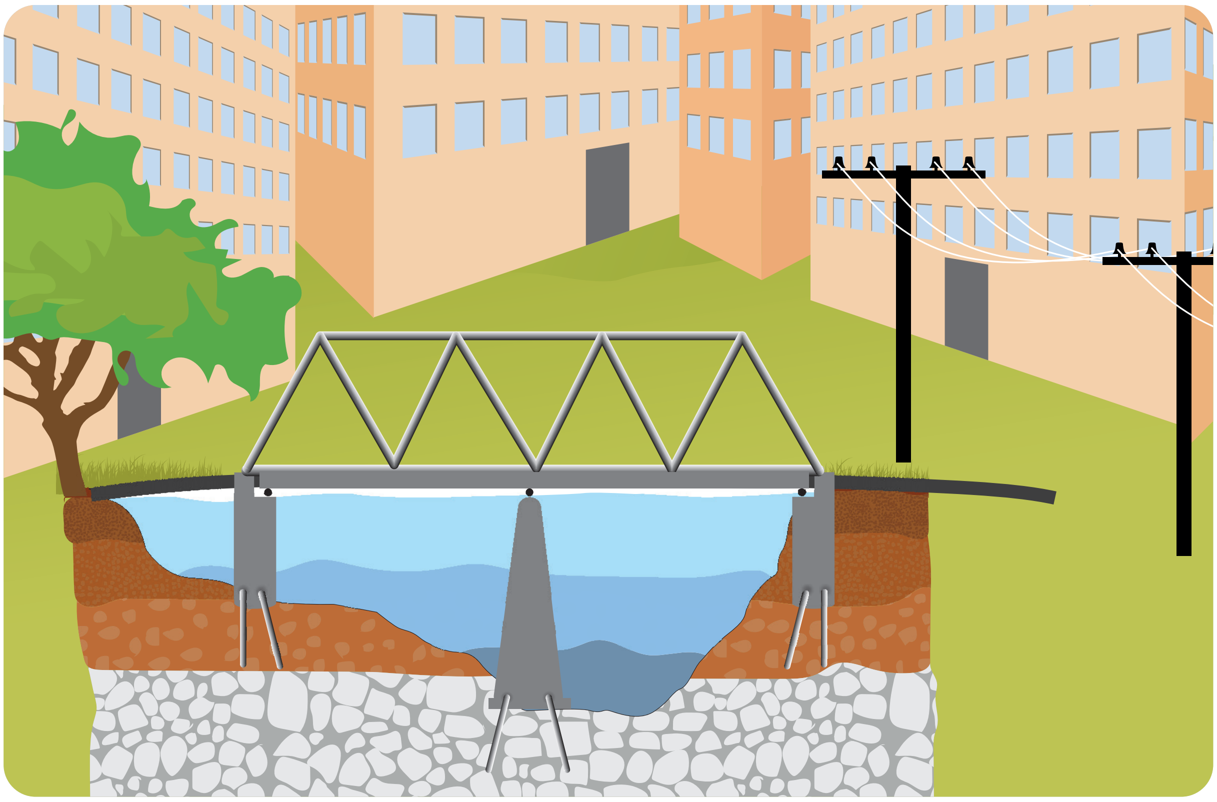
The socio-economic impacts of this event were severe, beyond the costs of the new bridge. During the reconstruction phase, the river crossing of people and smaller vehicles was provided by a ferry service, but larger vehicles had to do a long detour of approx. 80 km to a larger ferry further north, eventually leading to losses for fresh or frozen products. Commuting pupils and students from the Western banks had to leave their school buses at one side of the river, take the ferry and then climb on the next bus at the other side. The education statistics show a decrease in the final exam grades of commuting pupils. The health statistics of this time show a significant increase in pulmonary diseases among schoolchildren, especially in elementary school. Medical services had to operate by helicopter if there was an emergency case at the Western banks of Karibu River. Longer travel times of every day commuters from their apartments on the one side of the river to their offices on the other side of the river has caused reduced performance of companies limiting their annual turnover. The intra-regional as well as the inter-regional trade suffered from additional costs for transport as well as from a loss of customers and goods due to vast delays in service delivery. In the second year of reconstruction, the local traditional market, as well as several restaurants at the river banks that represent important touristic places, had to be closed as the expected number of tourists had dramatically fallen the year before causing a dramatic decrease of number of overnight stays and has only recovered since a few years.


