CHAPTER 15

Building Resilience in Infrastructure to Climate Change

Tuan Minh Le, Wei-Jen Leow, and Fabian Seiderer

INTRODUCTION

Governments face growing economic and fiscal liabilities because of the increased scope and scale of climate change and the disasters it induces. While the many spillover effects cause damage to private property, public infrastructure, and services such as communications, transportation, and utilities, the economic losses can well exceed the cost of replacement. A road bridge that is washed away not only drains resources to replace it and hits economic activity, but where alternative transportation routes are minimal or costly, the net private benefit to bridge users is also lost. The longer it takes to repair the bridge or provide alternative transport routes, the more the economic loss accumulates.

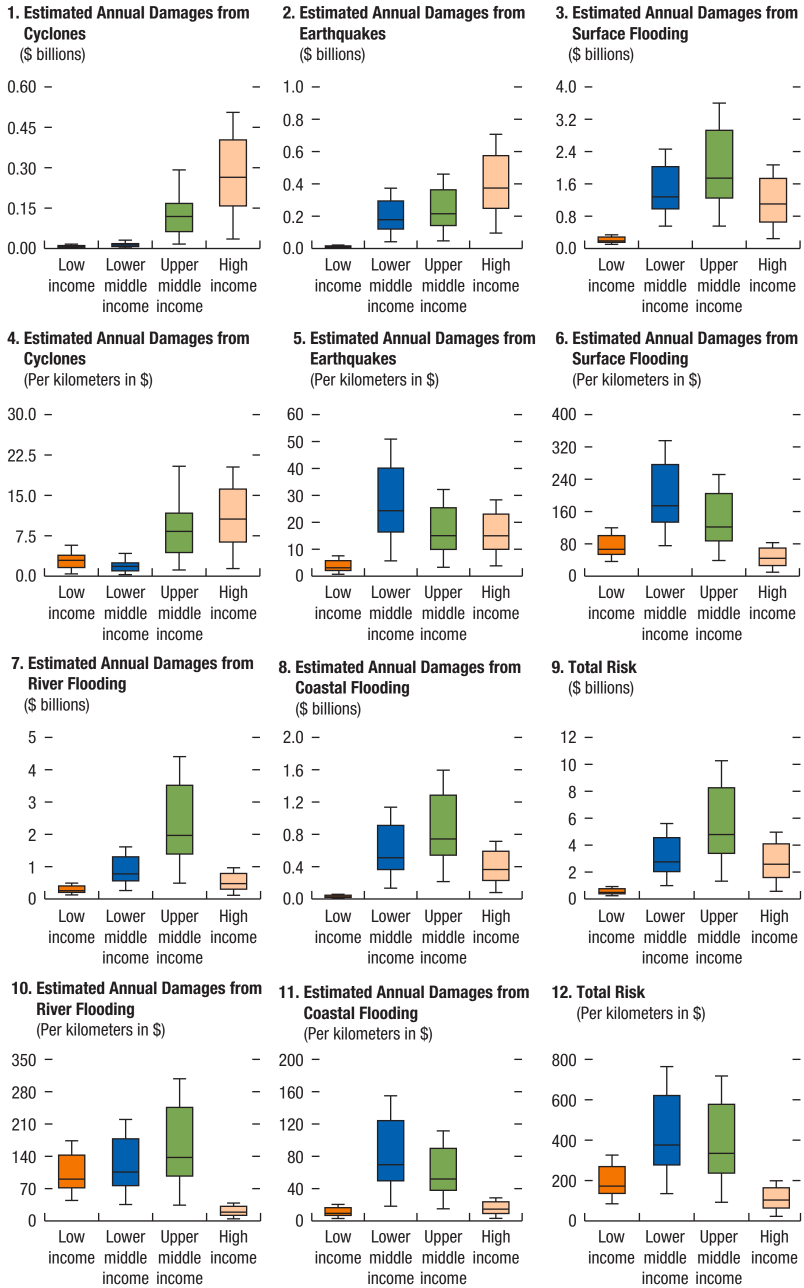
Worldwide, the expected annual damage for transport infrastructure alone is in the billions of dollars, with more damage expected among advanced economies, given their larger capital stock (Figure 15.1). Transport infrastructure damage first increases with income growth and then decreases. Damage to other infrastructure facilities, like energy and water systems, only adds to the total cost.[1]

One would expect that specific project locations with a history of hazards and known exposure to climate change will attract less investment interest. Yet this does not always happen. Look no further than the unabated trend of beachfront development and the supporting public infrastructure for that. The reality is that climate and disaster risks are not fully encoded into public and private investment decisions at all levels. In developing countries, capacity and institutional processes to screen public projects for climate-induced risks are often lacking. Private investment decisions rarely account for these risks, often because they are heavily discounted to favor short-term profit. Consequently, large amounts of capital continue to flow into hazard-prone areas, leading to significant increases in the value of exposed economic assets. This amounts to a "fiscal time bomb" of explicit and contingent liabilities on the government when climate change manifests.

In response, governments need robust infrastructure governance frameworks to strengthen climate resilience. In the opening example of a road bridge, the losses could

[1] Chapter 9 also provides additional information on total costs of natural disasters.

Figure 15.1. Expected Annual Damage to Transport Infrastructure per Hazard, by Country Income Group



Source: Hallegatte, Rentschler, and Rozenberg 2019.

have been prevented or minimized had the government designed and built a more resilient bridge, planned for alternatives in the event of collapse (the use of military pontoon bridges, for example), or developed rapid repair or replacement capacities. Responses should also include risk management, through investing in adaptation measures, as well as the resilience financing strategies explored in Chapter 9.

