Climate Resilient Infrastructure:

Getting the economics of infrastructure resilience right

Challenges

The high discount rate, especially in the private sector.

Challenges caused by the equity of impacts distribution.

Misaligned markets and a lack of ability to monetise certain costs and benefits.

The time period of analysis; future gains and losses may occur many years into the future.

A difficulty in identifying who is responsible for making decisions and consideration of the risk appetite of different stakeholders and their priorities.

Uncertainty and missing information, including climate change impacts, frequency and severity of weather events, regional or local effects, and impacts on environment, infrastructure and people.

Varied effectiveness of resilience measures.

Box 1: Challenges in constructing an investment case for increased climate change resilience[2].
Source: Arup 2014.

Introduction

This briefing note reviews the evidence relating to the costs and benefits of infrastructure resilience, considers potential financing options and discusses how DFID staff can ensure value for money during investment decision-making. Infrastructure investments typically have longer lifetimes than other forms of development finance. Operating lives of assets relating to the transport, water and power sectors may often be greater than 50 years and can exceed 100 years. Major shocks and stresses such as extreme weather events related to climate change are almost inevitable during these timescales. Failure to consider current and future climate risks within infrastructure planning can lock societies into development pathways that make them more vulnerable for decades to come, resulting in significant costs[1].

Despite continuous improvements in climate change modelling, there is still uncertainty as to how climate impacts will manifest in certain locations and what the local effects will be. As a result, it can be challenging to quantify and justify the additional or incremental costs and benefits of climate resilience for projects to investors and policy makers. Box 1 summarises challenges in constructing an investment case for increased climate resilience.

Costs of infrastructure resilience

Climate resilience benefits can be achieved through the delivery of a new stand-alone infrastructure project, for example delivery of the Thames Barrier to deal with flood risk in London (although this was not initially constructed with knowledge of future climate change). In reality, climate resilience benefits are more often created by modifications to existing or planned infrastructure projects. These modifications usually involve:

Physical measures to enhance the resilience of the asset changes to the infrastructure planning and design itself to accommodate current and future climate impacts.

For example, elevating a road to avoid damage from flooding, or using more durable materials for water pipes so they are more resistant to future levels of heat stress.

Planning decisions to enhance resilience outcomes for beneficiaries efforts to increase climate resilience benefits of the infrastructure to communities, the economy, and the environment.

For example, extending water supply access to underserved communities, including green infrastructure in road corridor design to improve catchment storm drainage, or retrofitting schools to serve as emergency community shelters during a disaster.

Organisational and institutional measures to enhance response and recovery of an infrastructure system when climatic shocks and stresses occur.

For example, ensuring that an organisation has comprehensive plans for managing its assets, and understands their vulnerability to extreme weather events in order to prepare and respond appropriately to short and longer term forecasts. Or, providing domestic water users with training and awareness on actions to take if the water system is contaminated.

Delivering resilient infrastructure will typically incur additional costs, whether in relation to design (e.g. technical advice, siting requirements), construction (e.g. higher engineering and material costs) and/or operation (e.g. more regular maintenance and monitoring regimes). Delivering resilience may also require additional investment in associated infrastructure systems upon which the asset depends to function, for instance transport and energy systems.

> *For example, a Climate and Development Knowledge Network (CDKN) study for the Government of Nepal estimated the additional engineering costs to increase the climate resilience of a small hydropower development at around 10% of overall capital costs[3]. However, the costs of resilience are highly location- and asset-specific and dependent on the climate hazard and risk being addressed.*

Not all climate resilience measures are high-cost; investments in resilience may simply require different approaches and implementations of solutions. More effective infrastructure siting and decision-making about contingency plans can be incorporated early in planning. For example, green infrastructure solutions can enhance resilience to coastal flooding more than concrete flood barriers. The costs of resilience rise when incorporated late in design and when applied during construction or retrofitted to existing assets[4]. Incorporating resilience measures at the time of asset renewals is more cost effective than ‘retrofitting’ adaptation.

Benefits of infrastructure resilience

There is a significant body of evidence suggesting that investing in infrastructure resilience can deliver strong financial and socio-economic returns. Key types of benefits are summarised in Box 2 below.

Benefits

Avoided losses. Avoiding damages and losses from disasters. For example, more robust transport network design standards might reduce or avoid costly repairs and minimise downtime and economic disruption in the event of a major flood or storm.