Frozen Fish Inc
School
Hospital
Toys
Shoes
Fashion

The new bridge spanning Karibu River that was built after the disastrous flood in 1998 was opened in 2000, thus dubbed the Millennium Bridge. Financing the new bridge was shared by the city administration of Metropolis and the Eastern Province. The bridge was built in adherence to the existing building codes. In 2001, it was nominated for the prize 'Innovative infrastructure of the year' by the National Engineering Society of South State. The technical details include (bridge components illustration courtesy of Alberta Transportation):

Road surface (asphalt cement pavement)	Design temperatures: Superpave Performance Grading (PG) 64-22 (highest temperature of asphalt of 64 degrees C) Design life = 15 years
Bridge deck	Carbon fiber reinforced concrete; design life 75 years Drainage system Guard rails and signage
Expansion joints	Designed for 30 degrees Celsius
Piers and abutments	Designed to resist scouring of 100-year flow (equivalent to 4.300 m^3/s)
Clearance of bridge deck above high-water level	Designed for 100-year (for a design flood of 6.5m above sea level = +4.5m above average)

The Millennium Bridge is managed by the Metropolis City Infrastructure Authority in cooperation with the Province's Road Maintenance Department. The bridge will be examined concerning functionality and maintenance in a thorough check-up in 2020. In this process, possible repairs or refurbishments can be programmed.



2 Climate Information

2.1 Current climate and hydrology

The following graph shows the current climate conditions in the catchment on a monthly basis for precipitation and on a daily basis for temperature.

The recent climate for Metropolis, South State & the Karibu River Hydrology

Month	Average Monthly Precipitation [mm]	Average Daily Temperature [° C]
Jan	252	22.3
Feb	193	24.1
Mar	120	21.3
Apr	52	20.5
May	33	19.1
Jun	16	18.3
Jul	8	18.1
Aug	7	19.8
Sep	22	23.1
Oct	253	24.5
Nov	298	24.3
Dec	280	23.7
Annual mean	**1534 mm**	**21.6°C**

The Karibu's River flow is determined by the precipitation patterns in the catchment – in normal years: majority of rainfall in November to February, negligible rainfall during the rest of the year.

The normal level of the river is at 2m (measure point: +1.5m above sea level), with a mean annual discharge pf $250m^3/s$. The highest recorded water level was 8.43m, the highest recorded discharge $4.300m^3/s$ (1998).

Besides the natural pastures at the Eastern & Western Bank there are no flood control/ defence mechanisms in place.

(Mean climate parameters 1981–2010)

2.2 Recent observed changes in climate and hydrology

The observed changes in annual mean temperature are +0,8°C since 1970. The lower parts of the Karibu River catchment regularly experience high water levels from December to February, due to the seasonal intensive rains. Overall, the frequency of strong rainfall events has increased. Although, the average amount of annual rainfall is largely unchanged, especially during El-Niño years, more precipitation in the rainy season (more rainfall and torrential rains) has been experienced in the past decade. The bridge had been partly damaged by flooding in the past, however, the last severe damage before the one leading to the reconstruction in 1998 had been before the beginning of the 20th century (had to be looked up at the town's archives). Thus, the flood in 1998 was called a centennial flood. However, the frequency of such disruptive high water levels appears to be increasing and a severe flood – similar to the one in 1998 – has reoccurred once since.

A relatively new feature are random thunderstorms accompanied by strong rains in the northern part of the watershed, where steep, bare rock slopes are common, leading to extraordinary high water levels, and eventually causing flooding of the cities original flood plain, that is now urbanized.

The other experienced extremes in recent years have mainly occurred during La-Niña, where precipitation has decreased accompanied by drought conditions and heat waves.