This chapter provides guidance on how to integrate considerations of climate-related risks into infrastructure governance, focusing on the planning, design, appraisal, selection, and financing of public investments. It begins by looking at the frequency and growing severity of climate-related disasters, the rising cost of damage and losses, the expected trends in extreme weather, and an assessment of the resilience and vulnerability of countries and regions to climate-related disasters. It then presents an approach for governments to integrate climate considerations into the upstream stages of infrastructure governance, including in project planning and appraisal. With this new approach in hand, the chapter proposes some country-based enhancements to the IMF Public Investment Management Assessment (PIMA)[2] framework and the World Bank PIM diagnostic assessment frameworks (presented in Rajaram and others 2010 and Rajaram and others 2014), combining climate-specific dimensions with quantitative measures of risk based on data on past damage.

THE EFFECTS OF CLIMATE CHANGE ON ECONOMIES AND INFRASTRUCTURE

Past Hazards: Frequency and Severity

A large body of evidence supports the existence, causes, and ramifications of climate change, as collected by the United Nations' body of climate experts (Intergovernmental Panel on Climate Change, IPCC). World Bank (2014) provides a summary of the key climate impacts caused by tropical storms, wind, drought, heat extremes, floods, and landslides across regions over recent decades (Annex 15.1). Among the main issues it highlighted were the early onset of climate impacts, their uneven regional distribution, and interaction among impacts, which accentuates cascade effects.

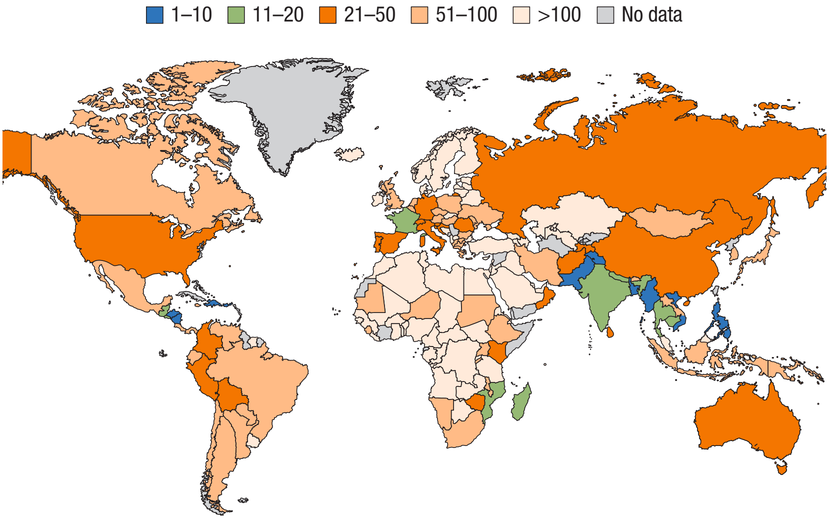
The cost of climate-related disasters has also increased, with water-related damage being a dominant component. A review of the Emergency Events Database (EM-DAT)[3] over the past six decades shows that natural disasters increased sixfold from the 1960s to after the turn of the century.

Climate change elevates the risk profile of many countries, given their historical record of climate-related disasters. In the long term, many countries risk being hit by at least one severe climate disaster. Figure 15.2 shows to what extent

[2] The Public Investment Management Assessment framework also aims to accommodate the World Bank's diagnostic assessment frameworks (Rajaram and others 2010 and Rajaram and others 2014).

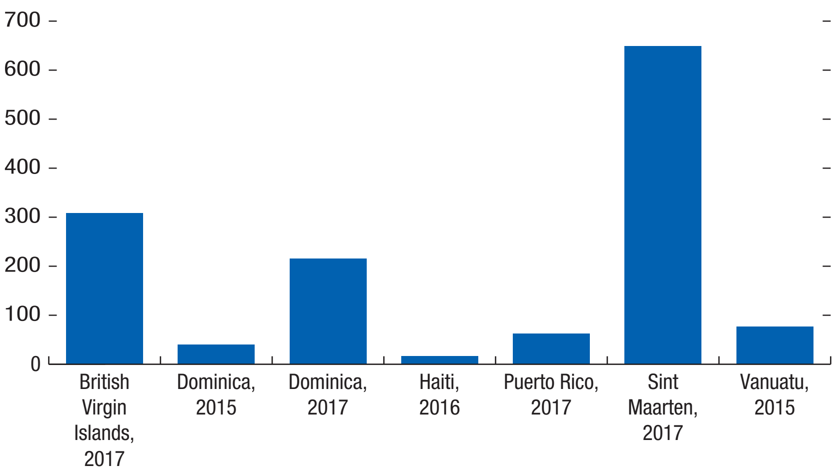
[3] Emergency Events Database (EM-DAT) by the Centre for Research on the Epidemiology of Disasters at the Université catholique de Louvain: https://www.emdat.be.

Figure 15.2. Global Climate Risk Index



Source: Global Climate Risk Index 2019, https://germanwatch.org/en/cri.
Note: The boundaries, colors, denominations, and any other information shown on the map do not imply, on the part of the International Monetary Fund, any judgment on the legal status of any territory or any endorsement or acceptance of such boundaries.

Figure 15.3. Economic Damage from Climate Disasters
(Percentage of GDP)



Sources: World Bank staff calculations, based on Acevedo 2016 and UNISDR 2018.
Note: Acevedo (2016) notes that the 20 largest of 148 hurricane disasters to Caribbean islands over 1950–2014 caused losses averaging 81.7 percent of GDP, with five causing losses of more than 100 percent of GDP. UNISDR (2018) reports the top 10 climate-related disasters ranked by loss as a share of GDP; all 10 are Caribbean islands with losses ranging from 69 percent to 797 percent of GDP.

countries and regions have been affected by weather-related loss events (storms, floods, heat waves, and the like). The annual climate risk index[4] ranks almost one-third of countries as worst affected. Many of these are developing countries, with Caribbean nations among those suffering climate disasters with high frequency over the long term, as seen in Chapter 9. Damages can be extraordinarily severe for small countries (Figure 15.3).