Unlocking economic potential. Stimulating economic activity due to reduced disaster risk. For example, increased land value associated with improved protective infrastructure, or enhanced access to markets resulting from improved transport infrastructure.

Generating development co-benefits. Resilience investments can serve multiple purposes and create co-benefits for communities day-to-day. For example, green infrastructure developed to improve flood control might improve air quality, reduce urban heat island effect and provide recreational space.

Box 2: Benefits of climate resilient infrastructure[5].

Policy makers and investors must decide 'how much' and 'what type' of resilience is acceptable by trading off the cost of investment against future financial or socio-economic benefits. Incremental costs should be justified by the potential benefits that resilience can deliver, which is normally achieved by incorporating avoided losses and the potential for resilience-oriented productivity gains into traditional cost-benefit analyses. Undertaking a cost-benefit analysis can be complex, due to the uncertainty associated with future climate change and the difficulties associated with adaptation as an investment decision. Figure 1 below illustrates key elements of the adaptation investment decision.

There may be occasions when high-cost engineering approaches cannot be justified by the benefits. In this case, it may be that lower 'physical' resilience, and shorter infrastructure lifetimes have to be accepted. In such cases, higher operation and maintenance costs should be expected, including 'reactive' costs to repair damage following an extreme weather event. Robust organisational procedures for responding to the likely high impacts of an extreme weather event should also be produced.

Invest if valuation of benefits exceeds costs

B>C if PV of future losses > cost of investment in resilience

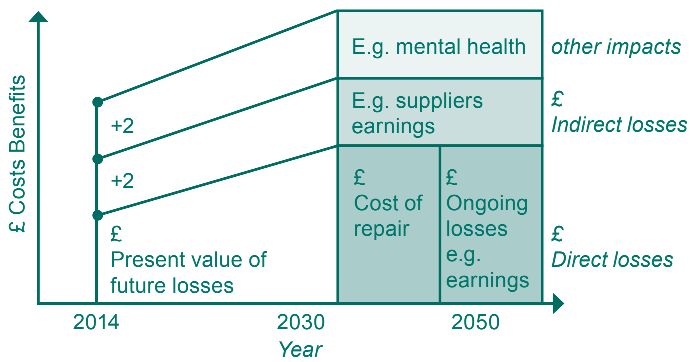

Figure 1. The main elements of cost-benefit appraisal for adaptation investment decision. Source: Arup 2016

Issues also exist around transferability of evidence. As with costs, benefits are highly location- and project-specific. A recent review found that the range of cost-benefit methodologies makes comparability between different studies challenging. More recent studies also tend to incorporate implementation and policy-related transaction costs, resulting in higher estimates than those using technical options only[6].

Financing Infrastructure Resilience

National and regional public finance institutions often have strong mandates to support infrastructure resilience. This is done in two ways:

Firstly, **climate risk screening** is an integrated part of the infrastructure project appraisal. For example, the EU Directive for Environmental Impact Assessments for new infrastructure projects in the EU and the UK requires climate change impacts and risks to be assessed.

Secondly, **infrastructure investment is targeted** in climate vulnerable sectors, for instance water supply. For example, the European Investment Bank recently raised its target spend on climate change adaptation and mitigation in developing countries to 35% of all investment.[7]

In developed markets, the capital and operational costs of resilience are generally identified during the project design process and incorporated into overall design costs. Additional funding mechanisms are rarely used for adaptation-specific initiatives, whether incremental costs or stand-alone initiatives[8]. To encourage private sector investment in infrastructure resilience, developed country governments may employ regulations and incentives, for instance by updating codes and standards for energy, water and transport to incorporate climate risk, or mandating reporting by infrastructure operators and utilities such as the UK Adaptation Reporting Power[9].

In developing countries, even where the benefits of infrastructure resilience outweigh the incremental costs, there may be issues around the availability of finance and the ability to implement regulations. There are also opportunity costs of investing scarce resources in resilience given existing infrastructure deficits7. There are, however, opportunities for governments and project developers to access concessional climate finance, for instance through the Green Climate Fund (GCF)[10] and the Pilot Programme for Climate Resilience (PPCR)[11] under the Climate Investment Funds.