2.3 Climate projections in the Karibu River Catchment

Temperature	Annual mean temperature rising by 2-3°C in the Upper Mountains and 1-3°C in the river valley by the 2050s (compared to the 1970 to 2000 average). Increase in heat waves in summer and during La-Nina years with • Likely occurrence of temperatures exceeding 35 degrees in three consecutive days • Probable occurrence of temperature exceeding 40 degrees in five consecutive days leading to asphalt temperatures exceeding 64° Celsius.
Precipitation	Slight increase in mean annual precipitation by the 2050s (compared to the 1970 to 2000 average). More intense precipitation in the rainy season and more intense El-Nino related rains. Precipitation focused on shorter periods. Increase in thunderstorms with high intensity rainfall events in summer (short and heavy rains with up to 35l/m² in 6h).
Wind and storms	Increase in thunderstorms with increased average and top wind speed.
Surface hydrology	More variable river flows. Likely more frequent floods exceeding discharge of 4.300m³/s and exceeding 6.5m water level above sea level. Longer periods without significant precipitation (dry spell). Lower late summer river flows. Increased erosion of sloping land and reservoir catchments. Larger sediment loads in lower Karibu River.
Sea-level	Predicted sea-level increase of 40-90 cm by the year 2070.

Annex 2
Glossary of key terms[5]

TERM	DEFINITION
ADAPTATION	The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects. (IPCC AR5)
CLIMATE	Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. (IPCC AR5)
CLIMATE CHANGE	Climate change refers to 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 forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes. (IPCC AR5)
CLIMATE SIGNALS	Climate signals are long-term trends and projections that carry the fingerprint of climate change. Examples of observed long-term trends linked to climate change include rising sea levels, increasing extreme precipitation, and warming sea surface temperatures. Model projections can identify conditions expected in a warming world such as an increasing frequency of intense hurricanes (www.climatesignals.org 2019).

[5] Sources
- IPCC AR5: www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_Glossary.pdf
- GIZ Risk Supplement to the Vulnerability Sourcebook www.adaptationcommunity.net/wp-content/uploads/2017/10/GIZ-2017_Risk-Supplement-to-the-Vulnerability-Sourcebook.pdf