Worrying Trends in Climate Change Hazards

The provisional 2019 statement by the World Meteorological Organization confirmed the global warming trend reported in its 2018 assessment: 2019 is likely to be the second- or third-warmest year on record. Greenhouse gas concentrations in 2018 reached new highs, with carbon dioxide, methane, and nitrous oxide all reaching record levels. The ocean heat content in 2019 surpassed the level in 2018, and the daily Arctic Sea ice extent in the month of October was at a record low. In autumn 2019, the global mean sea level reached its highest value since the beginning of high-precision altimetry records (January 1993).

The warming trend is set to continue, and even in the best scenario, the frequency and severity of extreme weather will increase. The IPCC *Special Report on Global Warming of 1.5°C* reported that the average global temperature for 2006–2015 was 0.87°C above the preindustrial baseline (IPCC 2018).[5] With a global target of limiting global warming effects to 1.5°C by 2050, even in the "best case" outcome, the report expects extreme weather (including tropical cyclones, extreme rainfall or drought, and extreme temperatures) will increase in frequency and intensity, and that sea levels will rise, along with damage inflicted on terrestrial and ocean ecosystems.

Vulnerability and Resilience of Infrastructure to Disasters Induced by Climate Change

The extent of actual damage to infrastructure and, more widely, to an economy depends on the vulnerability and resilience of the country in question and its location. A severe storm can wreak more economic losses on one country than another, depending on locational factors such as physical geography (for example, whether an area is already flood prone), population density, physical resilience of the infrastructure, and the preparedness and actions of the population

[4] The climate risk index is a measure computed from a weighted average of a country's rankings on four indicators (deaths, deaths per inhabitant, US dollar losses, and losses as a share of GDP) caused by weather-related events in a particular year.

[5] The IPCC Special Report's Technical Summary noted that "Human-induced warming reached approximately 1°C (±0.2°C likely range) above preindustrial levels in 2017, increasing at 0.2°C (±0.1°C) per decade (high confidence)." It also noted that "Since 2000, the estimated level of human-induced warming has been equal to the level of observed warming with a likely range of ±20 percent accounting for uncertainty due to contributions from solar and volcanic activity over the historical period (high confidence)."

Box 15.1. Infrastructure Washed Away: A Case from Kerala

The increasing frequency and severity of floods caused by climate change have a particularly devastating impact on countries' infrastructure and assets as seen in 2018 in Kerala. The Indian state is a climate change hotspot relative to the rest of India, as measured by Verisk Maplecroft's Climate Change Vulnerability Index.[1] The index for the state in 2018 stood at 2.09 out of 10 (which is the lowest vulnerability). The total loss from the 2018 floods was estimated at 2.6 percent of state GDP, which is higher than the total annual capital budget (2.3 percent of GDP). The recovery needs are estimated at $3.5 billion. The infrastructure sector was the most affected by the floods and has the highest share of total recovery needs ($2.2 billion). In response the government has adopted the Rebuild Kerala Initiative, with a focus on enhancing the state's resilience anchored upon rebuilding better institutions for public investment management.

Source: World Bank public investment management diagnostic and 2019 development policy operation, "First Resilient Kerala Program DPO (P1699074)."

[1] The Verisk Maplecroft's Climate Change Vulnerability Index measures the susceptibility of populations to climate change and shocks on a scale of 0–10, where 0 is the highest risk and 10 the lowest risk. https://www.maplecroft.com/insights/analysis/84-of-worlds-fastest-growing-cities-face-extreme-climate-change-risks.

and authorities in response to the storm threat. These "resilience" factors contribute to the true vulnerability of a location and its infrastructure, and may attenuate the actual number of affected lives, value of property damage, and days of service disruption.

These developments call for urgent infrastructure governance to account for the losses that an investment may suffer over its operating life because of compounded climate-related weather disaster risks. Accounting for losses will naturally reduce the expected net economic benefits that give rationale to the project, and so impacts project planning and appraisal. At the same time, this should also prompt infrastructure governance to be improved to ensure that it systematically encourages consideration of adaptation solutions in design and in cost-benefit assessments. Box 15.1 discusses how the State of Kerala of India decided to develop a climate-informed public investment management after a severe flood.

INTEGRATING CLIMATE CHANGE CONSIDERATIONS UPSTREAM IN PUBLIC INVESTMENT MANAGEMENT

This section provides guidance for mainstreaming climate screening and techniques in the upstream stages of public investment management, specifically project identification, prescreening, project appraisal, and selection[6] It discusses

[6] Climate sensitivity has to recognize both the climate impacts of projects and their adaptation to minimize the economic costs of expected and possibly worsening damage from natural hazards. Each of these two considerations requires the public investment management system to be climate informed.

the main dimensions (including the main climate hazards, risk identification and vulnerability assessment, climate-informed cost-benefit analysis, and climate impact of projects) that underpin the mainstreaming of climate change in the upstream stages of the public investment management cycle (Glenday and others 2019). These are followed by a discussion on the challenges and policy considerations involved in such an approach.