Ensuring Value for Money (VFM)

Even where financing is available, care must be taken to ensure that investments in infrastructure resilience are appropriate. Poor decision-making may in the worst case result in redundant or undesirable assets, or more likely create an under-utilised and over-engineered asset base.

There is therefore a need for robust decision-making processes and a clear value for money (VFM) framework. The Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5)[12] recommends that an iterative climate risk management approach is used, helping to sequence investment activities over time and prioritising early actions that deliver benefits under a wide range of climate scenarios. For the infrastructure sector, this means incorporating uncertainty into planning, a greater focus on climate risk screening, and a shift away from standard appraisal methods towards those that value flexibility or robustness. There are several techniques for supporting decision-making for adaptation and resilience projects that help address issues around uncertainty. These are set out in Box 3.

Tools & Resources

The European Community's Seventh Framework Programme (FP7) MEDIATION[i] project comprises a detailed review of decision support tools for climate resilience, and a series of case studies evaluating these[13]. The tools analysed include:

- **Cost-Effectiveness Analysis**
- **Multi-criteria analysis**
- **Real Options Analysis**
- **Iterative Adaptive Management/ Adaptation Turning Points**
- **Analytic Hierarchy Process**
- **Robust Decision-making**
- **Portfolio Analysis**
- **Social Network Analysis**

DFID has also developed a number of guidance notes which discuss the application of the above decision frameworks to climate change and development programming. These include:

Topic guide: Adaptation: Decision-making under uncertainty (2013). This guide focuses on how to address uncertainty in decision-making and discusses the potential use of decision tools in this context[14].

Early VFM Adaptation Toolkit (2014): This applied toolkit looks at how to ensure early value for money in DFID programming in the face of uncertainty, including approaches to decision-making for longer life infrastructure[15].

Box 3: Tools and resources for decision-making

[i] Methodology for Effective Decision-making on Impacts and AdaptatION

The key questions to be addressed to ensure VFM in resilient infrastructure development are set out in Box 4 below.

Key VFM questions		VFM implications for programming
Does the investment have a long lifespan and is it therefore potentially exposed to uncertain future climate impacts?	1	Use economic appraisal techniques that incorporate robustness and flexibility to ensure VFM under a range of climate scenarios. This can be combined with using more traditional scenario-based appraisal techniques (e.g. cost-benefit, cost-effectiveness) that seek to optimise a single outcome.
Are there low- or no-cost actions that could be adopted in the infrastructure development process that could enhance VFM both immediately and over the operating lifetime?	2	Identify potential quick wins (e.g. less vulnerable siting, access options) that do not carry large incremental costs. Examine incremental build approaches that allow for lower cost resilience upgrade or retrofit on the basis of emerging information on future risks.
Are there additional costs associated with incorporating resilience into infrastructure that potentially create opportunity costs for other development priorities?	3	Explore the opportunities for accessing climate finance for incremental costs by aligning investments and programming with wider resilience funds (e.g. GCF, PPCR, and the Adaptation Fund). Maximise resilience co-benefits from infrastructure for communities in catchment area to align further with climate fund objectives.
Are there potentially resilience co-benefits that could be achieved by extending access to infrastructure to vulnerable communities within the infrastructure catchment area?	4	Explore low cost opportunities for providing access for underserved and exposed communities to resilient infrastructure. Prioritise infrastructure that can enhance community level resilience (e.g. multi-purpose power and water, access roads that support Disaster Risk Recovery (DRR) as well as market access).

Box 4: Key Value for Money questions in infrastructure programme design and financing

Case studies

Investment under uncertainty[16]

A 2015 study by the World Bank reviewed the potential costs and benefits of incorporating resilience into Africa's water and power sector. The Program for Infrastructure Development in Africa (PIDA) lays out a long-term plan for closing Africa's infrastructure gap. Much of this investment will support the construction of long-lived infrastructure, such as dams, power stations, and irrigation canals. However, the direction and magnitude of changes in precipitation and water availability remain highly uncertain; the study therefore looks at the potential implications of uncertainty on these investments. It was found that failure to integrate climate change in the planning and design of power and water infrastructure could entail, in scenarios of drying climate conditions: losses of hydropower revenues between 5% and 60% (depending on the basin), and increases in consumer expenditure for energy up to three times the corresponding baseline values. In in wet climate scenarios, business-as-usual infrastructure development could lead to foregone revenues in the range of 15% to 130% of the baseline, to the extent that the larger volume of precipitation is not used to expand the production of hydropower. The solution to this dilemma is to identify an adaptation strategy that balances the risk of inaction with the risk of wrong action, taking into account the preferences of decision makers and attitudes toward risks.