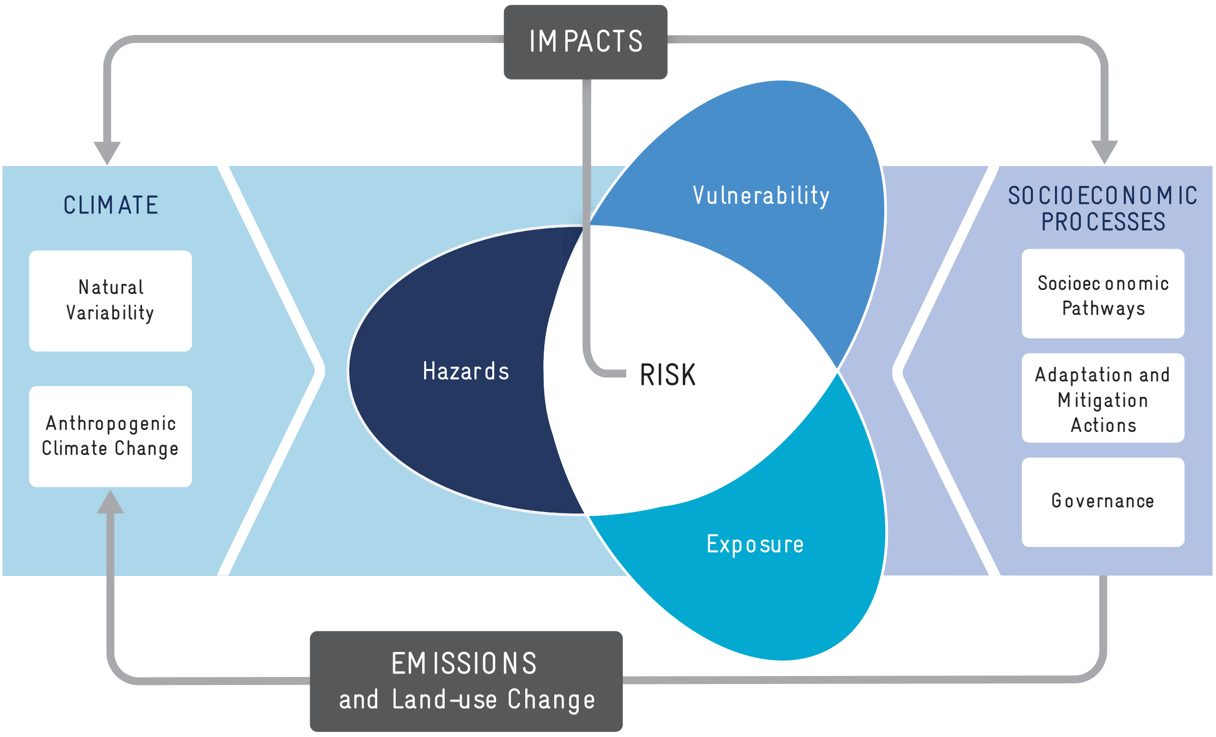
CLIMATE PARAMETER	Climate parameters are factors which influence the climate like air temperature, precipitation, heat waves, storminess etc. and which measurable to provide historic values and can be part of climate models under a number of given assumptions. Modern climate models do a good job of simulating many large-scale features of present-day climate. However, these models contain large numbers of adjustable parameters which are known, individually, to have a significant impact on simulated climate. While many of these are well constrained by observations, there are many which are subject to considerable uncertainty. We do not know the extent to which different choices of parameter-settings or schemes may provide equally realistic simulations of 20th century climate but different forecast for the 21st century (www.climateprediction.net 2019).
CLIMATE PROJECTION	A climate projection is the simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases (GHGs) and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission/concentration/radiative forcing scenario used, which is in turn based on assumptions concerning, for example, future socio-economic and technological developments that may or may not be realized. (IPCC AR5)
CLIMATE VARIABILITY	Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability). (IPCC AR5)
CRITICAL CLIMATE EVENT	A critical climate event is defined as a climate condition that exceeds the identified load capacity of an infrastructure component leading to an impact on the component.
DESIGN LOAD	The design load is the maximum load (or force) a system (or its individual components) is designed to sustain.
EXPOSURE	The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected. (IPCC AR5)
HAZARD	The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts. (IPCC AR5). An extreme hazard may turn into a critical climate event.

IMPACT	Effects on natural and human systems. In the AR5, the term impacts is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts and sea level rise, are a subset of impacts called physical impacts. (IPCC AR5)
MITIGATION	In the context of climate change the term refers to the reduction of greenhouse gases in the atmosphere through measures which reduce the emission of these gases or serve as sinks which trap and store them. This manual uses the term in the sense of reduction of climate threats related effects like flooding, storm surges, heat waves etc. by measures which increase water infiltration, serve as barrier or shade. These measures are considered measures to support adaptation to climate change effects.
PERFORMANCE RESPONSE CONSIDERATIONS	Also referred to as 'Infrastructure Response Considerations' in the PIEVC Protocol, infrastructure response criteria establish a range of outcomes of climate-infrastructure-interaction outcomes that are tailored to the specific assessment and provide a basis for the ➔ severity scoring. These may include performance considerations such as structural (e.g., will the asset or component fail?), functional/capacity (e.g., is the capacity of the asset or component to provide the service as designed affected?), or operations and maintenance (e.g., does the climate event affect access to the asset or component? Is the service life of the asset or component reduced due to the event?)
PROBABILITY/ LIKELIHOOD	The chance of a specific outcome occurring, where this might be estimated probabilistically. (IPCC AR5) Note: In the IPCC AR5 likelihood is expressed using a standard terminology.
RISK	The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. (IPCC AR5) Risk results from the interaction of vulnerability, exposure, and hazard. (GIZ Risk Supplement to the Vulnerability Sourcebook) The easy risk formula is Risk=probability*severity
SEVERITY (SCORE)	In the context of a PIEVC Protocol assessment, the Severity score (or rating) relates to the gravity (seriousness) of the effects and consequences a climate event occurring at the selected intensity threshold on the assets or components. Severity refers to impact in the IPCC risk model.