Climate-Informed Project Planning, Identification, Guidance, and Screening

The first challenge is to account systematically for the climate impacts of projects and their vulnerability to climate risks, and for their necessary adaptation. This requires developing an understanding of (1) the climate impact of large projects (such as greenhouse gas emissions), (2) the sources, types, and sizes of damage and economic losses from climate events, (3) how these relate to the size or strength of different natural hazards, and then (4) how to analyze the historical record and use models to predict the frequency of natural hazards of different strengths.

As part of the screening or preappraisal, project proposals should meet broader criteria of consistency with sustainable development goals that in turn should be addressing service delivery shortages, growth promotion, and distributional goals. However, these goals are impacted by climate change and related extreme weather events, as seen above. Consideration of these climate impacts and risks needs to be built into the public investment management framework and considered early in the project identification and design stage. As these are often new and complex dimensions for developing countries to consider, it is recommended to prioritize climate-informed public investment management modules in countries considered climate hotspots or for large infrastructure projects.

The first stage of a public investment management assessment involves the screening of project proposals to detect any potential major climate impact or risk from or vulnerability to natural hazards, especially climate- or weather-induced hazards. This should be part of the overall screening of infrastructure projects in feasibility studies, design, and selection for budgeting. Climate-sensitive screening of the project pipeline requires that projects identify potential climate impacts and exposure to natural hazards, and that some assessment of vulnerability to risks is provided.

Tools to support climate-informed project screening have been developed to a sophistication that is applicable to major transportation projects (Ebinger and Vandycke 2015). For example, a generic "traffic signal" guide that could rate the preliminary risk of hazards to specific sectors is shown in Figure 15.4.

The risk categories should be country specific and clearly identified, based on historical hazard and loss data and by disaster risk management and climate models. They should include more refined and sector- or location-specific quantitative criteria and data, vetted by central planning and finance agencies and requiring decisions in project preparation, such as reject, redesign, and reevaluate. Generally, the no- or low-risk cases could be ignored for the small, medium, and

Figure 15.4. A Traffic Signal Rating of Hazard Risks

Insufficient Understanding	Greater familiarity with the sector and/or hazards is needed. This rating should be revised once there is sufficient understanding.
No Risk	The hazard does not pose a risk to the sector and/or region and will not affect the achievement of development goals and priorities.
Low Risk	The hazard could have a modest negative effect on the sector, but the country and/or sector has sufficient institutional capacity to respond to the hazard.
Moderate Risk	The hazard could have a considerable negative effect on the sector, and institutional capacity to respond to the hazard might not be sufficient; this risk has the potential to affect the ability of the country to meet its development objectives.
High Risk	The hazard is likely to have a considerable negative effect on the sector, and institutional capacity to respond to the hazard will not lessen the impact; this risk will likely affect the country's achievement of development goals and priorities.

Source: Rating Guide of the World Bank Climate and Disaster Risk Screening Tool (https://climatescreeningtools.worldbank.org/content/risk-rating-popup).

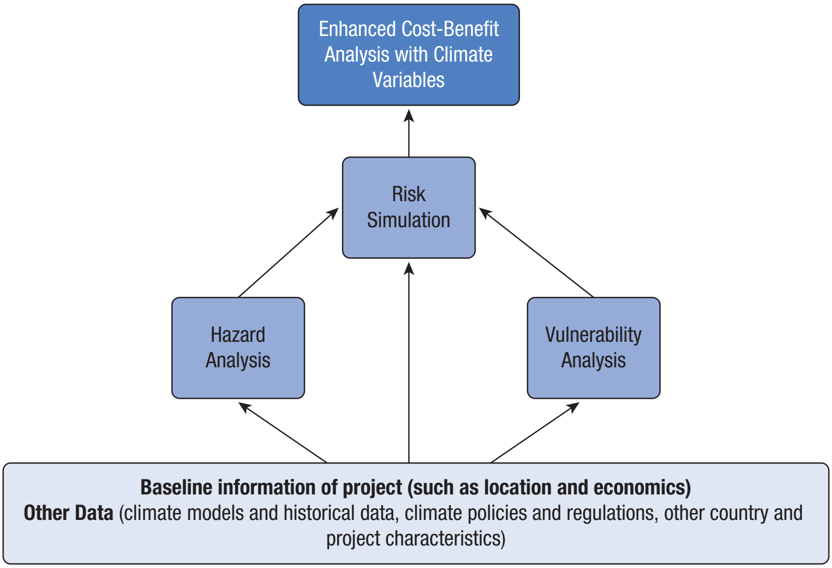
repetitive projects, and result in some reduction in the expected net benefits of large projects being subjected to full cost-benefit analysis. Moderate- and high-risk cases for large projects would be handled at the stage of project appraisal, whereby adaptive measures should be considered to mitigate the risks and lower the expected losses.

Climate-Informed Project Appraisal

While portfolio screening (mentioned previously) is relatively light and manageable for most governments, climate-informed project appraisal can be more demanding and so needs to be prioritized to prevent overwhelming already-limited appraisal capacity. A first set of criteria is the size, the unique characteristics, or the strategic importance of the project. A second criteria is potential impact and loss, in the expected number of people affected and expected value of the damage to project assets (infrastructure, buildings, inventories). Where the number of people affected or the share of project asset damage is high, a more in-depth climate-informed project appraisal is warranted. Specific, transparent thresholds for such filtering and differentiated appraisal methods need to be enacted as part of public investment management governance.[7]

[7] In the case of small and medium-sized repeat projects, the resources used to screen and select them can be streamlined, in terms of both the appraisal process and the approval authority. Large and complex projects often need to be subjected to full cost-benefit analysis, including financial, economic, distributional, and climate risk appraisal and need to be vetted by central or independent planning and finance institutions.

Figure 15.5. Components of the Climate-Sensitive Cost-Benefit Analysis



Source: Adapted from Fernholz and Erdem 2019.