Costs and benefits of flood risk management[17]

In 2008, Arup and the Environment Agency (EA) initiated the development of a flood management strategy for 27 areas in the Humber Estuary, which in the past has experienced catastrophic flooding from heavy rainfall and rising tides. Following the record floods of 2013, which resulted in damages in excess of £100 million, focus was shifted towards assessing the benefits and costs of the flood management strategy. A model of future overtopping of flood defences indicated that direct damages in excess for £10bn could occur, with the possibility of consequential national damages exceeding £20bn. However, a detailed cost-benefit analysis of protecting the Estuary to a 0.5% annual exceedance probability standard, revealed that the benefits of protection would outweigh the costs by a ratio of 4.6, and that investing in climate resilient flood defence could avoid at least £5.9bn of damages up to 2057. Furthermore, the analysis did not account for avoided consequential damage to national infrastructure, which would further magnify the economic benefits of resilience. Consequently, the strategy development has demonstrated that investing in climate resilient flood protection schemes can have significant economic and development co-benefits locally, regionally and nationally.

References

[1] Jones, L., Carabine, E. and Schipper, E. (2015), 'Reconceptualising maladaptation in policy and practice: towards and evaluative framework. ODI and Pathways to Resilience in Semi-Arid Economies'. London: Overseas Development Institute.

[2] RSSB / Arup (2014) Tomorrow's Railway and Climate Change Adaptation: Final Report, Task 1: Economics of climate change adaptation appendices.

[3] IDS-Nepal, PAC, GCAP, (2014) Economic Impact Assessment of Climate Change in Key Sectors in Nepal. Available from: https://goo.gl/Tq4gDj

[4] OECD (2015) Climate Change Risks and Adaptation. Linking Policy and Economics. Available from: https://goo.gl/PaosNC

[5] Asian Development Bank / ITAD (forthcoming 2017) Resilience Dividends of Community-Level Interventions: Evidence from Myanmar. ADB, Manila.

[6] Econadapt (2015) The Costs and Benefits of Adaptation. Results from the Econadapt Project. Available from: https://goo.gl/iii4Pc

[7] European Investment Bank (2017) Priorities. Available from: https://goo.gl/x3SxNx

[8] Mullan et al. (2013) National Adaptation Planning. Lessons from OECD Countries. Available from: https://goo.gl/RgcPxR

[9] Department for Environment, Food and Rural Affairs (2017) Climate change adaptation reporting: Second round of reports. Available from: https://goo.gl/qn5dKv

[10] Green Climate Fund (2017) www.greenclimate.fund/home

[11] Climate Investment Funds (2017) Pilot Programme for Climate Resilience. Available from: https://goo.gl/cPgWAt

[12] IPCC (2014) Fifth Assessment Report (AR5). Available from: https://goo.gl/qHjcPp

[13] FP7 MEDIATION (2013) Technical policy briefing notes. Available from: https://goo.gl/CpJuva

[14] Ranger (2013) Decision-making under uncertainty. Available from: https://goo.gl/WrsNP7

[15] Watkiss, P.; Hunt, A.; Savage, M. (2014) Early value-for-money adaptation: Delivering VFM adaptation using iterative frameworks and low-regret options. Evidence on Demand, UK. Available from: https://goo.gl/1UKvuu

[16] Cervigni, Raffaello, Rikard Liden, James E. Neumann, and Kenneth M. Strzepek. (2015) Enhancing the Climate Resilience of Africa's Infrastructure: The Power and Water Sectors. Africa Development Forum series. Washington, DC: World Bank. Available from: https://goo.gl/SVADKL

[17] Todd, H. (2014) The Humber Flood Risk Management Strategy - Managing Flood Risk Through Protection, Preparedness and Resilience Measures, Available from: https://goo.gl/yqrecs

[17] Raynor, P. (2014) The Humber Estuary Flood Risk Management Strategy: Summary Strategy and Business Case. Available from: https://goo.gl/YfKCTM

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