THRESHOLD	In the context of a PIEVC Protocol assessment, threshold relates to the intensity (magnitude) of a climate event that affects the performance of the asset or its components. ➔ 'Performance Considerations'
VULNERABILITY = SENSITIVITY + COPING AND ADAPTIVE CAPACITY	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. (IPCC AR5) Vulnerability has two relevant elements: 1. Sensitivity is determined by those factors that directly affect the consequences of a hazard. Sensitivity may include physical attributes of a system (e.g. building material of houses, type of soil on agriculture fields), social, economic and cultural attributes (e.g. age structure, income structure). 2. Capacity in the context of climate risk assessments refers to the ability of societies and communities to prepare for and respond to current and future climate impacts. It comprises: a. Coping capacity: The ability of people, institutions, organizations, and systems, using available skills, values, beliefs, resources, and opportunities, to address, manage, and overcome adverse conditions in the short to medium term (e.g. early warning systems in place). a. Adaptive capacity: The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences' (e.g. knowledge to introduce new farming methods). (GIZ Risk Supplement to the Vulnerability Sourcebook)
WEATHER	As distinguished from climate, weather consists of the short-term (minutes to days) variations in the atmosphere. Popularly, weather is thought of in terms of temperature, humidity, precipitation, cloudiness, visibility, and wind.[6]

[6] American Meteorological Society. Glossary of Meteorology: http://glossary.ametsoc.org/wiki/Weather

Figure



(Source: IPCC 2014, p.1046, GIZ Risk Supplement to the Vulnerability Sourcebook)

Annex 3
Abbreviations

ADB .... Asian Development Bank
AR .... Assessment Report
(e.g. Fifth Assessment Report = AR5)
C .... Celsius
CBA .... Cost-Benefit Analysis
CBO .... Community based Organization
CC .... Climate Change
CD .... Capacity Development
CEA .... Cost-Effectiveness Analysis
CH_4 .... Methane
CO_2 .... Carbon dioxide
CP .... Climate Proofing
CS .... Climate Service
CSI .... Enhancing Climate Services for Sustainable Infrastructure Investment
CSIS .... Climate Service Information System
DRR .... Desaster Risk Reduction
DWD .... Deutscher Wetterdienst
EbA .... Ecosystem based Adaptation
ECV .... Essential Climate Variable
EIA .... environmental impact assessments
ESM .... Earth System Model
GCM .... Global Climate Model
GFCS .... Global Framework for Climate Services
GHG .... Greenhouse gas
GIZ .... Deutsche Gesellschaft für Internationale Zusammenarbeit
GPCs .... Global Production Centers
H_2O .... Water
ICTs .... Information and Communication Technologies
INDC .... Intended Nationally Determined Contributions to Paris Agreement (2015)
IPCC .... Intergovernmental Panel on Climate Change
Km .... kilometer
MCA .... Multi-Criteria Analysis
mm .... millimeter
MoU .... Memorandum of Understanding
M$ .... Metropolis Dollar
M&E .... Monitoring and Evaluation System
NAP .... National Adaptation Plan
NBI .... Nile Basin Initiative
NCCS .... National Climate Change Strategy
NCS .... National Climate Service
NDC .... Nationally Determined Contributions to Paris Agreement
NFCS .... National Framework of Climate Services
NGO .... Non-governmental Organization
NMHS .... National Meteorological and Hydrological Services
NMP .... National Mitigation Plan
NO_2 .... Nitrous oxide
° .... Degree
O_3 .... Ozone
OECD .... Organization of Economic Cooperation for Development
OM .... Observation and Monitoring
O&M .... Operation and Maintenance
P .... Precipitation
PIEVC .... Public Infrastructure Engineering Vulnerability Committee (PIEVC)
RCCs .... Regional Climate Centers
RCM .... Regional Climate Model
RCP .... Representative Concentration Pathway
RMP .... Research, Modelling and Prediction
SWOT .... Strengths, Weaknesses, Opportunities and Threats
T .... Temperature
ToT .... Training of Trainers
UIP .... User Interface Platform
UN .... United Nations
UNFCCC .... United Nations Framework Convention for Climate Change
W .... Watt
WCC-3 .... 3. World Climate Conference (2009)
WI I .... Working Group II of AR5
WMO .... World Meteorological Organization

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