Methodology for Climate-Informed Project Appraisal

As indicated, all new, large, or complex projects should be subject to full-fledged cost-benefit analysis that integrates climate change impacts into the economic analysis. Figure 15.5 shows the components of the enhanced cost-benefit analysis for climate change considerations.

As indicated in Figure 15.5, climate-sensitive cost-benefit analysis is anchored in three building blocks (Fernholz and Erdem 2019). They are as follows: hazard analysis, vulnerability analysis, and risk simulation. All rely on the baseline information gathered for the projects supplemented by other data, for example, climate models and historical data.

- *Risk identification*. Based on past records, expert opinions, and probabilistic modeling, the potential costs of damage need to be assessed along with the vulnerability of the project to damage from different intensities of risks.
- *Hazard analysis*. For an infrastructure or facilities project that is potentially vulnerable to climate-related hazards (such as a road or a bridge that could be damaged by flooding), the project appraisal must account for projected hazards that may damage the asset and its ability to generate expected services and a return on investment.
- *Vulnerability analysis*. This type of analysis focuses on estimating loss functions. It would help clarify the economic impact of climate parameters at different intensities on specific infrastructure assets and property, or the whole economy.

Techniques of varying complexity can be applied depending on the importance of the project, risk, and country capacity and data availability. Ministries can be asked to consult with planning and disaster management departments to build some simplified climate risk assumptions and shock scenarios into their standard cost-benefit analysis. For large projects and climate hotspots, hazard and climate models can be used. First, this requires estimating the threshold strength for a hazard in a location that will bear significant damage, and then estimating the probabilities that hazards above the threshold could occur. This "exceedance" probability distribution then needs to be linked to damage and loss estimates. Second, differently costed risk-mitigation measures for the project, such as more resilient infrastructure design, redundancies, and asset insurance schemes, can be factored in to the project cost-benefit analysis. In addition, net economic losses that can be expected until the infrastructure or facility services are restored have to be assessed and also factored in. The overall economic loss of a disaster varies with the intensity of the hazard, the ability of the infrastructure to withstand it, the government's capability to reduce the hazard (for example, to divert or dam floodwaters), and the speed with which the government can restore the infrastructure services or provide alternatives.

The next step is to consider whether modifications can be made to the new infrastructure investment (a road system, say) that will make it more resilient while improving the expected net benefits. The approach here refers to real options analysis.

Real option analysis, in a nutshell, extends the conventional cost-benefit analysis. By taking into consideration future costs and benefits, it explores the opportunities to delay full implementation of adaptation measures until better information becomes available and allows resolution of uncertainty about climatic impacts.[8] The real option can include provisions in design and construction that accommodate adaptive reinforcement of structural elements in the future. As such, a so-called real option is the right but not the obligation to adjust the infrastructure system in ways likely to be more resilient, as needed for the infrastructure to to continue to function as expected in the face of change.[9]

Incorporation of Project Climate Impacts in Economic Appraisal

A key aspect of a climate-smart system is the inclusion of the evaluation of climate impacts of changing greenhouse gas emissions arising from a project. This may be either a direct impact from emissions reduction through expanded green power supply in place of fossil fuel–based power, or an indirect impact through changes in forest coverage or management that impact the carbon sequestration capacity of the country or the local climate. The climate change impacts of changing the level of carbon dioxide and other greenhouse gas emissions have

[8] Chapter 5 in Rajaram and others (2014).

[9] For an example of real options analysis, see Gersonius and others (2013).

both domestic and international economic values to be taken into account in economic analysis of a project. The two most common methods of estimating the emissions externality are either by estimating the added economic costs of damage from added carbon dioxide emissions[10] or by estimating the value of carbon emissions rights traded in an open market.[11] The challenge to cost-benefit analysis from an economic perspective is that the reduction of greenhouse gases is a global public good because benefits accrue nationally and to the rest of the world.

Challenges and Policy Considerations for Mainstreaming Climate Screening and Appraisal in Public Investment Management

Making public investment management climate smart is a new and important demand on the institutional capacity of a government. It requires gathering and managing the information on current and past natural hazards, forecasting the future occurrence of natural hazards or extreme climate events, and tracking the nature and costs of natural disasters as they occur. While this is increasingly done by countries' disaster risk management agencies, it often remains outside of public investment management institutions and processes. Conversely, these agencies are rarely informed at the planning stage about additional infrastructure investments, compounding locational climate vulnerabilities and risks. To succeed, integrating the adaptation to natural hazards—or accounting for the climate change impact of public investments—would require the combination of information, greater coordination, incentives, and disciplines.

Collection of Required Data and Information

Identification of natural hazards requires the accumulation of meteorological, geological, and other data to analyze and develop models to forecast the probabilities of extreme natural hazard events that can lead to significant damage and economic loss. Data for temperature and precipitation have been collected for more than 100 years; the density of earth-based weather stations has been increasing and has been supplemented by data from satellite-based platforms since the 1980s. This has allowed the development of sophisticated weather models for forecasting climate events in most regions of the world. These data and models have allowed access to climate event data provided by major international and national agencies. The challenge, however, comes in linking natural disaster data to the actual historical and projected potential disaster information by country, location, and sector. This requires a greater integration of national and international climate and disaster risk management

[10] Current estimates in the United States of the economic costs of an added ton of carbon dioxide emissions are $42 per ton (National Academies 2017).

[11] The value of carbon traded on the European Union emissions trading system as of March 2019 is $25 per ton.

databases and competencies in upstream public investment management functions and frameworks.

Institutionalization of Climate-Informed Public Investment Management

Policymakers determine four sets of actions to mainstream the collection and use of information into public investment management. First comes institutionalization of the channels and governance structure, leveraging national and international climate and disaster databases and models. Second, development of mechanisms and procedures to ensure climate screening, vetting, and amendment of project options and designs. Third is capacity building, and fourth, the appropriate treatment of the climate change impact of publicly financed projects. Some highlights of the authors' analysis along these four dimensions of policymaking are summarized in this section.

Institutionalize the Channels and Governance Structure for Climate-Sensitive Public Investment Management

Typically, countries face institutional fragmentation as a perpetual problem, which is intense for cross-cutting government functions such as public investment management and disaster risk management. It is critical, therefore, to develop channels by which information on natural hazards flows into government planning and can help guide investment design, selection, and budgeting.

Institutionalized processes and division of labor, a transparent accountability mechanism, and appropriate institutional incentives to reward cross-agency collaboration are ingredients critical for making public investment management sensitive to climate change. Countries can build on their experience with the environmental impact assessments done on most large projects. Therefore, functions that need to be allocated to specific government agencies—and coordinated and managed by sector and central ministries—include the following:

1. Building databases of the historical occurrence of natural hazards and predicting the strength and frequency of hazards.
2. Documenting and analyzing the damage and economic losses caused by past disasters by sector and location, and predicting the potential damage and economic losses by sector and location over time.
3. Establishing climate-sensitive construction regulations by sector and location.
4. Screening projects for climate impact and natural hazard vulnerability.
5. Developing climate-sensitive project designs for vulnerable projects and appraising them.
6. Selecting and financing projects, including the possible added climate adaptation costs, and sustaining appropriate levels of operations and maintenance financing.
7. Monitoring and evaluating project performance, particularly for climate-related impacts and valuation of disasters (to feed these observations back into the disaster damage prediction in point 2).

The coordination and aggregation function demands active involvement and direction from the central planning and finance agencies, thus the need to include these functions in regulations and processes for public investment management.

Develop Mechanisms or Procedures to Ensure Climate Screening, Vetting, and Amendment of the Investment Design

Climate screening needs to be included in a country's legal and regulatory framework for public investment management in the same manner as environmental impact assessments. Appropriate vetting and disclosure processes need to be in place to ensure screening is properly done and to inform the cost-benefit analysis and design (or design change) for large projects as warranted. This can be complemented by sector or through construction regulations that are location specific. Regulations are appropriate where a hazard is expected frequently and where the regulations can be applied to a wide range of investment types in a specific sector and location.[12] For example, minimum road drainage standards may be required where significant rainstorms occur regularly. Public disclosure of climate-informed public investment screening, feasibility studies, and construction permits enhances compliance and accountability.

Build Capacity

Developing countries and emerging economies face a significant lack of capacity to capture information on the damage estimates that would need to be collected by a combination of disaster risk management agencies and local governments and sector agencies (typically those responsible for transportation, environment, and agriculture).[13]

While initial qualitative and expert assessments can be carried out, a gradual buildup of quantitative methods of analysis (cost-benefit analysis and risk simulation) is required in government ministries responsible for planning and budgeting, focusing on the key tasks in points 1 to 7, leveraging knowledge and competencies across a government and globally. It is therefore essential that the reform—with support and commitments by donors in the case of developing countries—includes a proper training and capacity-building plan to ensure the climate-sensitive public investment management framework can be implemented effectively.

Assess Climate Change Impacts in Public Investment Management

Large projects or projects that are expected to impact environmentally sensitive areas such as forests, wetlands, and coastal zones are required to undergo some level of environmental impact assessment to identify vulnerabilities and the possible adaptations required to minimize the environmental impacts of a project.

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[12] Ideally, as with any regulation, climate-sensitive construction codes should be subjected to cost-benefit analysis to ensure that the costs of compliance are expected to result in cost savings when the construction is exposed to a natural hazard.

[13] Damage estimates are available in 98 percent of the occurrences in Australia and New Zealand, but only 12 percent of the occurrences in sub-Saharan Africa. Moreover, damage estimates are available in less than 50 percent of the countries in Latin America and the Caribbean and South Asia.

These environmental impact assessments are typically conducted as an early input into the appraisal of the project. The assessment of the climate impacts of the project should be part of that process. Clearly, where a country has no process for doing environmental impact assessments, special regulations or directives are needed so that climate impacts can be routinely assessed as part of project screening, appraisal, and approval.

DIAGNOSTIC PROMISE OF CLIMATE MODULE IN INFRASTRUCTURE GOVERNANCE

Existing infrastructure governance diagnostic tools have established a solid framework for assessing public investment management systems, but they were not specifically designed to deal with climate change impacts on public investments. The proposed climate module presented in Annex 15.2 aims to complement infrastructure governance diagnostic assessment tools or traditional diagnostic frameworks such as the PIMA and the World Bank's eight "Must-Haves" diagnostics (Rajaram and others 2010, 2014), as well as the Public Expenditure and Financial Accountability (PEFA) framework. It provides a more climate-informed assessment of countries' upstream public investment policies and actual practices. It asks the basic question of whether a public investment management system is climate sensitive or blind. It follows a PEFA/PIMA-type of questionnaire (and heatmap system) with the focus on the five core dimensions of public investment management (Table 15.1).

TABLE 15.1.

Mapping a Climate-Related PIM Module to the PIMA and PEFA Frameworks

Climate-Related Public Investment Management Module	Relevant Institutions in the PIMA Framework	Corresponding PEFA Indicators and Dimensions
1. Climate-sensitive legal and regulatory framework	Cross-cutting issue on the legal framework	Cross-cutting in respective dimensions
2. Climate-informed investment planning and guidance	Institution 2: National and Sectoral Planning	16.2: Alignment of Strategic Planning and Medium-Term Budgeting 17.2: Budget Preparation
3. Project identification and prioritization considering climate risks (portfolio level)	Institution 4: Project Appraisal (Prefeasibility stage)	11.2: Investment Project Selection
4. Climate-informed project appraisal and selection (project level)	Institution 4: Project Appraisal (Feasibility) Institution 5: Budgeting Institution 10: Project Selection	11.1: Economic Analysis
5. Climate-informed state-owned enterprise investments and public-private partnerships	Institution 5: Alternative Infrastructure Financing	10.1: Monitoring of Public Corporations

Source: Authors.
Note: Numbers represent the respective PIMA and PEFA indicators. PEFA = Public Expenditure and Financial Accountability; PIMA = Public Investment Management Assessment.

CONCLUSIONS

Governments are having to deal with growing economic and fiscal costs and risks from the increasing frequency and severity of climate-related extreme weather. Over the last four decades, natural disasters have increased sixfold and done significant damage to developing and emerging economies. Fixed capital accumulation, including in disaster-prone areas, exponentially increases the risk exposure, particularly as these climate and fiscal risks are rarely considered in investment decisions. Given the high stakes, mainstreaming climate-informed public investment management, including through the Helsinki principles adopted by the Coalition of Finance Ministers for Climate Action, is a priority for the international community.

This chapter proposes an approach governments could use to adapt their infrastructure governance frameworks to strengthen climate resilience in the upstream stages of public investment management: project planning, design, appraisal, selection, and financing. Some caution for policymakers is worth highlighting. First, to avoid overwhelming already-stretched public investment management systems, an upstream and differentiated approach is recommended to assess and mitigate the most severe climate risks and impacts for the most important public investments. Different qualitative and quantitative approaches and tools exist for climate risk identification and vulnerability assessments, portfolio and project screening and appraisal, and mitigation measures. They have yet to be further tested and incorporated in a country-specific public investment management framework. Second, upgrading a national system to factor in and mitigate growing climate risks requires a sequenced but holistic approach, including regulatory, institutional, and operational reforms and adequate capacity building. To improve the national climate-sensitive public investment management systems efficiently, it is imperative that government vision fits a comprehensive plan, with realistic milestones and timelines. And third, greater institutional cooperation serves as one of the major preconditions for a functional climate-sensitive public investment management system.

ANNEX 15.1. OVERVIEW OF CLIMATE CHANGE IMPACTS ACROSS REGIONS

The following is an overview of some of the climate change impacts (excluding storm- and flood-related impacts) across regions identified in the World Bank report *Turn Down the Heat* (2014):

1. *Unusual and unprecedented heat extremes*. These are expected to occur far more frequently and cover much greater land areas, both globally and in the three regions (Latin America and the Caribbean, North Africa and the Middle East, and Europe and Central Asia) examined. Heat extremes in Southeast Asia are projected to increase substantially in the short term and would have significant adverse effects on humans and ecosystems under 2°C and 4°C of warming.
2. *Rainfall regime changes and water availability*. Even without any climate change, population growth alone is expected to put pressure on water resources

ANNEX 15.2.

ANNEX TABLE 15.2.1

Climate PIM Module: Questionnaire

Dimension	Question	A	B	C	D
1. Climate-sensitive legal and regulatory framework	Does the government have an explicit legal or regulatory framework expressing the climate mitigation objectives or the adaptation requirements for programs and projects? How comprehensive is this framework? Does it apply to all levels of government?	The PFM/ PIM legal or regulatory framework does explicitly address both mitigation and adaptation and covers the entire public sector. Strong compliance: applied to more of 75 percent of the major public sector project sample.[1]	The PFM/ PIM legal or regulatory framework either (1) addresses only one climate dimension (mitigation or adaptation), or (2) limits its scope to the central government. Medium compliance: applied to 50 percent to 75 percent of the major public sector project sample.	The legal or regulatory framework does include some modest climate provisions, applicable only to the central government. Limited evidence of compliance: 25 percent to 50 percent of the major central government project sample.	None of the previous situation. No such legal framework or weak compliance. Less than 25 percent of the major central government project sample.
2. Climate-informed Investment planning and guidance	Do PIPs or sector strategies include the country's climate objectives (NDCs) and evidence-based vulnerability assessments?	PIP or sector strategies exist, include the country's main NDCs, and consider the vulnerability of its major sectors and public investment (more than 75 percent of capital budget) based on adequate hazard and exceedance data.	PIP or sector strategies include some NDCs and consider the vulnerability of some sectors and public investment (between 50 percent and 75 percent of the capital budget) based on hazard and exceedance data.	PIP or sector strategies either include the country's main NDCs or consider the vulnerability of its major sectors and public investment (less than 50 percent of capital budget) based on hazard and exceedance data.	None of the above.
3. Project identification and prioritization considering climate risks (portfolio level)	Are there climate-informed project selection and prioritization criteria and are large or new projects screened for their climate impact and resilience?	The government has published climate assessment and prioritization criteria for large or new public investments. The assessment covers the climate impact of the project and its exposure to climate risks, based on adequate hazard and exceedance data. Strong compliance: applied to more than 75 percent of the major public sector project sample.	The government has climate assessment and prioritization criteria for large or new public investments. The assessment covers either the climate impact of the project or its exposure to climate risks, based on hazard and exceedance data. Medium compliance: applied to 50 percent to 75 percent of the major public sector project sample.	The government accounts for the impact of large projects on climate change but not the climate risk exposure of major projects. Compliance is limited, and it is applied to less than 50 percent of the central government sample of major projects, or there is no or limited evidence it contributed to project prioritization.	None of the above.

Source: Authors.

(continued)

[1] Large projects are defined per the country's thresholds. The sample is expected to cover at least 1 percent of the capital expenditures.

ANNEX 15.2. (*continued*)

Climate PIM Module: Questionnaire					
Dimension	**Question**	**A**	**B**	**C**	**D**
4. Climate-informed project appraisal and selection (project level)	Do project appraisal guidelines exist that (1) mandate the evaluation of climate change impacts for large projects and provide a methodology or (2) require the real options or adaptation measures to be considered in project design to mitigate known climate risks.	Project appraisal guidelines (1) mandate the evaluation of climate change impacts for large projects and provide a methodology or (2) require the consideration of real options or adaptation measures in the project design to mitigate known climate risks. They are applied for large projects and compliance is vetted and high (more than 75 percent of the major project sample).	Project appraisal guidelines (1) mandate the evaluation of climate change impacts for large projects but do not provide a methodology or (2) do not mandate consideration of real options and adaptation measures in project design to mitigate climate risks are not systematic. Enforcement is medium: applied to 50 percent to 75 percent of the central government's major project sample, and vetting is limited.	Basic guidelines exist to incorporate the evaluation of climate risks and mitigation measures for major projects. Enforcement and vetting are limited (less than 50 percent of the central government large project sample).	None of the above.
5. Climate-informed state-owned enterprise investments and public-private partnerships.	Are there policies or guidelines mandating state-owned enterprises and public-private partnerships to assess the climate risk and include mitigation measures in the designs/contracts. Is there an independent review and vetting mechanism in place to ensure enforcement and accountability?	Specific polices or guidelines mandating state-owned enterprises and public-private partnerships to evaluate and mitigate major known climate risk for major investments, according to robust prescribed methodologies, exist. Compliance is high: more than 75 percent of the sample of major state-owned enterprise and public-private partnership projects apply these guidelines and are independently vetted.	Specific polices or guidelines mandating the evaluation and mitigation of the climate risk for their major investments exist for either state-owned enterprises or public-private partnerships. Methods are not specified or robust. Compliance is medium: 50 percent to 75 percent of the sample of major state-owned enterprise or public-private partnership projects apply these guidelines and are vetted.	Consideration of climate impact and risk in state-owned enterprises, investments, or public-private partnerships is nascent and compliance is limited: less than 50 percent of the sample of major state-owned enterprise or public-private partnership projects apply these guidelines.	None of the above.

Note: NDC = nationally determined contribution; PFM = public financial management; PIM = public investment management; PIP = public investment plan. The ranged colors mimic the traffic lights showing the various degrees of efficiency. Color scale: green (4); yellow (3); orange (2), red (1).

in many regions. With projected climate change, however, pressure on water resources is expected to increase significantly.

- Declines of 20 percent in water availability are projected for many regions under 2°C warming and of 50 percent for some regions under 4°C warming. Limiting warming to 2°C would reduce the global population exposed to declining water availability to 20 percent.
- South Asian populations are likely to be increasingly vulnerable to the greater variability of precipitation changes, in addition to disturbances in the monsoon system and rising peak temperatures that could put water and food resources at severe risk.

3. *Agricultural yields and nutritional quality*. Crop production systems will be under increasing pressure to meet growing global demand in the future. Significant crop yield impacts are already being felt at 0.8°C warming.
   - While projections vary and are uncertain, clear risks emerge as yield-reducing temperature thresholds for important crops have been observed, and improvements appear to have been offset or limited by observed warming (0.8°C) in many regions. There is also some empirical evidence that higher atmospheric levels of carbon dioxide could lower protein levels of some grain crops.
   - For the regions studied in this report, global warming above 1.5°C to 2°C increases the risk of reduced crop yields and production losses in sub-Saharan Africa, Southeast Asia, and South Asia. These impacts would have strong repercussions on food security and are likely to shrink economic growth and poverty reduction in the impacted regions.
4. *Terrestrial ecosystems*. Increased warming could bring about ecosystem shifts, fundamentally altering species compositions and even leading to the extinction of some species.
   - By the 2030s (with 1.2°C to 1.3°C warming), some ecosystems in Africa, for example, are projected to experience maximum extreme temperatures well beyond their present range, with all African ecoregions exceeding this range by 2070 (2.1°C to 2.7°C warming).
   - The distribution of species within savanna ecosystems is projected to shift from grasses to woody plants, as carbon dioxide fertilization favors the latter, although high temperatures and precipitation deficits might counter this effect. This shift will reduce available forage for livestock and stress pastoral systems and livelihoods.
5. *Rising sea levels.* Sea level rise has been occurring more rapidly than previously projected, and a rise of as much as 50 centimeters by the 2050s may be unavoidable because of past emissions: limiting warming to 2°C may limit the global sea-level rise to about 70 centimeters by 2100.
   - As much as 100 centimeters sea-level rise may occur if emissions increases continue and raise the global average temperature to 4°C by 2100 and

higher levels thereafter. While the unexpectedly rapid rise over recent decades can now be explained by the accelerated loss of ice from the Greenland and Antarctic ice sheets, significant uncertainty remains as to the rate and scale of future sea-level rise.

- The sea level nearer to the equator is projected to be higher than the global mean of 100 centimeters at the end of the century. In Southeast Asia for example, sea-level rise is projected to be 10–15 percent higher than the global mean. Coupled with storm surges and tropical cyclones, this increase is projected to have devastating impacts on coastal systems.

6. *Marine ecosystems.* Substantial losses of coral reefs are projected by the time warming reaches 1.5°C to 2°C from both heat and ocean warming.

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